ORKUSTOFNUN
National Energy Authority

Geothermal Policy Options and Instruments for Ukraine

Based on Icelandic and International Geothermal Experience

Report Prepared for the Ministry for Foreign Affairs in Iceland

April

2016

Geothermal Policy Options and Instruments for Ukraine

Based on Icelandic and International Geothermal Experience

Report Prepared for the Ministry for Foreign Affairs in Iceland

Orkustofnun,
National Energy Authority
Iceland

April 2016

Publisher:
Orkustofnun, Grensásvegi 9, 108 Reykjavík
Tel: 569 6000, Fax, 568 8896
Email: os@os.is
Website: http://www.nea.is/

Editors: Baldur Pétursson, Jónas Ketilsson.
Cooperation Team: Guðni A. Jóhannesson, Alicja Wiktoria Stoklosa, Jón Ragnar Guðmundsson, Sveinbjörn Björnsson, María Guðmundsdóttir, Erla Björk Þorgeirsdóttir, Kristján Geirsson, Skúli Thoroddsen, Rakel Jensdóttir, Hanna Björg Konráðsdóttir, Ingimar G. Haraldsson, Lúðvík S. Georgsson, Þorvaldur Bragason, Anna Lilja Oddsdóttir, Linda Georgsdóttir, Jón Ásgeir Haukdal, Kristinn Einarsson, Benedikt Guðmundsson, Sigurður Ingi Friðleifsson, Jakob Björnsson, Harpa Þórunn Pétursdóttir, Erna R. Bragadóttir and Petra S. Sveinsdóttir.

Geothermal Policy Options and Instruments for the Ukraine, is published on the Orkustofnun website and printed in limited copies.

OS-2016-01

ISBN 978-9979-68-380-3

April 2016

Table of Contents

Acknowledgements

This report was prepared by a team within the National Energy Authority of Iceland (Orkustofnun) working on International Geothermal Programs and Projects, but drew on resources throughout both domestic and international institutions.

Chapter I on Global Geothermal Experience was based on references and information from several international resources, e.g. EGEC and GEODH, European Commission, World Bank - ESMAP, Bloomberg Energy and domestic sources from National Energy Authority, Mannvit and others.

Chapter II on Geothermal Resources and Opportunities in Ukraine was based on references and information e.g. from European Bank for Reconstruction and Development (EBRD), World Bank, US Aid, European Union, IRENA, IEA, Ministry for Foreign Affairs in Ukraine, State Agency on Energy Efficiency and Energy Saving of Ukraine (SAEE) and Institute for Renewable Energy (IRE) in Ukraine, the University of Krakow in Poland, Ministry for Foreign Affairs in Iceland and the National Energy Authority of Iceland.

Chapter III on Geothermal Experience and Development in Iceland, was based on the contribution of the staff from the National Energy Authority in Iceland, Landsvirkjun, Geothermal ERA NET, the Icelandic International Development Agency (ICEIDA) and Ministry for Foreign Affairs and Ministry for Industry and Commerce. The chapters start with information regarding the main references and resources.

We would like to give special thanks to the following people: Mr. Vasyl Khymynets Ministry for Foreign Affairs in Kiev, Mr. Serhiy Savchuk, Mr. Maksym Polischuk and Ms. Lenska Olean, State Energy Agency on Energy Efficiency (SAEE) Kiev, Mr. Yuriy P. Morozov and Oleg Lysak Ukrainian Academy of Sciences Institute of Renewable Energy in Kiev.

We would also like to give special thanks to Mr. Þráinn Friðriksson and Mr. Pekka Salminen at the World Bank in Washington, Mr. Dmytro Glazkov from World Bank Kiev, Mr. Sergiy Maslichenko European, Bank for Reconstruction and Development (EBRD) Kiev, Mr. Adonai Herrera-Martínez, EBRD in Turkey, Ms. Monica M. Sendor, Embassy of the United States in Kiev, Mr. Luis Velazquez US AID in Kiev, Dr. Beata Kepinska and Mr. Marek Hajto Polish Geothermal Society. And last but not least, we would like to thank Mr. Benedikt Höskuldsson, Ms. Kristín A. Árnadóttir and Mr. Davið Bjarnason from the Ministry for Foreign Affairs in Iceland.

Introduction

The Ministry for Foreign Affairs requested in late 2014 that Orkustofnun (OS – National Energy Authority), would prepare a geothermal strategy document on how Iceland could support Ukraine to develop future strategy on utilisation of geothermal resource in certain prioritized areas of Ukraine.

The request was initiated following a visit of the Minister for Foreign Affairs Mr. Gunnar Bragi Sveinsson, to Ukraine 2014 where cooperation between the countries was discussed, in particular how Iceland could support the geothermal development in Ukraine by utilizing the expertise and experience of Iceland in the field of renewable energy.

As a follow up step, the National Energy Authority of Iceland (Orkustofnun) signed a Memorandum of Understanding in May 2015 with the Ukrainian State Agency on Energy Efficiency and Energy Saving (SAEE). According to the MoU, the purpose and the goal of the agreement is to:

- Develop cooperation between the countries for the mutual realization of events and projects by Ukrainian and Icelandic organisations and companies in the area of energy efficiency, energy savings and renewable energy resources.

- Evaluation of opportunities and potential for geothermal energy development in Ukraine based on the analysis of resources and technically achievable aspects in energy potential of geothermal energy in the regions of Ukraine identified as most advantageous and prospective for the above mentioned.

Work on the Report

An integral aspect of implementing the MoU was to prepare a geothermal assessment document that had the following goal:

- Form a strategy on how Iceland could support Ukraine in developing a policy plan for the utilisation of geothermal resources in identified priority areas of Ukraine.

During the work, information was collected from various institutions and contacts, e.g. institutions in Ukraine, World Bank ESMAP in Washington, Krakow University in Poland and European Geothermal Energy Council (EGEC) in Brussels, and others referenced in this report.

The collection of geothermal information took more time than initially anticipated and turned to be more challenging than planned, as detailed information was not very recent nor accurate specifically for geothermal for various reasons. Geothermal data in Ukraine is old and more importantly the data is derived from boreholes drilled for oil and gas.

In October 2015, a team from Orkustofnun and the Ministry for Foreign Affairs, held meetings with following institutions and ministries in Kiev in Ukraine: Ministry for Foreign Affairs, State Agency on Energy Efficiency and Energy Savings of Ukraine (SAEE), European Bank for Reconstruction and Development (EBRD), World Bank (WB), U.S. Agency for International Development (US AID) and Institute for Renewable Energy of the National Academy of Science of Ukraine (IRE).

From these meetings it can be stated that in order to build up geothermal programs and projects in Ukraine, several steps are required. Overall management of future geothermal programs and projects will require cooperation with international institutions that have the operational capacity to manage, finance, implement and evaluate such programs with access to international geothermal experience and expertise.

One such institution is the European Bank for Reconstruction and Development – EBRD, which is the biggest international institutional investor in Ukraine and has 346 projects in Ukraine today, with an investment value of €7,46 billion, where 24% or €1,8 billion is invested in the energy sector. Energy security is a major policy issue in Ukraine, according to the strategy of the EBRD in Ukraine; the energy dependency on external supplies is exacerbated by the low efficiency of energy use. Improving energy efficiency is therefore a key priority for the country.

Another institution might be the Nordic funding mechanism available, such as NEFCO and NDF, although at a much smaller scale than EBRD. In addition, the findings of this report indicate that there is an interest for potential geothermal development among several key countries that support Ukraine and offer interesting alternatives.

It is significant for future geothermal deployment in Ukraine to identify key partners within Ukraine that can provide important expertise in different regions of the country. In particular institutions that have expertise in energy projects at the regional level and can assist in identifying strong partnering communities in Western Ukraine where this report has found areas most likely to possess necessary geothermal resources for district heating development.This report highlights options and instruments for geothermal policy in Ukraine and focuses on three main topics:

I. GLOBAL GEOTHERMAL EXPERIENCE

Overall there is increasing knowledge regarding general strategy for geothermal development but the implementation must be adapted to the natural and social environment in each location and country. The World Bank has, for example, issued a thorough geothermal handbook on planning and financing power generation projects. The main objective of that handbook is to provide decision makers and project developers with practical advice on how to set up, design, and implement a geothermal development program. Geothermal projects are risky and capital intensive, and the key elements of geothermal development are: (ESMAP, 2012)

- ✓ availability of sufficiently accurate geothermal resource data,
- ✓ effective and dedicated institutions,
- ✓ supportive policies and regulations and
- ✓ access to suitable financing for the project developer.

On a global level, diverse types of renewable and geothermal policy tools, implementations and incentives have been used, individually or in parallel, and the policies have also changed over time, both in developed and developing countries. In most countries geothermal development has taken a long time. The methodology is well known but must be adapted to circumstances in each country. Generally, initial projects must be publicly or donor-supported to prove their viability and reduce the risk to a level that attracts new investors.

Countries considering development of geothermal resources can learn from the experience of other countries, which have been applying this methodology in their development strategy for decades. This report uses examples from global and Icelandic geothermal lessons learned for the development of geothermal projects. The first attempts of direct use of geothermal heat in Iceland for district heating, date some 80 years back, but generation of electricity with geothermal steam has been escalating over the last 40 years.

II. GEOTHERMAL RESOURCES AND OPPORTUNITIES IN UKRAINE

In chapter II the focus is on reliable geothermal information, district heating, economics of the district heating systems etc. The first estimation of geothermal resources in Ukraine was implemented in 1979 by the Central Thematic Expedition of the Geology Ministry. Total projected resources of thermal waters in Ukraine are 27,3 million m^3/day, of which 23 thousand m^3/day are from free flowing wells, 137 thousand m^3/day can be extracted using pumps, and 27,2 million m^3/day can be extracted with back pressure. However, although there is great geothermal potential in Ukraine, it is a challenge to get a clear and focused overview, with clear priorities regarding investments and utilization. Therefore, additional information and work is needed before investment policy regarding priority places can be highlighted.

III. GEOTHERMAL DEVELOPMENT AND EXPERIENCE IN ICELAND

In chapter III there is a focus on practicality and examples from Iceland regarding utilisation of geothermal district heating, as such information can be used in similar situations in Ukraine. However, development of district heating in Iceland has occurred based on several factors, both external and internal such as; geothermal resources, financial support, and awareness of key stakeholders and policy priority at the national and regional level.

Executive Summary

Key elements in the development of geothermal projects in Ukraine depend on international cooperation with experienced geothermal countries, international financial institutions and authorities and institutions in Ukraine. It is also important to base geothermal strategy proposals on challenges and opportunities in Ukraine, with focus on policy priorities and projects in each location, from further pre-feasibility studies and evaluations, towards development and implementation of geothermal district heating projects.

Policy Recommendation

General recommendations for Ukraine can be highlighted in the following key policy recommendations:

1. An independent policy based on assessment and conditions in Ukraine.
2. Awareness raising among policymakers, stakeholders and municipalities.
3. Support schemes for the geothermal development.
4. A properly structured policy system, is critical for success for each location.
    a. Priority 1 - Education capacity building, networking and awareness raising.
    b. Priority 2 - Evaluation of geothermal resources and district heating opportunities.
    c. Priority 3 - Promotion of geothermal district heating and power generation.
    d. Priority 4 - Development of framework conditions.
    e. Priority 5 - International cooperation based on geothermal and financial expertise.

Implementation

I. Step One - Pre-Feasibility Study

The main purpose of this project is to promote early stage development, strategy planning, capacity building, networking and awareness of geothermal utilisation, to increase the possibility of utilisation of geothermal resources, energy security, savings and quality of life in the concerning location.

Figure 1. **Boreholes that are appropriate for geothermal power generation and Geothermal district heating**

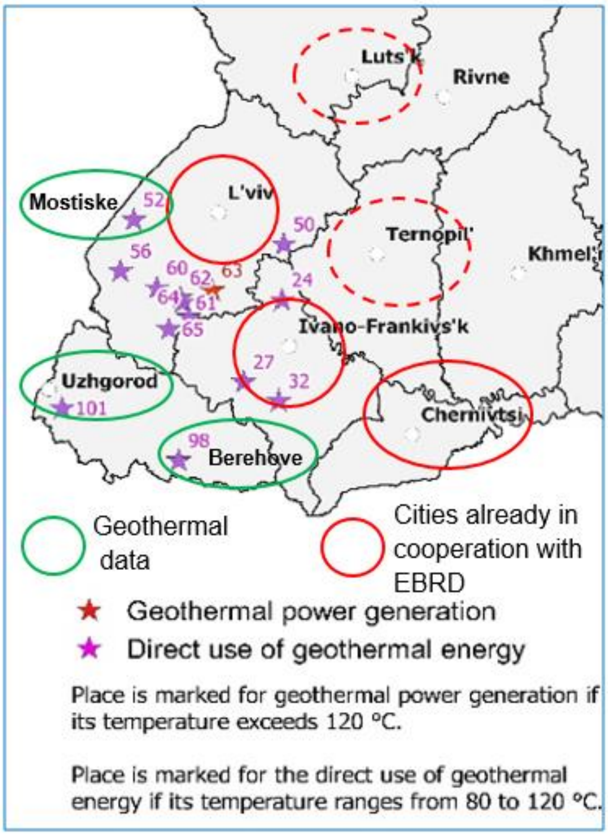
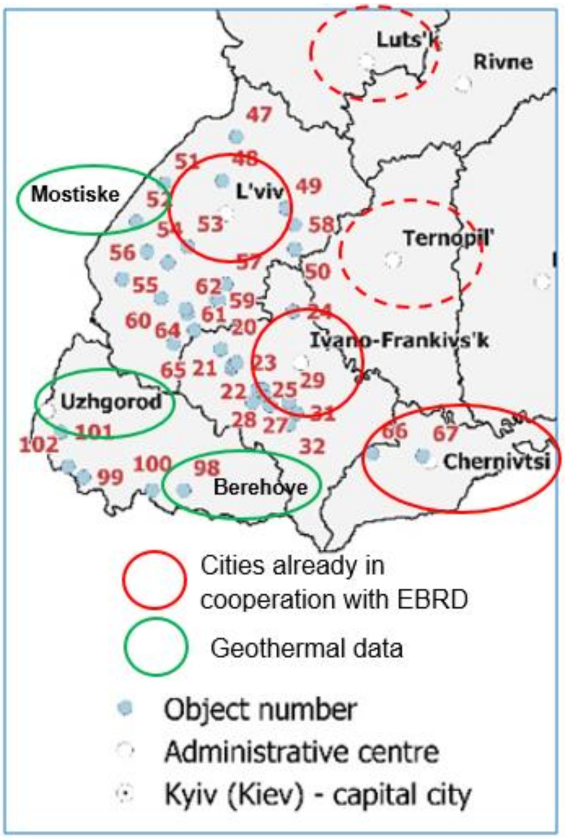


Figure 2. **Some prospective geothermal energy resources in Ukraine**



Location

Proposal of locations are based on three main priorities:

1) Potential geothermal resources.
2) Population/volume – as it is a base for the economic success of projects. 3) Cities in cooperation with EBRD/IFIs - as existing involvement of IFIs in concerning places are important for the implementation and development of geothermal projects.

It is recommended to focus on – three locations out of six, as an option for step one for further exploration and assessment of geothermal resources in West - Ukraine. These locations are:

- L'viv,
- Ivano Frankivsk,
- Chernivtsi.

Project Coordination

It is recommended that the project coordination will be based on cooperation between National Energy Authority in Iceland, International Finance Institutions (IFIs) (EBRD or other) and authorities and institutions in Ukraine.

Finance

The cost of such a pre-feasibility project, should be based on international donor grant contribution. It is estimated that the cost of each such project could be up to €500.000 per location/project.

II. Step Two - Project Implementation

After the conclusion of pre-feasibility studies in step 1, options and opportunities regarding possible investment projects that can be implemented in concerning locations will be clear.

III. Additional Framework Recommendations

Following recommendations are highlighted for Ukraine:

1. Simplify the administrative procedures to create market conditions to facilitate development.
2. Develop innovative financial models for geothermal district heating, including a risk insurance scheme, and the intensive use of structural funds.
3. Establish a level playing field, by liberalizing the gas price and taxing greenhouse gas emissions in the heat sector appropriately.
4. Train technicians and decision makers from regional and local authorities in order to provide the technical background necessary to approve and support projects.
5. Increase the awareness of regional and local decision-makers on geothermal potential and its advantages.
6. Modernize the district heating system.
7. Improve the role of independent regulators.
8. Improve the role of district heating companies.
9. Additional elements of public authorities.
10. Harmonization with EU Law.
11. What can international financing institutions do to help?

IV. Geothermal Options, Opportunities and Benefits

Geothermal heat generation has several advantages, such as:

1. Economic opportunity and savings.
2. Improvement of energy security.
3. Reducing greenhouse gas emissions.
4. Harnessing local resources.
5. Reducing dependency on fossil fuels for energy use.
6. Improving industrial and economic activity.
7. Develop low carbon and geothermal technology industry, and create employment opportunities.
8. Local payback in exchange for local support for geothermal drilling.
9. Improving quality of life – based on economic and environmental / climate benefits.

Conclusion and Recommendations

There is no simple formula for success for any country in terms of geothermal or industrial development. However, through experience both failures and success lessons can be learned and used as valuable guidelines for sound geothermal policies and implementations that take note of energy security, economic savings, economic growth and quality of life. This report focuses on three main subjects:

i. Global Geothermal Experience
ii. Geothermal Resources and Opportunities in Ukraine
iii. Geothermal Development in Iceland

The geothermal resources in Ukraine are measured against a set of criteria for using geothermal as a competitive resource and to highlight the main challenges and opportunities for deploying geothermal. The results can be used in combination with lessons learned from global and Icelandic experiences. The key conclusions and recommendations are as follows:

I. Global Geothermal Experience

The main lessons learned at the global level are:

1. Policy for geothermal development must be based on assessment of conditions in each region and country.
2. A properly structured policy system is critical for success.
3. Volume is not the same as efficiency.
4. Policy tools should be well coordinated and harmonised.
5. Policy and regulatory design are dynamic processes.
6. Key factors for competitive geothermal policies and renewables must be identified.
7. Support schemes for geothermal development are important and valuable.

II. Utilisation of Geothermal Resources in Ukraine

The geothermal resources in Ukraine should be examined in the light of following criteria:

1. An independent policy based on assessment and conditions for each location.
2. Awareness raising among policymakers, stakeholders and municipalities.
3. Support schemes for geothermal development.
4. A properly structured policy system is critical for success:
   a. Priority 1 - Education capacity building, networking and awareness raising.
   b. Priority 2 - Evaluation of geothermal resources and district heating opportunities.
   c. Priority 3 - Promotion of geothermal district heating & power generation.
   d. Priority 4 - Development of framework conditions.
   e. Priority 5 - International cooperation based on geothermal and financial expertise.

Further clarification will follow in this chapter.

III. Geothermal Development and Experience in Iceland

The following elements of policy priority have been shown to be important regarding geothermal development:

1. Awareness raising among policymakers, stakeholders and municipalities.
2. Education and capacity building.
3. Evaluation of geothermal resources.
4. Promotion of geothermal power generation and district heating projects.
5. Development of legal and regulatory framework.
6. Financial support for early stage development and exploration.
7. International cooperation, geothermal and financial expertise.

The economic savings from geothermal district heating in Iceland from 1914 – 2014 is equal to 2.680 billion ISK. (19 billion €), or 33 million ISK (240.000 €) per family (four persons). Furthermore, the CO_2 savings by using geothermal district heating instead of oil are approx. 100 million tons since 1944, which is equal to CO_2 bindings in 240.000 km^2 of forest. The savings of CO_2 in 2014 was 3 million tons, which is equal to CO_2 bindings in 7.000 km^2 of forest. Geothermal district heating has therefore been an important contribution to fighting climate change, which is increasing temperatures and sea levels around the world.

IV. Opportunities and Policy Options for Ukraine

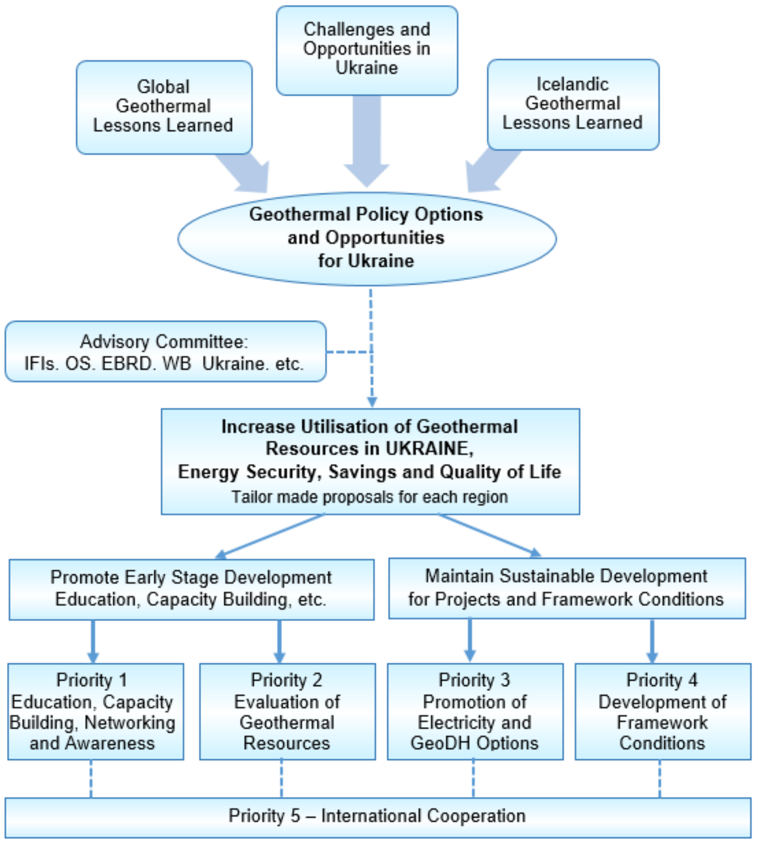
Key elements in the development of geothermal energy and financing of renewable energy projects in Ukraine depend on international cooperation with the most experienced geothermal countries, stakeholders, international financial institutions and donors. It is also important to base proposals on global lessons learned, and challenges and opportunities in Ukraine towards tailor made policy priorities, programs and projects. The general recommendations for Ukraine are as follows:

1. An independent policy based on assessment and conditions in Ukraine.
2. Awareness raising among policymakers, stakeholders and municipalities.
3. Support schemes for the geothermal development.
4. A properly structured policy system, is critical for success.
    a. Priority 1 - Education capacity building, networking and awareness.
    b. Priority 2 - Evaluation of geothermal resources.
    c. Priority 3 - Promotion of geothermal district heating & power generation.
    d. Priority 4 - Development of framework conditions.
    e. Priority 5 - International cooperation, geothermal and financial expertise.

In this report, Icelandic and international lessons learned are highlighted in combination with geothermal challenges and opportunities in Ukraine. Figure 3 illustrates how additional work and planning could be organised in cooperation with relevant stakeholders.

Iceland has successfully utilised renewable resources to improve the standard of living, by improving energy security and providing substantial economic savings, for the economy and consumers for more than 80 years. Iceland can assist others to benefit from that experience in one way or another. However, for more detailed policy recommendation and implementation for Ukraine, more consultations and a planning process is needed in cooperation with the concerning countries, and international bodies (EBRD), to establish geothermal and financial resources and expertise.

Figure 3. **Geothermal Policy Options and Opportunities for Ukraine**



Source: Orkustofnun (OS) (National Energy Authority), Iceland

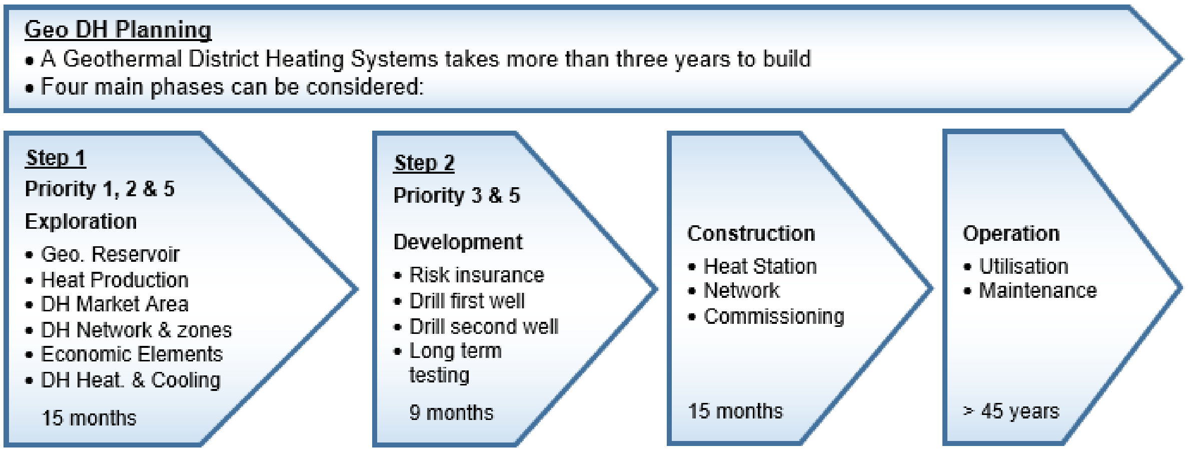
Proposal - Two Steps, 1. Feasibility Study and 2. Project Implementation

In this report it is proposed that geothermal programs and projects in Ukraine should be based on cooperation with international donors and cooperation with international financial institutions with solid experience of implementation of programs and projects in Ukraine. EBRD is one such international institution, as the bank has a long and varied experience in the implementation of such activity in Ukraine. Further consultation with EBRD would be appropriate to develop this process further if such an approach would be decided on by the concerning authorities. Further consultation and cooperation with EBRD and relevant donor countries should be a priority to evaluate such options and opportunities and formulate further proposals.

V. First step – Further Assessment of 2 – 3 Priority Locations in Western Ukraine

The opportunities and utilisation of priority locations are shown in figure 4, where the coordination of the project is explained step by step and can be treated as a model to promote the early stage development projects, (see also chapter 4.10).

Figure 4. **Two Step Strategy for Geothermal District Heating (GeoDH) in Ukraine**



Sources: GeoDH, and National Energy Authority Iceland

VI. Proposal – Step 1 - Pre- Feasibility Study of Geothermal District Heating

1. Proposed project

Geothermal resources can be economically successful in comparison with fossil based energy resources, improve economic savings, reduce greenhouse gas emissions, increase energy security, and improve air quality and quality of life.

2. Location

Proposal of locations are based on three main priorities:

1) Potential geothermal resources. 2) Population / volume as it is a base for economic success of projects. 3) Cities in cooperation with EBRD / IFIs as existing involvement of IFIs in concerning places are important for implementation and development of geothermal projects.

Based on these priorities, three locations out of six are highlighted as an option for step one for further exploration.

Figure 5. **Boreholes that are appropriate for geothermal power generation and Geothermal district heating**

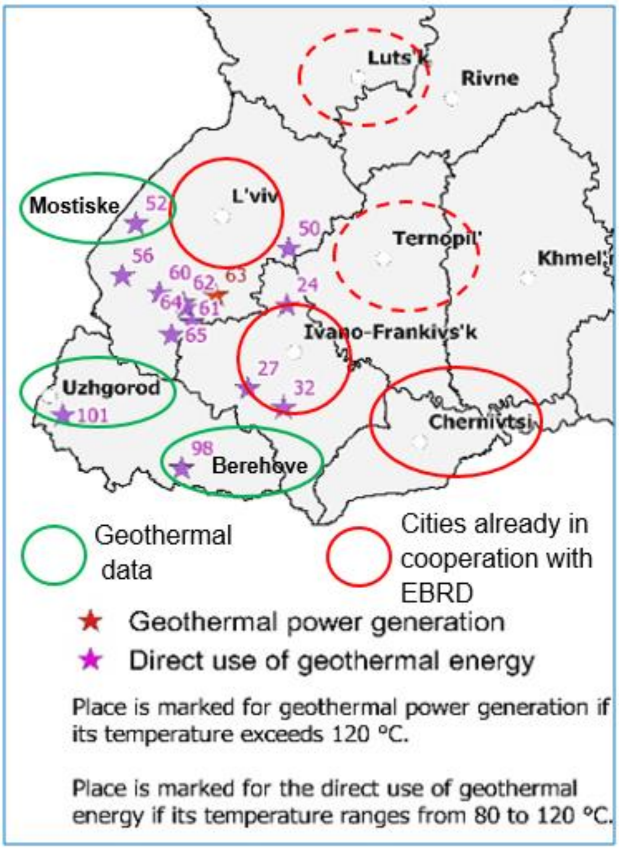
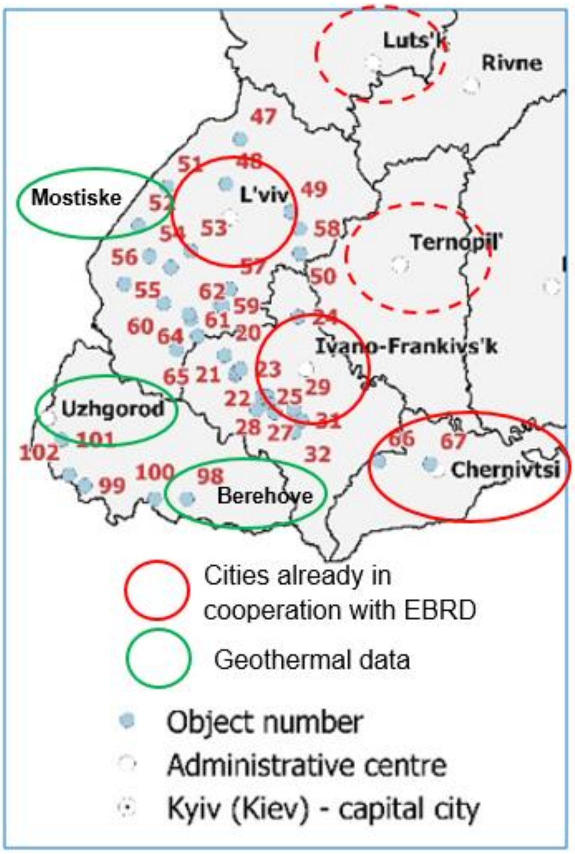


Figure 6. **Some prospective geothermal energy resources in Ukraine**



Location	Popu-lation	Exp. Utilisation m³/day	Temp-erature °C	Geo. inst. thermal pow. MW	Fuel economy, t.s.f./year*	Directions of using * (t. s.f./year = tons of standard fuel per year)
L'viv, city	730.000	Data needed	Data needed	Data needed	Data needed	Large district heating system, exploration of geothermal potential needed in the area
Ivano Frankivsk	229.000	Data needed	Data needed	Data needed	Data needed	Large district heating system, exploration of geothermal potential needed in the area
Chernivtsi	263.000	Data needed	Data needed	Data needed	Data needed	Large district heating system, exploration of geothermal potential needed in the area
Uzhgorod	115.000	65.300	60	120,4	117.707	Heat supply for communal and industrial facilities Uzhgorod
Mostiske	11.000	7.800	107	27,3	15.783	Heat supply for industrial premises railway station, depot, residential buildings of village Mostyske
Berehove	24.500	10.300	58	21,5	21.152	Heat supply of village Berehovo, balneology

3. Coordination

International Geo expertise in cooperation with EBRD and authorities and institutions in Ukraine.

4. Finance

Donor grant finance in cooperation with EBRD / IFIs up to €500.000 per location.

5. Why is the project needed?

To promote early stage development, strategy planning, capacity building, networking and awareness of geothermal utilisation, to increase the possibility of utilisation of geothermal resources, energy security, savings and quality of life in concerning location.

6. What will the project achieve?

Pre-feasibility study of geothermal district heating will achieve:

- Re-evaluation and updating of the production potential of the geothermal resource in each location.
- Increased awareness of local authorities, as well as the public, of the potential and benefits of sustainable geothermal utilization in the city and surrounding communities.
- Evaluation of the potential increase of geothermal utilization in the city and area.

7. How will it be achieved and who are the beneficiaries?

(a) The following main project phases are proposed:

- Assessment of the current status of utilization in each location, capacity of current wells, energy produced, utilization for district heating, other direct uses, etc.
- Potential assessment with simple reservoir models and predictions for some relevant future sustainable utilization scenarios with special emphasis on the benefits of reinjection.
- Potential improvements to the current utilization, in particular district heating. Involves the design of surface installations with emphasis on the economic and energy efficiency.
- Evaluation of the potential for expansion of the current utilization.
- Analysis of geothermal district heating development and international comparisons.
- Evaluation of geothermal policy options and opportunities.
- Dissemination of results locally and countrywide, to increase awareness of geothermal utilisation, energy security, savings and quality of life in concerning regions.

(b) The beneficiaries of the program are the municipalities in each location and its inhabitants.

8. Possible timeline of step 1 is 15 months.

VII. Step 2 - Priority 3 – Project / Investment Implementation

The conclusions of pre-feasibility studies in step 1 will list up options and opportunities regarding possible investment projects that can be implemented in the concerning locations by tendering process based on a PPP (Private Public Partnership) approach

Implementation of one or two projects in W-Ukraine for geothermal district heating and/or power generation**.**

Coordination – International geothermal expertise in cooperation with EBRD / IFIs in cooperation with donor countries and authorities in Ukraine.

Implementation – PPP-cooperation – based on tendering process.

Finance – Depends on type of projects and finance and donor contribution, development priority etc.

Time – 24 months.

VIII. Additional Framework Recommendations

In many countries in Europe, geothermal district heating has potential possibilities to replace a significant part of imported oil and gas for heating in households and industry. The following recommendations are highlighted for Ukraine:

1. Simplify the administrative procedures to create market conditions that facilitate development;
2. Establish a level playing field, by liberalizing the gas price and taxing greenhouse gas emissions in the heat sector appropriately;
3. Increase the awareness of regional and local decision-makers on geothermal potential and its advantages.
4. Modernize the district heating system:
    a. Better quality of service.
    b. Lower cost.
    c. Improved transparency.
    d. Following improvements of financial viability of district heating companies.
    e. Reduce cost of supply.
    f. Increase revenue.
    g. Quality service should be affordable.
5. Improve the role of independent regulators.
6. Improve the role of district heating companies.
7. Additional elements of public authorities.
    a. Finance energy efficiency programs.
    b. Support public awareness campaigns for benefits of metering.
    c. Providing incentives for demand-side management.
    d. Providing target support to poor customers.
8. Harmonization with EU Law.
9. Train technicians and decision makers from regional and local authorities in order to provide the technical background necessary to approve and support projects.
10. Develop innovative financial models for geothermal district heating, including a risk insurance scheme, and the intensive use of structural funds;
    a. Grants / risk loans to geothermal district heating for exploration and test drilling to lower the risk.
    b. Grants to individuals (apartments) for changing to geothermal district heating.
    c. Grants to district heating companies for transformation to geothermal district heating.
    d. Loans to district heating companies' tor transformation to geothermal district heating.
11. What can international financing institutions do to help?
    a. Financing / Support district heating transformation towards geothermal district heating
    b. Financing and implementing heat metering and consumption based billing.
    c. Financing energy efficiency measures along the supply line.
    d. Technical assistance to newly established regulators.
    e. Technical assistance for the design of targeted social safety nets.
12. Access to International Geothermal Expertise, Markets and Services.

Regarding additional elements, see also chapter 4.7.2, 4.7.3, 4.8, 4.9 and 4.10.

IX. Geothermal Options, Opportunities and Benefits

The geothermal heat generation has several advantages, such as:

1. Economic opportunity and savings.
2. Improvement of energy security.
3. Reducing greenhouse gas emissions.
4. Harnessing local resources.
5. Reducing dependency on fossil fuels for energy use.
6. Improving industrial and economic activity.
7. Develop low carbon and geothermal technology industry, and create employment opportunities.
8. Local payback in exchange for local support for geothermal drilling.
9. Improving quality of life based on economic and environmental / climate benefits.

I. Global Geothermal Experience

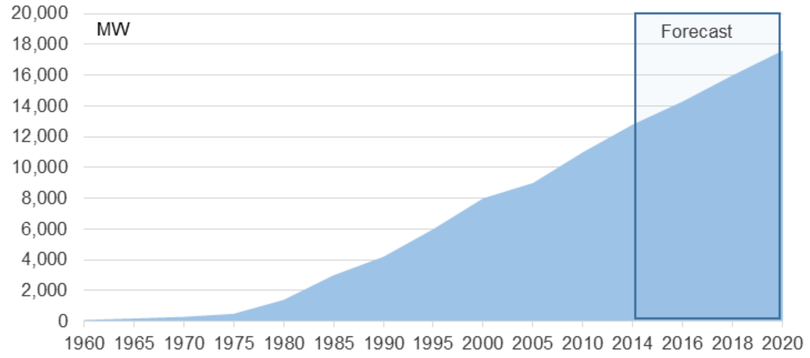
1. Development of the Geothermal Sector Worldwide

1.1. Overview and Challenges of the Geothermal Sector

International Trends in the Geothermal Sector
Since 1990 the global geothermal power market has continued to grow substantially. Geothermal energy generated twice the amount of electricity as solar energy did worldwide in 2010 and approximately 12,8 GW of installed geothermal power capacity was online globally in January 2015, spread across 24 countries. In 2015 the global geothermal market was developing about 11,5-12,3 GW of planned capacity, which was spread across 80 countries.

Growth of the geothermal market is driven by a number of factors such as: economic growth, espe-cially in developing markets; the electrification of low-income and rural comm-unities; increasing concerns regarding energy security and its impact on economic security, reducing green-house gas emissions, harnessing domestic re-sources and improving quality of life.

Figure 1.1.1. **Installed Geothermal Electric Capacity Globally, 1960 – 2012**



Source: International Market Overview Report, GEA, 2015

Furthermore, the majority of the growth in the development of global geothermal resources is occurring in countries with large, untapped, conventional resources. As more countries recognize and understand the economic value of their geothermal resources, their development and utilization becomes a higher priority.

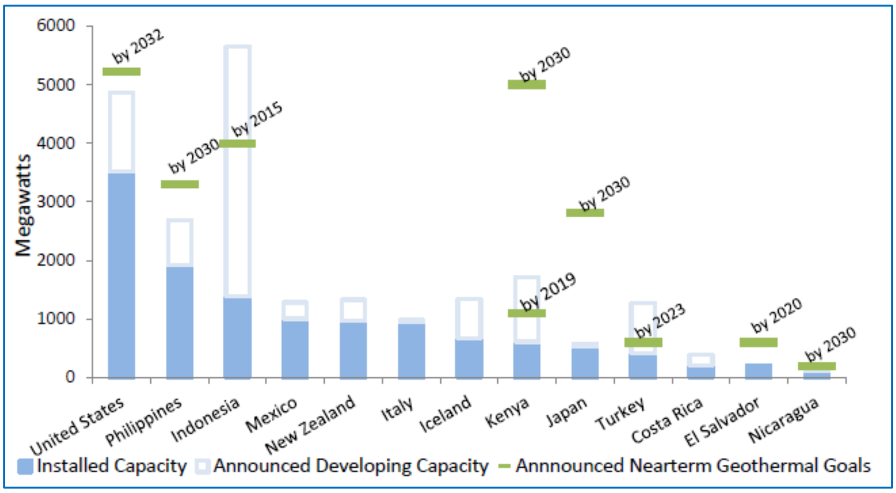
In 2014, the international geothermal power capacity grew at a rate of 5%, for the third consecutive, and GEA forecasts that the global market will reach 14,5 to 17,6 GW by 2020 and this growth will come from European, East African, and South Pacific markets as these regions lead geothermal growth by substantial capacity additions in the next five years.

This growth is also supported by the World Bank and other multi-lateral organizations focused on early risk mitigation. For example, the World Bank's Energy Sector Management Assistance Program (ESMAP) has mobilized $235 million through the Clean Technology Fund toward scaling up geothermal energy, as part of their Global Geothermal Development Plan (GGDP). Projects in Latin America including Mexico, Chile, Nicaragua, Dominica and St. Lucia and the Caribbean are expected to or already received funding from this program. ESMAP has identified 36 geothermal fields in 16 countries where surface exploration has been completed and additional financing is needed in the near future to confirm the commercial viability of geothermal resources. ESMAP has also estimated that 40 countries could meet a large proportion of their electricity demand through geothermal power. (Geothermal Energy Aassociation, Benjamin Matek, 2015).

Due to climate change challenges, many countries are more and more prioritising and utilising renewable resources, including geothermal, for power and heating. The United Nations expect e.g. that Latin American countries will be severely affected by climate change, despite the fact that the region's greenhouse gas emissions represent a small proportion of total global emissions. The melting of Andean glaciers, changing rain patterns and decreasing water supply will negatively impact local agriculture and residential patterns in those countries. To respond to these challenges regarding energy security and its impact on economic security, in addition to increasing demand, many countries have taken steps towards increasing domestic energy security by supporting the development of their renewable energy resources, including geothermal resources.

Since 2005, over 160 geothermal power projects have been built adding an additional 4 GW to electricity grids across the globe. Many countries are expecting that the threat caused by climate change will increase recognition and the awareness of the value and opportunities of geothermal power as a base load and sometimes flexible source of renewable energy. These projects and countries are on every continent and range from small island nations to large economies like China and the United States.

Figure 1.1.2. **Geothermal Power – Announced Planned Capacity Additions & Targets 2014** (GEA 2015)



If all countries follow through on their geothermal power development goals and targets the global market could reach 27-30 GW by the early 2030s, and the World Bank estimates that as many as 40 countries could meet a large proportion of their electricity demand through geothermal power. However, it is estimated by GEA that communities and governments around the world have only tapped 6,5% of the total global potential for geothermal power based on current geologic knowledge and technology. (Geothermal Energy Aassociation, Benjamin Matek, 2015).

Significant growth is expected in the global geothermal power industry over the next five years, due to construction of power plants in Kenya and Ethiopia with a capacity greater than 100 MW. In comparison the average size of a geothermal power plant in the United States is about 25 MW.

“Ukraine has already taken important steps towards energy sector reforms, but achieving the full potential for an energy revolution will require a greater policy focus on developing energy efficiency in the building and industry sectors and modernising district heating systems,” IEA Executive Director Maria van der Hoeven said in Kiev at the launch of Ukraine 2012 Energy Policy Review. “The country must make deep regulatory reforms to foster effective competition, alongside a progressive move towards market prices to attract investment to develop the sector.” In addition, energy use and demand is growing in Ukraine and is projected to increase by 72 percent through 2035, according to the EIA. By utilising geothermal resources, Ukraine is able to use an important and valuable opportunity to meet needs with a sustainable form of energy, particularly in the western part of the country.

In Ukraine there is a significant geothermal potential especially regarding heating, but the resources are still in the early stages of exploring and assessment. Experienced international companies in the renewable sector are also showing interest in developing Ukraine’s renewable resources in cooperation with domestic stakeholders. These companies are partnering with domestic companies, bringing local understanding to the project as well as making development more feasible and it is highly likely that there are several opportunities regarding harnessing geothermal resources in Ukraine.

1.2. Renewable / Geothermal Policy – Options and Instruments

Growing Importance of Geothermal Policy

It is recognised that renewable energy, including geothermal energy, plays an important role in the transition towards greater energy security and has an impact on economic benefits and safety, reduction of greenhouse gas emissions, enhancing technology diversification, hedging against fuel price volatility, strengthening economic growth and employment, promoting rural development and reducing poverty by access to electricity.

Global trends are also indicating a growing commitment to renewable energy, in developed and developing countries, both regarding specific policy instruments and flow of investment in that sector. The growth of renewable energy in developing countries has been outstanding in many cases and linked to similar growth in related services and manufacturing industries. As an example, Brazil, China and India were among the top 10 countries in the world 2009 when it comes to investment in sustainable energy with a combined amount of 44,2 billion USD, or 37% of the total investment in the sector. (Bloomberg New energy Finance, 2010)

Price Related, Quota and Auctions Policies

Both developed and developing countries have used different types of policy and implementation tools to support renewable energy development and the renewable energy market is in general, a policy-driven market.

Since the 1970s developed countries have been designing and implementing different types of price- and quota based mechanisms to promote renewable energy development. For example, the United States implemented its first feed-in tariff policy (FITP) in 1978 and a quota mechanism (RPS) from 1983. Germany was the first European country to introduce a feed-in tariff (FIT) 1990, and many European countries have familiarity with either price- or quota-based mechanisms. The United Kingdom, introduced competitive tenders during the 1990s.

Developing countries also have a history of designing and implementing policy and instruments to promote renewable policy. India was the first country to introduce some type of special tariff or FIT in 1993, followed by Sri Lanka in 1997, and Brazil and Indonesia in 2002. Quota systems have been less popular in the developing world, and for example an exact RPS, a quota or target[1] has only been introduced by a few countries, including Chile from 2008, Poland from 2005 and Romania from 2004. Competitive schemes or auctions in the developing world are less common, but some countries have or are now testing their effectiveness e.g. Argentina, Brazil, China, Peru, Thailand, and Uruguay. FITPs are now being implemented in 49 countries around the world and are often stated as the most effective policy for attracting private investment in the renewable energy / geothermal sector. Many developed and developing countries, however use quota based systems, including RPSs and auctions e.g. Brazil, Chile, China, France, Poland, Sweden, the United Kingdom, and the United States. (WB, 2012).

Financial Related Policy

Financial related policy has also been used, including fiscal and financial incentives and a range of other supplementary measures to stimulate investments in the renewable energy sector. All these measured have been adopted in parallel to price and quantity setting instruments in both developed and developing countries. (WB, 2012).

Iceland has used financial incentives to promote geothermal development for about 50 years, and it has been an important policy instrument to increase investments and facilitate the operation of geothermal district heating networks with success, without using other price related policy instruments for the sector. This has been successfully implemented for district heating both in cities and smaller municipalities in Iceland, in areas with both limited and abundant geothermal resources.

[1] A proportional obligation is imposed on utilities or retail companies, and the price is competitively determined by the market.

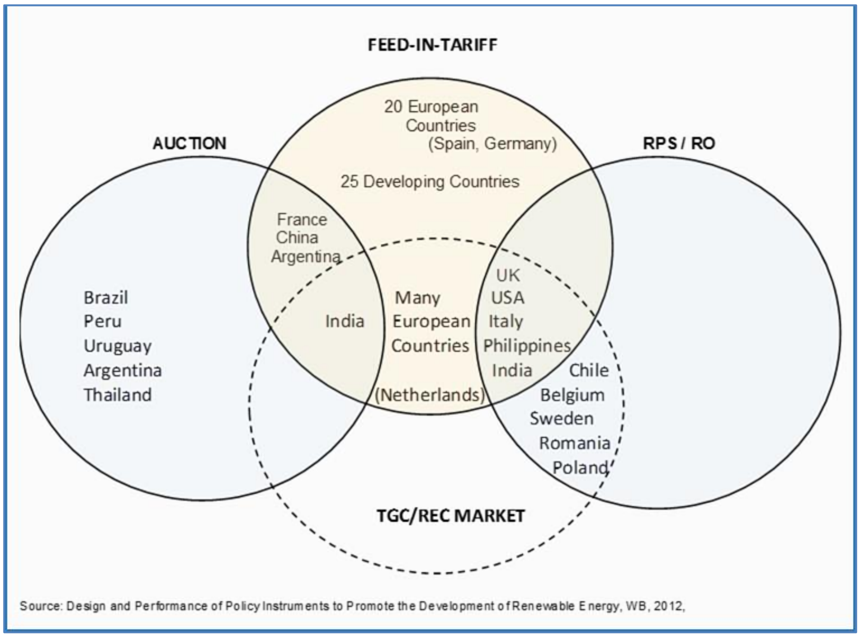
Emission Certificates / Tax Policy

A growing number of policies that indirectly promote renewable energy are known as cap-and-trade programs. The system uses a ceiling on the emissions of covered entities, issues allowances or emission certificates, and promotes their trading to generate a market price for emissions. This system can also be implemented through a tax policy. The cap-and-trade schemes have been implemented in many developed countries, e.g. the United States as the Regional Greenhouse Gas Initiative and as the Emissions Trading System (EU ETS) in 28 European Union countries. Some developed countries have also been applying carbon taxes since the beginning of the 1990s, e.g. the Netherlands and the Scandinavian countries, and recently the Canadian province of British Columbia. As of 2012, no developing country has formally implemented a greenhouse gas cap-and-trade scheme or a carbon tax. (WB, 2012).

Trends in Renewable / Geothermal Policy

In 2012 there were 31 developing countries that have introduced some type of price or quantity-setting instrument to increase the share of renewable energy electricity generation, 28 have opted for an FITP, and only a few have introduced an RPS or use auctions e.g. Brazil, Chile, China and Poland. Some countries have also made important policy shifts, and many are now also using both price- and quota based instruments.

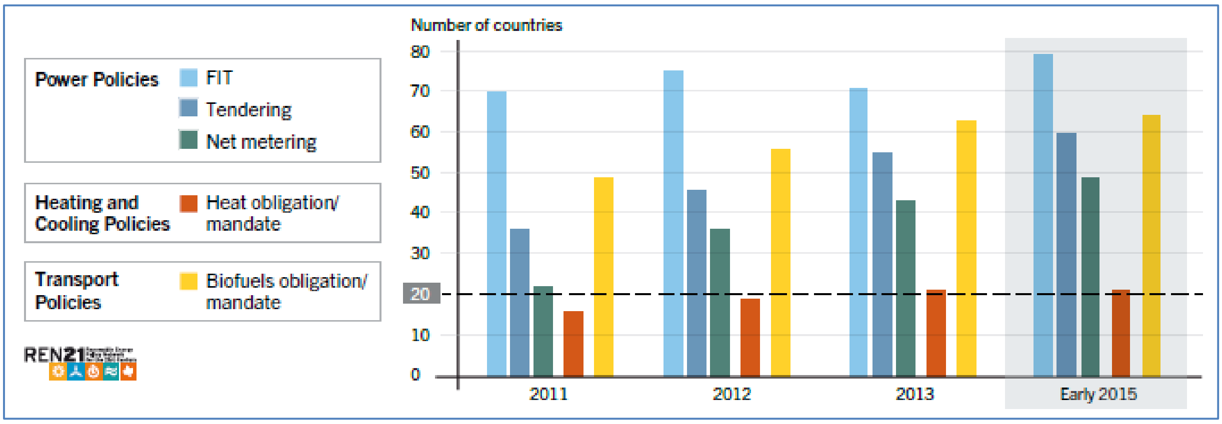
Figure 1.2.1. **Use of Renewable Energy Policy Instruments**



The policy structures of choice in various developed and developing countries in 2012 can be seen in figure 1.2.1 and 1.2.2. It shows the increasing acceptance of renewable energy policy tools by some of these countries as well as changes.

Even though, developing countries (middle income) have steadily adopted economic incentives such as FITPs, recent trends reveal that upper-middle income countries have started to introduce competitive mechanisms including renewable portfolio standards and auctions. (WB, 2012).

Figure 1.2.2. **Number of Countries with Renewable Energy Policy, by Type, 2011 – 2015**



Source: Renewables 2015, Global Status Report

Table 1.2.1. **Trend in Global Renewable / Geothermal Policy**

Year	FITP	RPS / REC	Auction
1970s	USA (PURPA) 1978		
1980s		USA	
1990s	Germany(90), Italy (92), Many EU Countries, India (93), Sir Lanka (97),	Italy (1999)	UK (1990)
2000-05	Brazil, Indonesia (2002), Nicaragua (2004), Turkey, Ecuador, China (2005)	UK (2002), Belgium, Austria, Japan, Sweden, Canada, Poland	China (2003)
2006-10	USA (different states from 2006), Argentina (2006), Philippines, Kenya, S-Africa (2008), 11 developing countries, Italy (2007-8), UK (2010)	Chile, Romania, Philippines (2008)	Brazil (2007), Peru (2008), Uruguay, Thailand, China (2010), India (2010)
Sources: (WB, 2012)			

ESMAP, has estimated the global growth of the geothermal sector until 2030. It will continue to grow to cumulated capacity of up to 25 GW, as can been seen in figure 1.2.3. It is estimated by ESMAP that based on information on currently planned projects and those that are actually under construction, by the year 2020 worldwide geothermal power capacity (from geothermal resources only) is expected to grow to 18 GW.

It is also stated in the report that countries in" Latin *America like, Mexico, Costa Rica, Nicaragua, and El Salvador are likely to continue developing new geothermal power projects with a total added capacity of 500 to 1.500 MW by 2020. Other countries (e.g., Peru, Chile, and Argentina) might start developing their first projects before 2020. Guatemala, Honduras, Panama, Colombia, Ecuador, Bolivia, and several Caribbean island states, including Cuba and Haiti and Dominica, also offer good prospects.*

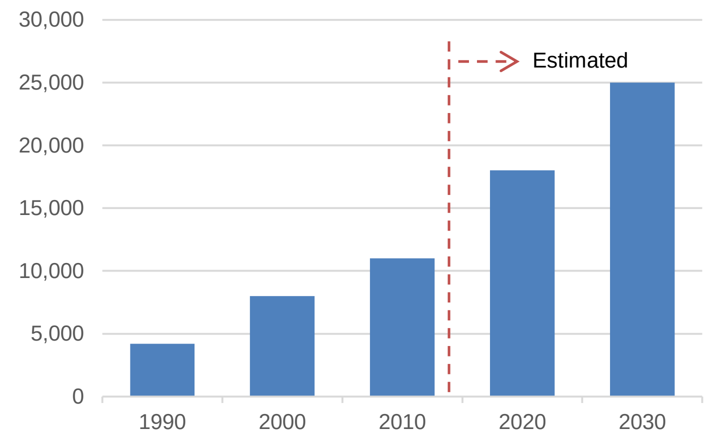
Looking to 2050, significant additions in installed capacity can also be expected in the following countries and regions:

• Pacific Asia: Malaysia and Papua New Guinea.

• Africa: Tanzania, Eritrea, Sudan, Somalia, Malawi, Zambia, Burundi, Rwanda, Uganda, Democratic Republic of Congo, Mozambique, Madagascar, Comoros and Mauritius, and several North African countries.

• Latin America: Guatemala, Honduras, Panama, Colombia, Ecuador, Bolivia, and several Caribbean island states, including Cuba and Haiti". (ESMAP, 2012).

Figure 1.2.3. **Estimated Global Geothermal Capacity 1990 – 2030**



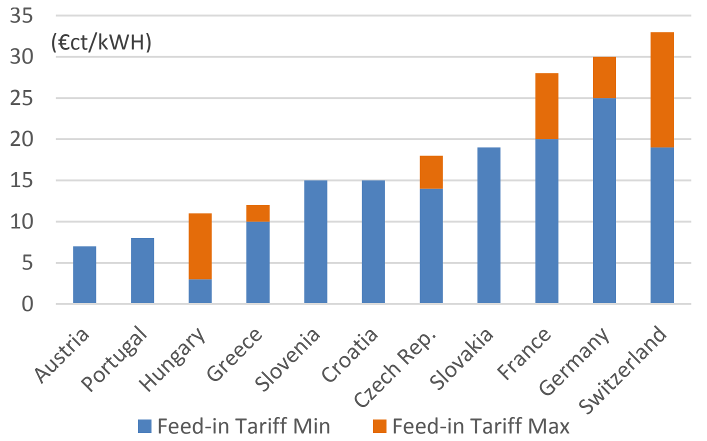
Source: ESMAP, 002/2012

1.3. Support for Renewable Energy in the European Union

1.3.1. Operational Support

Support for geothermal electricity has been given in various forms of public policy mechanisms. Generally, the support can be in the form of **1) investment support** (*capital grants, tax exemptions or deductions on the purchase of goods*) and/or **2) operating support** (*price subsidies, renewable energy obligations with green certificates, tender schemes and tax reductions on the production of electricity*). (EGEC, 2013).

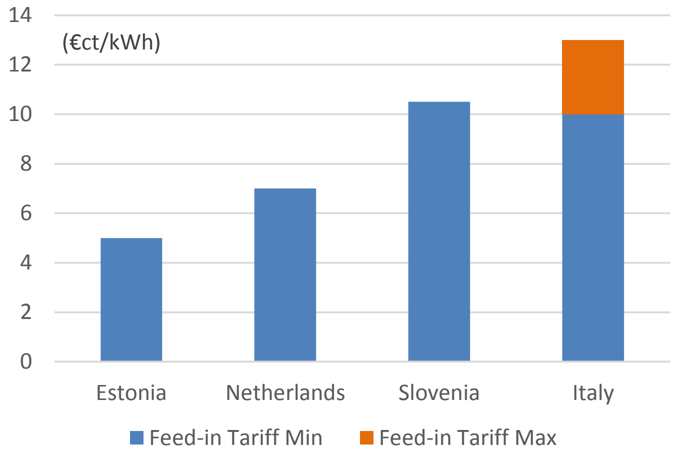
Figure 1.3.1.1. **Feed-in Tariff System in EU Countries**



Source: EGEC, 2013

For over 10 years a few EU member states have driven the development of renewable energy and invested in research and development, building demonstration plants, and finally in supporting deployment of renewable energy equipment. Some of these EU countries, (e.g. Germany, Denmark and Spain) now have major renewable energy companies, operating globally. The growth of these companies was in part based on support for renewable energy, paid by domestic energy consumers paying slightly higher energy bills to cover the extra cost of developing the renewable energy. The policy of the EU is that this kind of growth and commitment must occur across all member states, if they are to reach their targets. (Commission, 2011).

Figure 1.3.1.2. **Feed-in Tariff Premium System in EU Countries**



Source: EGEC, 2013

The policy on supporting renewable energy can be found in the report Review of European and National Financing of Renewable energy where it is stated: "*The Commission finds that the short term costs of investing in electricity grid infrastructure are far outweighed by the benefits of creating an integrated European electricity market capable of sustaining a future de-carbonized electricity sector. The urgency of the need for action has been highlighted most recently in the IEA's 2010 World Energy Outlook.*

Whilst energy infrastructure has traditionally been funded by the private sector or national governments, European intervention and funding for infrastructure projects of European importance can help create a more efficient energy network and create significant cost savings for Europe. Similarly, European intervention to promote efficiency in the achievement of the renewable energy targets could save billions of Euros". (Commission, 2011).

1.3.2. Financial Support

Regarding financial support to geothermal heating, investment requires capital expenditure to generate production and revenues to cover costs.

Geothermal heating has in general low operating costs but high capital costs as the structure is capital intensive. The financing structure therefore has to take this into account.

To increase the development and use of geothermal heating and meet the investment gap, efforts can be directed through direct or indirect support, to

- lowering the cost of capital by reducing technology, plant and construction costs, or
- by raising more revenues through support measures, to cover costs.

Table 1.3.2.1. **Financial Support to Geothermal Heating in EU countries**
Investment Grants France (Fonds chaleur renouvelable) for collective office buildings Germany, Hungary, Greece, Poland, Romania, Slovakia and Slovenia, Spain.
Feed-in tariff Italy (Conto termico), Netherlands (SDE+) and UK (Renewable heat incentive).
Tax rebate/VAT reduction France: (VAT reduction for district heating, rebate on tax on revenues for individual housings), Hungary, Italy, Netherlands
Low or zero interest loans France: (for individual housings), Germany, Hungary, Netherlands, Poland, Slovenia and Spain.
CO_2 tax Finland, Sweden and Denmark. *Sources:* (EGEC, 2013)

Table 1.3.2.2. **Types of Financial Support to Geothermal Heating in EU Countries**

Reducing capital costs	**Reducing capital costs through revenues**
Grants: taxpayer funded aid, often for innovative demonstration projects. **R&D grants**: grants, often for research into innovative, immature technologies. **Public loans**: offer cheaper access to capital due to public funds used to bear greater risk. Particularly useful for small and medium sized enterprise (SME) with less access to capital. **Equity funds**: private medium risk investors, expecting relatively higher returns, for later stage of projects and more mature technologies, and investment periods of 3-5 years. **Venture capital**: private equity investment for financing technology innovation, with active involvement of the fund managers in the project. **Mezzanine funds**: loans that take more risk than normal (“senior”) debt but less risk than equity; expecting relatively short term and variable but higher return. **Guarantees**: offer of compensating payment to a lender or an investor in case of payment default by a project developer. **Contingent grants or loans**: support that is converted into a loan when a project turns out to be successful, or treated as a grant if the project encounters financial difficulties.	(starting point: energy prices covering costs) **Regulated prices**: feed-in tariffs, (FIT) giving energy producers a fixed financial payment per unit of electricity or heat produced from renewable energy sources. Often fixed for 10-20 years, differentiated by technology and phased out. **Regulated premiums**: feed-in premiums, (FIP) giving energy producers a fixed financial payment per unit of electricity or heat produced from renewable energy sources for the green value; the producer receiving the market price for the physical energy. **Quota/certificates**: impose a minimum share or quota of renewables in the electricity, transport fuel or heating fuel mix, which can be met either through physical production (common for biofuels) or through purchasing “green certificates”, virtual, rather than physical energy. The producer of the green energy is paid for the green certificates by the supplier or other facing the obligation. **Fiscal incentives**: tax exemptions or tax credits for investments in renewable energy projects. **Tenders**: A government call for tender for a renewable energy project, often specifying the capacity/ production/ technology/ site. The winner is generally granted a long term power purchasing agreement at a competitive price.

Table 1.3.2.3. **NATIONAL SUPPORT FOR RENEWABLE ENERGY**

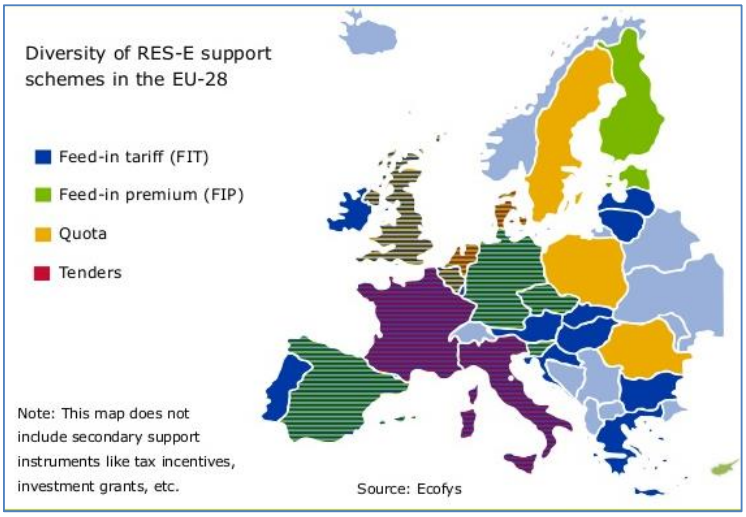
EU Member States' use of different instruments for electricity, heating and transport (biofuels).

		Austria	Belgium	Bulgaria	Cyprus	Czech Rep.	Germany	Denmark	Estonia	Spain	Finland	France	Greece	Hungary	Ireland	Italy	Lithuania	Luxembourg	Latvia	Malta	Netherlands	Poland	Portugal	Romania	Sweden	Slovenia	Slovakia	United Kingdom
Sources:		AT	BE	BG	CY	CZ	DE	DK	EE	ES	FI	FR	GR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
Electricity	FIT	x	x	x	x	x	x		x	x		x	x	x	x	x	x	x	x	x			x			x	x	x
	Premium					x		x	x	x											x					x		
	Quota obligation		x													x						x		x	x			x
	Investm. grants		x		x	x					x		x	x			x	x	x	x								
	Tax exemtions		x							x	x		x						x		x	x			x		x	x
	Fiscal incentives			x			x		x											x	x	x				x		
Heating	Investm. grants	x	x	x	x	x	x		x		x		x	x	x		x	x	x	x	x	x	x		x	x	x	x
	Tax exemtions	x	x					x				x	x			x	x				x				x			x
	Fiscal incentives			x			x		x			x											x					
	Premium											x																
Transport	Quota obligation	x		x	x	x	x	x		x	x	x			x		x	x	x		x	x	x	x		x	x	x
	Tax exemtions	x	x		x	x	x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x

Sources: SEC (2011) 131 Review of European and national financing of renewable energy in accordance with Article 23 (7) of Directive 2009/28/EC

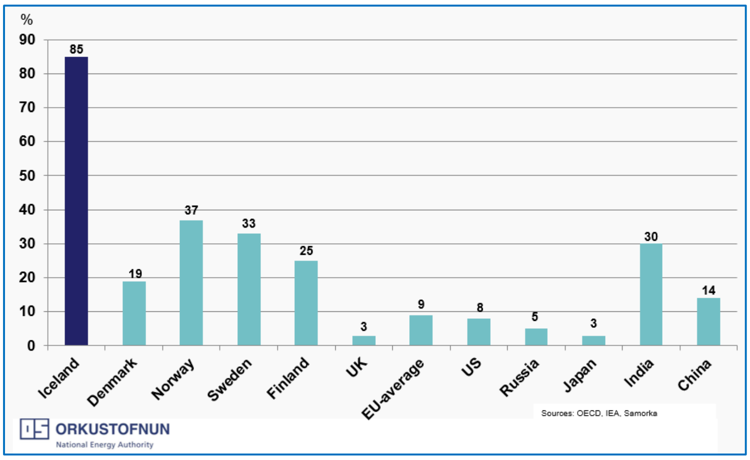
The choice of support measures to help reduce renewable energy costs depends on the technology and project development, and different forms of project risk, technology, construction, regulatory and in particular on the maturity of a project or technology. When technology and projects are capable of being deployed but are not yet competitive, support tends to shift from capital support to operating support, but there is a range of tools, depending on circumstances.

Figure 1.3.2.1. **The main RES-E Support Scheme in Europe**



Looking at national support schemes in Europe, it is interesting how EU member states use a range of different instruments. The use of multiple instruments can be appropriate, given the different economic status of different technologies, in terms of maturity. (Commission, 2011). When looking at the share of renewables in total primary energy use, it can be seen that Iceland has the highest share, with 85%, and the average for Europe is 9%, USA 8%, Japan 3% and China 14%. The high share of renewables in total primary energy used in Iceland, is not only due to great potential of renewable resources, but also because of long term priority and sustainable policy towards harnessing these renewable resources, through hydro and geothermal programs and projects generating electricity and geothermal district heating. This policy has created savings for businesses and homes, increased energy security and reduced greenhouse gas emissions. It has also created economic opportunities and savings and improved quality of life.

Figure 1.3.2.2. **Share of Renewables in Total Primary Energy use**



1.4. Global Renewable and Geothermal Policy – Lessons Learned

On a global level, diverse types of renewable and geothermal policy tools, implementations and incentives have been used, individually or in parallel, and policies have changed over time both in developed and developing countries. (WB, 2012).

1. An independent policy based on assessment and conditions in each country is important.
When designing and choosing policy, administration, regulation and implementation tools, it is important to design this policy based on overall assessments and evaluation of actual conditions, challenges and possibilities in each area e.g. type of market, supply, demand, volume, risks, organisational and administrative capabilities, etc.

2. Policy system in right structure is critical for policy success.
Policy success depends on the existence of basic legal and regulatory conditions, as well as organisational and administrative efficiency. Legal framework for grid connection, resources, land use and distribution of licences and rights must be prepared and implemented, so granting permits and implementation of projects will not be stuck in bottlenecks.

3. Volume is not the same as efficiency.
Volume based renewable energy policy may not necessarily be efficient. Even if the policy combination succeeds in prompting investments that achieve capacity targets, the economic efficiency (cost per unit of benefits) may be low.

4. Importance of coordination and harmony of policy tools.
The coordination of policy instruments has the potential to create complex interactions and unforeseen effects. Policy makers have to consider the possibility among policy and regulatory tools that the combined impact may result in various and inefficient outcomes. It is important that individual policies are coordinated with the wider set of framework conditions that impact the energy market.

5. Policy and regulatory design is a dynamic process.
Over the year’s countries have tried different types of policy tools to support renewable policy and many are now using both price and quantity setting mechanisms. Feed-in tariff policies (FITPs) have required successive adjustments and attracting private investment while at the same time reducing minimal payments. Policy changes should however be organised through systems that allow participants to manage the risks in order to maintain a certain level of regulatory stability and security.

6. Competitive renewable and geothermal policy depends on a number of key factors.
Well-designed policy does not always create a competitive and successful renewable or geothermal sector if various critical factors are not carefully included in the system, e.g. integration of renewable energy into the transmission infrastructure and rules on transmission access and connection.

7. Support schemes are important and valuable
Support schemes are crucial tools of public policy for geothermal to compensate for market failures and to allow the technology to progress along its learning curve. By definition, they are temporary and shall be phased out as this technology reaches full competitiveness;

2. Development, Competitiveness and Risks of Geothermal Projects

2.1. Risk and Financing of Geothermal Projects

It is generally recognized that geothermal exploration and development is a high-risk investment, due to uncertainty associated with a natural resource that cannot readily be observed or characterized without relatively large expenditures for drilling.

The long development time typically required to move a project from preliminary exploration through development to construction is an additional risk factor and many large geothermal projects (50 MW_e) have taken 10 years or more to develop. This is a long development and construction time for investment, with the added risk in the early phases of the project. From figure 2.1.1 it can be seen that the risk profile is greatest during the preliminary surveying and exploration phases, but in that part of the project the cost is comparatively low.

Figure 2.1.1. **Risk, Bankability and Cost of a Geothermal Project**

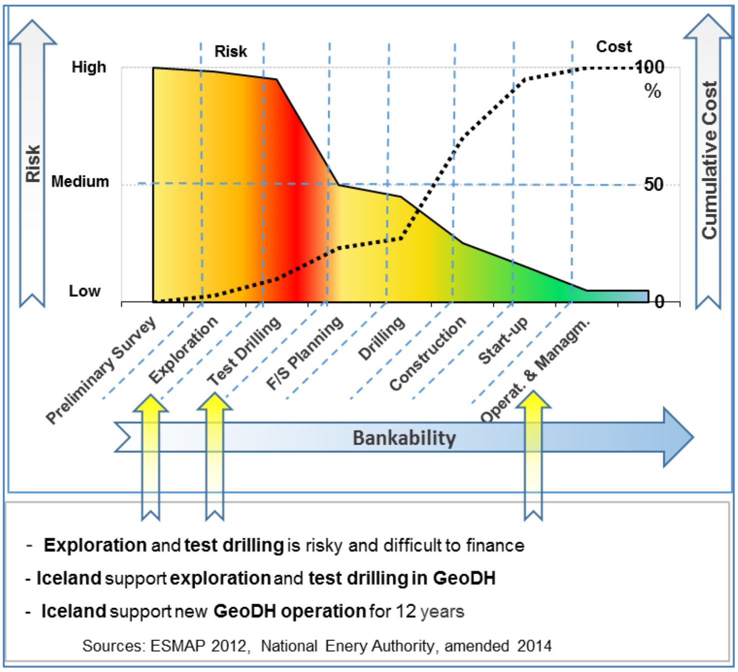
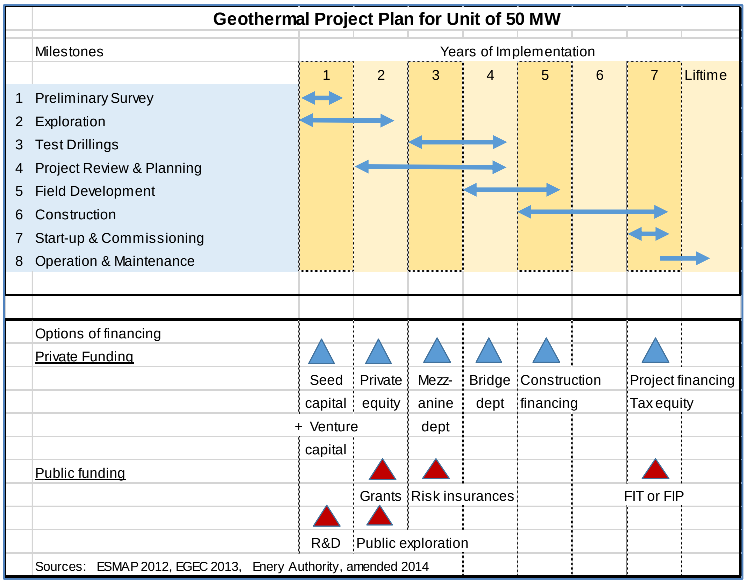


Figure. 2.1.2. **Geothermal Project Plan and Options of Financing**



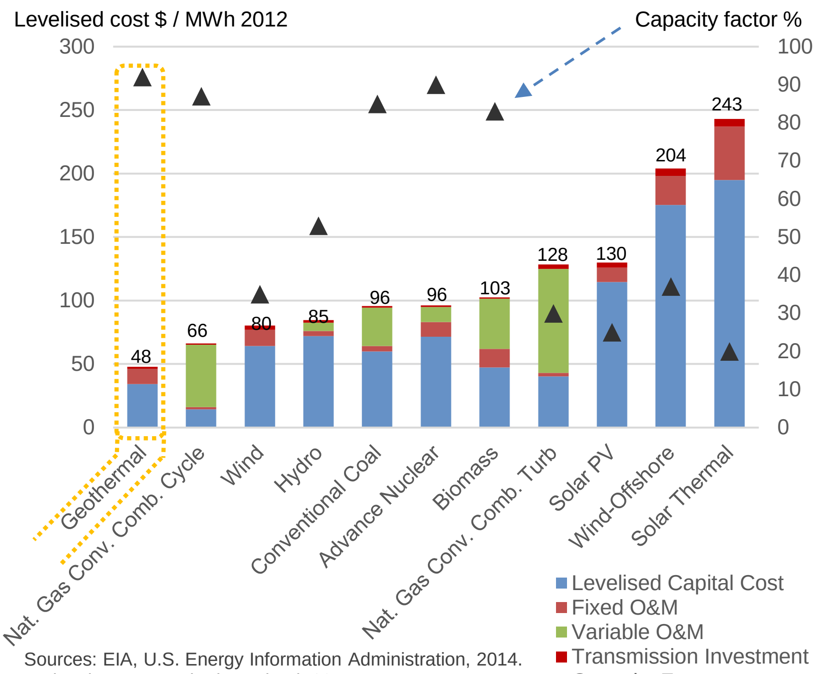
The test drilling phase requires a greater level of expenditure, although there is still a high level of uncertainty and risk involved and this step is frequently the biggest barrier for further development of the project. Therefore, numerous international aid agencies and governments around the world have recognized this as a barrier to the development of geothermal projects. Risk mitigation funds (private and public) have been established in some countries to assist projects through this exploration phase. In addition, more capital has also been spent on R&D in geothermal projects in recent years. Generally, funding is only committed to the test drilling part of project development if the investor believes there is an adequate financial return on investment ROI (in terms of a percentage of the committed capital per annum). In addition, risk mitigation funds (grant scheme) improve the predicted ROI by reducing the amount of capital invested by the investor. Usually, maximum ROI is only achieved if wells produce at or above their predicted outputs, and this result relies on high quality exploration methods and interpretation. Several mechanisms for supporting investments in geothermal energy exist around the world and at a national level. These financial mechanisms (public and private) can address different project stages and can come from different sources. In Iceland, public grants at early stages have helped many projects.

2.2. Competitiveness of Geothermal Technology – Comparison

When comparing total cost of electricity, levelised cost of electricity (LCOE) is often used as a classical summary of the overall competiveness of different generating technologies. It shows the per-kilowatt-hour cost (in real dollars) of building, maintaining and operating a generating plant over an assumed financial lifetime. Key elements of LCOE include capital cost, fuel cost, fixed and variable operations and maintenance (O&M) cost and an assumed utilization rate for each plant type.

However, cost factors vary between technologies, as cost structures are different (e.g. wind and solar have no fuel cost, etc.), and across regions, depending on overall framework conditions. This cost can also vary through time as technology changes. Additional items like, projected utilisation rate, resource mix and capacity value, have also an impact on decision making in each region.

Figure 2.2.1. **U.S. Average Levelised Cost of Electricity and Capacity Factor for Plants, entering services in 2019**



Sources: EIA, U.S. Energy Information Administration, 2014. National Energy Authority Iceland, 2014

In figure 2.2.1 the LCOE values and capacity factors, are shown as average numbers for each utility-scale generation technology in the USA and are calculated based on a 30-year cost recovery period, using a real after tax weighted average cost of capital (WACC) of 6,5%. However, in reality, the cost recovery period and cost of capital can vary by technology and project type. As the numbers are U.S. national average numbers for the electric generation, the numbers can be different between states and regions.

According to figure 2.2.1 the geothermal sector is the most competitive one, in comparison to other sectors as the levelised cost is only 48 $/MWh and next is natural gas-fired conventional combined cycle with 66 $/MWh, or 38% higher. Wind is estimated as 80 $/MWh or 67% higher, hydro is estimated on 85 $/MWh or 77% higher and other options beyond. (NEMS, US National Energy Modelling System, 2014).

From the U.S. comparison of LCOE, the competitiveness and low cost of geothermal generated electricity is further outlined, which is an important and valuable message and opportunity for energy policy formulation and policy makers, in various regions and countries, including the Ukraine.

2.3. Cost and Structure of Geothermal Projects

Geothermal Electricity

In Europe it is estimated that the capital costs for geothermal generation per MW_e range between 3 and 12 million euros and it can vary depending on environment and technology. The capital costs are also dependent on drilling, e.g. the number of wells required, the depth of drilling and the geological risk.

Figure 2.3.1. **Capital Cost of Geothermal Electricity**

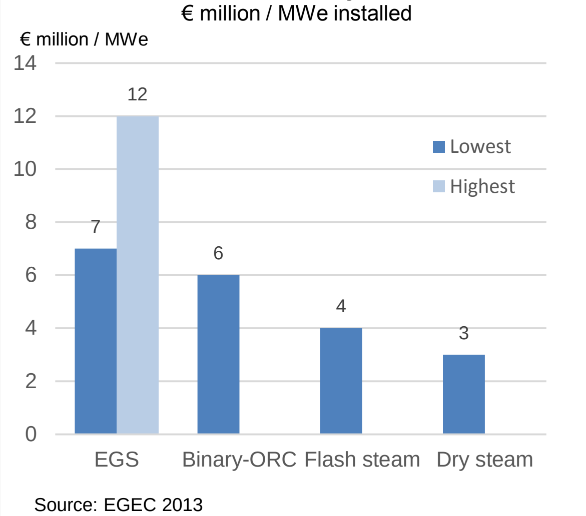
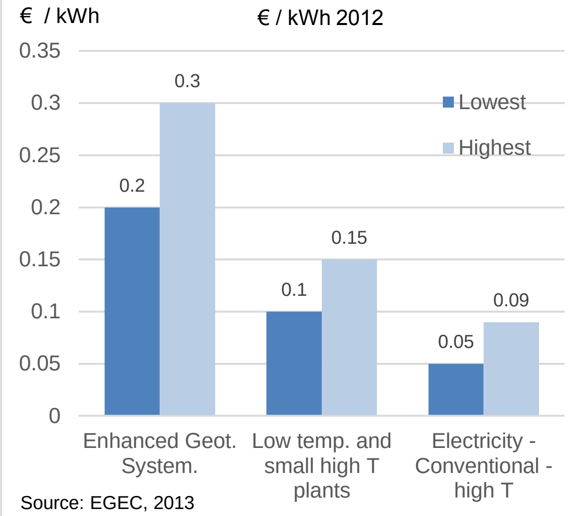


Figure 2.3.2. **Levelised Cost of Geothermal Electricity**



Geothermal electricity is competitive with newly built conventional power plants in Europe, where high-temperature hydrothermal resources are available. However, there are barriers for both geothermal electricity and heating sectors, sometimes in the form of unfair competition with gas, coal, nuclear and oil, in the form of prices, taxes or support, which is the reason for support schemes for geothermal.

Figure 2.3.3. **Recent US Geothermal Cost Trends**
Installed Cost per MW for US Utility-Scale Geothermal Projects (2009-2012)

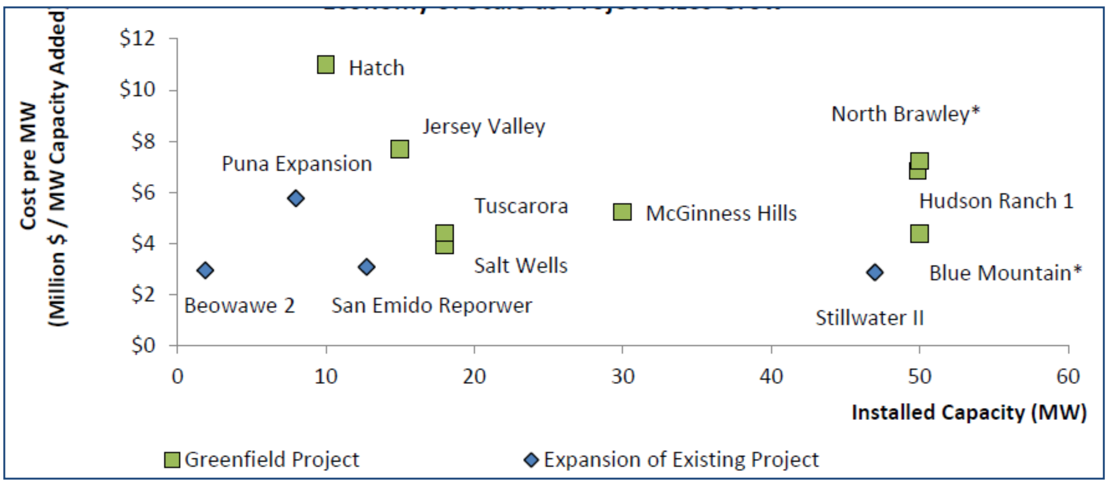
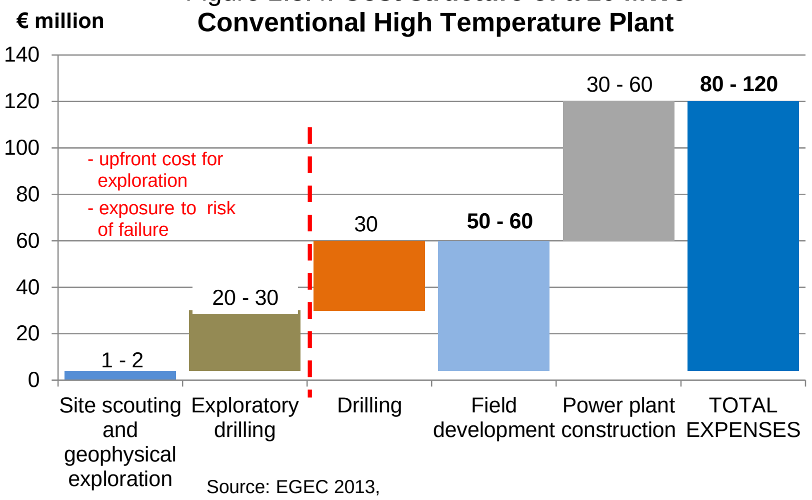


Figure 2.3.3. shows cost per MW ($/MW) of recent U.S. geothermal installations with each project's overall capacity, based on publicly available data from the U.S. Treasury's, grant database as of February 19, 2013, based on approved total "cost basis" under the Internal Revenue Code (IRC). As this is the cost base, some other elements are excluded such as transmission line upgrades, but this is the only publicly available data that can be compared across projects. As can be seen, there is a similar cost structure per MW for some of the projects but different for others, due to different external factors e.g. geothermal resources, and different for greenfield and expansion[2] project, etc. (Energy, 2014)

[2] Greenfield project = new project. Expansion Project = extension of existing project.

The levelised costs of geothermal power plants vary greatly. New plant costs in some countries are highly competitive (e.g. 50 €/MWh for high-temperature resources). This cost is largely depending on the main cost components such as drilling which can be 30% of total cost for high-temperature plants, and 50% for low temperature and even 70% for EGS. However, the high capacity factor for geothermal (>90%, the highest of all energy technologies including nuclear) mitigates the capital intensity to make geothermal technologies competitive.

Figure 2.3.4. **Cost structure of a 20 MWe Conventional High Temperature Plant**



Source: EGEC 2013,

On average in Europe, the capital cost for geothermal power generation range between 4 and 7 million euros per MWₑ, but is also dependent upon the specific site such as number and depth of geothermal wells and technology. Deployment of geothermal energy will require contribution and cooperation of private and public funding, but the engagement of the private sector is crucial. Nevertheless, there are financial barriers to develop geothermal power projects in many places of the world, which need to be overcome through public support at the beginning of geothermal development.

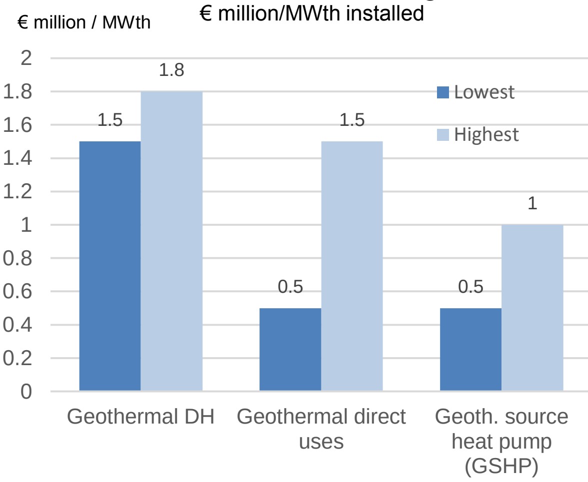
2.4. Geothermal District Heating

2.4.1. Cost Structure of Geothermal District Heating

Geothermal District Heating

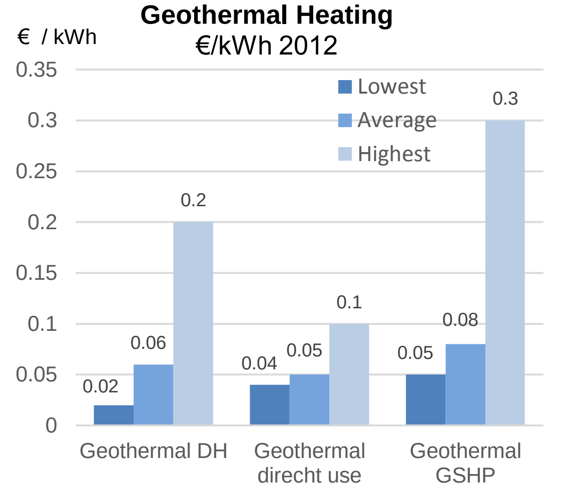
In most cases, geothermal district heating projects face the same issues as geothermal power plants. Furthermore, geothermal heat pumps can also be considered as a capital intensive technology in comparison with other small scale applications. (EGEC, 2013).

Figure 2.4.1.1. **Capital Cost of Geothermal Heating**
€ million/MWth installed



Source: EGEC, 2013

Figure 2.4.1.2. **Levelised Cost of Geothermal Heating**
€/kWh 2012



Source: EGEC, 2013

Geothermal heat is also important and competitive for district heating, where a resource is available, especially where a district heating system is already in place. Geothermal heat can also be competitive for industrial and agriculture applications. Geothermal heat pumps can also be profitable, in comparison with fossil fuel heating systems.

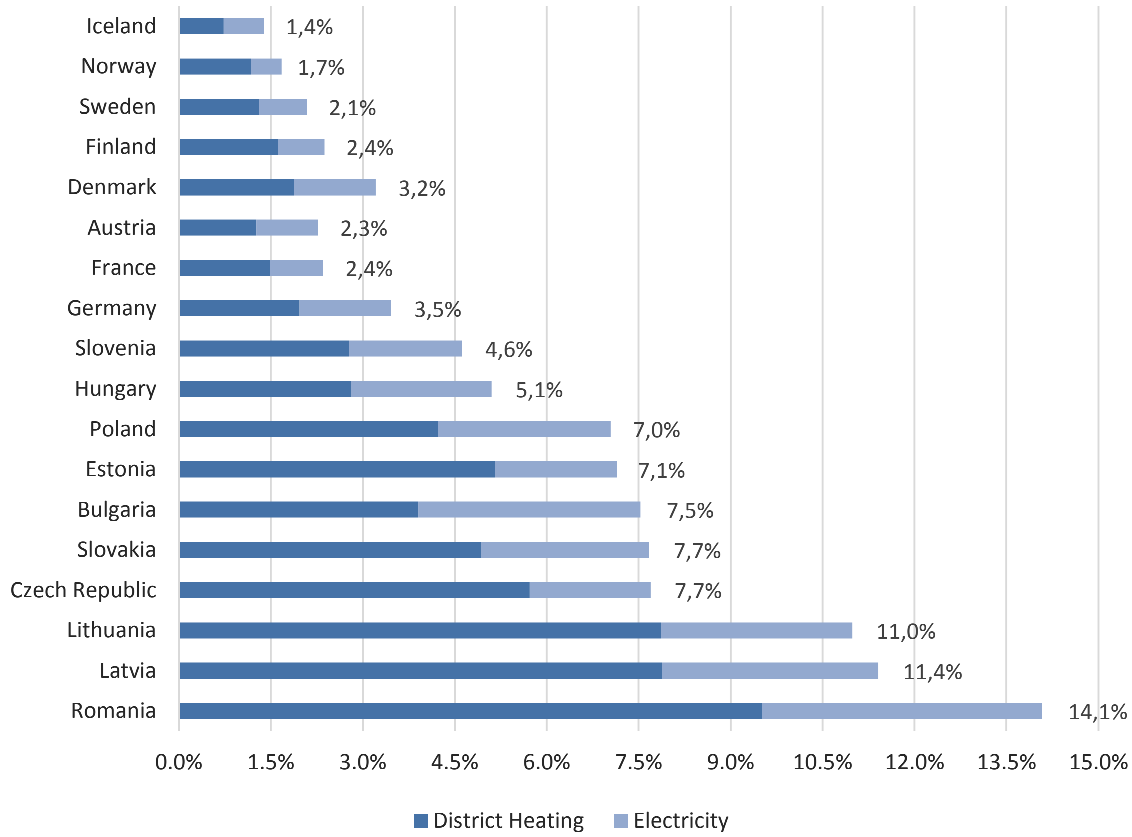
Geothermal heat may be competitive for district heating where a resource with sufficiently high temperatures is available and an adaptable district heating system is in place. Geothermal heat may also be competitive for industrial and agriculture applications (greenhouses). As geothermal heat pumps can be considered a mature and competitive technology, a level playing field with the fossil fuel heating systems will allow phasing out any subsidies for shallow geothermal in the heating sector.

In many cases, geothermal district heating projects face the same issues as geothermal power plants, the need of capital and risk mitigation is therefore also valid for this technology. Moreover, notably because of the drilling, geothermal heat pumps can also be considered as a capital intensive technology in comparison with other small scale applications. Geothermal heating and cooling technologies are considered competitive in terms of costs, apart from the notable exception of EGS for heating.

In addition, an important barrier for both electricity and heating and cooling sectors is the unfair competition with gas, coal, nuclear and oil, which is the primary reason justifying the establishment of financial support schemes for geothermal.

If we look at the proportion of annual's salaries of people for buying district heating and electricity for 100m^2 household in Europe, we can see that Iceland is paying the lowest proportion for both district heating and electricity, and Romania is paying the highest.

Fig. 2.4.1.3 **The Proportion of Annual's Salaries of people for buying District Heating and Electricity for 100m^2 Household in Europe**

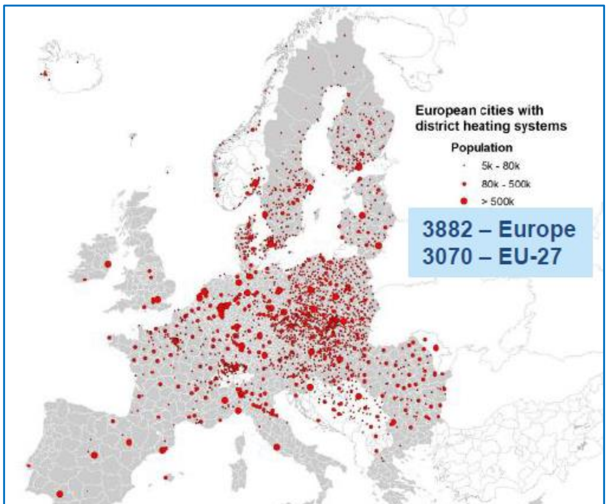


Source: Orkustofnun Data Repository: OS-2016-T006-01

2.4.2. Policy towards Geothermal District Heating in Europe

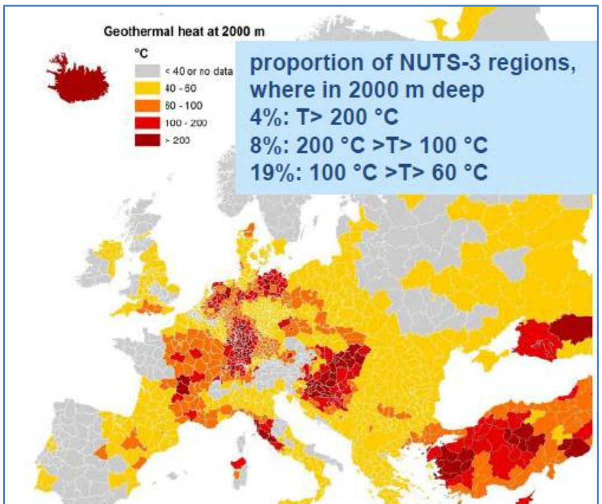
AEBIOM, EGEC and ESTIF, organizations representing the biomass, geothermal and solar thermal sectors respectively, addressed an open letter to the EU Heads of State and Government, 19th of March 2014. The letter states that "...Investing in renewables for heating and cooling will bring security of supply and more competitiveness, and could save EUR 11,5 billion per year, announces the industry. Over recent years, the lack of awareness and political support to renewables for heating and cooling has meant only modest market development in the sector. However, in view of the upcoming discussion of the European Council on EU climate and energy policies beyond 2020, there is a great opportunity to invert this trend." Dr. Guðni A. Jóhannesson Director General of the National Energy Authority of Iceland, also stated in the ERA NET Newsletter in May 2014 that, "It is important for policymakers and others to recognize the great opportunity regarding geothermal heating for savings for countries, as it is estimated that geothermal heating in Iceland is saving equal to 7% of GDP or 3000 US$ per capita or close to 1 billion US$ for the economy only for 2012.

Figure 2.4.2.1. ***Geothermal Cities with District Heating Systems***



Source: Heat Roadmap Europe 2050

Figure 2.4.2.2. ***Geothermal Heat at 2000 meters***



Source: Heat Roadmap Europe 2050

Untapped geothermal resources could significantly contribute to the decarbonisation.
According to Heat Road Map Europe 2050, untapped geothermal resources in Europe could significantly contribute to the decarburization of the district heating market as it has been estimated that geothermal district heating would be available to 25% of the EU-27 population. It has been estimated that 12% of the communal heat demand is from district heating and heat supply to district heating systems is 17% from power plants, 7% from waste, 3% from industrial heat, 1% from biomass and only 0,001% is coming from geothermal resources. According to Eurostat, about one third of the EU's total crude oil (34,5%) and natural gas (31,5%) in 2010 was imported and, 75% of that gas was used for heating (2/3 in households and 1/3 in the industry). Geothermal district heating therefore has potential possibilities to replace a significant part of imported oil and gas for heating households and industry. GeoDH consortium has proposed policy priorities towards such development which are: (GeoDH, 2014).

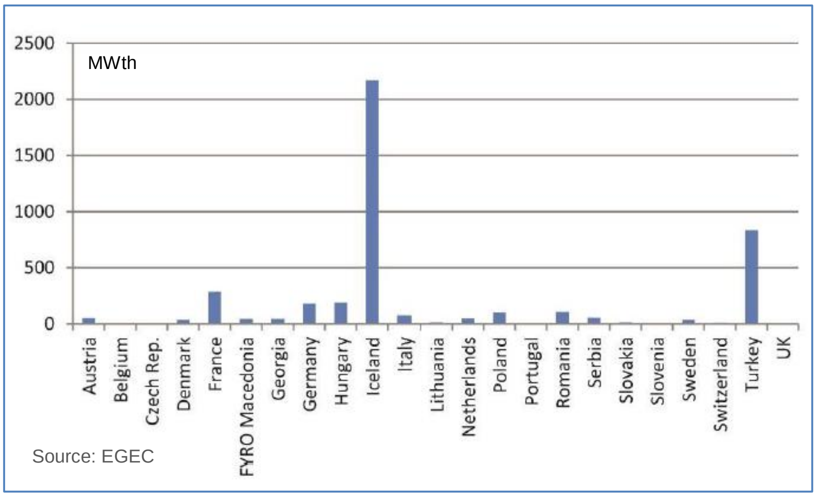
1. **Simplify the administrative** procedures to create market conditions, to facilitate development;
2. **Develop innovative financial models for geothermal district heating**, including a risk insurance scheme, and the intensive use of structural funds.
3. **Establish a level playing field**, by liberalizing the gas price and taxing green-house gas emissions in the heat sector appropriately.
4. **Train technicians and decision-makers** from regional and local authorities in order to provide the technical background necessary to approve and support projects.
5. **Increase the awareness** of regional and local decision-makers on deep geothermal potential and its advantages.

It is likely that all these elements could be similar in Ukraine, e.g. the possibility to use more geothermal resources in existing district heating systems, instead of oil, coal or gas, that would increase energy security, economic benefits and reducing CO_2.This general policy recommendation is also important.

Market Trends Towards Geothermal District Heating in Europe

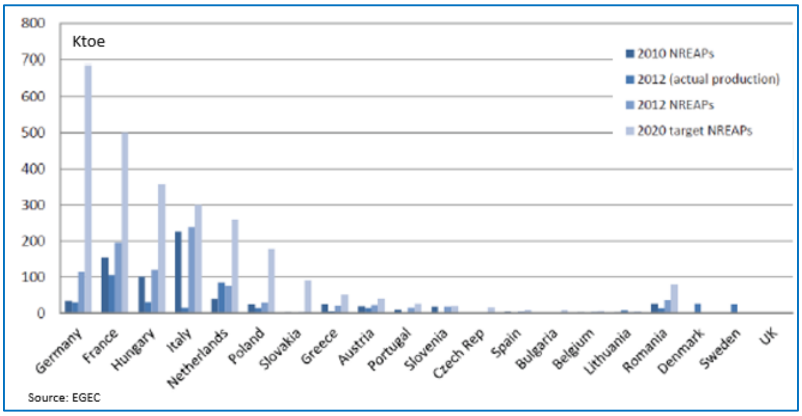
According to GeoDH there are around 250 geothermal district heating plants (including cogeneration systems) in Europe, total installed capacity is about 4,5 GWth and plants in operation in 2012-13 produced around 13 TWh/y for heating.

Figure 2.4.2.3. ***Installed Capacity per Country - 2014***



Within the European Union there are 162 geothermal district heating plants, with a total installed capacity around 1,3 GWth, producing some 4,3 TWh of heat, i.e. 366 ktoe in 2012. According to EGEC, the capacity will grow from 4,5 GWth installed in 2014 to at least 6,5 GWth in 2018. According to GeoDH, the main regions using deep geothermal wells include the Paris basin (France), Tuscany and Emilia-Romagna (Italy), Bavaria (Germany), the Pannonian basin (Hungary, Serbia, Romania, Slovakia, Slovenia and Croatia) and the doublet wells of Thisted in Denmark, which have been in operation for 30 years. (GeoDH, 2015).

Figure 2.4.2.4. ***Geothermal District Heating Potential in Europe, 2020 target***



In Europe there are over 5.000 district heating systems, representing about 12-15% of the European heat market, mainly located in Scandinavia, central and eastern Europe.

These district heating systems are mostly use fossil fuels and, to a lesser extent, waste, e.g. 80% of district heating systems in Germany are supplied by conventional combined heat and power (CHP), 76% by coal in Poland, 76% and 43% by natural gas in Italy and France respectively.

However, district heating is considered as a key technology to decarbonise the heat sector and reduce Europe's dependency on fossil fuels using renewable sources, including geothermal. The trend to adopt geothermal is clear, even in regions which may be recognised as being less favourable to operation.

The potential of geothermal for district heating is significant; however, the awareness of geothermal district heating technology is poor at present in many cases. There are several Eastern and Central European countries, such as Hungary, Poland, Slovakia, Slovenia, the Czech Republic, Romania, and Ukraine with geothermal district heating systems installed.

However, the potential is much larger. In other Eastern and Central European countries, including Bulgaria, the Czech Republic, Slovenia and Ukraine, there is both the need to convince decision makers and to adopt the right regulatory framework, but also to establish the market conditions for a development of thegeothermal district heating market. Several Western European countries have 2020 targets for geothermal district heating, of which Germany, France and Italy are the most ambitious. In order to reach these targets, simplification of procedures is needed and more financing required. (GeoDH, 2015).

2.4.3. Legal, Financial and Cost Structure of Geothermal District Heating Projects

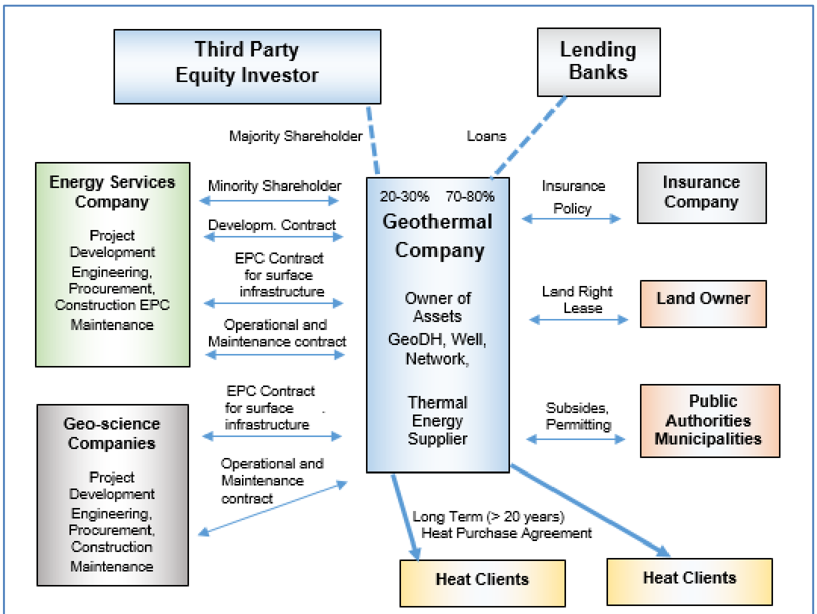
Legal and Framework Structure

Legal and financial structure and planning are main elements of geothermal district heating planning and risk assessment. However, risk assessments depend on each type of project which can be different based on location, regulation, technology, management, finance etc.

Nevertheless, there are also general similarities for such projects regarding legal and financial frameworks for geothermal district heating – as can be seen in enclosed figure 2.4.3.1.

A Geothermal Company (GC) financed by the equity investor (20-30%) and by bank by loans (70-80%), is established to centralise the assets, rights and operational agreements. This company signs long term (>20 years), heat purchase agreements with end users with a fixed charge (capacity charge) linked to kW of capacity subscribed, and a variable charge ("consumption charge") proportional to kWh supplied.

Figure. 2.4.3.1. **Legal and Financial Framework for Geothermal District Heating**



Sources: GeoDH 2014, B. Petursson National Energy Authority amended 2016

The company should also sign key contracts regarding engineering, procurement and construction and operating and maintenance, for both the geothermal well and the district heating network. The company also has to have insurance policies (civil liability, damage, geothermal resource risk if possible, etc.). Finally, the company has to secure land rights, permitting and subsidies with the land owners and public authorities or municipalities. (GeoDH, 2014).

Cost structure for Geothermal Heating

The risk characteristics of a geothermal heating project are different depending on the three stages of the projects, which are: 1. Exploration, 2. Drilling, and 3. Building, which is less risky.

In a calculation presented in a GeoDH paper from 2014, it is estimated that, *"a private investor who would be given the opportunity to invest 20 million Euros in the building, and receives a feed-in tariff of 90-96 Euros/ MWh would earn around 9-10% per annum on the 20 million € invested. If that investor financed two-thirds of this investment with debt, as is common practice for such investments, the return on equity can rise to 20%. This observation leads us to the conclusion that a feed-in tariff, such as is already available in the wealthier member states of the European Union, is sufficient to attract investment for the building and operation stage of a geothermal electricity generating plant, <u>if only the exploratory and drilling stages are completed</u>."* (Christian Boissavy, 2014).

It is therefore an important element of a geothermal heating project that there are options and possibilities of support from public authorities towards the exploration and the drilling stage of such a project. In the above mentioned paper it is recommended that the support should cover 75%-80% of the exploration and drilling cost if the project fails. This is especially important due to the risk of test drilling. In Iceland for example, the test drilling for such projects can be refunded by the Energy Fund if the test drilling is not successful. On average the electricity generating geothermal plants are considerably larger and more expensive than heat generating geothermal plants and the risks (investment & operation) for electricity generating geothermal plants over longer period of time is therefore larger. Regarding heat generating geothermal plants, the benefits are greater when high temperature resources is used to generate both heat and electricity than when it is used for heat alone.

The geothermal heat production has several advantages, such as:

1. Economic opportunity and savings.
2. Improvement of energy security.
3. Reducing greenhouse gas emissions.
4. Harnessing local resources.
5. Reducing dependency on fossil fuels for energy use.
6. Local payback in exchange for local support for deep drilling.
7. They complement existing district-heating networks offering an alternative to other fuels.
8. They can be combined with smaller binary cycle (if reservoir and economics allow) electricity generating plants to bring the utilisation of the reservoir to the maximum.
9. May be a useful complement to regional and local economic development programmes with positive effect on employment and the viability of public infrastructure.
10. They raise public awareness for the geothermal energy to a broader section of the public
11. Improving quality of life based on economic and environmental / climate benefits.

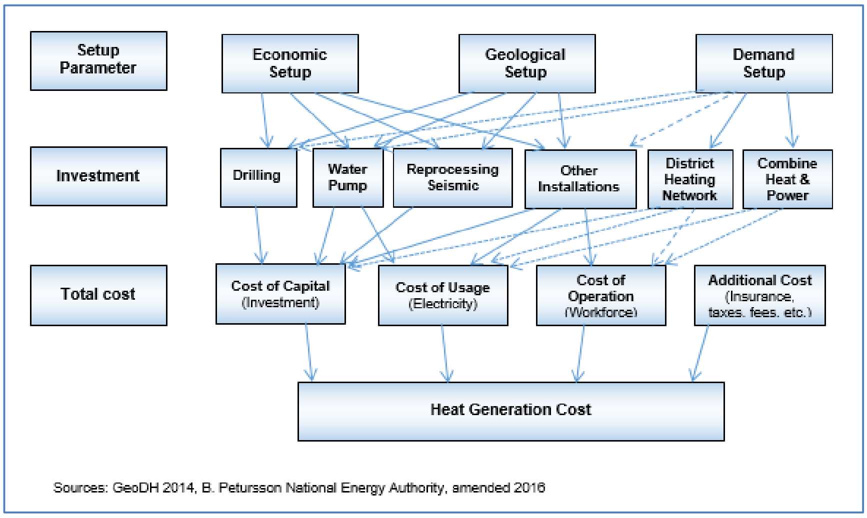
It is difficult or impossible to present standard costs of geothermal district heating projects, as the cost vary between regions and variable conditions. Nevertheless, the costs of such a project can be estimated, based on the most important parameters for the understanding of the individual projects, by:

- first defining the basic conditions affecting the heat generation cost,
- secondly by developing theoretical projects in order to explore economic viability.

Key factors for geothermal district heating projects are:

- geological framework,
- economic conditions and
- demand.

Figure 2.4.3.2. **Cost Structure of Geothermal Heat Generation Project**



Although it is difficult to estimate the profitability of such projects, the cost for each project can be based on the demand structure, the geological conditions, the costs of capital and the existing geological data, as is shown in figure, 2.4.3.2.

The demand aspect plays an important role in defining the project and the investments e.g. drilling, size of the water pump, buildings, district heating network and a power plant's mechanisms. In addition, the evaluation of heat production costs depends on the geothermal energy resource. It should also be noted that many of these cost elements are the same as for a standard heat production installation.

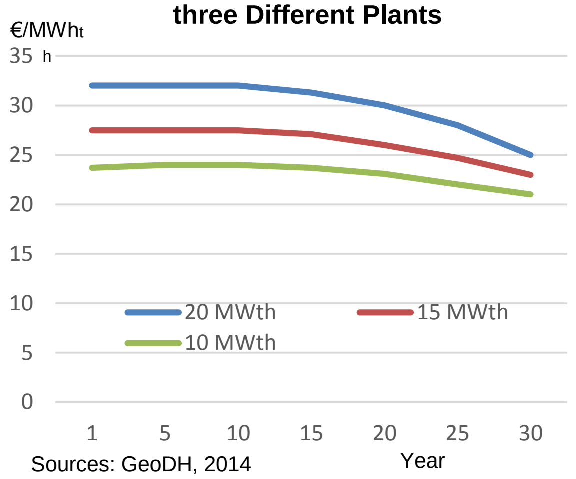
However, due to the fact that every location has different demand conditions, it is not possible to incorporate these factors in a general heat production cost calculation. Moreover, many costs are equal to those of a conventional heat generation installation. A paper for GeoDH from 2014 presented a calculation estimating the cost of a geothermal heat production project. The calculation was based on the following costs elements:

- capital cost (investments for drilling, water pump, substation, depreciation),
- operational cost (electricity for pumping & equipment, maintenance).

However, in addition to these costs, geothermal heat generation plants have to be connected to a network of plants using other energy sources, like a gas-fired or coal-fired power plant to be able to cope with peak loads. That kind of cost is not included in the project example that will be described in figure 2.4.3.3.[3]

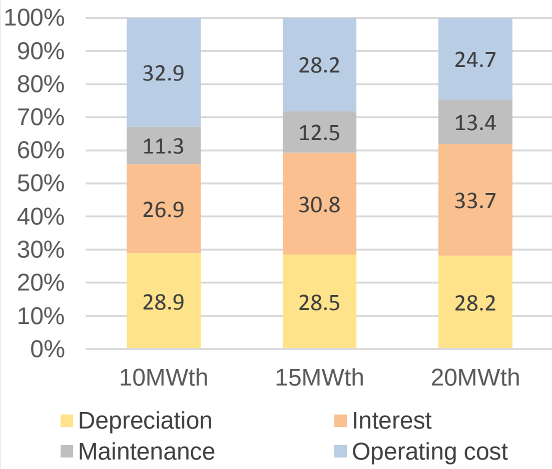
Calculations on geothermal heat generation cost carried out for GeoDH in 2014, involved three projects 10, 15 and 20 MW_{th} as shown in figure 2.4.3.3. It is interesting that the figure illustrates that the generation cost is stable for a period of 30 years, (due to lower costs of capital over time), which is opposite to the trend for forecasted prices for fossil fuels. Higher cost for 15 and 20 MWth projects than 10 MWth, is due to a higher capital cost in form of interests due to more expensive drilling.

Figure 2.4.3.3. **Heat Generation Cost of three Different Plants**



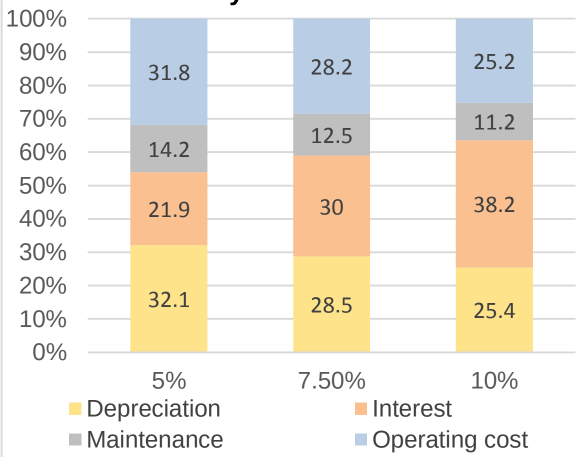
Sources: GeoDH, 2014

Figure 2.4.3.4. **Cost Structure of Generation Project Depending on Size**



Source: GeoDH, 2014

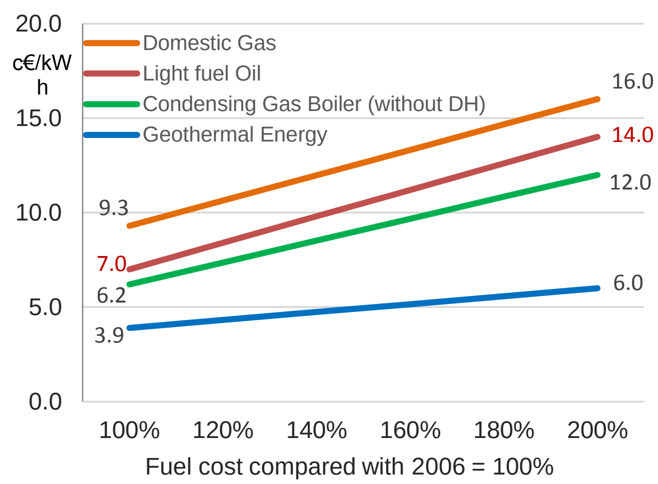
Figure 2.4.3.5. **Cost Structure of a 15 MWth Project and Sensitivity Analysis of Interest**



Source: GeoDH, 2014

As can be seen from figure 2.4.3.4, the cost structure is different depending on size of project, but for all projects the capital cost (depreciation and interests) is the biggest part of the overall cost, as this is a capital intensive sector. For the 10 MW_{th} case, the biggest single cost factor is operation coming from electricity cost to run the water pump. For the biggest project the largest cost factor is interest. As these projects are capital intensive, interest plays a major role regarding profitability, as can be seen for the sensitivity analysis in figure 2.4.3.5, where the 5% interests cost go from 21,9% up to 38,2% if the interests are 10%. Rates of interest are therefore one of the biggest risk factors.

Figure 2.4.3.5.A. **Heat Generation Cost for District Heating Network by Fuel**



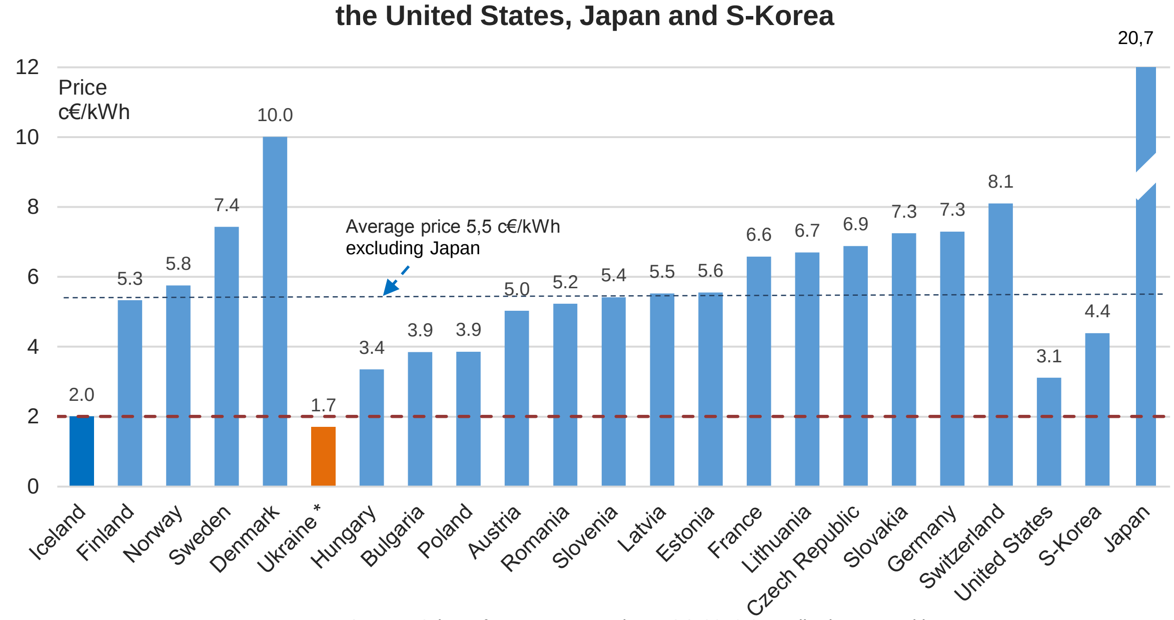
Source: GeoDH 2014.

[3] The geothermal generation heat project provides the base load energy for district heating, which will be delivered to the district heating network, total hours of the plant will be 8.000 hours/year. The focus will be on generation cost so no revenues will be calculated. Life time of the project is estimated 30 years of operation; repayment of loans is 30 years, depreciation off the drilling is 50 years, depreciation of the substation is 30 years, depreciation of the pump is 3 years and interest rate will be 7,5%. The costs for a district heating network and special installations, as well as taxes and fees, are not included.

Fraunhofer Institute for Environmental, Safety and Energy Technology carried out a study for Germany, comparing the heat generation costs between fossil fuels and geothermal heat plants delivering heat to district heating networks, (2006 prices). The study shows, that cost structure of generating heat from fossil has higher operating costs than geothermal which has higher fixed costs. Total heat generation costs of geothermal energy are low in absolute terms due to the high utilisation rate and low variable cost. During increase of primary energy prices, the total costs of generating heat from fossil fuels are rising more rapidly due to high variable cost, than from geothermal, as can be seen on figure 2.4.3.5.A.

2.4.4. Global Price Comparison of Geothermal District Heating

Figure 2.4.4.1 **Average District Heating Prices in Europe, the United States, Japan and S-Korea**



* Subsidised Price, without VAT 2015. Source: Orkustofnun Data Repository: OS-2016-01. All prices are without VAT

Due to its diffusive nature, there are economic limits to the geographic transport of heat. As a result, the utilization of geothermal resources for direct applications is quite localized, as demonstrated by the fact that the longest geothermal heat transmission pipeline in the world, found in Iceland, is 64 km in total (Georgsson et al., 2010). In contrast, electricity can be transmitted thousands of kilometres and oil can be shipped around the globe. In Europe, gas is a common source of heat that can be transported in pipelines over thousands of kilometres. Nevertheless, local resources are commonly used where possible, which results in substantial differences in the energy mix between countries. Figure 2.4.4.1 shows this variation for heating in the Nordic countries. District heating systems are in many of the regions, with the exception of Norway, where electricity covers 70-80% of heating demand, with the remainder primarily met by bioenergy (7%), oil (7%) and district heating (4%) (NVE, 2013).

Out of all countries surveyed by Euroheat & Power, Iceland has the lowest unsubsidised, district heating price of 2,0 €¢/kWh compared with an average value of 5,5 ¢€/kWh, and a maximum value of 20,7 ¢€/kWh. The great variation in prices within the Nordic countries, which all have cold climates and therefore a considerable need for heating, is of particular interest. Out of the 20 surveyed countries, the highest price is encountered in Denmark (except Japan) and the second highest in Sweden. It is probable that the reasons are not only economic, but also political. In general, taxes tend to be high in the Nordic countries and countries with limited domestic energy options, such as Denmark, have been supporting and subsidising renewable energy such as wind, which have resulted to higher price to customer. The fortune of Icelandic consumers is therefore the abundance of low-price, environmentally friendly geothermal heat that translates to the lowest average district heating price on record in Europe and possibly the wider world. In the United Kingdom, one of Iceland's neighbouring countries, the main source of energy for heating is gas (Association for the Conservation of Energy, 2013). In 2009, the average gas price in the UK was 11.84 EUR/GJ, including all taxes and levies (Eurostat, 2014). Assuming 80% efficiency (Association for the Conservation of Energy, 2013), brings the price up to

14.80 EUR per GJ of usable heat. This translates to 5.33 EUR¢/kWh, or 7.12 USD¢/kWh, which is slightly above the average price for district heating in Europe, and substantially higher than the price in Iceland. From these comparisons, it is evident that Icelandic geothermal district heating prices are very competitive. However, it is important to be aware of differences in climatic conditions between countries that lead to differences in the length of the heating season. Shorter heating seasons may lead to higher unit prices, as district heating companies must cover incurred costs based on sales over a limited time period each year. Other factors that influence heat demand, and thus consumers' wallets, include:

- ***Ambient temperature:*** The heat flow through a building wall is directly related to the temperature difference over the wall, indicating that year-to-year fluctuations in ambient temperature affect heat demand as was clearly observed in Norway in 2010 (NVE, 2013).
- ***Indoor temperature***, which is influenced by personal comfort choices, habits, prices and other factors, and can therefore vary over the population of a country.
- ***Insulation and airtightness of buildings***, which may vary between countries.
- ***Ventilation,*** preferences of home owners.
- ***Heat metric and pricing system (HMPS).*** The HMPS is a key element regarding the price and consumption. In some less developed countries there is no individual HMPS, and even confusing management and ownership of the GeoDH companies, damaging price, demand and efficiency.

CONCLUSION

Despite hypothetical arguments, imprecision in data, and a rough methodology, the comparisons presented show that the utilization of geothermal resources for space heating can be of substantial economic benefit to consumers. (Haraldsson, Economic Benefits of Geothermal Space Heating from the Perspective of Icelandic Consumers, 2014).

2.4.5. The Geothermal Global Market Structure

Geothermal Project at Stage of Development (Examples of companies)						
Preliminary Survey	**Exploration**	**Test Drilling**	**Field Development**	**Engineering**	**Construction**	**O&M**
ISOR (Iceland) West –JEC (Japan), GEO-t (Germany), SKM (New Zealand), GeothermEX (USA),		Icelandic Drilling (Iceland) Thermasource (USA), Baker Huges Drilling (US),		Mannvit, Verkís, Efla, Reykjavik Geothermal (Iceland), Power Engineering (US),	Mitsubishi, Fuji, Toshiba (Japan), UTC Power (US, Italy), Alstom (France)	CFE, EDC
	Landsvirkjun, Reykjavík Energy, HS Energy (Icelandic Geothermal Companies) PT Pertamina (Indonesia), Ormat (Israel, USA)					
CFE (Mexico), EDC (Philippines)						
Worldwide only a few companies cover all phases of geothermal development Sources: ESMAP, 2012, US Department of Energy 2014, National Energy Authority Iceland, 2014.						

The global geothermal sector includes about 20 large firms providing a wide range of services, expertise with specific set of services for a project developer. A geothermal development process normally lasts 5 - 7 years, and around half the cost of a geothermal project is incurred prior to the drilling of production wells, front-loading both the costs and risk profiles of a geothermal project compared with alternative technologies. Few vertically integrated firms are active at all stages of a project's development, but the majority of geothermal firms specialize in a specific niche or set of niches, including Icelandic companies. One such firm from Iceland (ISOR) is a world leader in the exploration and confirmation of geothermal resources, through the use of geophysical, geological, and geochemical analyses.

2.4.6. Demo I - Business Model for Geothermal District Heating and Gas

This demo case is based on comparison between a district heating network using natural gas and a geothermal district heating network, in the Paris area, described in GeoDH paper from 2014. The project (geothermal doublet) has been running for 31 years. However, the geothermal water flow rate is decreasing. (GeoDH, 2014).

Table 2.4.6.1. **Comparison of District Heating Powered 100% with Gas and Geothermal + Gas.**

Annual expenses (K Euros no VAT)	Gas	Geothermal
(k = 1000)		solution
Gas to be purchased on the market	3.830	
Gas to be purchased on the market		1.099
Electricity consumption for gas plant	22	22
Electricity for geothermal pumping		240
Ordinary geothermal maintenance		550
Ordinary gas station maintenance	423	
Ordinary gas station maintenance		200
Ordinary network maintenance	326	326
Geothermal installation replacement		246
Total annual expenses	**4.601**	**2.683**

Table 2.4.6.2. **Operating and Maintenance Cost**

	Operating costs and maintenance	k Euros
	Geothermal loop	
P1	Electricity	240
	Corrosion inhibitors	70
	Water	5
P2	Regular maintenance	30
	Electrical Logging	20
P3	Heavy maintenance	88
	Equipment replacement	40
	Work force and 24/24h follow up	15
	Stock ,for repairs	15
P´3	Work over in the wells	55
	Insurance	45
	District heating network surface installations	
P1	Electricity	20
	Natural gas	1.100
P2	Work force and 24/24h follow up	420
P3	Equipment replacement	320
P´3	Stocks for repair	50
	Insurance	150
	Total	**2.683**

It has been decided to re-drill a new doublet in order to continue to exploit the heat underneath the city. The two deviated wells are expected to be drilled in 2015 and the new doublet will be put in production in the winter of 2016. The new doublet is designed with abig diameter in order to allow the production of m^3/h, which represents a heat capacity of 12,2 MW assuming a production temperature at 70°C and reinjection at 40°C.

These new doublets can be re-cased after 35 years of exploitation and restart an exploitation period of 35 years even at a reduced production flow rate. Consequently, the new doublet will be exploited for a minimum time period of 70 years from 2016 to 2086.
Technical aspects of the project were as follows:

> Heating needs of the existing network: 67.480 MWh/year.
> Total needs including the losses: 81.980 MWh/year.
> Geothermal station capacity 15 MW.
> Geothermal annual production: 5.300 MWh.
> Pumping system power for production: 400 kW and 1.650 MWh/year.
> Pumping system power for injection: at 600 kW and 1.900 MWh/year.
> Back up and complementary energy used is natural gas.
> Back-up power installed at 41MW with boiler efficiency at 90%.
> Annual gas consumption: 20.347 kWh.

Operational benefits of geothermal

If we look at the operating and maintenance costs it is expressed into four sections for both systems: geothermal loop including the well, the main heat exchanger, and surface and network installation downstream from the heat exchange with hot geothermal water (Table 2.4.6.2.). Table 2.4.6.1, shows that the annual benefits to exploit the district heating network using the geothermal doublet are of 1918 K€ (difference between 4.601 with gas and 2.683 with geothermal + gas).

Investment cost of a new geothermal doublet

The total investment cost for the new geothermal doublet is 11,9 million € + 2,3 million € (see table 2.4.6.3 and 2.4.6.4) or total 14,3 million €. (This includes doublet of drilling in 9''5/8 casing at the top of the reservoir with a maximum deviation of 50°, and all the equipment in the well and at the surface to exploit the geothermal water). (1 k € = 1.000 €)

Investment cost – Payback time of the geothermal CAPEX

If we look at the CAPEX[4] model, for geothermal the value is 14,3 million € and the annual benefit of expenses using geothermal - amounts to 1,9 million €. The conclusion is payback period of 7,45 years of the investment, if we exclude the financial approach and the fact that the community has to borrow the main part of the investment.

The main financial factors

The main financial factors of the project were as follows. Project life is 20 years, discount rate at 6%, interest rate at 3,2% inflation rate at 2%, annual escalation electricity price at 2%, annual gas escalation price at 5%, annual heat escalation price at 3%, and electricity purchase at 70€/MWh. The investment is 14,3 million € and the equity at 400 thousand €.

Table 2.4.6.3**. Investment Cost, Geothermal Loop at the Surface.**

Geothermal loop at the surface	K Euros
EurosProduction pump (300 m3/h)	215
Pumping tubing (DN 175 coated)	140
Transformer	100
Piezometric tubing	10
Inhibitors line and accessories	180
Injection pump	60
Frequency variators	80
Regulation cos phi	20
Titanium plate heat exchangers	215
Handling of equipments	20
Geothermal water piping at the surface	210
Filters station	25
Monitoring of the loop including instruments	15
Water tank (4m3)	25
Digital systems	20
Architect, engineering and control	300
Heat station surface piping (DN 200 to 350)	450
Connection to the grid	90
Electric rack	95
Pumps for secondary loop	100
Total	**2.370**

Table 2.4.6.4**. Investment Cost of Drilling two Deviated Wells**.

Drilling of 2 deviated wells	K Euros
EurosGrant application ADEME	10
Insurance application SAF Environment	10
Geothermal lease and application for permits	95
Civil works (platform, fence, anti-noise , cellars)	700
Cranes works, transportation, storage	60
Drilling rig mob, demob and moving	650
Drilling (energy included)	2.200
Overreaming	250
Drilling mud	520
Drilling tools	170
Deviational including personnal	700
Electrical logging	520
Casings	920
Installation of casings (accesories , screwing)	310
Cementing	900
Stimulation and development	85
Acidizing jobs	130
Mud treatment and cuttings removal	960
Well heads and valves	130
Geological follow up	410
Supervision on site 24/24	400
Cleaning of the platform	500
Insurance SAF short and long term	630
Engineering	190
Provision for unexpected	480
Total	**11.930**

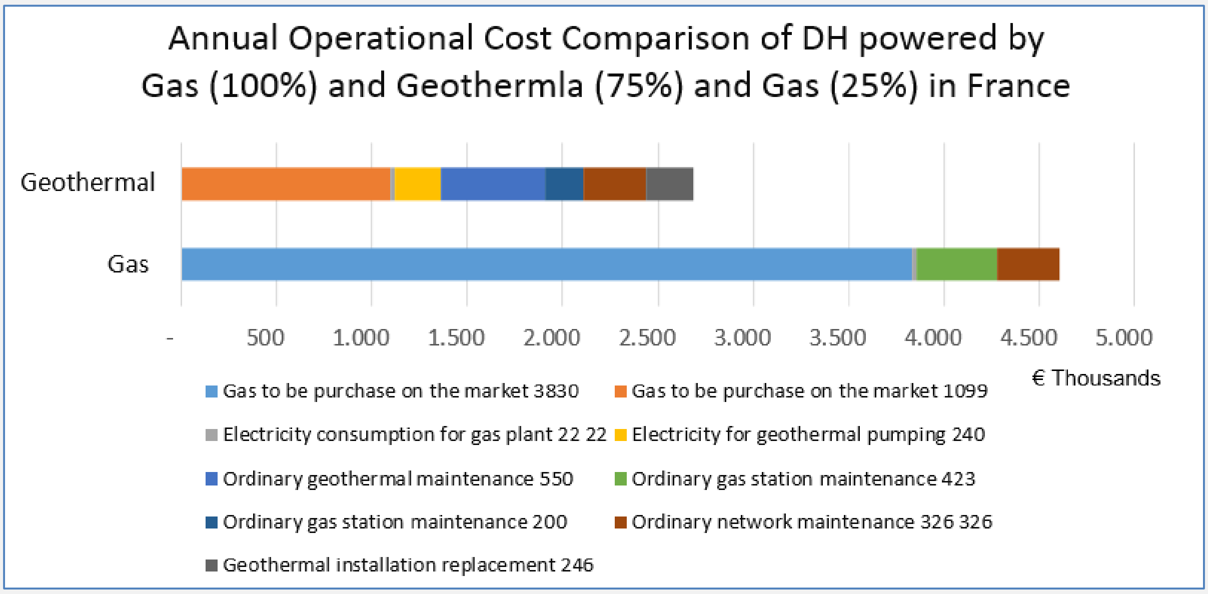
Key Findings – Cost Comparison – kWh Produced by Natural Gas and Geothermal Heat

The key findings of this demonstrative example in France is that the actual production cost of the heat produced using 100% gas is about 5,6 c€/kWh for a final selling price to the consumer at 70 c€/kWh, all inclusive. However, the same kWh produced with a mix of natural gas (24,82%) and geothermal (75,18%) is 3.27 c€/kWh. The benefits and difference, which is 2,33 c€/MWh, will allow to finance the construction of the doublet. The annual production of the project is 81.980 kWh/ year with a turnover of 5,739 k€. The annual profit using geothermal is 1.918 K€.

This profit will pay back the investment cost in 7,45 years, meaning that after 8 years the community will start to gain about 2 million euros per year, or it would be possible to lower the price of 2,33 c€/kWh and keep the profit as before (GeoDH, 2014). This demo example, shows the opportunities and economic benefit that may be gained from geothermal resources in combination with other energy resources in district heating.

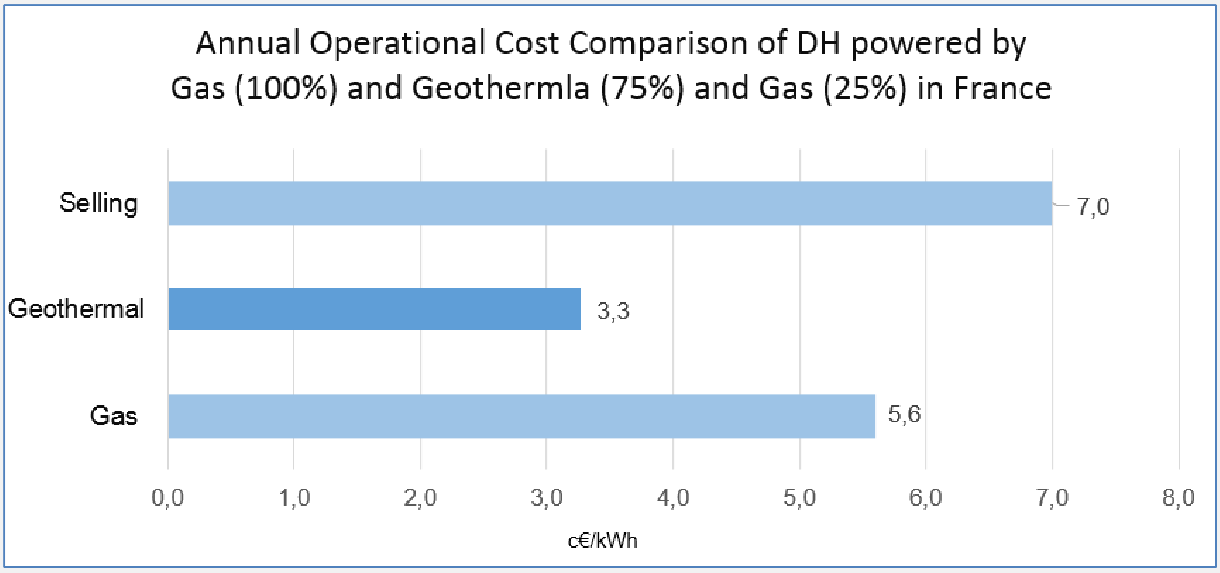
[4] CAPEX = Capital expenditure

Figure 2.4.6.1.



As can be seen from the case in France, the actual annual operational / production cost of the heat generated using 100% gas is about 4,6 M€ (5.6 c€/kWh) - but only 2,7 M€ (3,27 c€/kWh) with a combination of geothermal (75%) and gas (25%).

Figure 2.4.6.2.



The benefits and difference which is 2,33 c€/MWh will allow to finance the construction of the doublet – and the profit will pay back the investment cost in 7,45 years – meaning that after 8 years the community will start to gain about 2 million euros per year – or it would be possible to lower the price of 2,33 c€/kWh and keep the profit as before.

Table. 2.4.6.5. **Business Model - for Geothermal District Heating and Gas**

Years	Base	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
BASIC DATA																					
Project life (years)	20																				
Investments K €	14.300	7.150	7.150																		
Debt k €	12.297																				
Debt k €																					
Debt K €																					
Equity k €	4.000																				
Discout rate %	6																				
Interst rate %	3,2																				
Inflation %	2																				
Annual OM cost k €		0	0	2.683	2.737	2.791	2.847	2.853	2.910	2.968	3.028	3.088	3.357	3.424	3.493	3.562	3.634	3.706	3.781	3.856	3.933
Geothermal production				78.161	78.161	78.161	78.161	77.223	77.223	77.223	77.223	77.223	80.662	80.662	80.662	80.662	80.662	80.662	80.662	80.662	80.662
Geothermal selling price €/MWhr	70	0,00	0,00	70,00	72,10	74,26	76,49	78,79	81,15	83,58	86,09	88,67	91,33	94,07	96,90	99,80	102,80	105,88	109,06	112,33	115,70
Equity depreciation (linear) k €	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Profit taxation rate %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Geothermal revenues k €				5.471	5.635	5.804	5.979	6.084	6.267	6.454	6.648	6.847	7.367	7.588	7.816	8.050	8.292	8.540	8.797	9.061	9.333
ECONOMIC ANALYSIS																					
Years of loan repayment	20	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Years of loan repayment	14							0	1	2	3	4	5	6	7	8	9	10	11	12	13
Years of loan repayment	9												0	1	2	3	4	5	6	7	8
Dept 1 repayment annuity k €		1.008	989	969	949	930	910	890	871	851	831	812	792	772	753	733	713	694	674	654	635
Dept repayment annuity k €								0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dept repayment annuity k €													0	0	0	0	0	0	0	0	0
Dept repayment annuity k €		1.008	989	969	949	930	910	890	871	851	831	812	792	772	753	733	713	694	674	654	635
Interest on debt k €		394	374	354	334	315	295	275	256	236	216	197	177	157	138	118	98	79	59	39	20
Interest on debt k €																					
Annula interests on debt (depti)																					
Interest on debt k €		394	374	354	334	315	295	275	256	236	216	197	177	157	138	118	98	79	59	39	20
Net income k €		-8.358	-8.339	1.619	1.749	1.883	2.022	2.141	2.286	2.435	2.589	2.747	3.018	3.192	3.370	3.555	3.745	3.940	4.142	4.351	4.565
Cost effectiveness		0,00	0,00	0,30	0,31	0,32	0,34	0,35	0,36	0,38	0,39	0,40	0,41	0,42	0,43	0,44	0,45	0,46	0,47	0,48	0,49
FINANCIAL RATIOS																					
Net present value (NPV) k €	**12.727**																				
Internal rate of return (IRR) %	**12,7**																				
Profitability index (PI)	**1,99**																				

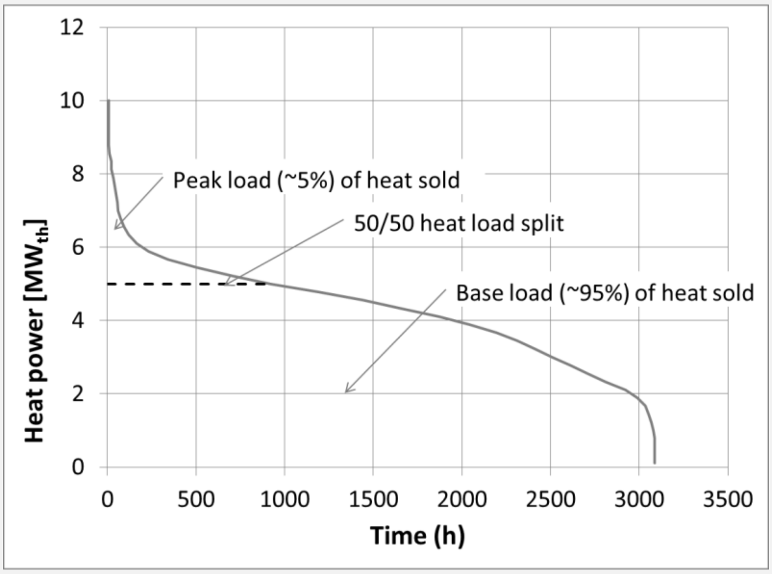
2.4.7. Demo II - Business Model for Geothermal District Heating and Gas

This demo case is based on comparison between eight scenarios of a geothermal district heating network in Eastern Europe using geothermal resources for district heating as a base load and gas for peak loads. The demo case is based on calculation made by Mannvit Engineering in Iceland and the Icelandic National Energy Authority. (Iceland M. E., 2015) Geothermal energy has been used successfully for district heating systems in many parts of the world including Central and Eastern Europe, there are therefore no unknown technological factors to this project. [5] The following economic assumptions are made for the financial analysis:

> Cost/benefit analysis is based on “Guide to Cost Benefit Analysis of Investment Projects” (EU in July 2008), see more detailed assumptions in Table 2.4.7.1.
> Cost data is based on quotes from similar projects.
> Gas and electricity prices based on industry prices obtained from EU data (3,0 and 8,1 cEUR/kWh respectively).
> Selling price is optimized utilising EU Grant.

The following technical assumptions are made:
> Gas powered district heating networks are in place.
> Gas boilers will be replaced with a geothermal system.
> Some of the existing gas boilers will be retained and used for topping up at peak loads.
> Geothermal will provide the base load.
- A 50/50 geothermal/gas boiler load division is assumed.
- Utilising gas only for peak load results in geothermal/gas heat sold division approximately 95/5.

Figure 2.4.7.1 **Heat load duration curve**



Models for two types of geothermal wells were prepared:

Well type	Depth (m)	Cost (MEUR)		Temp in/out (°C)	Yield (kg/s)	Utilization method	Total heat load (incl. gas boilers) (MW)	Heat sold (GWh)	
		New	Existing					Geo (95%)	Gas (5%)
A	1500	1.8	0.40	95/70	25	Direct use	10	12.3	0.6
B	1200	1.0	0.15	50/30	25	Heat pump	5	6.1	0.3

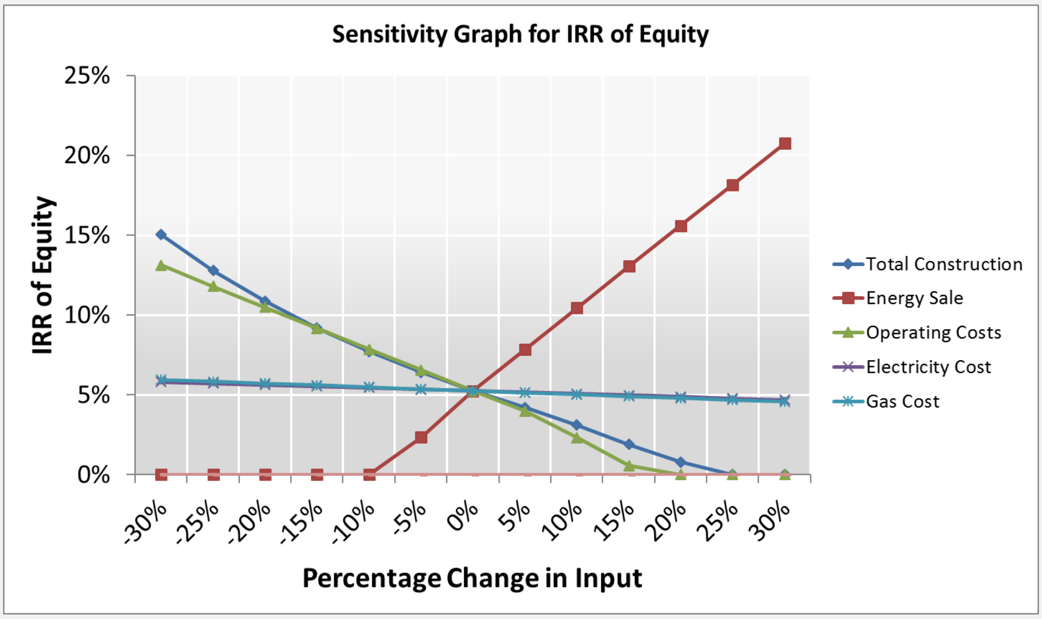
[5] This case was prepared by National Energy Authority and Mannvit Engineering in Iceland.

From these models eight scenarios are introduced:

	Existing or new well	Well type	No of wells	Geo selling price to DH (c€/kWh) X	EU grant %	DH cost (c€/kWh)	End Price GeoDH to con-sumer (c€/kWh)	Gas selling price to DH (c€/kWh) Y	Price difference of GeoDH & Gas to DH (c€/kWh) (X-Y)	CAPEX (M. €)
1	New	A	1	7.5	21.6	1.5	9.0	3.6	3.9	5.8
2	Existing	A	1	4.8	22.6	1.4	6.2	3.7	1.1	2.3
3	New	A	2	5.7	20.6	0.8	6.5	4.3	1.4	10.2
4	**Existing**	**A**	**2**	**2.9**	**19.3**	0.7	**3.6**	4.4	**-1.5**	**3.1**
5	New	B	1	7.4	21.5	1.5	8.9	3.6	3.8	4.7
6	Existing	B	1	5.8	23.0	1.6	7.4	3.5	2.3	2.7
7	New	B	2	5.4	21.4	0.9	6.3	4.2	1.2	8.0
8	**Existing**	**B**	**2**	**3.8**	**22.1**	0.9	**4.7**	4.2	**-0.4**	**3.8**

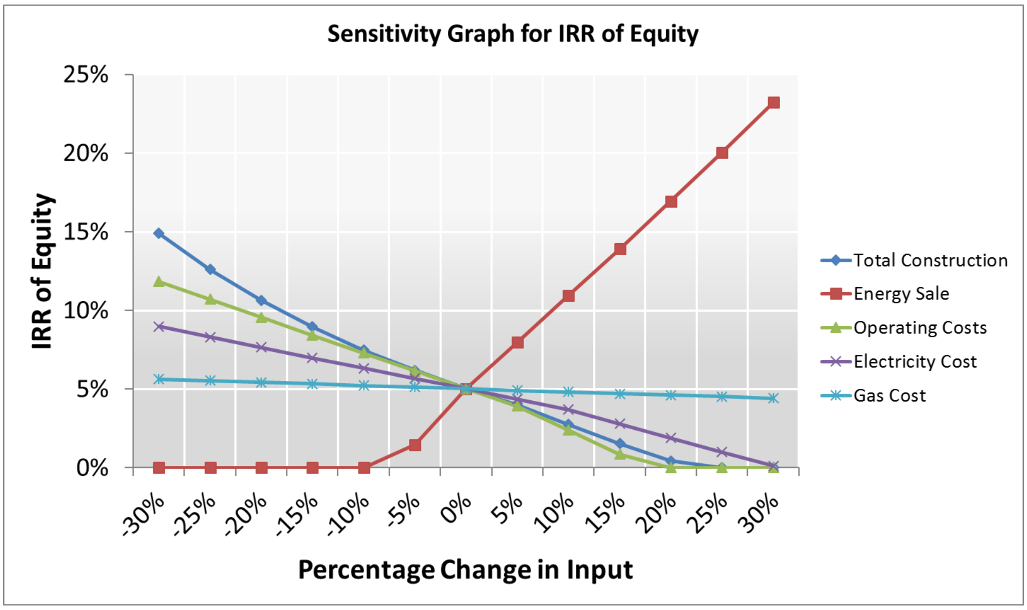
Compared to average district heating prices in the western part of Ukraine (2,04 EURc/kWh, subsidised price) the optimized selling price to district heating companies (wholesale price) of heat is more economical for scenarios 4 and 8. This shows that at least two existing wells are needed in order to reduce the average heat prices. Drilling two new wells is less economical. The following sensitivity analysis shows how individual inputs affect the total outcome. In this case it is also important that geothermal district heating prices are at least competing on equal terms with gas, coal or other alternative energy resources, and not competing with subsidised resources.

Figure 2.4.7.2.A. **Sensitivity Analysis of Scenarios 1 – 8**

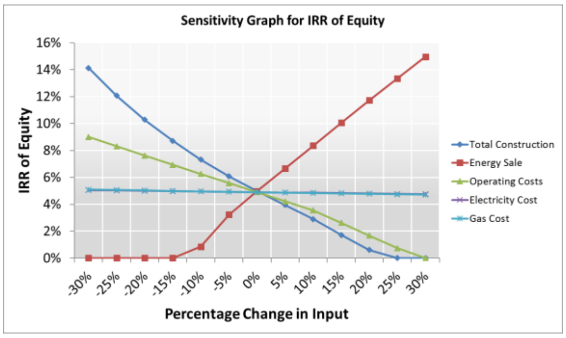


Scenario 4 – 2 existing wells, 95°C

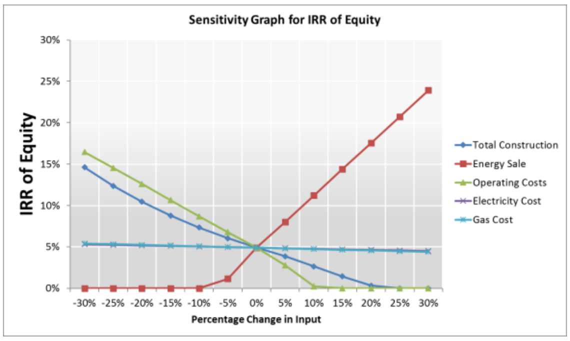
Figure 2.4.7.2.B. **Sensitivity Analysis of Scenarios 1 – 8**



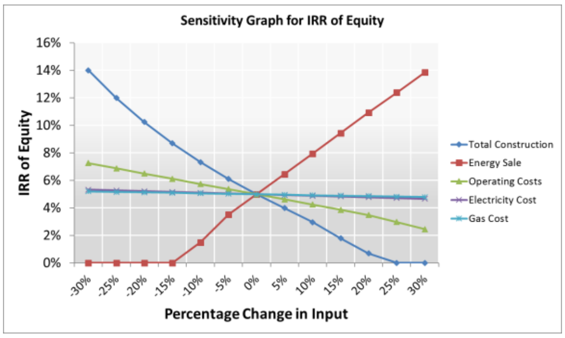
Scenario 8 – 2 existing wells, 50°C



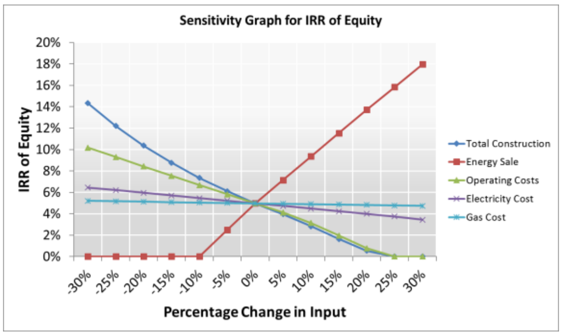
Scenario 1 – 1 new well, 95°C



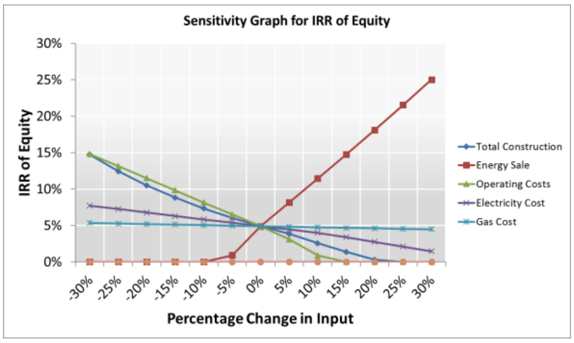
Scenario 2 – 1 existing well, 95°C



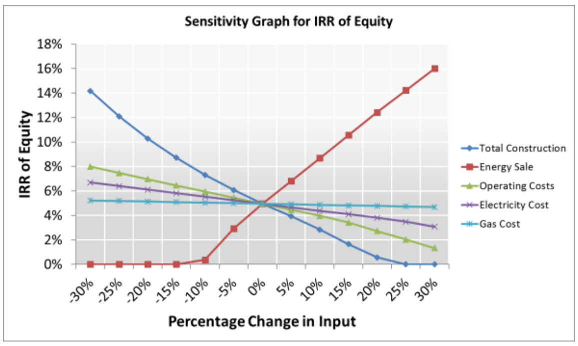
Scenario 3 – 2 new wells, 95°C



Scenario 5 – 1 new well, 50°C



Scenario 6 – 1 existing well, 50°C



Scenario 7 – 2 new wells, 50°C

Summary - comparison of scenarios

Following is the breakdown of the capital costs (CAPEX), of yearly income and operational costs (OPEX) for the two most economical scenarios, 4 and 8. Scenarios 4 and 8 involve utilizing two existing wells either directly (sc 4) or with a heat pump (sc 8). Examining the tables leads to the following conclusions:

> Well costs (restoration of existing wells and well pump) are greater for scenario 4. Deeper wells are needed to reach higher temperatures as required for direct use.
> Heat plant costs are greater for scenario 8 because of the heat pump.
> Heat sales are greater for scenario 8 due to higher selling prices. Higher selling prices are required to achieve the desired 5% IRR of equity while maximizing the EU grant.
> Electricity costs are greater for scenario 8 due to electricity consumption of the heat pump.

These conclusions are an example, regarding geothermal district heating projects in Ukraine. However, each geothermal district heating project depends on technical, economic and environmental conditions in each place.

District Heating Network - The above calculations assume that there is no cost incurred due to District Heating Network (DHN) systems. Assuming that costs for a new 10 MW system is similar to the primary pipeline (1.100.000 EUR), a percentage increase can be calculated for each scenario and the effect on IRR can be investigated through the sensitivity graphs. Given the above cost assumptions for DHN, the price for scenario 4 would need to be increased to3.7 cEUR/kWh to obtain a 5% IRR.

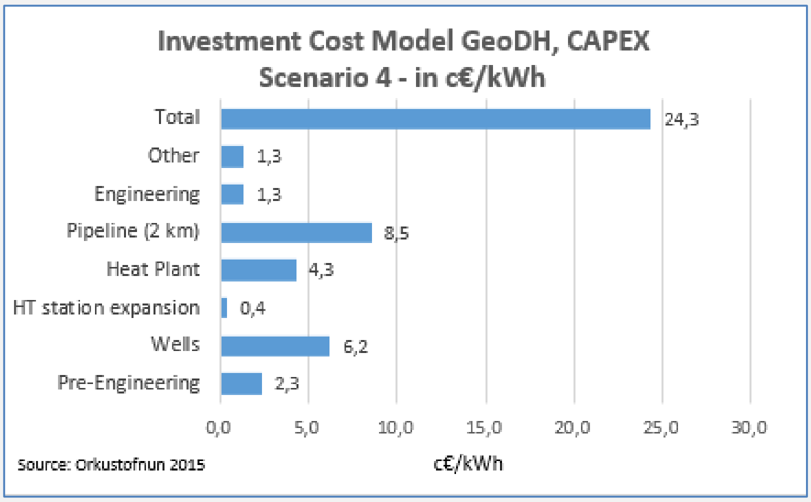
CAPEX (Thousands EUR)	Scenario	
	4	**8**
Re-Engineering	300	300
Wells	800	300
HT station expansion	50	50
Heat Plant	550	1,500
Pipeline (2 km)	1,100	1,100
Engineering	170	265
Other	170	265
Total	***3,140***	***3,780***

Yearly income and OPEX (Thousands EUR)	Scenario	
	4	**8**
Heat sales	375	491
Organization & Overhead	(27)	(27)
Operation & Management	(162)	(162)
Electricity	(14)	(109)
Gas	(17)	(17)
EBITDA	***155***	***175***

Table 2.4.7.1 Major Assumptions for the Financial and Economic Analysis

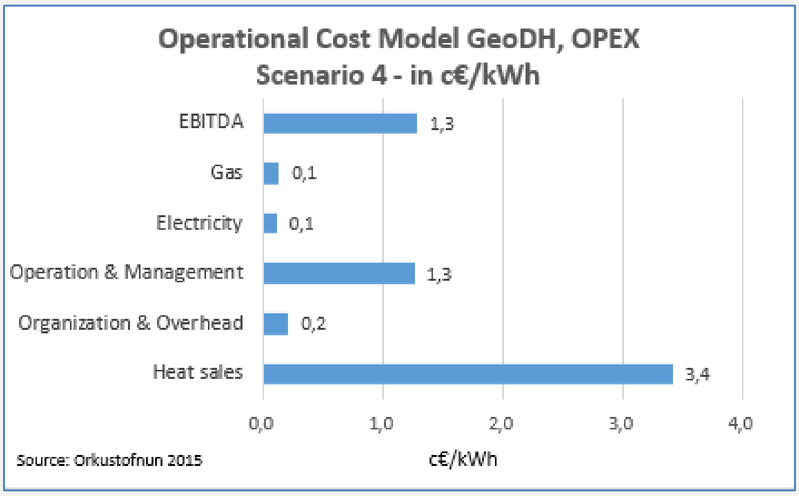
Item	Value	Comment
Project lifetime	30 years	30 years projected lifespan
Methodology		See "Guide to Cost Benefit Analysis of Investment Projects" (EU in July 2008)
Type of Analysis	flat rate	Yield is in real terms, not nominal
Income Tax	16%	Used in Financial Sustainability Analysis only
Discount Rate (DR)	5%	As suggested in the guide
Debt Interest Rate	3%	Used for comparison purposes in this analysis
Debt Fee	0,5%	
Payback Start	3 years after start	
Payback Period loans	20 years	Equal Principal Payments
Payback Period	25 years	Net cash flow & equity, based in 5% discount rate
EU Grant	X%	Calculated with the "Funding Gap" Method (~12-16% in analysis). Yearly payments as a proportion of spent CAPEX.
Debt Percentage	80%*(1-X)	80% of CapEx not supported with EU Grant
Equity Percentage	20%*(1-X)	20% of CapEx not supported with EU Grant
Price of Gas & Electricity	3,0 – 8,1 €c/kWh	Gas and electricity prices based on industry prices from EU data
Selling Price difference in the model	3,4 – 8,7 €c/kWh	Output in the model – depending on Donor grant

If the investment and operational cost model is analyzed further in scenario 4 per c€/kWh, the cost structure can be seen in following graphs.



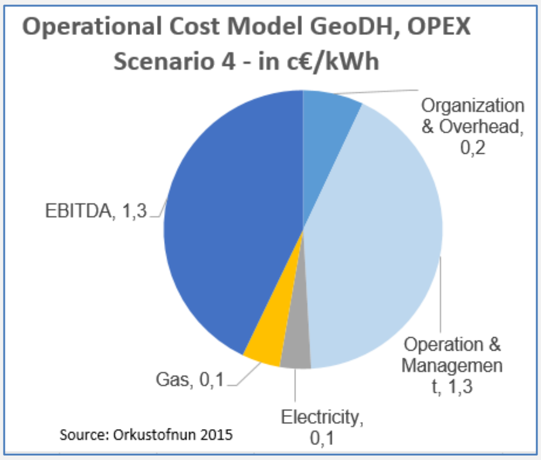
In general, a geothermal district heating project is based on the estimated geothermal heat that can be produced from the reservoir and an analysis of the heat demand.

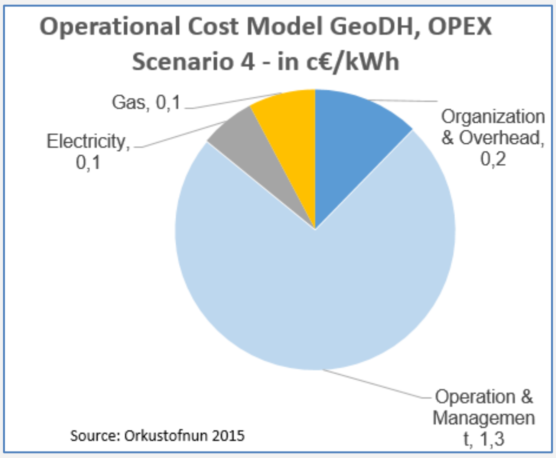
However, the business model of costs and revenue streams are specific to each individual project.



Because geothermal district heating projects involve uncertainties and risks, solid project planning and risk management are essential from the earliest stage.

The opportunities and utilisation of them are shown in figure 2.4.7.2 where step by step the coordination of the project is explained and can be treated as a model to promote the early stage development projects.

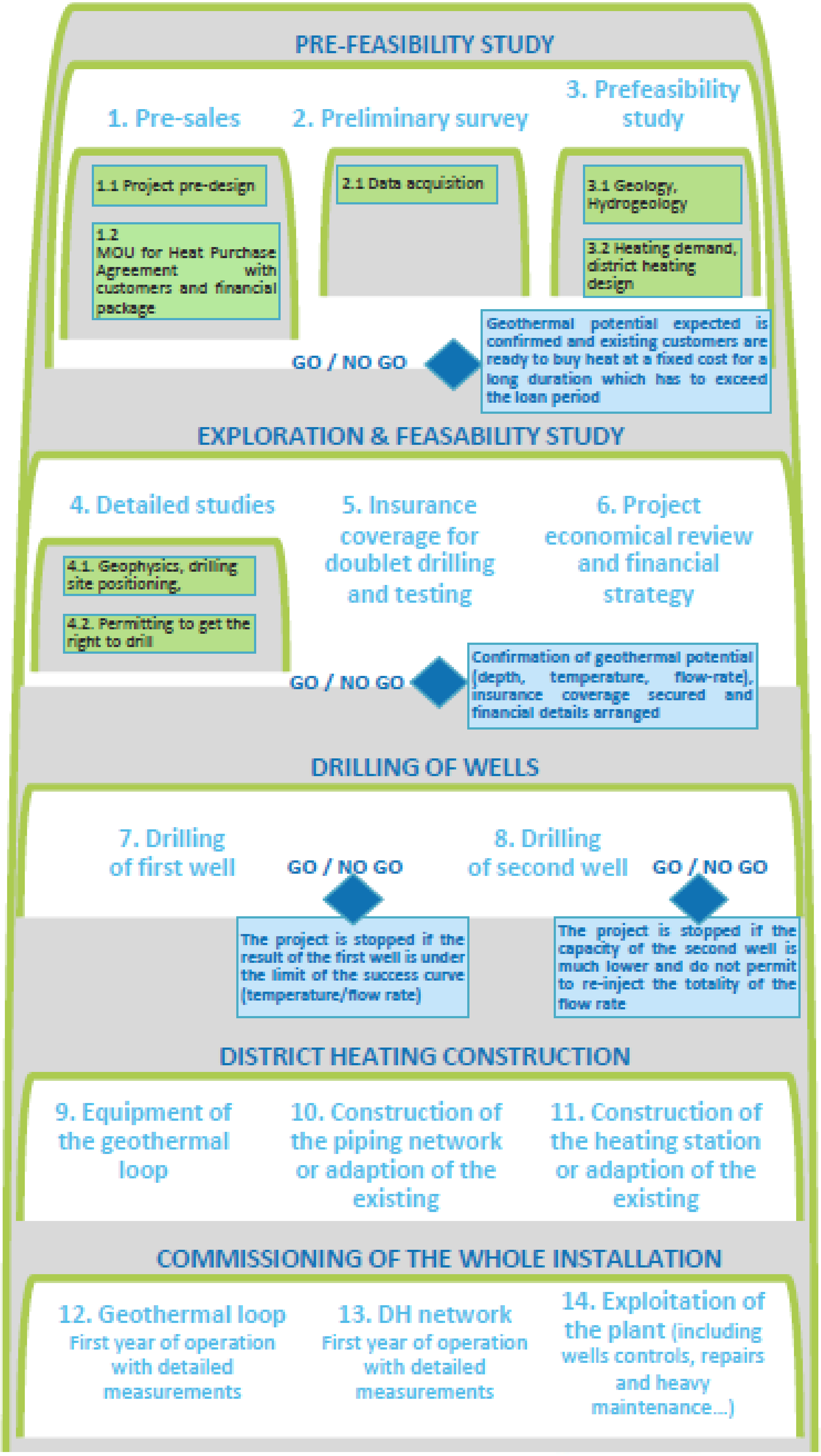




The operational cost structure (OPEX) of scenario 4, can also be seen in this pie charts with and without EBITDA. If we look at the EBITDA, (chart to the left) it can present the cost of the investment and what is needed to pay back the investment cost and other financial cost included rate of return.

The picture to the right is the operational cost without EBITDA.

Figure 2.4.7.3. **Model for Geothermal District Heating – Go / No-Go Options**



Main Challenge of geothermal district heating projects

- Matching resources and demand.
- Evaluating the thermal energy that could be produced at the surface.
- Dealing with risk management linked to the geology.
- Financing and refurbishing/ developing new heat grid infrastructures.
- Increasing profitability of geothermal district heating projects by developing systems which can also provide cooling. (GEODH, 2014)

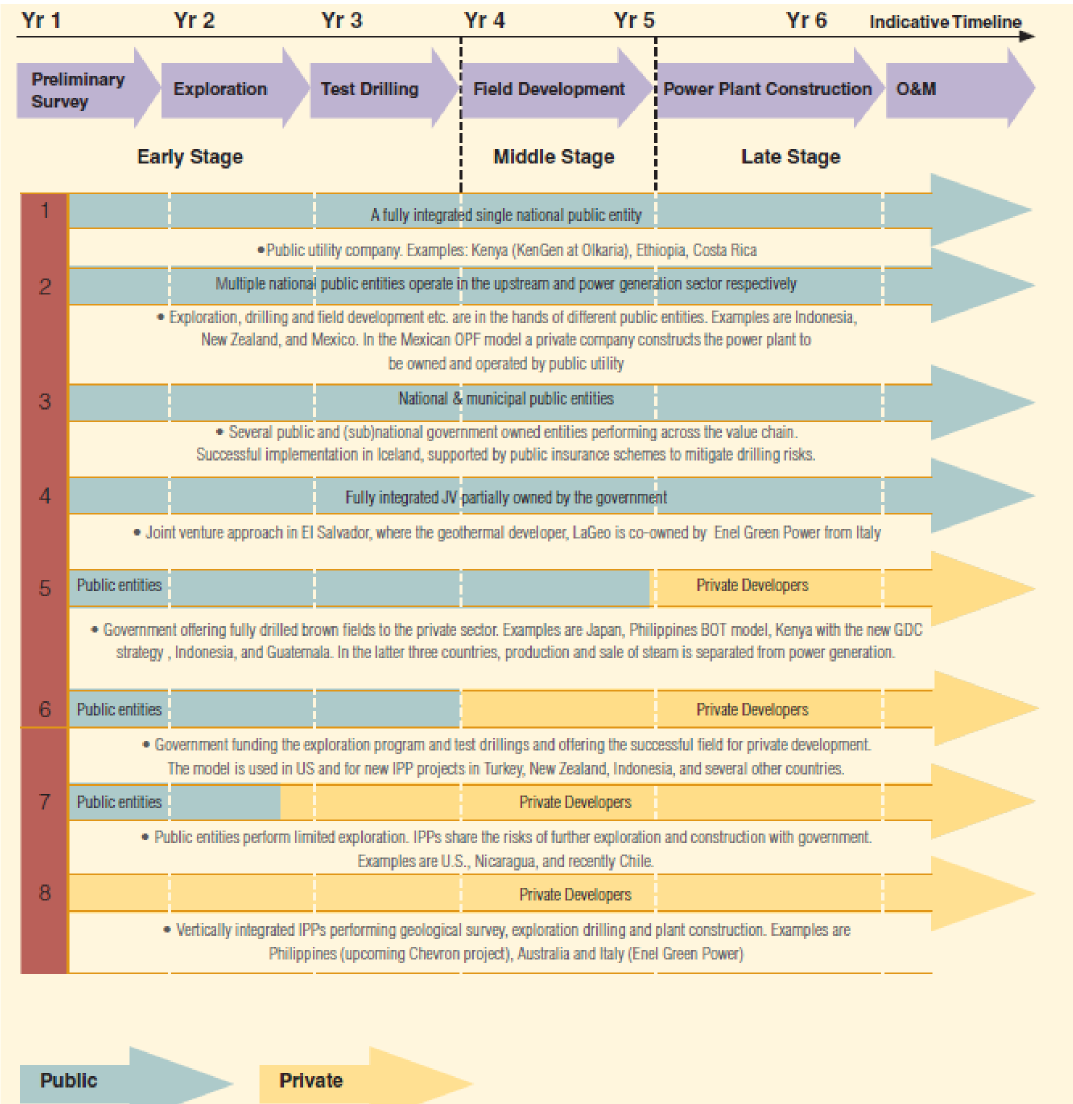
3. International Development and Financing of Geothermal Projects

3.1. International Development Models of Geothermal Projects

When looking at international experience regarding development of geothermal models, one finds that there are different models all over the world, as can be seen in figure 3.1.1 with eight different models that have been utilized in geothermal power development. As the figure shows, the early stage of geothermal project development depends heavily on public sector investments, but the private sector has a tendency to enter the project at later stages.

The financing arrangements and the risk can vary widely. In Mode 1 the project is financed either by the national government and state-owned utility, or by government in conjunction with grants from donor nations and loans from international lenders. In this model, risk is borne almost exclusively by the national government and will only be reduced by revenues from the sale of electricity and by grants from donor nations, if available. It can be seen that most private investors stay away from taking the full resource risks in geothermal projects. Model 7 is a more typical case for a privately led development. In this model, government companies perform limited exploration, the data being in the public domain and accessible by developers. (ESMAP, 2012)

Figure 3.1.1. **Different Models of Private and Public Geothermal Projects**



Source: ESMAP, 2012

3.2. International Financing Models of Geothermal Projects

3.2.1. Financing Options for Different Project Phases

As the previous discussion indicates, mobilizing capital for geothermal development projects from commercial sources is more complicated than for conventional power projects, and for most other renewable energy technologies. This is especially true for early stages of project development, particularly the test- and initial production drilling, when the risk is still high and the cost of each well can be millions of dollars. However, the conditions for financing are different at various phases of the project, each phase calling for a different menu of financing options. Table 3.1 summarizes these options, breaking the geothermal development process into three distinct stages:

- early stage (high risk)
- middle stage (medium risk and
- late stage (low risk).

Figure 3.2.1.1. **Financing Options for Different Stages of a Geothermal Development Project**

Project Development Stage	**Early Stage** Surface exploration, test drilling, initial production drilling	**Middle Stage** Resource confirmation, field development, complete production drilling	**Late Stage** Power plant engineering, construction and commissioning
Risk of Project Failure	**High**	**Medium**	**Low**
Typical Financing Sources	• Balance sheet financing by large developer • Private equity (project finance) possible but with high risk premium • Government incentives (capital cost sharing, soft loan or guarantee) • Concessions funds from international donors.	• Balance sheet financing, corporate debt or bonds issued by a large developer • Public equity issuance • Construction (short-term) debt • Loan guarantee by government • Long-term debt or guarantees from IFIs • Export credit agency financing	• Construction debt • Long-term debt from commercial sources • Long-term debt from IFIs • Partial risk guarantee or partial credit guarantee instruments to attract or improve tenor and terms of commercial debt • Export credit agency financing

Source: ESMAP, 2012

It is not considered possible to depend on commercial capital for geothermal development, even in developed countries. Since it is difficult to get access to support capital in those markets, incentives like loan guarantees and investment tax credits are often granted by the government to geothermal developers. As the challenges to attract private capital to geothermal projects are often greater in developing countries, the burden of the public sector (governments, international donors, and financial institutions) to contribute financial support is likely to be an essential element of success in mobilizing capital to such projects. It has been estimated by ESMAP that since the financial crisis in 2008, development banks have provided 53% of total geothermal project financing, and the financing provided by those banks was a major factor in bringing geothermal project financing to a record-high level of US$ 1,9 billion invested in 2010 (BNEF 2011). (ESMAP I. W., 2012).

3.2.2. Geothermal Development Assistance – Global Lessons Learned

When looking for guidelines for successful geothermal development assistance at global level, it is valuable to look for key lessons learned from international financial institutions. The Energy Sector Management Assistance Program (ESMAP) is a global, multi-donor technical assistance trust fund administered by the World Bank and cosponsored by 13 official bilateral donors, established in 1983.

Based on their long and professional experience - their recommendation regarding geothermal development assistance is as follows: "*Official Development Assistance (ODA) available from multilateral and bilateral development banks, as well as from climate finance facilities, has a key role to play in supporting geothermal energy development. The concessional nature of capital supplied by climate finance vehicles, such as the Clean Technology Fund (CTF) and the Scaling-up Renewable Energy Program (SREP), coupled with the involvement of major international development organizations, such as multilateral development banks (MDBs), creates unique opportunities for leveraging capital from various other sources to support low carbon investments.*

Considerable efforts and resources in recent years have been devoted to attempts to set up funds that use concessional financing to mitigate geothermal resource risk. Two significant programs, the Europe and Central Asia (ECA) GeoFund and ArGeo, supporting the development of such funds have been initiated under the auspices of the World Bank. In both cases, the Global Environment Facility (GEF) has been the main source of concessional capital. The design and operation of these programs has helped the international community learn valuable lessons and develop a better understanding of the available options for the future.

Key principles underlying the design of a successful global or regional MDB-supported facility to promote geothermal development have emerged from this experience that can be summarized as follows:

1. *The facility needs to be well staffed and professionally managed.*
2. *It needs to have a critical mass of concessional capital sufficient to leverage co-financing from the market at large, including private sector debt and equity.*
3. *The greatest impact from concessional financing on the bankability of a typical mid-size geothermal power project can be expected when such financing is for the test drilling phase of project development.*
4. *Success during the test drilling phase is key to bridging the crucial gap between the early start-up phases that are unlikely to attract debt financing and the more mature phases of the project when financiers begin to see the project as increasingly bankable.*
5. *The geographic scope of the project portfolio should cover areas containing well established and highly promising geothermal reservoirs, principally those suitable for electricity generation. The areas should also be sufficiently wide to allow for a diverse portfolio of geothermal project locations to reduce the concentration of resource risk.*
6. *The operational procedures of the facility should include incentives for the management to apply prudent investment risk management principles and techniques.*

Possible designs for a donor-supported geothermal development facility include: a direct capital subsidy or grant facility; a loan (on-lending) facility; and a risk guarantee or insurance facility. The choice of the design depends on the particular circumstances of the country or region and of the donor agencies involved. In principle, any of these designs can reduce the private investors' risk and thus reduce the risk premium for the return on equity and the overall cost of capital, opening up new opportunities for attracting investments to scale up geothermal power." (ESMAP I. W., 2012)

II. GEOTHERMAL RESOURCES AND OPPORTUNITIES IN UKRAINE

4. Ukrainian Geothermal Challenges and Opportunities

4.1. Ukraine National Renewable Energy Action Plan, to 2020[6]

4.1.1. Policy Overview

Ukraine is an energy-scarce country, imports account for about 70% of its natural gas consumption. At the same time, the energy intensity of domestic economy is 3-4 times higher than for economically developed countries, which renders Ukraine extremely sensitive to the natural gas import conditions and makes it impossible to guarantee normal conditions of the vital activity of people and budget-funded institutions. Chapter 4.1 is based on contribution and edition from State Agency for Energy Efficiency and Energy Saving of Ukraine. (SAEE, 2014).

Utilisation of renewable energy sources is one of the most crucial areas in Ukraine's energy policy aimed at saving conventional fuel and energy resources and improving environmental conditions. Increasing the use of renewable energy sources in Ukraine's energy balance will diversify the country's energy sources, by promoting the country's stronger energy independence.

At present, the annual technically achievable energy potential of renewable energy sources in Ukraine, as calculated by the Institute of Renewable Energy of the National Academy of Sciences, is 68,6 Mtoe, which is about 50% of the overall energy consumption in Ukraine. Key areas of renewable energy sources use in Ukraine are: wind energy, solar energy, hydro, biomass, geothermal energy, and heat pumps.

Figure 4.1.1.1. **National Action Plan for Renewable Energy for the Period until 2020**

As of the end of the first half of 2014, overall electrical capacity of renewable energy facilities working under the feed-in tariff scheme in Ukraine was 1.419 MW, including wind – 497 MW, solar – 819 MW, small hydro – 77 MW, biomass and biogas 26 MW. Installed capacity of the facilities producing heat from renewable energy sources is greater than 1.070 MW.

The year 2013 became generally emblematic for the domestic renewable energy that not only maintained but also substantially accelerated its development rates. For example, in 2013 installed capacity of renewable energy facilities almost doubled to exceed 1 GW, whereas annual production of electricity from renewable sources exceeded 1 billion kWh already in September. The first contract for delivery of Ukrainian-made wind generators to Kazakhstan was signed.

The rapid and positive development dynamics of the renewable energy sector has resulted from a consistent and prudent state policy aimed at developing the use of renewable energy sources, which ensures greater environmental and energy security, development of industry and diversification of energy sources.

[6] National Renewable Energy Action Plan by 2020

To encourage development of renewable energy and use of renewable energy sources and alternative fuels in Ukraine, the Tax and Customs Codes of Ukraine contain provisions that envisage: land tax reduction for renewable energy enterprises and tax exemption of:

- operating profits of the energy companies producing electricity from renewable sources,
- biofuel producers' profits earned from biofuel sales,
- company profits earned from combined electricity and heat production and/or production of heat using biological fuel types,
- profits of producers of machines, equipment and devices for the manufacture and reconstruction of technical and transport means consuming biological fuel types,
- VAT exemption for the transactions related to importing of equipment intended for renewable energy sources, equipment and materials for production of alternative fuels or for production of energy from renewable sources, as well as import duty exemption for the above-mentioned equipment and materials.

Figure 4.1.1.2. **Targets for the National Action Plan in Renewable Energy Sphere**

Electric power engineering

Category of Electric Power Engineering Facility	2009		2016		2020	
	МВт	GW*h	МВт	GW*h	МВт	GW*h
Photoelectric power plants	0	0	1 250	1 310	2 300	2 420
Wind power plants	76	41	1 350	3 240	2 280	5 900
Hydroelectric power plants, including:	4 549	11 430	4 987	12 440	5 350	13 340
< 10 MW	*49*	*30*	*107*	*240*	*150*	*340*
> 10 MW	*4 500*	*11 400*	*4 880*	*12 200*	*5 200*	*13 000*
Bioenergy plants	0	0	380	1 680	950	4 220
Geothermal power plants	0	0	10	56	20	120
Total:	4 625	11 471	7 977	18 726	10 900	26 000

The Law of Ukraine on Electric Power Engineering envisages setting a feed-in tariff at which electricity produced by electric power facilities from renewable energy sources is purchased (except blast-furnace and coke-oven gas; and with the use of hydro energy – produced only by micro-, mini- and small hydropower plants).

The Cabinet of Ministers of Ukraine Executive Order No. 1071 of 24th July 2013 approved the updated Energy Strategy of Ukraine up to 2030.

The Energy Strategy of Ukraine up to 2030 specifies that adoption of renewable energy sources is an important factor for raising the energy security level and for reducing the energy sector's environmental anthropogenic impact. Large-scale utilisation of the renewable energy sources' potential in Ukraine is not only of domestic but also of great international importance as a weighty factor for counteraction to global climate change in general and for improvement of the overall energy security of Europe.

According to the basic scenario in the Strategy, electricity demand in Ukraine in 2030 will be 50 percent higher than in 2010. It will be mainly caused by higher electricity consumption in industry (by 55 percent) and in services (by 100 percent)[7]. Such a forecast of electricity consumption was developed with account of effects ensuing from implementation of energy saving measures. The Strategy provides for an increase in the share of renewable energy sources in the total balance of installed capacities up to about 20 percent by 2020, which under the basic scenario is 12,1 GW (including large hydro) whereas electricity production is 25 TWh. The basic electricity demand scenario foresees about 40 percent decrease in the gross domestic product (GDP)[8] of electricity intensity.

According to the basic scenario of the Strategy document, total heat consumption should increase to 271 million Gcal in 2030. In the basic scenario of the transport fleet development, aggregate domestic demand for main light oil products in 2030 will be about 17,4 Mtoe (including 6.3 Mtoe of petrol, 10,1 Mtoe of diesel fuel, and 1 Mtoe of kerosene) whereas electricity consumption in transport will reach 14 TWh. To achieve such indicators, fuel consumption efficiency needs to be raised by 25-30 percent[9].

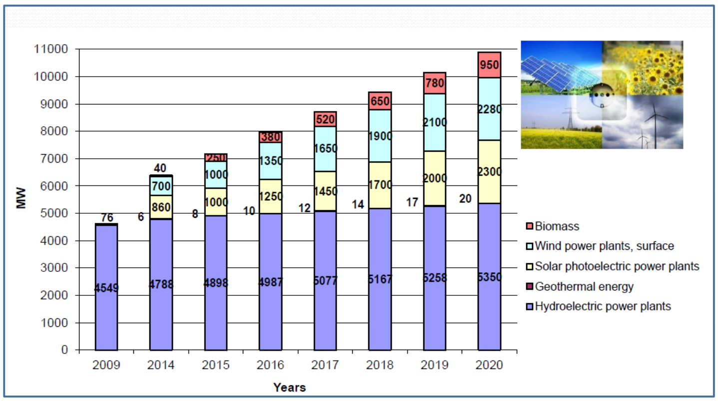
---

[7] CoM, 2014
[8] https://www.irena.org/remap/IRENA_REmap_Ukraine_paper_2015.pdf, April, 2015, p.13, 3.2
[9] Remap 2030: Renewable Energy Prospects for Ukraine

The indicators suggested in the Strategy and energy efficiency measures envisaged therein were used in this National Action Plan for calculations of various scenarios of energy consumption in Ukraine up to 2020.

In September 2010, the Protocol concerning the Accession of Ukraine to the Treaty Establishing the Energy Community was signed; later it was ratified by the Law of Ukraine on the Ratification of the Protocol concerning the Accession of Ukraine to the Treaty Establishing the Energy Community (15 December 2010). According to the Law, Ukraine became a full member of the Energy Community since 1st February 2011.

Figure 4.1.1.3. **Installed capacity for Energy Facilities Producing Electricity form Renewable Sources.**



In October 2012, the Ministerial Council of the Energy Community approved Decision D/2012/04/MC-EnC on the implementation of Directive 2009/28/EC and amending Article 20 of the Energy Community Treaty, pursuant to which each Contracting Party shall bring into force the laws, regulations and administrative provisions necessary to comply with Directive 2009/28/EC of the European Parliament and of the Council of 23rd April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

The above-mentioned Directive 2009/28/EC sets mandatory national targets for renewable energy, first of all to provide certain guarantees to investors and encourage development of novel technologies and innovations in this field. Therewith, it contains rather strict requirements to the criteria of sustainable production of biofuels and reduction of greenhouse gas emissions. Pursuant to Decision D/2012/04/MC-EnC, Ukraine undertook to achieve by 2020 an 11 percent share of energy from renewable sources in its gross final consumption of energy, which will provide a powerful stimulus for further development of the use of renewable energy sources in Ukraine.

Membership in the Energy Community provides Ukraine opportunities for implementation in its domestic market of greater competition, European technical standards and transparent regulation rules, and a better investment climate. It also means deeper integration of the Ukrainian energy sector in the Member State markets, and stronger energy security of Ukraine itself. The membership also provides a benefit of additional opportunities for the Member States to engage international credits and technical assistance.

Considering the commitments assumed by Ukraine in joining the Energy Community, the Government-approved policy documents on energy (in particular, the State Target Economic Programme on Energy Efficiency and Development of Production of Energy Carriers from Renewable Energy Sources and Alternative Fuels for 2010-2015, and the Energy Strategy of Ukraine up to 2030), and renewable energy development dynamics in the country, achievement of mandatory targets is expected in the following areas.

4.1.2. Geothermal Energy [10]

Ukraine has potential for development of geothermal energy, due to the country’s thermogeological features of relief and specificities of its geothermal resources. However, currently in Ukraine scientific, geological prospecting and practical works focus only on geothermal resources represented by thermal waters. According to various estimates, the economically reasonable energy resource of thermal waters in Ukraine is up to 8,4 Mtoe per year. The country has enough geothermal deposits with a high temperature potential (120-180°C), enabling the use of geothermal energy for electricity production.

Practical development of thermal waters in Ukraine is carried out in the Autonomous Republic of Crimea where 11 geothermal circulation systems have been built, compliant with modern technologies of extraction of geothermal heat. All the geothermal installations are in an experimental industrial phase.

Large thermal water deposits were found in Chernihiv, Poltava, Kharkiv, Luhansk and Sumy oblasts. Hundreds of wells with thermal water, not being currently used, can be used for further operation as geothermal heat extraction systems.

When calculating the possible consumption amounts of low-temperature geothermal resources in various regions of Ukraine, one should consider that their intense operation can lead to decrease in the soil mass temperature and to the depletion of the resources. It is necessary to maintain a rate of extraction that would allow operating a source of energy resources without any harm to environment. For each region of Ukraine, there exists a maximum intensity of geothermal energy extraction that can be maintained for a long period of time.

Figure 4.1.2.1. **Volume of Termal Energy Production form Renewable sources in Heating an Cooling**

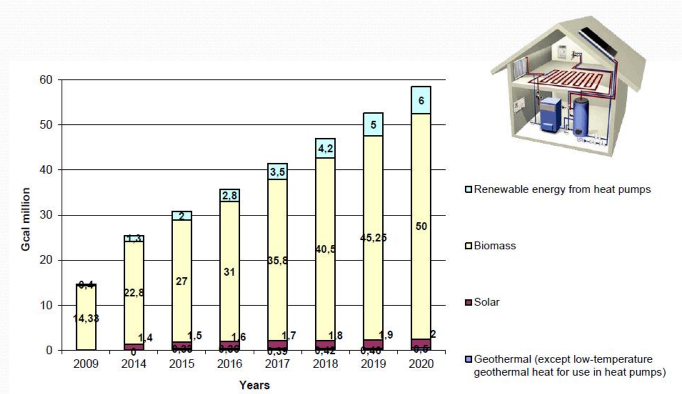
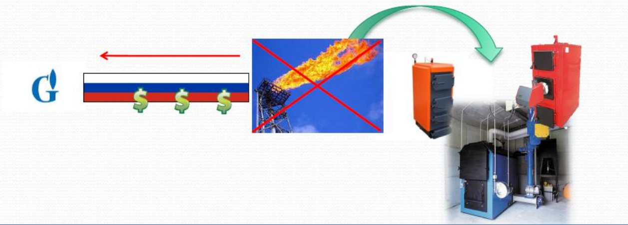


Figure 4.1.2.2. **In the Heating and Cooling Sector, Implementation of the NAP RE in full is to ensure:**

- Replacement of traditional FER in 2015 by **3,1 mn t o.e.**
- Replacement of traditional FER in 2020 by **5,85 mn t o.e.**

In 2020, energy from RES in the heating and cooling sector will make it possible to replace 6.3 bn m^3 of natural gas



4.1.3 Implementations Priorities

Active development of renewable energy surces ensures increase of strategy capacities. Therewith, installed capacity of renewable energy sources should be enlarged within the limits technologically admissible for maintenance of reliable work of Ukraine’s energy system. When increasing production of electricity based on renewable sources, grids should be upgraded to so-called smart grids. In case production of electricity from renewable sources is increased, the system operator of Ukraine’s Unified Energy System must ensure fulfilment of

Figure 4.1.3.1. **Implementation of the NAP RE in full will enable achivements of the following objectives by 2020**

- by 2020, decrease use of traditional FER by 8,6 mn t o.e. (9.2 bn m^3 of natural gas);
- Improve the environmental situation;
- create favorable conditions for investment in energy carriers production from renewable energy sources;
- improve energy carriers production from renewable energy sources to meet the EU requirements;
- Improve competitiveness of Ukraine’s economy.

[10] NATIONAL RENEWABLE ENERGY ACTION PLAN UP TO 2020, 2014, p.6

the daily load curve with account of the most efficient and safest use of all types of generation. An effective mechanism for regulation of RES capacities (particularly wind and solar plants) can be provided by the use of regulator consumers based on heat pumps, heat accumulators, or similar technology.

To solve the problem of shortage of manoeuvring and regulating capacities, construction of hydro and pump storage capacities, are proposed as priority projects:

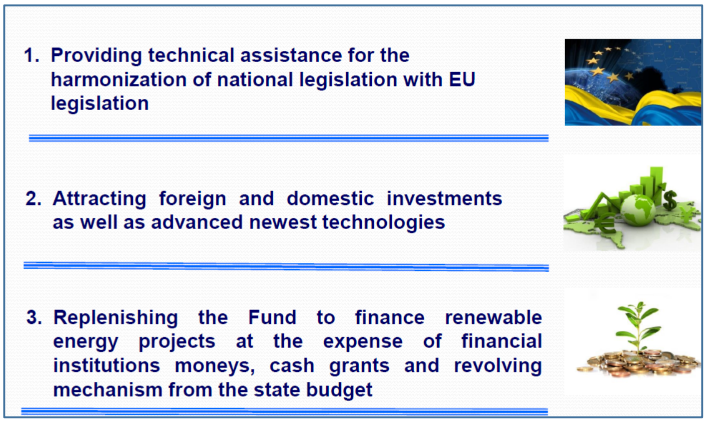
- completion of the first stage of Dniester PSPP and the first stage of Tashlyk PSPP by 2015;
- construction of the second stage of Tashlyk PSPP and the second stage of Dniester PSPP by 2020;
- continuation of construction of 1.000 MW Kaniv PSPP, and start-up of its first hydro unit in 2015;
- completion of designing of 270 MW Kakhovka HPP by 2014, and its enlargement by 2020;
- reconstruction and enlargement of Tereble-Rikska HPP with 30 MW capacity increase by 2020.

Separate attention should be paid to the necessity of developing and implementing effective mechanisms for people's investment involvement in a wider use of renewable energy sources.

Considering that the share of energy from renewable sources in gross final energy consumption in 2009 was 3,8 percent, this National Action Plan envisages achievement of the following national overall targets:

- target of energy from renewable sources in gross final consumption of energy in 2020: 11 percent;
- expected total adjusted energy consumption in 2020: 78.080 ktoe;
- expected amount of energy from renewable sources corresponding to the 2020 target: 8,590 ktoe.

Figure 4.1.3.2. **In order to reach the objectives of the National Action Plan for Renewable Energy for the period until 2020, the following are necessary.**



Expected final consumption of energy was calculated according to the Energy Strategy of Ukraine up to 2030. For the 2015-2020 level, indicative figures of the basic electricity development scenario were used; for interim values of heating and cooling, transport and energy efficiency and forecasted data of the basic scenario up to 2030 were used.

Full-scale realisation of provisions of this National Action Plan will allow:

1. enhancing the level of Ukraine's energy independence;
2. increasing the share of energy carriers from renewable sources in the structure of Ukraine's total final energy consumption in 2020 to at least 11 percent;
3. optimising the structure of Ukraine's fuel and energy balance, particularly ensuring reduction of the use of conventional energy carriers by 35 Mtoe by 2020;
4. improving the mechanism of public management and regulation in the field of renewable energy sources;
5. ensuring wider involvement of intellectual property entities in the process of development of renewable energy sources;
6. raising competitiveness of the national economy;
7. improving the ecological situation in the country by reducing atmospheric emissions of harmful substances created in combustion of organic fuel (biomass);
8. raising the development level of production of energy carriers from renewable sources up to the European Union requirements and the Energy Charter provisions;
9. ensuring renovation of fixed assets in Ukraine's energy sector;
10. creating jobs in the energy sector and other industries.

4.2. Geothermal Potential in Europe

The possibilities in Europe from geothermal energy provided 0.2% of the total final electricity demand (2800TWh) and 0,9% of the electricity generated by renewable sources (660TWh) in 28 European Union countries.[11] Based on the experience of European countries in implementation of geothermal power plants, production of electricity by geothermal units in Ukraine can be ensured by means of commissioning new capacities in the amount of 44 GWh in 2015 (total capacity 8 MW) and 120 GWh in 2020 (total capacity 20 MW).[12]

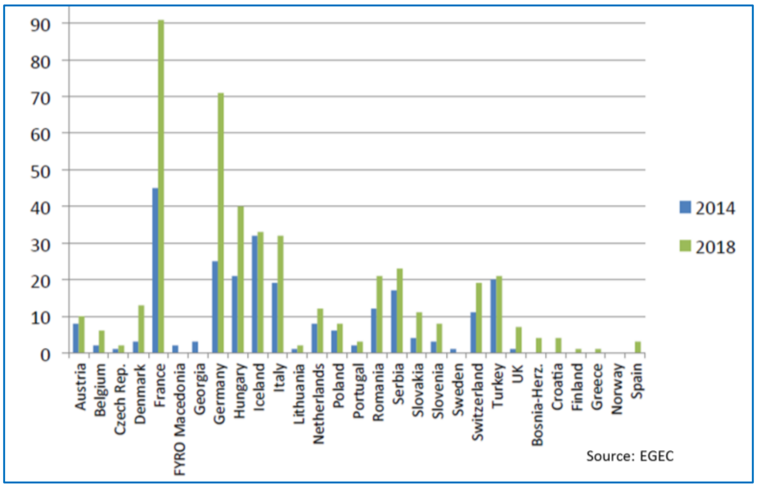
4.2.1. Heat Production from Geothermal sources in European Union

Use of Low and Medium Energy Applications[13]

Direct use of geothermal heat (excluding heat pumps) in the European Union is determined at 2.975,7 MW_{th} in 2012 and the production at 660 ktoe. This is the assessment of experts from the European Geothermal Congress (EGC 2013) including official estimates of national statistical authorities which helps "EurObserv'ER"[14] barometer measures the progress made by renewable energies in each sector and in each member state of the European Union. Statistics shows a sharp increase compared to the data published in the latest issue of "State of Renewable Energy" review, due to better assessment of geothermal capacity used in balneology, especially in Italy.

The data published in the EGC 2013, with the advantages of a breakdown of figures on three main application uses: district heating, heat utilization in agriculture and industry, and balneology and other purposes. On the basis of these figures, adding data from Slovakia, which is not included in this study, heating networks are the main use with 42,3% of thermal capacity, followed by balneology (34,9%) and agriculture and industry (22,9%).

Fig. 4.2.1.1. **Number of Geothermal District Heating systems in Europe – Potential Possibilites.**



Classification from "EurObserv'ER" thermal capacity ranking puts Italy on top of the direct use of heat (excluding heat pumps) at 778,7 MW, including 400 MW in balneology, 289 MW in agriculture and industry, and 80,7 MW in district heating. In second place is Hungary with 714 MW (no data on the breakdown), which is 60 MW more than in 2011. In third place is France with a heat capacity of 365 MW, of which 295 MW is in district heating, 50 MW in balneology, and 20 MW in agriculture and industry.

If we look at energy recovery, Italy is in first place (133,8 ktoe according to the Ministry of Economic Development), followed by Hungary (120 ktoe) and France 94 ktoe according to the Ministry of Environment´s Service of Observation and Statistics (SOeS).

Regarding further assessment on geothermal district heating possibilities in Europe, see chapter 2.4.2.

[11] jrc_geothermal_report_final
[12] Ibid.
[13] NATIONAL RENEWABLE ENERGY ACTION PLAN UP TO 2020, 2014, p.6
[14] European barometer http://www.eurobserv-er.org/

4.3. Geothermal Conditions in Ukraine

Ukraine has a number of geothermal deposits with mid-temperature potential, between 120°C and 180°C. These temperatures are sufficient for power generation. Annual technically achievable energy potential of geothermal energy in Ukraine is equivalent to 8,4 Mtoe[15] , and its use can save around 10 bcm of natural gas.

Geothermal energy (10,9 MW_t) is used for heating, water and air conditioning in residential and public buildings and facilities in urban and rural areas. Approved by the Ministry of Ecology and Natural Resources of Ukraine, the cogeneration potential of geothermal water resources is 27,3 million m^3 / day, and their thermal power capacity at 351 million GJ/year

One of the promising directions of development of geothermal energy is to create combined energy technology components for electricity, heat and valuable components contained in geothermal fluids.

The negative environmental impact of the operation of geothermal fields is minimal compared to the energy sources used at present. New technologies allow the reduction of the negative impact arising from the operation of geothermal energy to a minimum. Assessments conducted by a number of organizations have determined that the development of geothermal district heating will not only save use of fossil fuels, but also reduce environmental issues, which increases the quality of life for the population.

When assessing the number of possible low-temperature geothermal resources in different regions of Ukraine, it should be considered that intensive exploitation can lower the temperature of the resource and rapid depletion. It is necessary to maintain sustainable utilization of geothermal energy, which would utilise a source of energy without harming the environment. For each region of Ukraine there is a maximum sustainable level of extraction of geothermal energy, which can be maintained for a long time.

Geothermal assessments were carried out in Zakarpattia region (near settlements Velikay Palad, Velikay Bacta, Hust, Kosino, Beregovoe) and The Crimean Peninsula (Novoselovskyy, North Sivashskaya, Octjabrskaya Square).

The distribution of geothermal resources in Ukraine is primarily determined by the values of heat flow and the presence of highly permeable porous or cracks - vein reservoirs. Formation of the heat flow values depends on geological age of the area and the activity of tectonic and magmatic processes, accompanied by discharging of huge amounts of energy from the earth.

According to above mentioned parameters the Ukrainian territory is divided into three zones. Low thermal flow (22-60 mW/m^2), Ukrainian Crystalline Shield heat flow (22-45 mW/m^2), and geothermal gradient in most cases does not exceed 2°C/100m. The relatively young geological folding regions such as the Crimean Mountains and the Carpathians are characterized by weak geothermal background. Despite the fact that within these territories heat flow have higher values (60-90 mW/m^2 and more), geothermal gradients appears between 1,5-2°C/100m. This explained by high hypsometric position of these structures, deep relief dismemberment and the absence of insulating strata.

These mountain structures (the Crimean Mountains and the Carpathians) are the source of heat for adjacent regions, but they cannot be regarded as territory promising to form geothermal deposits.

Intermediate values of heat flow (50-70 mW/m^2) correspond to the structures, which completed its development in the Paleozoic. These include Steppe Crimea, Donetsk folded region, Subcarpathian region.

[15] REmap 2030: Renewable Energy Prospects for Ukraine, Chapter 6, p 21

Figure 4.3.1. **Distribution of Geothermal Energy Potential in Ukraine**

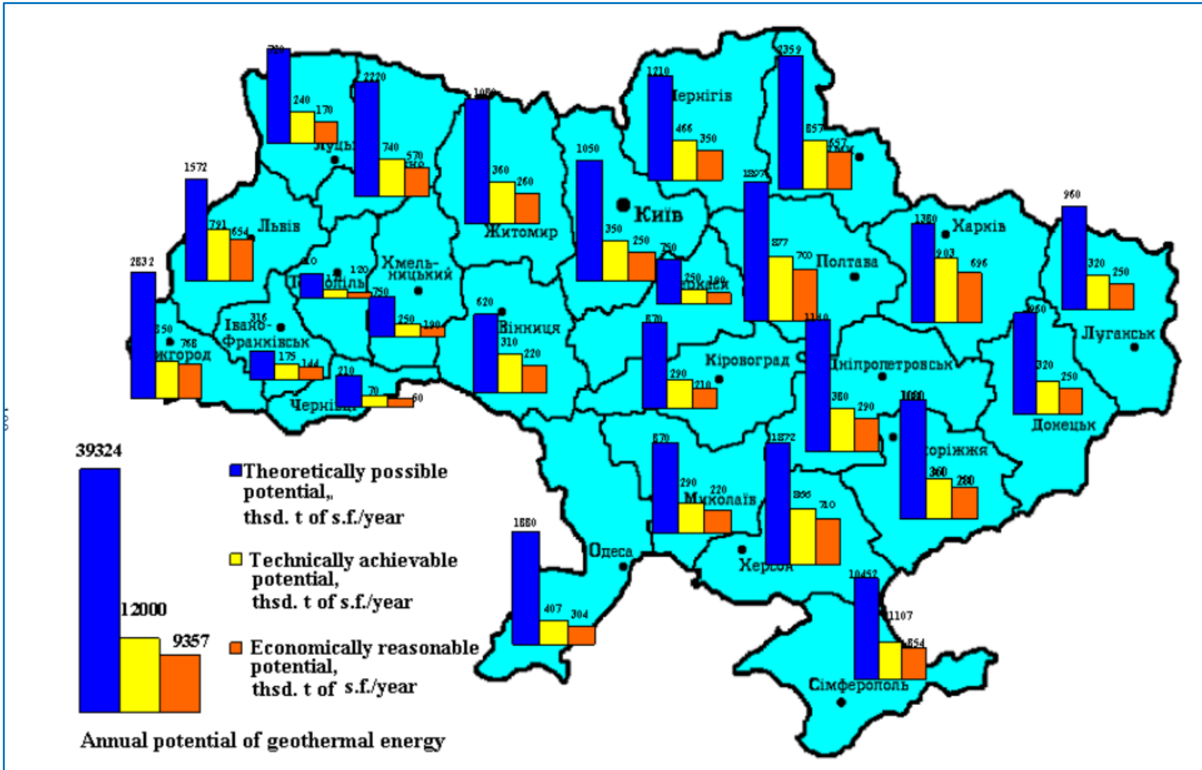


Figure 3.9 – Geothermal Energy Potential in Ukraine

Central part of the Dnieper-Donets basin (Chernihiv, Poltava, Kharkiv, Dnipropetrovsk, Sumy administrative regions) are characterized by relatively favorable geothermal conditions within which heat flow varies from 70-90 mW/m^2.

The highest heat flows (above 80 mW/m^2) and geothermal gradients (7-8,4°C/100m) are observed in Zakarpattya depression, in the central part of the Crimean peninsula and the Black Sea Coast (Odessa and Kherson regions). The Institute of Geophysics (National Academy of Sciences of Ukraine - NASU) made the map of the rock temperature at the depths of 3 to 10 km for the Ukrainian territory. Maps contain information about forecasted temperatures that were calculated for the actual measured values of geothermal heat flow.

Based on the analysis and extrapolation of these maps we made the map of forecast temperature rocks at depth of 5 km. According to this, the rock temperature values at a depth of 5 km in Ukraine ranges from 80 to 280°C. Low temperatures are prevalent on the Ukrainian Crystalline Shield and its slopes and in the northern part of the Volyno-Podolsk plate. The highest temperatures are in the Zakarpattia depression and along the Black Sea Coast. The most widely represented temperatures range from 90 to 130°C (in the Ukrainian Crystalline Shield and its slopes, the Volyn-Podolsk plate, the Dnieper-Donets depression, on the slope of the Voronezh array) and from 130 to 190°C (in the Carpathians, the Crimea, the Black Sea-Azov shelf, in the Donbass).

4.3.1. Overview of Geothermal Potential Resources in Ukraine

The first estimation of geothermal resources in Ukraine was implemented in 1979 by the Central Thematic Expedition of the Geology Ministry (main author E.E.Sobolewskij). At the present time results of these calculations are officially accepted and approved by the State Commission of Ukraine on Mineral Resources reserves. It was estimated that the predictive reserves of thermal waters, i.e. their maximum amount that can be extracted when production wells place evenly across the investigated area. Evaluation was performed by hydrodynamic method.

Total projected resources of thermal waters in Ukraine are 27,3 million m^3/day, of which 23 thousands m^3/day (free flowing well), 137 thousands m^3/day (pumping extraction), 27,2 million m^3/day (back pressure).

Defined resources are estimated to be 1.970 million GJ/year of which 2.5 million GJ/year (free flowing well), 8,93 million GJ/year (pumping extraction) and 1.895 million GJ/year (back pressure). Estimation was performed only for the Zakarpattia and Black Sea regions (the Crimean peninsula and Kherson southern region) on the results of drilling, which was carried out at that time.

The Production Geological Enterprise "Krymgeologiya" (heat S.M.Taletskiy) determined the prospects of extracting thermal waters that located within work of this geological association in 1991. They made regional assessment of deposit operational stocks of thermal water area, namely Crimea Plain, northern and western Black Sea regions and the Kerch Peninsula. The total projected operating reserves are on amount of 34 million m^3/day or 1.635 million GJ/year.

The Institute of Geological Sciences of NASU in cooperation with the Ministry of Ecology and Natural Resources of Ukraine in 2001 issued "Geology and mineral resources of Ukraine (scale 1: 5.000.000), which has a section dedicated to geothermal resources.

According to IGS NASU, projected resources of geothermal energy in Ukraine to a depth of 3 km constitute: $3{,}3 \cdot 10^{22}$ J or $1{,}12\ 10^{12}$ toe and to a depth of 10 km: $6{,}9 \cdot 10^{22}$ J or $2{,}38 \cdot 10^{12}$ toe respectively.

According to geological-structural features defined areas of high use of geothermal resources, these include: Zakarpattia depression ($0{,}32 \cdot 10^{22}$ J; $1{,}11 \cdot 10^{12}$ toe), Precarpathian deflection ($0{,}16 \cdot 10^{22}$ J; $0{,}56 \cdot 10^{12}$ toe), Plicate Donbass ($0{,}3 \cdot 10^{22}$ J; $1{,}02 \cdot 10^{12}$ toe) and Crimea ($0{,}74 \cdot 10^{22}$ J; $2{,}48 \cdot 10^{12}$ toe).

Institute of Geophysics (IGPH) at NASU in 2004 year issued "Geothermal Atlas of Ukraine", in which estimates were made of geothermal resources to the depth of 3, 4,5 and 6 km. Calculations were based on the average geothermal gradient and thermal properties of rocks, which were defined by the actual data and specific to certain calculation areas.

Note that defined IGPH NASU resources reflecting actual petrothermal energy sources, while thermal water resource (hydrothermal) in this assessment are not included. The total value of geothermal resources of Ukraine in the depth at interval 5,5 - 6 km according to calculations of IGPH NASU was 0,56 trillion toe.

The best perspective of geothermal resources is in the Zakarpattya region. In 2006 an evaluation was done on the operational reserves of geothermal waters of region as whole, and some geothermal fields. Seven fields operating reserves of thermal waters (Uzhhorod, Berehovo, Kosinski, Velyko-Baktynske, Velyatynske, Velyko-Paladske, Zaluzhske) were approved in the State Commission of Ukraine on Mineral Resources reserves.

Institute of Renewable Energy at National Academy of Sciences in 2013 published "Atlas of energy potential of renewable energy in Ukraine." The Atlas presents data about geothermal potential distribution of individual administrative regions of Ukraine. It estimates the total annual technically attainable geothermal potential to equal 8,4 million toe or 98,6 TWh·h (see Table 4.3.1.1). The energy potential included hydrothermal resources (thermal waters), petrothermal resources and resources of upper layers of the earth. Note that hydrothermal resources were in the following areas: Crimea, Zakarpattia, Ivano-Frankivsk, Poltava, Chernihiv, Chernivtsi, Zaporizhia, Donetsk, Dnipropetrovsk, Odessa, Kharkiv and Kherson regions.

Table 4.3.1.1. **Energy Potential of Geothermal Energy in Ukraine**

№	Areas	Technically achievable geothermal heat potential		№	Areas	Technically achievable geothermal heat potential	
		thousand TOE per year	thousand MWh per year			thousand TOE per year	thousand MWh per year
1	Crimea	775	9.011	14	Lviv	554	6.439
2	Cherkasy	175	2.035	15	Mykolaiv	203	2.361
3	Chernigiv	326	3.793	16	Odessa	2.845	3.313
4	Chernivtsi	49	570	17	Poltava	614	7.139
5	Dnipropetrovsk	266	3.093	18	Rivne	518	6.024
6	Donetsk	224	2.605	19	Sumy	600	6.976
7	Ivano-Frankivsk	123	1.425	20	Ternopil	119	1.392
8	Kharkiv	632	7.350	21	Vinnytsa	217	2.523
9	Kherson	606	7.049	22	Volyn	168	1.954
10	Khmelnitsky	175	2.035	23	Zakarpattia	596	6.919
11	Kirovograd	203	2.361	24	Zaporizhya	252	2.930
12	Kyiv	245	2.849	25	Zhitomyr	252	2.930
13	Lugansk	224	2.605	TOTAL		8.400	97.681

* Kyiv represents both Kyiv city and Kyiv oblast. Crimea represents both Sevastopol city and AR Crimea. Other areas represent oblasts.

4.3.2. Development Forecast of Geothermal Capacities in Ukraine

In this part we represent materials that are going to be included in the "Roadmap of development geothermal energy and energy of environment for period up to 2020" that contains the following characteristics: installed capacity, annual production of electric and thermal energy, annual conventional fuel savings both in tones of equivalent oil and natural gas volumes.

Table 4.3.2.1. **Tasks and Measures of the Implementation of the Roadmap of Geothermal Power and Energy of Environment until 2020**

Name of task	Name of indicators	Indicator value					
		Total	Year				
			2016	2017	2018	2019	2020
1. Using geothermal energy considering of associated gas	1. Energy indicators						
	1.1. Installed capacity, MW	152,0	8,0	16,0	32,0	32,0	64,0
	1.2. Annual electricity production, million kWh/year	2296,0	56,0	168,0	392,0	616,0	1064,0
	1.3. Annual electricity production in oil equivalent, ths TOE	197,5	4,8	14,5	33,7	53,0	91,5
	1.4. Annual savings of conditional fuel, Mtoe/year	8,2	0,2	0,6	1,4	2,2	3,8
	1.5. Substitution volumes of natural gas, mln. m³	9,348	0,228	0,684	1,596	2,508	4,332
2. Use of geothermal heat	2. Energy indicators						
	2.1. Installed capacity, MW	400,0	40,0	60,0	80,0	100,0	120,0

	2.2. Annual production of heat ths. Gcal	1420	140	210	300	350	420
	2.3. Annual heat production in oil equivalent, ths. TOE	142,0	14,0	21,0	30,0	35,0	42,0
	2.4. **Annual savings of conditional fuel, mln. TOE/year**	0,2	0,02	0,03	0,04	0,05	0,06
	2.5. Substitution volumes of natural gas, mln. m³	0,232	0,023	0,035	0,046	0,058	0,07
3. Use of geothermal energy (excluding low temperature geothermal heat for use in heat pumps)	3. Energy indicators						
	3.1. Installed capacity, MW	400,0	40,0	60,0	80,0	100,0	120,0
	3.2. Annual production of electricity, ths. Gcal	1420	140	210	300	350	420
	3.3. Annual heat production in oil equivalent, ths. TOE	142,0	14,0	21,0	30,0	35,0	42,0
	3.4. **Annual savings of conditional fuel, mln. TOE/year**	0,2	0,02	0,03	0,04	0,05	0,06
	3.5. Substitution volumes of natural gas, mln. m³	0,232	0,023	0,035	0,046	0,058	0,07

Name of task	**Name of indicators**	**Indicator value**					
		Total	**Year**				
			2016	**2017**	**2018**	**2019**	**2020**
4. Energy from heat pumps, including: A) air; B) geothermal; C) hydrothermal	4. Energy indicators						
	4.1. Installed capacity, MW	350,0	30,0	50,0	70,0	90,0	110,0
	4.2. Annual production of electricity, ths. Gcal, including:	1205,0	103,0	172,0	241,0	310,0	379,0
	A	602,5	51,5	86,0	120,5	155,0	189,5
	B	482,0	41,2	68,8	96,4	124,0	151,6
	C	120,5	10,3	17,2	24,1	31,0	37,9
	4.3. Annual heat production in oil equivalent, ths. TOE, including:	120,5	10,3	17,2	24,1	31,0	37,9
	A	60,2	5,15	8,6	12,05	15,5	18,9
	B	48,27	4,15	6,88	9,64	12,4	15,2
	C	12,03	1,0	1,72	2,41	3,1	3,8
	4.4. **Annual savings of conditional fuel, Mtoe/year, including**:	0,172	0,015	0,025	0,034	0,044	0,054
	A	0,086	0,0075	0,0125	0,017	0,022	0,027
	B	0,0688	0,006	0,01	0,0136	0,0176	0,0216
	C	0,0172	0,0015	0,0025	0,0034	0,0044	0,0054
	4.5. Substitution volumes of natural gas, mln. m3, including:	0,197	0,017	0,03	0,04	0,05	0,06
	A	0,0985	0,0085	0,015	0,02	0,025	0,03
	B	0,0788	0,0068	0,012	0,016	0,02	0,024
	C	0,0197	0,0017	0,003	0,004	0,005	0,006

4.3.3. Assessment Results of Potential Geothermal Resources in Ukraine

For the purpose of energy potential of geothermal deposits at Ukraine, a database was created that includes more than 400 actual specifications on boreholes drilled in Poltava, Ivano-Frankivsk, Lviv, Chernivtsi, Kherson, Zakarpattia, Chernihiv, Kharkiv, Dnipropetrovsk and Odessa regions and the Autonomous Republic of Crimea. Actual data was obtained from reports, archives and printed sources.

Figure 4.3.3.1. **Map of Placement Geothermal Objects in Ukraine**

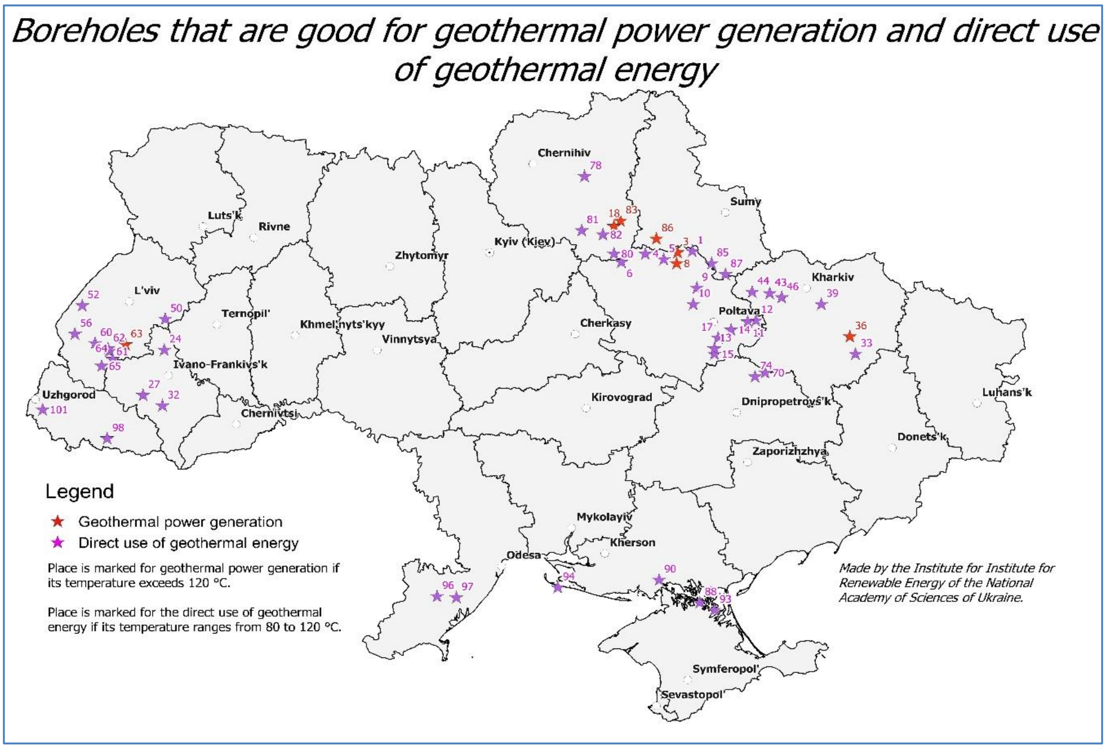
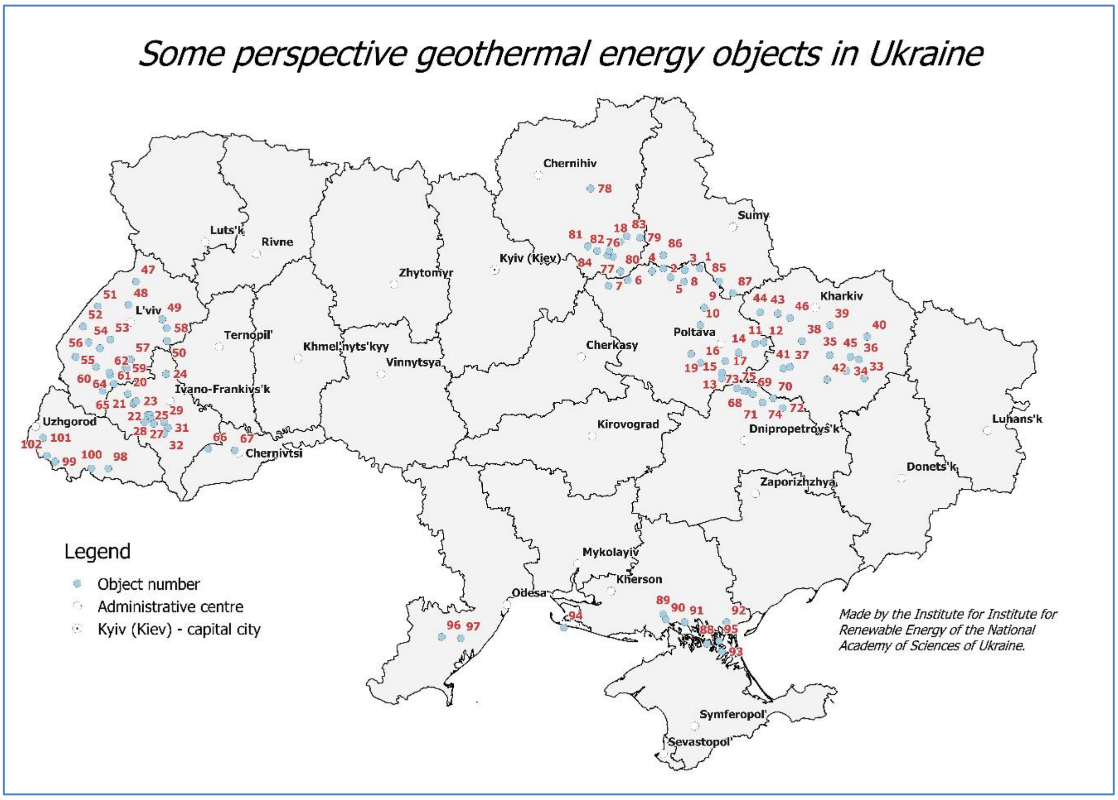


Figure 4.3.3.2. **Geothermal Objects with Thermal Water Temperature Exceeding 80°C**



The database included information about depth and thickness of productive horizon, bed temperature and static pressure, debit of borehole at corresponding decrease of level, groundwater mineralization and organization name that received permission to use this deposit with permit number.
Actual data covering deposit is uneven, some deposits are presented by dozens of boreholes and other by a single borehole. Baseline data was analyzed, summarized, and average values were identified for each deposit. Averaged values were determined for 102 deposits.

Calculation covers 47% from total number of gas and gas condensate deposits. Figure 4.3.3.1 provides a map of geothermal objects in Ukraine that were entered to the database. Figure 4.3.3.2 shows those geothermal objects in which thermal water temperature exceeds 80 °C. Maximum temperature is 126 °C.

4.3.4. Priority Development of Geothermal Resources in Ukraine

Priority objects are defined on the grounds of analysis of exploratory data, hydrogeological parameters and assessment of their operational characteristics. Table 4.3.4.1. presents the most studied geothermal objects.

Table 4.3.4.1. **Priority Geothermal Objects**

№	Name of geothermal object	Location	Bed temperature ° C	Depth of productive horizon, m
1	Russkie Komarovtsy	Zakarpattia area	89	1350
2	Henichesk	Kherson area	89	2620-2651
3	Monastyryshche	Chernigiv area	96-98	3374-3384
4	Spivakovskaya	Kharkov area	98	2780
5	Gadyach	Poltav area	119-120	4950
6	Mostyska	Lviv area	90-95	3160
7	Hlinsko-Rozbyshevskoe	Poltav area	127	5060

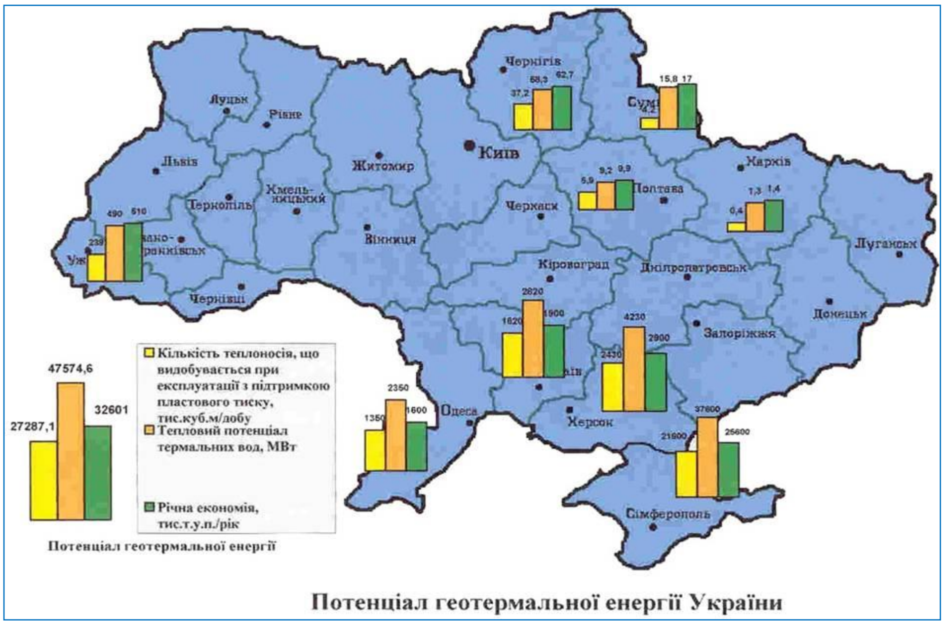
The presented data can be used as priority objects after tests conducted and definition of technological parameters, as well as estimates of reserves of geothermal deposits. For further studies it is recommended to focus on the Zakarpattia region, Lviv due to the West location and availability of already existing research.

4.4. The use of Geothermal and Mineral waters in the Area of Ukrainian Carpathians[16]

Following chapter 4.4 presents the summary of use of the geothermal waters in the Ukrainian Carpathians, which is based on the analysis from „Geothermal Atlas of the Eastern Carpathians" [17]

4.4.1. The use of Geothermal Waters in Carpathian Ukraine

Figure 4.4.1. **The use of Geothermal Waters in Carpathian Ukraine – Current Status of Geothermal Energy Development in Carpathian Ukraine**



Geothermal resources in Ukraine are represented primarily by thermal waters and heat of hot dry rocks. In addition to promising for use in industrial scale, geothermal resources include heated subterranean water resources, which are derived from operating wells of oil and gas fields. The reserves of thermal and superheated waters are formed and circulate at depths exceeding 1.000 m within the boundaries of geosynclinal type artesian basins. Ukraine has four basins containing industrially feasible reserves of thermal and superheated waters: Transcarpathian (or Zakarpattia), Ciscarpathian, Dnieper-Donets and Black Sea (Prychornomorski) basins.

According to official data of the Ministry of Ecology and Natural Resources, reserves of thermal waters are 27,3-106 m^3/day. Technical potential of geothermal resources is estimated to be 97,7 TWh/year. In 2000 geothermal energy utilisation amounted to 0,1 TWh. It is expected that total capacity of constructed geothermal district heating systems will be 9.000 MWth and that of geothermal power plants will be 400 MWe in 2030.

That will ensure a production of 42 TWh, and in 2050 the production will come to 57 TWh (Ministry of Fuel and Energy of Ukraine, 2002). However, such degree of geothermal energy use seems to be too optimistic. Geothermal energy is renewable only on a geological scale of time. As stated in (Geletukha et al., 2003), the promising under geological conditions of Ukraine geo-circulating systems will exhaust their aquifer resource over 20-30 years. It is assumed that the amount of utilized geothermal energy will reach 8 TWh/year in 2030 and 14 TWh/year in 2050 which is equivalent to current use of geothermal energy in the whole Europe.

---

[16] Gordienko I., Gordienko V, Zavgorodnyaya O., Geothermal Resources of Ukraine, Proceedings World Geothermal Congress 2005

[17] Gorecki W., Hajto M., Geothermal atlas of the Eastern Carpathians, AGH, Krakow 2013

It should be pointed out that within the boundaries of these basins there are localities containing waters superheated to more than 170°C at the depths exceeding 3.500 m. Results of the exploratory wells testing have shown that the pioneering work on superheated waters extraction can be organized on localities in Zakarpattia Oblast (Zaluzhzhia), Kharkiv Oblast and AR Crimea (Tarkhankut). Total dry-rocks-accumulated heat potential reserves are estimated to be around 322,7-1.012 GJ, according to Zabarny (Zabarny, 2003). Presently, however, industrial utilization of the geothermal reserves in full measure is rather problematic due to the comparatively low (up to 100°C) temperature of the major part of the thermal waters and dry rocks. Thus, their use is limited mainly to heating purposes and is possible within the limits of cities and settlements.

4.4.2. The use of Geothermal Waters for Heating Purposes in Ukraine[18]

Practical harnessing of geothermal resources in Ukraine have been in progress starting from early 90s. Particular emphasis in the development of Ukrainian geothermal power engineering was laid on the development of geothermal heat-supply systems as well as on the construction of cogenerating units based on geothermal fields with gas-containing thermal waters.

Table 4.4.2.1 Active Geothermal objects in Ukraine

Geothermal Energy use	Geothermal object	Years of introduction in operation	Thermal (electric) capacity (MW_t)	Annual economy of fuel (t c.f.)[1]
3 in Ciscarpathia in Western Ukrine **9 geothermal plants** (list from Khvorov et al., 2005) **6 in Scythian platform** of which 5 on Crimea, 1 in Khersonskaya Oblast **in 2003: 10,0 MW heat installed 33 GWh heat production**	1. System of the geothermal heat supply of the Beregovsk´s sport center. **Beregovskiy** area, Zakarpatskaya region	1978	2,1	1.215
	2. System of the geothermal heat supply of the sanatorium "Kysyno**". Beregovskiy** area, Zakarpatskaya region.	1988	1,2	860
	3. System of the geothermal heat supply of the sanitary complex "**Latorytza**" Mukachevskiy area Zakarpatskaya region.	1985	0,2	210
	4. System of the geothermal heat supply of the settlement Yantarnoe. Krasnogvardeyskiy region, AR Crimea.	1991	4,6	2.700
	5. System of the power supply of the objects budgetary sphere in the settlement changer. Khersonskaya region.	1998	1,0 (0,1)	900
	6. System of the geothermal heat supply of children's establishments and of the social culeture household spheres of settlement Medvedevka, Dzhankojsky area, AR Crimea.	2002	0,8 (0,06)	650
	7. System of the geothermal heat supply of the objects in the settlement Zemovoe. Sakskiy area, AR$ Crimea.	1997	0,4	355
	8. System of the geothermal heat supply of the objects of municipal economy of settlements Piatykhatky. Krasnogvardeyskiy region, AR Crimea.	1996	0,3	300
	9. System of the geothermal heat supply of the objects in the settlements Nizinnoe. Sakskiy area, AR Crimea.	1998	0,3	300
	TOTAL		**10,9 (0,17)**	**7.470**
	(Zabarny 2003).			

The abovementioned activity is financed within the framework of the State R&D Program „Environmentally Friendly Geothermal Power Engineering of Ukraine" which is focused on the development of scientific and technical foundation of and material basis for the introduction of geothermal energy in the national fuel and energy complex. Currently, the State R&D Program „Environmentally-Friendly Geothermal Power Engineering of Ukraine" is being implemented with the financial support of the State. The Administration of Crimea, as well as those of Zakarpattia and L'viv Oblast earmarked funds for building new geothermal units in addition to already existing installations listed in Table 4.4.2.1.

[18] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013, p. 718

As estimated in the EBRD Country profile for Ukraine (EBRD, 2009), the state's considerable geothermal resources can be used mainly for heat supply. There are also prospects for binary geothermal power plant creation based on existing wells at abandoned oil and gas fields. Separate wells are used in the Transcarpathian region to supply thermal water in swimming pools or as an additional source of heat for the local boiler houses. The total thermal installed capacity of Ukraine of 10,9 MWth generates 119 TJ of energy per year. Currently, the geothermal energy is supplied to nine different systems. Two of the systems are associated with power plant co-generation producing 0,16 MWe and 1,8 MWe.

Currently there is no updated data available, disclosing actual volumes of direct use of geothermal energy in Ukraine. According to Antics and Sanner (Antics and Sanner, 2007) and their assessment of direct uses in Europe 2007 update (after Lund, 2005, Rybach, 2006) and International Geothermal Association (IGA) data, taken from the paper by Lund, Freeston and Boyd (Lund et al., 2010), the direct-uses in the country are for individual space heating (3,5 MWt and 36,3 TJ/year); and district heating (10,9 MWt and 118,8 TJ/year) as presented in Table 4.4.2.2.

Table 4.4.2.2. Direct uses of Geothermal Energy in Ukraine

Total thermal installed capacity in MW^t	10,9
Direct use in TJ / year	118,8
Direct use in GWh / year	33,0
Capacity factor	0,35

4.4.3. The use of Geothermal Waters in Ukraine - Electricity Production[19]

Total thermal and electric capacity of the operational geothermal energy units in Ukraine today amounts to 10,9 MW and 0,17 MW respectively. Exploitation of the existing units listed in Table 4.4.2.1, results in saving 7.470 tons of conventional fuel per year.

Two of the systems are associated with power plant co-generation producing 0,16 MWe and 1,8 MWe. According to estimation results, presented by Zabarny (2003a) in the study of power-generating potential of the geothermal resources of Ukraine (Zabarny, 2003b), the technically accessible power generation potential of Ukraine is estimated in $33{,}12 \cdot 10^6$ MWh/year for thermal waters of artesian basins with the temperature of up to 100°C; for dry rocks – in $18{,}02 \cdot 10^6$ MWh/year. The technically accessible power generation potential of superheated geothermal waters with the temperature exceeding 150°C amounts to $2{,}36 \cdot 10^6$ MWh/year.

Total operational reserves of geothermal waters in scale of Ukraine are estimated in 3.093.103 m^3/day, superheated waters – 1.008.103 m^3/day. On condition that these predicted reserves could be incorporated into the fuel-and-energy complex of Ukraine, it will be possible to create 12.390 MW of thermal and 414 MW of electric capacities, annually save 7,78-106 tons of conventional fuel, cut down the use of fossil fuel in energy sector by 8,35%, reduce annual CO_2 emissions by 17.106 tons. To harness the above-mentioned potential, it is necessary to create heat generating units with total capacity of 12.390 MW and electricity generating units with total capacity of 414 MW. Partial estimates of the potential geothermal power-generation reserves for western regions of Ukraine are given in table 4.4.3.1.

[19] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013, p. 718

Table 4.4.3.1. **Predicted usable Reserves of Geothermal Energy and Energy Potential thereof as estimated for Western Regions of Ukraine.**

Region	Operational reserves			
	Geothermal/ superheated waters	**Dry rocks, thermal capacity**	**Energy potential thermal/electrical**	**Annual saving in fuel**
	(10m^3/day)	MW	10^3MWh/year	10^6 t c.f.
Zakarpacki (Carpathian)	264 / 371	-	2.77 / 1.0	0.84
Iwanufrankowski (Ivano- Frankvisk)	181	-	1.89	0.24
Lwowski (Lviv)	197	-	2.07	0.27
Tarnopolski	-	77	0.32	0.04
Czerniowiecki	-	155	0.64	0.08
Total	**642 / 371**	**232**	**7.69 / 1.01**	**1.47**

It should be marked, that the predicted usable reserves of thermal and superheated waters of the artesian basins and the amount of heat stored in dry rocks have been evaluated down to 5.000 m depth, as that is attainable by standard-made drilling equipment and reinjection of the geothermal fluid.

4.4.4. Prospective Areas of use of Geothermal Energy in Carpathian Ukraine[20]

In accordance with the National report of Ministry of Environment and Natural Resources of Ukraine (Bystriakova and Stashuk, 2011), hydrothermal resources in Ukraine are concentrated mainly in Transcarpathian inner trough and in the plains of Crimea. The territory of the Dnieper- Donets and Black Sea basins also have elevated temperature gradients and with appropriate study can be considered as promising for geothermal energy.

In the 1980s Sobolevsky E.E. (CTE Mingeo URSR1) performed regional assessment of predictive thermal groundwater resources, which was based on the following criteria: lower limit of reservoir temperatures of groundwater – 40-45°C; background performance of individual wells – at least 2-3 dm^3/s (170-250 m^3/day) mineralization of thermal waters – should not exceed 200 g/dm^3. Evaluation results of expected thermal water resources are listed in (Table 4.3.2.1.).

According to different studies of prospective geothermal resources and current development state of geothermal energy in Ukraine, conducted by both domestic and foreign experts, it is decided to focus on three regions suitable for geothermal exploitation.

Stoyanov and Taylor (Stoyanov, Taylor, 1996), followed by Battocletti (Battocletti, 2001) mark out the Crimea peninsula (including Sivash, Alminski and Indolski artesian basins), the Ciscarpathia (incl. the Ciscarpathian depression and the Vigorlat-Gutynski volcanic range) and the Kharkiv-Poltava region in the Dnieper-Donets basin as the most prospective geothermic regions of Ukraine; Zabarny, Shurchkov (Shurchkov et al., 2003; Zabarny, 2003b), as well as other authors (Meliychuk et al., 2010; Gordienko et al., 2005; Rudko, 2010) and as stated in National report of Ministry of Environment and Natural Resources of Ukraine (Bystriakova, Stashuk, 2011), locate the most perspective region for geothermal exploration in Ukrainian Carpathians (Zakarpattia) and the nearby territories – partly in Lviv and Ivano-Frankivsk regions.

According to Gordienko (Gordienko et al., 2005; Gordienko, 2011), the western area of Ukraine has total reserves (as sum of C3) value about 0,2-1.012 toe. Network density of geothermal research in parts of the Carpathians and the Cis-Carpathians is currently maximal for Ukraine. Especially a lot of deep heat

[20] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013, p718

flow values of the Earth is set in the Transcarpathian and Carpathian basins. However, there often is not enough information to identify local anomalies, which have, in particular, the importance for the investigation of the connection of oil and gas with the deep processes.[21]

4.4.5 Geothermal Projects in Carpathians[22]

The Zakarpatsky area is an important fuel and energy region of the Ukraine. About 200 petroleum and gas wells have been drilled there. However, some of these wells are no longer profitable for such use. These wells provide thermal water and could be used economically for district heating.

The temperature of the thermal water is usually within the limits of 45-120°C, and the depth of the productive aquifers ranges from 1.000 to 3.000 m. Thus, the already existing wells may be used for the purpose of providing the heat supply for this region. The **Beregovsky** field is also ranked among several prospective geothermal areas of the Ukraine (Zabarny et al., 1997)[23].

The geothermal resources in Eastern Europe contains information on 28 specific geothermal sites or projects in Ukraine with the highest enthalpy geothermal resource identified in Zakarpattia in ***Zaluzhzhia*** (Zaluzska 3 deep well, 4.050 m depth) with a temperature of 210°C.

The average temperature of all sites in Ukraine is 59,8°C. Thirteen sites have a temperature of 100°C or more. There is a number of sites with wells located in the Carpathians area, which are characterized by different development status, temperature (°C), and electric power generation potential.

The site in **Berehove** (Zakarpattia region) is currently in a stage of feasibility study. The temperature of discovered thermal water resources reaches 70°C. In 1997**, the Danish company Houe and Olsen,** assessed the resource and project through the **DANCEE program.**

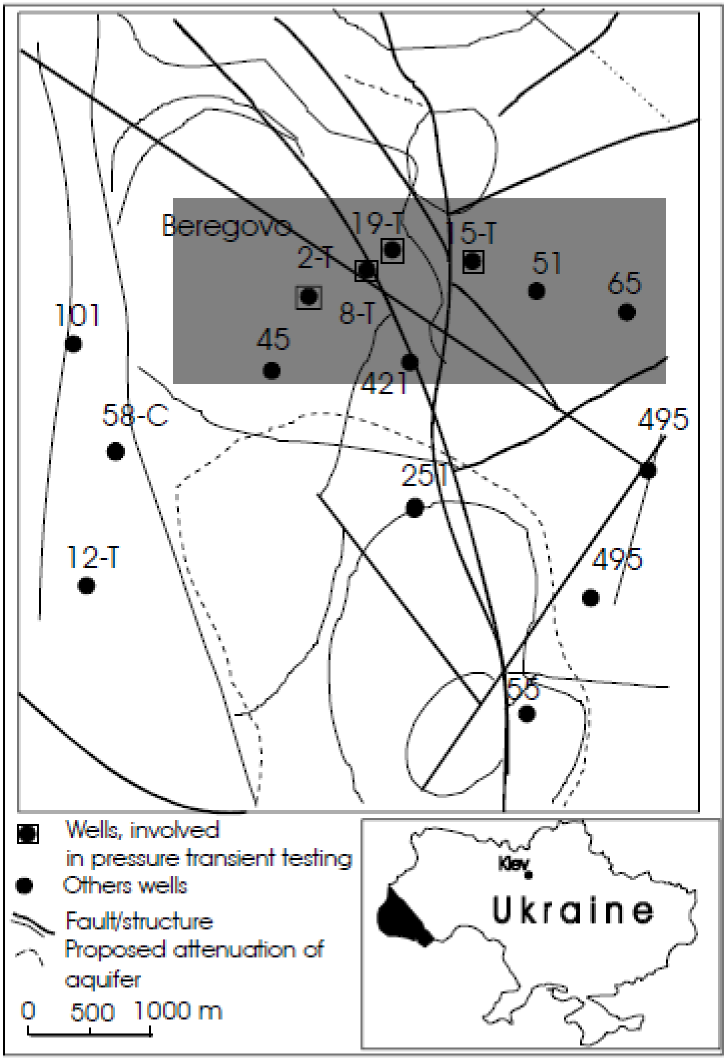
About 15 wells have been drilled for various purposes. In all the boreholes, well-logging, well tests, and geochemical sampling of thermal water have been carried out. Analysis of well test data indicates that the average transmissivity of the **Berehivsky** reservoir is about 0,5-10-5 m^3/Pa/s. A lumped parameter model using the LUMPFIT computer program was used to simulate the **Berehivsky** geothermal area and predict the reservoir response to three constant production rate cases over the next 10 years (Barylo, 2000). The location of the wells has been presented in the Figure 4.4.5.1.

The project in **Berehove** comprises reconstruction of existing wells and drilling of new wells (1 doublet). The district heating network requires renovation and extension. The current fuel is natural gas. The total heat demand is 73.300 MWh, of which geothermal energy is expected to cover 50 percent. The geothermal resource will be used to heat three five-story buildings, replacing a gas-fired boiler. Total project cost is USD 30 million.

It is estimated that the energy potential of the **Berehivsky** geothermal area is 1,23c10^{17} J and the possible direct use potential (e.g. space heating) produced for a 25-year period is estimated to be about 15 MWt. The aquifer depth is 900-1.500 m (Dolinsky et al., 2001).

[21] 1 Central Thematic Expedition of Ministry of Geology of the Ukrainian SSR 2 t c.f. (tons of conditional fuel) = t s.f. (tons of standard fuel)– the unit of standard fuel used in the former countries of USSR. An arbitrary unit used in calculations of organic fuels to compare efficiencies of different types of fuel and to make general evaluations. One kilogram of fuel with a heat of combustion of 7.000 Calories (kcal) per kg (293.076 MJ/kg). 1 t s.f. ≈ 0,7 toe (tons of oil equivalent).
[22] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013
[23] Barylo A., *Assessment of the energy potential of the Beregovsky geothermal system, Ukraine*, UNU, Report 2000/3

Figure 4.4.5.1. **Locations of Wells and main Geological Structures Beregovsky Geothermal Area** [1]



Some of the drillings in the region of the town of **Irshava** (Zakarpattia region) also demonstrated significant free-flowing hot water. At that site, an anticline crypto-diapir fold is to be found under the Neogene mantel. Most promising are the waters in Cretaceous sedimentary environments. Such waters and environments have been discovered by the drillings at Irshava 2, located in the area of the Danilovo – Nevitskovo abyssal fracture. The water-bearing rock is of fissured type, probably due to the fracture zone. Mineralization is about 189 g/dm^3 (Stoyanov, Taylor, 1996).

A well drilled near the city of **Mostyska** (Lviv region) indicates the availability of a prospective geothermal resource, revealing 128°C at a depth of 1.950 m.

As a result of studies carried out in **Tereblia** (Zakarpattia region) in 1980s, the site was determined to be of the second highest priority for commercial utilization.

Well Tereblia 6, drilled in the central part of the syncline, reached pressurized water-bearing horizon in the interval between 2.009 and 2.360 m. The well is a gushing type, with flow-rates between 500 and 900 m^3/day. The pressure at the well head was measured at 1,2 atm. The pressure at 1.767 m was 217 atm. Water mineralization is in the range of 138 g/dm^3. Water temperature measured at 2.350 m was 105°C, and at the wellhead was 95°C (Tereblia 6).

The hydro-geothermal complex at the **Tereblia** site is of significant interest. The formation is located in the central part of the Solotvyno depression. The maximum thickness of the water bearing tuffs is 700m. The dip angle of the thrust fault planes of the Cretaceous blocks of the base is between 5-20 degrees. The water bearing suites are enveloped between these practically water-impermeable blocks and talabor rock which is also water impermeable. This creates very favourable conditions for the accumulation of geothermal waters. The size of the Tereblia water-bearing complex is 15 x 5 km. Assuming, the thickness of the water bearing rock is 300 m and the porosity of the rock is 10%, the accumulated reserves are 3 km^3. With a temperature of over 100°C, the accumulated thermal energy is $1{,}5{\cdot}10^{18}$ J (Stoyanov, Taylor, 1996).

The **Uzhgorod** site is characterized, as is the territory of the entire depression, by a block structure of pre-Neogene folding base. Multi-directional tectonic movements of the blocks have resulted in significant variations in the depth of the base. The highest part is the Uzhgorod transversal uplift. The roof of the base is located at a depth of less than 1.000 m. Uneven, but sometimes up to hundreds of meters thick, the sedimentary mantle of lower Miocene is a significant structural element of the hydrothermal environment of this site.

The most productive area proved to be the sandstone water bearing horizon of the adjacent Rusko-Komarivsky uplift. The name of the drill-site is Uzhgorod 2T. The mineralization of the water is 16-30 g/dm3. The formation pressure at 1.700 m is 167,9 atm and at 1.300 m, 134,64 atm. A maximum water temperature of 108°C was measured at a depth of 1.940 m. The discovered hydro-geothermal resources have been determined to have no commercial value and are currently in conservation. The geological and hydro-geological investigation carried out at the site is however considered insufficient to a large extent (Stoyanov, Taylor, 1996).

4.4.6. Prospective Areas of use of Geothermal Energy in Zakarpattia Region[24]

As mentioned above, the region of Transcarpathia is the most prospective area for geothermal exploration. According to Taylor and Stoyanov (Stoyanov, Taylor, 1996), the investigation of Cis-Carpathian depression proved that from a hydro-geological point of view, the area is a first class, pressurized water-bearing basin. It is sub-divided into two second class water-bearing basins: the Chop-Mukachevo and Solotvyno pressurized water-bearing basins. Mineralization of the geothermal waters of the Chop-Mukachevo basin vary in quantity and kind from 10 g/dm^3 to 300-350 g/dm^3.

Figure 4.4.6.1. **Thermal basins in Berehove**

Significant flow-rates of waters from Paleozoic, Early Miocene and Sarmat deposits have been observed during prospective drillings in the area of the town of Uzgorod, situated in the north-western part of the Cis-Carpathian depression, close to the borders with Romania and the Republic of Slovakia.

The most productive area proved to be the sandstone water-bearing horizon of the adjacent Rusko-Komarivsky uplift (drill-site Uzhgorod 2T) (Table 4.3.3.2.). Some of the drillings in the region of the town of Irshava also demonstrated significant free-flowing hot water, most promising are the waters in Cretaceous sedimentary environments (Irshava 2).

Figure 4.4.6.2. **Thermal basins in Kosyno**

Among the different sites of the Chop-Mukachevo and Solotvyno pressurized water-bearing basins, sites in Uzhgorod, Mukachevo, Irshava, Vynohradiv and Berehove were deemed promising for geologic prospecting for thermal waters. Artesian wells, located in the Zakarpattia basin in the Transcarpathian trough produce 60-90°C thermal waters from reservoirs located between 1.000-2.500 m depth (Berehove, Uzhgorod, Kosyno, Tereblia). For the assessment of geothermal potential of the Zakarpattia region, the Carpathian geological expedition had drilled over 20 exploratory wells in different parts of the territory.

The main (and best) option to use geothermal resources of the region is to meet the needs in heating and hot water supply of agricultural and industrial facilities and residential settlements, located directly near the fields. However, given that most consumers are far from energy sources (wells fields), heat

[24] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013

losses during transporting will be inevitable. Exploitation of most geothermal fields is possible only with the use of coercive methods to extract the thermal waters. In this respect, there is a problem of relevant supply with deep pumps of high quality and performance rate, to supply corrosion-aggressive heat medium with temperature of 60°C. On the territory of Zakarpattia region are located seven most prospective deposits of thermal water with a total energy potential of more than 140 MW (Table 4.3.3.1.).

Currently the thermal waters of Berehove, Kosyno and Velyatyno fields are used for recreational purposes in outdoor thermal pools and sanatoriums (Fig. 4.4.6.1, Fig. 4.4.6.2).

4.4.7. Prospective Areas of use of Geothermal Energy in L'viv Region[25]

The Lviv region of Ukraine is often listed among the prospective regions for geothermal exploration. However, there is a lack of information about the current and former researches and estimation of geothermal resources of the territory.

According to data, presented by „Zakhidukrgeologia", during the search for oil and gas within the L'viv region large deposits of thermal waters were discovered. A result of studies that were carried out at a depth of 3.000 m, was discovery of isotherm with 120°C and identification of 5-6 wells with high temperature performance. Thermal water deposits for balneological purposes were identified in two locations: near L'viv and Briukhovychi (objects are now conserved). During 1986-89 two wells were drilled near Briukhovychi, to depths of 1.500 and 1.400 m with low-temperature mineral iodo-bromine waters (34-37°C), suitable for therapeutic purposes.

However, the application of thermal waters for curative purposes is still not as popular as in Zakarpattia. The reason for this is a different microclimate, absence of natural landscape, mineral and thermal water complex in L'viv region, so a profitable use of thermal waters is not to be expected.

Figure 4.4.7.1. **Exploratory borehole "Pn 6" in**

According to State Department of Environmental Protection in L'viv Region, 2010, a unique field of geothermal waters is found in Mostyska and Yavoriv districts, which extends to Przemyśl (Poland). Waters are lying at a depth of 3.000 m and have a temperature of 95-130°C.

The list of the investment attractive objects in context of an overall strategy for economic development of Mostyska district, includes two wells with thermal water. In accordance with the budget documentation, developed together with podkarpackie Voivodship (Poland), it is planned to establish and launch a geothermal heating system for cities of Mostyska and Przemyśl, of total capacity of 12,57 MW and 87 MW respectively. Installation of heat-generating units is planned, operation of which will save traditional fuels and reduce emissions of carbon dioxide into the atmosphere.

In 2004, on the initiative of „Lvivoblenergo" at the IV Investment Fair in L'viv, an agreement was signed to attract UAH 300.000 to the geothermal investigation of the well Mostyska 2.

According to Dobush (Dobush, 2009), iodine-bromine waters were explored and exposed by groups of wells for oil and gas areas at Volia-Blazhivska and Rudky in Sambir district, Sudova Vyshnia in Mostyska

[25] Gorecki W., Hajto M., *Geothermal atlas of the Eastern Carpathians*, AGH, Krakow 2013

district, Kokhanivka in Javorivsky district, Urizh in Drohobych district and others. Mineral water of this group is high-thermal, for gas composition belonging to methane.

Around the town of Zhovkva were found pressured hydrosulfuric waters with 39°C on surface. It is reasonable to further explore and conduct research on the use of these waters. A private owner has put on sale a land property near Zhovkva, on which territory a geothermal well is located. The official field researches with injection-pumping and chemical analysis were held in 1989. The well was drilled during 1989-90 with a purpose to find and study groundwater reservoirs. Well depth reached 1.565 m, after drilling completion and hydraulic tests the well was never exploited. On the depth in intervals of 967-1.565 m the well exposed Devonian aquifer (Paleozoic) in fractured limestone. In a preliminary pilot testing of this aquifern by means of compressor and with the additional action of natural gas lift a discharge of 336 m^3/day was obtained. The chemical composition of water: bromine-hydrogen-sulphide-chloride sodium-water of high salinity (28,4 g/dm^3), alkaline (pH 8,75). The water also revealed a significant content of valuable in the balneology hydrogen sulphide (33,19 mg/dm^3). Minimal concentration of this component for allocating water to hydrogen sulphide waters for treatment is 10 mg/dm^3. With geothermal gradient in the area of Zhovkva at 2,5-3,5°C/100 m, the expected water temperature at the wellhead with a stable intake 60-130 m^3/day can reach 30-38°C.

As listed among the investment-attractive offers from the Sambir district state administration, an area within **Pyniany** village (outside the settlement) is located and intended for use as a recreational and industrial zone at the source of underground thermal water (Figure 4.4.7.1). The territory has 3 wells with depths ranging from 2.000 to 4.000 m with a rich geothermal waters reserve. Well testing of the exploratory holes 1 and 6 in the south-eastern part of the productive horizon of the Pyniany gas field obtained strong inflows of water with a large gas factor. Daily flow rate of a 3.094 m deep well „Pyniany 1" reaches 794,8 m^3 at a temperature in the stratum ranging from 25 to 70°C, accompanied by the daily output of 8.000 cubic meters of gas. Iodine content in thermal water is 26,2 g/dm^3.

4.5. The Cis-Carpathian Depression [26]

4.5.1. Cis-Carpathian

The Cis-Carpathian, depression from a hydro-geological point of view, is a first class, pressurized water-bearing basin. It is sub-divided into two second class water-bearing basins: the Chop Mukachevskii and Solotvinskii pressurized water-bearing basins. The hydro-geological environment in the Cis-Carpathian water-bearing basin is not homogenous. It is not uniform even within the two sub-basins. The mineralization of the geothermal waters of the Chop-Mukachevskii basin vary in quantity and kind from 10 g/l to 300-350 g/l.

Significant flow-rates (see Table 4.5.1.1) of waters from Paleozoic, Early Miocene and Sarmat deposits have been observed during prospective drillings in the area of the town of Uzgorod, situated in the north-western part of the Cis-Carpathian Depression, close to the borders with Romania and the Republic of Slovakia.

The Uzgorod site is characterized, as is the territory of the entire depression, by a block structure of pre-Neogene folding base. Multi-directional tectonic movements of the blocks have resulted in significant variations in the depth of the base. The highest part is the Uzgorod transversal uplift.

The roof of the base is located at a depth of less than 1000 meters. Uneven, but sometimes up to hundreds of meters thick, the sedimentary mantle of lower Miocene is a significant structural element of the hydro-geothermal environment of this site. The most productive area proved to be the sandstone water bearing horizon of the adjacent Russko- Komarovskii uplift. The name of the drill-site is Uzgorod - 2T Table 4.4.7.1.

[26] Stoyanow B., Taylor A., *Geothermal Resources in Russia & Ukraine*, Bob Lawrence& Associates, 1996, p.13

Table 4.5.1.1. **Geothermal Prospective Drillings in the Transcarpathian region (after Stoyanov, Taylor, 1996)**					
Location	**Hydro-geothermal complex**	**Depth of temperature measurement m**	**Flow-rate in m3 / day**	**T_1 in °C**	**T_2 in °C**
Uzgorod – 1T	Paleozoic	1.900	300-500	50,5	88,6
Uzgorod – 2T	Early Miocene	1.350	46.8	-	76,15
Uzgorod – 2T	Early Miocene	1.700	12.4	-	90,8
Uzgorod – 2T	Early Miocene	1.940	214	-	97,6
Uzgorod – 2T	Early Miocene	1.820	79.3	-	92,7
Uzgorod – 2T	Early Miocene	-	138 – 273	-	-
Uzgorod – 4T	Early Miocene	1.300	43	-	72,2
Uzgorod – 5T	Paleozoic	1.012	40 – 90	-	65
Tereblia – 6	Tuffs	2.350	500 – 900	86,5	96,5
Irshava – 2	Cretaceous	3.200	115	-	136,3
Beregovo – 2T	Early Samat	-	346 - 691	44,5	-

Prospective areas presented on Figure 4.5.1.1. (Stoyanov & Taylor, 1996):

- Dneprovsko-donetskaia through
- Donetskoe folding system
- Ciscarpathian depression
- Transcarpathian depression

Skifskaia (Scythian) platform

Conclusion based on study by Geophysical methods

- geothermal heat flux
- depth of the 150°C isothermal

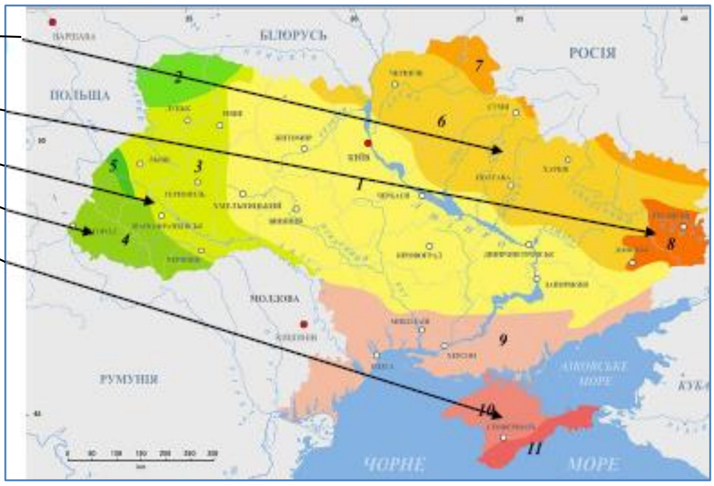
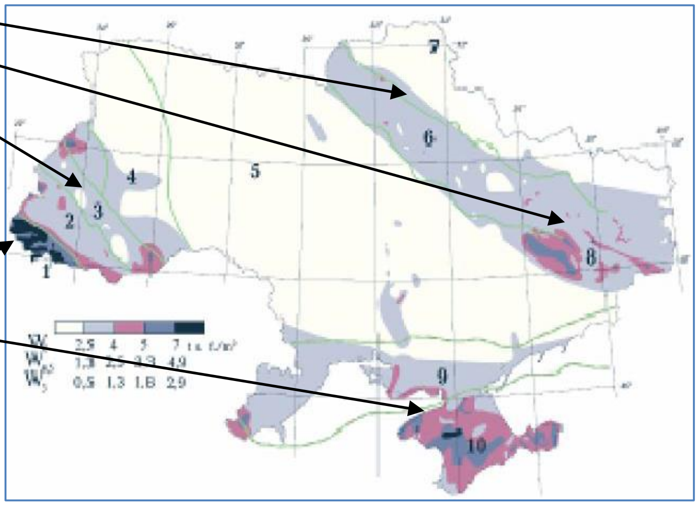


Figure 4.5.1.2 **Geothermal resources after Gordienko et al., 2005**

Regions presented on Figure 4.5.1.2:

- Dneprovsko-Donetskaia (6)
- Donetskoe folding system (8)
- Ciscarpathian depressions (2)
  - Part of the Ciscarpathian area:
  - Thermal water within the limits of 45-120°C
  - Depth of the productive aquifers from 1.000 to 3.000 m.
- Transcarpathian depressions(1)
- Skifskaia (Scythian) platform (10)



The study conclusion shows geophysical methods of geothermal heat flux and depth of the 150°C isotherm. The mineralization of the water is 16 - 30 g/l. The formation pressure at 1.700 m is 167,9 Atm. and at 1.300 m, 134,64 Atm. A maximum water temperature of 108 °C was measured at a depth of 1.940 m. The discovered hydro-geothermal resources have been determined to have no commercial value and are currently in conservation. The geological and hydro-geological investigation carried out at the site is however considered insufficient to a large extent.

Some of the drillings in the region of the town of **Irshava** also demonstrated significant free flowing hot water. At that site, an anticlinal crypto-diapir fold is to be found under the Neogene mantel. Most promising are the waters in Cretaceous sedimentary environments. Such waters and environments have been discovered by the drillings at Irshava - 2, located in the area of the Danilovo- Nevitskovo abyssal fracture (see Table 4.4.7.1). The water-bearing rock is of fissured type, probably due to the fracture zone. Mineralization is about 189 g/l.

The hydro-geothermal complex at the **Tereblia** site (see Table 4.4.7.1) is also of significant interest. The formation is located in the central part of the Solotvinskaia depression. The maximum thickness of the water bearing tuffs is 700 meters. The dip angle of the thrust fault planes of the Cretaceous blocks of the base is between 5-20 deg. The water bearing suites are enveloped between these practically water-impermeable blocks and talabor rock which is also water impermeable. This creates very favourable conditions for the accumulation of geothermal waters.

Well **Tereblia** 6, drilled in the central part of the syncline, reached pressurized water-bearing horizon in the interval between 2009 and 2.360 meters. The well is a gushing type, with flow-rates between 500 and 900 cubic meters per day. The pressure at the well head was measured at 1.2 Atm. The pressure at 1.767 meters was 217 atm. Water mineralization is in the range of 138 g/l. Water temperature measured at 2.350 meters was 105°C, and at the well head was 95°C (Tereblia 6).

The size of the **Tereblia** water-bearing complex is 15 by 5 km. Assuming, the thickness of the water-bearing rock is 300 m. and the porosity of the rock is 10% the accumulated reserves are 3 km^3. With a temperature of over 100°C, the accumulated thermal energy is then $1,5x10^{18}$ J (A. A. Andrusenka et.al.).

Another geothermal site that is being packaged for attracting international partners is the **Kusminka** site in Stavropolskii Krai. The field offers waters with temperatures of 130°C. The Committee of Geology and Utilization of the Earth’s Crust has prepared a complete business plan. Another example is the Mutnovka site. In addition to the existing 50 to 60 MW, an additional 70 MW of geothermal resources with potential for electricity generation has been identified. A 70 MW geothermal power plant project will be financed by the European Bank for Reconstruction and Development (EBRD). However, the project is still open for investors and for equipment suppliers.

To conclude, regardless of the general problems of existing environment economy, the Ukrainian geothermal industry sub-sector offers selected possibilities for promising international cooperation.

Table 4.5.1.2. **Parameters for Existing Boreholes**

Name	Type	Temperature, °C	Ownership	Customer
1	Borehole	89	State-owned	Local communities
2	Borehole	95	State-owned	Local communities, especially Mostyska

4.6. Additional Area of Interest for Geothermal District Heating[27]

The main geothermal regions in Ukraine are focused on West, East and South. There have been evaluated opportunities for geothermal energy in **Zakarpats** oblast, **Lvivska** oblasts and **Khersons** oblast. Currently the focus is on the Western part such as **Zakarpats** and **Lvivska** regions. (Figure 4.6.1).

Figure 4.6.1 **Geothermal areas in Ukraine Region**

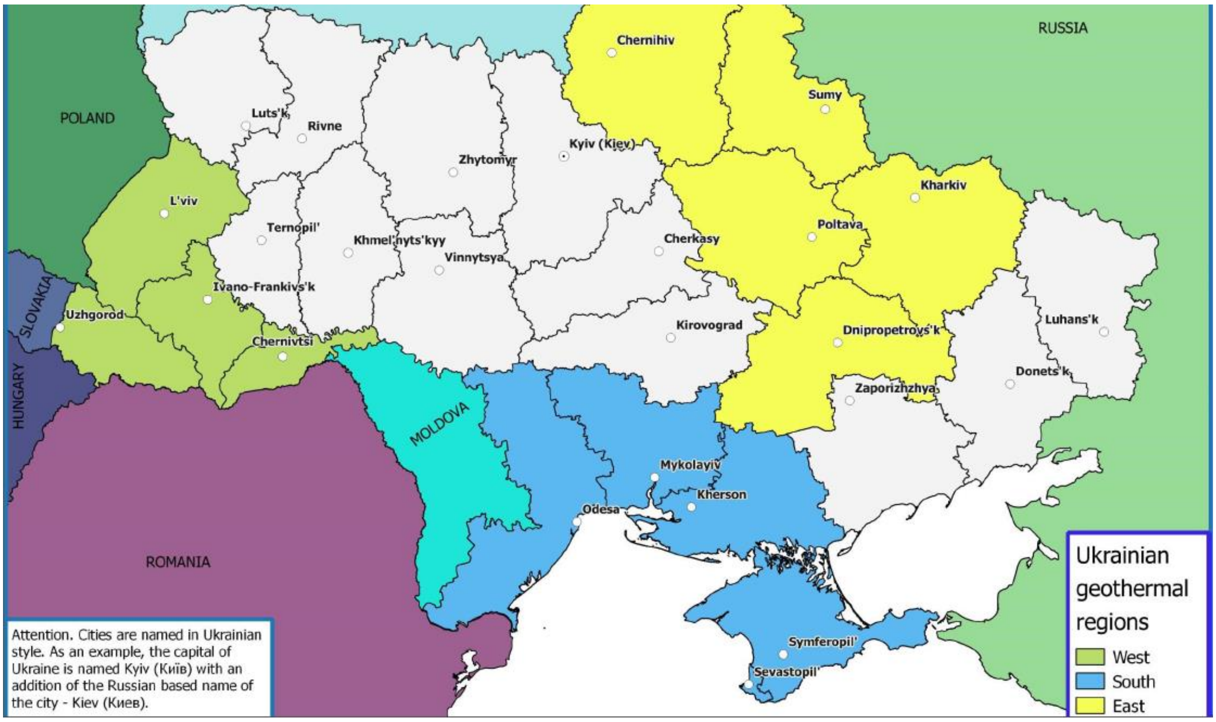
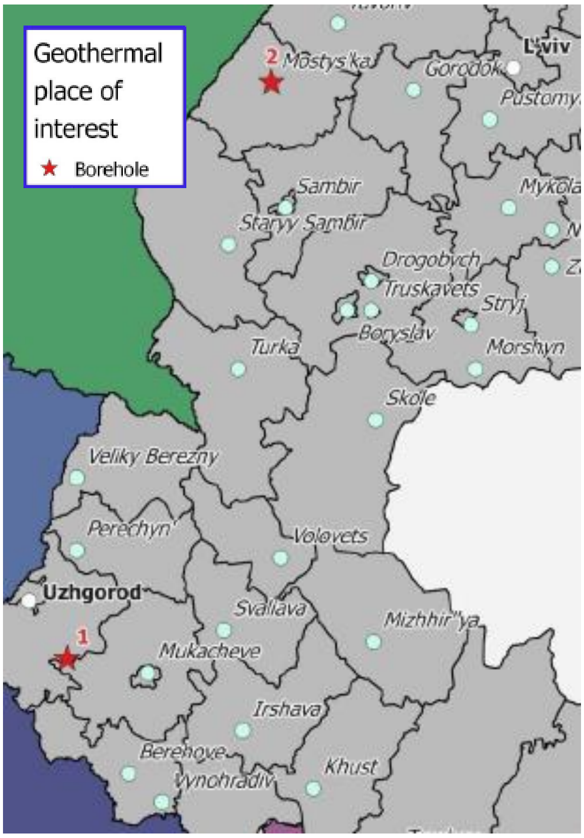


Figure 4.6.2. **Geothermal places of interest for boreholes**



In these areas there are already existing boreholes which can be used for further geothermal utilisation. In figure 4.6.2, presented by Institute of Renewable Energy there are two points of interest. Both of them are existing deep boreholes. They are being viewed not only as possible for geothermal district heating but also geothermal power (electricity generation). The following parameters from both boreholes presented are in Table 4.6.1 and map- Figure 4.6.3.

Most boreholes are owned by the state (state companies). Therefore, the work on introduction of geothermal energy could be done through the central Ukrainian government and the local communities.

The heat demand in cities changes from year to year because of different factors, such as poor quality of district heating supply systems and the growing popularity of individual heating systems. All of them creates a value for high demand on the electricity and heat production.

[27] *Some areas or interest for geothermal district heating*, Institute of Renewable Energy in Ukraine, 25.09.2015

Figure 4.6.3. **Geothermal Fields and Cities in Ukraine**

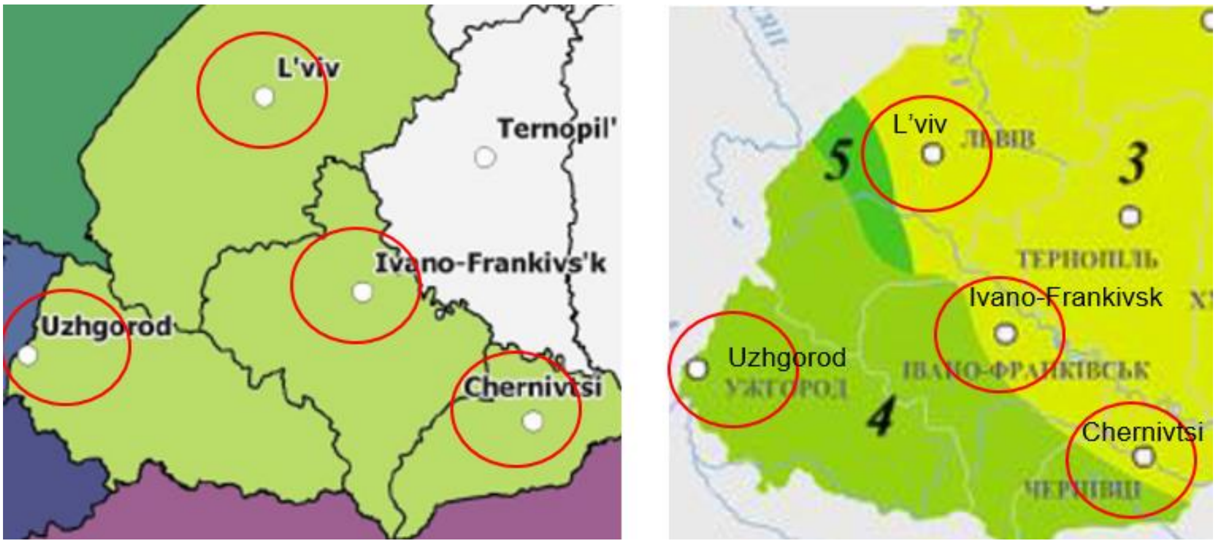


Figure 4.6.4. **Geothermal Fields and Cities in Ukraine**

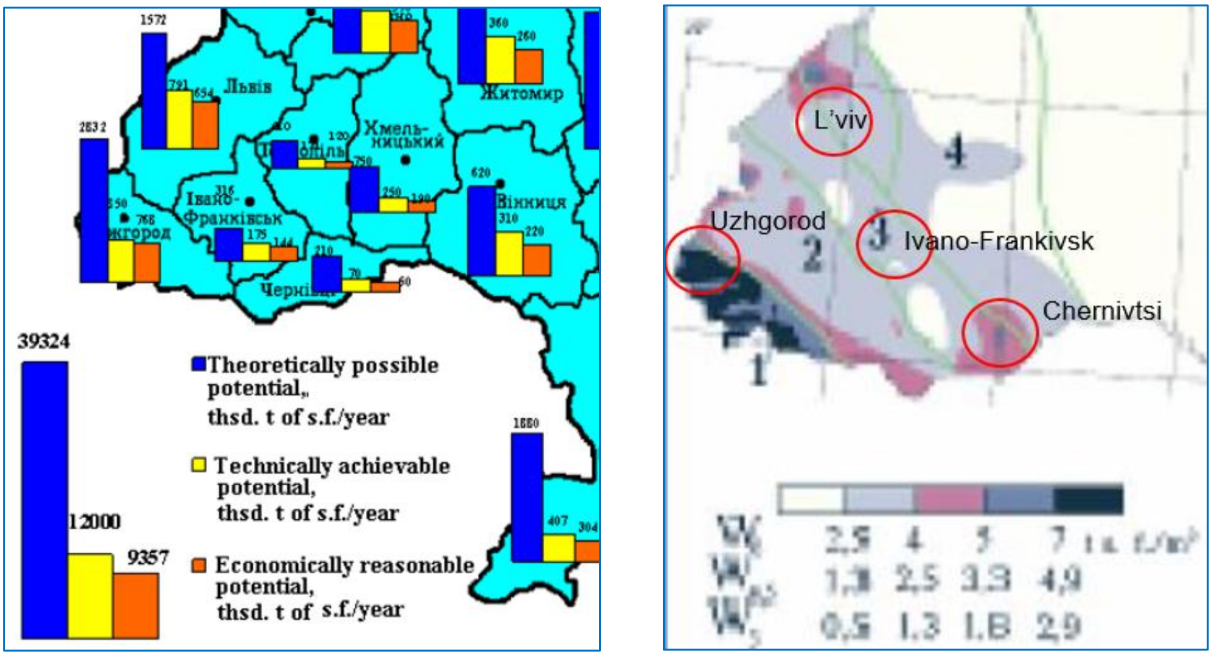


Figure 4.6.5. **Plan of Development of Geothermal Fields in Ukraine (Pilot Project)** [28]

Indicator	Indicator by years			
	2012	2013	2014	2015
Installed capacity, MW	15.00	20.00	26.00	39.00
Annual electricity generation, mln. kW·h/year	60.00	140.00	244.00	399.00
Annual economy of standard fuel, mln. t s.f./year	0.01	0.02	0.03	0.05
Amount of natural gas replacement with geothermal energy, mln. m^3	0.01	0.01	0.03	0.04
Reduction of carbon dioxide emissions, thsd. t	0.01	0.03	0.05	0.09
Creation of additional jobs, thsd. persons	0.03	0.04	0.05	0.08

[28] Rethinking The Strategy of Development, State Agency on Energy Efficiency and Energy Saving of Ukraine, 2010-11 National Report about Implementation of the Energy Efficiency State Policy, Monograph, Appendix B.5

4.7. Summary of Potential Area for Geothermal District Heating in West Ukraine

4.7.1. Potential Area for Geothermal District Heating in West Ukraine

In Ukraine there is a considerable amount of geothermal resources, however still less are in use than in the neighbouring countries. Total potential is estimated as 438 billion kWh annually, which is a reasonable amount of resource for space and water heating, cooling, residential, public and industrial purposes.

In most of the regions geothermal boreholes are used for thermal water in swimming pools and as additional heat supply for boilers at private residents. The installed capacity of heat supply systems are on a level of 13 MW. The country plan was to increase the volumes of thermal water by 2005 to 200 MW and by 2010 to 250 MW. At present there has been confirmed to use the most thermal waters for municipal heat supply. Thermal installed capacity of Ukraine is 10,9 MWt generating 119 TJ of energy annually. The current geothermal energy structure, supply energy to nine different systems developed in the regions of big towns and surrounding villages.

However, the Ukrainian geothermal potential is not the highest one among the East European countries. The country is using just 2% of the possible geothermal utilization, but has the potential to develop to 15% and even with the uncertainty of the prices and operation of energy production and supply, geothermal district heating seems to be steady solution.

Due to the developments and pre-feasibility studies the good prosperity regions are located on the West side of the country, including regions such as Lviv oblast, Carpahtinas oblast and also Ivano- Frankvisk oblast. Three of the areas have potential for commercial use of geothermal energy and have been in development for at least 20 years. However, their technology needs to be mastered

Geothermal resources in the country profile are based on the thermal data base, which differs dependently on the regions geological structures. The areas that have been identified for further development have already had some initial investments as well as feasibility studies.

For commercial exploration and definition on which areas to focus there should be proposed to receive a high resolution maps of thermal resources, information on the thermal waters flow and précised resource research due to the lack of data. The thermal energy in the western part of the country is much wider than the energy from other resources.

Table 4.7.1.1. presents the available borehole parameters in West Ukraine with information on their depth, temperature and assumed purpose. The table is missing data on the thermal waters flow, which would be essential for further study and receiving accurate results. Table 4.7.1.3 presents data on the possible studies of the geothermal areas with its potential future development.

Table 4.7.1.1. Geothermal well Parameters in West Ukraine

Region	Borehole Symbol [29]	Depth, m	Temperature of the outflow, °C	Wells	Well purpose
L'viv		3.000	120	5 or 6	
	50				Direct use
	52				Direct use
	56	2.500 to 4.200 m	55 - 70		Direct use
	61				Direct use
	62				Direct use
	63				Power generation
	64				Direct use
	65				Direct use
Zakarpathia		1.000 - 2.500	60-90	2	Direct use
	98				Direct use
	101				Direct use
Ivano- Frankvisk		3.500	80-120	3	Direct use
	24				Direct use
	27				Direct use
	32				Direct use

First area of interest would be **Lviv region**, which has great prospectives, but there is a lack of data on the exact size of resources. The main data represents the delivery of thermal waters with an isotherm of 120˚C at the depth of 3000m using approx. 5- 6 boreholes. The balneology therapies can be found in the regions of Briukhovychi (1400- 1500m and temperature of 34-37ºC).

Figure 4.7.1.1. **Boreholes that are good for Geothermal Power Generation and direct use of Geothermal Energy**

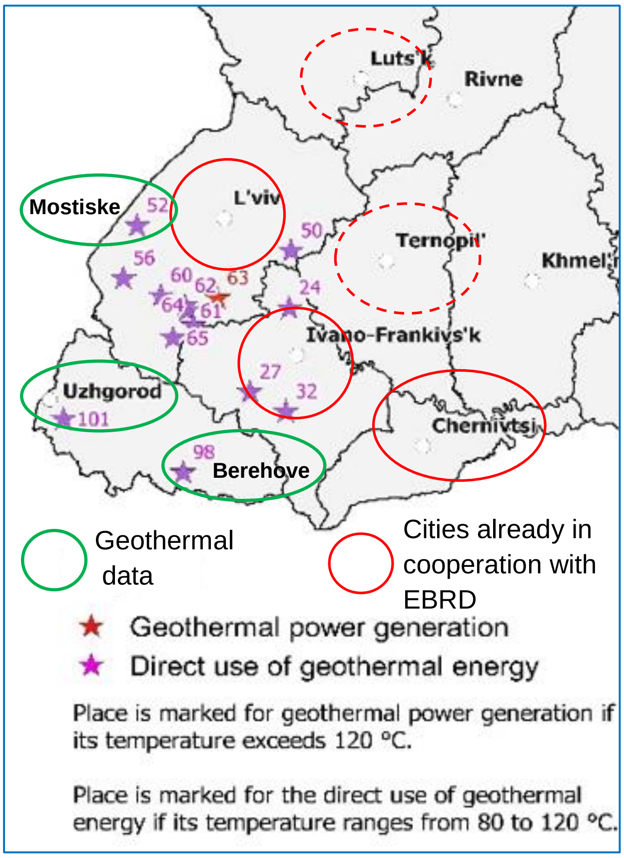
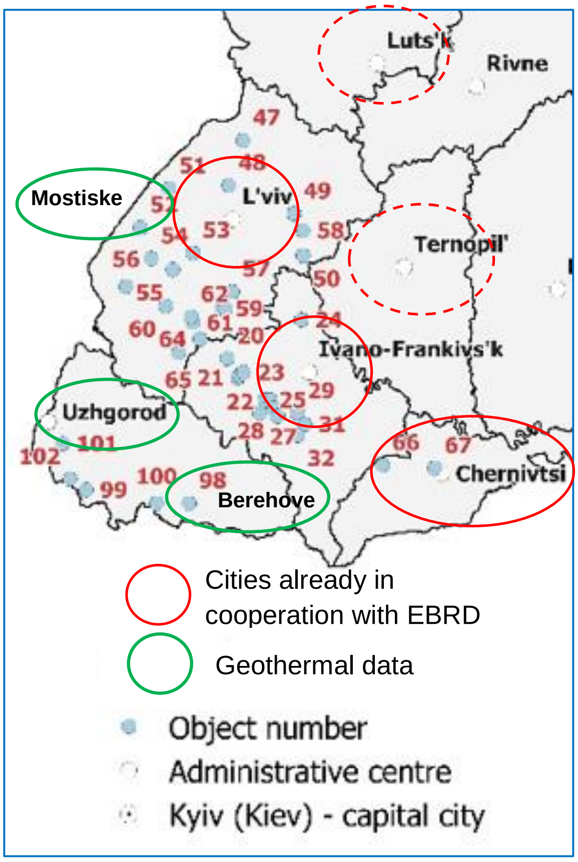


Figure 4.7.1.2. **Some perspective Geothermal Energy objects in Ukraine**



29 Borehole symbol refer to figure 4.3.3.1

Small Towns Priority

- Within the **L'viv region**, there is availability for district heating in **the Mostyska** (population of approx. 11.100 people). The region poses two boreholes with good performance parameters. It can deliver, on the depth of 3.000 m, waters with temperature of 95˚C-130˚C. There is no information on the flow rates of production wells, which should be at least 100m^3/hr. Therefore, it is recommended to take the geothermal wells for further expansion and focus on new utilization proposals due to the fact that current projects are being in development in cooperation with the nearest Polish town.

- Second area of interest would be **Pyniany gas region** (approx. 700 people) with two wells. It is located in the western part of Sambir District (population of 69.000 people) located in **L'viv Region.** The wells are from 2.500 to 4.200 m deep (Table 4.7.1.1). According to geophysical studies, all the wells are watered, productive thermal aquifers belonging to the lower Dashava and upper Dashava rock located at the depth of 1.740 – 2.420 m. The layer temperature of these horizons varies from 55 to 70˚C. The Pyniany-1 well is good for creating and operating a system of complex use of geothermal energy. The Pyniany-2 well is recommended for reinjection of used thermal water. It is located at a distance of 1 km to the north-east of the Pyniany-1 well. The Pyniany-1 and Pyniany-2 wells were drilled in the 1970s and abandoned after drilling due to their gas non-productivity. At present both wells need to be restored. According to SC Zakhidukrgeologia, the estimated cost of restoring each well is USD 60.000.[30]

- Third area of interest is the **Zakarpattia region,** one of the primary geothermal regions. Wells located in this area are able to deliver the thermal waters up to 90˚C from reservoirs at a depth of 1000- 2500 m such as **Berehove**, **Kosyna**, **Uzhgorod** (population of 115.000 people) (see location on map- Figure 4.6.3). Geothermal waters in this regions have high potential to be used for heating and hot water resources. Zakarpattia alone is an area which delivers 1/3 of total of the Ukraine's geothermal thermal capacity (Table 4.7.1.2).

- Exploration sites for further development should be **Berehove, Uzhgorod** sites in Zakarpattia region and **Mostyska** in Lviv region. (Table 4.7.1.2)

Table 4.7.1.2. **Example of current Geothermal Projects in Zakarpattia Region**

	Geothermal object	**Year of introduction in operation**	**Thermal capacity (MWt)**	**Annual economy of fuel**
1	System of the geothermal heat supply of the Beregovsky's sport center. Beregovskiy area, Zakarpatskaya region.	**1978**	**2,1**	**1.215**
2	System of the geothermal heat supply of the sanatorium "Kosyno". Beregovskiy area, Zakarpatskaya region.	**1998**	**1,2**	**860**
3	System of the geothermal heat supply of the sanitary complex "Latorytza". Mukachevskiy area, Zakarpatskaya region.	**1985**	**0,2**	**210**
	Total in Zakarpattia		**3,5**	
	Total in Ukraine		**10,9**	
	Percentage		*32%*	

- Fourth area of interest should be **Ivano- Frankvisk region** (population of 223,000 people)**.** The region had a prefeasibility study of geothermal facility in Ivano- Frankivsk town (see map on Figure 4.6.1), which could obtain an alternative solution for surrounded region for housing and industry using a binary system. The project had plans to produce 139.000-230.000 GWh/year which could

[30] Rethinking The Strategy of Development, State Agency on Energy Efficiency and Energy Saving of Ukraine, 2010-11 National Report about Implementation of the Energy Efficiency State Policy, Monograph, Appendix B.5

fully supply the residents of the region. Due to the uncertainty with the finances, project has not been finished. It is recommended to be able to focus on the further development due to its valuable output.

Recommendations for choosing the boreholes to further development should consider information on the flow rates which are gathered from well tests. Evaluation of flow rates and enthalpies of production wells determine the deliverability of the wells.[31] It is recommended to take into consideration for geothermal wells with large flow rates that they require larger-diameter production intervals than typical oil and gas wells. It is important due to the fact that most of the Ukrainian geothermal wells were drilled with the purpose of oil and gas exploration. In case of unexpected problems, they require an extra string of casing, which was not in the original design so the production casing will be smaller than planned, reducing the potential flow rate and adding cost.[32] To guard against such a situation the casing program is often designed with the upper casing one size larger than required, in case a contingent string is needed.

Statistically, one well can generate 2-5 MW of heat energy[33]. The optimal work of the heat delivery the piping systems should not be longer than 10 km ensuring efficient operations.

Due to the fact that the geothermal wells produce a relatively low-value fluid, flow rates must be much higher (more than 100 m^3/hr) than for oil and gas wells, and geothermal wells produce directly from the reservoir into the casing, instead of through production tubing inside casing as in most oil wells. Productivity of most production wells up to 34 cm casing is 750-10.000 million m^3/hr, so the formation has very little skin damage initially. Recommended overview of the geothermal fields that are suitable for industrial development are stated in table 4.7.1.3 in the region of West Ukraine.

Table 4.7.1.3. **List of Geothermal Fields suitable for Industrial Development**[34]

Name of geothermal deposit	**Expected exploitation resources of thermal waters (to the maintenance of formation pressure) m3/day**	**Temperature of thermal waters at the wellhead, °C**	**Thermal power of geothermal install-mations MW**	**Fuel economy, t.s.f./ year (tons of standard fuel per year)**	**Directions of using**	**Population**
Zakarpattia oblast / region						
Berregivske Berehove	10,300	58	21,55	21.152	Heat supply of village Berehovo, balneology	24.458 (2013)
Kosinske	12.700	52	22,84	22.375	Heat supply sanatorium-preventive clinic “Kosino” balneology	Very small
Tereblyanske	27.800	89	100,00	82.359	Heat supply of sanatorium “Tereblya” and village “Tereblya” balneology	8.500 (2001)
Velyatynske	82.800	60	181,121	176.405	Heat supply sanatorium “Tepli Vody”, balneology	
Veloiko Paladske	43.300	53	78,92	77.079	Heat supply sheep farm hotel, bath, club and village counal	
Veliko Baktyske	6.200	59	13,25	12.953	Heat supply of pig farm residential multi-storey buildings	
Uzhgorodske Uzhgorod	56.300	60	120,42	117.707	Heat supply communal and industrial facilities Uzhgorod	115.000 (2015)
Total / oblast	**239.400**		**538**	**510.030**		

[31] The role of the well testing in geothermal resource assessment
[32] Handbook of Best Practices for Geothermal Drilling
[33] Rethinking The Strategy of Development, State Agency on Energy Efficiency and Energy Saving of Ukraine, 2010-11 National Report about Implementation of the Energy Efficiency State Policy, Monograph,
[34] Rethinking The Strategy of Development, State Agency on Energy Efficiency and Energy Saving of Ukraine, 2010-11 National Report about Implementation of the Energy Efficiency State Policy, Monograph, Appendix B.5

Pre-Carathian deflection, L'viv oblast / region						
L'viv, region						730.000
Mostiske	7.800	107	27,3	15.783	Heat supply industrial premises railway station, depot, residential buildings of village Mostyske	11.000
Chizhkivske	2.600	98	8,0	4.625	Heat supply of warehouses, residential buildings	
Sudovo Vyshnyansky	12.860	63	17,5	10.117	Heat supply agro industrial complex objects, residential buildings	
Totatl / oblast	**23.260**		**52,8**	**30.525**		
Pre-Carpathian deflection, Ivano-Frankivsk oblast / region						
Ivano-Frankivsk,						229.000
Dolynske	3.197	73	5,9	3.411	Heat supply of oil refining factory facilities, residential buildings	Small
Pivnichno-Dolinske	1.296	76	2,6	1.503	Heat supply of oil industry, residential buildings	
Total by oblast:	**4.493**		**8,5**	**4.914**		
Chernivtsi oblast / region						
Chernivtsi						263.000

In Ukraine (not only Western Ukraine) there are more than 170 companies that supply district heating and hot water. Usually, every city has their own organizations and a number of small district heating organizations.

The heating sector can be divided into two main components:

- the district-heating sector, owned and operated by municipal heating companies; and
- heating systems to serve industry, such as boilers or direct firing units. Today there are 79,908 boilers for heat generation in Ukraine.

The district heating sector is composed of about 7.000 heat-only boilers and another 250 CHPs (Radeke and Kosse, 2013). Ukraine's district heating sector is inefficient for multiple reasons, and addressing them will be important for Ukraine's energy-security goals as well as for the promotion of renewables.[35]

In Western Ukraine there is a widely used two-part tariff for district heating. One is paid the whole year for the maintenance of district heating systems. The other is paid only through heating season for used energy.

For price policies in Ukraine, the government made different prices for district heating for different customers.

- The households pay less than industry and commercial customers.
- Secondly, the lower household prices than the market price brings a gap which is compensated by regulating higher price for industry and commercial customers.
- Between the cities, there is also a price differences in regards to the regional industry and household ratio.

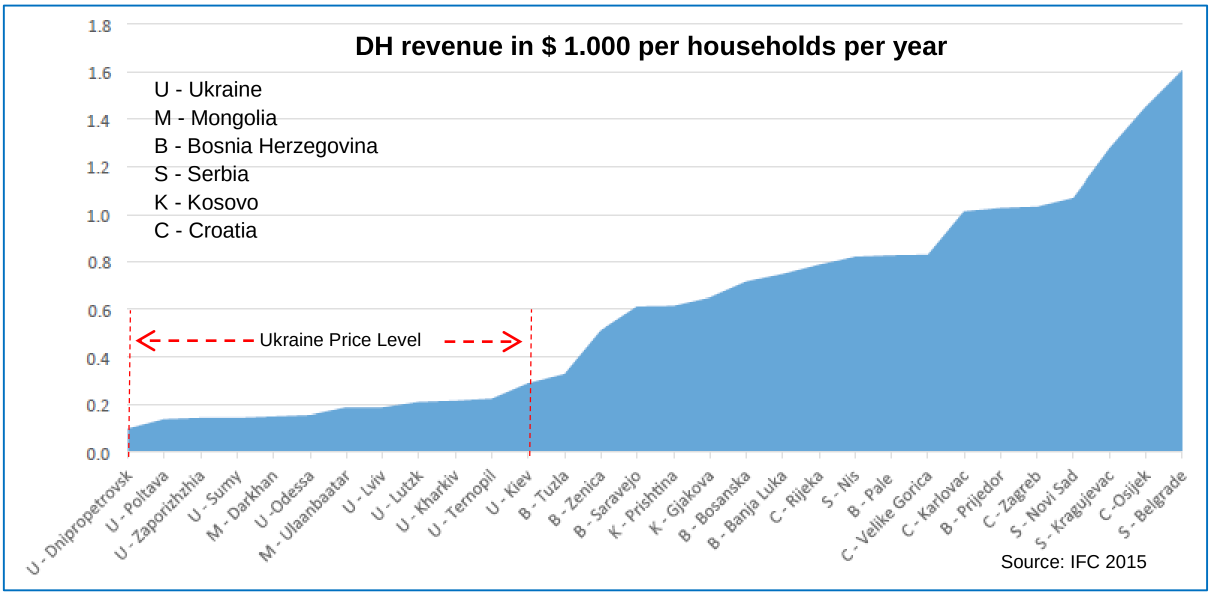
[35] REmap 2030: Renewable Energy Prospects for Ukraine, Chapter 3, p 6

Table 4.7.1.4. **Price for used heat energy**[36]

Type of customer	Price, EURc/kWh
Household	2,04
Other (industry, commercial)	4,76
Government-financed organization	4,76
Estate managers of the apartment house	1,68

The Renewable Energy Institute confirmed the continuation on the research of geothermal potential of Ukraine. The geothermal potential of petroleum boreholes has been investigated and more than 400 boreholes throughout Ukraine were analysed. Besides geothermal energy, the institute investigates heat pumps with different heat sources: surface water, external air, waste resources and etc. The data was used to analyse and create the resource heat potential atlas.

Figure 4.7.1.3**. Regional and National Differences in Tariff Levels**



As can be seen from Figure 4.7.1.3. the district heating prices in Ukraine are very low in international comparison, this can also be confirmed looking at Figure 2.4.4.1. This is mainly because district heating prices have been heavily subsidised in Ukraine, far more than in other countries. Therefore, it is important to stop subsidising district heating prices in general, although it would mean the lowest income homes would need support.

The main rule for Ukraine's district heating should be efficiency improvements for the sector, as one of the main tasks for energy- intensity reduction goal of 50% by 2030. The main improvements should focus on boiler houses, replacing network pipes, installation of heat substations and installing heat meters.[37]

Today's challenge is upgrading the systems to make the households more responsive and bring the amount of used gas per capita to lower number. It has been shown that only 20% of households have a functioning metering system, which is too low in comparison to other European countries and also to step forward with efficiency improvements. Currently the main focus could be on the district heating systems and their restructuring process. The promotion of these steps should be among individual heating systems and industrial buildings connected to grid.

[36] - Gcal=10^9 calorie (1 calorie ≈ 4,1868 J), It shows the price for district heating in L'viv by the organization "L'vivteploenergo". The price for households is inclusive in VAT (value-added tax), the others are shown without VAT. Rate of exchange on 25 September 2015: 100 EUR = 2412,8210 UHR

[37] IEA (2012b), Energy Policies beyond IEA Countries: Ukraine. OECD/IEA, Paris, http://www.iea.org/publi cations/freepublications/publication/Ukraine2012_free.pdf

IFC Report 2015

In a recent report from IFC, it is stated that, *"In August 2014, a National Energy and Communal Services Regulatory Commission (NECSRC) was established as an independent regulator for the larger DH utilities, and it presently regulates the 227 largest DH utilities.*

NECSRC's main responsibilities include issuing licenses and regulating tariffs for generation, transmission, and supply of heating and hot water supply services. In addition, the regulator is responsible for approving the investment programs of utilities, monitoring them through review of their annual and quarterly reports, and controlling compliance with the license conditions.

NECSRC's current work program includes increasing all of the mentioned tariffs to a full cost-recovery level and eliminating cross subsidies among the public, budget organizations, and other customers.

However, NECSRC is in a challenging position because of the significant increase in natural gas prices, the non-cost-recovery tariffs of DH utilities for the public, and the reduced affordability for end-users due to the current political situation in Ukraine. One of NECSRC's current priorities is to stimulate utilities to switch to alternative fuels and reduce gas dependence". (IFC, 2015)

4.7.2. The Authorities have made Progress in Reforming the Inefficient Energy Sector

In a recent transition report from EBRD, it is stated the "*efforts have been made to put Naftogaz's finances on a more sustainable footing and to reduce the quasi-fiscal deficit. Household gas and heating prices were increased by 285 percent and 67 percent, respectively, in the first half of 2015, with plans to reach a 100 percent cost recovery level by April 2017.*

This will help to curb corruption in the sector, foster energy saving and energy efficiency and attract investment. A programmed scale-up in social assistance is expected to protect socially vulnerable households and ongoing social safety net reforms aim to better target beneficiaries in 2016. The gas market law, which was approved by parliament in April and enters into force in October, introduced a new model of gas market and paved the way for the Naftogaz unbundling, increased competition and potential investment in the sector.

In 2014 Ukraine further diversified its gas supply sources by increasing the share of imports from the European Union (EU) to approximately 25 pe cent of total imports. In the first half of 2015 the share of gas imported from the EU interconnectors represented approximately 60 percent of the total import.

Ukraine stopped buying Russian gas after breakdown of the June 2015 EU-Ukraine-Russia trilateral gas talks, which were an attempt to find a follow-up agreement to the EU-brokered "Winter Package" that had ended in March 2015 and had been partially extended to June 2015. On 12 October 2015, Russia resumed gas deliveries to Ukraine. Before the resumption of gas flows, Ukraine prepaid for approximately half of the gas deliveries planned in October 2015". (EBRD, EBRD Transition Report on Ukraine 2015 - 2016, 2015)

4.7.3. Legislative base of Geothermal Energy in Ukraine

In recent years, in legislative basis of Ukraine a lot has been done to regulate legal relations in the field of conservation, scientifically proven natural resource management, environmental protection, development of alternative and renewable energy sources, including, geothermal waters. There have been accepted Codex "On Subsoil" (from 27.07.94, № 132/94-VR), "Water Codex" (from 06.06.95, № 213/95-VR), the law "Of alternative energy sources" (from 20.02.03, № 555-IV) and others.

The classification of geothermal waters reserves, approved provisions for preparedness of geothermal deposits to commercial operation, defined procedure for conducting geological exploration works at geothermal deposits, set technical requirements for safe, reliable and economic operation of heat sources were brought up into accord to the international standards. The procedure for development of geothermal deposits, requirements for provision of special permits (licenses) is based on the Cabinet of Ministers of Ukraine № 615 of May 30, 2011 "On approval procedure for giving special permits for subsoil use".

Requirements forresearch on geothermal deposits, that are used to calculate their reserves and government calculation, are set on the basis of "Instructions of reserves classification and mineral resources of subsoil state fund to thermal power underground water deposits", which was approved by the Cabinet of Ministers of Ukraine from 21.06.07, №707/13971). In the field of standardization adopted state national standards of Ukraine: "Geothermal energy. Terms and definitions", "Geothermal energy. Geothermal heat stations" and "Geothermal energy. Geothermal power stations". Developer of standards - Institute of Renewable Energy, NASU.

4.8. The District Heating System in Ukraine

4.8.1. Modernization of the District Heating Systems in Ukraine[38]

New projects in the geothermal sector in Ukraine, will have to take into consideration the overall framework conditions regarding the profitability of concerning projects. The overall district heating system is a part of such framework conditions. The World Bank, (ESMAP) did analyse the district heating system in Ukraine 2012, in the report *"Modernization of the District Heating Systems in Ukraine: Heat Metering and Consumption-Based Billing.".* Chapter 4.5 is a reference in the report. (WB E. , 2012).

Ukraine's district heating sector is in physical and financial crisis. During the past 15 years, many of Ukraine's neighbouring countries have upgraded District Heating (DH) systems making DH a financially sustainable way of providing good quality heat and hot water services at affordable prices. Ukraine has not made this transition. It did not follow the sector reform path of most neighbours. Countries in the region implemented policy reforms through effective changes to the legal and regulatory framework, enabling them to create independent regulators, raise tariffs to reflect full cost of service, involve the private sector and enable new investments. The introduction of heat metering at the building level was among the first steps in implementation of the investment programs.

Ukraine has kept regulation, ownership and operation of DH companies in the hands of local governments, and kept tariffs well below the levels needed to provide good quality service. Heat metering and consumption-based billing are important steps toward improving service, lowering household costs.

Building-level heat metering and consumption-based billing are critical steps in meeting customer expectations for heating and hot water service. Public consultations with customers in two typical mid-sized cities in Ukraine, L'viv and Mykolaiv, confirm that customers want better quality service at affordable prices and that they do not trust the current system. Investing in building-level heat metering and implementing consumption-based billing can address these concerns in the following ways:

- **Better quality of service**. Building-level meters are typically installed along with a building-level substation package (ITP) which allows supply to be matched with demand through better temperature control at the building level.
- **Lower cost**. These investments reduce heating demand by roughly 15-25 percent, thereby, combined with consumption-based billing, decreasing average household expenditure on heating.

[38] Report on Modernization of the district heating system in Ukraine, p. xii

- **Improved transparency**. Consumption-based billing provides information about customers' heat consumption and how it relates to their bills as well as provides the incentive to balance heat supply and demand.
- **Following improvement of financial viability of DH companies**. Heat meters with ITPs allow DH companies to:
- **Reduce the cost of supply**. Building-level metering helps optimizing the design of the heat supply system thus reducing costs further, particularly through controlling network losses.
- **Increase revenues.** Because meters with ITPs help improve the quality of service and transparency, they improve customers' trust and, hence, their willingness to pay. Additionally, improved quality of service can help improve collections from existing customers, attract new customers, and re-gain customers who had disconnected in favour of other heating solutions.
- **Services of quality DH should be affordable**. There are obvious tensions between the objectives of improving quality of service for customers, while keeping DH affordable. Tariffs would need to more than double to reflect the economic costs of heat production. A one-off tariff hike of this magnitude would make DH services unaffordable for most Ukrainian households at current consumption levels.

The proposed solution is to reduce heat consumption by 50 percent to compensate for a doubling of prices, coupled with a targeted social safety net to protect the poor. This can be done by:

- Assigning high priority to providing targeted subsidies to poor consumers to advance tariff increases;
- Installing ITPs with temperature controls (15-25 percent savings);
- Implementing energy efficiency measures to improve building envelops (20-25 percent savings);
- Installing heat-cost allocators (15-20 percent savings);
- Decreasing supply costs by reducing network losses and increased use of combined heat and power plants (10-20 percent savings).

Complementary reform measures are required within institutional, legal and regulatory to support investments including:

- Complete de-politicization of the tariff regulation by passing responsibility to an independent sector regulator;
- Making DH companies clearly responsible for the financing, purchasing, installation, servicing of ITPs and meters as well as reading of meters;
- Standardizing heat supply contracts. Heat supply contracts vary substantially across Ukraine. The language is often confusing, excessively detailed and, in some cases, contradictory;
- Fostering the creation of homeowners' associations (HOAs). DH companies prefer to have contracts with HOAs because they are legal entities with an organized administration.

The financial support required includes:

- Targeted subsidies for poor customers. The Government could better serve poor customers by providing direct subsidies to the individual households, rather than to DH companies;
- Financing energy efficiency improvements. The Government could facilitate such investments through grant or concessional loan programs, funded or financed by donors.

The International Financial Institutions (IFIs) can help, as they have in other countries, with:

- Concessional financing for heat meters and ITPs. IFI financing could be on-lent to municipal governments to use for investment by municipally-owned DH companies;
- Technical assistance (TA). IFIs could fund TA for tariff-setting, affordability studies, setting-up a country-wide Building Certificates program; provide advisory services for the new utilities regulator; and assist with the design of targeted social safety nets; Funding for pilots. Given the potential for demand-side energy savings in Ukraine's buildings, IFIs could also assist with the design and funding of energy efficiency pilots in buildings.

4.8.2. What Needs to Happen Next

Heat metering with ITPs is not widespread in Ukraine even though, as Section 4.5 showed, both customers and DH companies could benefit from it. At current tariff levels, DH companies have little incentive to invest in building-level heat meters and ITPs. Although heat metering with ITPs could provide cost savings to consumers at current tariff levels, organizational and funding challenges deter most DH customers from taking the initiative to install heat meters in their buildings, and most of them are not aware about ITPs and their benefits. (WB E. , 2012).

Role of the Independent Regulator

Creating an independent regulator is an important step to improving the financial sustainability of the DH sector while maintaining affordability for customers. An independent regulator could help gradually increase tariffs to cover the full, unsubsidized cost of providing DH services while promoting cost saving measures. For example, including meter installation as a requirement in the licenses of DH companies can help keep heating bills affordable for households. The independence of the regulator is key to this process. By maintaining an arms-length relationship with regulated DH companies, consumers, and political authorities, an independent regulator could make decisions that although politically difficult, have long-term benefits for both DH companies and customers.

Proper tariff setting serves as the regulator's most effective tool to protect customers while ensuring the financial sustainability of the sector. Proper tariff setting should induce cost saving incentives for DH companies and customers alike. Heat meters in conjunction with a good tariff methodology play an important role in helping create these regulatory incentives. Specifically:

- For the regulator, heat meters provide accurate data on actual consumption at the building level. This allows regulators to accurately set volumetric tariffs and create benchmarks for efficiency improvements for heat suppliers;
- For district heating suppliers, metering will indicate how big actual network losses are and provide incentives to reduce them through targeted investments in networks. Moreover, heat metering and consumption-based billing will be the first steps for the companies to improve their image and regain trust of the customers;
- For customers, heat meters along with tariff methodologies that allow customers to pay for heat based on actual consumption as determined by meter readings provide incentives to reduce heating bills through energy efficiency improvements.

Once incentives are properly aligned, an independent regulator is well-placed to help share costs and benefits equitably between customers and DH companies. To do this, the regulator could eventually consider implementing incentive-based regulation (for example, price-cap or revenue-cap) with clear service quality targets in order to give the DH companies an incentive to cut costs while maintaining required levels of services.

The Government of Ukraine recently began the process of developing an independent regulator. In 2010, the Government transferred responsibility for tariff setting from local authorities to a newly created independent regulator. In July 2010, the Parliament of Ukraine passed a law on the National Commission for the Regulation of the Utilities Market in Ukraine. While the Commission was being formed, the National Electricity Regulatory Commission served as the DH sector regulator. In July 2011, the President of Ukraine signed a decree creating the National Commission on the Regulation of the Utilities Market.

Role of DH Companies

DH companies are best placed to carry out the tasks of financing, installing, owning, servicing of building-level heat meters and ITPs, as well as reading heat meters. Worldwide experience shows that DH companies are normally responsible for installing and owning ITPs and building-level heat meters. International best practice should resonate with customers in Ukraine since, as public consultations showed, most respondents trust DH companies to install and manage building-level heat meters due to their technical expertise. Assigning these responsibilities to DH companies has a number of additional benefits as well.

Role of the Government

The Government should play an important role in governance by helping to promote heat metering and consumption-based billing as well as improving the financial sustainability and affordability of DH services. The Government can do this by gradually eliminating gas subsidies to DH companies while simultaneously promoting initiatives that help reduce heating costs to households. Timing these efforts will be key; a phased approach in which gas subsidies are eliminated over a medium term can help ensure that customers and DH companies have time to implement necessary cost saving measures. Moreover, the Government can support initiatives that reduce costs—and improve affordability—in the DH sector by:

1) **Financing energy efficiency improvements**. In addition to heat metering, investments in production efficiency and consumer-end energy efficiency can reduce the cost of heat production. The Government can help finance these investments for DH companies and for consumers. For example, the Government could obtain concessional financing for DH sector energy efficiency improvements. This could, in turn, be on-lent to municipally-owned DH companies, thereby reducing financing costs for investments in rehabilitation and replacement. Or, the Government could develop a program to help fund energy efficiency capital improvements in residential buildings. Unlike existing subsidies to DH companies, which simply offset costs that would otherwise be incurred by customers, Government support for energy efficiency helps reduce costs;
2) **Supporting public awareness campaigns about the benefits of metering.** Public consultations clearly showed that customers believed heat metering would reduce their heating bills. However, they also showed that customers did not think of implementing heat metering as a way to cope with higher heating costs. As tariffs for DH services begin to increase, the Government can support public awareness campaigns that help customers see heat metering and demand-side energy efficiency investments and behaviour as a viable solution to reducing heating bills;
3) **Providing incentives for demand-side management.** Annual energy consumption of a typical household in Ukraine averages roughly 250-275 kWh/m^2. By comparison, a typical household in the European Union consumes approximately 120 kWh/m^2 annually. Additionally, the EU aims to reduce average household energy consumption to 60 kWh/m^2 by 2020. Achieving current EU consumption levels by 2020 and the 60 kWh/m^2 consumption target by 2030 could be a realistic goal for Ukraine. The Government could help reach this goal through measures, such as implementing building codes and EE standards, loan guarantees or tax relief for EE investments in residential buildings;
4) **Providing targeted support to poor customers.** Some customers may still not be able to afford DH services even after a reduction in costs through efficiency improvements. The Government could better serve these customers by providing direct subsidies to the individual households. Subsidies to DH companies effectively subsidize all customers – even those that can afford DH services. Eliminating these subsidies frees up fund which could be more effectively targeted towards the poorest households.

Harmonization with EU Law [39]

The Government has a major incentive to address heat metering because it is a necessary component of Government efforts to harmonize Ukrainian laws with EU laws. Specifically, Ukraine must make heat metering compulsory in order to comply with EU law.

Ukraine signed its Accession Protocol to join the Energy Community (EnC) on 24 September 2010, ratified the Protocol on 15 December 2010, and is exercising its full membership powers as of January 14 2011. In December 2009, the Ministerial Council of the EnC decided to include the Energy End-Use Efficiency and Energy Services Directive 2006/32/EC, of 5 April 2006 in the acquis mandatory under the Treaty.

As a member of the EnC, Ukraine is required to enforce this Directive. Article 13 (1) of this Directive requires Member States to "ensure... that final customers for electricity, natural gas, district heating and/or cooling and domestic hot water are provided with competitively priced individual meters".

[39] Report on Modernization of the district heating system in Ukraine, p.55

In order to harmonize Ukraine norms and standards with EU law, the Law in Ukraine should clearly require that every building, or group of adjoining or related buildings belonging to the same owner, which are connected to a DH network have building level heat and domestic hot water meter. The law should be enforced step by step and supported by a clear action plan.

4.8.3 What Can the International Financial Institutions Do to Help? [40]

Ukraine can take the following steps to begin to improve the financial sustainability of the DH sector while maintaining affordability to customers:

- Financing and implementing heat metering and consumption-based billing with ITPs/EU;
- Financing energy efficiency measures along heat supply chain;
- Technical assistance to the newly established regulator;
- Technical assistance for the design of targeted social safety nets.

The International Financial Intuitions (IFIs) can help the Government of Ukraine begin to address these issues through a combination of loans for physical infrastructure and technical assistance for pilot studies, public outreach and regulatory support.

Loans for heat meters, ITPs and other energy efficiency measures to improve of heat supply [41]

DH companies are best placed to purchase, finance, and install building-level heat meters. However, most DH companies lack the financial resource to undertake this type of capital investment without additional resources. Furthermore, commercial banks in Ukraine are unwilling to lend to most DH companies because of their poor credit-worthiness. Unfortunately, the current poor financial condition of DH companies coupled with the difficulty of raising tariffs before customers perceive benefits means DH companies will struggle to attract financing for heat meters and related investments that will lead to improved financial performance in the longer term. The IFIs can help break this cycle by providing low cost financing. Providing a loan for heat metering with ITPs can most effectively break this cycle because heat meters with ITPs and other energy efficiency measures:

- Improve comfort and reduce costs for customers, allowing the regulator to more easily justify necessary tariff increases;
- Help DH companies identify areas in the network with highest losses allowing them to better prioritize investments in rehabilitation and modernization. Reduction of network losses and better use of CHPs could reduce the cost of supply could by roughly 10 percent, thus improving affordability of DH services.

Heat metering - a first-step to DH sector reform in Poland [42]

During the mid-1990s, Poland experienced many of the problems facing Ukraine today. In the early 1990s, the Government of Poland transferred ownership and responsibility for DH companies to the municipalities. The decentralization of ownership and a phasing out of investment subsidies meant DH companies lacked funds to effectively operate, maintain, and rehabilitate their infrastructure. This, in turn, led to high heat and hot water losses, which further deteriorated the financial sustainability of DH companies.

World Bank financing played an important role in helping the Government tackle the problems facing the DH sector. From 1991 to 2000, the World Bank provided US$340 million for the Heat Supply Restructuring and Conservation Project in Poland. The project included support for: i) energy sector restructuring, commercialization of restructured enterprises, introduction of a transparent regulatory framework, and pricing policy reform, ii) rehabilitation and modernization to extend DH infrastructure asset life, and iii) energy conservation and pollution reduction through investments in energy efficiency improvements. The Government’s dual effort-supporting investments in energy efficiency and conservation along with pricing policies that led to gradual increases in residential tariffs in conjunction with reductions in budget layouts for energy subsidies was key to the project’s success. Energy

[40] Ibid., p.29
[41] Ibid., p.29
[42] Report on Modernization of the district heating system in Ukraine p. 30

efficiency measures carried out by DH companies achieved a 50 percent reduction in heat transmission and distribution losses, which led to 22 percent energy savings, equivalent to roughly US$55 million per year.

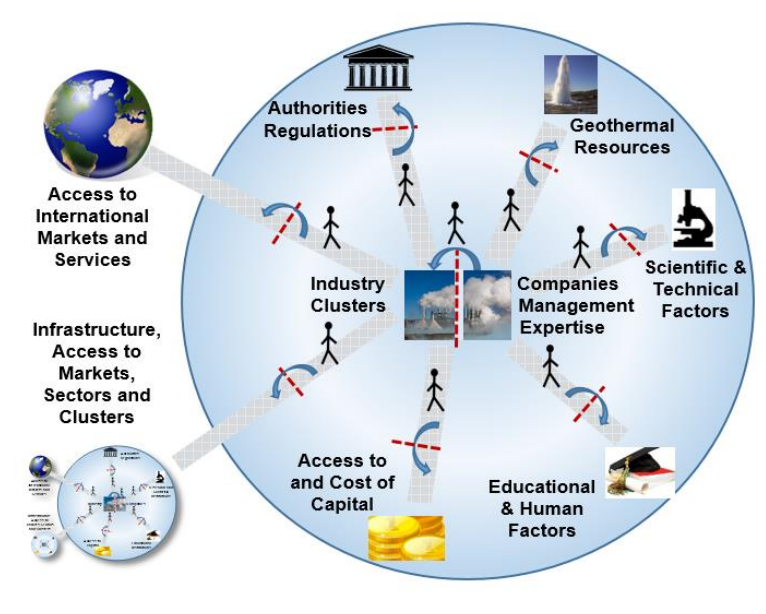
Building level heat metering was a crucial component of these energy efficiency improvements. Metering in the buildings covered by the five DH companies targeted in the project increased from 21 percent at the start of the project to 100 percent by project completion. Further evaluation of the project underlined the significance of metering: without accurate measurement of the heat supply, DH companies often vastly underestimated the level of heat transmission losses in the network (which could reach up to 20 percent of heat purchased and represent up to 17 percent of variable operating costs). As a result, the companies failed to properly prioritize heat loss mitigation and lost major opportunities for cost savings. Evaluation of the project concluded that, “future Bank projects with DH companies should assign top priority to metering of total purchases and sales of heat as early as possible during project implementation.” *Source: World Bank. Implementation Completion Report: Heat Supply Restructuring and Conservation Project in Poland. 5 June 2000.*

4.9. Competitiveness of the Geothermal Sector in Ukraine

Evaluation of the Geothermal Sector – Opportunities and Policy Options

When recommending formulating policy recommendations for the geothermal sector in Ukraine, the enclosed model of 8 factors of geothermal competitiveness, challenges and opportunities, was used to highlight the key elements for policy recommendations and options in the concerning countries. (Petursson, 2014, 2012). Success for the geothermal sector in the concerning countries is not only based on geothermal resources, but also on these factors for competitiveness.

Figure 4.9.1. **Competitiveness of the Geothermal Sector**



Source: Sölvell & Lindquist 2012, Amended, B. Petursson, National Energy Authority, 2014

The cluster competitiveness model can be used in many different ways to increase competitiveness and growth of companies. One possibility is to use the enclosed model to analyse the seven main framework conditions in the geothermal sector;

1. Authorities and regulation.
2. Geothermal resources.
3. Scientific & technical factors.
4. Companies, management, expertise - industry, clusters assessment.
5. Education & human factors.
6. Access to capital.
7. Infrastructure and access to markets, sectors and other clusters.
8. Access to international markets and services, and finally.

By evaluating these seven factors of the geothermal competitiveness in the concerning country, it is possible to highlight the key weaknesses and strengths of the frameworks conditions as a base for the formulation of a better competitiveness policy for the geothermal sector; to increase competitiveness, growth, jobs, productivity and quality of life.

4.9.1. Opportunities and Policy Options

There are several options regarding geothermal possibilities and policy formulation, based on opportunities and by steps towards overcoming barriers and challenges already identified.

1. Authorities and Regulatory Factors

- Publicise the characteristics and benefits of geothermal energy for regional development
- Design regulation specific to the promotion of direct uses of geothermal energy.
- Promote cooperation with international organisations.
- See also additional elements page 15.

2. Geothermal Resources

- Improvement of geothermal regulation.
- Improvements for data analysis of reservoirs in regions.

3. Scientific and Technical Factors

- Promote relationships with industry.
- Promote alliances with research centres and educational institutions for the formation of specialised human resources.

4. Companies, Management, Expertise – Industry Clusters.

- Promote alliances with research centres and educational institutions for the formation of specialised human resources.
- Promote cooperation with IFI for financing, donor support and consulting.
- Organize workshops and conferences to improve knowledge on geothermal energy.
- Identify geothermal energy-related productive chains.

5. Educational and Human Factors

- There is not enough support for the generation of the human resources needed for the geothermal industry**.**
- Creating seminars and specialized courses on the different stages of a geothermal project and adding them to the existing engineering degrees.
- Give the personnel technical training to participate in the different stages of a project.
- Implement programs for scientific development.
- Implement programs for technical development.
- See also additional elements page 15.

6. Access to, and Cost of Capital

- Promote additional access to financing geothermal projects – domestic and international.
- Increase access to capital by providing capital to exploration and test drilling and DH networks e.g. soft loans or donor grants, to lower the risks at the beginning of projects.
- See also additional elements page 15.

7. Infrastructure, Access to Markets, Sectors and Clusters

- Promote training in the banking system for the development of financial mechanisms specific to geothermal energy.
- Awareness; organize workshops & conferences to improve knowledge of geothermal energy.
- Increase the available knowledge about opportunities and benefits of geothermal resources.

8. Access to International Markets and Services

- Support international cooperation in area of geothermal knowledge, training and service.
- Promote international cooperation with IFI and donors on finance, grants and funding.
- Support international consulting cooperation on various fields of geothermal expertise.

Regarding additional elements, see also chapter VIII (page15), 4.7.2, 4.7.3, 4.8, 4.9 and 4.10 on competiveness of the geothermal sector in Ukraine.

4.9.2. Demo – Example of possible Geothermal District Heating Project in Eastern Europe

Enclosed is a demo, example of a geothermal district heating project in Eastern Europe. In this case the selling price / operational cost is approximately 3,8 c€/kWh. This conclusion can be variable between locations – both higher and lower – deepening on several factors, like drilling cost, population (the larger the better, due to economics of scale), etc.

Technical information

Population of town	28.000
Capacity	8,6 MWt
Estim. geoth. energy prod.	23.000 MWh/year (38 l/s)
Water outflow temp.	112°C,
Bottom temp.	115 -140°C
Well depth.:	2.300 m
Flats in town	8.000
Production well	1
Injection well	1
Primary and secondary pipeline already in place before	
Heating period	6 months

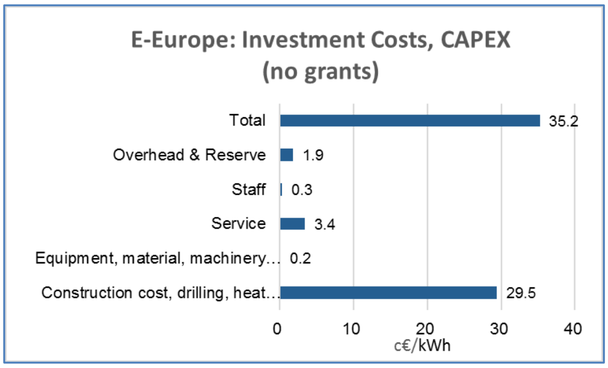
Project Finance

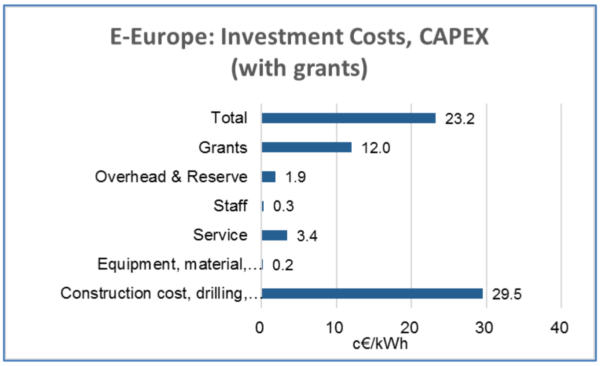
Total project	€ 8,5 million
Grant	€ 3 million.
Project minus grant	€ 6,7 million
Grant %	€ 35%

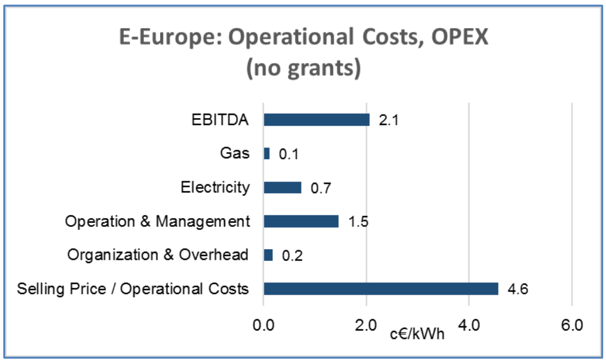
CO_2 Emissions:

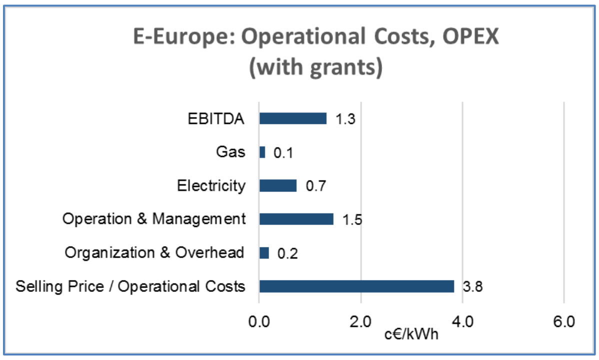
Estim. CO_2 avoidance per kWh	203 g/kWh
Estim. CO_2 avoidance per year	4.800 tonnes/year
Equal to CO_2 bindings per year in	2,4 million trees/year
Equal to bindings in km^2 of trees	11,4 per year

Equal to avoidance of burning oil equal to 1.600 tonnes (1 tonne of oil = 3 tonnes of CO2)







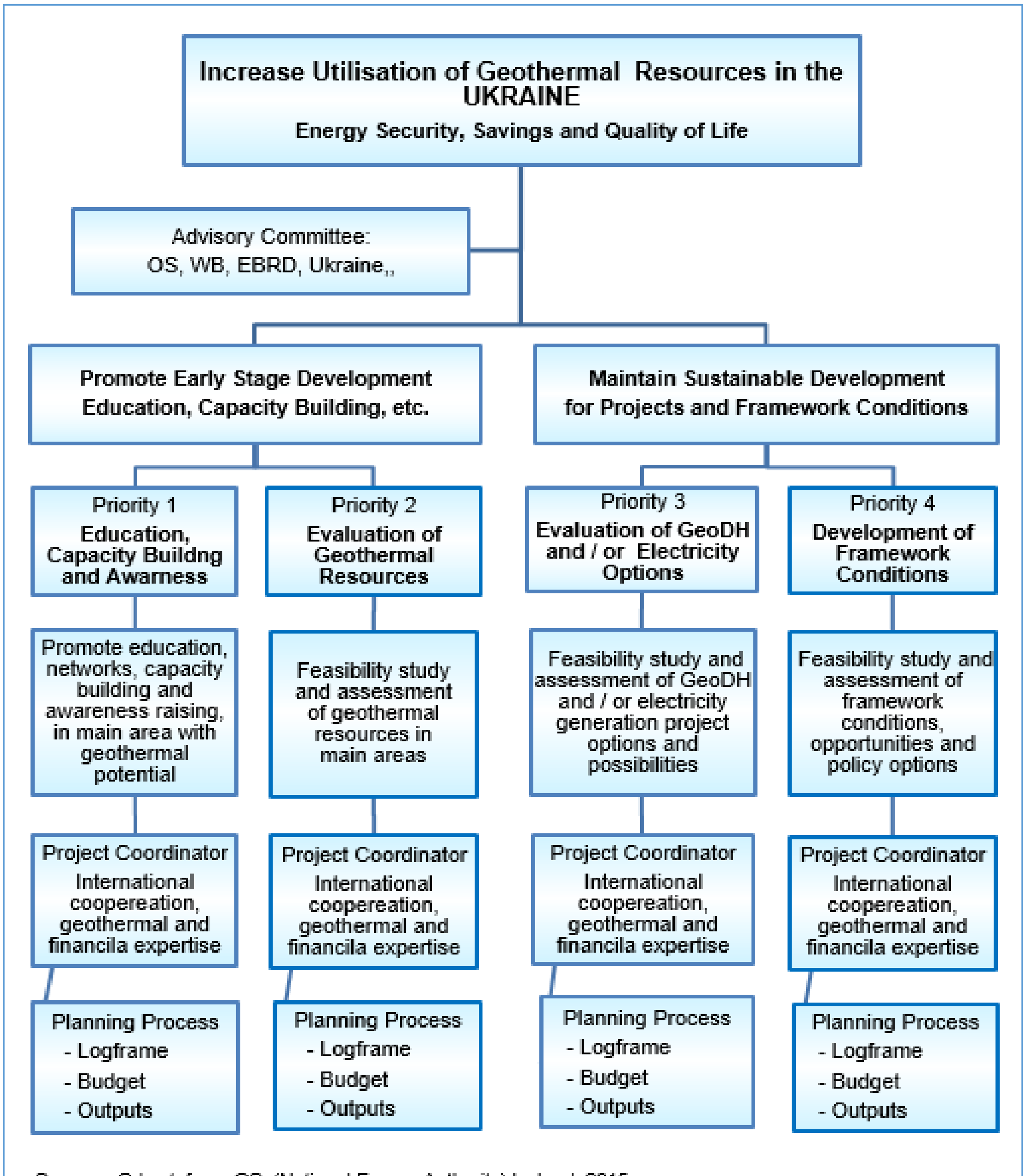


4.10. Opportunities and Policy Options for Ukraine

Key elements in the development of geothermal energy and financing of renewable energy projects in Ukraine depend on international cooperation with the most experienced geothermal countries, stakeholders, internationals financial institutions and donors. It is also important to base proposals on global lessons learned, and challenges and opportunities in Ukraine, towards tailor made policy priorities, programs and projects. The general recommendations for the Ukraine are as follows:

1. An independent policy based on assessment and conditions in Ukraine.
2. Awareness raising among policymakers, stakeholders and municipalities.
3. Support schemes for the geothermal development.
4. A properly structured policy system, is critical for success.
    a. Priority 1 - Education capacity building, networking and awareness.
    b. Priority 2 - Evaluation of geothermal resources.
    c. Priority 3 - Promotion of geothermal district heating & power generation.
    d. Priority 4 - Development of framework conditions.
    e. Priority 5 - International cooperation, geothermal and financial expertise.

Figure 4.10.1. **Opportunities and Policy Option for Ukraine**



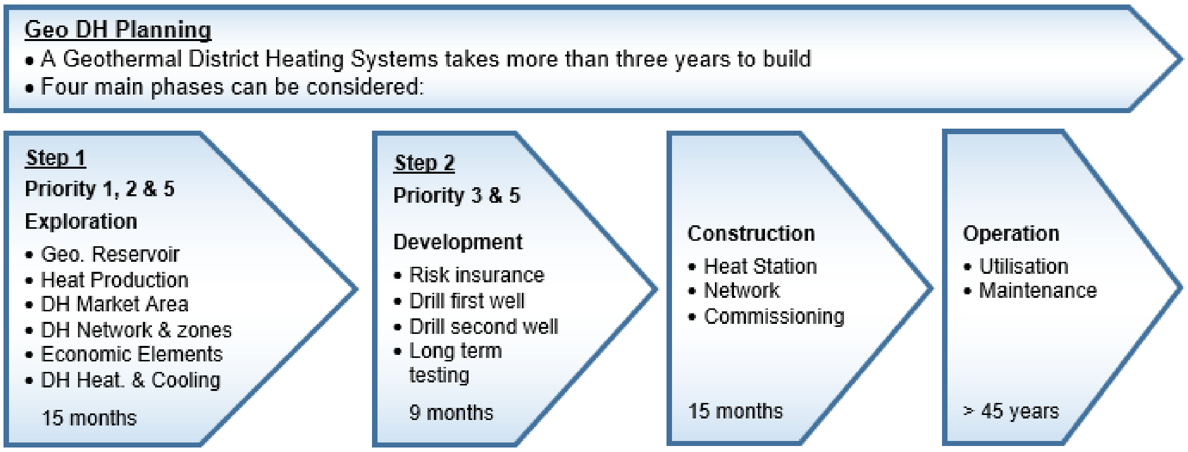
Sources: Orkustofnun, OS, (National Energy Authority) Iceland, 2015

4.10.1. Proposal - Two Steps, 1. Pre-Feasibility Study and 2. Project Implementation

First step – Further Assessment of 2 – 3 Priority Locations in Western Ukraine

The opportunities and utilisation of priority locations are shown in figure 4.10.1,1, where the coordination of the project is explained step by step and can be treated as a model to promote the early stage development projects.

Figure 4.10.1.1. **Two Step Strategy for Geothermal District Heating (GeoDH) in Ukraine**



Sources: GeoDH, and National Energy Authority Iceland

Step 1

Pre-Feasibility Study and assessment of geo resources in 2 – 3 areas in West- Ukraine

Cities
- L'viv,
- Ivano Frankivsk
- Chernivtsi,

Towns
- Uzhgorodske
- Berregivske
- Mostiske

Co-ordination – International Geo expertise & EBRD, IFIs and authorities and institutions in Ukraine

Finance – donor grant finance – EBRD / IFIs – up to € 500.000 per location.

Time – 15 months

Step 2

Implementation Project / Investment of Geothermal District Heating (GeoDH) Projects

Implementation of 1 – 2 projects in W-Ukraine – for GeoDH and / or Power Generation**.**

Coordination – International geothermal expertise in cooperation with EBRD / IFIs in cooperation with donor countries and authorities in Ukraine

Implementation – PPP-co-operation – based on tendering process.

Finance – depends on type of projects and finance and Donor contribution, development priority etc.

Time – 24 months.

4.10.2. Proposal – Step 1 - Pre- Feasibility Study of Geothermal District Heating in Ukraine

1. Proposed Project

Geothermal resources can be economically successful in comparison with fossil based energy resources, improve economic savings, reduce greenhouse gas emissions, increase energy security, and improve air quality and quality of life.

2. Location

Proposal of locations are based on three main priorities:

1) Potential geothermal resources. 2) Population / volume, as it is a base for economic success of projects. 3) Cities in cooperation with EBRD / IFIs, as IFIs involvement is important.

These, three locations out of six are highlighted as an option for step one for further exploration.

Location	Popu-lation	Exp. Utilisation M3/day	Temp-erature °C	Geo. inst. thermal pow. MW	Fuel economy, t.s.f./ year*	Directions of using * (t. s.f./year = tons of standard fuel per year)
L'viv, city	730.000	Data needed	Data needed	Data needed	Data needed	Large DH, – exploration of geothermal potentials needed in the area
Ivano Frankivsk	229.000	Data needed	Data needed	Data needed	Data needed	Large DH, – exploration of geothermal potentials needed in the area
Chernivtsi	263.000	Data needed	Data needed	Data needed	Data needed	Large DH, – exploration of geothermal potentials needed in the area
Uzhgorod	115.000	65.300	60	120,4	117.707	Heat supply communal and industrial facilities Uzhgorod
Mostiske,	11.000	7.800	107	27,3	15.783	Heat supply industrial premises railway station, depot, residential buildings of village Mostyske
Berehove	24.500	10.300	58	21,5	21.152	Heat supply of village Berehovo, balneology

Figure 4.10.2.1. **Boreholes that are good for geothermal power generation and Geothermal district heating**

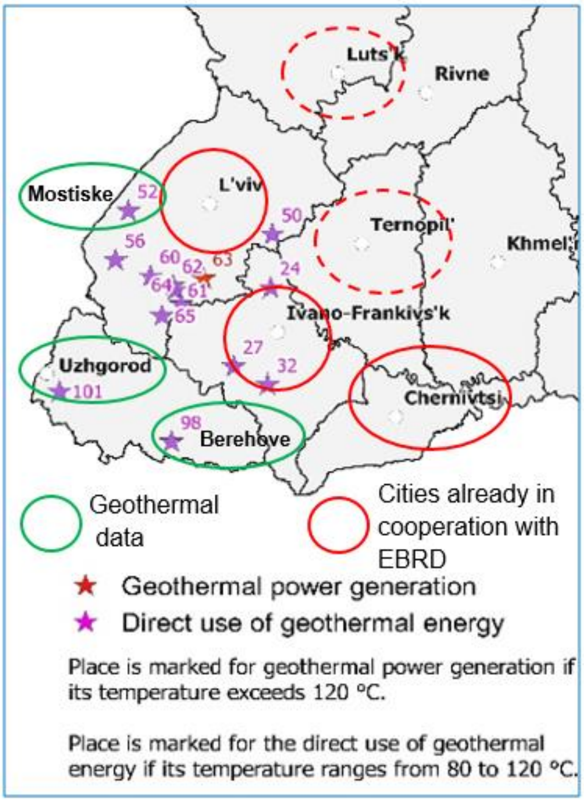
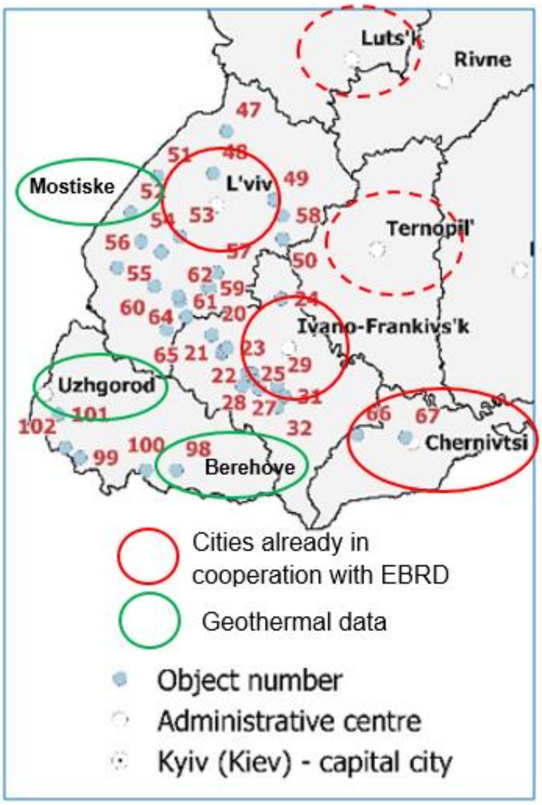


Figure 4.10.2.2. **Some perspective geothermal energy objects in Ukraine**



3. Co-ordination

International geothermal expertise in cooperation with EBRD and authorities and institutions in Ukraine

4. Finance

Donor grant finance, in cooperation with EBRD / IFIs, up to € 500.000 per location.

5. Why is the project needed?

To promote early stage development, strategy planning, capacity building, networking and awareness of geothermal utilisation, to increase the possibility of utilisation of geothermal resources, energy security, savings and quality of life in concerning location.

6. What will the project achieve?

Pre-Feasibility Study of Geothermal District Heating will achieve:

- Re-evaluate and update the production potential of the geothermal resource.
- Increase the awareness of the local authorities, as well as the public, of the potential and benefits of sustainable geothermal utilization in the city and surrounding communities.
- Evaluation of the potential increase of geothermal utilization in the city and area.

7. How will it be achieved and who are the beneficiaries?

(c) The following main project phases are proposed:

- Assessment of the current status of utilization in each location; capacity of wells used, energy produced, utilization for district heating, other direct uses, etc. as well as highlighting framework barriers for geothermal district heating possibilities.
- Potential assessment with simple reservoir models and predictions for some relevant future sustainable utilization scenarios with special emphasis on benefits of reinjection.
- Potential improvements to the current utilization, in particular district heating. Involves the design of surface installations with emphasis on the economic and energy efficiency.
- Evaluation of the potential for expansion of the current utilization, both concerning district-heating and other possible direct uses. Report includes e.g. engineering and financial benefits of geothermal district heating in comparison to gas and oil.
- Analysis of geothermal district heating) development – international comparisons.
- Evaluation of geothermal policy options and opportunities.
- Dissemination of results locally and countrywide – to increase awareness of geothermal utilisation, and utilisation, energy security, savings and quality of life in concerning regions.

(d) The beneficiaries of the program are the City x and its citizens.

8. Possible timeline of Step 1 is 15 months.

Example of possible Timeline of Step 1			201x				201y										
No.	**Activity**	**Work package leader**	Sept	Oct	Nov	Dec	Jan	Feb	Marc	Apr	May	June	July	Aug	Sept	Oct	Nov
1	**Project preparation**																
2	**Review of documents and site visit**																
2.1	Site visit, data collection, meeting with stakeholders																
2.2	Desk review of documents																
3	**Assessment and report preparation**																
3.1	Assessm. of GeoDH current utilisation																
3.2	Assessment of reinjection																
3.3	Potential improvem. of GeoDH systm. & markets																
3.4	Evaluation of optional expansion and opportunities																
3.5	Evaluation of policy options and opportunities																
3.6	GeoDH - international comparison																
3.7	GeoDH - Icelandic experience																
3.8	Recommendations																
4	**Dissemination of results**																
4.1	Report on Pre-Feasibility Study																
4.2	Conclusion Meeting / Seminar / Website Information																

III. GEOTHERMAL DEVELOPMENT AND EXPERIENCE IN ICELAND

5. Geothermal Resources in Iceland

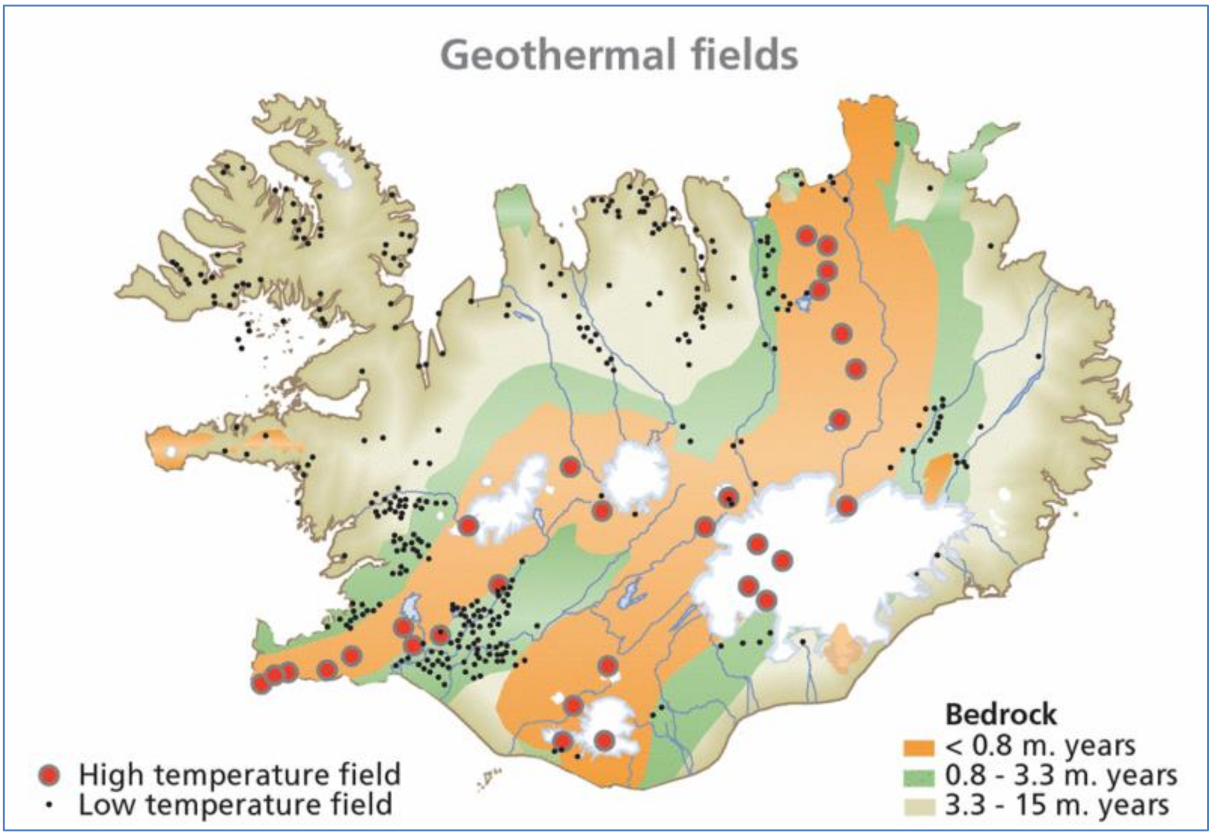
5.1. The Nature of Geothermal Resources

Geological background
Iceland is a young country geologically. It lies astride one of the Earth's major fault lines, the Mid-Atlantic ridge. This is the boundary between the North American and Eurasian tectonic plates. The two plates are moving apart at a rate of about 2 cm per year. Iceland is an anomalous part of the ridge where deep mantle material wells up and creates a hot spot of unusually great volcanic productivity.

This makes Iceland one of the few places on Earth where one can see an active spreading ridge above sea level. As a result of its location, Iceland is one of the most tectonically active places on Earth, resulting in a large number of volcanoes and hot springs. Earthquakes are frequent, but rarely cause serious damage.

More than 200 volcanoes are located within the active volcanic zone stretching through the country from the southwest to the northeast, and at least 30 of them have erupted since the country was settled. In this volcanic zone there are at least 20 high-temperature areas containing steam fields with underground temperatures reaching 200°C within 1.000 m depth. These areas are directly linked to the active volcanic systems. About 250 separate low-temperature areas, with temperatures not exceeding 150°C in the uppermost 1.000 m, are found mostly in the areas flanking the active zone. To date, over 600 hot springs (temperature over 20°C) have been located (Figure 5.1.1).

Fig. 5.1.1. **Volcanic zones and Geothermal Areas in Iceland.**



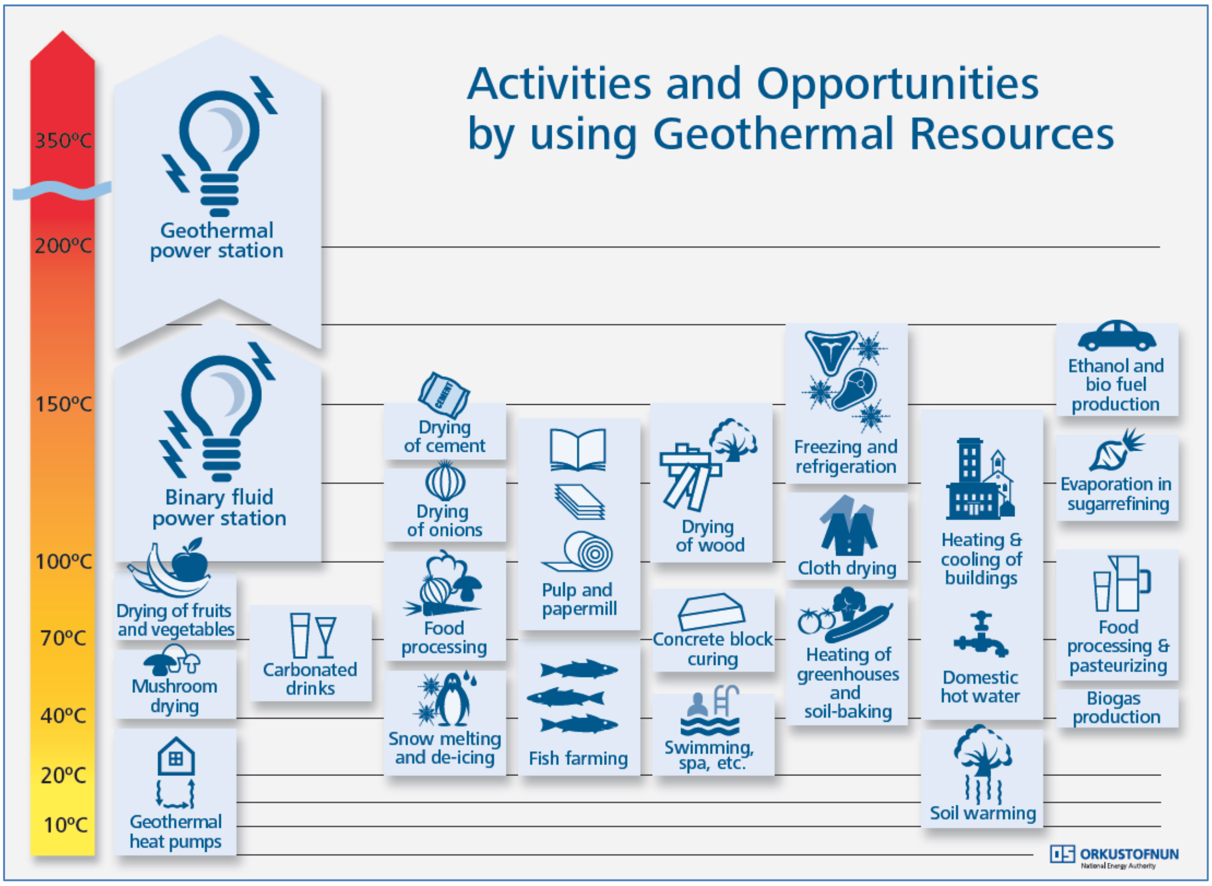
5.2. The nature of ow-temperature Systems

The low-temperature systems are all located outside the volcanic zone passing through Iceland. The largest of these systems are located in southwest Iceland on the flanks of the western volcanic zone, but smaller systems can be found throughout the country. On the surface, low-temperature activity is manifested in hot or boiling springs, while no surface manifestations are observed on top of some systems. Flow rates range from almost zero to a maximum of 180 l/s from a single spring. The heat-source for low-temperature activity is believed to be Iceland's abnormally hot crust, but faults and fractures, which are kept open by continuously ongoing tectonic activity, also play an essential role by providing channels for the water to circulate through the systems, and mine the heat. The temperature of rocks in Iceland generally increases with depth. Outside the volcanic zones the temperature gradient varies from about 150°C/km near the margin to about 50°C/km farther away. The nature of low-temperature activity may be described as follows: Precipitation, mostly falling in the highlands, percolates down into the bedrock to a depth of 1 - 3 km, where the water is heated by the hot rock, and subsequently ascends towards the surface because of reduced density. Systems of this nature are often of great horizontal extent and constitute practically steady state phenomena.

The most powerful systems are believed to be localised convection systems where the water circulates vertically in fractures of several kilometers of depth. The water then takes up the heat from the deep rocks at a much faster rate than it is renewed by conduction from the surroundings. These fields are therefore believed to be of transient nature, lasting some thousands of years.

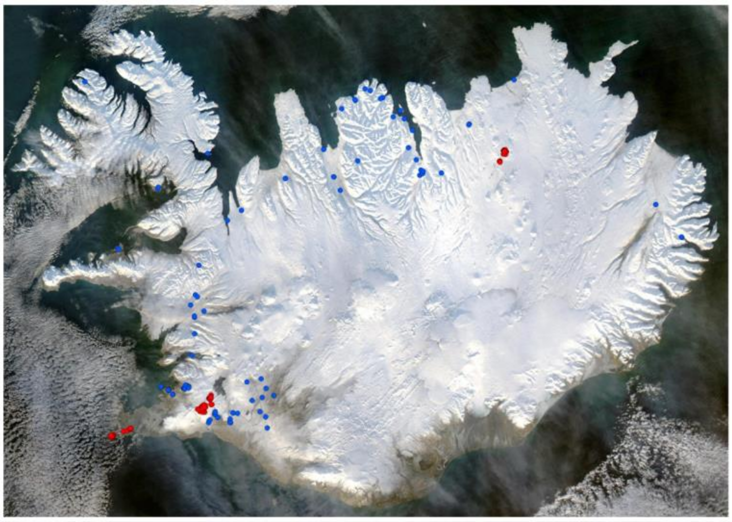
5.3. Geothermal for Industrial use

Geothermal resources can be used for various activities, as can be seen from the picture. In Iceland it has also been done, e.g. for greenhouses, fish farming, bathing etc.



5.4. Wells in use in Iceland

Figure 5.4.1. **Satellite image of Iceland in winter time illustrating geothermal production wells in operation in year 2014 for geothermal power plants (red) and wells operated by heat utilities with a natural monopoly for distribution of heat. Over 100 production wells operated by small auto-producers are excluded.**



The average high temperature well is 1866 m deep, cased down to 1.585 m.

For low temperature systems in total 173 wells and 9 hot springs are used, with an average well depth of 1055 m, cased down to 223 m (Oddsdóttir and Ketilsson, 2012).

See Figure 5.4.1 for wells that generate electricity (red) and only heat (blue) for district heating systems.

5.5. The History of Geothermal District Heating

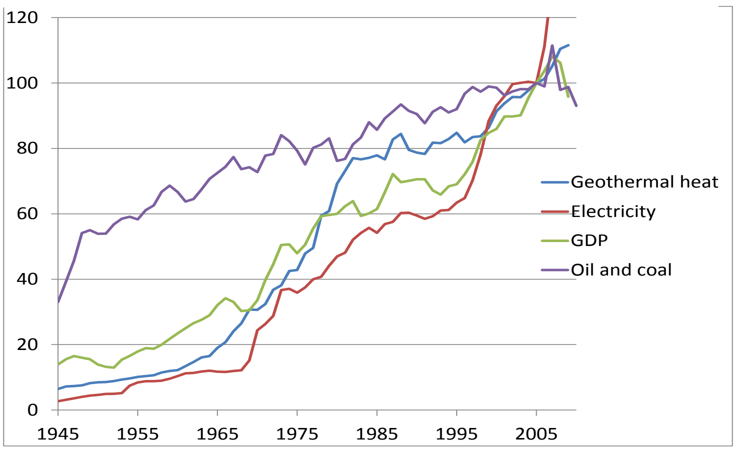
Fuel for Heating Houses

In a cold country like Iceland, the need for space heating is greater than in most countries. In earlier centuries, peat was commonly used for heating houses, as well as seaweed. This continued even after the importation of coal for space heating was initiated after 1870. In the rural regions, the burning of sheep-dung was common, as the distribution of coal or peat was difficult due to the lack of roads. The use of coal for heating increased in the beginning of the 20th century, and was the dominating heat source until the end of WWII. Oil for heating purposes first became significant after WWI, but by 1950 about 20% of families used oil for heating, while 40% used coal. At that time about 25% enjoyed geothermal heating services. Coal was practically eliminated from space heating in Iceland around 1960. Heating homes with electricity did not become common until larger electric power plants were erected in the 1930s and 1940s.

Current Geothermal Heat Use

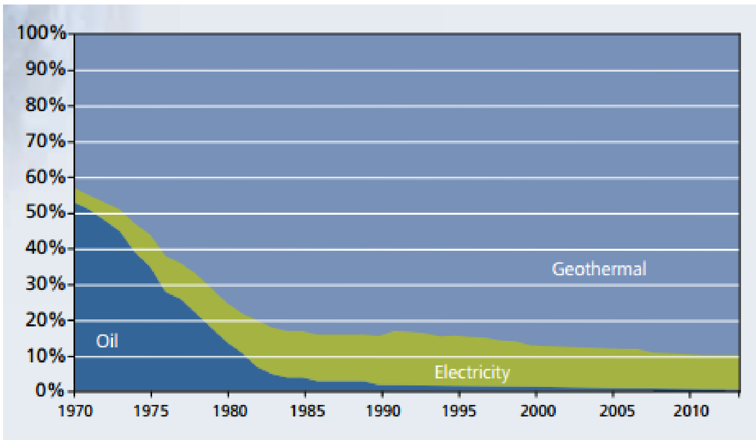
Geothermal utilization amounted to 28,1 PJ in 2014. Residential use amounted to 13,3 PJ, commercial services to 0,7 PJ, fisheries to 2,5 PJ, industry 0,9 PJ and services 10,7 PJ using IEA categories. Space heating amounted to 20,0 PJ, swimming and bathing 2,0 PJ, snow melting 2.0 PJ, fish farming 2,5 PJ, industrial use 0,9 PJ and greenhouses 0,7 PJ.

Figure 5.5.1. **Development in GDP, used Electricity, Geothermal Heat, Oil and Coal per capita 1945 – 2010.**



Space Heating
Over the last 70 years, there has been considerable development in the use of energy for space heating in Iceland. After WWII, The National Energy Authority (Orkustofnun) and Iceland Geosurvey (and their predecessors) have carried out research and development, which has led to the use of geothermal resources for heating of households for 90% of the population. This achievement has enabled Iceland to import less fuel, and has resulted in lower heating prices.

Figure 5.5.2. **Relative share of Energy Resources in the Heating of Houses in Iceland 1970–2014.**



5.6. Public Support of Geothermal District Heating

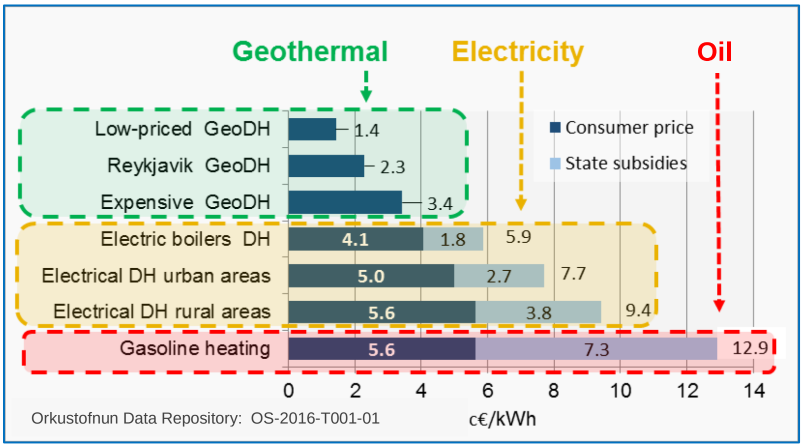
Public Support towards Geothermal District Heating
Already by the 1940s, the State Electricity Authority promoted geothermal development and carried out a regional survey of geothermal areas suitable for space heating and explored promising fields with exploratory drilling. The capital Reykjavik obtained by law a monopoly on operating a geothermal heating service in the town and took initiative in production drilling and establishment of the first large geothermal district heating system. The State guaranteed loans for the construction of the system. In 1950 about 25% of families in the country enjoyed geothermal heating services, 40% used coal and 20% oil for heating. The cheap geothermal heating was attractive and intensified the flux of people from rural areas to the capital.

Lessons learned from Iceland

- Important to recognize the importance of GeoDH for
  - economy (savings),
  - energy security and
  - mitigate climate change
- Important to lower the risk of projects in the beginning e.g. by supporting exploration and test drilling
- Importance for Financial Institutions to recognise opportunities within GeoDH

To balance that, the national parliament approved an Act in 1953 on geothermal heating services in communities outside Reykjavik which permitted the State to guarantee loans up to 80% of the total drilling and construction cost of heating services. Further, to encourage the development, the State started a Geothermal Fund in 1961. The fund gave grants for reconnaissance and exploratory drilling carried out by the Geothermal Department of the State Electricity Authority and offered loans to communities and farmers for exploratory and appraisal drilling covering up to 60% of the drilling cost. If the drilling was successful, the loans were to be paid back with highest allowed interests in 5 years after the heating service was up and running.

Figure 5.6.1 **Comparison of Energy Prices for Residential Heating in Iceland in 2014**



If exploratory drilling failed to yield exploitable hot water, the loan was converted to a grant and not paid back. In this way the fund encouraged exploration and shared the risk. Within the next 10 years many villages used this support and succeeded in finding geothermal water. In 1967 the fund was merged with the Electricity Fund and named the Energy Fund. The Electricity Fund had since the 1940s supported electrification and transmission in rural areas. By 1970 about 43% of the nation enjoyed geothermal heating, while oil was used by 53% of the population, and the remainder used electricity. Space heating of residential buildings is subsidized by the state as shown in Figure 5.6.1. for those areas where geothermal based district heating systems are not reachable. The lump sum for 8 years of this state subsidization has been available to support home owners to transform to renewable heating (Act No. 78/2002). This has recently been increased by 50% to be equivalent of a 12 year lump sum. In addition, if the project receives other grants it will not effect in any way this lump sum payment. This has stimulated new geothermal based district heating systems to be installed, like in the town of Skagaströnd, operated by RARIK, in 2013.

The Government's role in Developing Geothermal Energy

The government has encouraged the exploration for geothermal resources, as well as research into the various ways geothermal energy can be utilized. As stated earlier this work began in the 1940s at The State Electricity Authority, and has been in the hands of its successor, Orkustofnun (The National Energy Authority), since its establishment in 1967. The aim has been to acquire general know-ledge about geothermal resources and make the utilizatin of this resource profitable for the national economy.

This work has led to great achievements, especially in finding alternative resources for heating homes. This progress has been possible thanks to the skilled scientists and researchers at Orkustofnun. After the electricity market was liberalized with adaption to EC Directive in year 2003 Orkustofnun only contracts research in the field of energy and a new state institute, Iceland GeoSurvey, was created which on a competitive basis takes part in projects mainly for the energy companies and heat utilities but also for Orkustofnun. According to a new Energy Act in 2003, the Energy Fund is now under Orkustofnun.

Fig. 5.6.2. **Policy Priorities for Geothermal District Heating in Iceland**

1. **Political, sectorial and public recognition / awareness for the importance for GeoDH Policy**
   - For **energy security, economic and environmental** due to oil crises 1973-, the GeoDH policy was recognized, national and in main cities.
2. **Loans (Grants) to GeoDH for exploration and test drillings have lowered the risk for GeoDH - improved implementation**
   - The National Energy Fund (NEF) has provided loans to exploration and test drilling. If the drilling is unsuccessful, the loan can be written off.
3. **Space heating support for homes which are out of geothermal areas**
   - Space heating of residential buildings is subsidized by the state for those areas where geothermal energy is not available.
4. **Policy to replace electricity (high exergy) for space heating**
   - Aims at reducing electricity (high exergy) for space heating and replacing it with geothermal heating (low exergy) and contributing to improved energy quality management.
5. **Grants to individuals (apartments) for transformation to GeoDH – improved implementation**
   - Grant for 8 years accumulated support for transformation from electricity heating to GeoDH or Heat Pump - is provided.
6. **Grants to GeoDH companies (GeoDH Area) for transformation to GeoDH – improved implementation**
   - Grant for 12 years support transformation from electricity heating to GeoDH
7. **Some element of the policy has been changed, since it was first implemented.**

New and effective exploration techniques have been developed to discover geothermal resources. This has led to the development of geothermal heating services in regions that were thought not to have suitable geothermal resources. Iceland's geothermal industry is now sufficiently developed for the government to play a smaller role than before. Successful energy companies now take the lead in the exploration for geothermal resources, either geothermal fields that are already being utilized, or discovering new fields.

5.6.1. Demo – Icelandic Geothermal District Heating Project in Operation

Enclosed is a demo, example of a geothermal district heating project in operation in Iceland. The demo - example is related to small municipality in the countryside, with population of approximately 1.500 people. Despite the small size of the town, and therefore not much benefits of economic of scale, in comparison to the cost of the investment (drilling etc.) – it is more economic to use this GeoDH than to use other resources of heating, for example electricity or oil. See also figure 5.6.1. In Iceland there is policy promoting the utilisation of GeoDH, as it is less costly than oil and electricity, and therefore more economically beneficial in the long term, both for the concerning towns and the economy. In an addition, it has great environmental effects as opposed to heating by oil.

Technical information

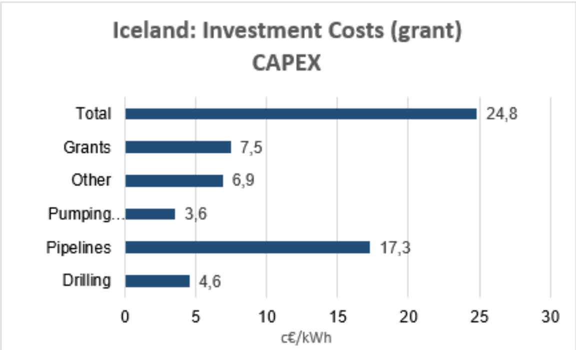
Population	1.500
Capacity	1,35 MWt
Water in temp.	60°C,
Water out temp.	30°C,
Well depth	1.000 meters
Production:	11.800 MWh/year (338.373 m3/year)
Production well	1
Pumping stations	3
Estim. primary pipeline	34 km
Estim. secondary pipeline	10 km
Heating period	10 months

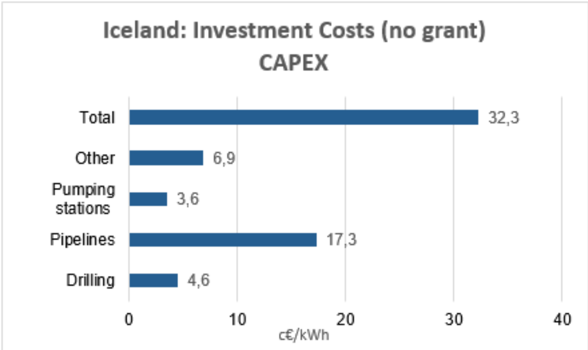
Project Finance

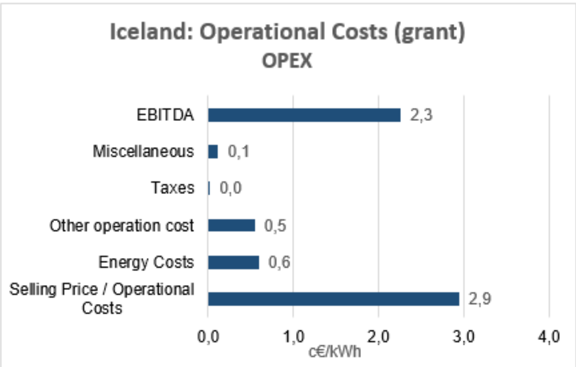
Total project	€ 3,812 million
Grant	€ 0,880 million.
Project minus grant	€ 2,932 million
Grant %	€ 23%

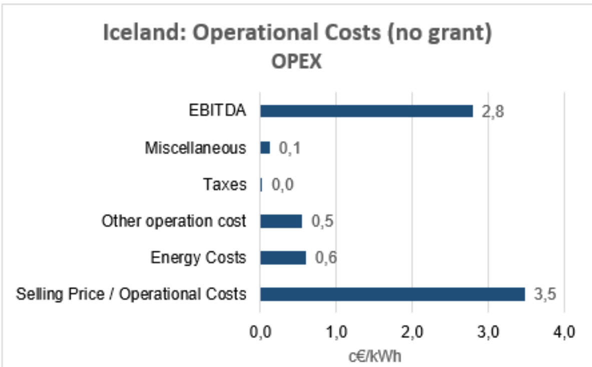
CO2 Emission:

Estimated CO_2 avoidance per kWh 193 g/kWh
Estimated CO_2 avoidance per year 2.277 tonnes
Equal to CO_2 bindings per year in 1,1 million trees
Equal to bindings in square kilometres of trees 5,4 per year
Equal to avoidance of burning oil equal to 760 tonnes (1 tonne of oil = 3 tonnes of CO_2)









5.7. Economic impact

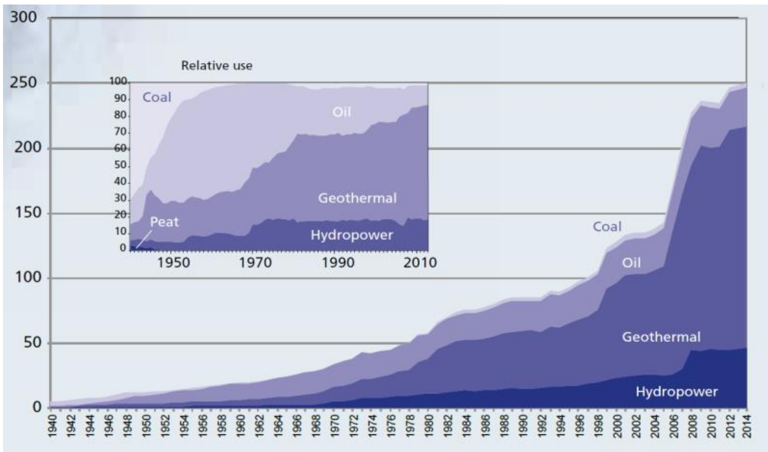
Influence of the Oil Crisis on Energy Prices

When the oil crisis struck in the early 1970s, fuelled by the Arab-Israeli War, the world market price for crude oil rose by 70%. At the same time, close to 90.000 people enjoyed geothermal heating in Iceland, about 43% of the nation. Heat from oil served over 50% of the population, the remainder used electricity. In order to reduce the effect of rising oil prices, Iceland began subsidizing those who used oil for space heating. The oil crises in 1973 and 1979 (Iranian Revolution) caused Iceland to change its energy policy, reducing oil use and turning to domestic energy resources, hydropower and geothermal.

This policy meant exploring new geothermal resources, and building new heating utilities across the country. It also meant constructing transmission pipelines (commonly 10-20 km) from geothermal fields to towns, villages and individual farms. This involved converting household heating systems from electricity or oil to geothermal heat. But despite the reduction in the use of oil for space heating from 53% to 7% from 1970 to 1982, the share of oil still remained about 50% to 60% of the total heating cost due to rising oil prices.

The relative share of energy resources used to heat households has changed since 1970 (Figure 5.7.1). The increase in geothermal energy is clear, but after 1985 it has been steady for heat use. However according to Statistics Iceland a population growth of 36% is estimated until 2050, and therefore the total heat use is expected to increase by 70% until 2050 to almost 50 PJ. The proportion of the population using geothermal energy is also increasing, and could in the long run rise from its present ratio of 89% to 92% for residential heating. The share of oil for heating continues to decrease and is at present about 1%. The share of electric heating is about 10% but one third of that comes from combined heat and power plants using geothermal where electricity is used to heat water for district heating systems.

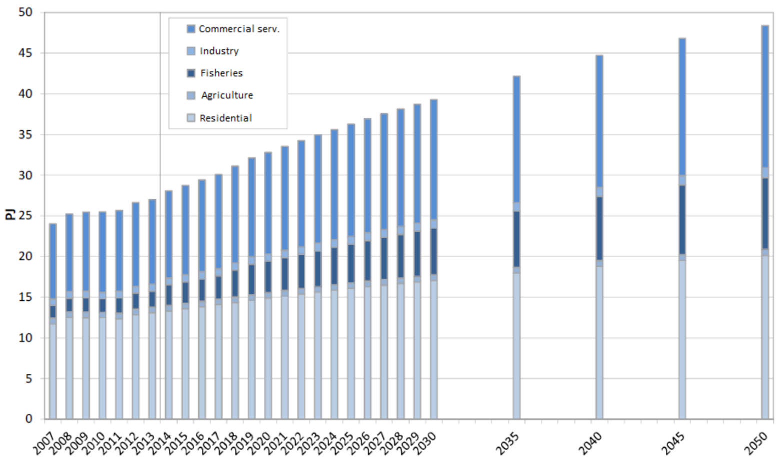
Figure 5.7.1. **Primary Energy use in Iceland 1940 – 2014**



Source: Orkustofnun Data Repository: OS-2016-T002-01

Primary energy use in Iceland has increased by large amounts in the last few decades. The primary energy use in 2010 was approximately 750 GJ per capita, which is among the highest in the world. Furthermore, when looking at the share of renewables in total primary energy use in the world, it can be seen that Iceland has the highest share, with 85%, the average for Europe is 9%, USA 8%, Japan 3% and China 14% see. Figure 1.3.2.4, earlier in this report, chapter 1.

Figure 5.7.2. **Geothermal utilization in [PJ] for the period 2007–2050 (Orkustofnun, 2015).**



Source: Orkustofnun

The predominant reason for this is the large proportion of large industries in the consumption of electricity. Additional reasons are the relatively large proportion of electricity production from geothermal, heavy energy use by the fishing fleet and transportation sector, and more need for energy for space heating due to cold climatic conditions.

Figure 5.7.3. **Economic Benefits of Geothermal District Heating**

Price of a space heating by geothermal district heating

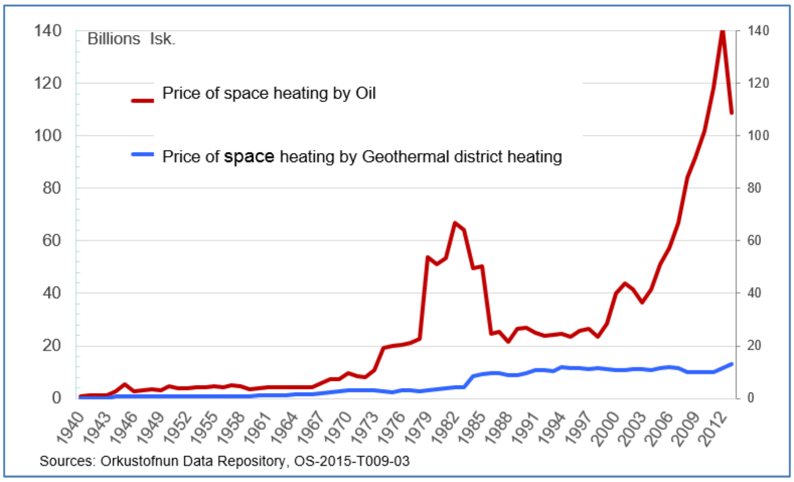
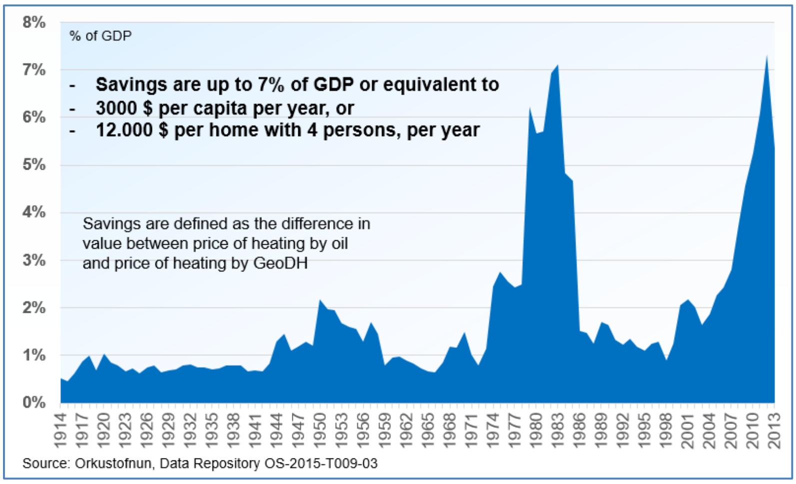


Figure 5.7.4. **Economic Benefits of Geothermal District Heating**

National Savings by Geothermal District Heating as % of GDP



Benefits of using Gothermal Heat instead of Oil

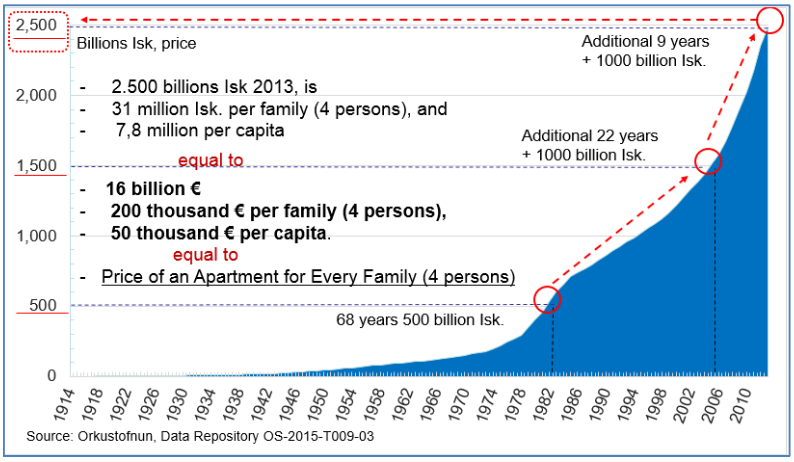
The economic benefits of the government's policy to increase the utilisation of geothermal energy can be seen when the total cost of hot water used for space heating is compared to consumer cost if oil would be used, as shown in Fig. 5.7.3. The stability in the hot water cost during strong variations in oil cost is noteworthy.

In Figure 5.7.3 the blue line shows price for geothermal district heating, and the red line the calculated price for heating by oil,(adjusted to the consumer price index 1 USD = 120 ISK).

Oil heating is 2-6 times more expensive than geothermal heating throughout most of the period but peaks to 16 times more expensive in the period 1973 to 1985 and has risen again since 2007 to a present ratio of 10. In 2012 the difference in cost amounted to 80% of the state budget cost of health care in the same year.

Figure 5.7.5. **Cumulative Savings from Geothermal District Heating in Iceland, 1914 – 2013**

2% interests, fixed price 2013



Evaluations of the estimated savings might vary somewhat as some might claim that sources other than oil could be used for heating. Heating energy could have been obtained through an increased generation of electricity with hydropower, as is done in Norway.

Nevertheless, it is beyond dispute that the economic savings from using geothermal energy are substantial, have had a positive impact on the currency account and contributed significantly to Iceland's prosperity, especially in times of need. The annual savings have been in the range of 1-2% of GDP for most years but rise to

7% in the period 1973 to 1985, and have been nearing that peak again in recent years. The 7% of GDP is equivalent to 3.000 USD per capita.

Besides the economic and environmental benefits, the development of geothermal resources has had a desirable impact on social life in Iceland. People prefer to live in areas where geothermal heat is available, in the capital area and in rural villages where thermal springs can be utilised for heating dwellings and greenhouses, schools, swimming centers and other sports facilities, tourism and smaller industry. Statistics show improved health of the inhabitants of these regions.

In recent years, the utilisation of geothermal energy for space heating has increased mainly as a result of the population increase in the capital area, as people have been moving from rural areas to the capital area. As a result of changing settlement patterns, and the discovery of geothermal sources in the so-called "cold" areas of Iceland, the share of geothermal energy in space heating is still rising. It is also possible to evaluate cumulative savings of geothermal district heating from 1914 – 2013, based on real price (fixed price 2013) and 2% annual interest rate**.**

Based on these calculations, the overall savings is equal to 31 million ISK per family (€200.000), which is equal to the price of an apartment for a family (4 persons) in Iceland.

From 1982 – 2013 the majority of savings has happened after the geothermal district heating implementation and is about 2.000 billion ISK. This is equal to 64 billion ISK. (€412.000.000) per year, or 800.000 ISK (€5.160) per family, or about 70.000 ISK. (€450) per month per family, after taxes.

Figure 5.7.6**. Reykjavik**

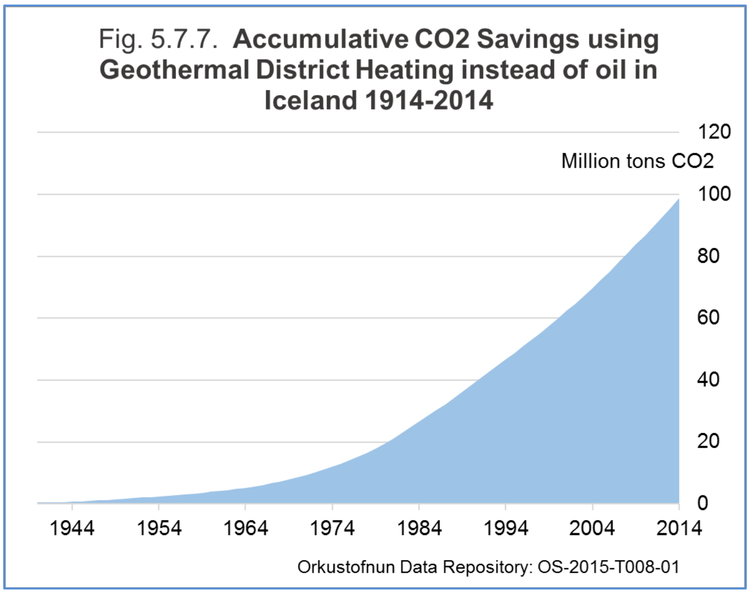
According to information from Statistics Iceland, 2.500 billion ISK, is equal to 80% of the total value of all residential houses and apartments in Iceland which was estimated around 3.200 billion ISK in 2013.

CO_2 Savings due to Geothermal District Heating

The use of geothermal energy for space heating and electricity generation has also benefited the environment, as both geothermal energy and hydropower have been classified as renewable energy resources, unlike carbon fuels such as coal, oil and gas.

The benefit lies mainly in relatively low CO_2 emissions compared to the burning of fossil fuels.

Since 1940 to 2014 the CO_2 savings by using geothermal district heating have been around 100 million tons, which is equal to saving of using 33 million tons of oil.



In 2014 the geothermal district heating savings of CO_2 in Iceland was about 3 million tons of CO_2, or equal to 1 million tons of oil, equal to CO_2 bindings in 1,5 billion trees and 7.150 km^2 of forest.

CO_2 Savings due to Renewables in Iceland

If we look at the accumulated savings of CO_2 by all renewables in Iceland 1914 – 2014, that savings is about 350 million tons, mostly since 1944. That is equal to CO_2 bindings in 175 billion trees, or 850 km^2 of forest and is equal to 120 million tons of oil.

In 2014 the annual savings of CO_2 from renewables in Iceland was 18 million tons, equal to bindings of CO_2 in 9 billion trees, equal to 43.000 km^2 of forest. It is also equal to 6 million tons of oil.

These saved tons of CO_2 have been an important contribution for mitigation of climate change, not only in Iceland but on a global level as well, as climate change has no border between countries or regions.

Geothermal District Heating in Iceland and the use of other renewables, contributes towards economic savings, energy security and reduction of greenhouse gas emissions.

Fig. 5.7.8. **Accumulative CO2 Savings using Renewables instead of oil in Iceland 1914-2014**

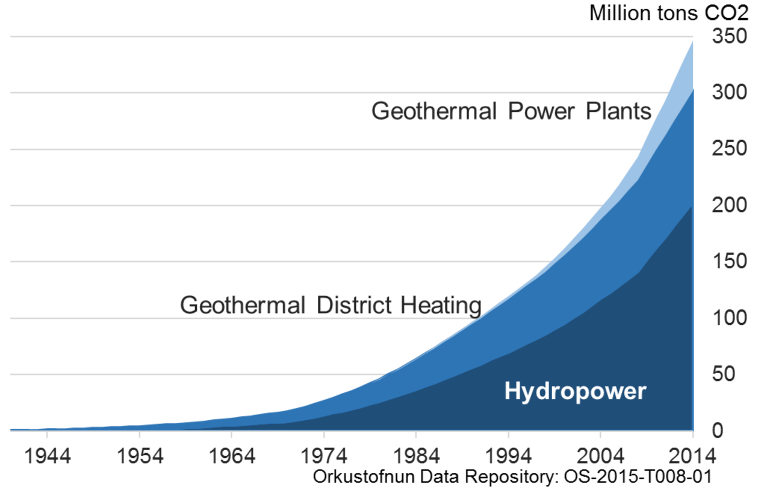
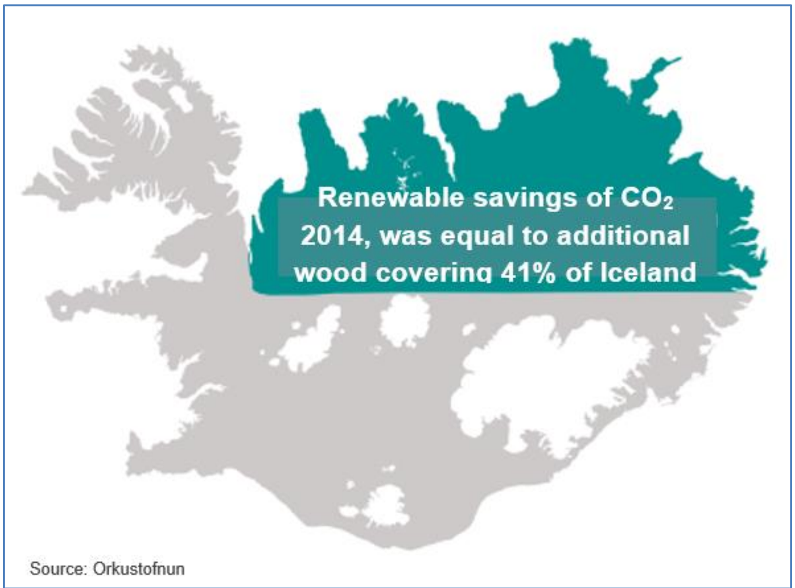


Fig. 5.7.9. **The Annual Savings of CO_2 2014 from Renewables in Iceland was equal to bindings of CO_2 in 9 billion trees, equal to 43.000 km^2 of Forest or 41% of Iceland.**



6. Geothermal Development

6.1. Development in Iceland

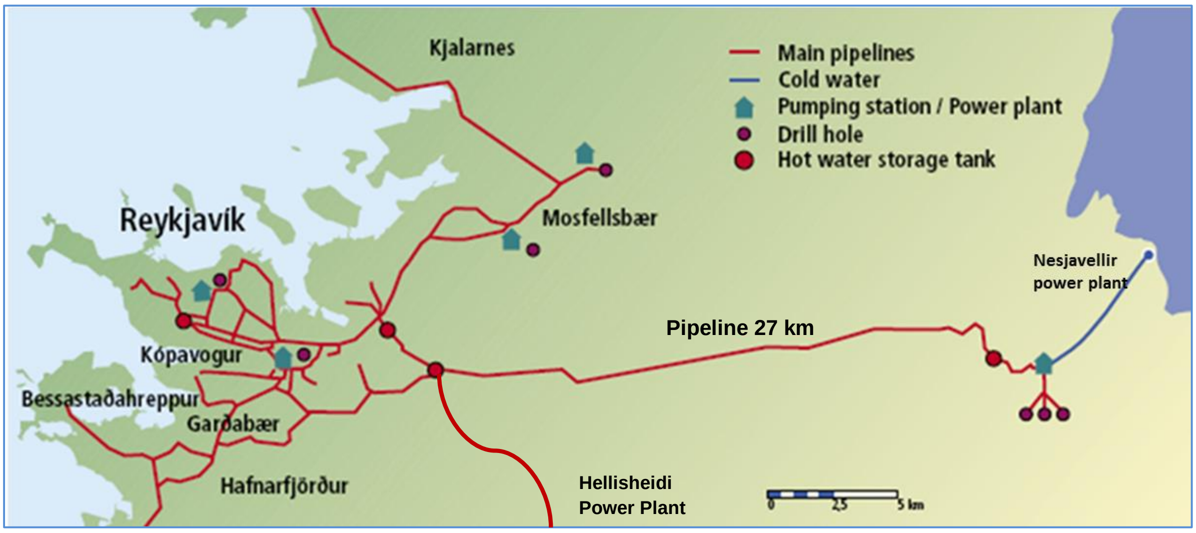
Geothermal resources have only a minor share in the worldwide generation of electricity but they have become of major importance in many volcanic regions which lack other resources for electricity generation. Leading countries in this development have been Italy, USA, New Zealand, Mexico, the Philippines, Indonesia, Iceland and Japan. In Africa, Kenya is the leading country but no development has occurred in S-America despite its large potential.

The initial build-up of capacity worldwide was slow but accelerated in the seventies due to rising prices of oil. In the last 25 years the capacity has increased on average by 250 MW per year. Compared to solar energy and wind power the development has been slow, despite considerable support from funds, public institutions and academic research. Science, technology and finance have not always succeeded in outlining to possible investors the barriers and risks involved, and how they can be mitigated.

The successful development of geothermal electricity generation in Iceland has raised interest. A country with 320 thousand inhabitants had in the year 2014 installed a capacity of 663 MW in geothermal power plants. This occurs in a country with a large potential in hydropower. Generally the risk in hydropower projects is considered less than in geothermal projects but the geothermal plants have the competitive advantage of serving a base load with full availability throughout the year. Power plants in Iceland have a total capacity of 2.637 MW, generating in total 18,12 TWh in year 2014. The share of hydropower is 71% and that of geothermal 29% in electricity generation. Oil is only used for electricity generation in emergency cases.

Iceland has an area of 103.000 km^2. Two thirds of the population live in the capital area in the SW-part. Other inhabitants are settled in a number of villages, mostly around the coast, and in rural areas. Electrification has been developed over the last century. The country has many rivers draining water from the mountainous inland and glaciers. The electrification was initially in the hands of communities which erected small hydropower plants to serve their inhabitants but the networks were not interconnected.

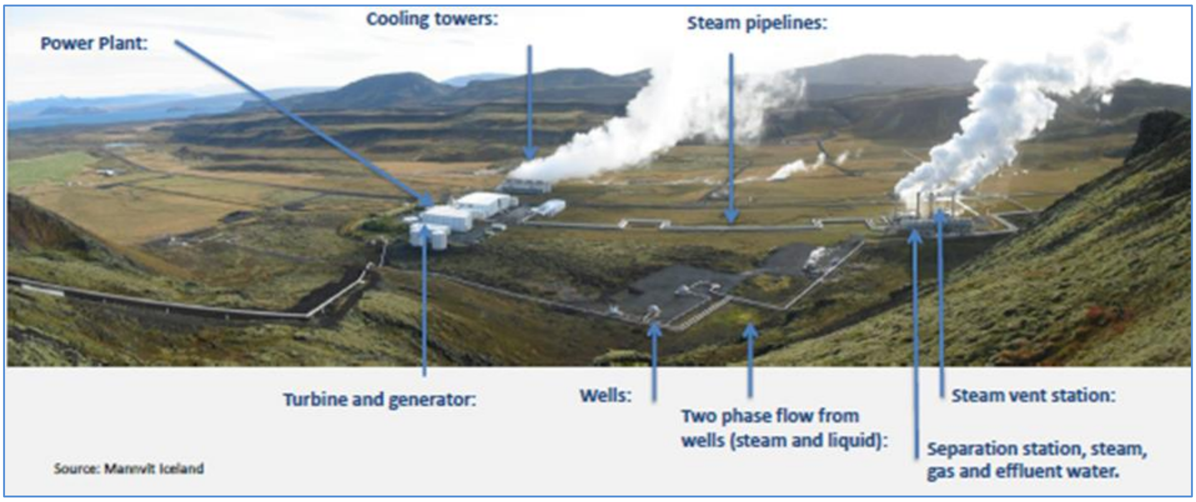
Figure. 6.1.1. **The Reykjavik District Heating System**



Geothermal district heating started on a small scale in Reykjavík in 1930 and today Reykjavík Energy operates the largest municipal district heating system. The system serves about 195.000 people in the capital area with hot water. From 1998 electricity has been co-generated from geothermal steam along with hot water at Nesjavellir. However, about 70% of the energy used for district heating comes directly from low temperature geothermal fields, and about 30% from heating up cold water in CHP plants using geothermal energy as the primary energy source.

A major change occurred in 1965 when the State and the capital Reykjavik established Landsvirkjun (the National Power Company) with the aim of building larger power plants and interconnecting the countrywide electrical networks. The company built a hydropower plant of 210 MW to provide electricity for an aluminium smelter in 1969, with financial support from the World Bank. Landsvirkjun has continued developing hydropower and geothermal power to serve energy intensive industries. The installed capacity in hydropower in Iceland is now 1.895 MW. The company also operates one 60 MW geothermal power plant.

Figure 6.1.2. **The Nesjavellir Geothermal Power Plant in Iceland,**
120 MW Electric and 300 MW Thermal for Space Heating



Other major power companies are Reykjavik Energy with 423 MW installed in two geothermal power plants and HS Orka operating two geothermal power plants of a combined 176 MW electric capacity. Three of the geothermal plants combine generation of electricity and production of hot water for space heating. Smaller companies operate hydropower plants with a total capacity of about 80 MW.

The State and municipalities own 93% of the installed capacity but only 7% are in the hands of the private sector. The electricity market is dominated by a few energy intensive industry companies which buy 77% of the production. The risk of having few customers is balanced by power purchase agreements (PPA) which ensure steady use of energy and sales over decades. This leads to high utilisation factors in the power plants, about 75% in the hydro power and 90% in the geothermal plants. Long term contracts with trustworthy companies have also eased financing of the power projects.

Figure 6.1.3. **The Hellisheiðarvirkjun Geothermal Power Plant**
303 MW Electric and 133 MW Thermal for Space Heating

6.2. Drilling for Geothermal Water and Steam

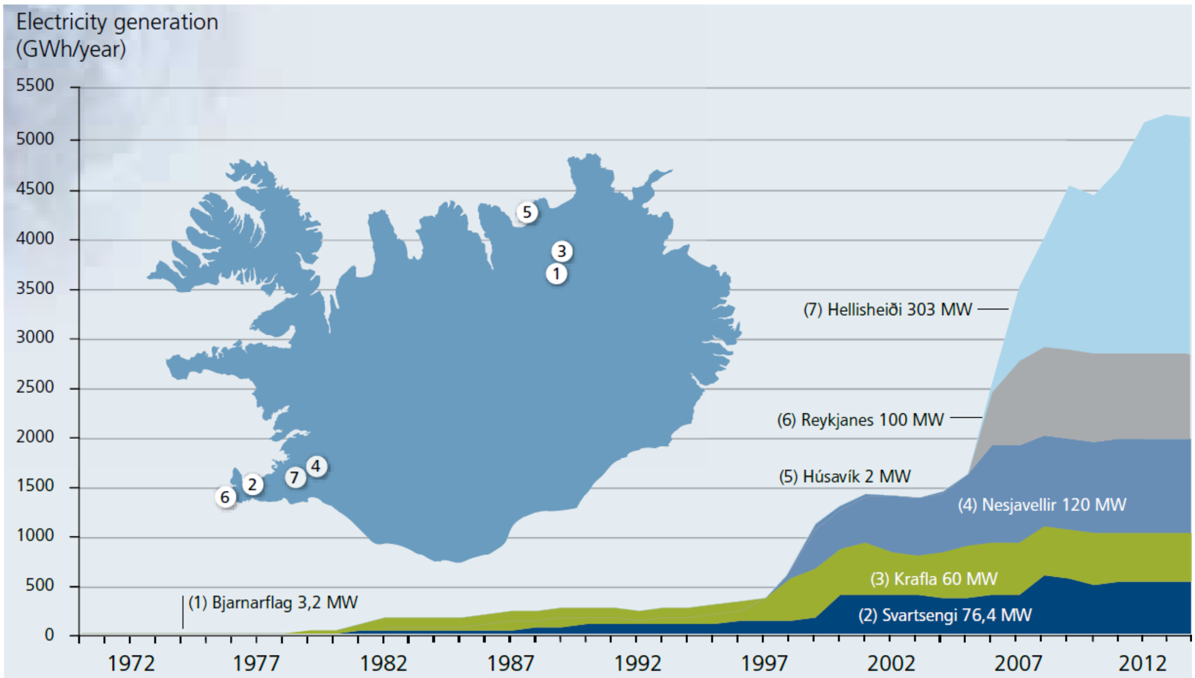
First attempts to drill wells in geothermal areas in Iceland began as early as in the year 1755 when exploration wells were drilled in search for sulphur near the Laugarnes hot springs in Reykjavík and in the high temperature field Krýsuvík on the Reykjanes Peninsula. In Krýsuvík the hole reached 10 m depth and erupted a mixture of steam and clay. Drilling with percussion rigs for potable water in Reykjavik shortly after 1900 was not successful but rumors that the boreholes had encountered traces of gold led to the purchase of a new percussion drilling rig which was nicknamed the "gold drilling rig".

The Reykjavik Electricity Service became interested in drilling as they learned of successful drilling for steam in Lardarello in Italy to generate electricity. They bought the "gold drilling rig" and used it to drill 14 wells in the hot spring area of Laugarnes in Reykjavík 1928–30. The deepest well was 246 meters. No steam was found but the wells yielded significantly greater artesian flow of hot water than the hot springs prior to drilling. This success led to the first step in geothermal heating of houses in Reykjavik in 1930.

Until 1986 nearly all drill rigs were operated by the State Drilling Company. The emphasis was on discovering hot water for space heating all over the country. The wells were located near hot springs and also in regions where exploratory surveys and drilling indicated a high geothermal gradient. Some drilling also took place in the high temperature fields. Exploratory wells were drilled in Reykjanes to provide hot brine for a sea chemicals factory.

Drilling for cogeneration of hot water and electricity took place at Svartsengi and Nesjavellir and wells were drilled in Krafla to provide steam for the generation of electricity. There the drilling ran into difficulties because volcanic activity caused an influx of corrosive gases into the geothermal reservoir. The drilling company was privatized in 1986 and now operates as Iceland Drilling Ltd but several other smaller drilling companies have also been established.

Figure 6.2.1. **Generation of Electricity using Geothermal Energy 1969–2014**



These smaller firms have overtaken most of the drilling in hot spring areas whereas Iceland Drilling Ltd has emphasized drilling boreholes in the high temperature fields. Among recent innovations in drilling technology are downhole hydraulic turbines that are driven by the circulation fluid and can rotate the drillbit much faster than the rotating string.

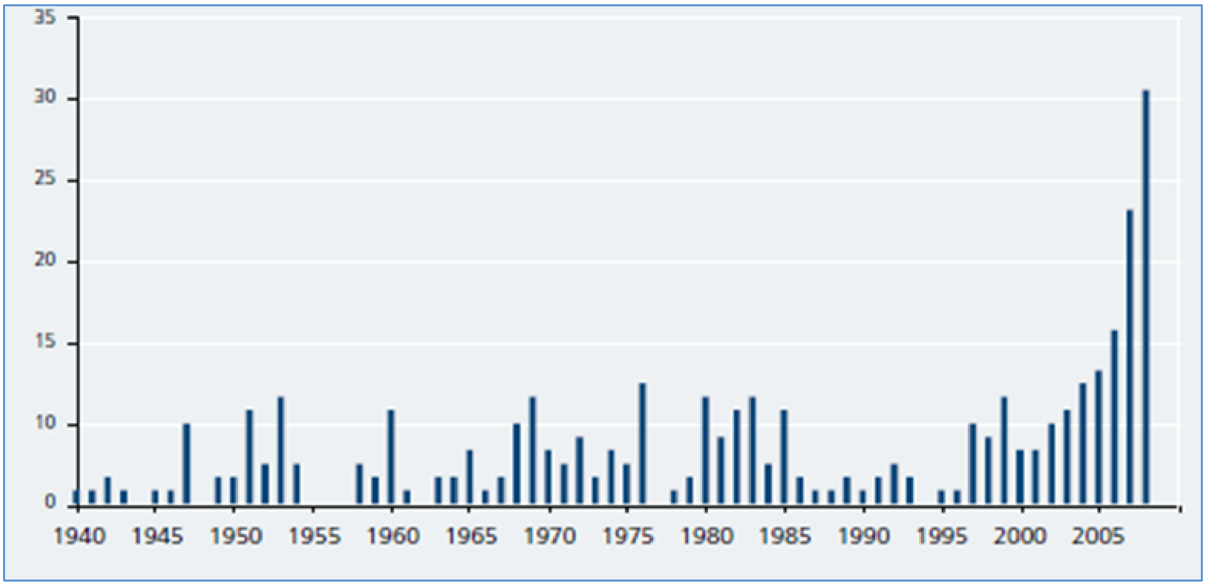
This technique yields a faster penetration rate and also allows for inclined directional drilling to intersect targets off the drilling platform. A cluster of wells can thus be drilled to different directions from the same drilling platform. Another novelty used in shallow holes is pneumatic hammers implanted with carbide balls that hammer the whole bottom several thousand times per minute and give a penetration rate of 10–30 m/hour.

The first geothermal unit was a 3 MW back pressure turbine installed in Bjarnarflag in 1969. The Krafla plant (2x30 MW) was constructed in 1975-1977 but volcanic activity injected reactive gases into the reservoir and made the best part of it unexploitable for the next 15 years. The first unit began operating in 1977 but the second unit was not installed until 1997. The project was financed by the State with the purpose of providing electricity for northern part of Iceland.

These difficulties were discouraging for further construction of geothermal power plants while there was more feasible potential available in hydro power. HS Orka installed several small units at Svartsengi for cogeneration with the production of hot water for space heating. This escalated with a 30 MW unit installed in 1999 and another in 2007, bringing the total capacity up to 76,4 MW. Reykjavik Energy also began cogeneration with hot water production at Nesjavellir with 2x30 MW units installed in 1998, and two more 30 MW units in 2001 and 2005.

Until 2003 only Landsvirkjun could sell electricity to the energy intensive industry but this changed with the new Electricity Act in 2003 which opened the door for competition between Icelandic energy companies serving that industry. Increased demand from the aluminum industry led HS Orka to build a 100 MW geothermal plant at Reykjanes in 2006 and Reykjavik Energy to build the Hellisheidi plant of 303 MW in the years 2006 to 2011. Without this increased demand from the aluminum industry the development of geothermal power plants in Iceland would have been much slower as the domestic market did not call for more than a minor increase in generation. Nowhere else do aluminum smelters rely as much on geothermal plants for electricity as in Iceland.

Figure 6.2.2**. Number of Wells Drilled in High Temperature Fields 1970–2008**



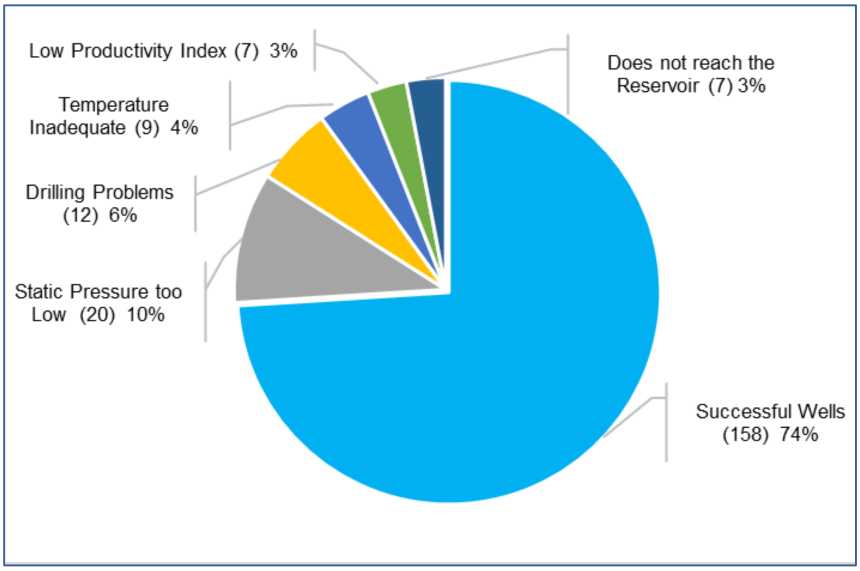
More than 300 wells have been drilled in steam fields for production. Of those 208 are deeper than 500 m, 36 reach more than 2.000 m and six beyond 3.000 m. In hot water fields about 860 production wells have been drilled. Thereof 291 are deeper than 500 m, 19 reach more than 2.000 m and one beyond 3.000 m. Wells drilled in search of high temperature gradients are more than 2.600. Most of them are shallower than 100 m but some exceed 1.000 m in depth. These wells are rarely intended for production. Steam field drilling for generation of electricity has dominated in the last decade as can be seen in Figure 6.2.2. In 2008 31 wells were drilled in six steam fields with a combined depth of 67 km.

6.3. Success of High Temperature Geothermal Wells in Iceland

Recent report from ISOR (Sveinbjornsson, 2014), presents data on success rates in drilling 213 geothermal production wells and 21 injection wells drilled in seven high temperature fields in Iceland. The data was classified using the same criteria as in the International Finance Corporation (IFC) 2013 Report on the success of geothermal wells from 14 countries. A production well was deemed successful when it had sufficient capacity to be connected and utilized in the respective power plant. Injection wells that have shown a good injectivity or have been used for reinjection were deemed to be successful.

The main conclusions of the report were as follows: Of the 213 production wells analyzed, 158 or 74% were deemed to be successful. None of the fields has a success rate below 50%. About 6% of the total wells failed because of drilling problems, 4% found inadequate temperatures, 10% could not be operated at high enough static pressure, 3% had too low permeability and 3% were so shallow that they did not reach the reservoir.

Figure 6.3.1. **Success Rate and Problems of Production Wells in Iceland**



The average success rate improves from 43% for the first well to 60% for the first five wells and reaches a plateau of 74% after the fifteenth well. The first five wells drilled in a field are classified as Exploration Phase, the next 25 as Development Phase and wells drilled thereafter as Operation Phase. The Exploration Phase has the most variable well success rates, which has though improved in recent decades. The probability of successful wells in the Development Phase is nearly 80%. It increases until the year 2000 but declines after that. The same trend is observed for wells drilled during the Operation Phase. The reduction in the success rate may reflect step-out wells or rapid development where adequate results did not arrive in time to impact the drilling plan.

The average capacity of all 213 drilled production wells is 4,9 MWe but 6,7 MWe for the 158 productive wells. The capacity has a lognormal distribution with a mean and most likely value of 4,8 MWe and a standard deviation of 2,3 MWe. The cumulative average capacity increases from 2,5 to 4,8 MWe during the Development Phase, and reaches 4,9 MWe during the Operation Phase.

The five main operating geothermal power plants in Iceland have a ratio of installed capacity divided by number of drilled production wells ranging from 1,3 to 5,3 MWe/well and a weighted average of 3,5 MWe/well. Wells of 2.000–2.500 m drilled depth have the highest average capacity of 5,8 MWe followed by wells of 1.500-2.000 m with an average capacity of 5,5 MWe. Wells with a regular production casing diameter of 200–250 mm have an average capacity of 5,5 MWe whereas wells with a large casing diameter of 300–350 mm have a capacity of 8,9 MWe.

The average capacity of directionally drilled wells is 6,1 MWe compared to 4,0 MWe in vertical wells. There is a clear increase in capacity with increased enthalpy. Wells drilled into steam caps above two-phase reservoirs at 230–240°C have the highest capacity of 11,0 MWe and a 100% success rate. Wells in two phase reservoirs with T>300°C, are with an average of 6,2 MWe and 86% success rate.

7. Legal and Institutional Framework in Iceland

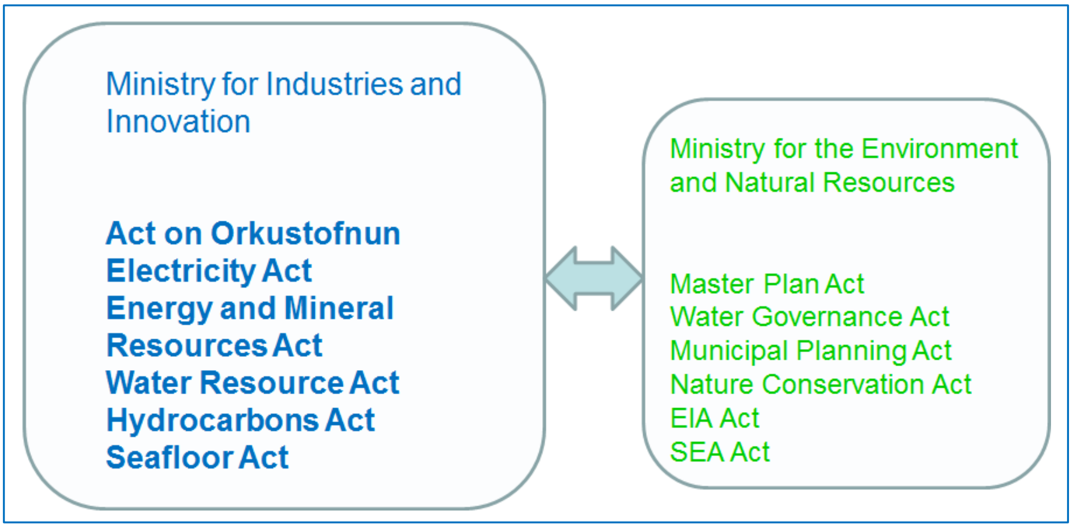
7.1. Introduction

A recent paper presents the current legal framework and national policy for geothermal development in Iceland (Ketilsson, 2015) where a broad overview is given.

The development of geothermal energy in Iceland has been on-going for many decades. Considerable experience and technical skills have been accumulated but the legal framework is fairly recent. Despite the lack of appropriate legislation, access to natural resources has led to an exceptionally high proportion of renewable energy in the country's total energy utilisation. Adaptation to the growing geothermal industry, as well as implementation of directives and regulations from the EU have called upon new laws and reorganisation of authorities and institutes. As this history and the resulting legal and institutional framework can be a useful reference for other countries which are considering geothermal development a short description is presented here.

The *Act on Survey and Utilisation of Natural Resources* (*the Natural Resources Act*) entered into force in 1998, replacing *the Mining Act* from 1973. The main reason for the new act was to declare the ownership of the country´s natural resources after many years of debate in the Parliament on how the matter should be handled.

Figure 7.1.1. **Public Administration in Iceland, related to Geothermal Development**



The *Electricity Act* entered into force in 2003, thereby implementing European legislation, according to the Agreement on the European Economic Area (EEA) which has since entering into force in 1994 provided for an active Europeanization for Icelandic society. The new act replaced the *Energy Act* from 1967 and was grounded on new perspective in the electricity sector. It's main objective was to liberalize the market for generation of electricity and retail while having the transmission and distribution regulated as natural monopoly.

Many other acts affect the sector of geothermal energy exploration and utilisation. Mainly the *Environmental Impact Assessment Act* and the *Act on Master Plan for the Protection and Utilisation of Natural Resources*. Other acts relating to the sector are, among others, the *Nature Conservation Act* and the *Planning Act*.

7.2. The Act on Survey and Utilisation of Natural Resources

The ownership of resources in the ground is attached to a private land, while on public land resources in the ground are the property of the State of Iceland, unless others can prove their right of ownership. Even though the ownership of resources is based on the ownership of land, Orkustofnun can grant licenses anywhere for the research and utilisation of the resources according to the *Act on Survey and Utilisation of Natural Resources*, No. 57/1998 and the *Electricity Act*, No. 65/2003. Survey, utilisation and other development pursuant to these Acts are also subject to the *Nature Conservation Act*, *Planning and Building Act*, *Environmental Impact Assessment Act* and other acts relating to the survey and utilisation of land and land benefits.

The *Natural Resources Act* covers resources in the ground, at the bottom of rivers and lakes and at the bottom of the sea within netting limits. The Act also covers surveys of hydropower for the generation of electricity. The term resource applies to any element, whether in solid, liquid or gaseous form, regardless of the temperature at which they may be found.

The State, municipalities and companies, entirely owned by them, are prohibited to sell directly or indirectly the ownership of geothermal and ground water more than for household or agricultural use. A landowner may exploit geothermal energy, without permission, on his or her private land for household and agricultural use, including for greenhouse cultivation, industry and cottage industry, up to 3,5 MW of thermal energy based on the heat extracted from the ground within private land.

Figure 7.2.1**. Ownership, Resource Control, Operation and the Grid**

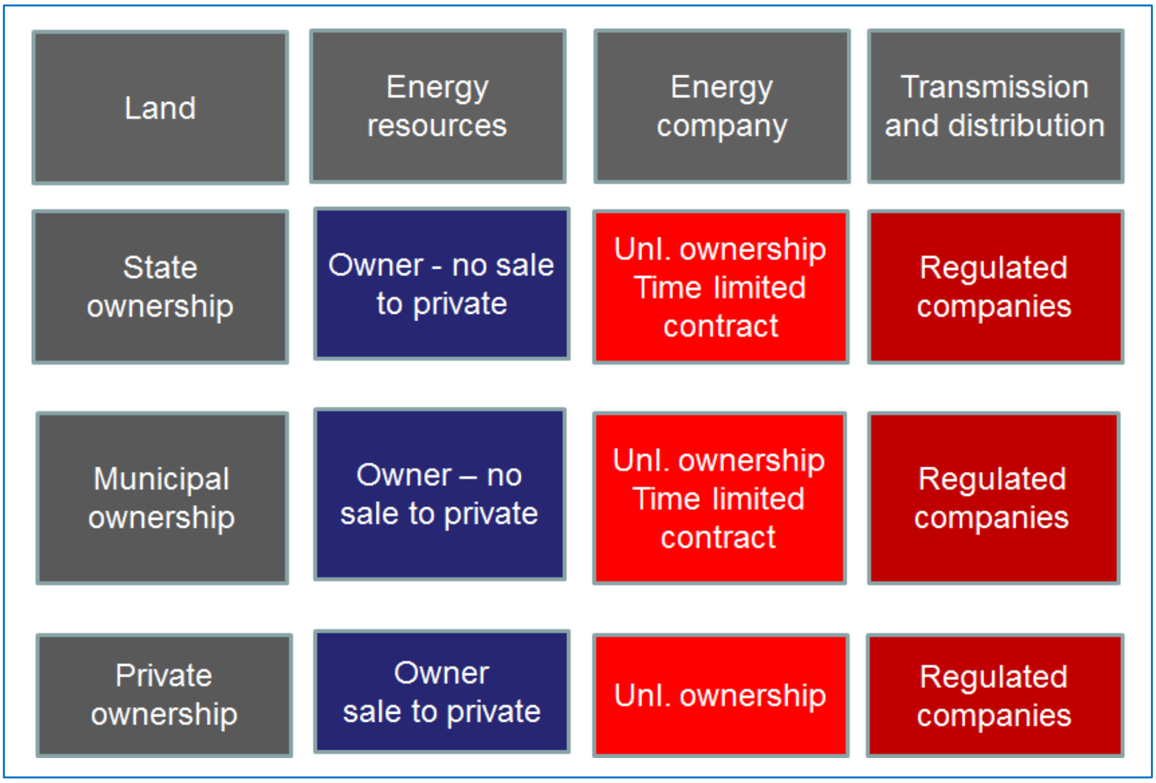
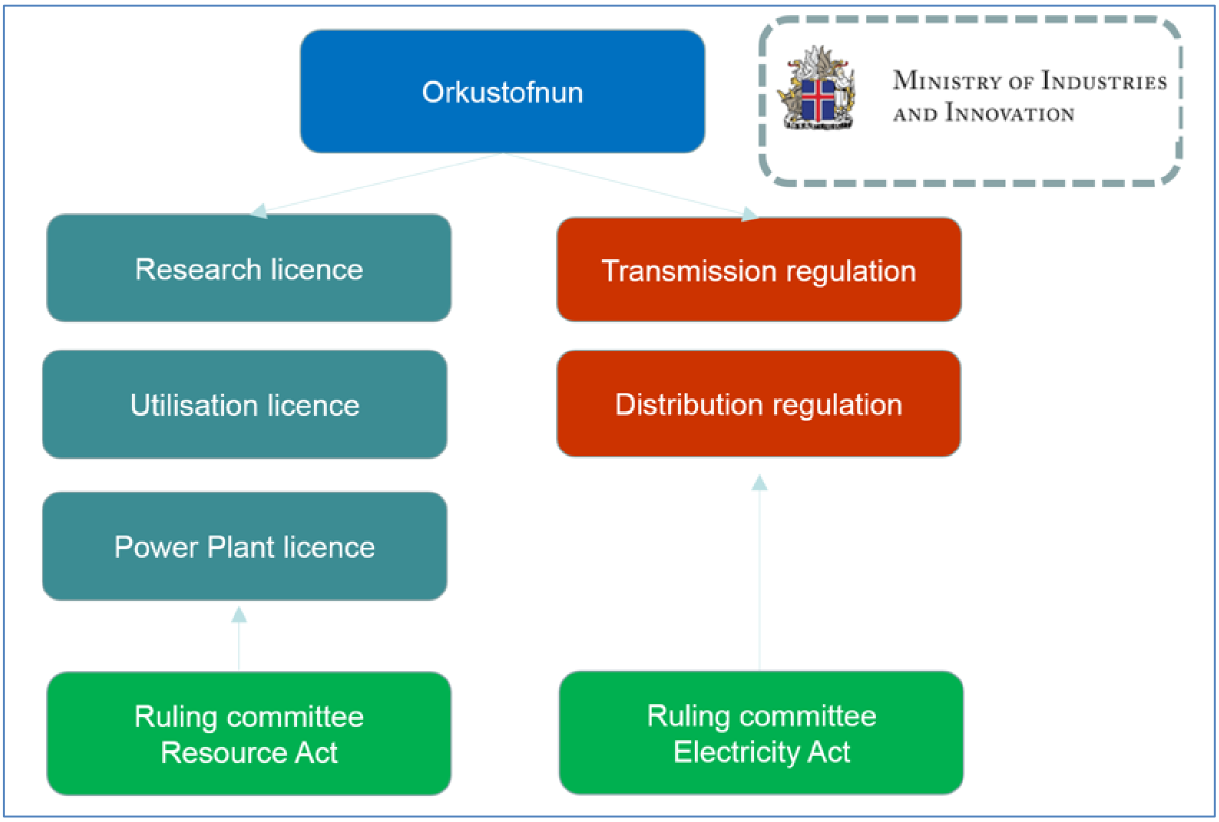


Figure 7.2.2. **Role of Orkustofnun as a Licensing Authority and the two Ruling Committees that can be appealed to.**



Research License

According to the *Natural Resources Act* Orkustofnun is permitted to take the initiative in and/or give instructions on surveying and prospecting for resources in the ground anywhere in the country, regardless of whether the owner of the land has himself or herself begun such surveying or prospecting or permitted other such surveying or prospecting, unless the party in question holds a valid research license pursuant to the Act. A research license confers the right to search for the resource in question within a specific area during the term of the license, survey the extent, quantity and potential yield and to observe in other respects the terms which are laid down in the Act and which Orkustofnun considers necessary.

Therefore Orkustofnun can issue a research license even if the land owner has not agreed to it himself unless he has a valid research license. If the land owner, on the other hand, decides to prospect himself he does not need a license but is only required to inform Orkustofnun of the research scheduled. Before granting a license Orkustofnun must confer with the landowner, the Environment Agency of Iceland, The Icelandic Institute of Natural History and in some cases the Institute of Freshwater Fisheries. Only one person or legal entity can be granted a license in one area during the term of the license. More than one person or legal entity can be granted such a license if they have applied for the license jointly and have agreed upon dividing the prospecting cost.

Orkustofnun can grant a pre-emptive right to a utilisation license if the foreseen exploitation is for space heating. The pre-emptive right can last for up to 2 years after the research license expires which also prevents others to be granted research license in the respective area. In order to be granted a research license, the applicant must file the exploration scheme which he will then need to comply with, shall he be granted a license. In the case of non-compliance the license holder must ask Orkustofnun for an alteration in the scheme or Orkustofnun can cancel the license.

Utilisation License

The utilisation of resources in the ground is subject to a license from Orkustofnun, whether it involves utilisation on private land or public land, with the exceptions provided for in the *Natural Resources Act*. A landowner does not have the priority to an utilisation license for resources on his or her land, unless such an owner has previously been issued a research license. The utilisation license permits the license holder to extract and use the resource in question during the term of the license to the extent and on the terms laid down in the Act and regarded necessary by Orkustofnun.

Before the holder of an utilisation license begins extraction on private land the holder needs to reach an agreement with the landowner on compensation for the resource or obtain permission for expropriation and request assessment. In the event of neither an agreement made on compensation nor expropriation requested within 60 days immediately following the date of issue of an utilisation license, the license shall be cancelled. The same applies if utilisation on the basis of the license has not started within three years of the issuance of the license. This also applies to the utilisation of resources on public land. With these limitations, a license holder cannot reserve areas, and in the same manner withhold the exclusive rights to exploit the areas in question. Orkustofnun has therefore the power to cancel the license shall there be a non-compliance with the exploitation scheme presented in the application for the license.

If a landowner has himself explored the resources on his or her land or allowed it to others, but an utilisation license has not been granted, the land owner or the one who did the research, can demand that the utilisation license holder reimburses him the cost for the research useable to him or her.

Orkustofnun may revoke the above license if their conditions are not fulfilled. If a license holder does not comply with the conditions established in the license or contracts relating to the license, Orkustofnun shall issue a written warning and provide time limits for rectification. Should the license holder not comply with such a warning, the license shall be revoked.

Recent Amendments to the Law

In 2008 the Parliament decided to prevent any further sale of water resources, including geothermal energy, to private entities. As of that same year, all natural resources that were not privately owned were guaranteed to remain in the possession of the State. As described previously the State can grant licenses for utilisation, for up to 65 years, according to the *Act on Survey and Utilisation of Natural Resources*. As of that same year the Parliament also decided to implement into the Act, a clause stating that the Minister of Energy could delegate the power to grant licenses to Orkustofnun. Prior to that time, the Minister himself granted such licenses.

The decisions made by Orkustofnun, deriving from the newly granted power, could be appealed to the Ministry for revision. In that way, the civilians had the possibility to have a decision revised in the administrative sector and without having to turn to the courts. Another amendment that same year dictates that CHP power plants are obliged to keep separate accounts for heat and power production to prevent cross subsidisation of electricity. Producers of electricity compete in an open market in Iceland whereas the heat is sold based on a natural monopoly license within a certain area, therefore it is necessary to keep financial records separate. In 2012, the Parliament decided to move that same license granting power to Orkustofnun by amending the law, making Orkustofnun fully independent in its decision making. Such decisions can today be appealed to the Appeals Committee for Environmental and Resource Matters.

7.3. The Environmental Impact Assessment Act

The Environmental Impact Assessment (EIA) Act has been set to implement the EU-EIA directive (now Directive 2011/92/EU). In the act, projects listed in Annex I are classified into three categories, A, B and C, according to the size, location and/or nature of the project. Category A projects are always subject to an EIA whereas projects in categories B and C are subject to a decision by the National Planning Agency whether they should be assessed.

In short, the procedure is as follows: The applicant notifies the Planning Agency of a project which may be subject to assessment. The Planning Agency has 4 weeks to decide upon its answer. If the project is subject to such an assessment, the applicant submits a scoping document proposal as early as possible in the preparatory stage of the project. Again the Planning Agency has 4 weeks to decide whether the proposal is approved or not. If the proposal is approved the applicant shall compile a report on environmental impact assessment of the proposed project.

The Planning Agency then has only 2 weeks to assess whether the report meets the criteria provided for in the act and is consistent with the scoping document. If it does meet the criteria it shall be publicised and subjected to written comments from anyone. The applicant shall then respond to the written comments, possibly by altering the document in accordance. Within 4 weeks of receiving the environmental impact statement, the National Planning Agency shall deliver a reasoned opinion on whether the report meets the criteria of the Act and regulations and whether the environmental impact is satisfactorily described.

Decisions on individual steps of the environmental impact assessment procedure, i.e. on whether a project is subject to an assessment, decisions of the NPA on suitability of scoping document and EIA report, can be appealed to the Appeals Committee on Environmental and Resource Matters. The reasoned opinion of the NPA is however not prone to an appeal.

7.4. Act on Master Plan for the Protection and Utilisation of Energy Resources

Earlier energy developments in Iceland were focused on meeting the basic energy needs of the society for space heating and electricity for the general market. Through the years it has become more and more evident that utilisation of energy resources (as other development) must take into account not only the energy needs and the economic aspects of the development, but also a range of other interests as well. This includes other use of land and the impact of the development on the environment and the cultural heritage. The first step towards such an evaluation was undertaken by a collaboration committee of specialists from the Ministry of Industry, the National Power Company, Orkustofnun and the Nature Conservation Council. This committee was active during the 1970’s to the 1990’s. It discussed plans for various electrical power plants with special emphasis on the natural conservation aspects of the projects.

A general view on the energy policy and the nature conservation policy was needed for the country. This became even more important by 1994 when the Parliament of Iceland passed the first *Act on Environmental Impact Assessment*. The Icelandic Government published a white paper on sustainability in the Icelandic society in 1997. There the need of the development of a long term Master Plan for energy use in Iceland was once again stressed. All proposed projects should be evaluated and categorized on the basis of energy efficiency and economics, as well as, on the basis of the impact that the power developments would have on the environment.

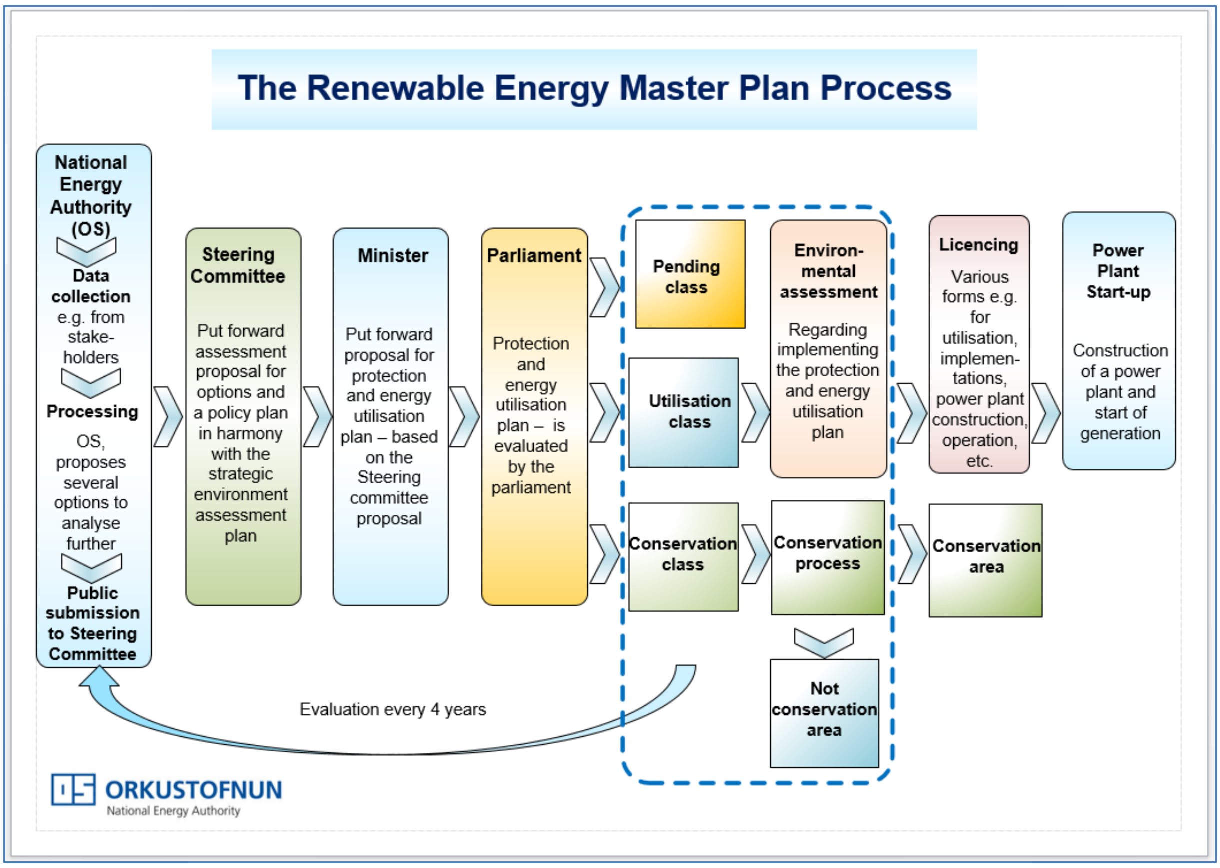
A Master Plan of this kind is comparable to the planning of land use and land protection. It is not supposed to go into the details required for environmental impact assessment (EIA). The vision is to prepare an overview of the various potential energy projects in hydro and geothermal and to evaluate and rank these based on their energy and economic potential, feasibility, national economy and the estimated impact that each project would have on nature, environment, cultural heritage and the society, as well as the potential for other uses of the areas in question.

The Master Plan should be based on the best available scientific information and conclusions should be transparent and reproducible and made available to the public. It was considered of vital importance to establish public confidence in the evaluation process. The Master Plan aims to identify power projects that rank high from an economical point of view, have a minimum negative impact on the environment, and a positive impact on the society. Such a score card for the energy projects helps decision makers to filter out which of the proposed projects are likely to become controversial and disputed and which ones not. It also directs the attention to those project areas that might have protective value and should be left untouched by the power industry.

Master Plan

The Government decided to use the work on the Master Plan to establish a permanent planning tool, with regular re-evaluation phases followed by subsequent confirmation of the Master Plan by Parliament. For that purpose, a new *Act on a Master Plan for Protection and Development of Energy Resources* was passed in Parliament in May 2011. According to the act the Minister for the Environment, shall in co-operation with the Minister of Industry, at least every four years, propose a Master Plan to the Parliament. The plan shall divide the different projects in three categories, projects for utilisation, projects awaiting further research or projects in areas appropriate for protection. A total number of 84 potential power projects was evaluated during the second phase in 2011 and a Master Plan ranking 28 hydropower projects and 38 geothermal projects was approved by the Parliament in 2012.

Figure 7.4.1. **Flow Diagram Illustrating the Processes around the Master Plan**

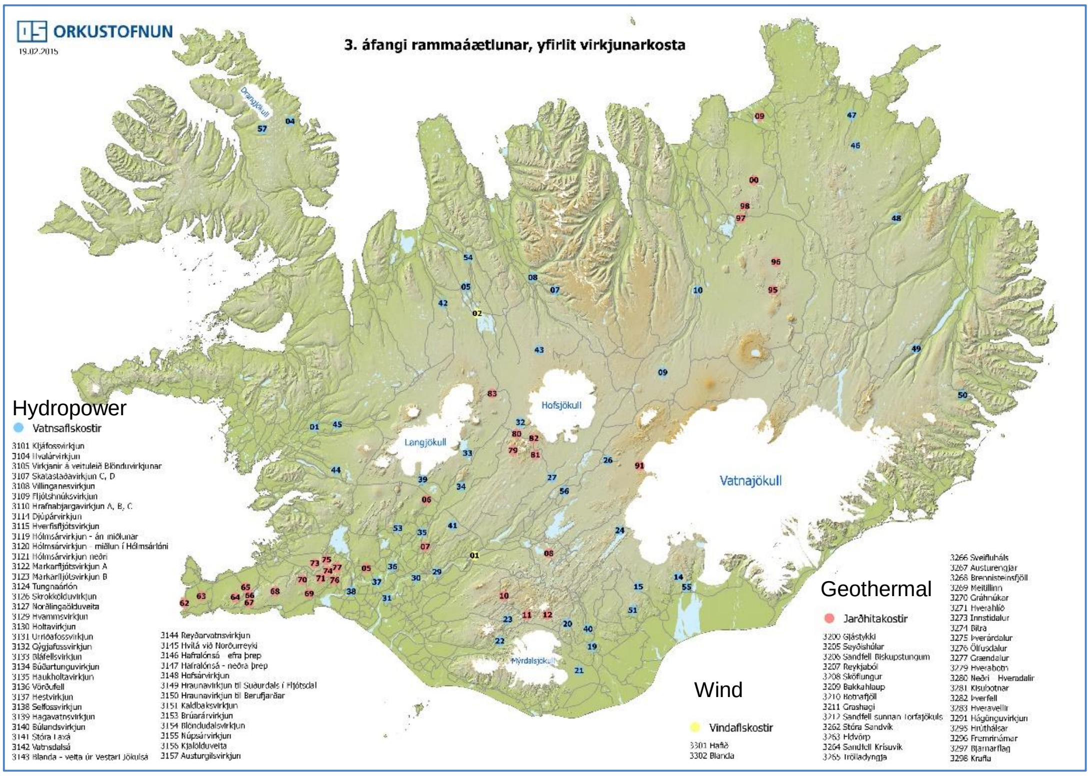


The Master Plan only covers projects that have the potential of at least 10 MW electric or at least a thermal potential of 50 MW. The plan is binding for all municipalities and is to be included in their general land use plans. Administrative bodies can grant licenses relating to projects that are categorized for utilization and all research that does not require licenses can be carried out. Administrative bodies cannot grant licenses for projects that await further research if the intended work requires assessment of environmental impact. Research that does not require licenses can be carried out in these areas with the same restriction. Administrative bodies cannot grant any licenses for projects that are in areas categorized for protection except for a limited research license for prospecting on surface without affecting the environment.

The flow diagram in Figure 7.4.1 illustrates the processes from an idea to realization of a power plant or a decision on conservation of an area. In the first step, Orkustofnun sets forth ideas for an advisory Steering Committee. Private or state owned companies can suggest the projects to Orkustofnun and Orkustofnun can also suggest projects on its own. At this point only, the basic ideas on location, power and larger structures related to each project is defined. Master Plan details such as the feasibility of the geothermal systems or environmental assessments are not necessary for the process at this point. The steering committee is advisory to the minister and it makes suggestions regarding which resources in a designated area, should be utilized, protected or further studied. The Committee reports to the minister of Environment, who may pass the suggestions on to the parliament with or without some changes. The final decision on each project is made by the parliament and is valid until a new parliamentary decision has been made.

All of the projects can be reevaluated at least every four years until the municipalities have adjusted their regional plans, the projects have been realized or the area where the project is located has been protected against projects of this kind The municipalities could also take the initiative to designate a certain area for protection and another area for reevaluation. This process of reevaluation is necessary because increased understanding on the effects of these projects can result in different decisions regarding utilization or conservation.

Figure 7.4.2 Renewable Energy Master Plan Projects Options for Utilisation



The proposal of the Steering Committee must be justified by solid arguments for the decision regarding each project. Before presenting the proposal to the Minister of Environment the Steering Committee of the Master Plan must both ask for written comments and publicize the draft proposal. If the Minister of Environment decides to make changes to the Steering Committee, the new proposal shall be publicized and written comments shall be asked for again. After the confirmation of the Parliament, the Master Plan is valid and binding for all parties for up to four years, unless the Parliament changes its resolution. The municipalities are required to adjust their regional plans accordingly within 15 years from the decision of the Parliament.

Figure 7.4.2 illustrates the options set forth by Orkustofnun in 2015 for the Steering Committee of the third evaluation process; it involves 48 hydro power plants (blue dots), 33 geothermal power plants (red dots) and two windfarms (yellow dots). In some cases, there are more than one scenarios for each of the hydro power plants but those variations account for only one dot on the map. The Steering Committee has publicized a draft report for comments and a final report is planned to be finished in the autumn of 2016.

8. Competitiveness, Internationalisation and Clusters of the Icelandic Geothermal Sector

8.1. Iceland, WB and NDF - International Geothermal Cooperation in Africa

The Icelandic International Development Agency (ICEIDA) and the Nordic Development Fund (NDF) launched in 2012 a project to support geothermal exploration in East Africa. ICEIDA is the Lead Agency in the Geothermal Exploration Project with joint co-financing of NDF. The project is the initial phase of the Geothermal Compact partnership, initiated jointly by the Ministry for Foreign Affairs in Iceland and the World Bank. The World Bank's Energy Sector Management Assistance Program (ESMAP) serves as the focal point at the Bank for the Compact.

13 countries in East Africa Rift Valley
The geothermal potential in Africa is mainly in the East Africa Rift Valley States (EARS) covering 13 countries from Eritrea in the north to Mozambique in the south. The project aims to mitigate and distribute the risk associated with geothermal exploration thus contributing to the acceleration of geothermal development in the region.

The main objective of the Geothermal Exploration Project is to assist all EARS countries in completing the exploratory phase of geothermal development and build capacity and expertise in the field of geothermal utilization and related policy. The project support will extend up to the stages of exploratory drilling.

The project will be demand-driven and activities funded by the project will be based on specific requests from governments in the countries of the region. Project funding can cover the following activities:

1. Reconnaissance and geothermal exploration leading up to exploratory drilling.
2. Technical assistance and capacity building:
    a. Training, e.g. through the UNU Geothermal Training Programme.
    b. Institutional capacity building.
    c. Policy and legal framework for geothermal utilization.

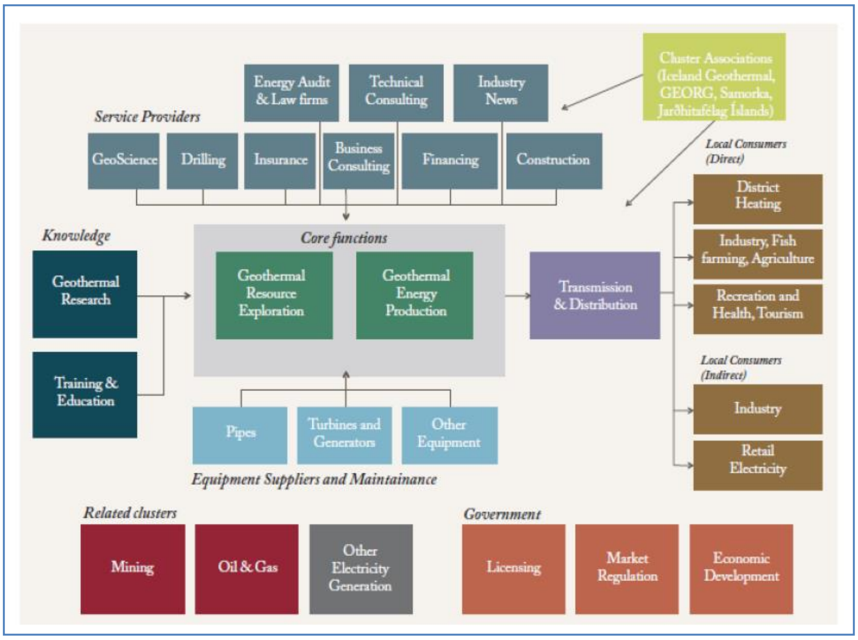
Five years
The financial framework for the project is estimated at USD 13 million over a period of five years. The project could extend to 13 countries in the East Africa Rift Valley: Burundi, Comoros, Djibouti, DR Congo, Eritrea, Ethiopia, Kenya, Malawi, Mozambique, Rwanda, Tanzania, Uganda and Zambia.

At the end of the project it is expected that participating countries have 1) a realistic assessment of potential geothermal sites, 2) plans for further action where applicable, and 3) capacity to move forward on the basis of those plans and submit exploration drilling projects into funding pipelines. The Geothermal Exploration Project formally started in January 2013.

8.2. Clusters and Competitiveness of the Icelandic Geothermal Sector

In 2010, Dr. Michael Porter and Dr. Christian Ketels performed an analysis of the Icelandic geothermal cluster in cooperation with Gekon, an Icelandic consulting firm. Nearly 60 different stakeholders within the cluster were involved in the project. According to the results Iceland is naturally uniquely situated in terms of access to a quality resource.

Figure 8.2.1. **The Icelandic Geothermal Cluster**



The term cluster is defined as a geographical group of companies and associated institutions in a particular field, linked by commonalities and complementarities. In a cluster there is a system of interconnected firms and institutions whose value as a whole is greater than the sum of its part. The cluster policy has been part of the structure of the Icelandic economy for two decades. So far, such work has mainly been formed by local conditions and initiated by the government. In recent years this development has grown towards more private governance of clusters, and now several clusters in Iceland are governed by private partners, e.g. the Geothermal Cluster, Ocean Cluster, the Tourism Cluster and the Health Cluster. (Institute, 2014) [43]

Table 8.2.1. **Some of the Icelandic Geothermal Cluster Expertise**

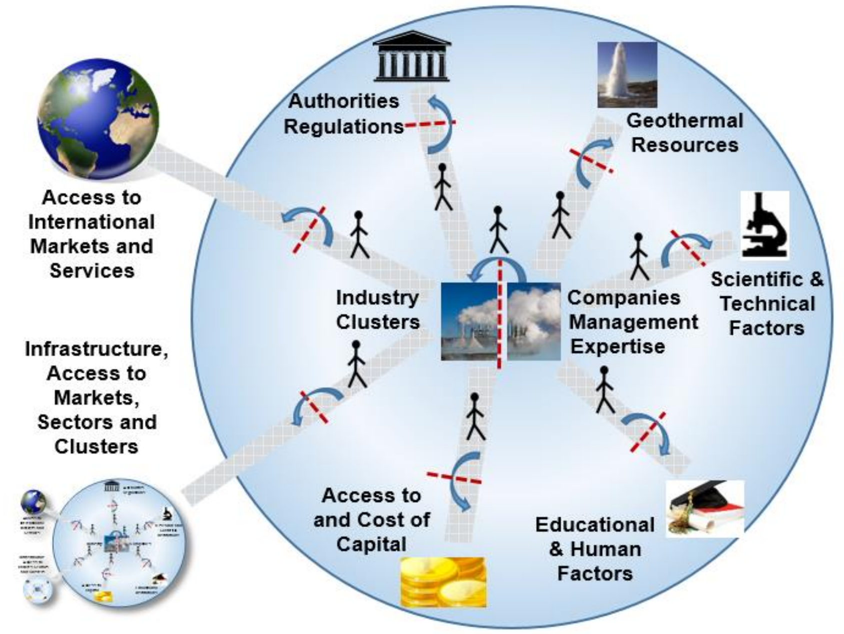
GeoScience	ISOR, Mannvit, Vatnaskil
Technical Consulting	Mannvit, Verkís, Efla, Reykjavík Geothermal, Landsvirkjun Power, Reykjavík Energy Invest
Business Consulting	KPMG, Capacent Corporate Finance, Íslandsbanki
Drilling	Jarðboranir, Ræktunarsamband Flóa og Skeiða
Construction	ISTAK, ÍAV and Loftorka
Energy Audit & Law Firms	KPMG, Pricewaterhouse Coopers, Deloitte, Lex (law firm), Logos (law firm)
Financing	Arionbanki, Íslandsbanki, Landsbankinn
Geothermal Research	ISOR, Mannvit, Vatnaskil, Utilities, Universities
Research Funding	Orkusjóður, Geothermal Research Group, Landsvirkjun´s Energy Fund, OrkuveitaReykjavíkur Energy Fund, Rannís
Training and Education	University of Akureyri , University of Iceland, Reykjavík University, Reykjavík Energy Graduate School of Sustainable Systems, Keilir – Atlantic Center of Excellence, United Nations University – Geothermal Training Programme

The high percentage of geothermal energy as proportion of Iceland's total primary energy consumption is unique in the world. Most of the development of geothermal utilization in Iceland has occurred for the last one hundred years or so, especially in the latter half of the 20th century. Iceland is a strong player in the global geothermal market, enjoying the benefits of a powerful geothermal cluster. The cluster's strength consists of a developed system for using geothermal energy in multiple ways, experienced specialists, and a strong international reputation and network. The cluster's weaknesses include poor access to capital, a lack of critical mass of companies, a complex domestic market environment, and fragmented educational activities. (Gunnarsson Hákon, 2011).

[43] Geothermal Cluster - http://www.gekon.is/,
Ocean Cluster - http://sjavarklasinn.is/en/,
Regional Clusters - *http://www.byggdastofnun.is/is/verkefni/vaxtarsamningar*

A cluster can contribute to national competitiveness efforts that include policy reform, trade capacity building, a private-public dialogue, regional economic development, workforce development, technology and trade development, drive export etc. Competitive Clusters may well be one of the most effective tools in a broader context of policy reform and other private sector development initiatives.

Figure 8.2.2. **The Competitiveness of Icelandic Geothermal Cluster**



Source: Sölvell & Lindquist 2012, Amended, B. Petursson, National Energy Authority, 2014

The importance of clusters has grown rapidly in recent years to increase competitiveness, growth and productivity, as a reaction to increased competition in all areas and sectors, more globalisation, and rapid changes in technology, services and trade. The cluster competitiveness model can be used in many different ways to increase competitiveness and growth of companies.

One possibility is to use the enclosed model to analyse the seven main framework conditions in the geothermal sector;

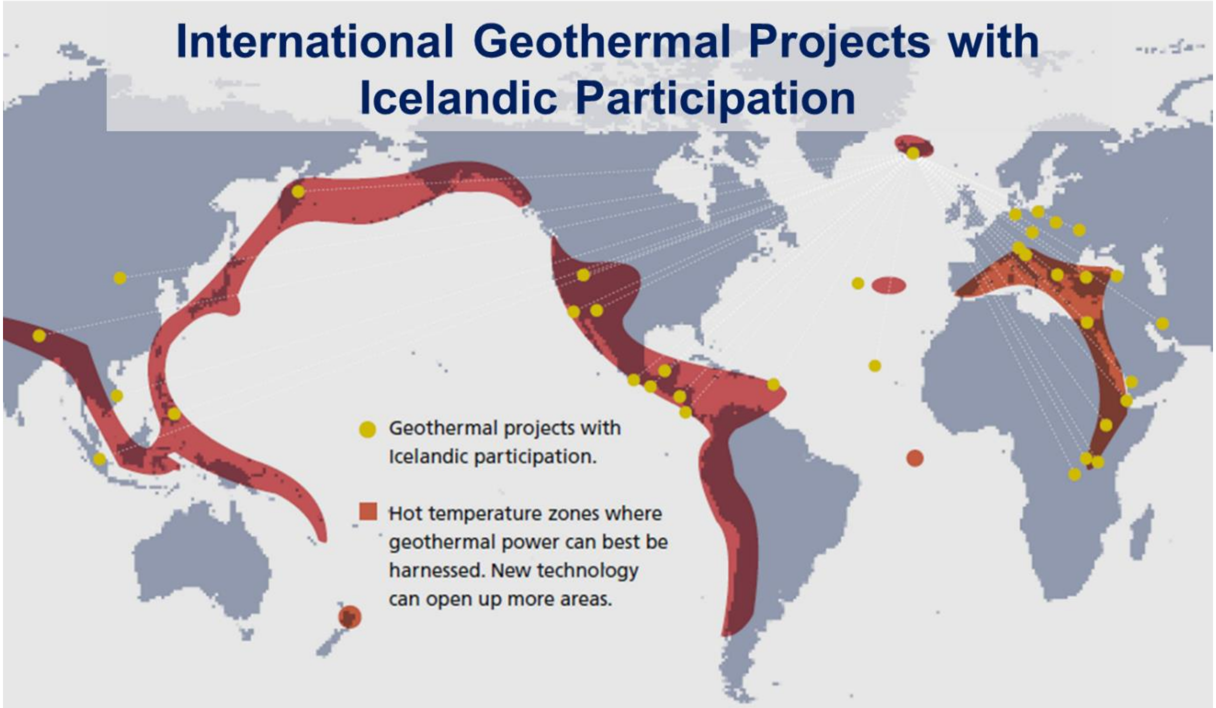
1. Authorities and regulation.
2. Access to geothermal resources.
3. Scientific & technical factors.
4. Companies, management, expertise & industry, clusters assessment.
5. Education & human factors.
6. Access to capital.
7. Infrastructure and access to markets, sectors and other clusters.
8. Access to international markets and services.

By evaluation of these seven factors of the geothermal competitiveness in the concerning country, it is possible to highlight the key weaknesses and strengths of the frameworks conditions as a base for the formulation of a better competitiveness policy for the geothermal sector; to increase competitiveness, growth, jobs, productivity and quality of life.

8.3. International Cooperation of the Icelandic Geothermal Sector

8.3.1. International Work and Projects of the Business Sector

As global warming poses a threat to the world, it is now mostly acknowledged that an increased use of renewable energy could play a key role in reducing this development. Geothermal energy can play a significant role in the electricity production of countries and regions rich in high-temperature fields which are associated with volcanic activity.



Capacity building and transfer of technology are key issues in the sustainable development of geothermal resources. Icelandic emphasis in bi-lateral development assistance has therefore focused on geothermal energy and cooperation with countries that have unexploited geothermal resources. The objective is to assist them in developing their renewable energy resources. In addition, several Icelandic companies make it their business to export geothermal and hydropower know-how and experience. Icelandic experts participate in geothermal projects worldwide, and have contributed to the world's best known geothermal projects. Geothermal experts from Iceland are now at work in the United States, China, Indonesia, the Philippines, Germany, Hungary, Djibouti, Eritrea, Nicaragua, and El Salvador to name but a few examples.[44]

[44] **Examples of Engineering and Consulting Companies:**

- Icelandic Geosurvey – www.isor.is
- Mannvit – www.mannvit.is
- Verkís – www.verkis.is
- Efla – www.efla.is
- Reykjavik Geothermal, www.rg.is/

Energy and Contracting Companies:

- Iceland Drilling – www.iceland-drilling.com
- Icelandic State Electricity – www.rarik.is
- HS Orka – www.hsorka.is
- Landsvirkjun Power – www.lvp.is
- Reykjavik Energy – www.or.is

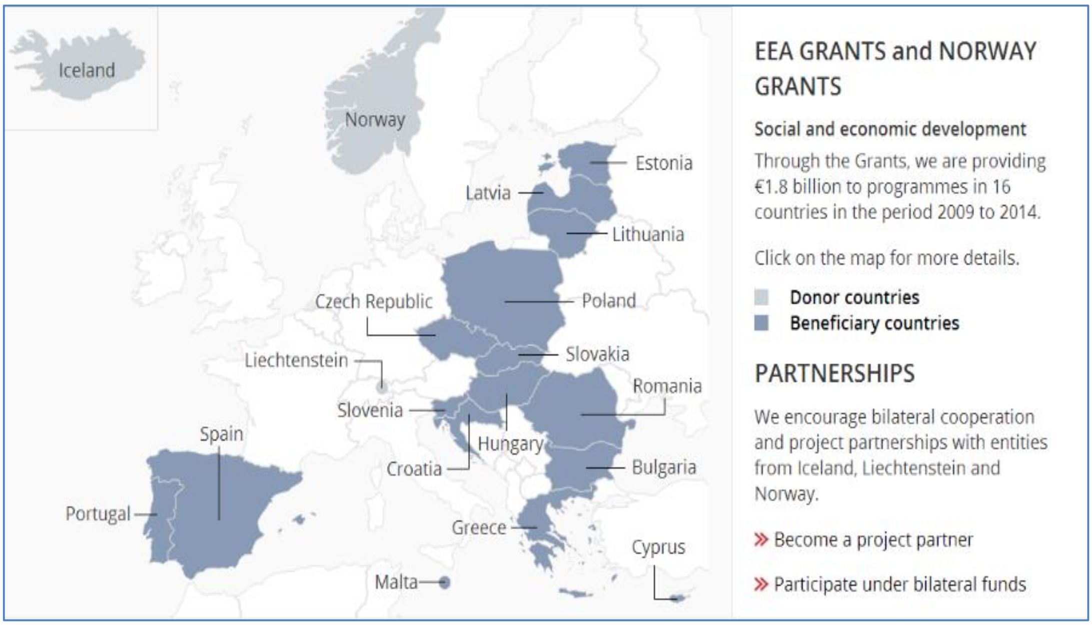
Energy Institutions / Cooperation Platforms

- Orkustofnun, (National Energy Authority) – www.os.is
- Iceland Geothermal Cluster http://www.icelandgeothermal.is/

8.3.2. EEA Grant Cooperation in Eastern Europe

Through the European Economic Area (EEA) Agreement, Iceland, Liechtenstein and Norway are partners in the internal market with the 28 EU member states. Ever since the establishment of the EEA Agreement in 1994, Iceland, Liechtenstein and Norway have provided funding to reduce social and economic disparities in the EEA. The expansions of the EU in 2004 and 2007 brought a 20% increase in the EU's population, but only a 5% increase in GDP. The EEA and Norway Grants, are helping to reduce disparities. The funding is targeted on areas where there are clear needs in the beneficiary countries.

Fig. 8.3.2.1. **The EEA Grants and the Beneficiary and the Donor Countries**



Orkustofnun (National Energy Authority), work as EEA Donor Program Partner

Funded by the EEA Grants, Hungary, Portugal and Romania will work together with the National Energy Authority of Iceland to develop and exploit the potential of geothermal energy in their countries. With its expertise in securing long-term sustainable use of geothermal resources, the National Energy Authority in Iceland will, as a Donor Programme Partner, offer assistance in creating, implementing and monitoring geothermal resource management plans in these three beneficiary states. This cooperation aims at securing long term sustainable yield of the geothermal resource.

Figure 8.3.2.2. **The launch of the EEA Grants in Hungary 2013. The Hungarian State Secretary for Energy, Attila Imre Horváth, the Icelandic Foreign Minister Gunnar Bragi Sveinsson, the Norwegian Ambassador Tove Skarstein and Guðni A. Jóhannesson, Director General of the Icelandic Orkustofnun**.

Renewable Energy Supported by EEA Grants

In the EEA Grants scheme, €135 million has been set aside in eight countries for projects that promote energy efficiency and the share of renewable energy in the energy mix, in line with the EU/EEA, Europe 2020 targets. Renewable energy comes in many forms. Both Iceland and Norway have had great success with hydroelectric energy and Iceland is a pioneer in harnessing geothermal energy. Geothermal energy sources account for 68% of Iceland's primary energy use.

Figure 8.3.2.3. **The launch of the EEA Grants in Romania 2013. Jónas Ketilsson, Project Manager from NEA Iceland, the Icelandic Minister of Industry and Commerce, Ragnheiður Elín Árnadóttir and Adrian Gearap, President of EFA.**

Figure 8.3.2.4. **The launch of the EEA Grants in Azores Islands (Portugal) 2013. The Icelandic Minister of Industry and Commerce, Ragnheiður Elín Árnadóttir and others from Azores and Iceland.**

Example of a Renewable Program within the EEA Grant Programme – the RONDINE

On Tuesday, November 26, 2013, the RONDINE (RO 06) Renewable Energy Program was launched in Romania. The aim of the RONDINE Program, which is based on the EEA Grants 2009 - 2014, is to promote sustainable use of natural resources and reduce emissions of greenhouse gases through the use of renewable energy, by hydro- and geothermal projects. The program is operated by the Romanian Environmental Fund Administration, EFA.

What will the Programme Achieve and who are the Beneficiaries?

The programme will increase the share of renewable energy in energy generation in Romania. This will be done by way of financially supporting the construction or refurbishment of three or more small scale hydropower plants in order to make them more efficient. Moreover, the programme will support the construction of one or more geothermal heat plants in areas where there already is a heat distribution system in place. The new or refurbished plants, will contribute to the replacing of fossil fuels with renewable energy. The programme will benefit local public administration, local institutions, enterprises and households.

Example of one Geothermal Project in Romania

Figure 8.3.2.5. **The City of Oradea, in Romania**

An example is the geothermal project in the city of Oradea, which is one of the biggest city in western Romania with 200.000 inhabitants. One of the biggest universities in Romania (with 20.000 students) is located in the city. The aim of the project is to install pumps in an existing borehole, as well drilling injection wells, to utilize hot water for heating. The additional geothermal fluid that will be extracted will be used for the city district heating system to reduce the use of coal, the current fuel being used.

Orkustofnun
http://www.nea.is/the-national-energy-authority/international-relations/
Ministry of Foreign Affairs
http://www.utanrikisraduneyti.is/verkefni/evropumal/verkefni/nr/4582
EFTA / FMO / EEA Grants
http://eeagrants.org/

8.3.3. UNU – GTP Programmes

The Geothermal Training Programme of the United Nations University (UNU-GTP) is a postgraduate training programme, aimed at assisting developing countries in capacity building within geothermal exploration and development. The annual programme consists of six months training for practicing professionals from developing and transitional countries with significant geothermal potential. Priority is given to countries where geothermal development is under way, in order to maximize technology transfer. The programme has operated in Iceland since 1979. It is a cooperation between the United Nations University and the Government of Iceland and is hosted by the National Energy Authority (Orkustofnun).

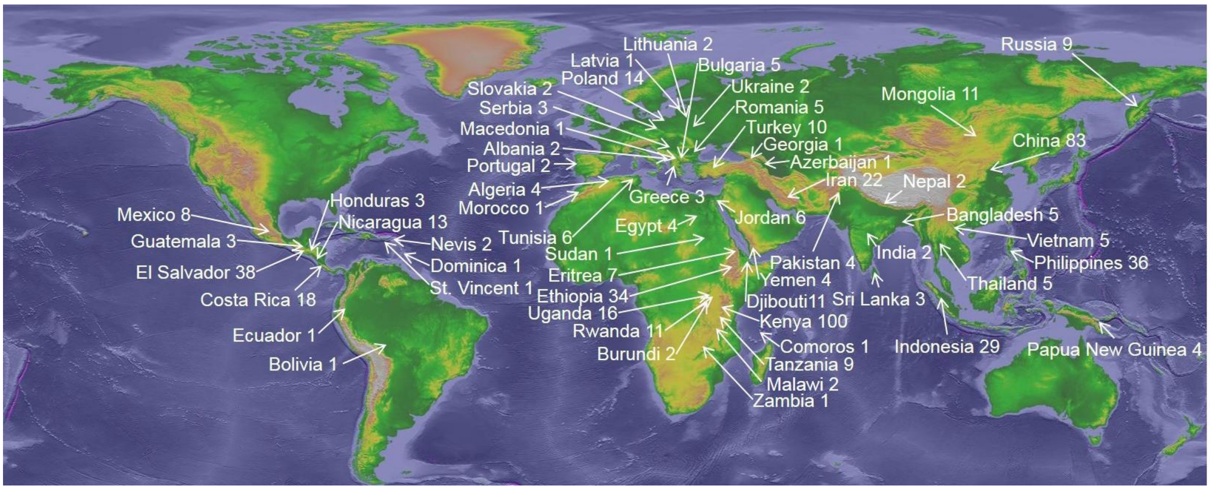
The UNU-GTP has three main activities:

- The Six Month Training Programme
- MSc and PhD Fellowships
- Workshops and Short Courses

The core focus of the UNU-GTP is an annual six month specialized training programme initialized in 1979. New countries are continuously added in the training but care is taken not to spread the efforts too thin. Experience strongly suggests that it is necessary to build up groups of ten or more geothermal specialists in a given country in order for technology transfer to be successful and sustainable. In association with the Six Month Training Programme a leading specialist in geothermal energy is invited every year to give a series of lectures over a duration of one week on a specific geothermal subject. The lectures are open to all interested in geothermal sciences.

The UNU-GTP also offers an opportunity for outstanding fellows to pursue their MSc and/or their PhD degree through a cooperation with the University of Iceland (UI) and Reykjavík University (RU). The Six Month Training Programme counts 25% towards the MSc degree.

Figure 8.3.3.1**. UNU-GTP Fellows in Iceland, 1979-2014 – 583 from 58 Countries**

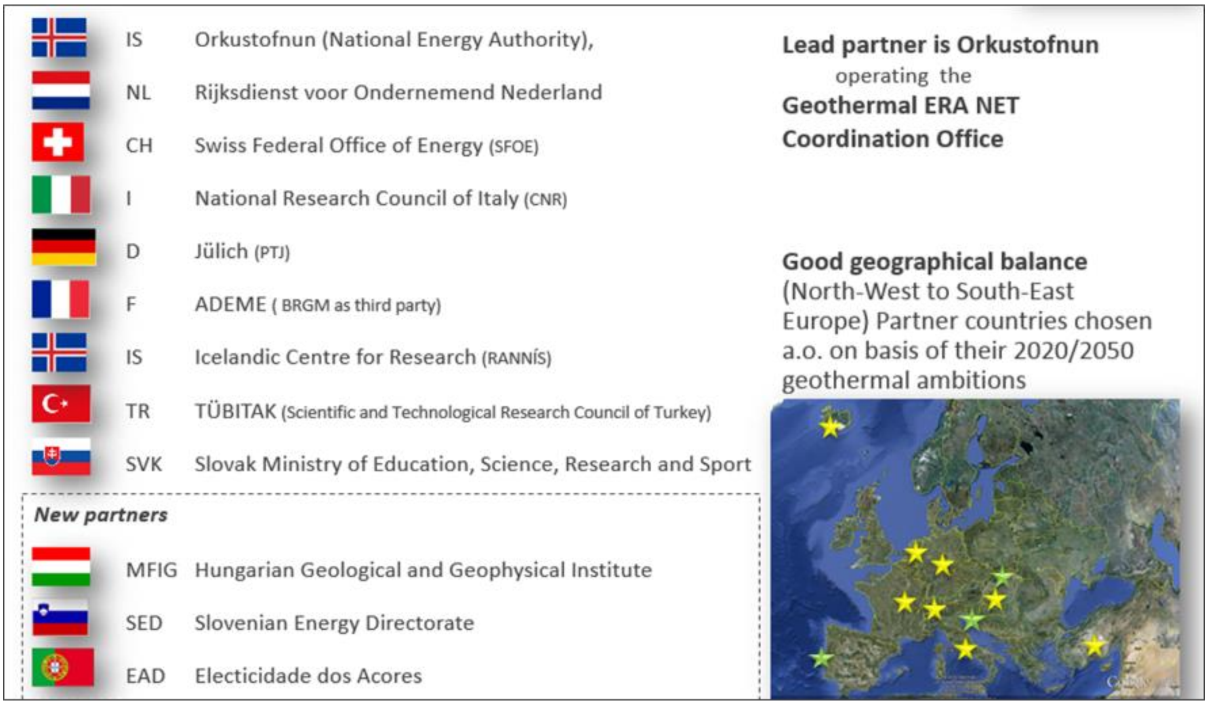


The United Nations University Geothermal Training Programme (UNU-GTP) can support the Ukraine in strengthening the skills of experts who are tasked with the responsibility of carrying out geoscientific exploration, utilizing and managing geothermal resources. Since its inception in Iceland in 1979, the programme has graduated 515 fellows from 53 countries. The fellows have obtained both a broad overview of the major geothermal disciplines as well as committing to in-depth studies in one or more of the nine available lines of specialization, which are: Geothermal geology, reservoir engineering, geophysical exploration, borehole geophysics, reservoir engineering, environmental studies, chemistry of thermal fluids, geothermal utilization, drilling technology and project management and finances.

8.3.4. ERA Net Cooperation

The Geothermal ERA-NET is a cooperation started on May 1st 2012 within the EEA Agreement, and will last for four years. It is estimated that the project will support geothermal research in Europe - that could lead to greater cooperation between energy agencies and ministries in Europe and make it possible for them to work on common goals. The Geothermal ERA NET focuses on direct use and higher enthalpy uses of geothermal energy. The general vision of the Geothermal ERA NET is as follows:

- Minimize the fragmentation of geothermal research in Europe.
- Build on European know-how and know-who to utilize geothermal energy
- Contribute to a framework to realise large opportunities in the utilization of geothermal energy through joint activities.

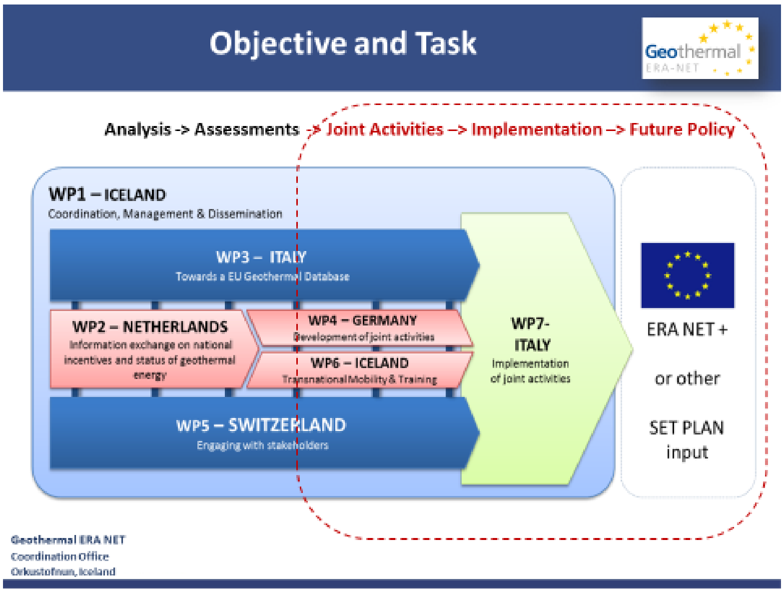


Geothermal energy utilisation accounts for 68% of energy consumption in Iceland, and one could say that the potential that this energy source holds for this country is largely deployed. Italy also has a significant geothermal production and ranks fifth in the world for geothermal electricity production. After Turkey, Iceland and Italy, Hungary is ranked at 4th place regarding geothermal direct use in Europe. For all other participating countries, geothermal energy is an energy source with potential.

All the countries have ambitious agendas for an increase of the market for geothermal energy.

In all the ERA NET countries except for the Netherlands and Slovenia, this includes a significant growth in electricity production using geothermal energy.

Up to 2020, the Netherlands will focus on direct use. In all participating countries, there are policy instruments in place to forward geothermal energy utilisation. This includes R&D efforts, but in some countries also soft loans or guarantee funds.

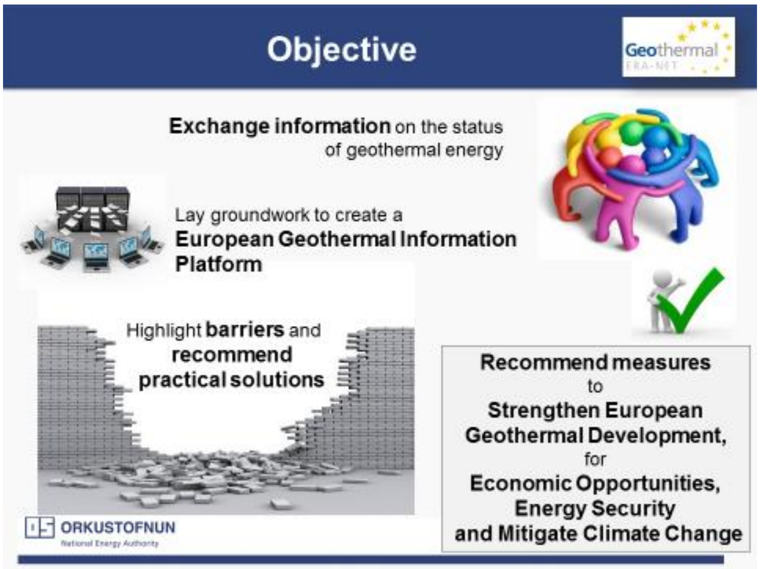


The Geothermal ERA NET program is split into 7 Work Packages:

1. Coordination and Management
2. Information exchange on national incentives and status on geothermal energy
3. Towards a European Geothermal Database
4. Development of Joint Activities
5. Coordination with Stakeholders
6. Transnational Mobility and Training
7. Implementation of Joint Activities

"It is important for policymakers and others to recognise the great opportunity geothermal heating gives regarding savings for countries, as it is estimated that geothermal heating in Iceland is saving equal to 7% of GDP or 3.000 USD per capita or close to 1 billion USD for the economy only for 2012. It has also been estimated that renewables for heating and cooling could save EUR 11,5 billion per year within EU, improve the energy security and mitigate climate change", says Guðni A Jóhannesson Geothermal ERA NET coordinator.

More information regarding the program and progress can be seen at the website.
www.geothermaleranet.is/



8.3.5. Additional International Geothermal Promotion

For many years the authorities in Iceland e.g. the **Ministry of Industries and Innovation and its Ministers,** has strongly supported the geothermal sector in various forms, at domestic level by highlighting the importance of the sector in policy making as well as implementation for harnessing the geothermal resources both for electricity generation and district heating.

Figure 8.3.5.1. **Left - Ragnheiður Elin Árnadóttir, Minister of Industry and Innovation and Daniel Ortega President of Nicaragua. Right – the Icelandic Delegation in Nicaragua.**

The Icelandic authorities have also supported various events on renewables and seminars at international level, with conferences trade missions etc. For example Ragnheiður Elin Árnadóttir, Minister for Industry and Innovation, chaired an Icelandic delegation on a visit to Nicaragua in November 2014, focusing on geothermal and hydro where she signed a Memorandum of Understanding (MoU) on Renewables Cooperation with Mr. Daniel Ortega, President of Nicaragua. http://eng.atvinnuvegaraduneyti.is/

The **Ministry for Foreign Affairs and its ministers** have also supported the geothermal sector, especially in the form of international aid, by helping several developing countries to harness geothermal renewable resources, by education and capacity building in cooperation with United Nations University Geothermal Training Programme (UNU-GTP), International Financial Institutions (IFI) and various countries. It has also be done by meetings and conferences at international level. http://www.mfa.is/

Figure 8.3.5.2. **Mr. Gunnar Bragi Sveinsson, Minister for Foreign Affairs, with United Nations Secretary-General Mr. Ban Ki-moon, at Hellisheiðarvirkjun**

The presidents of Iceland have also highlighted the importance of the geothermal renewable resources at various occasions at domestic and international levels, at meetings, conferences and other occasions, especially in recent years. http://english.forseti.is/

Figure 8.3.5.3. **Mr. President, Ólafur Ragnar Grímsson, at the World Future Energy Summit.**

Íslandsstofa, Promote Iceland offers the business community various marketing and trade promotional services, including the organisation of trade fairs and business delegations, in-depth consulting, training programmes and market information. http://www.islandsstofa.is/en

Such policy support and awareness raising through the years for the harnessing the geothermal resources by ministers, ministries and the presidents, is valuable awareness building at domestic and international level. This has also assisted concerning countries, regions and stakeholders to further utilisation of geothermal resources, to mitigate climate change and increase energy security, economic opportunity and savings, and quality of life.

9. Capacity Building in Iceland

To promote and build up confidence in geothermal development it is essential that a governmental institute leads the regional survey for promising geothermal fields and evaluates the geothermal potential. This institute is required to encourage and supervise the first steps in exploration and demonstrate the methodology and value of the first geothermal development.

After this initial phase of encouragement confidence in geothermal development may have reached the stage that private investors and entrepreneurs are willing to take over projects. Then the role of the governmental institute changes to supervision and administration of the development like what has occurred in Iceland in the last few decades. For the initial phase of the regional survey for promising geothermal fields and evaluation of the geothermal potential, an institute with a staff with specialized training in geothermal exploration and sustainable development is needed. The main disciplines required are:

- **Geological exploration**
  Practical training in basic geological and geothermal mapping, which is commonly the first step in the geothermal exploration of an area.
- **Geophysical exploration**
  Practical training in conducting geophysical surveys of geothermal areas and/or interpretation of such data.
- **Chemistry of thermal fluids**
  Thermal fluid chemistry in geothermal exploration and exploitation, including sampling, analysis of major constituents and the interpretation of results.
- **Drilling technology**
  Selection of drilling equipment, well design, casing programs, cementing techniques, cleaning and repairs of production wells.
- **Borehole geology**
  Training in making geological logs, analyses of drill cuttings and cores. Identification of alteration minerals (microscope and x-ray diffraction) and interpretation of the alteration mineralogy.
- **Borehole geophysics**
  Geophysical measurements in boreholes used for geothermal investigations, with an emphasis on temperature and pressure measurements.
- **Reservoir engineering**
  Hydrological characteristics of geothermal reservoirs and forecast of the long term response of the reservoirs to exploitation
- **Environmental studies**
  Environmental impact assessments (EIA), laws and policies, the planning and execution of EIA projects and environmental auditing. Environmental monitoring, biological impact, pollution and occupational safety.
- **Geothermal utilisation**
  Civil, mechanical and chemical engineering aspects of geothermal fluids in pipes, equipment and plants. Feasibility of projects and environmental factors.
- **Law**
  Legal and institutional framework. Laws on survey, protection and utilization of natural resources, environmental impact assessment.
- **Financial analysis and planning of geothermal projects.**
- **Project Management.**
- **General geothermal framework assessment, evaluation and development.**

Training in these disciplines is offered at the United Nations University Training Programme (UNU-GTP) in Iceland and at many universities in other countries that have pursued geothermal development. The candidates for UNU-GTP must have a university degree in science or engineering, a minimum of one year practical experience in geothermal work, speak English fluently, and have a permanent position at a public energy agency/utility, research institution, or university. In selecting the participants the UNU-GTP sends representatives to the countries requesting training.

The potential role of geothermal energy within the energy plans of the respective country is assessed, and an evaluation made of the institutional capacities in the field of geothermal research and utilisation. Based on this, the training needs of the country are assessed and recipient institutions selected. The directors of the selected institutions are invited to nominate candidates for training in the specialized fields that are considered most relevant to promote geothermal development in the respective country. Further information on the UNU-GTP is attached in an Appendix.

When confidence in the geothermal development has reached the level that private investors are willing to take over in projects, the role of the governmental institute changes to supervision and administration of the development along the lines defined in laws like the Act on Survey and Utilisation of Natural Resources in Iceland. At this stage the institute will require staff trained in legal affairs, economy and business administration. The exploration and appraisal of geothermal fields would then be carried out by specialized consultants but the institute would still require staff members with expertise in geothermal development to handle issues of granting licenses and supervision of the operating holders of licenses.

10. Conclusions and Lessons Learned in Iceland

Ownership, Pricing and Financing

In Iceland the energy sector has been built up by companies owned by the State or municipalities where the aim has been to utilize the natural energy resources for development and offer energy to the public at favourable prices, both electricity and hot water for space heating. In financing larger projects the owner of the respective energy company has given its guarantee and provided long term loans on favourable terms from development banks and commercial banks.

Profitability and Savings for Economy and Citizens

The energy companies have not returned much profit on their equity, but companies and the public have enjoyed a relatively low energy price and a tremendous development has taken place in energy intensive industries and related services. The economic savings from using geothermal energy in space heating in Iceland are substantial, and have contributed significantly to Iceland’s prosperity, especially in times of need. The electricity price in Iceland is among the lowest in Europe.

Risks

Geothermal projects require considerable initial capital and investment long before the stream of income. The risk involved in new geothermal projects is generally a major barrier for the development as well as the difficulty persuading independent power producers (IPP) and investors to accept the risk and complete the total financing.

Cooperation

Geothermal development requires balanced cooperation of many disciplines such as geosciences, engineering, law and finance. This balance has though not always been reached. In many countries the legal framework and regulatory directives are incomplete or not existing. Conferences are held on science and technology but the discussion of finance, contracts and legal framework is often limited. As a result scientists and engineers have limited understanding of finance and the financial experts know little of the nature of resources and the applied technology. A description of the financial aspects gives decision makers basic understanding of the assumptions and risk involved in geothermal projects and aids in finding methods to reduce the risk and utilize opportunities in the geothermal development.

Administration

To promote and build up confidence in geothermal development it is essential that a governmental institute leads the regional survey for promising geothermal fields and evaluates the geothermal potential. This institute is required to encourage and supervise the first steps in exploration and demonstrate the methodology and value of the first geothermal development. When the geothermal development reaches the stage that private investors and entrepreneurs are willing to take over projects, the role of the governmental institutes changes to supervision and administration of the development. It is vital for carrying out an effective law on the sector of geothermal energy, that the administrative body, responsible for the regulation and official monitoring of the law, be active and visible to those subject to regulation. It is also very important that this same body has effective remedies to bring into actuality each article of the act. Lastly, an appeals committee is important to give the regulator the necessary restraint.

Due to uncertainty it is important that the planning process for utilization takes above mentioned factors into account as well as the fact that the environmental effects can sometimes be difficult to predict. Therefore, the licenses issued need to take that into consideration and active cooperation is needed between the developer and the authority to mitigate unforeseen effects. The licensing authority also needs to make sure that the economic model of the plant takes into account the uncertainty of reinjection strategies, gas emissions and rate of make-up well drilling to ensure that the developer will be able to run the facilities properly and within requirements stipulated in the legal framework and the licenses issued.

Financial Factors

The risk involved in new geothermal projects is generally a major barrier for the development as well as the difficulty persuading independent power producers (IPP) and investors to accept the risk and complete the total financing. Geothermal projects require considerable initial capital and investment long before the stream of income.

The World Bank, development banks, and development agencies have examined how they can best assist new geothermal projects in developing countries.

To explain this complicated problem one must present clearly the basic assumptions and results of financial analyses. It must be clear what matters most and which assumptions are essential. Case histories from countries which have attained successful development may be of help in that respect.

The case of Iceland is a good example, since in many countries the conditions for development may be similar to those in Iceland some 40 years ago. For comparison it may also be worth to examine why countries that have most of the natural conditions required have not succeeded in their development.

References

Atlas for Geothermal Resorces in Europe. (2002). European Commission.

Bloomberg New energy Finance, U. S. (2010).

Christian Boissavy, V. S.-B. (2014). *Manual for implementation sustainable support shemes for GeoDH.* GEODH.

Commission, E. (2011). *Review of European and national financing of renewable energy in accordance with Article 23(7) of Directive 2009/28/EC.* Brussels.

EBRD. (2011). *STRATEGY FOR UKRAINE - 2011 - 2014.* London: EBRD.

EBRD. (2015). *EBRD Transition Report on Ukraine 2015 - 2016.* London: EBRD.

EGEC. (2013). *Financin Geothermal Energy.*

Energy, U. D. (2014). *2013 Market, Trends Report, geothermal technology Office.* Booz Allen Hamilton.

ESMAP. (2012). *ESMAP.* Washington DC.

ESMAP, I. W. (2012). *Geothermal Handbook: Planning and Financing Power Generation.*

Forum, W. E. (2014). *Global Competiveness Report 2014 - 2015. .*

GEA. (2014). *2014 Annual U.S. & Global Geothermal Power Production Report.*

GeoDH. (2014). Retrieved from www.geodh.eu.

GEODH. (2014). *Financing of Districht Heating .* Brussels: GEODH / EU.

GeoDH. (2015). *Developing Geothermal districht Heating in europe.* Brussels: GeoDH.

GeoDH, M. H. (2014). *GeoDH BUSINESS MODELS ON GEOTHERMAL DH SYSTEMS.*

Geothermal Energy Aassociation, Benjamin Matek. (2015). *2015 Annual U.S. & Global Geothermal Power Production Report.* Geothermal Energy Aassociation.

Geothermal: International Market Overview Report. (2012). Washington, DC.: Geothermal Energy Association.

Gunnarsson Hákon, Þ. Þ. (2011). *The Icelandic Geothermal Cluster; Mapping and Mobilization.*

Hagstofa Íslands. (6. mars 2014). *Talnaefni*. Sótt frá Vefsíða Hagstofu Íslands: http://hagstofa.is/

Haraldsson, I. G. (2013). *Geothermal Activity in South America.* United Nations University Geothermal Training Program.

Haraldsson, I. G. (2014). *Economic Benefits of Geothermal Space Heating from the Perspective of Icelandic Consumers.* UNU - GTP, Orkustofnun, Iceland.

ICEIDA, N. (2011). *The Geothermal Exploration Project.*

Iceland, M. E. (2015). *Geothermal DH in Eastern Europe.*

Iceland, U. . (2014). *UNU - GTP Training Program*. Retrieved from http://www.unugtp.is/en

IFC. (2015). *Unlocking the Potential for Private Sector Participation in District Heating.* Washington: IFC.

Institute, R. D. (2014). *http://www.byggdastofnun.is/is/verkefni/vaxtarsamningar*.

Energy in the ANDEAN Countries: Bolivia.

Landsvirkjun. (2012). *Landsvirkjun Annual Report 2012, p. 59.*

National Energy Authority Iceland, N. (2014). *Newsletter, Geothermal ERA NET*. Retrieved from www.geothermaleranet.is.

NEMS, US National Energy Modelling System. (2014).

Orkustofnun, M. o. (n.d.). *http://www.nea.is/the-national-energy-authority/international-relations/*.

Petursson, B. S. (2014, 2012). Geothermal Competitiveness. Reykjavik.

SAEE, S. A. (2014). National Renewable Energy action Plan to 2020.

Status Report of Geothermal Energy in Chile. (2013). IRENA.

Sveinbjörnsson, B. M. (2014). *Success of High Temperature Geothermal Wells in Iceland.*

WB. (2012). Design and performance of Policy Imstruments to Promote the Development of Renewable Energy. Washington DC.

WB, E. (2012). Modernization of the District Heating Systems in Ukraine: Heat Metering and Consumption-Based Billing.