D.6.2.1. Transnational Danube Region Geothermal Strategy

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1. Introduction

A joint transnational strategy for the uptake of geothermal heating and cooling in the Danube Region is one of the key-outputs of DARLINGe and is considered as an important step towards the Region's transformation into a low-carbon economy. However it is imptant to underline that this Strategy does not reflect any official opinion of the partner countries' authorities, ministries but is considered as a "supporting document" compiled by the project consortium in order to address the project's main objective ("to make the energy mix more balanced by increasing the sustainable and energy-efficient use of deep geothermal energy in the heating sector"), as well as its three-specific objectives [(1) to increase the share of energy efficiency on cascade geothermal systems, (2) to establish transnational management of geothermal reservoirs, (3) advance institutional capacities and stakeholder dialogue to foster geothermal developments].

Another important aspect to underline is that despite the similar favourable geological conditions all over the project area, the level of development of the geothermal energy sector is very different in the six DARLINGe countries (including rate of exploration, awareness on the advantages of geothermal energy, its inclusion in national energy policies, etc.). It is well reflected in the highly heterogenous number of thermal water wells in the project area expressed in number of wells/ 1000 km^2, with a value of 26 for Hungary and 1 for Croatia, Bosnia and Herzegovina an Serbia respectively. In line with the general aims of the EU Strategy for the Danube Region of moving towards a more baanced development of the regions' countries, DARLINGe was also putting emphasis on showing good practices, knowledge sharing in order to help countries with less developed geothermal utilizations.

Strategy making in general has its own methodology, rules and steps (Figure 1), which DARLINGe is following. These are:

I. **Baseline / State of art: analysis of the present status.** For each strategy the starting point is the detailed assessment of the existing situation, definition of the "baseline" circumstances. In DARLINGe detailed analyses have been performed for the entire project area in WP5 for the following main topics: (1) potential geothermal reservoirs were identified, delineated and characterized at regional level including their resource assessment (report D.5.1.1); (2) current thermal water uses were systematically collected and assessed (report D.5.2.1.); best practice case studies were selected and evaluated in details (report D.5.3.1.); the areas's heat sector and heat market conditions were analysed in order to be able to identify the main areas of heat demand to match them with regions with the best geothermal potentials (i.e. tie supply and demand) (report D.5.4.1.); the relevant regulatory frameworks have been overviewed at EU- (report D.5.5.1.) and at national levels focussing on licensing procedures (report D.5.5.2.); furthermore the existing financial support mechanisms in the partner countries have been also analysed (report D.5.5.3).

II. **Identification of potentials, challenges, barriers.** Once a clear picture on the state-of-the-art is set up, the next step is its evaluation. In DARLINGe this has been completed in the frame of a detailed SWOT analyses (report D.6.1.1.), which was performed for each of the above main topics, thus allowed the project to identify the main strengths and opportunities to build on, as well as the weaknesses and threats the Strategy has to deal with.

III. **Ambition settings.** This refers to the phase when the involved parties, stakeholders start to collect ideas for an idealized future situation. In DARLINGe this has been partly done during the 2nd Transnational Stakeholder Forum Meeting, held in Zagreb on June 12-13, 2018 (report D.3.2.2.), when the outcomes of the state-of-art studies, as well as results of the SWOT analyses have been presented and jointly discussed among the consortium members and key-stakeholders.

IV. **Vision development.** In this phase the desired future scenario, compiled and streamlined from the numerous ideas coming from phase "Ambition setting" is set up. In order to achieve a real break-through in the given topic, scenarios beyond BAU (Business As Usual) should be set up.

V. **Roadmapping.** This period is devoted to the definition of priority areas for reaching the vision, definition of possible routes to the desired future scenario.

VI. **Action Plans** are specific programs in order to start realizing the future scenarios. It contains concrete measures and gives concrete answers to "what? when? where? by who? It comprehends indicators and a monitoring plan as well.

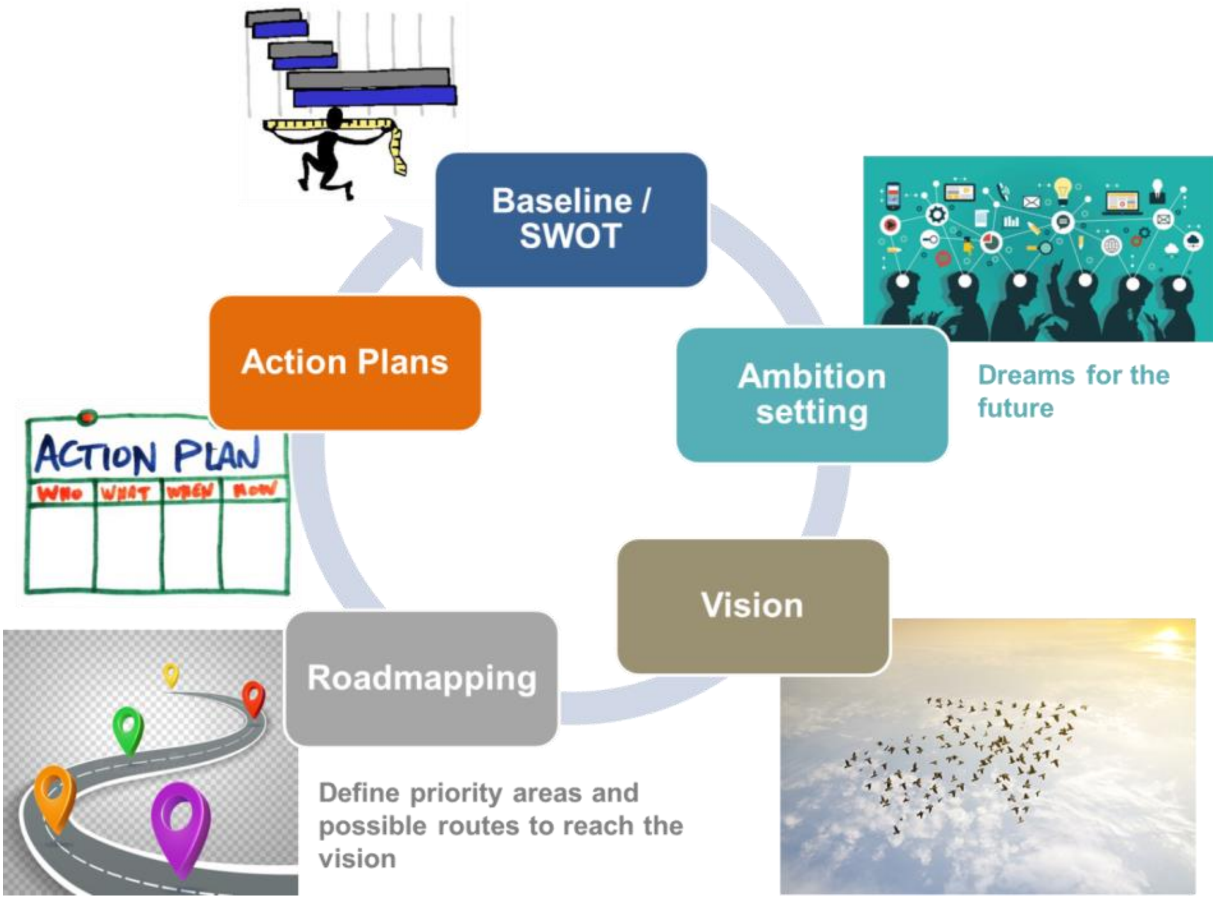

Figure 1: Phases of Strategy development followed by DARLINGe

Out of the above described phases, the present report is focussing on phase IV (Vision development), as the main stage of strategy making. It briefly summarizes results of phase I (state-of-the art analyses) as well as phase II (Identification of potentials, challenges, barriers) as the main inputs to the strategy, furthermore the key ideas collected from the stakeholders and consortium members during the phase III of Ambition setting.

Phases V (Roadmapping) and VI (Action Plans) will be assessed during the elaboration of the Danube Region Geothermal Actions Plans (D.6.4.1.) to be completed towards the end of the project.

After providing a brief introduction on geothermal energy, the present Strategy addresses seven key areas: (I) Policy framework relevant for geothermal energy direct use at EU-, Danube Region- and national levels, (II) Geothermal resources and utilization, (III) Operational and technical aspects of geothermal heating systems, (IV) Economics of geothermal projects and heat markets, (V) Social aspects and contributions to regional development, (VI) Data policy, and (VII) Research priorities.

2. Geothermal energy framework

Climate change and energy supply are the two major challenges that the World is facing today. To tackle these issues in a comprehensive manner, the European Union's policy is moving towards the establishment of a reliable, sustainable and competitive energy system, in which renewables (RES) have a key role. The 2030 climate and energy package sets ambitious targets regarding the minimum shares of renewable energy consumption and energy savings, thus paving the way to the decarbonisation of the European economy with more than 80% reduction of greenhouse gas emission by 2050. As the share of renewables is still relatively low in the EU final energy consumption (Figure 2), the development of low-carbon technologies is a key part of the EU Strategy.

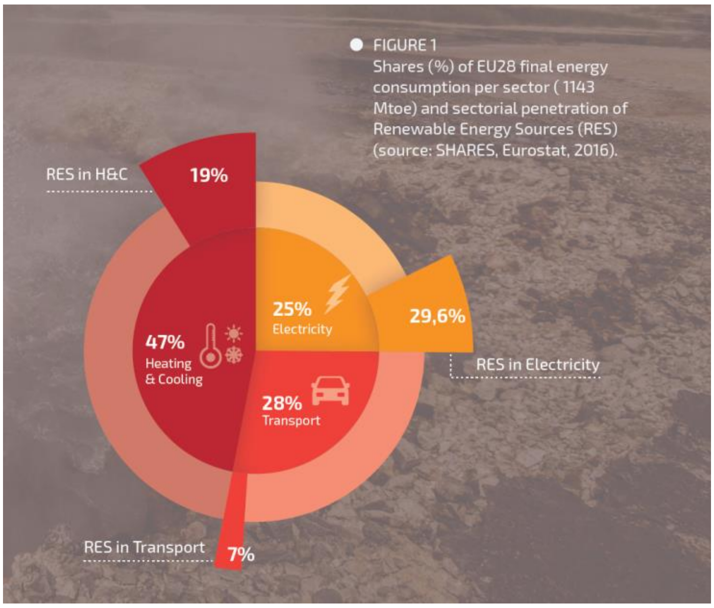

Figure 2: Shares of EU28 final energy consumption per sector. (From: Vision for deep geothermal ETIP-DG 2018)

Geothermal energy – the energy stored in the form of heat in rocks and in trapped vapour or liquids under the surface and which is continuously renewed by the constant terrestrial heat flow largely fed by the decay of radioactive isotopes found in the Earth crust – can contribute to the local, regional and global energy transition towards reliable, clean and affordable energy sources. In addition to its unambiguous role in power generation (which is out of the scope of DARLINGe project, therefore not discussed in this report), geothermal energy has a crucial role in the decarbonisation of the heating-cooling (HC) sector, providing affordable energy for the society, and allowing competitiveness of the European industry.

Geothermal energy has been a source of energy to humankind since the dawn of civilization. For centuries, hot springs have been used for bathing, healing, heating, and as a secure source of water in hundreds of places all over Europe, including the DARLINGe countries (Figure 3).

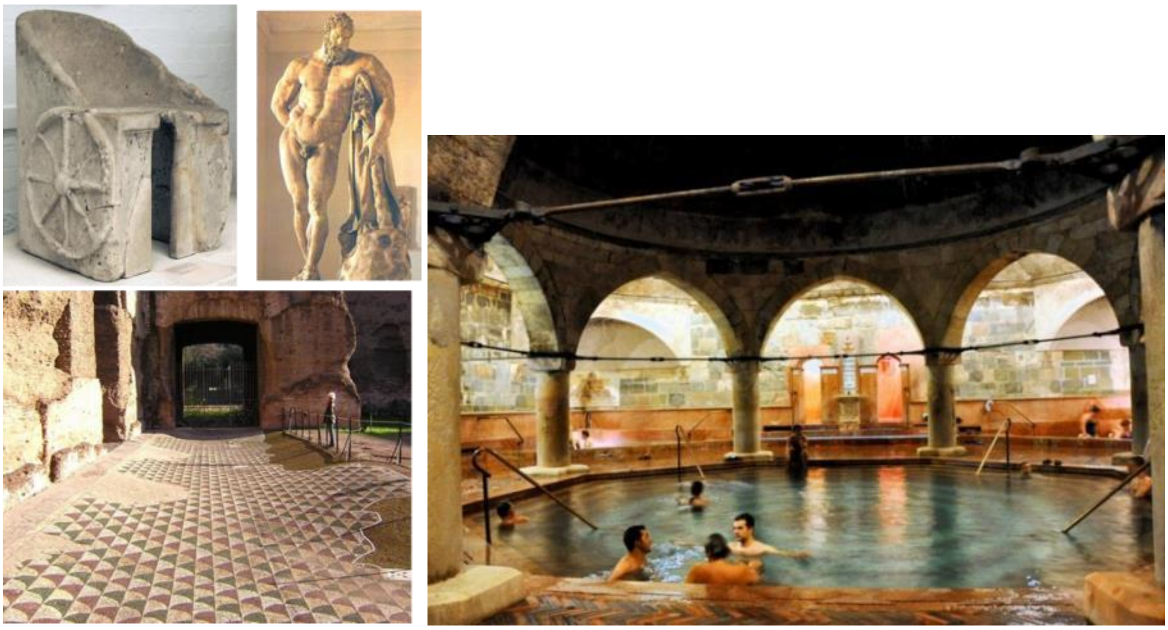

Figure 3: Thermal bath of Caracalla, Thermae Antoninianae (Italy) (left), 400 yrs old Turkish bath (Rudas) in Budapest (right)

Geothermal energy has numerous advantages:

- ✓ a renewable energy source, which is local
- ✓ improves security of supply
- ✓ widely available, since underground heat is global
- ✓ a base-load energy source, provides a 24/7 delivery with predictable outputs irrespective of weather conditions, therefore the Capacity Factor (i.e. actually produced energy with respect to the full capacity) is much higher than for other RES, resulting in lower total costs (LCoE) (Figure 4)
- ✓ has huge untapped potentials which can be economic boosters
- ✓ has numerous applications: geothermal heating and cooling can supply energy at different temperatures from low (15-20 °C) to high (100 °C or above), furthermore multiple applications can be optimized by cascade users of heat at progressively lower temperatures
- ✓ different loads (base load, or flexible, adjusted to the actual demand) and capacities matching different demands (from a few kW_{th} to tens of MW_{th}) providing extra flexibility for operators
- ✓ can be combined with other energy sources to increase efficiency
- ✓ has low environmental footprint, the resource is invisible

Figure 4: Comparison of capacity factors and LCoE of various renewable. From: Renewables 2017 Global Status Report, REN 21, EUROSTAT, IRENA 2017)

Currently geothermal energy sources provide more than the equivalent of 4 million tonnes oil (Mtoe) per year for heating and cooling in the EU, equivalent to more than 15 GW_{th} installed capacity, where geothermal heat pump systems contribute to the larges part. Following current trends in the EU-28 the contribution in 2020 will amount up to 40 GW_{th} installed, corresponding to about 10 Mtoe *(Geothermal Technology Roadmap, European Technology Platform on Renewable Heating and Cooling (2014).*

Although geothermal development in Europe dates back more than a century, it still occupies a niche market compared to other energy sources, in spite of the fact that a still untapped and huge potential exists in many parts of Europe, also in the DARLINGe project territory. The development of geothermal energy is hindered by limited knowledge about the technologies and their potential among policy makers, economic actors and the public. Other challenges are financial, legal, logistic and technical. Complex and incomplete regulations, fragmented among EU Member States, and long and complex authorization processes are one of the main barriers of geothermal deployment. The relatively high geological risk at the exploration phase coupled by high upfront costs of capital intensive investments also makes geothermal projects less attractive for investors. Despite the fact that EU support for geothermal research development and innovation has increased, it is still lower compared to other renewable energy sources.

3. Policy context

3.1. State-of-the-art

3.1.1. Global landscape

The **UN 2030 Agenda for Sustainable Development** and its **17 Sustainable Development Goals** (Figure 5) adapted in 2015 are the blueprints to achieve a better and more sustainable future for all and as such it provides the global framework. They address the global challenges humans face, including those related to poverty, inequality, climate, environmental degradation, prosperity, and peace and justice. Among those, **Goal 7**. addresses energy challenges: **“Ensure access to affordable, reliable, sustainable and modern energy for all”:**

7.1 By 2030, ensure universal access to affordable, reliable and modern energy services

7.2 By 2030, increase substantially the share of renewable energy in the global energy mix

7.3 By 2030, double the global rate of improvement in energy efficiency

7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology

7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

Figure 5: The UN Sustainable Development Goals

3.1.2. EU energy policy

Although geothermal energy per se is mentioned at a relatively few places in the overall European energy policies, as an important renewable energy resource it plays a key role in making energy more secure, affordable and sustainable, as the overall goals of the EU energy policies framework.

The EU imports more than half of all the energy it consumes. Its import dependency is particularly high for crude oil (90%) and natural gas (69%). Many countries (including most of the DARLINGe coutries) are also heavily reliant on a single supplier, especially on Russia for their natural gas. This dependence leaves them vulnerable to supply disruptions, whether caused by political or commercial disputes, or infrastructure failure.

In response to these concerns, the European Commission released its **Energy Security Strategy** in May 2014. The Strategy aims to ensure a stable and abundant supply of energy for European citizens and the economy. It proposed actions in five key areas to ensure addresses long-term security of supply challenges:

- Increasing energy efficiency and reaching the proposed 2030 energy and climate goals. Priorities in this area should focus on buildings and industry, which use 40% and 25% of total energy respectively in the EU.
- Increasing energy production in the EU and diversifying supplier countries and routes. This includes further deployment of renewables, sustainable production of fossil fuels, and safe nuclear energy where this option is chosen.
- Completing the internal energy market and building missing infrastructure links to respond quickly to supply disruptions and redirect energy across the EU to where it is needed
- Speaking with one voice in external energy policy
- Strengthening emergency and solidarity mechanisms and protecting critical infrastructure.

The other major package, the **2030 Framework for Climate and Energy** defined EU-wide targets and policy objectives for the period between 2020 and 2030. The targets are (Figure 6):

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 27% share of renewable energy consumption
- indicative target for an improvement in energy efficiency at EU level of at least 27% (compared to projections), to be reviewed by 2020 (with an EU level of 30% in mind)
- support the completion of the internal energy market by achieving the existing electricity interconnection target of 10% by 2020, with a view to reaching 15% by 2030

This new approach (targets defined solely at EU level and not translated to into binding national targets as in the 2010-2020 period - NREAP-s) needs to build on the Energy Union Governance and Member States' national energy and climate plans for the period up to 2030, which are expected to include national contributions towards the EU-level renewable energy target. In addition, the new framework also enables the collective delivery to be done without preventing Member States from setting their own, including more ambitious, national targets. Member States can support renewable energy, subject to State aid rules.

These targets aim to help the EU achieve a more competitive, secure and sustainable energy system and to meet its long-term 2050 greenhouse gas reductions target, i.e. reducing EU GHG emissions by 80%. The objective of the strategy is to send a strong signal to the market, encouraging private investment in new pipelines, electricity networks, and low-carbon technology. The targets were based on a thorough economic analysis measuring how to achieve decarbonisation by 2050 in a cost effective way.

Given that the renewable energy target for 2030 is binding on the EU as a whole, it is necessary to:

1. create a market-based environment in which renewables can attract the required investments cost-efficiently;

2. foster regional cooperation and regional projects;

3. empower consumers to deploy cost-optimal renewable energy solutions;

4. incentivise the roll-out of new and innovative technologies; and

5. ensure that any potential gap arising in reaching the at least 27% renewable energy target, in terms of either ambition or delivery, is filled.

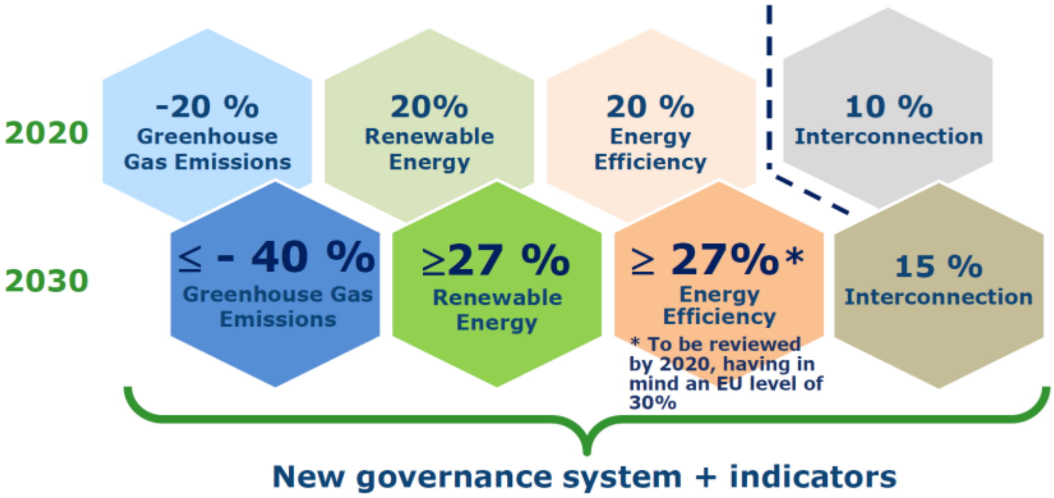

Figure 6: The EU 2030 goals

The **Energy Union** strategy adapted in 2015 builds further on the 2030 Framework for Climate and Energy and the Energy Security Strategy. The overall aim of the Energy Union is to facilitate the free flow of energy across borders and a secure supply in every EU country and put the consumer at the centre stage. The Energy Union also targets the development of new technologies and renewed infrastructure that will contribute to cutting household bills and creating new jobs and skills. It will lead to a sustainable, low carbon and environmentally friendly economy, putting Europe at the forefront of renewable energy production, clean energy technologies, and the fight against global warming.

The Energy Union is made up of five closely related and mutually reinforcing dimensions with 15 concrete actions and 43 initiatives:

- security, solidarity and trust: diversifying Europe's sources of energy and ensuring energy security through solidarity and cooperation between EU countries
- a fully integrated internal energy market: enabling the free flow of energy through the EU through adequate infrastructure and without technical or regulatory barriers
- energy efficiency: improved energy efficiency will reduce dependence on energy imports, lower emissions, and drive jobs and growth

- decarbonising the economy: the EU is committed to a quick ratification of the Paris Agreement and to retaining its leadership in the area of renewable energy
- research, innovation and competitiveness: supporting breakthroughs in low-carbon and clean energy technologies by prioritising research and innovation to drive the energy transition and improve competitiveness. Its key implementing pillar is the **Strategic Energy Technology Plan (SET Plan)**, which aims to accelerate the development and deployment of low-carbon technologies (Figure 7).

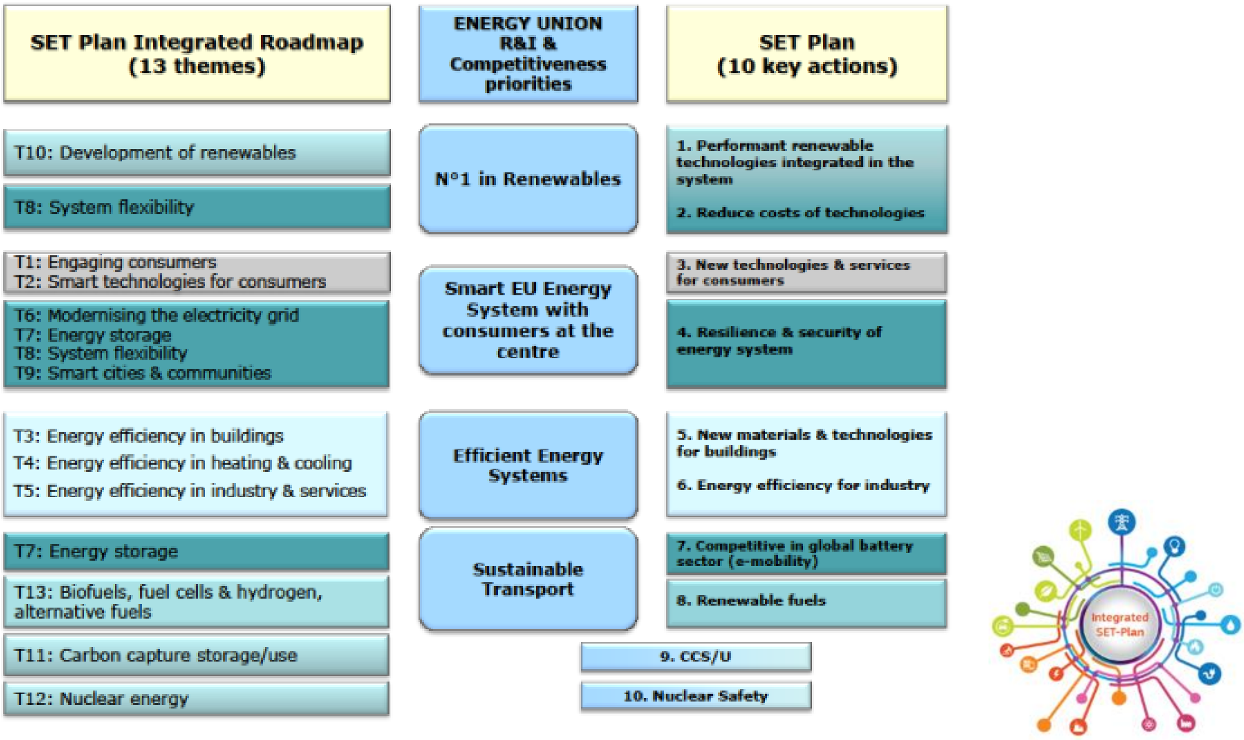

Figure 7: The SET Plan Roadmap and key actions

The SET Plan recognises the essential role of renewables (RES) as part of the EU's strategy to improve energy security, create markets for highly innovative technologies that are useful for society and where European industry can lead.

The European Energy Research Alliance (EERA) established in 2008 became the public research pillar of the SET Plan, whilst the European Technology and Innovation Platforms (ETIP-s) the industrial pillars which bring together stakeholders from industry and research to define short- and long-term research and technological development objectives. Both EERA and ETIP-s have strong links to geothermal: the EERA Joint Program on Geothermal and the ETIP-s on Deep Geothermal Energy and on Renewable Heating and Cooling.

Given DARLINGe goals' strong links to heating, the **EU Strategy for Heating and Cooling** also has to be mentioned. In EU households, heating and hot water alone account for 79% of total final energy use (192.5 Mtoe), while in industry 70.6% of energy consumption (193.6 Mtoe) was used for space and industrial process heating. 84% of heating and cooling is still produced by the combustion of fossil fuels (oil, gas and coal) with a damaging environmental impact associated with greenhouse gas emissions and also from resource extraction processes. It also raises strong concerns about the security of supply: the EU's building sector consumes up to 61% of all net imported gas, mainly from Russia) (Figure 8).

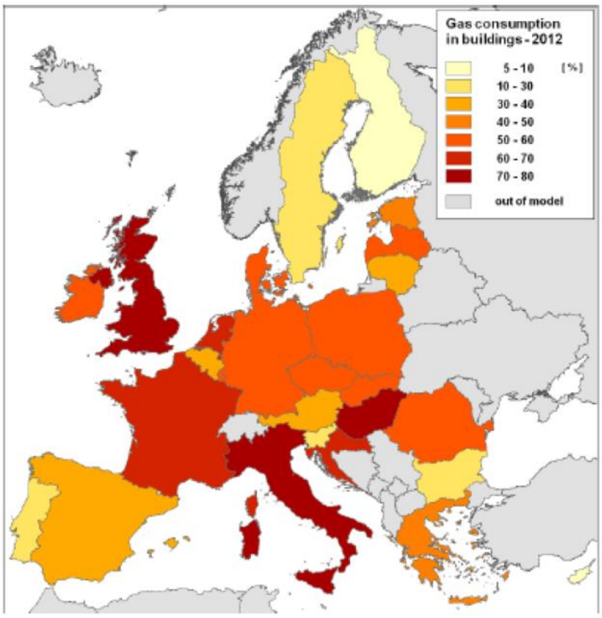

Figure 8: Gas consumption in residential buildings in 2012. Source: Joint Research Centre, "Energy Renovation, the trump card for the new start for Europe", March 2015

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Although the current policy framework foresees an increase in the use of renewable energy in the heat sector up to 21.4% in 2020, the post-2020 the sector will remain dominated by imported fossil fuels (Figure 9).

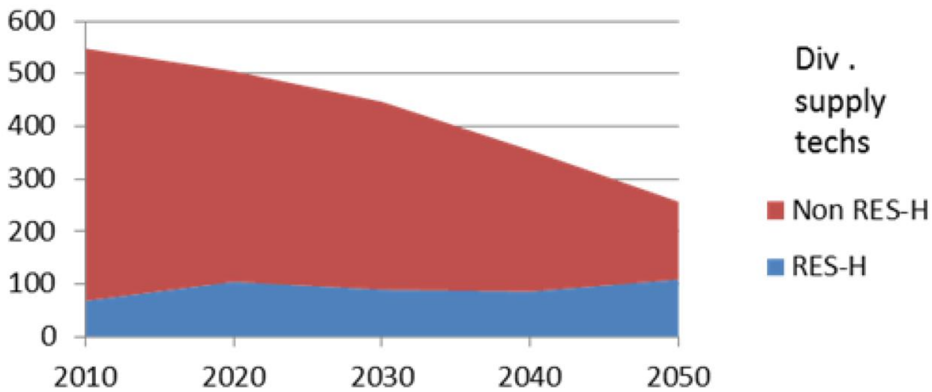
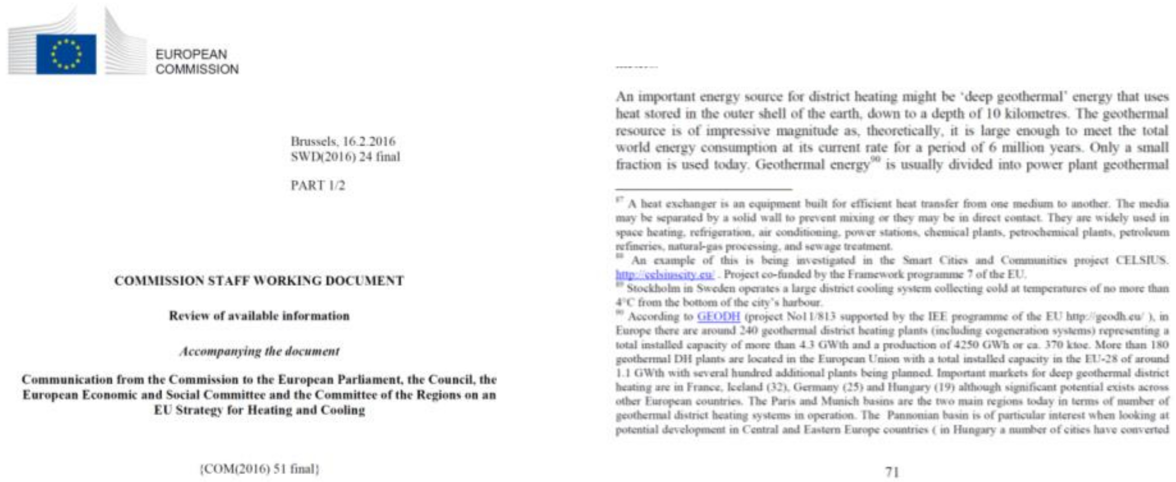


Figure 9: Trends in Heat production (Mtoe). Source: EGEC policy paper on the European Commission's "Energy Roadmap 2050".

In order to fulfil the EU's climate and energy goals, the heating and cooling sector must sharply reduce its energy consumption and cut its use of fossil fuels. To face these challenges the Commission proposed an EU heating and cooling strategy in 2016, realizing that although various EU instruments have relevance for heating and cooling (e.g. Energy Efficiency Directive, Energy Performance of Building Directive, EU Ecodesign and Energy labelling framework, Renewable Energy Directive, EU Emissions Trading System) as they provide for specific measures regulating or influencing heat consumption or production, but often only indirectly target heat. The Strategy provides a framework for integrating efficient heating and cooling into EU energy policies by focusing action on stopping the energy leakage from buildings, maximising the efficiency and sustainability of heating and cooling systems, supporting efficiency in industry and reaping the benefits of integrating heating and cooling into the electricity system. Its accompanying working document (Figure 10) refers directly to the importance of geothermal district heating and its large untapped potential, especially in the Pannoninan Basin region (DARLINGe project area).



EUROPEAN COMMISSION

Brussels, 16.2.2016
SWD(2016) 24 final

PART 1/2

COMMISSION STAFF WORKING DOCUMENT

Review of available information

Accompanying the document

Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy for Heating and Cooling

{COM(2016) 51 final}

An important energy source for district heating might be 'deep geothermal' energy that uses heat stored in the outer shell of the earth, down to a depth of 10 kilometres. The geothermal resource is of impressive magnitude as, theoretically, it is large enough to meet the total world energy consumption at its current rate for a period of 6 million years. Only a small fraction is used today. Geothermal energy[90] is usually divided into power plant geothermal

[87] A heat exchanger is an equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment.

[88] An example of this is being investigated in the Smart Cities and Communities project CELSIUS. http://celsiuscity.eu/ . Project co-funded by the Framework programme 7 of the EU.

[89] Stockholm in Sweden operates a large district cooling system collecting cold at temperatures of no more than 4°C from the bottom of the city's harbour.

[90] According to GEODH (project No11/813 supported by the IEE programme of the EU http://geodh.eu/), in Europe there are around 240 geothermal district heating plants (including cogeneration systems) representing a total installed capacity of more than 4.3 GWth and a production of 4250 GWh or ca. 370 ktoe. More than 180 geothermal DH plants are located in the European Union with a total installed capacity in the EU-28 of around 1.1 GWth with several hundred additional plants being planned. Important markets for deep geothermal district heating are in France, Iceland (32), Germany (25) and Hungary (19) although significant potential exists across other European countries. The Paris and Munich basins are the two main regions today in terms of number of geothermal district heating systems in operation. The Pannonian basin is of particular interest when looking at potential development in Central and Eastern Europe countries (in Hungary a number of cities have converted

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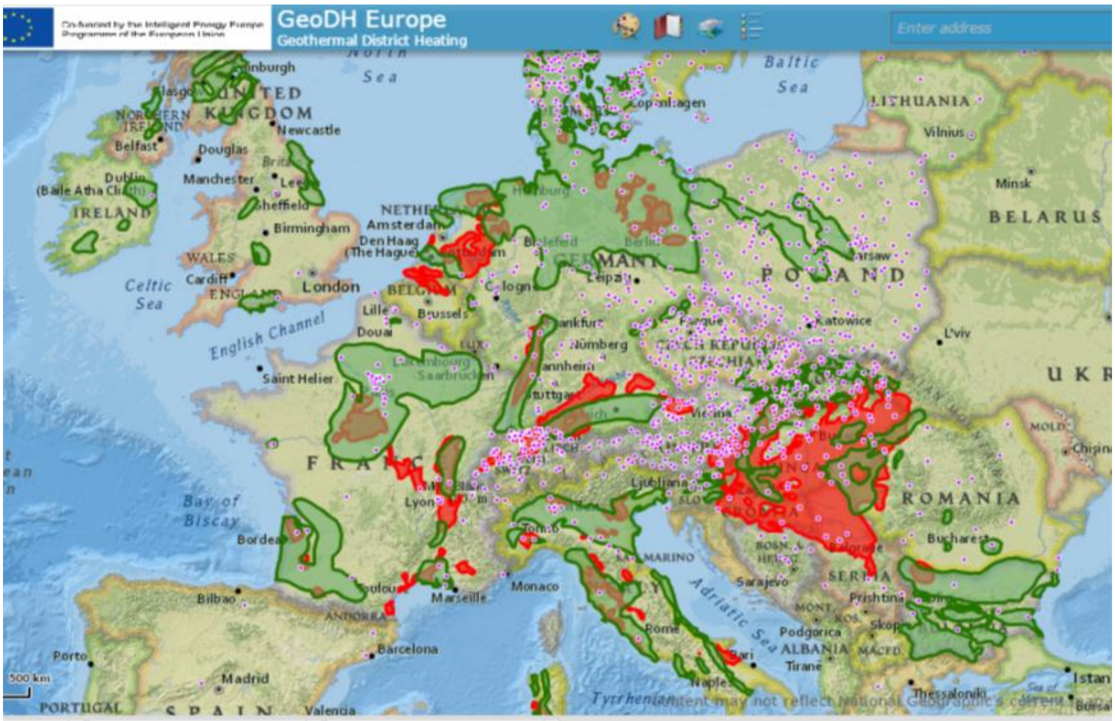

Figure 10: The supplementary material for the EU Heating and Cooling Strategy emphasizes the importance of geothermal district heating and its large untapped potential in the DARLINGe region

In addition to the aforementioned key strategic documents, the main EU regulations affecting the geothermal energy sector are connected to protocols on energy, water and environment and are summarized briefly below.

The most important **energy-related** regulation is the **Directive 2009/28/EC** on the promotion of the use of energy from renewable sources (RES). This Directive establishes a common framework for the promotion of energy from renewable sources. It favoured the rapid deployment increase in the share of renewables from 10.4% in 2007 to 17% in 2015.

In relation to deep geothermal energy for heating it **defines geothermal energy** [Art 2 (c)], sets mandatory national targets for the overall share of energy from renewable sources in gross final energy consumption [Art 3], prescribes the adoption of the national renewable energy action plan (NREAP) for each Member State [Art 4], requires Member States to streamline and rationalize relevant administrative procedures [Art 13 (1)], recommend all actors to consider the installation of equipments and systems for the use of electricity/heating-cooling from renewable energy sources when planning local infrastructures [Art. 13 (3)], and to introduce, where appropriate the use minimum levels of renewable energy in buildings (e.g. geothermal district heating) [Art. 13 (4-6)].

In 2016, the Commission published a proposal (COM(2016) 767 final/2) for a **revised Renewable Energy Directive (RED II)**. The recast of the RESD Directive was necessary, because EU energy system projections indicated that current Member States and EU policies, if no new policies are put in place, would only lead to approximately 24.3% of renewable energy consumption in 2030. This level would be well below the at least 27% EU level binding renewable energy target, and would prevent the Union from collectively delivering on the commitments made in the 2015 Paris Agreement. At the same time, and in the absence of an updated regulatory framework, there is a risk that greater differences within the EU will arise, whereby only the best performing Member States will continue the increasing trajectory in renewables' consumption, while those who are lagging behind will not find any incentive to increase their production and consumption of renewable energy and this would further distort the internal energy market. This is especially relevant for the DARLINGe countries.

This new policy framework – as part of the Clean Energy for All Europeans Package:

• provides long-term certainty for investors and speeds up procedures to receive permits for projects

• puts the consumer at the centre of the energy transition with a clear right to produce own renewable energy (“prosumer”)

• increases competition and market integration of renewable electricity

• accelerates the uptake of renewables in the heating/cooling and transport sectors

• strengthens the sustainability of bio-energy and promotes innovative technologies

The main provisions which substantially change Directive 2009/28/EC or add new elements are the following (only those listed that are relevant for deep geothermal):

- Article 3 sets out the 2030 EU target. It establishes the 2020 national targets as baseline (i.e. Member States cannot go below the 2020 national targets from 2021 onwards
- Article 4 lays down the general principles that Member States may apply when designing cost-effective support schemes to facilitate a market-oriented and European approach, subject to State aid rules.
- Article 15 includes a new calculation methodology (anchored on the Energy Performance of Buildings Directive) of minimum levels of energy from renewable sources in new and existing buildings that are subject to renovation.
- Article 16 establishes a permit granting process for renewable energy projects with one designated authority ("one-stop-shop") and a maximum time limit for the permit granting process.
- Article 23 aims to exploit the renewables potential in the heating and cooling sector, ensuring a cost-efficient contribution of the sector to target achievement, and to create a larger market for RES-H&C across the EU. Accordingly, Member States will endeavour to achieve an annual increase of 1% in the share of renewable energy in the heating and cooling supply. Member States will decide how to implement it.
- Article 24 empowers energy consumers by providing them information of district heating energy performance, and enabling them to stop buying heat/cold from a district

heating/cooling system at building level if the consumers, or a party on their behalf, can achieve a significantly better energy performance by measures taken at building level. It also opens local heating and cooling systems for producers of renewables heating and cooling and waste heat or cold and third parties acting on their behalf.

The EU Directive **2010/31/EU on energy performance of buildings** applies to new and existing buildings undergoing major renovation: high-efficiency alternative systems (e.g. geothermal district/block heating) need to be considered before construction. All new buildings owned, or occupied by public authorities must become "nearly zero-energy" by the end of 2018, and all new private buildings by 2020.

According to the **EU Directive 2012/27/EU on energy efficiency** Member States have to set up energy efficiency obligation schemes to achieve new savings each year of 1.5% of the annual energy sales to final customers. In order to improve energy efficiency Member States must assess the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, which paves the road for the application of various geothermal technologies as well.

In 2018 the European Parliament finally approved the revision of the Renewable Energy Directive (RED) and the Energy Efficiency Directive (EED), to make them fit for the challenges and commitments up to 2030. The Renewable Energy Directive contains new important measures for the deployment of renewable heating and cooling technologies, setting an ambition of a yearly increase of the share of RES in heating and cooling of 2 percentage points in the next decade (recast of Art. 23). Yet, as Member States do not have to abide to an obligatory target for such a critical sector, uncertainty remains for renewables in heating and cooling.

Among the **water-related regulations**, the most important is the **Water Framework Directive (2000/60/EC)**, whose ultimate goal is to achieve/maintain the good quality and quantity status of (groundwater) bodies by 2015 („environmental objectives"). Considering that geothermal aquifers can be also seen as (parts of) groundwater bodies, their good quality (amount) and quantity (hydrogeochemical composition) status are essential to ensure sustainable production of thermal water (carrying medium of geothermal energy). The good quantity status means that the available groundwater resource is not exceeded by the long-term annual average rate of abstraction (no overexploitation), whereas the good quality status means that there are no effects of saline or other intrusions, and water chemistry values do not exceed the Community quality standards. Provisions related to groundwater quality are further emphasized in the **Groundwater Directive 2006/118/EC.**

Reinjection, as an important aspect of thermal water utilization for direct use purposes are addressed in several water-related legislations. Art. 11 of the WFD gives Member States the option to authorize the reinjection into the same aquifer of used geothermal water as long as it does not compromise the environmental objectives (i.e. good quality status). National governments have the competency to decide as to whether reinjection of the geothermal fluids is required. The Groundwater Directive includes principles for the assessment of good groundwater chemical status and criteria for the identification and reversal of significant and sustained upward trends. Reinjection of water into the aquifers is also mentioned in Articles 4, 6, 10 and 17 of the **Directive 80/68/EEC on the protection of groundwater against pollution** caused by certain dangerous substances. Accordingly, Member States may, after prior investigation, authorize reinjection of water used for geothermal purposes into the same aquifer on a case-by-case basis only if there is no risk of polluting the groundwater. With regard to discharges into transboundary groundwater aquifers, the competent authority of the Member State which intends to grant authorization for such discharges shall inform the other Member States concerned before an authorization is issued.

Environmental-related EU legislations are not geothermal specific, they rather ensure that plans, programmes and projects likely to have significant effects on the environment are subjected to an environmental assessment prior to their approval or authorisation (Directive 2011/92/EU on Environmental Impact Assessment), not threatening the habitats (Directive 92/43 on the conservation of natural habitats and of wild fauna and flora), and establish the 'polluter-pays' principle to prevent and remedy environmental damages (Directive 2004/35/EC on environmental liability). According to the EIA Directive, the **national authority** determines whether and which geothermal projects should be subject to an environmental impact assessment.

3.1.3. Energy policy at macro-regional level in the Danube Region

In order to increase growth and strengthen cooperation at macro-regional level, the European Union adopted its second macro-regional strategy, the EU Strategy for the Danube Region (EUSDR) in 2011, during the Hungarian EU presidency. Since its creation, the Strategy aims at forming synergies and coordination between existing policies and initiatives taking place across the Danube Region when tackling common challenges and sharing common benefits.

The region is comprised of 14 countries altogether, nine EU member states (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia and Slovenia), three accession countries (Bosnia and Herzegovina, Montenegro, Serbia) and two neighbour countries (Moldova and Ukraine) (Figure 11) with significant economic and social inequalities, disparities. The cooperation in the framework of the EUSDR facilitates sustainable economic growth, and aims at reducing regional differences between countries.

The EUSDR has 4 pillars and 11 priority areas (PA) to harmonize the development policies within this heterogeneous macro-region, in which Priority Area 2 ('To encourage more sustainable energy') – coordinated by Hungary and the Czech Republic – is dealing with energy issues.

In line with the Energy Union Strategy, the key challenge to be addressed in the Danube Region in terms of energy is to provide secure, affordable and sustainable energy. Therefore PA2 has chosen a threefold approach:

- Coordinating regional energy policies
- Generating and supporting projects
- Enhancing cooperation with other initiatives

Figure 11: Countries of the EUSDR

In line with the Europe 2020 Strategy, the EU has been making significant efforts for completing the internal energy market and moving towards a competitive low carbon economy. Increased share of renewable energy, improvements in energy efficiency as well as better and smarter energy infrastructure are essential to achieve these objectives. The Priority Area committed itself in assisting to achieve these goals through the promotion of the use of sustainable energy sources and diversification of supply.

The EUSDR adopted its Action Plan in 2010 and it is currently under revision. The Action Plan is the key document of the Strategy, which sets the goals, targets and actions of each priority area. The current **Action Plan of PA2** focuses on four topics: energy infrastructure, energy markets, energy efficiency and renewable energy. In the last years energy security was the main topic within the area but due to the changing attitude in energy related issues, **the focus slowly shifts towards energy efficiency and renewable energy** and the Priority Area is currently working on the elaboration of new actions and priorities. In the following targets and related actions relevant for DARLINGe are summarised briefly.

<u>Target I: To help to achieve the national targets based on the Europe 2030 climate and energy targets</u>

Action 1: To further explore the sustainable use of biomass, solar energy, geothermal, hydropower and wind power to increase the energy autonomy and to promote and support multipurpose cross border RES utilization projects.

In order to contribute to the dissemination of the renewable energy sources use in the region, Priority Area 2 of the EUSDR should provide data and overview for the policy makers and focus on sharing best practices (including learning from inadequate practices) to support achieving 2030 climate-energy targets and to help countries to successfully navigate to meet the energy challenges of the 21st century.

Action 2: To facilitate networking and cooperation among national stakeholders (national and local authorities, businesses and citizens) in order to promote energy efficiency, mitigation of climate change and to increase the use of renewable energies.

Relevant institutions, policy-makers, actors from the private and public sector, universities and other stakeholders on different levels are crucial for tackling various issues across the member states. In the Danube Region the heterogenity of experiences and knowledge of the many stakeholders on the national and local level posses a unique opportunity for information sharing based cooperation. In the following years, PA2 should pay greater attention to the "last segments of the chain" in the energy field – its users and local stakeholders. It is necessary for PA2 to focus on engaging private and public authorities, providing information on financing opportunities and setting up exchange and cooperation channels based on the concrete needs in order to promote energy efficiency, mitigation of climate change and to increase the use of renewable energies.

Action 3: To improve energy efficient, cost efficient and innovative low-carbon technologies, including smart solutions while respecting the principle of technological neutrality.

Transitioning from a carbon-intensive economy to a low-carbon future presents challenges and opportunities for less developed countries. As the EU strives to improve its economic competitiveness, energy security as well as reducing emission, which is well reflected in the policy frameworks of the Energy Union Strategy (from 2015), as well as the EU energy efficiency targets for 2030, we need to support the increase of energy efficiency at all stages of the energy chain from its production to its final consumption. In order to support the development of research and innovation activities in the countries of the Danube Region, PA2 will offer the opportunity to develop cross-linkages between various actors, e.g. enterprises, R&D institutions and public sector and support the development of project ideas, sharing of experience and providing networking platform in the field of sustainable use of RES.

<u>Target II. To remove existing bottlenecks in energy to fulfill the goals of the Energy Union within the Danube Region</u>

Action 4: To promote energy efficiency and use of renewable energy in buildings and heating systems including district heating and combined heat and power facilities.

The Directive on Energy Efficiency (EED) (2012/27/EU) lays down the EU 20% headline target for energy efficiency and establishes a common framework of measures for the promotion of energy efficiency within the EU. In general, energy efficiency - which is below the EU average in most of the EUSDR countries - has to be increased at all stages of the energy chain from generation to final consumption. Measures should focus on sectors where the potential for savings is greatest such as buildings. Heating and cooling are the largest single source of energy demand in Europe and is also a low-developed sector within the Danube Region with lot of obsolete heating systems. In order to fulfil the EU's climate and energy goals, this sector must sharply reduce its energy consumption and cut its use of fossil fuels.

Action 6: To exchange best practices and to develop activities to decrease energy poverty, to increase the protection of vulnerable consumers and to empower consumers to engage in the energy market.

Energy poverty – when households are not able to adequately heat their homes at an affordable cost – is estimated to affect around 54 million people. The scale of the problem is due to rising energy prices, low income and poor energy efficient homes, and it is particularly prevalent in Central, Eastern and Southern Europe. A comprehensive synthesis study needs to be commissioned regarding the energy poverty situation in the Danube Region, identifying existing economic, political and technical bottlenecks and putting forward appropriate policy measures.

Target III. To better interconnect regions by joint activities with relevant initiatives and institutions

Action 8: To ensure that actions are coherent with the general approach of the Energy Community and explore synergies between the Energy Community and the Danube Strategy processes

The Energy Community which has been established in 2005 with the aim to implement the relevant EU energy acquis communautaire, to develop an adequate regulatory framework and to liberalize their energy markets in line with the acquis under the Treaty, is the most important part of the Priority Area 2 in terms of cooperation with the non-EU participating countries. In order to support the non-EU participating countries, the Priority Area 2 should ensure that its actions are coherent with the general approach of the Energy Community and to support sharing of information and encouraging cooperation either on the policy level or the project level between the EU and non-EU participating countries.

Action 10: To encourage exchange of information and best practices to improve cooperation, create synergies and to initiate joint projects with other macro-regional initiatives and relevant stakeholders from national, European and global level.

The number of initiatives to establish and strengthen links among EU and non-EU countries is constantly growing. However, the EUSDR should further explore synergies with other macro- regional strategies (EUSBSR, EUSALP, EUSAIR, Carpathian Convention, Energy Community, etc.) as well as with other regional, international initiatives.

3.1.4. RES / geothermal policies at national levels in the DARLINGe countries

Of all the participant countries, **Bosnia and Herzegovina** has the most complex policy system. The partly independent regions, called Entities (Federation of Bosnia and Herzegovina, Republic of Srpska and the Brčko District) are competent for their energy policies, while at state level the Ministry of Foreign Trade and Economic Relations of Bosnia and Herzegovina (MOFTER B&H) is responsible for overall energy issues and coordination with respect to international integration and obligations.

Based on the Action Plans of the two Entities and aimed at implementing the RES Directive (2009/28/EC), MOFTER B&H developed "Renewable Energy Action Plan of Bosnia and Herzegovina" (NREAP B&H), adopted in 2016 which has a binding target of 40% share of energy from renewable sources in the gross final energy consumption in B&H in 2020. In the heating and cooling sector, an increase in the share of renewable energy sources is envisaged, from 805.8 ktoe in the baseline year to 1,085.2 ktoe in 2020. This will increase the share of energy from renewable sources from 43.3 % to 52.4 %, meaning a 9.1 % increase. Nevetheless the BH NREAP is based largely on hydro-energy and to a smaller extent on biomass, solar and wind energy with a subordinate role of geothermal energy (some increase from the current 0,5%) in the heating sector.

Croatia's energy strategy was elaborated and accepted by the Parliament in 2009. The Energy Strategy is adopted for the period until 2020. The goals of the Strategy are to build a sustainable energy system that makes a balanced contribution to security of energy supply, increase competitiveness and environmental protection and to provide a secure energy supply to the Croatian citizens and business sector. In October 2018 an analysis and background for the elaboration of the Energy Strategy has been intoduced which will be pillar for new energy startegy.

The following elements are recognized as the main determining factors in the energy sector:

• increasing energy efficiency in all parts of the energy chain (production, transport/transmission, distribution and consumption of all forms of energy);

• moving as many activities as possible to the use of electricity (where technologically possible and cost-effective in the long term);

• production of electricity with reduced greenhouse gas emissions (renewable energy sources, nuclear - optional, low emission specific fossil fuels and fossilized CO_2 emission and storage technology).

The Croatian NREAP predicts a 39% RES share in electricity production and 19.6% in heating and cooling from geothermal sources.

The ultimate document of **Hungary's energy policy** is the **„National Energy Strategy 2030"** which was elaborated in 2010-2011. The National Energy Strategy's main goal is to seek ways out of the country's energy dependency and ensure the long-term sustainability, security and economic competitiveness of energy supply. The ways to achieve the above goal include energy savings, increasing the share of renewable energy sources, use of safe nuclear energy, the establishment of bipolar agriculture enabling to shift between food production and energy-geared biomass production, and integration to the European energy infrastructures. It is based on the 'Nuclear-Coal-Green' scenario and its most important elements are as follows:

• the long-term preservation of nuclear energy in the energy mix;

• the maintenance of the current level of coal-based energy generation, with full compliance with the committed sustainability and GHG emission criteria (carbon capture and clean coal technologies);

• the linear extension of Hungary's National Renewable Energy Action Plan (NREAP) after 2020.

The main areas of the Energy Strategy where different actions will contribute to the sustainable and secure energy supply are the following:

In terms of *energy savings* the aim is preferably to reduce the 2010 level of domestic primary energy use of 1085 PJ. Hungary's National Reform Programme set an indicative, voluntary energy saving target of 10% up to 2020. The key components of energy savings comprise the building energy programme, replacing of obsolete, low-efficiency coal- and gas-based power plants, reducing grid-loss and replacing low-efficiency renewables and the reduction of the energy needs of industrial workflows and transport. Energy-efficiency projects in the building sector are key components. The goal is to reduce, the heating energy requirements of buildings by 30% by 2030 through energy-efficiency programs in the building sector in accordance with European Union targets.

The increase of the share of renewable energy in primary energy use from the current 7% to the vicinity of 20% by 2030 is a key component of the sustainable energy supply. The estimates for growth until 2020 (the target set being a share of 14.65% in terms of gross final energy consumption) are described in detail in Hungary's NREAP. In terms of renewable energy sources, combined heat and power biogas and biomass power plants and geothermal energy utilisation will be treated as priorities. The geothermal target number is 16423 PJ by 2020.

For the *modernisation of community district heating and private heat generation,* the competitiveness of the district heating services must be ensured, for which technology development and the use of renewable energy sources are indispensable. The share of the generation of renewable heat energy within the total heat energy consumption is expected to increase to 25% from the current 10% by 2030.

Romania's national energy strategy for the period 2015-2035 has the following objectives:

- Security of energy supply and ensuring the social and economic development in the context of a future energy demand;
- Ensuring economic competitiveness by maintaining a bearable price to final consumers;

- Protection of the environment through the limitation of the effects of climate change.

Considering these principles Romania wishes to establish a diverse and balanced energy mix, using efficiently all sources of primary internal energy, as well as modern technologies that allow a long-term use of fossil fuels with low-emission of greenhouse-effect gases, and sources of renewable and nuclear energy.

The policy framework for 2030 is based on the full implementation of the 20/20/20 targets including new targets, like maintaining the dynamism that underpins the development of renewable energy sources. The geothermal target number in Romania's NREAP is 3,349 PJ by 2020. In next years, Romania's energy strategy must be based on the following tasks: energy efficiency, efficient systems to support renewable energy, encouraging research and development, nuclear energy, hydrogen–based energy, natural gas as transition fuel, full integration into the internal energy market.

In **Serbia** the Energy Law defines the measures and activities to be undertaken for achieving the long-term targets of safe future energy. Among the other measures, competitive energy market, reliable and sustainable energy-related systems, energy efficiency and production of energy from renewable energy sources (RES) and combined electricity and heat production are in the focus. Serbia targets 27% share for renewable energy sources in the gross final energy consumption in 2020 (with a 10.2% of RES in the heating and cooling sector achieving an increase from 1 059 ktoe to 1167 ktoe.). RES share in building sector by the year 2020 is projected on 35%: residential 27%, public 5%, industrial 3%, nevertheless geothermal is not foreseenat all. In the overall share of RES in the energy use geothermal energy also have a subordiate role at the expense of wind and hydro power plants and biomass to a smaller extent. In addition a set of energy sector development strategy documents have been established: National renewable energy action plan of the Republic of Serbia; Energy sector development strategy of the Republic of Serbia for the period by 2025 with projections by 2030; The Third action plan for energy efficiency of the Republic of Serbia for the period by 2018.

The new strategy, the **Energy Concept of Slovenia** (EKS) and the Long-Term Development Strategy of Slovenia until 2050 are under preparation at the moment. EKS's gives directions and vision of Slovenia's energy policy, which will be determined in the more concrete form of measures in future action plans. Its headline targets by 2020 are the reduction of greenhouse gas (GHG) emissions by at least 13%, have 25% share of RES in the gross final energy consumption and reach 23% primary energy savings by 20% compared to the level of the year 1990.

The key measures of the EKS are:

• Increasing energy efficiency,

• Raising awareness among consumers and providers of sustainable supply and energy management,

• Supporting the development of knowledge in the area of sustainable energy supply and energy management,

• Abandoning fossil resources and gradually switching to renewable and low carbon sources,

• Introduction of advanced energy systems and services.

In buildings, the current 40% share of the final energy consumption will be reduced by 30% by 2030 compared to 2005 due to new standards and consequently better energy efficiency of buildings, and at least two thirds of the energy consumption will be from RES.

Geothermal energy is mentioned poorly, only along aerothermal and hydrothermal energy and preferably being produced by geothermal heat pumps. Energy and economic analyses of current use will have to be tested by different scenarios for each user, together with reinjection possibilities.

In 2017 the Slovenian NREAP 2010-20120 was updated. The renewed goal for the share of RES for heating and cooling increased to 34.5 %, with overall share of RES in all three sectors (electricity, heating and cooling and transport) staying at 25 %. The renewed share of electricity dropped from 39.3% to 38.6%. Most of the renewable energy from RES is derived from wood and wood biomass.

Regarding the **state of geothermal energy** and the **regulatory framework related to the licencing procedures**, DARLINGe studies revealed that geothermal energy is state-owned in all countries, however its utilization falls under the auspices of several laws: most often Mining Law, Water Law and Law on Geological explorations. The use of geothermal energy is possible only having a licence, issued by various state authorities. While in Bosnia Herzegovina, Romania and Serbia the type of licence is irrespective of the various type of geothermal resources, in Croatia different licences apply for balneology and energy use; in Hungary the type of licence depends on the depth; whilst in Slovenia licences are differentiated whether the used water is reinjected or not. The duration of licences for exploration vary between 2 to 5 years, whilst exploitation licences are generally valid for 20 to 50 years. **None of the DARLINGe countries have binding forces on reinjection.**

3.2. Strategy to buid on: strengths and opportunities - barriers to overcome: weaknesses and threats

Renewables in general have a well articulated role in the clean energy transition in the **EU climate and energy framework package**, which goals and performance is thoroughly and continuously monitored and amended if necessary by the Commission and relevant organizations. Among renewables **geothermal energy** and its application for heating purposes is also relatively **well positioned**: the RES directive paves the pathway for the development of geothermal energy in general. Art. 13 and 23 of the RES / REDII directive, as well as EU Directives on the energy performance of buildings and on energy efficiency promote geothermal (district) heating.

Nevertheless **some targets** (e.g. 1% of a yearly increase of the share of RES in heating and cooling - recast of Art 23 of the RES Directive) **are still not ambitious enough** and the lack of binding targets might hold back the desirable growth rate (EGEC policy paper on the European Commission scenarios for the Clean Energy Package, 2017). The 2030 RES targets could also be increased to 35%, whilst the energy efficiency to 40% for consistency with the Paris Agreement (source: MEP Blanco Lopez report on the Renewable Energy Directive 2017).

Another weakness is that the existing policy framework does not address uncertainties with regard to national policies, governance and regional cooperation to ensure a timely and cost effective target achievement for the period after 2020.

In the **heating and cooling sector**, which represents almost half of the EU energy consumption, there are numerous weaknesses: the current regulatory environment does not incentivise cost-optimal deployment of renewables in heating, cooling and hot water use. The current market conditions are hampering the development of renewable heating and cooling. It includes regulated prices of gas and electricity, no carbon pricing in the heat sector which falls mainly in the non-ETS, slow opening and protection of the gas market. The increase of renewables in the heat sector has often not been driven by regulatory changes, but rather by the initiative of isolated local authorities using available EU funds to promote local development and increase security of supply.

When discussing conventional deep geothermal energy resources (like in the DARLINGe project), where the carrying medium of the heat is groundwater, i.e. the utilization of geothermal energy happens with the abstraction of thermal groundwater, there are **some discrepancies** among the policy aims. Although speaking of the same "medium" (a hydrogeothermal system) the "objects and targets" of the **water policy and the energy policy** are somewhat different. The Water Framework Directive addresses groundwater bodies (groundwater within an aquifer, in this case aquifers with thermal groundwater / geothermal aquifers) and sets up environmental targets during their use, i.e. to achieve/maintain their good quality and quatity status. With other words its attention is on the protection of the (geothermal) aquifers. At the same time the RES directive addresses the heat content (defines geothermal energy as energy stored beneath the surface) and according to the NREAP-s defines binding targets for the increased use (energy objectives). The programmes of measures are also different: the status of the groundwater bodies is assessed in the frame of national River Basin Management Plans performed every 6 years (2009, 2015, 2021, etc), whilst the progress of the NREAP-targets submitted by the Member States in 2010 is supervised every 2 years.

At macro-regional level various DARLINGe activities were identified as contributions to the different targets and actions of the PA2 Action Plan, as discussed in chapter 3.1.3. These strengths are the following:

- In the field of geothermal energy DARLINGe data, best practices are key contrbutions to Target I Action 1
- DARLINGe's Transnational Stakeholder Database and its Transnational Stakeholder Forum, as well as its established direct contacts with the local thermal water users, especially in the frame of the pilot actions is a valuable input to Target I Action 2.
- DARLINGe as leader of Thematic Pole 8 (an initiative of the Danube Transnational Program Capitalzation Strategy of thematically clustering relevant projects) has already established good connections and common platforms with other RES projects in the region (3Smart: real-time energy management in buildings and distribution grids; and ENERGY BARGE: biomass supply chain management) which network is expected to expand in the future and serves as inputs for Target I Action 3.
- DARLINGe project's main objective is tackling the decarbonisation of the heating sector in the Danube Region by an enhanced and more efficient use of geothermal energy, therefore is considered as a main contribution to Target II Action 4.
- Geothermal heat of homes can be a local and affordable solution to decrease energy poverty of the region, that serves as an input to Target II Action 6.
- The long-term strategy of DARLINGe for the durability and transferability of its results is well established. The Danube Region Geothermal Information Platform (DRGIP portal), as a web-based information system will disseminate results widely beyond the project area. The developed tool-box for sustainable management of deep geothermal resources can meet the requirements of other interested regions as well, which may stenghten the cooperation with them, thus contributing to Target III. Action 10.

At national level all DARLINGe countries have common goals regarding the aims of their energy strategies (mostly addressing security of supply, competitiveness, sustainability/ environmental protection, increasing energy efficiency and the share of renewables). Nevertheless geothermal energy per se is either not mentioned, or its importance is minimized when speaking of the increase of renewables in the heating and cooling sector (e.g. Serbia, Bosnia and Herzegovina) despite of the favourable potentials. Furthermore their NREAP target numbers are growing slower, than expected. Biomass and wind (and solar in some cases) are the preferred RES.

Regarding the **regulatory framework of geothermal energy utilization** in the DARLINGe countries, a strength is that geothermal resources are state owned and their use is well regulated (harmonized with EU legislation) and possible only based on licences issued by various authorities. Nevertheless the main weakness in all countries is the lack of a comprehensive geothermal regulatory framework, the licensing procedures are complex, lengthy and far too administrative. Laws are often changing, in many cases they are far from real situations, so it is impossible to apply them efficiently, and contain many exemptions which makes possible their vague and different interpretation by different authorities. Furthermore laws are adapted slowly, and the changing political support, as well as the passivity of decision makers often impedes the uptake of geothermal (renewable) projects.

3.3. Future vision / Recommendations

First of all a strong Energy Union requires **a clear political objective** and structural reforms **to replace natural gas consumption with local renewable energy,** which should be also reflected in the national energy strategies. A **robust and reliable governance framework**, including sound planning and steady renewable deployment trajectories is therefore needed. A **responsive policy environment** is a must.

It is necessary to **enhance the EU regulatory framework through binding measures** to ensure predictability for investors. Particular attention should be given to those measures capable of ensuring measurable increase of renewable energy, e.g. minimum share of renewable energy in buildings, district heating. At the same time **implementation of existing legislation** is also essential.

It is important **to recognize geothermal energy's essential role in the European energy transition.** Provisions supporting geothermal technologies as a solution for the decarbonization of the heating and cooling sector, in district heating services or industry uses are of otmost importance. Geothermal energy should have a much more articulated role in the national energy strategies as well.

It is important to ensure that **streamlining and improving a time-effective permitting granting processes** is performed in accordance with existing internal EU legislation, as well as the national competences and procedures enabling renewable energy deployment.

The establishment of a competent authority or authorities integrating or coordinating all permit granting processes (**'one-stop-shop'**) should **reduce complexity, increase efficiency and transparency of licensing procedures.** Administrative procedures for geothermal licensing have to be fit to purpose - they should be streamlined wherever possible and the burden on the applicant should reflect the complexity, cost and potential impacts of the proposed geothermal energy development. Licensing procedures must be simplified, and transferred to regional (or local if appropriate) administration level. However more effective and efficient administrative procedures should not compromise the high standards for protection of the environment and public participation. Transparency means that **information should be publicly available** on the licencesed objects (names of wells and springs, location, at least as the nearest settlement if not coordinates), purpose of use, licenced quantity (either per site or per an object, either cumulative abstraction or discharge rate). It is also recommended that the official time for a decision on granting the licence after the submitted application is complete should be shorter than 2 months.

When amending legislation, it is recommneded **to go beyond a 'one-size-fits-all-approach'** and to take into account the untapped potential of a wide variety of geothermal technologies, their different size, application, features, and market and technology maturity (e.g. high- or medium temperature resources, geothermal heat for district heating or industrial purposes, and geothermal heat in new or existing buildings, etc.).

Rules for district heating (DH) **should be as** decentralised **as possible in order to be adaptable to the local context,** and stipulate a mandatory minimum level of energy from renewable sources**, in line with Article 13 of the RES Directive.**

A more efficient policy framework – including binding measures – should be introduced to stimulate switching from fossil fuels to renewable heating and cooling and hot water generation in the large number of households with individual heating equipment. More targeted measures should be considered to further increase renewables deployment in the heating and cooling sector, building on and interacting with energy efficiency and security of energy supply legislation.

Renewable energy and energy efficiency generate synergies. They must be addressed at the same time in the relevant policies.

The existing nearly-zero energy building (NZEB) standards (mandatory from 2021 for all new building) should be made more ambitious to also include an obligation to use renewable energy heating (including water heating) and cooling in the existing building stock, effective if and when the building is subject to major renovation or the heating system is replaced.

At last but not at least it is also of vital importance to **harmonize the objectives and measures of the „energy" and "water/ environmental" policies.**

4. Geothermal resources and utilizations

4.1. State-of-art

The Pannonian Basin extending across nine countries in Central and Eastern Europe is well-known of its good geothermal potential (heat flow density ranging from 50 to 130 mW/m^2 with a mean value of 90-100 mW/m^2, and geothermal gradient of about 45 °C/km) due to its favourable geological conditions, being rich in thermal waters. Much of the large geothermal aquifers of this deep sedimentary basin, determined by regional geological structures, are shared by neighbouring countries and significant basin-scale cross-border groundwater flow occurs. Due to sufficient number of drillings and wells and long-term history of exploitation geological and hydrogeological conditions, especially of the thick porous basin fill sediments, and flow systems are well known at regional scales, therefore exploration risk is relatively low. Available data and knowledge serve as a good basis for further and more detailed investigations.

In DARLINGe work two main types of **potential geothermal reservoirs** were determined (Rotár-Szalkai et al. 2017): (1) the geothermal aquifers within the thick (several hundreds to several thousand meter) porous (sandy-silty) basin fill sedimentary sequence (called **"basin fill – BF reservoirs"**), and the (2) geothermal aquifers associated with fractured, karstified zones of the different carbonate and crystalline rocks forming the deep basement of the Pannoninan sedimentary basin (called **"basement – BM reservoirs"**). Detailed evaluation of geological and geothermal data (subsurface temperature distribution maps) made possible to delineate these reservoir types and within the BF reservoirs also a further subdivision according to different temperature intervals (i.e. BF30-50: porous reservoirs storing thermal waters with temperature between 30-50 °C, BF50-75: porous reservoirs storing thermal waters with temperature between 50-75 °C, etc.).

The assessment of the hydro-chemical characters of the different reservoirs allowed a regional hydro-chemical evaluation of the stored fluids as well. Thermal waters stored **in the BF reservoirs** have low mineralization with TDS less than 1000 mg/l, especially in shallower depths. However in the deeper parts of the BF reservoirs the average TDS's is around 2500 mg/l. These **chemical conditions are** nevertheless **favourable for smooth operations** (no corrosion, scaling), although locally challenging chemistry exists (high TDS, gases, aggressiveness of the water), which may cause operational issues and increase operational costs. The CH_4 content of thermal waters in BF reservoirs can be a danger for explosion.

In order to quantify the recoverable heat energy in these reservoirs, the entire project area was subdivided into 11 sub-basins. Based on the results of a simplified resource estimation (with applying Monte Carlo–based prediction) was performed (Figure 12, Table 1).

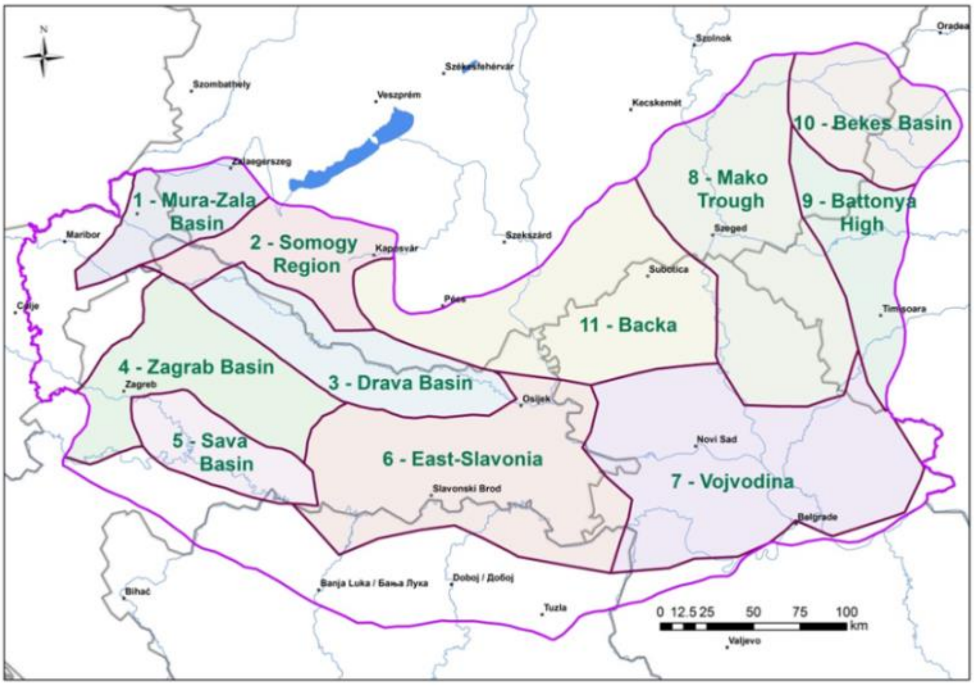

Figure 12: Regions of resources estimation

As the calculations revealed (Table 1) **the greatest heat content belongs to basin fill reservoirs having a temperature between 50-75 °C** (229 335 PJ - P50 values). The top of these reservoirs varies between -620 to -1420 m below the surface, i.e. they are easy drilling targets. Although the basin fill reservoirs of 30-50 °C have the greatest territory (Figure 11), their sum heat content (124 582 PJ – P50 values) is only a half of the BF50-75 reservoirs, which is due to their shallower depth (top surface varies between -280 to -934 m below the surface). The BF 75-100 reservoirs are more restricted in dimensions (associated with the central depression of the basins), but their heat content is still significant (101 217 PJ - P50 values), about half of the heat content of the BF50-75 reservoirs. Nevertheless they still represent easy drilling targets as the top of these reservoirs is found at a depth of -1000 to -1700 m below the surface.

The distribution of the various basin fill reservoirs with different temperature sub-categories (i.e. temperature of stored thermal water within them) are shown on Figures 13, 14, 15, 16. Basin fill reservoirs storing thermal water with temperature above 125 °C are assumed only from the deepest parts of the Dráva Basin (HR).

Region (sub-basin) ID and name	30-50 °C			50-75 °C			75-100 °C			100-125 °C			125-150 °C		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1. region Mura-Zala Basin	5365	7399	9750	6782	9395	12329	874	1201	1579	103	143	189			
2. region Somogy region	8308	11522	15169	10937	15154	20055	235	325	427						
3. region Drava Basin	9500	13014	17228	22945	32041	42005	10265	14164	18798	1933	2691	3531	90	125	164
4. region Zagreb Basin	3119	4317	5667	892	1227	1628									
5. region Sava Basin	4820	6665	8837	6888	9510	12545	372	513	680						
6. region East-Slavonia	4870	6745	8900	2159	2979	3933									
7. region Vojvodina	7776	10683	14052	1497	2075	2751									
8. region Mako Trough	27219	37607	49658	78234	108496	143502	42474	59153	78067	9575	13278	17482			
9. region Battonya High	5562	7628	10077	6499	8924	11835	1597	2213	2930						
10. region Bekes Basin	10057	13925	18391	26802	37267	49258	17255	23648	31213	3509	4832	6410			
11. region Backa / Bačka	3637	5032	6633	1629	2267	2976									

Table 1: Estimated heat content of effective porosity in the BF reservoirs in the different sub-basins, confidence levels at P10, P50, P90

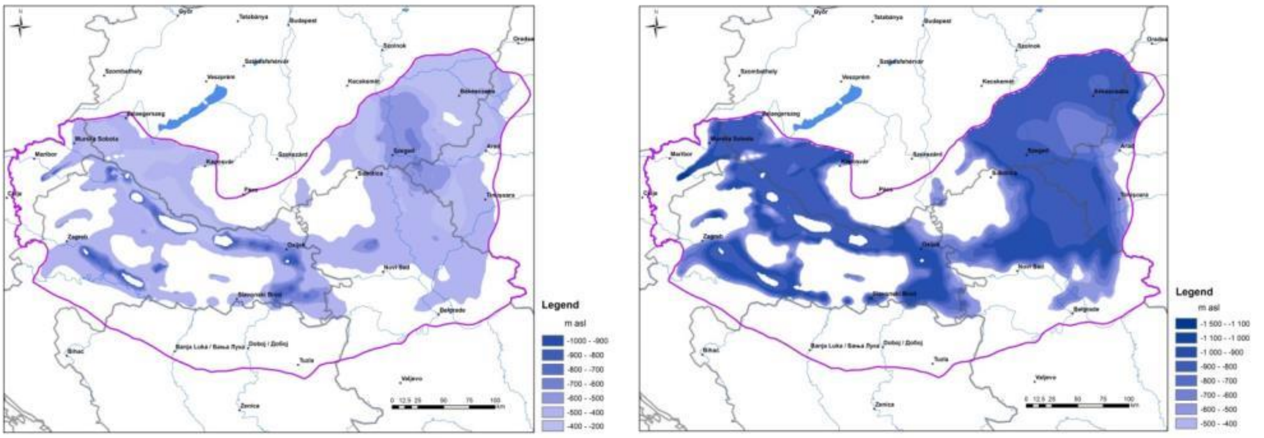

Figure 13: Top and bottom surfaces of the BF30-50 reservoirs. They are regionally extended in the entire project area (except for the marginal S-ern parts of the Pannonian Basin in Bosnia Herzegovina and S-ern Vojvodina in Serbia, the W-ern marginal parts in Croatia and Slovenia and the slightly elevated Backa region) with an average depth between 400/600 m (top) to 800/1000 m (bottom) below the surface.

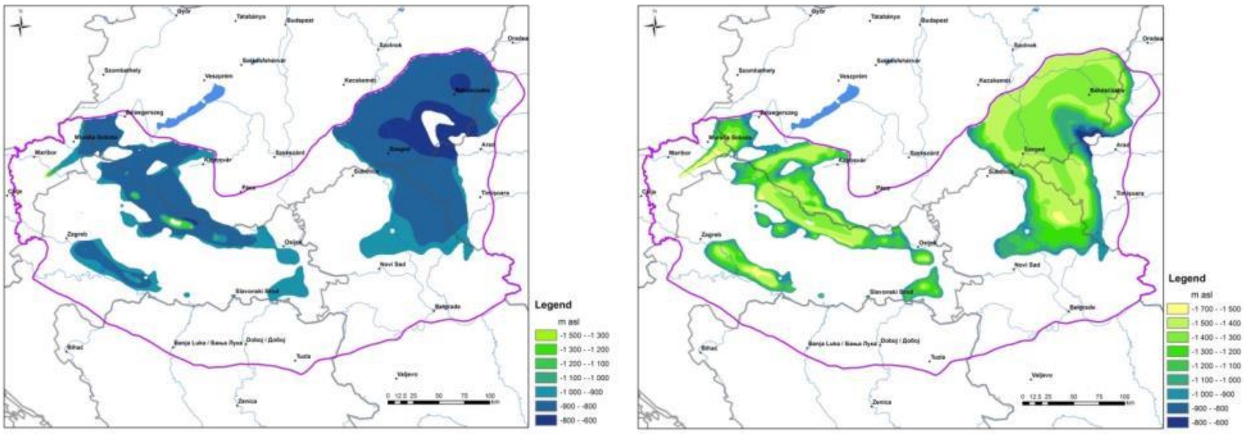

Figure 14: Top and bottom surfaces of the BF50-75 reservoirs. Their extension is still considerable, (however smaller than the BF30-50 reservoirs - Figure 11) especially in the Mura-Zala, Dráva and Sava basins (HR, SLO, HU areas) as well as in the SE-ern part of the Great Hungarian Plain (Makó Trough, Békés Basin, Vojvodina) with an average depth between 1000/800 m (top) to 1200/1400 m (bottom) below the surface.

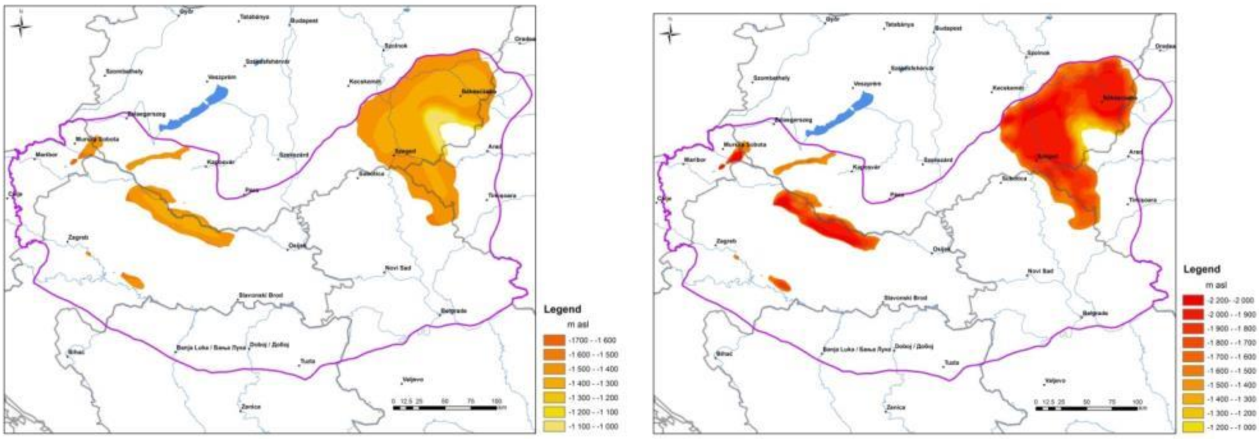

Figure 15: Top and bottom surfaces of the BF75-100 reservoirs. Their extension is further limited to the Dráva Basin (HR-HU cross-border area) and to the Makó Trough –Békés Basin areas (HU, RO, SRB), and only small occurences exist in the Mura-Zala and Sava Basins and in the S-ern part of the Makó Trough with an average depth between 1300/1500 m (top) to 1800/2000 m (bottom) below the surface.

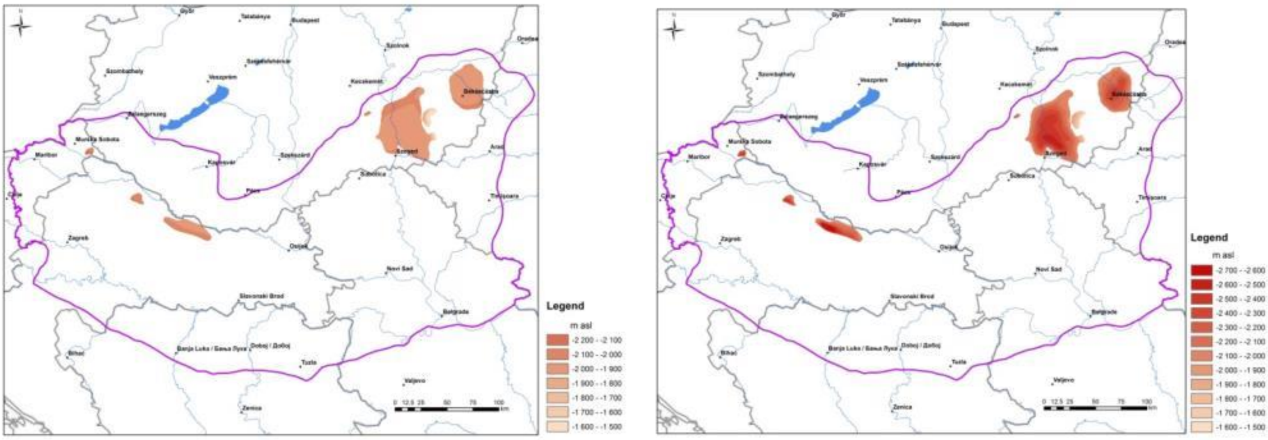

Figure 16: Top and bottom surfaces of of the BF100-125 reservoirs. They occur only in the deepest (central) parts of the Drava Basin the Makó Trough and the Békés with an average depth around 2500 m (top) to 3000 m (bottom) below the surface.

The **current utilization of these geothermal reservoirs** (thermal water aquifers) is widespread (Rman et al. 2017). Altogether **767 geothermal objects** (mostly thermal water wells, and to a smaller extent springs, by agreement those ones having outflow temperature higher than 30 °C) were identified on the project area with a great diversity in their number and distribution among the participating countries (Table 2, Figure 17).

Country	No. of objects	Project area (km²)	No. of objects per km²	No. of objects per 1000 km²
BA	10 wells	11,590	0.0009	0.9
HR	6 springs and 21 wells	27,690	0.0010	1
HU	606 wells	23,150	0.0262	26.2
RO	55 wells	8,033	0.0068	6.8
RS	1 spring and 24 wells	24,010	0.0010	1
SI	44 wells	4,874	0.0090	9
Project area	***767***	***99,347***	***0.0077***	***7.7***

Table 2: Number and distribution of geothermal objects in the DARLINGe area

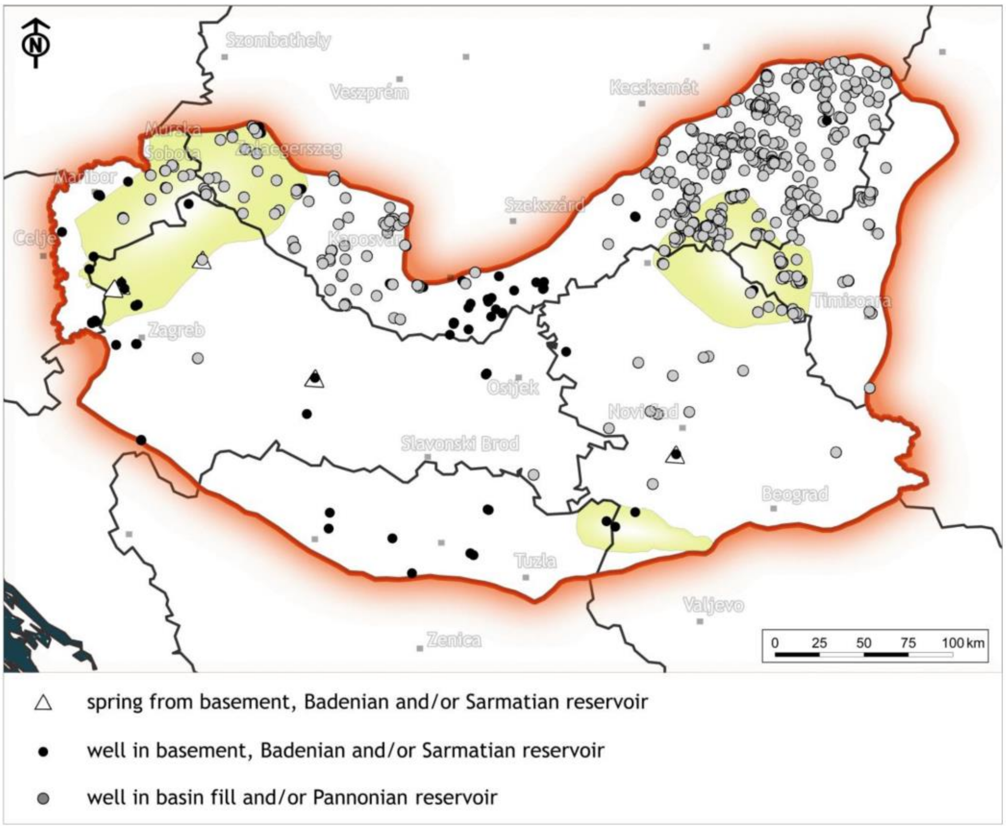

Figure 17: Distribution of geothermal objects on the project area. Majority of the thermal water wells produces from "basin fill" reservoirs

The average operational depth of the thermal water wells is appr. 1145 m with a great diversity among the countries (Figure 18), which is related to the geological position (i.e. shallower depths at the basin margins and deeper wells in the basin centres).

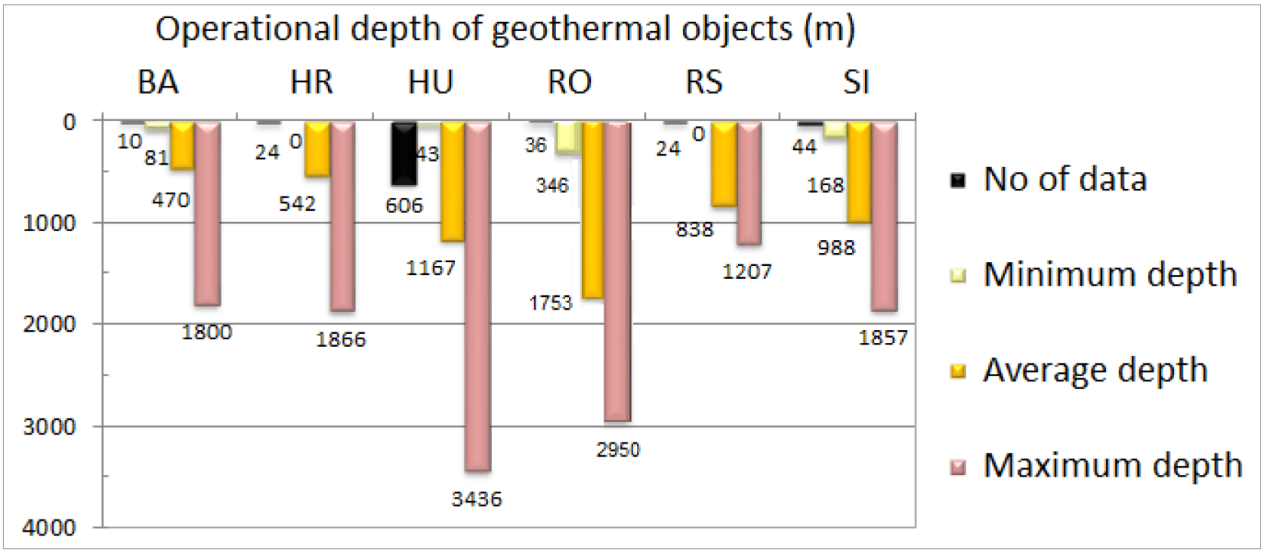

Figure 18: Distribution of depths of the thermal water wells

The **wells on the project area are rather "old"**: only 13% of the wells are younger than 10 years, 8% are 10-20 years old, 9% are 20-30 years old, 22% are 30-40 years old, 22% are 40-50 years old, 20% are 50-60 years old and 6% are older than 60 years (Figure 19). As the average lifespan of a geothermal well is about 30 years (on the DARLINGe area only 30% of the wells) this is alarming for maintenance issues for the majority of the wells (e.g. questionable status of the iron casing, weakening cemeneting and plugs, etc.). Nevertheless the long production history underpins the excellent geothermal potentials of the region's reservoirs. The number of new wells put in operation has been decreasing in the region since 2008 (Figure 19), which is an alarming sign and shows decreasing support from new investors.

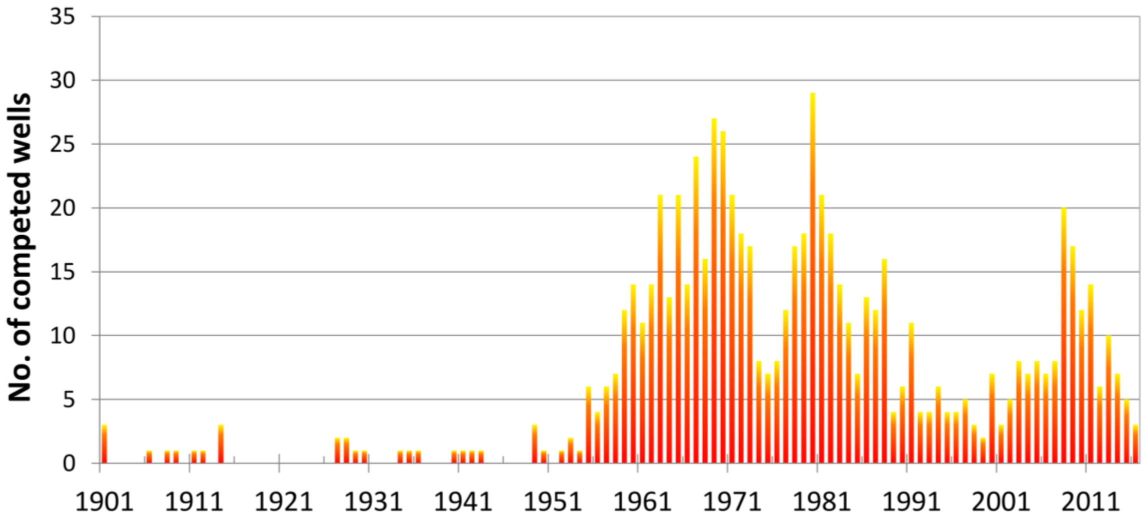

Figure 19: Number of completed wells by years in the whole project area

About **half of the objects have outflow temperature higher than 50 °C**, a favourable temperature for geothermal heat production (Figures 20, 21). The temperature range is 30-75 °C in Bosnia and Hercegovina, 32-97 °C in Croatia, 25 °C (originally 30 °C)-101 °C in Hungary, 29-85 °C in Romania, 25 °C (originally 31 °C) -72 °C in Serbia, and 30-75 °C in Slovenia.

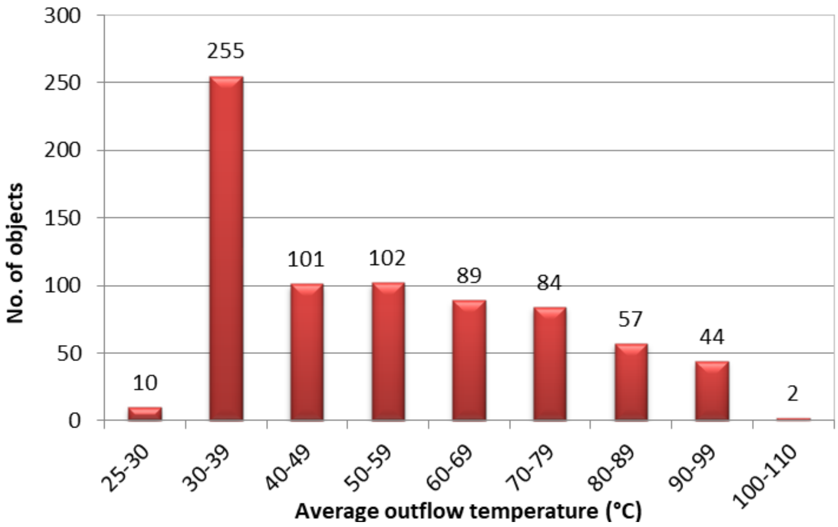

Figure 20: Distribution of average outflow temperatures

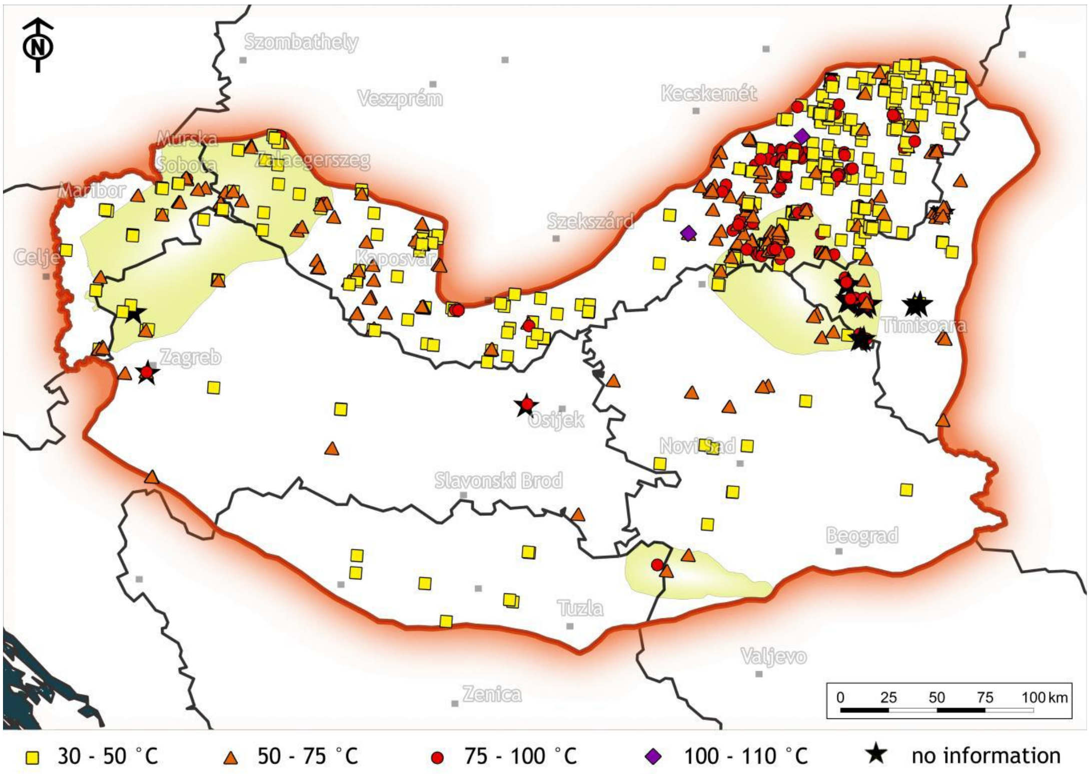

Figure 21: Distribution of average outflow temperatures at wellheads

Regarding the **utilization of the wells** (Figure 22), information on their production (e.g. continuous, periodical, purpose of use etc.) was not complete. The distribution is the following:

- 21% (155) have balneological use, out of these 23 are also used for heating,
- 17% (130) have drinking water utilization, however some of these might be used also for other purposes,
- 14% (104) different types of heating, out of these 13 use the water for district heating,
- 10% (70) for agricultural use dominantly for heating, out of these 18 are used only for greenhouse heating, the rest is used also for other purposes,
- 8% (58) other unlisted uses,
- 5% (39)are reinjection wells,
- 5% (36) are industrial wells, and
- 2% (11 objects) operate as monitoring wells.

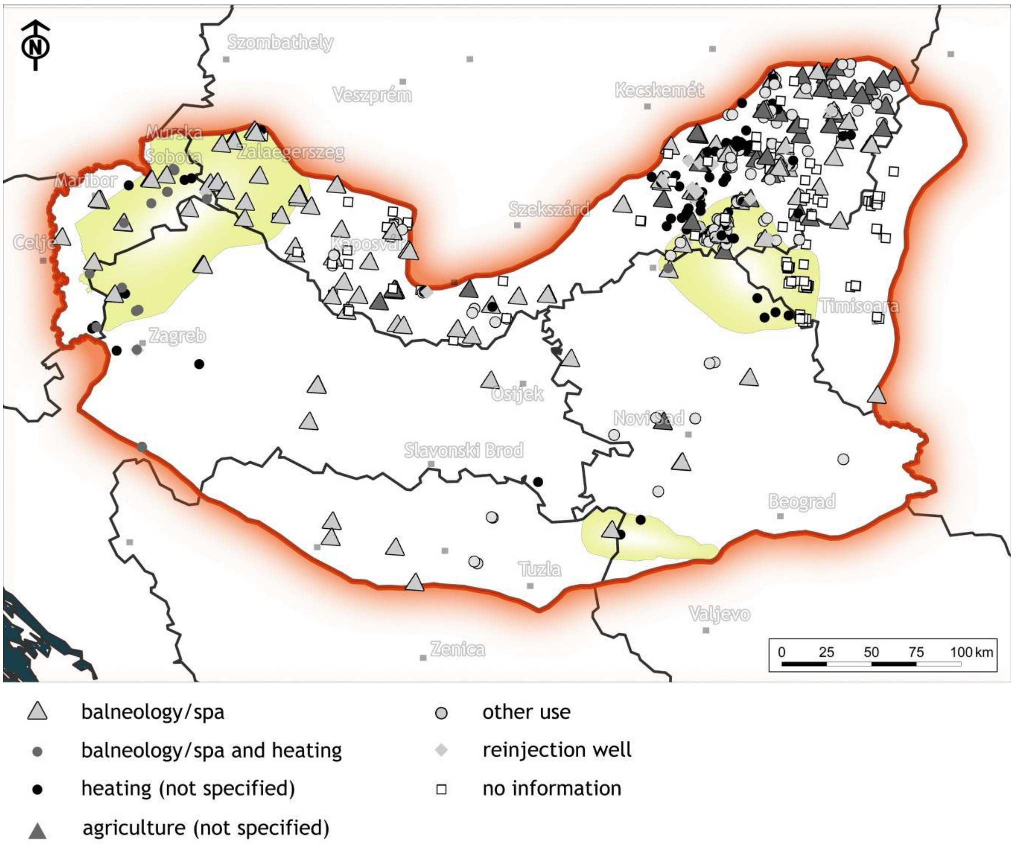

Figure 22: Distribution of utilization types

There was even less information available on the **production** (both on the reported annual as well as on the licensed amounts, altogether only from 62% of the objects). In total, **more than 40 x 10⁶ m³ was produced in 2015** (Figure 23) on the entire project area, 85% from basin fill reservoirs while the rest from the basement reservoirs (also including Miocene limestones which have local importance especially in Bosnia and Herzegovina and Croatia).

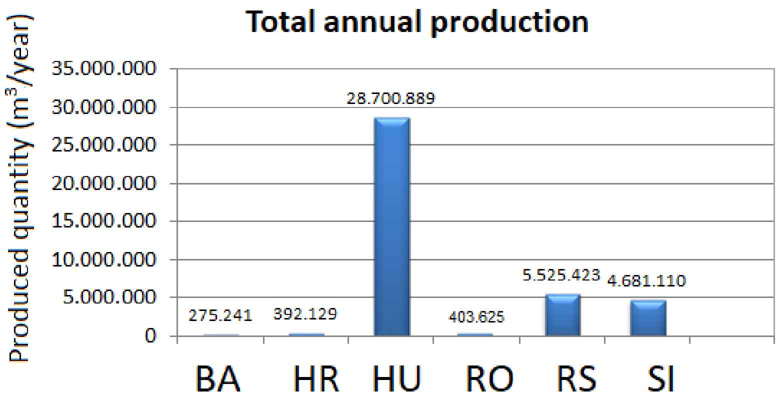

Figure 23: Annual production quantity per countries. Notice that 90% objects had production information in BA, 19% in HR, 55% in HU, 96% in RS, 29% in RO and all in SI

In contracts the **licensed maximum annual production sums to at least 62.3·10⁶ m³ per year** (Figure 24), but information source is even less available (only from 51% of the objects). Out of this amount about 30% (18,7·10⁶ m³) is expected from basement reservoirs and 70% (43.7·10⁶ m³) from basin fill reservoirs. Due to concentrated thermal water abstraction and low level of reinjection there are some areas where overexploitation may pose a threat to good status of the aqufiers locally (Figure 25).

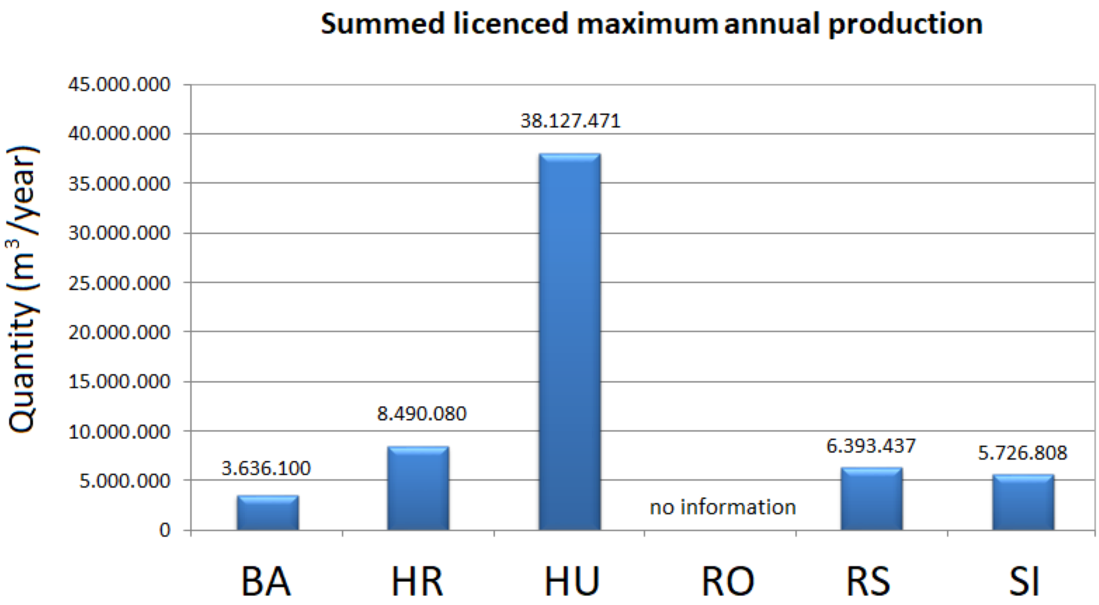

Figure 24: Granted annual production quantity per countries

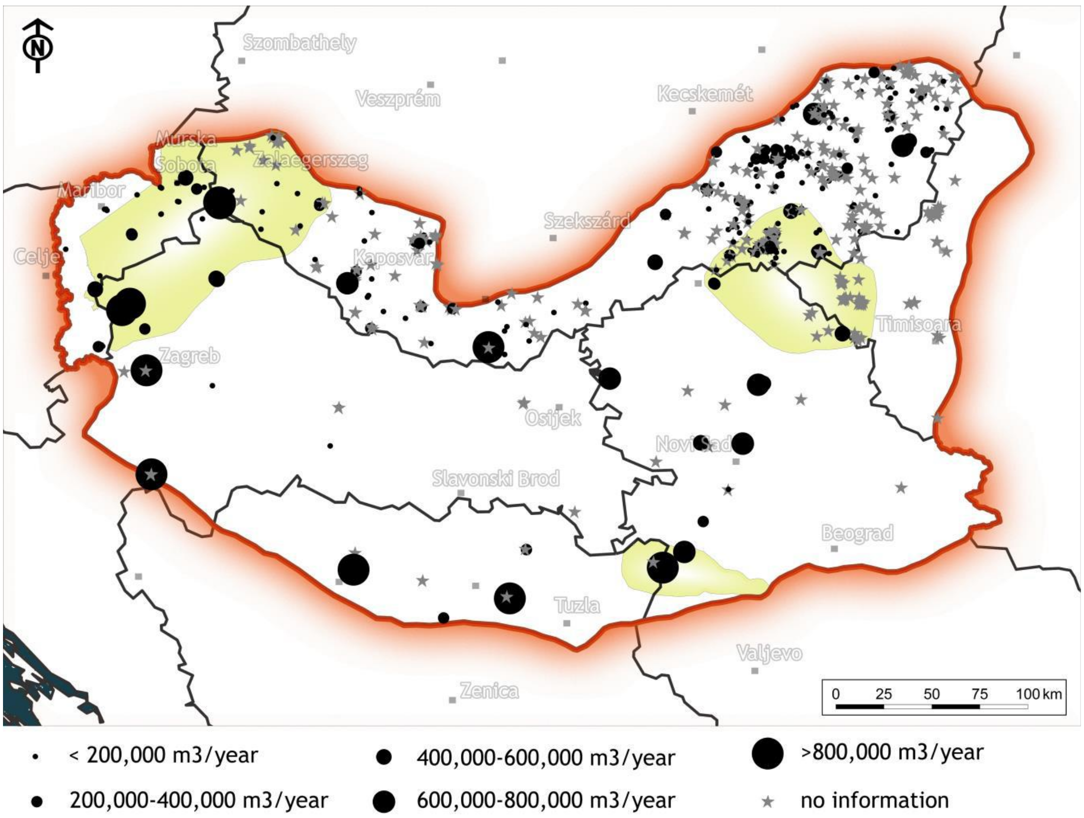

Figure 25: Areal distribution of licensed maximum annual production/reinjection quantities

4.2. Strategy to build on: strengths and opportunities - barriers to overcome: weaknesses and threats

There are many exaggerating estimations on the geothermal potential of the region without sound verifications, which might result in unrealistic expectations. The **science-based approach and novel methodology** developed in DARLINGe of delineating and characterizing **transboundary geothermal reservoirs** and quantifying their **exploitable heat content** is therefore an important step forward. This also makes possible to distinguish between prosperous and non-prosperous regions which provides a basis for sustainable management of geothermal resources on the south-eastern part of the Pannonian Basin and can serve as an example for other regions.

The **favourable geothermal conditions** (high geothermal gradient, extensive and productive aquifers at depth of 1000-2000 m with favourable hydrogeological and geochemical conditions), the **long-term experience on thermal water exploitation** (especially from the basin fill reservoirs) make the Pannonian basin **an attractive region for geothermal investments**. This was also proven by identifying 767 geothermal objects (mostly thermal water wells) on the project area, of which 51% have outflow temperature higher than 50 °C. Although about 24% of the wells are already used for some sort of heat production, this is still well below the potentials.

The "transboundary reservoirs approach" was also especially relevant; because the different (thermal) groundwater bodies (aquifers and their stored water which have similar hydrogeological conditions) - as basic planning units of the national River Basin Management Plans (RBMP) in the implementation of the Water Framework Directive - are not directly comparable among the neighbouring countries. The reason is that there are no common rules for the delineation of (thermal) groundwater bodies, some countries (e.g. Slovenia, Serbia) make differentiation according to depths, while others (e.g. Hungary) according to lithology and temperatures of the aquifers. Another weakness is that although the different groundwater bodies are delineated in a 3D space, the bottom boundary surface of the thermal groundwater bodies (the deepest lying aquifers) is missing in most of the countries.

Given their subsurface position, the basin fill geothermal reservoirs may interact both with the shallower drinking water aquifers and the deeper hydrocarbon reservoirs. This **concurrent use of the subsurface** raises several issues: e.g. the impacts of the co-uses, the priorities of utilization, which can be solved only by a holistic approach by investigating the whole subsurface as an unabridged system.

There is a **large number** of geological, hydrogeological and geothermal **data** (drillings, seismic sections, etc.) available in the project area, also partly deriving from the long-lasting hydrocarbon exploration of the region, which assures a good level of geological knowledge, therefore a low-level of exploration risk. However, this is less the case for the deep-lying basement reservoirs, where the level of investigation is much lower and the relatively poor knowledge (e.g. 3D location of permeable fractures, hydraulic parameters, etc.) result in a higher exploration risk. It also has to be highlighted, that many of the geoscientific data are old (more than 30 years), acquired by old methods, therefore the reliability of data has to be handled with great care. Furthermore, a large heterogenity characterizes the project area (i.e areas with extremely dense data – mostly zones of hydrocarbon explorations compared to "white spots"). The **lack of sharing knowledge** (on exploration, reservoir geology and engineering, drilling technology, etc.) **with the petroleum sector** is definitely a **weakness** of the geothermal sector.

Nevertheless, **available data and knowledge** serve as **a good basis for further and more detailed investigations**. Applying new methods in geothermal exploration (3D seismic interpretations and 3D geological models, 3D flow and heat transport modelling etc.) and possibilities of using state of the art and innovative exploration technologies support further potential for utilization of geothermal energy of the region.

Although the natural recharge conditions of this large sedimentary basin are very good, the **long-lasting and voluminous thermal water abstraction** warns for the need of a science-based management of the geothermal aquifers to assure sustainable production levels. Concentrated areas with thermal water abstraction coupled with **insufficient reinjection** lead to **overexplotation** in certain regions - to pressure drops and lowering of the hydraulic heads. As the project area is characterized by large-scale regional (thermal) groundwater flow systems, the unfavourable effects may impact distant areas as well. Parallel hydrocarbon and thermal water extractions from the same reservoir may also pose challenges to operators.

Even though there are a large number of thermal water **wells** on the project area, 70% are **old**er than 30 years, which is a **threat** in terms of technical failures. Furthermore, there is an unknown number of illegal wells in some countries. The **large number of users** may generate some conflicts on land use or on the use of the commonly shared geothermal resources (geothermal aquifer) and on potential impacts of the co-uses in areas of dense utilization. This is a more serious problem in those countries where the legislation does not require the delineation of a 3D protection zone around the production well.

Bathing and balneology without any energy use is the most common type of thermal water use, the **heating of the spa buildings** (in case of lower temperature waters also with the help of heat pumps) is a big yet unexploited **opportunity** for the future. At the moment the lack (low number) of cascade uses and the high outlet temperature of spent water underpin the general existence of **non energy-efficient systems**, which is a major **weakness**.

The **lack of** appropriate **monitoring** of the current uses as well as regional monitoring on the status of the geothermal aquifers is also a **weakness**.

Public knowledge on the actual use of the wells and energy use is rather **poor**. Together with the restricted communication among users, professional and authorities, this hinders the **share of knowledge** and dissemination of some good practices, which though exist in the area.

The **lack of well trained and skilled personnel** (both at the users and the authorities) is also significant **weakness**.

The **emerging direct heat use sector** as well as the fast developing (health)**tourism sector** is a big **opportunity** for the DARLINGe countries as there are / will be a large number of future potential users, especially in the vicinity of the already existing wells. However, these regions have to be developed with great care and science based evidence on the capacities of the given aquifers in order to avoid overexlpoitations. Another development potential is the **reactivation of the inactive wells** (a large number of such wells exist on the project area) instead of drilling expensive new wells.

Assuring continuos local food production in greenhouses also provides a great opportunity for extent of traditional farming experience into more high-tech systems as zero energy consumers, where geothermal doublets play a significant role being possible to deliver heat and cold to the agricultural farms and food drying units.

4.3. Future vision / Recommendations

The varios strategic documents (e.g. IEA Technology Roadmap for Geothermal Heat and Power 2011, RHC Platform Geothermal Technology Roadmap 2014, ETIP-DG Vision for Deep Geothermal 2018, etc.) consider that hydrothermal resources (where geological conditions permit the circulation of a medium to high-temperature fluids to transfer heat from the subsurface) are relatively well-known globally; furthermore their exploitation technologies are mature. The major future challenges and the boost of geothermal development (both in electricity and in heat production) lie in the development of "Enhanced Geothermal Systems – EGS", where the heat is extracted from globally widespread deep lying hot rock volumes with low porosity through artificially enlarged (stimulated) fractures, along which the water is circulated via injection-production wells. Nevertheless our state-of-the-art studies showed, that on the DARLINGe project area, which is a classical hot sedimentary basin, the untapped hydrothermal resources and their utilisation are still far below the potentials, therefore the most efficient strategy is to grab the low-hanging fruit (i.e. to look at the more efficient utilisation of the hydrothermal resources) instead of investing into emerging and costy technologies of EGS projects with much higher geological, economical and environmental risks. Therefore, in the following we skip the discussion on the EGS potentials (which though exist for certain parts of the Pannonian basin) and focus on the more efficient use of the available hydrothermal resources.

The **long-term and sustainable geothermal energy production** in the Danube Region has to be based on a thourough **understanding of the entire geothermal regime and flow system** of the Pannonian basin with a **science-based approach.** Harmonized **geoscientific models** (numerical flow and heat transport models) based on a uniform geological framework following the natural geological / tectonical structures as "borders" instead of state boundaries among the countries are the best tools to answers questions, such as: how much fluid / heat can be produced without threatening the good quality / quantity status of the thermal water aquifers (i.e. define and maintain the sustainable production levels of the geothermal reservoirs), make forecasts on the effects on various future production scenarios, etc. These **regional models** can serve the basis for further **sub-regional / local scale studies,** as **no "one-size-fits-all" solution exists** (e.g. in some areas the reinjection of the spent thermal water is a must, while on others with a better natural recharge it can be an option)).

The basis of good governance is that the **renewable and available volume of thermal water** (carrier of the geothermal heat) **is assessed by applying different measures**, e.g. the **critical water level** (below which water level should not decrease during production compared to the original pre-exploitation potential), or the **maximum allowed amount of abstracted fluid**. The concrete values for these measures (which can vary from region to region depending on the local geological-hydrogeological conditions) can be defined on regional transient hydrogeological models calibrated on the water level of monitoring wells further from the production sites. These measures are important indicators to **alarm for overexploitation** (e.g. if there is a significant decrease of the piezometric level, a decrease in outflow temperature, water quality, or if there is a decrease in groundwater availability (lower yields, pump lowering is necessary).

For the good quantity status of the geothermal reservoirs, it is of utmost importance to **foster reinjection.** Reinjection is only possible for the thermal water that has not been polluted after production (i.e. water used for balneology cannot be reinjected due to potential human contamination). Although balneology is the predominant utilization type in the DARLINGe area, but the necessary water amount to feed a spa is still much smaller than the thermal water quantity necessary to supply a heating system, where hot water has to be continuously circulated. Therefore, it is necessary that **all direct heat uses apply reinjection wells**. As reinjection has some technical limits in porous aquifers / basin fill reservoirs (e.g. clogging of the pore spaces) according to the benchmark methodology of the DARLINGe project reinjection can be considered very good if at least 80% of the used water is reinjected into the same aquifer, and good if this ratio is above 60%. In fractured (mostly basement) reservoirs a 100% reinjection rate is technically feasible and recommended.

Monitoring and appropriate **reporting** is a must to follow the productions and their effects. DARLINGe recommendations differentiate between monitoring of the active (production) wells reported to authorities by the users themselves at national levels, and the "passive" or observational monitoring, which is related to a monitoring network (composed of wells drilled or adjusted for the purpose of monitoring) where meaurements and reporting are done by the relevant authorities, state organizations. Active monitoring should include the regular (whereas the frequency of measurements is defined in the legislative requirements at national levels, or permits) measurements of the cumulative quantity of the abstracted water, the discharge rate, the piezometric level and outflow water temperature, as well as chemical analysis and hydraulic testing (pumping tests, step tests, etc.). The passive (observational) monitoring should focus on the regular measurement of piezometric levels in the aquifers or wellhead pressures, water temperatures and chemical compositions. These monitoring wells should be placed sufficiently far away from actual abstraction sites to monitor the background and boundary conditions of the regional thermal water system far from the active production zones in order to be able to follow the regional water level and water flow directions and the trends. Frequency of measurements should be:

- Sufficient to reveal significant oscillation of parameter values and to statistically assess the standard deviation and error
- Sufficient to reveal any significant trend
- Sufficient to forecast any eventual need to implement additional measures on time for safe operation and not to increase costs.

In addition to the above summarized aspects concentrating on the good status and long-term productivity of the geothermal aquifers / reservoirs, the other group of recommendations are focused around **utilisation efficiency**. Similarly to the basic principles of energy savings ("the cheapest energy is that one which is not used"), the more efficient use of the already exploited geothermal fluids makes **unnecessary to produce additional amounts of thermal water**, thus directly contributes to the above described "good status" of the reservoirs.

In terms of efficient use, **cascade systems** has to be put at first place. The principle of cascade use is that different uses are sequentially linked according to their decreasing heat demand: the hottest fluid can be used first for power production (not the case in the DARLINGe territory) or combined heat and power production, followed by large-scale (district) heating systems, then heating of individual spaces (e.g. greenhouses or separate buildings), followed at the end by low temperature applications (e.g. fish farming or snow melting, or even balneology). According to the benchmark methodology of the DARLINGe project, cascade use is considered very good, if there are at least 3 successive stages of energy extraction, the water is not mixed with cold water prior to use (e.g. when letting into pools) and there is no surplus of unused heat at the end of the utilisation chain: waste water temperature is close to the ambient fresh groundwater temperature (12 °C).

Cascade systems or individual uses should be also assessed by **their thermal efficiency and utilisation efficiency.** The former is related to the ratio of the temperature differences between the outflow temperature of the resource and actual temperature of waste thermal water, and to the temperature difference between outflow temperature of the resource and the ambient temperature (12

°C). According to the benchmark methodology, thermal efficiency is considered good above 60% and very good above 70%. This can be achieved – among others – by maximizing the extraction of heat (by heat pumps) even from each energy extraction stage (temperature interval). Utilisation efficiency describes the ratio of the average annual water production to the maximum water quantity that could theoretically be produced (i.e. the licenced allowed maximum production). DARLINGe recommendations for a good utilisation efficiency are above 45%, whilst for the very good category above 60%.

All these will make possible a much wider deployment of the exisiting and proven geothermal resources of the DARLINGe project area.

5. Operational and technological issues of geothermal heating systems

5.1. State-of-art

There are two ways of extracting geothermal energy from the ground for direct use (heating) purposes:

- by heat recovery (closed loops in depths – deep geoprobes)
- by extracting thermal water (as this is characteristic for the DARLINGe project area, in the following only this wil be discussed in details)

The extraction of thermal water can happen in two different ways:

- During direct thermal water utilization, the extracted fluid is used in the heat exchangers of the consumers (i.e. the abstracted thermal water itself is circulated in the heating system). This can happen if the thermal water has favourable chemistry, i.e. low dissolved content does not cause scaling, it is not corrosive, has little free gas content, etc.
- During indirect thermal water utilization, the primary geothermal loop transfers the heat via heat exchangers to a secondary heating loop circulating "clean" water, which provides the heat towards consumers. This solution is preferable when the extracted thermal fluid cannot be fed directly into the heating system due its unfavourable chemical characteristics (e.g. high dissolved content, aggressive composition, etc.).

After utilization, the used and cooled thermal fluid can be discharged:

- Into the sewerage or rainwater system
- Into an open surface channel (preferably through a cooling tank),
- Into streams, or rivers
- Returned back into the aquifer (reinjected)

The possible consequences of surface discharge can be:

- Salinisation and thermal load of natural surface waters, methane and carbon-dioxide emission from the associated gases
- Decrease of the thermal water resources and of the reservoir energy, which may be reflected in a significant reduction of the water level and/ or pressure drop in the production wells.

However by using reinjection into the same geothermal aquifer, these problems are eliminated, and production becomes renewable and sustainable from the water-balance point of view, and also energetically since the reservoir is replenished and the reinjected cool water warms up again in the subsurface if the flow rates are not too large.

In the DARLINGe countries, the typical wellhead temperature is 60-110 °C, which provides the possibility of satisfying the heat demands of different consumers at different temperatures. It is always a custom process to **match the energy source** (geothermal brine with a certain flow rate and temperature) **and the local energy needs** (heating/cooling with certain temperature steps and variance vs. time).

The typical use cases are the following:

geothermal district heating (geoDH): typically in big cities with an existing district heating network and heating stations, originally fed by fossil fuels. In some cases these systems (or parts of them - certain heat loops) are fed by geothermal water.

thermal water town heating systems: in these cases a few buildings (typically public buildings, such as town hall, hospital, school, library, etc.) are heated by thermal water through a specially designed thermal water pipeline loop, connecting the production well, the buildings and in most cases a reinjection well. The systems are typically operated by municipalities, or municipality owned companies and there is no separate energy service company (ESCO). The systems normally don't have high capacity enough to supply 100% the heat demand, especially in the cold winter days, so the fossil fuel based (typically gas) boilers of the individual buildings are necessary. This is much more common on the DARLINGe area than geoDH systems.

individual space heating: this is typical in spa complexes where the heat content of the produced thermal water for balneology is used (most commonly through heat exchangers) to heat the building(s). Also these systems often lack reinjection wells, although the thermal water used solely for the heating could be reinjected (in contrast with the water used for swimming). Often, part of the water is used also for sanitary water heating or as the sanitary water itself.

agriculture use: the thermal water is used for a great variety of purposes: heating of greenhouses, plastic tents, stables, hatcheries, soil heating, fish farming etc. In most of the cases there is only a single production well and the used water is discharged into surface recipients.

This **cascade utilization** multiplies the economics of a project. A typical cascade utilization example of 80-100 °C brine is to apply it for space-heating through a heat exchanger cooling it down to ca. 40-50 °C. Then the 40-50 °C brine still can be used for heating greenhouses, sanitary water or simply for balneological purposes in a spa. Many other combinations can be realized.

The **general operation** of existing (large scale) heating systems can be summarized as follows (Figure 26):

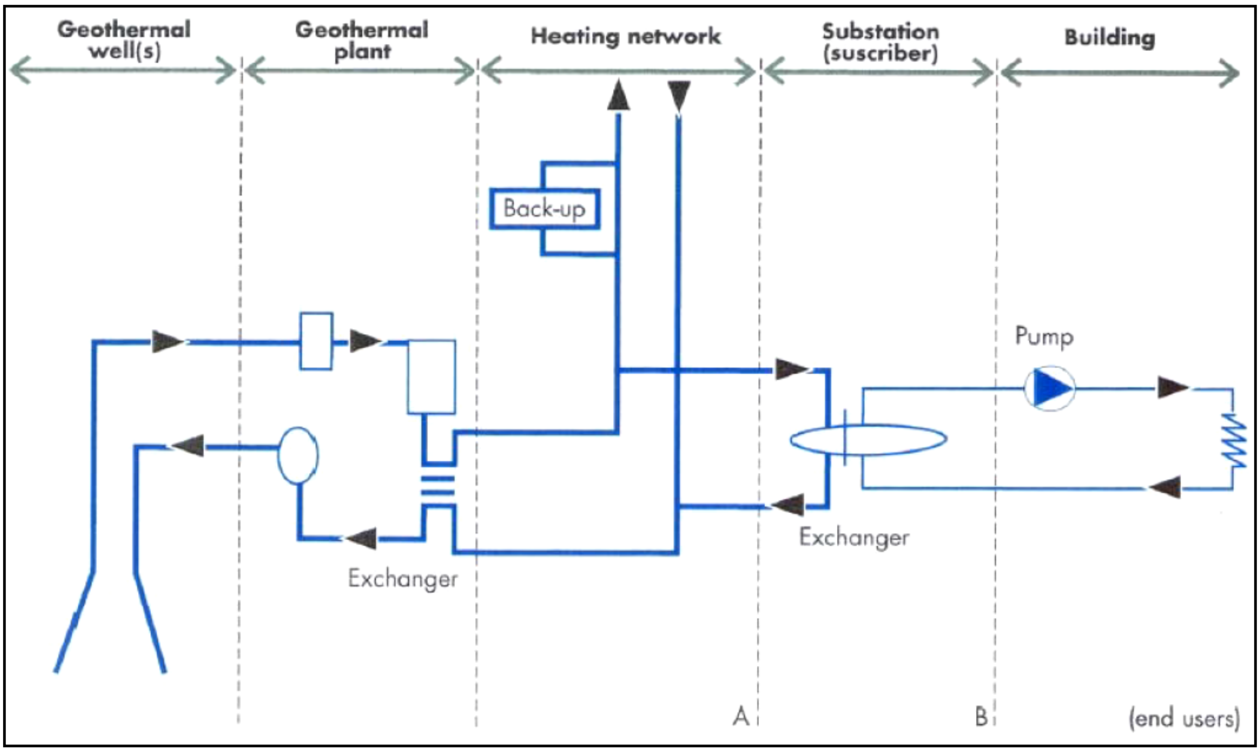

Figure 26: A typical system design of a geoDH system (source: GeoDH project)

In a typical geothermal system a submersible pump installed in the production well, and the surface pumps installed near the well (or in wells with overpressure, the "positivity" of the well) pump the thermal water into a large insulated degassing buffer tank near the well (Figure 27). In renovated or new systems, the programming of the yield of the submersible pump according to the water level of the tank guarantees the fluctuation-free operation of the well.

Figure 27: The production well (B–45) and the gas separator in the Hunyadi Park, Mórahalom, Hungary

Booster pumps in the engine room pump the degassed thremal water through pipelines to the consumer heating stations (Figure 28). In the case of a few new thermal projects, the deaerated natural gas content is collected, cleaned and used in gas engines for cogeneration purposes. The long pipeline network with a narrow cross-section experiences a significant pressure drop of 5-10 bars (depending on the length and diameter of the pipe). This drop of pressure is to be considered during the dimensioning of the pumps. The booster pumps in many operating systems operate at a constant rotational speed in a stationary mode. In modern systems, the operation of the booster pumps with frequency converters is controlled by an automatic pressure control system of the pipeline.

Figure 28: The heat exchanger with mechanical equipment in the Szentlőrinc geothermal district heating system, Hungary

In several older systems the heating medium is directly transported through radiators without any kind of control. The motor valves in modern consumer heating stations are controlled by consumer heat demands (local temperature-dependent control systems) and transmit the heating medium to the heat exchangers at volumes that satisfy actual heat demand. An increase in heat demand in the consumer systems results in the opening of the relevant motor control valve, a drop of supply pressure, the increase of the speed of the booster pump in the well's engine room, and the entering of more fresh thermal water into the system. The resetting of water production takes place in the opposite case.

In older thermal systems, the facilities to be heated are able to use only a part of the medium's thermal content, thus the discahrged fluid is still frequently hot. The new systems are trying to order the consumer network into cascade systems. Heating circuits with various temperature differences are aligned in the system in order to maximize the specific heat capacity of the thermal water. The secondary medium of one district appears as the primary medium in another district according to lowering temperature demand. This cascade system guarantees the most efficient utilization of the heat content of the abstracted thermal water.

From the last consumer (e.g. pool heat exchanger), the cooled thermal water reaches – in compliance with the given licences – either an overground recipient (such as a cooling tank, wastewater or rainwater channel, river, natural or artificial lake, etc.) (Figure 29) through the return pipeline with the help of installed booster pumps, or a reinjection buffer tank through a reinjection pipeline. From the reinjection tank, adjacent reinjection pumps pump the cooled fluid through an overground filter system and a reinjection well into the reservoir close to the production site (Figure 30). The tank's water level controls the operation of the reinjection pumps.

Figure 29: Discharge of cooled geothermal water (30 °C) into a melioration channel in Bošnjaci (Croatia) where the thermal water is used for heating of greenhouses

Figure 30: Fibre filters for waste thermal water before being reinjected into Le-3g well in Lendava geothermal district heating system, Slovenia

The operation of older, outdated systems is not monitored at all, the primary purpose of operation is the availability of thermal water.

Data recording systems have been installed in newer, or renovated systems for the control of operational parameters and the protection of the environment. The following parameters are monitored and recorded during operation:

- the operating water level of the production well, main operating parameters of submersible pumps (operating hours, frequency), pressure, quantity and temperatures of outflowing water,
- the water level of the buffer tank, main parameters of the forwarding pump (operating hours, frequency, quantity of transported water),
- the sectionalized pressure values of the pipeline network,
- the pressure, temperature and quantity of the medium arriving at the consumers' heating stations, the quantity of supplied heat,
- Buffer water level of the reinjection well, pressure values before and after (wellhead) the overground filter, main operating parameters of the reinjection pump (operating hours, frequency, quantity of reinjected water), reinjection temperature.

Competent environmental inspectorates can order the regular quality control of the water discharged into the recipient, the installation of monitoring wells and periodical samplings.

5.2. Strategy to buid on: strengths and opportunities - barriers to overcome: weaknesses and threats

Much of the thermal water wells are old in the project area (Figure 19) with **not properly constructed and mantained well and wellhead**, which is a weakness (i.e. they are not isolated, not protected from unfavourable weather conditions and unauthorized persons, not furnished for monitoring equipments to measure temperature and abstraction rate, etc) (Figure 31).

Figure 31: Examples of well- and poorly maintained wells from the same area (Bogatić, Serbia): BB-1 (on the left) and BB-2 (on the right)

Depending on the chemistry of the produced thermal waters, different **operational issues** may arise as threats (scaling, blowouts, explosion zones, clogging of screens, corrosion, sand abrasion of pump, etc.) (Figure 32). There is a great variety of technical solutions to successfully address these issues (e.g. use of inhibitors - acids to prevent scaling), which most of the users apply, as it is their own interest to assure a smooth operation.

Figure 32: High mineralization and CO2 degassing of the water cause scaling which clogs the well (Benedikt, Slovenia)

Many wells produce thermal water with significant **dissolved gas content** (methane, nitrogen, CO_2, H_2S). Degasification units are often installed next to the production wells and in some cases the separated gas (methane) is used in auxiliary equipment, however often the gas is just released to the atmosphere. The **further use of the free gas** (e.g. burning of methane for heat or electricity, bottling and selling CO_2) **is an opportunity** to make the current uses more economic and environmental friendly (Figure 33).

Figure 33: Messer BH gas d.o.o, Republic of Srpska, extraction of CO_2 from thermomineral waters

The major operational issue (weakness) is nevertheless **reinjection into porous aquifers** (basin fill reservoirs), as the necessary injection pressure can substantially increase within a relatively short time. The highly heterogeneous lithology (silt, clay intercalations) and high clay content often cause the plugging of screens (perforation) in the not-optimally designed wells and pore throats of the reservoir formation, which leads to the decrease of permeability due to clay swelling, pore-space blocking by fine particles, or precipitation of dissolved solids due to the mixing of injected and formation water. The precise mechanisms which determine injectivity are site specific and processes are not entirely understood yet, although several local experiments including theoretical analyses, numerical simulations, laboratory and in-situ experiments were carried out especially in SE–Hungary. The main lessons learned from these studies are that long-term sustainable injection is possible, but instead of ad hoc approaches, scientifically sound solutions must be found were the right selection of the injection well (location and depth), specially designed and completed well in technical terms, good hydraulic performance, very slow transient performance process (pressure, temperature, flow rate) are needed. Special investigations are needed as early as the drilling phase to determine permeability, conductivity, rock-mechanical, pressure, geothermal properties of the reservoir as well as hydrogeochemistry of the formation fluids. It was also revealed that the main reason for the initial failure was that early projects tried to transform existing abstraction wells into re-injection wells, not paying attention to micro-filtration prior to reinjection.

Over the last decades, the supply and return temperatures of DH networks have been reduced. Since modern, energy efficient buildings and new heating systems allow rooms to be comfortably heated at supply temperatures of 40 °C and less, the **operative temperatures of the DH network can be further reduced** and it will be possible to integrate low temperature geothermal resources in district heating in urban areas anywhere in Europe, which is an opportunity.

Through **demand site management** or **thermal energy storage** it will be possible to balance heat demand and supply in a DH network. While demand in a DH network fluctuates on a daily, weekly and seasonal basis, the supply from a geothermal source is constant all year round. One way to balance supply and demand is demand site management in order to lower peak demands. Another option is to use thermal energy storage systems, to supply additional thermal power during periods of peak demand. Thermal energy storage can take different forms, e.g., local water storage tanks to balance day-time fluctuations in demand, large underground seasonal storage systems, or thermo-chemical storage systems. These are future opportunities of making geothermal district heating systems more effective and widespread.

5.3. Future vision / Recommendations

The drilling of boreholes constitue the major share of investment. Therefore **reductions in drilling costs** can substantially impact the overall economics of a deep geothermal project. RD should focus both on novel drilling concepts and on improvements to current drilling technology, as well as to optimize the economics of drilling operations (horizontal, multidirectional, multi-well, etc). New sites for heat production should be developed by using geothermal doublets (production and reinjection well) from the start, as this is a common practice in other parts of Europe.

Novel production technologies can improve efficiency, reliability and cost of heat production (well – design and completion, definition of suitable materials). The target is to reduce operation and maintenance costs, improve system reliability and energy efficiency of operation as well as to increase the lifetime of boreholes and system components by monitoring coupled with in-depth understanding of reservoir and thermal loop processes.

In an ideal case the **well and wellhead should be properly constructed** (isolated, protected from unfavourable weather conditions and unauthorized persons, has enough fittings to install monitoring equipment for heads, temperature and abstraction rate). There is wide range of potential **operational problems** (scaling, blowouts, explosion zones, clogging of screens, free gases, corrosion, cavitation of pump, sand abrasion of pump particles, discharge) depending on the local geological, hydrogeological conditions. The risks of such problems should be examined carefully, preferably on the basis of thorough analyses of samples taken downhole in the geothermal wells. Based on these analyses, there is a wide range of **preventive actions**, which should be chosen individually for each site:

- Increasing the pressure in the surface installations in order to stay above the bubble point (avoid precipitation)
- Filtering - both at reservoir level (screens and gravel packs) and at surface (mechanical, bag and/or cartridge filters)
- Choosing more proper materials that are less prone to corrosion /precipitation
- Injection of inhibitors to prevent scaling or corrosion, perhaps even downhole
- Regular treatments like (soft) acidizing and cleaning the wells (mechanical, back-washing)

If free gas is also produced from the well, it is recommended to utilize it (e.g. burning of methane for heat or electricity, bottling and selling CO_2, etc.).

During operation energy demand for pumping can be a burden on the overall efficiency. Therefore it is needed **to improve pump efficiency and longevity** to secure reliable production.

Cascade sytems should be **more common** which provide an efficient use (see also chapter 4.3.). Research, development and demonstration (RD & D) projects are essential to better understand the **technical constrains of reinjection**, which must be applied much wider than at present.

A holistic framework is necessary that **addresses technical barriers** relating to various production technologies, e.g. development of methods that allow for a truly load-following system. As the temperature of geothermal fluid increases, problems, such as degassing of fluid, corrosion and insufficient pump technology have to be solved, too. **New and advanced technologies**, such as co-production of hot water from oil and gas wells, or from geo-pressured reservoirs need further RD funding.

It is also necessary to develop innovative solutions for **refurbishing existing buildings**, and optimizing the existing networks to be able to accommodate lower temperature fluids, which are rather engineering tasks. When old, inactive wells will be used, they should be tested also as deep geoprobes, if they are capable of producing needed quantities of energy also without direct water abstraction.

As climate change is manifested in more and more hot and dry summers, cooling is becoming an issue. **Geothermal district cooling** is poorly developed at the moment, however could provide a summer use for geothermal district heating systems. Geothermal heat above 60 °C can produce chilled water in sorption chillers that can be piped to the consumer via the same circuit used for heating. These opportunities should be considered as future options in the DARLINGe area as well.

The use of geothermal heat for district heating, i.e. heating of large buildings requires specific technologies to transfer the geothermal energy into useful heat inside a network. The basic technologies to exchange heat between the geothermal source and the heat transfer fluid in the system still faces challenges both in energy efficiency and resistance to corrosion, i.e. development of new materials or innovative geometries is necessary.

It is envisaged for the future that the net efficiency, performance and cost-effectiveness of production systems will be optimized, the temperature range of applications will be extended and the production will be responsive to the demand.

6. Heat market aspects and economics of geothermal heating

6.1. State-of-art

Geothermal heating projects, especially larger systems are costy investments. This is one reason why despite the rich available resources, the number of geothermal district heating systems (including thermal water town heating systems) is relatively low in the DARLINGe countries, compared to the EU members (Figure 34). The existing systems are relatively small ones (Figure 35).

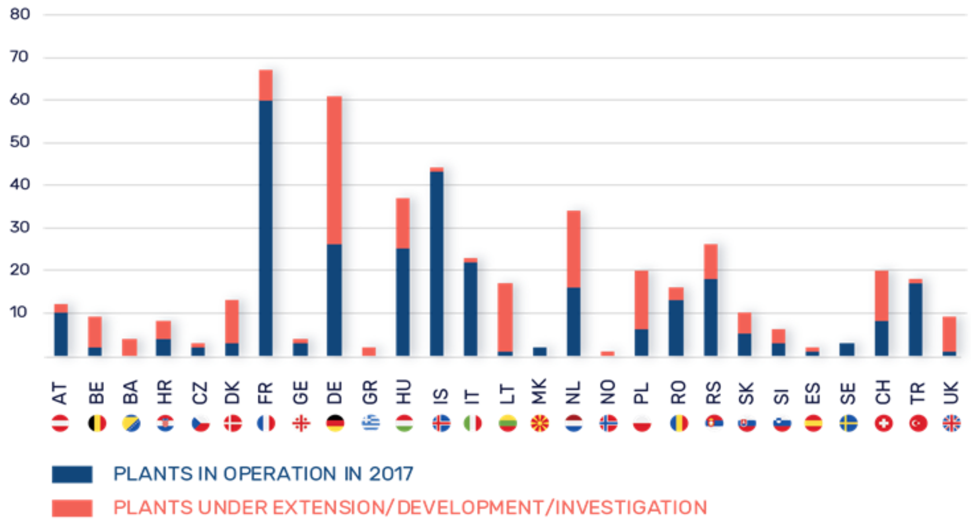

Figure 34: In 2017 there were 280 GeoDH systems in operation in Europe and another 164 under development or investigation (source: EGEC Market Report 2017)

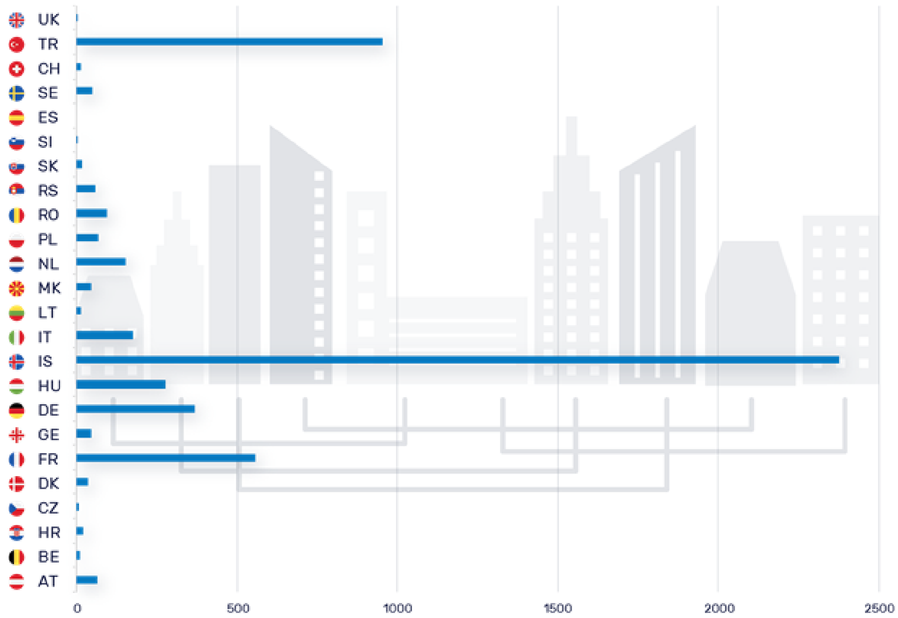

Figure 35: Total installed capacity 4,8 GWth (2017) of geoDH systems (EGEC market report 2017)

In spite of efforts by the geothermal community, market conditions in the EU electricity and heat sectors have prevented geothermal energy from fully competing with conventional technologies developed historically under protected, monopolistic market structures. The internal market is still far from being perfect and transparent. Firstly, in many countries electricity and gas prices are regulated, thus they do not reflect the full costs of the electricity and/or heat generation. Secondly, fossil fuel and nuclear sectors still receive many subsidies. Thirdly, in several EU countries there is still lack of market transparency, including lack of information provision to customers and tax-payers and a clear billing. Fourthly investors, political decision makers and the public often favour other forms of renewable energy that are less risky and capital intensive to develop. A fresh approach is therefore needed in promoting geothermal energy as a key source in the future European energy mix and to compensate for current market-failures.

The policy drive for expanding geothermal district heating systems is strong: Europe's long-lasting dependency on fossil fuel imports mainly aiming at covering its heating demand fully contradicts the EU's objective to ensure security of energy supply in the Union. Combined to energy efficiency programmes, **renewables (geothermal) for heating** (and cooling) **proves to be the most effective alternative in the decarbonisation of the heating sector in the long-run**.

In order to address the **heat sector**, it is of crucial importance to **understand the characteristics of its demand**. Heat users quite often have specific demand profiles comprising issues of temperature, capacity, and timing. Therefore, a variety of applications and sources are required to cover this demand (Figure 36). For an efficient use of primary energy, **technologies used should match as closely as possible the temperature levels of the thermal energy demand**. Geothermal and other renewable heating and cooling (RHC) technologies are already competitive under certain conditions and are available to supply the low-temperature heat demand for space heating/cooling, domestic hot water and for certain industrial processes. Additionally, with current technology geothermal and other renewables can reach medium temperature heat for industrial processes.

End-user	Services	Temperature level	Role of RES
Households	Space heating / cooling and domestic hot water	Low-temperature heat (up to 60° C)	Covered by geothermal and other RHC
Tertiary (Supermarkets, malls, offices, hotels, swimming pools, etc.)	Space heating / cooling and hot water	Low-temperature heat up to 95° C	Covered by geothermal and other RHC
Industry	Greenhouse heating Irrigation with warm water in agro-industries	Low-temperature heat between 60-90° C	Covered by geothermal and other RHC
	Heat and hot water for washing, rinsing, and food preparation.	Low-temperature heat up to 95° C	Covered by geothermal and other RHC
	Steam for industrial processes, notably to evaporate or dry	Medium temperature between 95° C and 250° C	Can be covered by geothermal and other RHC
	Heat for the manufacture of metals, ceramics, glass (through hot flue gases, electric induction, etc.)	High-temperature heat from 400° C up to 1000° C	Can be covered with renewable electricity

Figure 36: Heat demand by service, end-user, and temperature (source EGEC Policy paper: Fuel switch to renewables in the Heating and Electricity sectors, 2015).

Energy generation of the facility must match the different energy needs it serves, both in terms of temperature and time. Residential facilities have a high heat demand in winter and only a basic demand in summer; however, then the need for cooling is great. Industrial consumers have a more static need of heating/cooling throughout the year. In terms of annual heating degree days most of the DARLINGe areas belong to a moderate climate (Figure 37).

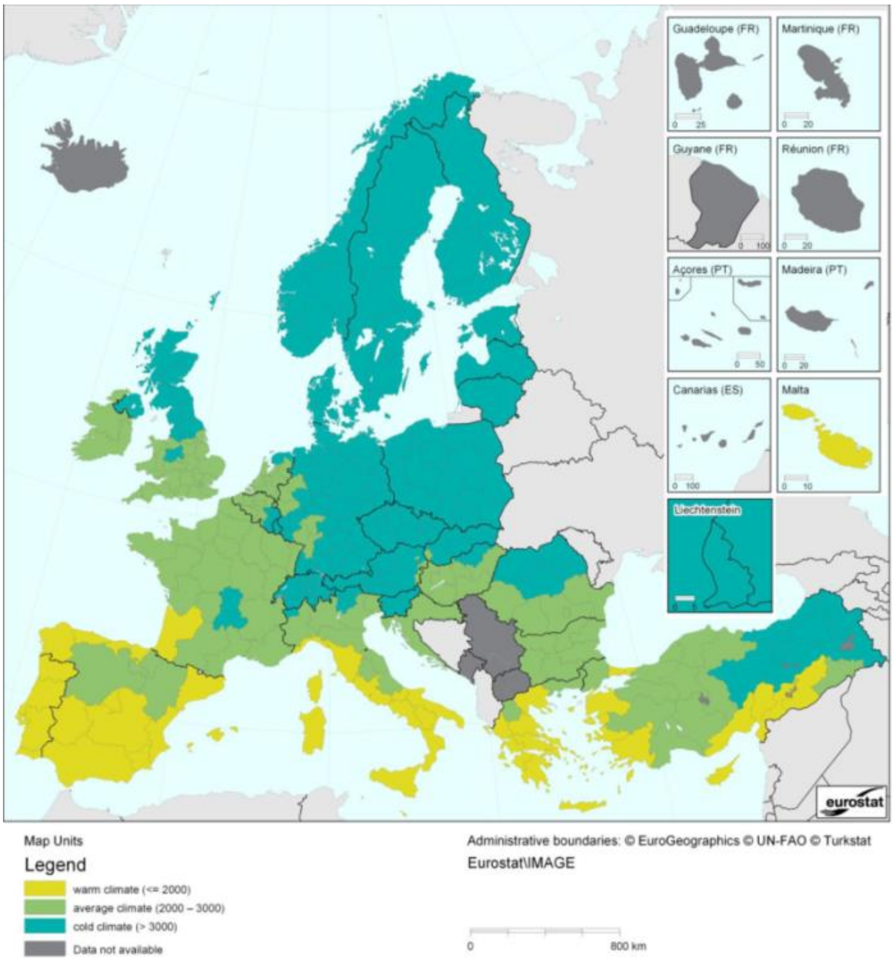

Figure 37: European climate conditions based on annual heating degree days

Since heat (and cool) cannot be transported economically on a long distance, heating and cooling is produced and consumed locally. The heating market is fragmented and no single market has so far emerged either nationally or EU-wide. Instead, heat markets are local and are composed by many different technologies and economic players (vendors, installers and builders, engineering companies and energy advisors, energy utilities and energy service companies) selling the heat and cool as a commodity or service, often bundled with other services. Heating and cooling are closely linked with other energy markets, in particular the fuel and the electricity markets, but also with non-energy markets such as water, waste, real estate and technology.

In the DARLINGe area all six countries (Bosnia and Herzegovina, Croatia, Hungary, Slovenia, Romania, Serbia) have some similarities in their geographical, geological, economic and social parameters. As far as the population distribution is concerned, the southern part of the Pannonian Basin is sparsely populated compared to the western regions of Europe, and its economy as well as its infrastructure are underdeveloped. The energy demand of the population in this area is mainly covered by the burning of non-renewable energy sources, mostly coal and natural gas. The renewable energy market in this region needs fundamental developments to reach its full potential. Currently, biomass burning, water power plants and solar collectors cover the bulk of renewable energy use, however energy produced with these technologies combined only cover about 10% of the total energy needs.

In terms of **heat markets** categories (RHC Common Vision for the Renewable Heating & Cooling sector in Europe, 2011), the DARLINGe project area can be characterized as the following:

Urban areas: > 500 inhabitant/km^2:

Urban areas include city centres, suburban areas and village centres. They are characterized by a dense population building density, heterogenous functionality (living, working, recreation). They often have higher average temperature compared to surrounding areas ("heat islands"). The relatively dense network of energy distribution infrastructure makes it possible to use remotely generated RES (e.g. geothermal well drilled at the vicinity of the settlement) and its cost-effective distribution through district heating networks.

On the DARLINGe area the **majority of the population is urban (69.2%).** However the number of significant cities (inhabitants near or above 50 000 people) is rather low, e.g. Tuzla, Živinice, Gračanica, Tešanj in the Federation of Bosnia and Herzegovina; Banja Luka, Bijeljina, Doboj, Prijedor, Zvornik in the Republic of Srpska; Zagreb, Osijek, Karlovac, Sisak in Croatia; Zalaegerszeg, Kaposvár, Pécs, Szeged, Hódmezóvásárhely in Hungary; Arad, Salonta and Timisoara in Romania; Maribor and Murska Sobota in Slovenia; Novi Sad, Subotica, Beograd, Zrenjanin, Pančevo, Šabac in Serbia. Due to the widespread existence of (fossil-based) district heating systems established in the communist era, the overwhelming majority of these cities have district heating infrastructure, although much of them are obsolete and need renovation / modernization.

In addition, there is a relatively large number of "smaller towns" (20 000-40 000 inhabitants) in the project area. Due to the historically widespread district heating infrastructures, many of these cities also have DH pipelines. Furthermore, these smaller towns are typically suitable (in case of available resources) for "thermal water town heating" systems, where a specially established thermal water pipeline provides the heat for the main buidings in the city centres (e.g. Town Hall, school, hospital, library, etc.). On the DARLINGe project area several such heating systems already exist, and there is a wide range of potential for future developments.

Rural areas < 500 inhabitant/km^2:

These include population densities ranging from those of small villages to garden cities with lots of green spaces. Distribution network for heat are often absent, therefore tend toward local generation and use of RES / geothermal.

As large territories of the DARLINGe project are typical agricultural regions, these areas represent potential heat markets for a wide range of application of geothermal heat in this sector (e.g. greenhouses, plastic tents, stables, drying of products, hatcheries, soil heating, fish farming, etc.).

Another important segments of the potential heat market are those areas – which are also numerous in the project territory – where thermal water is already in use, e.g for balneology. In these areas the additional use of thermal energy for heating of the spa (and nearby) buildings is a significant unexploited potential. The other advantage of such sites is that the resource is already proven (well is drilled), which eliminates a major part of cost for project development, as well as risks.

Industry

Industrial applications are typically found in designated industrial zones with high building density. They have high energy intensity and higher required temperature compared to residential use, and also require more constant round-the-clock energy demad.

Such areas are relatively rare on the DARLINGe territory.

Geothermal projects have **special characteristics** in terms of **costs structures** and their distribution along the project life-cycle compared to other renewables and even more to fossil-based projects. Figure 38 shows the variation of cumulated investment cost and risks through the progress of a large scale geothermal project, from preparation to putting into operation. Significant part of the investment happens at the beginning of the project deriving from drilling, which is the major cost component of a geothermal project (high CAPEX). At this stage the project risk level is still high due to the low level of confidence on the subsurface conditions (i.e. whether the drilling will confirm the expected reservoir temperature, yield, etc.). However, once the resources are confirmed and the field is developed, the operational costs of a geothermal project are low.

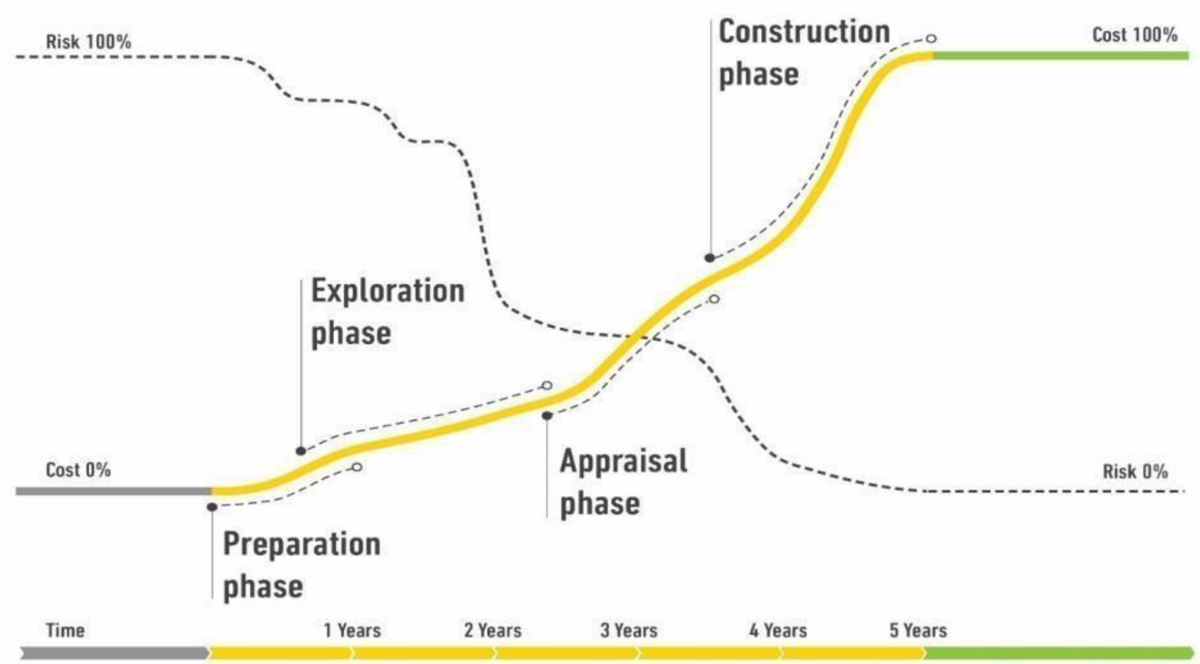

Figure 38: Variation of cumulated cost and risk level of large geothermal projects (Source: Sigurður Lárus Hólm, Mannvit Kft.)

The main financial barrier of geothermal projects is the **lack of capital for drilling the first** well in a phase when there is still a reasonable chance of complete failing of the project. **The combination of high upfront investment cost and the geological risk** in the same time makes almost impossible to finance these projects on pure market conditions. In DARLINGe countries, which represent juvenile geothermal markets, there are regularly available direct investment subsidies, low interest loans or indirect investment subsidies, but they cannot solve the major problem above, because they are repayable if the project is unsuccessful.

Whilst remarkable technology development has been driving down costs of wind and solar projects, which thus became competitive against newly built fossul fuel power generation, this is not the case for geothermal. High upfront costs still make them uncompetitive on the market, especially against subsidized fossil-based projects.

Costs of a plant (thermal power station) vary widely as they may include different installation, technologies and services and depend strongly on the individual sites and conditions (e.g. resource temperature and pressure, yield, reservoir depth and permeability, fluid chemistry), but also whether the project is a greenfield site or expansion of an exisiting plant. Development costs are also strongly affected by the prices of other commodities such as oil, steel and cement. Therefore reported "average numbers" have a great range (Figure 39). In 2011, IEA reported an average range of 45 to 85 USD/MWth for district heating and 40 to 50 USD/MWth for greenhouse heating. However due to much cheaper labour and material costs and these numbers are definitely lower in the DARLINGe countries.

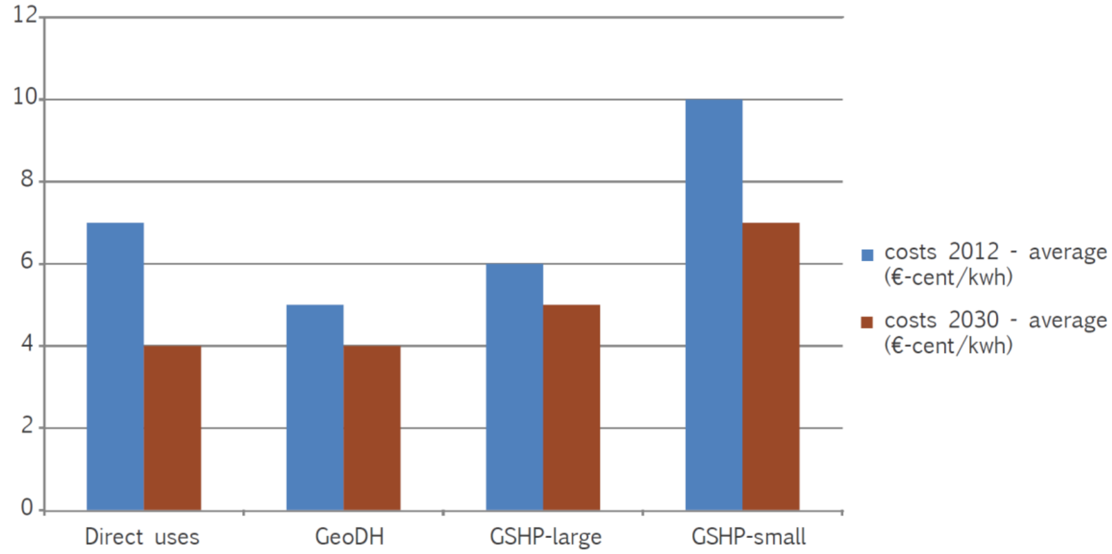

Figure 39: Levelized cost reduction for geothermal HC technologies 2012-2030 (Source: Geothremal Technology Roadmap, European Technology Platform on Renewable Heating and Cooling (2014)

Geothermal projects are often considered expensive. However, if you compare the economics of a geothermal and a fossil fuel based project, there is not so much difference in the total costs, differences rather exist in the distribution of costs along the full life-cycle of the project. The full costs of a fossil fuel based project (i.e. environmental damages) are paid by next generations, however these externalities are hardly ever taken into account. Geothermal projects are paid upfront.

Tables 3 and 4 show reference numbers based on actual geothermal project plans in SE-Hungary. One must keep in mind though, that not two projects are the same, and while some differences are minor, it is, for instance, difficult to compare a development utilizing surface discharge with another one using reinjection. But there are many other variable factors too: drilling prices have increased in recent years due to high demand, while oil (and natural gas) prices are relatively low – both of these affect payback periods of geothermal investments. Therefore benchmarking needs to be used with a certain level of caution, and should neither deter developers, nor should it get unsubstantiated hopes without site specific studies and analyses.

	Average
Investment costs (Euro)	3,159,000
Produced geothermal energy (GJ/year)	56,700
Investment costs per unit of produced geothermal energy (Euro/GJ)	55.7
Operation costs (Euro/year)	180,917
Decrease in natural gas use (million m3/year)	1.6
Decrease in CO2 emmission (tCo2/year)	3,202

Table 3: Average costs of geothermal cascade systems as in Mórahalom, Makó, Csongrád, Szeged in Hungary. Numbers stand for newly developed systems in which 1 production and 2 injection wells are drilled, 1-3 km pipeline system is used to distribute geothermal water to end users, usually with balneological / agricultural utilization at the last stop.

	Average
Investment costs (Euro)	7,813,000
Produced geothermal energy (GJ/year)	65,500
Investment costs per unit of produced geothermal energy (Euro/GJ)	119.3
Operation costs (Euro/year)	141,917
Decrease in natural gas use (million m3/year)	2.2
Decrease in CO2 emmission (tCo2/year)	4,050

Table 4: Average costs of integration of geothermal into district heating systems. Examples are four Szeged (Hungary) systems under development with 1 production and 2 injection wells drilled, geothermal energy is introduced via a short pipeline to the nearest existing heating centre of an already operating district heating circuit to provide heat and decrease natural gas use.

Geothermal can be promoted only if it is economically attractive, so the price in comparison to the one of fossil fuels is reasonable.

Regarding the **competitiveness of geothermal projects**, the general method of evaluating is to compare them to a fossil project. In many cases a simple, natural gas fired, warm water boiler is the benchmark. Finally the CAPEX and OPEX values of projects define the viability of the geothermal option against the conventional gasboiler option. CAPEX and OPEX values are depending on many factors, including but not limited to

- price of natural gas
- price of electricity (parasitic loads of pumps, etc.)
- well properties (necessary depth, available yield, temperature, etc.)
- distance between the wells and the place of energy utilization
- energy demand distribution throughout the year

6.2. Strategy to buid on: strengths and opportunities - barriers to overcome: weaknesses and threats

In terms of heat market conditions, the DARLINGe project area has several strengths and opportunities to buid on. There is a **significant number of cities and towns** accommodating nearly two-third of the area's total population, which represent a **considerable heat demand**. Most of these settlements have district heating systems, i.e. the infrastructure is already available. There is a growing interest from municipalities willing to invest into RES / geothermal projects. Furthermore the agriculture sector also represents a substantial potential heat market. Nevertheless the peripheralization of rural areas is a threat.

Developing geothermal **projects** in this region **is cheaper** compred to other parts of Europe **due to lower costs** (cheaper drilling-, labour-, service costs).

Although financial risks are considerable in geothermal projects (especially in the exploration phase), in the DARLINGe area this is decreased in many perspective zones by results of former geothermal explorations. To support project development, **regularly available, not repayable direct subsidy schemes exist** in all partner countreis and there is also a high rate of possible EU-funds, especially for new-comers and for accession countries (SRB, BH).

There are **good European examples** for subsidy systems demonstrating that the financial barriers can be successfully overcome which led to the boom of geothermal development (The Netherlands, Iceland, France, Germany, Switzerland, Denmark). Based on the evaluation of the financial instruments in these countries a clear vision could be created about the necessary steps in DARLINGe countries.

Nevertheless the weakness and threats are numerous. The most serious threat impacting the economics of geothermal projects is **the unfair competition with (subsidized) conventional sources**, and the existence of **regulated energy prices**. These seriously destroys free market conditions where geothermal could compete with fossils on a fair basis.

Furthermore the current environment **does not** properly **reflect externalities of energy production** in market prices, including environmental, social, innovation and economic externalities. Together with persistent and distortive fossil fuel subsidies, this is one of the reasons leading to high capital costs that hinder cost-optimal renewable energy deployment. In addition, a lack of smart solutions, including demand-response, also hinder cost-optimal deployment of geothermal energy.

The **unfavourable cost profile of a geothermal project** (**high upfront CAPEX**, long, extensive and expensive project development period) coupled with significant risks at the same time, does not make geothermal projects attractive for investors before a successful exploration phase. Also the relatively long pay-back time (10-15 years on average) makes these projects **unappealing for the financial sector**. Once a RES project is an option, investors are more for renewable electricity projects, which are more "simple" if the grid access is ensured, furthermore existing feed-in tariffs make the project economically viable, rather than to heating projects, where the building of a new pipeline infrastructure is costy, the renovation of the old systems - where technical parameters might have been designed for a higher temperature – is complex, and green heat tariffs are practically missing.

The **lack of risk mitigation/insurance funds and operational support schemes** (e.g. green heat premiums) is another major weakness. There are no-, or hardly any financial sources available for upgrading existing heating systems. Shifting from juvenile (such as the DARLINGe countries) to mature markets support mechanisms from direct, non-repayable subsidies change to simple private risk insurance funds operating on market rates. A juvenile market must be directly subsidized and taking all risks, while in the latter case the market-priced service of a private insurance company may be enough for boosting the development. However it is reasonable to expect that support schemes and other incentives (financial and regulatory) will still be the main policy tools that Member States will use to implement their renewable energy projects that are not yet able to be fully financed by the internal energy market.

Although some larger towns have sizeable heat markets, the overall settlement infrastructure is not favourable for a widespread deployment of geothermal energy for heating, as there are many small villages scattered around territory. Furthermore the overwhelming part of the large number of **existing district heating infrastructures are obsolete** and need modernization in order to be theoretically suitable to accommodate thermal waters. The poor energy performance of the buildings (lack of proper insolation) asks for bivalent systems.

There is a lack of interest from users to join a new (district) heating system if they are already used to another, which is cheaper (see subsidized fossil fuel process). There is also an unfortunate trend of dispatching from the existing district heating networks.

6.3. Future vision / Recommendations

There is an enormous untapped potential in the heating and cooling sectors for the decarbonisation of EU economy, for the reduction of energy dependency and to increase competitiveness. Geothermal technologies are already available and, under certain circumstances, cost-competitive but they could progress even further if the right decisions are made today. In particular, **policy-makers should ensure the following crucial elements:**

As long as a much higher level of “environmental awareness” and responsible thinking on sustainability is not reached, consumers will always choose cheaper solutions. This is especially true for Central and SE-Europe, where the average level of living standards is still below the European average.

The geothermal sector remains small at the European level and quite fragmented, being more dynamic in some states, less so in others. The availability of the resource in a given country’s geology plays a role, but so does the existence of a suitable regulatory framework, sufficient political and public support, and, not least the available financial instruments. The purpose of different financial support mechanisms is common: increasing profitability, reducing payback period or risk mitigation.

In order to achieve a truly competitive EU internal energy market, full competition should be guaranteed beyond electricity and gas markets to include the heat sector. However the heat sector is dominated by heavily subsidised fossil fuels, ensuring the control of markets by unavoidable historical operators. As an example, an EC study “Subsidies and costs of EU energy” (ECOFYS 2014) highlighted that subsidies to natural gas amounted to €6.5 bn, while support to an emerging technology such as geothermal only reached €70 million. To be able to make competitive geothermal heating, it is necessary **to phase-out fossil fuels subsidies and price their externalitites, as well as terminate regulated prices.** Furthermore in most EU countries there is no carbon price, as 90% of the heat sector falls outside the scope of the ETS, and only a limited number of countries have a carbon tax in place in non-ETS sectors. Therefore it would necessary to price greenhouse gas emissions in the non-ETS sectors. **Where this is not politically feasible, fuel switch to renewable sources of heating should be supported**.

As highlighted by an EGEC Policy Paper (EGEC 2015: Fuel switch to Renewables in the Heating and Electricity Sectors) another important driver for fuel switching is **access to financing**, which is currently a huge barrier for integrating RHC into buildings and industrial processes. Decentralised and small scale RHC technologies, such as geothermal heating systems require investment by households, commercial and industrial consumers, and the higher upfront investment is an obstacle. It has to be emphasized that renewables for heating and cooling and energy efficiency should be addressed at the same time, notably in the building sector, as they face similar barriers and can generate synergies. In this regard it is crucial to mobilise existing Structural and Investment Funds as well as the new European Fund for Strategic Investments to finance RES heating and cooling, also to boost the renovation of the existing building stock. Financing tools must include risk capital, guarantees and grants. In order to overcome the main barrier for the development of deep geothermal energy, i.e. the geological risk, **public risk insurances** in the form of repayable grants **in emerging geothermal markets** to public-private funds in more mature markets are attractive support schemes. The idea of a pan-European risk mitigation fund, where risks and resources are pooled, should be further explored.

Risk Mitigation Funds are mainly state-owned, and they provide financing in case of (partly or totally) unsuccessful exploration well. Two types of Risk Mitigation Funds have been used in the geothermal sector so far:

- post-damage guarantee
- guaranteed loan

Guaranteed loan is a smart combination of financing source and risk mitigation instrument. The loan is provided for a certain period and interest rate as a conventional loan, but when the exploration risk materializes the repayment obligation is partly or fully released. The fund must pay out the loan amounts when signing the contract, so the amount has to be in the fund already at the beginning.

As the **guaranteed loan** provides financing source and risk mitigation instrument at the same time we suggest this subsidy measure **to apply in DARLINGe countries**. The parameters have to be defined case to case. Additionally, **some direct investment subsidy** also should be provided to ensure the competitiveness to fossil projects, but the amount has to be defined in a way to motivate project developers and operators to work according to the good professional practice as well. Thus, a certain ratio of own contribution and own risk have to be left at the project owner.

Some kind of financial support has to be maintained during **the operation phase** of the project too, to ensure continuous economic motivation of the project owner to maintain the production. **Feed-in premium** may be the best instrument to ensure the long-term profitability of the project by providing a balance compared to fossil fuels. For the magnitude the French "Fonds Chaleur" system shows a good example, which has got a final aim of resulting 5% lower renewable heat price than fossil heat price (natural gas fired boiler is the benchmark). The value of feed-in premium has to be defined case to case based on the business plan of the project taking the before mentioned subsidy schemes into consideration as well.

Support schemes can be designed efficiently only if **technology-specific**. Likewise regulatory measures, it is necessary to go beyond a 'one-size-fits-all-approach' and to take into account the different size, application, features, and market and technology maturity of RES / geothermal technologies. Attention should be paid to the required aid to the investment (and less on operating aid).

The overaching question whether **geothermal energy is competitive or not** depends, among others on the reference prices paid for energy, which varies among countries. Cost competitiveness can be assesssed by comparing the levelized cost of energy (LCoE) to reference prices. However this is not black and white. First of all there is not a single „technology cost", this also depends on location, operation aspects, etc. It is **recommended to make detailed case studies**, preferable for the cross-border pilot areas with similar geographical-geological conditions, where the economic differences between the partner countries can be analysed in details. This requires a multi-disciplinary team work, including economists, engineers.

It is also necessary to **supervise the currently existing pricing of geothermal heat production** in the DARLINGe countries. Thermal water production – if it happens for direct heat purposes – often suffer **double taxation**, i.e. the user has to pay water fee after the abstraced amount of water and mining royalty for the exploited heat amount from the same fluid. Furthermore if the spent geothermal water is not reinjected, the wastewater fee is also higher. These puts extra burden on thermal water producers for energy purposes (in comparison to balneological use) and should be terminated.

In order to deploy the geothermal resources for space heating (district heating or decentralized town heating systems) it is necessary to make a **detailed matching of the resources and the demands**, i.e. to check whether:

- cities with existing district heating networks lie on an area where potential geothermal reservoirs storing thermal water at least above 50 °C, but preferably above 75 °C have been identified
- cities with inhabitants more than 15 000 people lie on an area where potential geothermal reservoirs storing thermal water at least above 50 °C, but preferably above 75 °C have been identified
- there are sizeable heat demands in the vicinity of already exisiting thermal water wells
- make detailed feasibility studies about the potential technical conversion of the existing DH infrastructures

In the heat sector it is crucial to collect and update regularly reliable statistics and distinguish between energy sources, enablers, and end-users. This would enable informed decision making.

7. Social awareness

7.1. State-of-art

To make sure that geothermal energy can play its role in Europe's future energy supply in an optimum way, it is essential **to engage with strategic groups** including political decision makers, possible investors into geothermal projects, the general public, and local communities in order **to highlight the advantages of geothermal energy**: it provides opportunities for local development, providing competitive heating and domestic hot water, creates local jobs and ensure regional security of supply. The other streamline of raising awareness is **to alleviate possible concerns** which might hamper the increased use of geothermal technologies.

Deep geothermal projects are complex infrastructure projects, which can only be implemented together with the local citizens. Due to the **low awareness on the advantages of using geothermal energy**, social resistance often results in obstacles, such as significant slowdowns.

Main principles for public acceptance of geothermal are:

- early communication
- increased local awareness and
- participation in the planning and implementation of geothermal projects,

During the planning stage of the intended project it is important to contact public administrators of the area concerned to provide them with information on the project objectives, the environmental measures in program, and the social benefits that the project is expected to produce. At the same time it is important also to start to shape the public opinion through a plain and timely information campaign on duration of works, potential impacts of the construction and benefits during the operating phase.

During the implementation stage of the intended project, developers should release periodical dissemination of information on the activities already completed through meetings with local administrators, and by means of media. Guided visits to drilling sites and plants for local students and other interested people also help a lot.

In the **DARLINGe countries**, where the **use of thermal water has long lasting traditions**, the social obstacles against geothermal projects are rather low. Furthermore the main environmental and social concerns against geothermal energy are rather related to power generation (noise, emission of gases) and deep EGS projects, where the stimulation of the reservoir may induce perceptible seismic events. In the case of direct heat use projects – in the focus of the DARLINGe project - using the technlogy of producing thermal water the possible negative impacts are rather associated with the potential pollution of surface and groundwaters (e.g. thermal or chemical load from the brines).

In the Danube Region **the main gap of information** exists on the **potential advantages of using geothermal energy and the knowledge of the available resources.** Many of the settlements are **historically comitted to fossil-based heating**, and the sustainable development of the city is not a priority for decision makers. **Mayors are often not aware of the local resources (heat under their feet)** and are focussing only on their own settlements without showing interest in regional approaches, which would reduce costs for the overall society (systems costs, externalities, greenhouse gas emission, etc.). They are not aware of the (geothermal) technologies available either, and in the fear of being not re-elected they are not challenging changes to transform the energy systems of their settlements. **Incomplete information on geothermal energy solutions can hinder its cost-optimal deployment at city and community level.** The smart cities concept – that addresses the decarbonisation of a city's energy system as a whole (including its lightening, heating and cooling, as well as transport) – is not well known in the DARLINGe area.

Nevertheless there is quite a number of **settlements on the DARLINGe area that signed the Convenat of Mayors**, which brings together thousands of local governments voluntarily committed to implementing EU climate and energy objectives (Annxes 1-5). In Serbia no such settlements fall on the DARLINGe territory. Signatory local authorities share the common vision for making cities decarbonised and resilient where citizens have access to secure, sustainable and affordable energy.

The **Sustainable Energy and Climate Action Plans** (SECAP-s) (formerly SEAP-s) reveal in most cases that the **main sector being responsible for the majority of CO_2 emission is the building sector.** Renewables, as an option are part of the SECAP-s in a lot of cases, however geothermal energy per se is mentionned only rarely.

7.2. Strategy to build on: strengths and opportunities - barriers to overcome: weaknesses and threats

Geothermal energy is invisible, found underground, that's why the general **awareness on its advantages is low,** which is a major weakness. However due to the overall increasing consciousness on renewables, their role in mitigating climate change effects and providing local energy sources to decrease the import dependence, as well to the growing number of successful geothermal projects, this disadvantageous situation is slowly changing. The relatively high number of settlements in the DARLINGe area signing the **Convenant of Mayors** and elaborating their Sustainable Energy Action Plans is a very positive sign and provides a big **opportunity to address the Mayors of these cities**, and explain them (where it is relevant) that they should also think of geothermal energy, as an option to decarbonise their heating systems (as the main agents for CO2 emission) and thus make their cities greener.

7.3. Future vision / Recommendations

It is important to **launch national information campaigns, roadshows** to increase awareness of citizens on the advantages of geothermal energy and facilitate access to information regarding suppliers and installers. The campaign should focus on the actual costs, benefits, risks, available technologies, provide a comprehensive information on the potential, present good practices. The trainings, messages, dissemination materials should be always tailored to the region's / locality's needs and to the target audience, as it was summarised in DARLINGe's Communication Plan (Table 5).

Target group	Expected change in knowledge in relation to DARLINGe objectives	Expected change in opinions in relation to DARLINGe objectives	Expected change in practice / actions in relation to DARLINGe objectives	Key message
ministries	get familiar with the basics of geothermal energy systems and their operations including non-technical aspects (e.g. economics) in order to properly adjust the national policies and regulatory systems	be aware that geothermal energy is a local, baseload and flexible renewable energy resource which can provide economic development opportunities for countries in the form of taxes, royalties, technology export, and jobs	prioritize geothermal energy in national energy strategies and policies	**Geothermal energy is a smart and sustainable solution for energy resource diversification.**
public authorities	geothermal energy resources - although it is a renewable form of energy - are	there's is a great potential in geothermal energy in the	make a faster and more transparent licensing system	**Management strategies based on geoscientific models can ensure**

	not infinite due to the limited recharge of the groundwater as carrier media impacts of co-uses threats of overexploitation	region, it is a real alternative for fossil fuels but needs to be used in a smart and controlled way	set up management policies based on DARLINGe tool-box methods and pilot test results	**a sustainable and long-term use of geothermal energy**
financing institutions	risks and costs at various stages of a geothermal project	geothermal projects are bankable, even at the exploration stage geothermal direct use projects can be profitable within 10-15 years	establishment of a geological risk mitigation scheme (adaptation of the DARLINGe tool-box methodology modul)	**Risks of a geothermal project can be understood and reduced by well-established exploration strategies**
project developers	increased knowledge (via the DRGIP portal) on the potential, but still untapped geothermal reservoirs as future project development sites learn about the concrete steps of project development (as part of the tool-box)	there is a great potential in geothermal projects	more new direct use projects	**Untapped geothermal resources represent a big potential for future direct use projects**
project operators	learn about the risks of overexploitation and operational issues (e.g. scaling, corrosion, gas content) learn from best practices	cascade uses are energy efficient solutions even at existing sites	increase the number of cascade systems and the rate of reinjection	**Up-to-date information on the utilized geothermal reservoir is needed to avoid operational problems and to plan future utilization strategies**
municipalities	learn about the various utilization possibilities of geothermal energy	geothermal energy is a real alternative for fossil energy	join the Covenant of Mayors involve geothermal in the Sustainable Energy Action Plans	**Look for geothermal opportunities at your location – you might sit on a hot-spot!**
governmental and sectoral	learn about the various utilization	geothermal energy is an	Join and support regional	**Think green – geothermal is an**

agencies	possibilities of geothermal energy	alternative in regional development plans	geothermal project initiatives	**opportunity in your development plans**
service providers	more knowledge on the operational issues can assist the development of new technologies, be informed about the latest developments in geothermal energy field	be aware of the new business possibilities in connection with geothermal energy	think about geothermal energy when looking for new business opportunities	**More exploited geothermal energy – more opportunities for your business**
network institutions	there is a huge international and national geothermal energy network	there are a lot more stakeholders in the geothermal energy field	more alive and extended contact with the key-players of the geothermal sector	**Expand your contacts via DARLINGe stakeholder network and Transnational Stakeholder Forum**
academia	discover the new scientific results about the project area's geothermal systems	there are a lot of new discoveries in connection with geothermal energy based on geoscientific research	use project results as seeds for future research projects, educational and training materials, MsC, PhD thesis	**Discover more about the geothermal systems of the Pannonian Basin**
general public	raise the awareness on the advantages of geothermal energy	Geothermal energy is available, affordable and environment-friendly	Use more geothermal energy for heating	**Think about the future, think about the planet - make your homes warm by geothermal energy**

Table 5: Identified target groups and key messages of DARLINGe

It is recommendend to **foster local ownership of renewable energy** (e.g. community and citizen participation in renewable energy cooperatives). It seems particularly important **to support local authorities in preparing strategies for the promotion of renewable energy,** to align urban planning with energy planning and objectives, enable cooperation between relevant actors at the local or municipal level and facilitate access to finance.

It is desired that settlements that are already part of the Convenant of Mayors **expand their SEAP-s and include geothermal energy** (where relevant), furthermore **new settlements with good geothermal potentials join the Convenant.**

8. Data policy

8.1. State-of-art

Territorial management requires informed decisions based on **access to authentic and timely data and information.** The ability to access and re-use data is not only a technical activity but also a concern of policy. This includes a range of legal acts dealing with data protection, data accessibility and the intention to create digital economy from the reuse of public sector information. The most important EU policies regarding data reuse are the Public Sector Information (PSI) Directive (2013/27/EU) working on Open Data and the INSPIRE Directive (2007/2/EC). The European Commission works to overcome the barriers limiting the re-use of public sector information also through non-legislative measures.

In addition to EU legislation, the Commission also:

- engages with Member States experts in the Public Sector Information expert group (PSI Group);
- funds an Open Data incubator assisting small and medium-sized entreprises in building sustainable business ideas on the basis of Open Data;
- funded the Legal Aspects of Public Sector Information (LAPSI) - thematic network of lawyers specialising on PSI re-use, including academics and practitioners;
- commissioned studies on the following issues:
  - Presence of exclusive agreements in member states;
  - Studies on the economic potential of PSI re-use;
- developed an Open Data Portal for its own documents and a pan-European digital service infrastructure aggregating content of existing open data portals inside the EU. Find more information;
- contributed to the G8 process on opening up government information, also for re-use, leading to the adoption of a G8 Open Data Charter. Read how the EU intends to implement the principles of the G8 Open Data Charter.

Data policy highly varies across Europe in terms of its maturity, which also the case in the DARLINGe project.

In the Danube Region an outstanding scientific support was provided by the European Commission's Joint Research Centre (JRC) by creating the **Danube Reference Data and Services Infrastructure (DRDSI)**, which has been build upon JRC's extensive experience in Spatial Data Infrastructure (SDI) as technical coordinator of the INSPIRE Directive and the emerging initiatives in Open Data. DRDSI is an open platform containing almost 10 000 datasets. It contains 9 geothermal datasets: deep geothermal data from Northern and Southern Bavaria, Geothermal Atlas of Slovakia, Geothermal and mineral water resources, as well as groundwater bodies in geothermal structures in Slovkia, Geothermal map of Slovenia, Geothermal object-sin Bulgaria, as well as some information on the geothermal probes in Vienna and superficial geothermal energy in Bavaria.

Regarding the development of the geothermal sector and policies associated with the enhanced use of geothermal energy publicly available digital geoscientific and other technical and non-technical information are also vital to tackle challenges such as sustainable supply of energy, mitigation of climate change by exploiting renewable energy resources and addressing conflicting claims on the co-use of the subsurface space. **Different geological databases** of content related to geothermal energy **exist** all around the world, however these are **fragmented in terms of contents, formats and their**

geographical coverage.. Providers of geothermal information differ in their data sharing concepts and services, and hence each designs and builds its own information system independently. Scientists, operators and consultants organize and use geothermal databases, which contain underground data most often in the form of different subsurface maps (e.g. temperature and heat flow distribution, various geological units) and are seldom accessible to the public. Regional, national and European administrations produce, collect, organize and publish regulations, documents, descriptions and maps of geothermal licences, and energy production values in the form of texts and figures. Funding and insurance agencies require and organize information necessary for risk management and economic analyses of the proposed projects. When available, these various databases and data-sharing systems mostly **exist at national level, and are in local languages**, serving mostly local or specialized applications. This is also the situation in the DARLINGe area.

In general one can state that **data sharing is not mature** in the DARLINGe region, **Open Data policy /** culture is especially **low developed** in some countries. Data accessibility varies a lot within DARLINGe countries. Some organisations focus more on data protection rather than on data use and reuse.

In the past few years several EU funded projects aimed to provide pooled knowledge and data sharing services where geothermal information can be accessed, retrieved and queried to support geothermal projects development. One of the pioneering work was the concept of the **European Geothermal Information Platform- EGIP** (http://egip.igg.cnr.it/) prepared in the frame of the Geothermal ERANET project in 2013, which was designed as a distributed system: each (national) data provider delivers its data according to a common standard data model and services (INSPIRE compliant). This has several advantages:

- Guaranteed data interoperability: retrieval, viewing and access of information from partners and other providers (via WMS, e.g. protected areas)
- Harmonized geothermal domain at a European level
- Efficiency, thanks to the non-multiplicity of data sources, the latter being directly related to national databases
- Guaranteed ownership: data belong to and stay in the country they are related to. Each country decides what to share and what to keep private
- Durability and maintainability, since this information is directly related to national data sources
- Economically viable, requiring only coordination with respect to what each country would need to develop independently
- Productivity, by covering all published data in the long term.

In the EGIP concept each data provider at a national level shares data and documents (managed by its own information system) with the EGIP portal according to common rules which are compliant with INSPIRE principles. These rules are related to the common data model for the EGIP, the metadata to describe the datasets, and the web services to deliver data and metadata. With the metadata registered in the catalogue, the EGIP portal finds the services and then processes the data (view, download, or any other process such as computing statistics). The portal then puts all national pieces together to make an end European product (Figure 40).

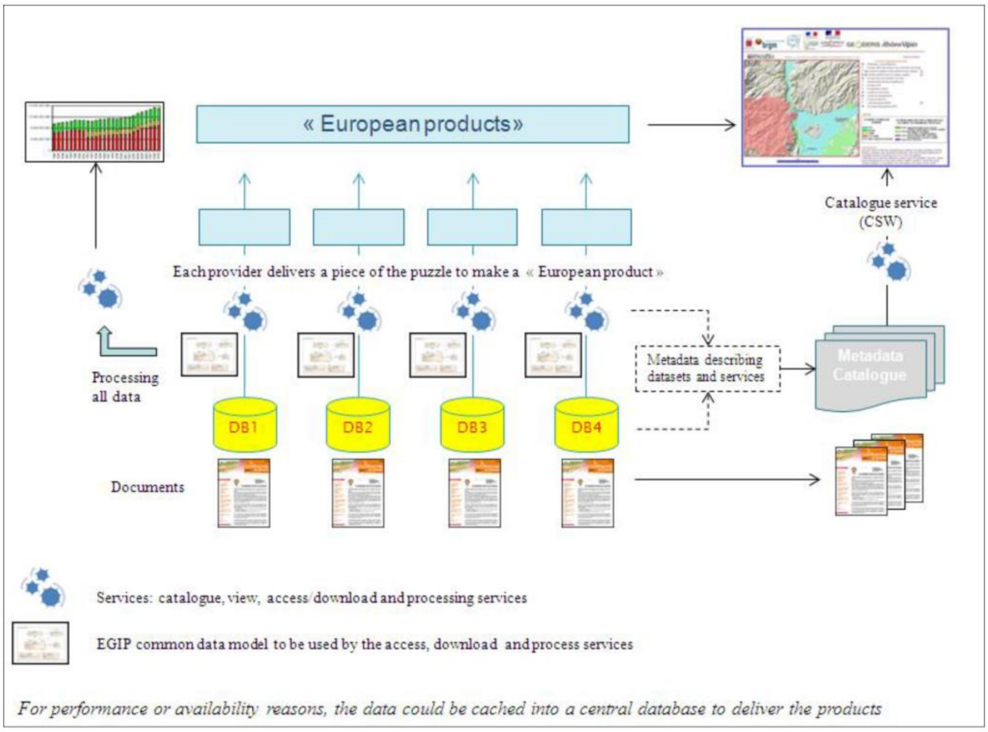

Figure 40: The concept and architecture of EGIP (source: Geothermal ERA-NET project D.3.2.)

Furthermore almost all international geothermal RD projects prepared some sort of "web-viewer", where the content-specific end-results are shown in the form of intercative maps, databases (e.g. Transenergy, GeoDH, Geoelec, GeoMOL). In addition several national geothermal information portals also exist (e.g. GeoTIS for Germany, ThermoGIS for The Netherlands and also a wordwide viewer) that provide easy-to-understand information about the given area's geothermal potential, utilization, subsurface conditions. Depending on the available resources for the technical development of these portals, their functionalities vary from simple to highly sophisticated ones, which allow even the edition of individual profiles, diagrams (e.g GeoTIS).

Inspired by these earlier works, one of the main aims of DARLINGe project is also to establish an entry point to advance collaboration, and facilitate exchange of methods and ideas between those working in the field of geothermal energy in the Danube Region, to integrate and harmonise geological, hydrogeological, geothermal- and to some extent other technical information and services. This is called the **Danube Region Geothermal Information Platform- DRGIP**, which can be also considered as a pilot of the EGIP. In short, the DRGIP will be a data infrastructure that provides data- and information services, as well as core services allowing discovery, access, validation and download of data and information and maintenance of the system. It will follow an open-access policy, meaning that no user authentication will be required and that the content enabled by DARLINGe will be accessible by accepting only the general terms and conditions of the data providing institutions. It is expected to be an informative, user-friendly and stakeholder-engaging site.

8.2. Strategy to buid on: strengths and opportunities - barriers to overcome: weaknesses and threats

Rich information in the form of various scientific and technical datasets, publications are available in general on the geothermal energy potential and its utilisation in the DRALINGe countries, however these are **fragmented** and most often available only in **national languages**, which is a weakness. Only a few systematic databases exist and **most of the data are scattered** (e.g. at individual users), so an organized collection on any segment of geothermal energy use in this geographical area is a big challenge. **Data accessibility varies a lot** in DARLINGe countries: due national regulations, different levels of digital maturity as well as IPR and confidentiality issues, data availability vary from data provider to data provider. It turned out that it was particularly difficult to obtain data from Romania, where organisations focus more on data protection rather than on data use and reuse. Therefore creating harmonised / cross-border datasets is still remains a matter of pilot activity rather than a full-scale implementation. In general one can state that **data sharing is not mature in the region,** and there is a relatively low awareness at policy level on the value of Open Data, which is another drawback.

As the INSPIRE Directive focuses on the Member States, **it remains difficult to find comparative data and statistics covering the candidate countries and countries in accession** (in DARLINGe case Serbia and Bosnia-Hercegovina). Not all project partners are part of the EU, so they are not obliged to follow EU Directives. Anyway, to increase maturity of data sharing the DARLINGe consortium decided to include INSPIRE principles as a common standard, which is an opportunity.

DARLINGe follows the above mentioned EGIP benefits through common information system, DRGIP, since some partners don't have possibility to manage their own information system, which is a strength.

Building a strong stakeholders network in DARLINGe area to support data driven decisions, to promote the use (re-use) of relevant data is also a strength.

However the utilisation of state-of-the-art technologies in combination with user-guided implementation and present-day advances in data standardisation and interoperability is a big opportunity in maximizing use of data for better policy making.

8.3. Future vision / Recommendations

As an overall principle it is necessary to maximize use of data for better policy making. Readily available and shared data resources should be the base for more transparent policy, following the **FAIR** principles: standardised and reusable data to make the data easily **f**indable, **a**ccessible, **i**nteroperable and **r**eusable.

This is in line with the European Commission's priorities of the Digital Single Market's interests for the free flow of data and interoperability:

- develop new technologies in sharing and visualizing Open Data in 3D (geological models) and 4D (models supplemented with monitoring time-series)
- establish common data policies
- interoperability solutions among public adinistrators

It is especially important in the Danube / DARLINGe region to further **raise awareness on Open Data**:

1. Data availability and access: data must be available in full and at no more than the reasonable reproduction cost, preferably by downloading over the internet. Data must be available in a convenient and modifiable form.
2. Reuse and redistribution: data must be provided under terms that permit reuse and redistribution including intermixing with other datasets. Data must be machine-readable.

3. Universal participation: everyone must be able to use, reuse and redistribute, there should be no discrimination against fields, persons, or groups. E.g. „non-commercial" restriction that would prevent commercial use, or restrictions for certain purposes (only in education) are not allowed.

DARLINGe countries must **create a culture with a strong political support for data and knowledge sharing**, improve information retrieval and delivery, improve interoperability, adopt standards for corporate data and metadata management.

In addition to the above described general data policy priciples, reinterpretation, harmonization and standardization of existing geoscientific databases complemented with new data and measurements would enable to create **publicly accessible databases for assessing and exploiting geothermal resources** in the DARLINGe region. It is important to create an **Open Data platform** for the Danube Region (as will be the case of the **DRGIP portal**), which is envisaged as an informative, user-friendly, stakeholder engaging site. The platform should have specific technical functionalities to capture, store and display data including map visualizations. It is also very important to **involve stakeholders in the creation of the platform to ensure it fulfills its purposes.** Establishing such a platform should be not just transfer of knowledge, but also a capacity building exercise: the objective is not only to create a pool of common and harmonised maps, databases, but build the partner's capacities in data transformation techniques and technologies to ideally share in the future and offer experience and lessons learned for other countries in the region.

Wider acceptance of Open Data initiative resulted in more Open Data portals being implemented and available in the Danube Region, that is why it is envisaged that DRGIP will be part of the **Danube Reference Data and Services Infrastructure** (DRDSI) . With becoming a part of DRDSI, DARLINGe will also support one of DRDSI main conclusion, that "...data is crucial for macro-regional strategies as a means to support policy-makers, as a shared asset to support economic growth and as a cultural artefact for the regions citizens… "

9. Research priorities

The **DARLINGe** project, by its nature is not a research project, but is comprised of **science-based policy support** activities. Therefore in this last chapter we do not provide a state-of-art and SWOT analysis like for the other topics discussed in the previous chapters of this document, just highlight the most important areas for future research activities. Nevertheless we firmly believe that such progress in this geographical area is essential to be able to provide sound, science-based recommendations for the development of the geothermal sector in the Danube Region.

The main instrument for RDI funding of topics related to geothermal energy has been the H2020 Program, especially topics and calls under the theme „Secure, clean and efficient energy". Now the new **Horizon Europe Program** providing research and innovation funding opportunities between 2021 and 2027 is in the gate, so DARLINGe research communities should find the right calls to apply.

There are also **national RD** funds available in the DARLINGe countries, which should be progressively increased; furthermore **synergies** among these funds should be exploited in order to successfuly address topics of regional interests, such as geothermal energy which occurs irrespective of state borders. The existing cooperation mechanisms should pave the way for an enhanced regional cooperation.

The Pannonian Basin, and its shared geothermal resources provide an ideal **natural laboratory** for region specific, science-based strategy development. Therefore further development of a joint knowledge base, already well established in the DARLINGe project, capacity building, as well as investing in the training and mobility of young researchers is well recommended.

The most relevant topics associated with enhanced geothermal heat production in the Danube Region, where further RDI is necessary are the following:

- **Further develop geological, geophysical, geothermal, hydrogeological, geochemical exploration and monitoring methods** and the interpretation of data, which aim to estimate underground temperature, permeability, presence of fluids as well as the lateral extent and thickness of the reservoir rocks. A better understanding of complex and deep geological processes will enhance the predictibility of the physical and chemical subsurface conditions.
- Develop internationally accepted protocols and tools for **geothermal resource assessment**, focussing on a probabilistic approach.
- Advancement in 3D and 4D geological modeling and reservoir modelling of exploited resources, geochemical modeling for mitigation of chemical operational issues (2-phase flow, scaling....)
- In term of exploration, reservoir management **cross-fertilise with hydrocarbon industry**
- Establish new **methodologies for analysis of quantity and quality state** of geothermal aquifers with advanced on-line monitoring systems. Common methodology as applied from the water management side is not directly applicable as the natural variability of the systems differs much from groundwater aquifers with active recharge, the magnitude and type of changes and their (ir-)reversibility caused by use of geothermal water. There is also a need to develop methodologies to reliably assess the critical groundwater levels and quantities in geothermal reservoirs.
- Improve methods for dating of old (Pleistocene) waters with stong signal on carbonate dissolution and/or CO2 content.
- Improve on-site drill-cutting analysis and downhole instrumentation, measurement-while-drilling (MWD) technologies to collect reliable information on reservoir and fluid properties, and well monitoring as well as data interpretation technologies.
- Improve technologies for cascade use of thermal water also by use of addtional heat pumps.
- **Reinjection into porous reservoirs** need massive RDI support from all aspects (technological solutions, sub-horizontal drilling, water filtering systems, clogging, scaling and gas issues mitigation, numerical prediction of future scenarios, etc.). This also requires a detailed national survey, which accurately defines the usable thermal water resources, followed by well-founded proposals for the eventual relaxing of the reinjection obligation. The ecological and chemical impact of the disposal of thermal waters into surface recepients - currently not obliged to reinjection - must be analyzed, too.
- Development of **more competitive drilling technology, restoration of old wells, transformation of water producing wells into deep geoprobes.**

For geothermal drilling and reservoir management **skilled companies and well-trained personnel** are needed. This means that geothermal science and engineering programs need to be improved and expanded and information exchange platforms need to be developed in order to increase awareness on geothermal technologies.

Although not a research topics, but at the end we emphasize that **large scale demonstration and dissemination projects** should be also supported. Furthermore it is necessary to develop the geothermal industry in a complex manner including all sectors (well drilling, well repair, thermal centre engineering, automation, water treatment, greenhouse construction, agricultural plant production, wellness and thermal tourism, balneology, etc.).

Annex 1: Settlements part of Convenant of Mayors in the DARLINGe territory of Bosnia and Herzegovina, their CO2 emission targets and SEAP goals

Settlement	Population	CO2 emission target	Strategy (SEAP)
Banja Luka	250,000	20%	The priority areas in the scope of SEAP activities are: **building and household sector**, **district heating**, city lighting, and transportation sector. Most of the activities in the first years will be focused to change their habits and behavior of the citizens. One of the crucial challenges in the first years of the SEAP implementation will be establishing of functional body which will be in charge for the SEAP activities realization. Another aspect is definition and establishment of promotional measurements which have to make whole these activities sustainable.
Bijelina	153,000	31%	The priority sectors of reducing CO2 emissions are the sectors of **buildings,** transport, public lighting and **renewable energy**. The main activities in this sectors are: •Increasing energy efficiency of Bijeljina municipal buildings ; •Education and change in behavior of citizens in the field of efficient energy use; •Encouraging citizens and potential investors to increase the energy efficiency of and commercial buildings; •Construction and modernization of roads and traffic optimization; •Replacing existing lamps with more efficient lighting and environmentally friendly; •Utilization of the great potential of renewable energy sources (**geothermal** water, solar and biomass);
Gradiška	62,000	28%	Long-term vision of local authority is seen in education and change in behavior of public in the area of energy efficiency, and regarding the sector of construction engineering which is with the biggest emission of CO2. Afterwards, insisting on expending the number of facilities that are under energy certification on local level, as well as promotion of **renewable energy sources** that are of use for citizens and local community. One of the main challenges will be displacing Border crossing Gradiška from the narrow town center, as well as promotion of hybrid and alternative transportation means, with the construction of necessary infrastructure first for this area.
Doboj	69,343	20%	By applying the EE measures and **renewable energy** resources with reduction of CO2 emission, the City of Doboj is going to 2030. become environmentally friendly environment for living of all its citizens.
Tuzla	174,000		Priority sectors in which the highest CO2 emission reduction is expected at the territory of Tuzla Municipality are **buildings** and traffic. The **district heating system** of Tuzla generates heat through co-generation from Tuzla Power Plant, and CO2 emission could be substantially reduced by means of connecting the individual and collective residential houses/buildings and business facilities. Therefore it is planned for all state-owned

			residential and business buildings to be included in the district heating system, together with all residential and business buildings with heating installations and all state-owned residential buildings without installations (ground floor + 4 and more). With this objective the Tuzla Municipal Council agreed to the Boundaries of the District Heating Zone of Tuzla Town in 2001 and this resulted in Tuzla Municipality territory being divided into **39 heating zones**. A yearly increase in the number of vehicles creates an opportunity for introduction of measures of distance traffic monitoring, popularization and modernization of public transport and promotion of ecological driving and cycling, leading to significant energy saving in traffic sector of Tuzla Municipality. Besides these two priority sectors, substantial reductions in water supply sector due to very complex water supply system in Tuzla Municipality, solid waste management sector due to inexistence of a contemporary recycling system, and in the sector of public lights due to obsolete lighting fixtures and plans for extension of the network through the entire territory of Tuzla Municipality. Therefore these five priority sectors together with introduction of renewable sources of energy and upgrading of spatial planning represent the main action lines aimed at reduction of CO2 emission at the territory of Tuzla Municipality.
Prijedor	97,500	20%	The priority areas in the scope of SEAP activities are: **building and householdsector, district heating**, city lighting and transportation sector. Most of activities in the first years will be focused to change their habits and behavior of the citizen. One of the crucial challenges in the first years of the SEAP implementation will be establishing of functional body which will be in charge for the SEAP activities realization. Another aspect is definition and establishment of promotional measurements which have to make whole these activities sustainable. Municipality of Prijedor is recognized CoM as a chance to take leading position in the region in this sector.
Zvornik	65,000	20%	The priority areas in the scope of SEAP activities are: **building and household sector, district heating**, city lighting, and transportation sector. Most of the activities in the first years will be focused to change their habits and behavior of the citizens. One of the crucial challenges in the first years of the SEAP implementation will be establishing of functional body which will be in charge for the SEAP activities realization. Another aspect is definition and establishment of promotional measurements which have to make whole these activities sustainable. SEAP implementation will be use for improvement of economy and local sustainability of the municipality.

Annex 2: Settlements part of Convenant of Mayors in the DARLINGe territory of Croatia, their CO2 emission targets and strategies

Settlement	Population	CO2 emission target	Strategy (SEAP)
Beli Manastir	10,549	20%	Beli Manastir, town in heart of Baranja regtion, leader of region, town of small but succesful enterpreneurs, town with rich natural resource, settled in clean enviroment, desirable for peacefull and pleasurable family life.
Petrovac	2,407	20%	n.a.
Belišće	10,790	21%	Long term vision of Belišće is to reduce CO2 emissions by the year 2020 by 21,45%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2009 year will increase for 10,84%. Implementation of all defined measures within Belišće SEAP by 2020 will result in decrease of CO2 emissions by 21,45% compared to the base year. Of the total 2009 CO2 emissions the **building sector accounts for 71,04%,** the transport sector for 27,83% and public lightning sector for 1,13%. Therefore, most important measures that can significantly contribute to CO2 emission reduction are measures defined for building and transport sectors. The most important are measures for residential buildings (e.g. refurbishment of thermal insulation, behavior change campaign and others) and measures for increased usage of public transport instead of private individual transport in Belišće.
Osijek	107,784	22%	Long term vision of Osijek is to reduce CO2 emissions by the year 2020 by 22,38%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2010 year will increase for 11,33%. Implementation of all defined measures within Osijek SEAP by 2020 will result in decrease of CO2 emissions by 22,38% compared to the base year. Of the total 2010 CO2 emissions the **building sector accounts for 83,59%,** the transport sector for 15,72% and public lightning sector for 0,69%. Most important measures that can contribute to CO2 emission reduction are measures defined for building and transport sectors.
Vinkovci	35,375	21%	Long term vision of Vinkovci is to reduce CO2 emissions by the year 2020 by 20,83%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2011 year will increase for 11,84%. Implementation of all defined measures within Vinkovci SEAP by 2020 will result in decrease of CO2 emissions by 20,83% compared to the base year. Of the total 2011 CO2 emissions the **building sector accounts for**

			78,80%, the transport sector for 20,12% and public lightning sector for 1,08%. Therefore, most important measures that can significantly contribute to CO2 emission reduction are measures defined for building and transport sectors. The most important are measures for residential buildings (e.g. refurbishment of thermal insulation, behavior change campaign and others) and measures for increased usage of public transport instead of private individual transport in Vinkovci.
Sisak	52,236	20%	Sisak long term vision is to turn into a smart energy city, based in two axes: The first goal aims at the transformation of the city into an environmentally sustainable and energy efficient city, being able at the same time to set the means to attract the establishment of businesses and companies, based on new technologies, with the final aim to move from a heavy industry city to a clean technological industry. As stated in the BEI, the CO2 emission trends from included sectors for 2020 show a 21% of the emissions coming from the transport sector, where the main source of emission being private vehicles, and **79% of the emissions coming from buildings** and urban lighting (residential buildings accounting for 59% of the total emissions). Therefore the biggest challenges are: improving the residential stock performance, and providing the city with an integrated transport strategy as a means for energy consumption reduction. Consequently, the priority areas for action are oriented at (1) acting on the improvement of energy performance in the building stock, focusing on residential, and covering all the relevant aspects (demonstrators, incentives to owners, regulation strengthening and awareness actions), and (2) rearranging of city transport in a more sustainable way. As a result, the expected reductions in emissions are at 74% in the buildings sector and 25% in the transport sector, in the most optimistic scenario that would achieve a total 27% CO2 emission reduction.
Jastrebarsko	5,419	30%	Long term vision of Jastrebarsko is to reduce CO2 emissions by the year 2020 by 30,57%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2009 year will increase for 11,54%. Implementation of all defined measures within Jastrebarsko SEAP by 2020 will result in decrease of CO2 emissions by 30,57% compared to the base year. Of the total 2009 CO2 emissions the **building sector accounts for 78%,** the transport sector for 21% and public lightning sector for 1%. Therefore, most important measures that can significantly contribute to CO2 emission reduction are measures defined for building.
Velika Gorica	63,517	51%	Long term vision of Velika Gorica is to reduce CO2 emissions by the year 2020 by 50,71%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2

			emission in 2020 in comparison with base 2008 year will increase for 11,81 %. Implementation of all defined measures within Velika Gorica SEAP by 2020 will result in decrease of CO2 emissions by 50,71 % compared to the base year. Of the total 2008 CO2 emissions the **building sector accounts for 69 %,** the transport sector for 30 % and public lightning sector for 1%.
Dugo Selo	19,260	21,7%	Long term vision of Dugo Selo is to reduce CO2 emissions by the year 2020 by 21,70%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2009 year will increase for 13,84%. Implementation of all defined measures within Dugo Selo SEAP by 2020 will result in decrease of CO2 emissions by 21,70% compared to the base year. Of the total 2009 CO2 emissions the **building sector accounts for 54,12%,** the transport sector for 44,61% and public lightning sector for 1,27%.
Sveta Nedelja	15,506	25%	Long term vision of Sveta Nedelja is to reduce CO2 emissions by the year 2020 by 25,18%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2009 year will increase for 12,41%. Implementation of all defined measures within Sveta Nedelja SEAP by 2020 will result in decrease of CO2 emissions by 25,18% compared to the base year. Of the total 2009 CO2 emissions the **building sector accounts for 69%**, the transport sector for 30% and public lightning sector for 1%.
Zaprešić	23,125	21%	Long term vision of the City of Zapresic is to reduce CO2 emissions by the year 2020 by 21%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2008 year will increase for 9,51 %. Implementation of all defined measures within Zapresic SEAP by 2020 will result in decrease of CO2 emissions by 22,82 % compared to the base year, therefore it is not necessary to implement all defined measures to achieve goal of CO2 emissions reduction. Of the total 2008 CO2 emissions the **building sector accounts for 76,94 %**, the transport sector for 21,39 % and public lightning sector for 1,67%. Therefore, most important measures that can significantly contribute to CO2 emission reduction are measures defined for building and transport sectors. The most important are measures for residential buildings (e.g. refurbishment of thermal insulation, behavior change campaign and others) and measures for increased usage of public transport instead of private individual transport in City of Zapresic.
Ludbreg	9,177	21%	Vision of the Suistainable energy action plan of the City of Ludbreg is to develop a sense of responsibility and awareness of citizens for rational use of energy, reduce

			energy consumption, make financial savings and promote environmental conservation throught the fulfillment of the objectives of the Kyoto Protocol.
Klanjec	3,234	27%	Long term vision of the City of Klanjec is to reduce CO2 emissions by the year 2020 by 21%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2008 year will increase for 7,63 %. Implementation of all defined measures within Klanjec SEAP by 2020 will result in decrease of CO2 emissions by 29,83 % compared to the base year, therefore it is not necessary to implement all defined measures to achieve goal of CO2 emissions reduction. Of the total 2008 CO2 emissions the **building sector accounts for 59 %,** the transport sector for 40 % and public lightning sector for 1%. Therefore, most important measures that can significantly contribute to CO2 emission reduction are measures defined for building and transport sectors. The most important are measures for residential buildings (e.g. refurbishment of thermal insulation, behavior change campaign and others) and measures for increased usage of public transport instead of private individual transport in City of Klanjec.
Pregrada	7,165	21%	The main objective is to reduce CO2 emission for more than 20% by 2020 on the Sectors of Bulidings, Traffic and Public Lighting through various actions and measures. The City of Pregrada needs to achive the implemetation of projects of energy saving, application of energy efficiency measures, **renewable sources of energy use** and ecologically acceptable fuels on the city level which will result in the reduction of CO2 emission in the City.
Varaždin	47,056	21%	Vision of City of Varazdin is to become a greener city.
Križevci	11,541	20%	Long term vision of Krizevci is to reduce CO2 emissions by the year 2020 by 20,81%. According to projections of population and energy consumption growth, without implementation of defined EE measures CO2 emission in 2020 in comparison with base 2010 year will increase for 14,58%. Implementation of all defined measures within Krizevci SEAP by 2020 will result in decrease of CO2 emissions by 20,81% compared to the base year. Of the total 2010 CO2 emissions the **building sector accounts for 64,2%,** the transport sector for 35,3% and public lightning sector for 0,5%.
Bjelovar	40,443	21%	The main objective is to reduce CO2 emission for more than 20% by 2020 on the Sectors of Bulidings, Traffic and Public Lighting through various actions and measures. The City of Bjelovar needs to achive the implemetation of projects of energy saving, application of energy efficiency measures, **renewable sources of energy use** and ecologically acceptable fuels on the city level which will result in the reduction of CO2 emission in the City.

Koprivnica	30,872	50%	The City of Koprivnica is committed to become a role model for sustainable small and medium cities, not only within Croatia but also in the region. Sustainability is one of corner stones in the development strategy of the city and local authorities plan to build its competitive edge by increased usage of renewable energy sources and energy efficiency. In the area of RES, the City plans to increase the share of RES in order to be able to offer competitive conditions for industry. This will be done mainly by focusing on solar, **geothermal** and biomass sources where several projects are under way. In the area of EE, main focus will be put on buildings, both public and residential/tertiary.
Prelog	7,840	20%	n.a.
Čakovec	27,104	20%	n.a.
Ozalj	7,932	21%	The main objective is to reduce CO2 emission for more than 20% by 2020 on the Sectors of Bulidings, Traffic and Public Lighting through various actions and measures. The City of Ozalj needs to achive the implemetation of projects of energy saving, application of energy efficiency measures, **renewable sources of energy use** and ecologically acceptable fuels on the city level which will result in the reduction of CO2 emission in the City.
Ivanic-Grad	7,714	21%	Long term vision of the City of Ivanic-Grad is to reduce CO2 emissions by the year 2020 by 21%. Whithout implementation of defined EE measures GHG emission in 2020 in comparison with base 2008 year will increase for 6,59 %. Implementation of all defined measures by 2020 will result in decrease of CO2 emissions by 33,95% compared to the base year. It is evident that it is not necessary to implement all defined measures to acchieve goal of GHG emissions reduction for 21%. Implementation of priority measures define in SEAP will result in defined goal. In total GHG emission **building sector accounts for 70,29%** and transport sector contributes with 29,12% and public lightning sector with 0,59%.
Samobor	36,206	21%	In its long-term vision, City of Samobor has included an intention to be a city of **low-energy and passive houses**. We have developed a program that encourages investors and citizens to act economically with energy and has made a communication strategy that rises public awareness on energy efficiency . Our vision is to proceed with existing programs as well as developing new programs that will achieve all SEAP targets.

Annex 3: Settlements part of Convenant of Mayors in the DARLINGe territory of Hungary, their CO2 emission targets and SEAP goals

Settlement	Population	CO2 emission target	Strategy
Nagykanizsa	49,652	25%	Our goal is the renewal of the municipal and regional energy management from long-term sustanaibility aspect. In addition to promote energy saving aspects it is necessary to build a sustainable decentralized energy supply system taking into consideration the local conditions of the settlement, and the local interests. The successful implementation of the above mentioned systems can be realised involving public and third sectors cooperating with local government. The central element of the conception – beside the energy saving ang energy sufficient implementations- **using geothermal energy**, additional elements mainly the utilization of solar and biomass energy sources. Marketing actions, communication and dissemination, the green marketing to change the habitants'/consumers energy using habits should play important role. Specific goal and function of the city to **implement a geothermal power plant**, a pilot plant, teaching-research institute, investments for using solar and biomass energy sources, to supply locally energy, with technology transfers and supports. With these implementations we can achive the energy independence, and enforce environmental protection interests, furthermore the operation and maintenance and supply of these systems create jobs. Completing these systems with environmental and energy efficient infrastructure, enforcing other urban development and traffic management aspects could result the achievement of the goals on the field of energy saving and environmetal protection and the increasing the usage of renewable energy sources.
Kaposvár	63,742	n.a.	n.a.
Pécs	156,801	34%	n.a.
Szeged	161,137	n.a.	n.a.
Békéscsaba	61,325	n.a.	n.a.

Annex 4: Settlements part of Convenant of Mayors in the DARLINGe territory of Romania, their CO2 emission targets and SEAP goals

Settlement	Population	CO2 emission target	Strategy (SEAP)
Arad	172,827	23%	Clear vision of the municipality is:"Safety, energy efficiency for sustainable development of Arad" The mission is aimed at energy efficiency at the local level in almost all sectors (mainly those that can be influenced by the municipality) and the development of new alternative sources of sustainable energy generation.Main objectives: increasing the efficiency of local energy production; **use of new energy sources**; encourage and support investment and public - private partnerships in the production of energy from **renewable sources**; promoting energy efficiency in all sectors; awareness of all stakeholders; development of local regulations to encourage energy efficiency; green procurements.
Pecia	13,024	21%	Pecica City Council led by Mayor engage in a joint effort involving all stakeholders, including citizens, to achieve the objectives and measures established by directing financial efforts and administratively, within the rigors of national and local legislation. The PEAD's development is desirable but oriented local action to a global target, the CO2 emission reduction and climate mitigation locally and globally. The overall objective is the energy needs both now and in the medium and long term, at a price as low as suitable a modern market economy and a decent standard of living, in terms of quality, food safety, with the principles of sustainable development. " Peccica, the greenest city in the west of Romania"
Nadlac	7,500	21%	For increasing efficiency in environmental protection, complex activities and sensible actions are required to improve environmental and health conditions for population, involving the development of appropriate attitudes of the community, prioritization and development of corresponding strategies to foster civic responsibility in order to ensure a clean and healthy environment. An important role in the development and maintaining optimal environmental conditions in urban and rural areas is assumed by the local authority.
Giarmata	6,456	20%	Giarmata Town developed a policy of energy management at the local level, which covers energy consumption in municipal and residential buildings, street lighting, transport, town planning, education/awareness raising, training, waste management, green areas, and agriculture, covering a number of 64 actions. Objective 1. Reduction of energy consumption and C02 emissions in the private houses and public owened buildings; Objective 2. Reduced fuel consumption and C02 emissions and mobility;

			Objective 3. Spatial planning, green public procurement and local networking; Objective 4. Encouraging the use of **renewable energy sources**. Objective 5: Sustainable waste management and agriculture. Objective 6: Education, training and raising awarness of citizens.
Remetea Mare	2,267	20%	Long term vision of public administration of Remetea Mare aimed on "Sustainable development of Remetea Mare Town in order to ensure the transition to the next decade with reduced carbon emission with 20%", as an example for smaller communities in Western part of Romania. This vision, from the perspective of SEAP becomes a mission for the local public administration. The main priority domains of actions of Remetea Mare Town are:- Development of local strategy for reduction of CO2 with 20%;- Improving the energy performance of public buildings in the residential and tertiary sectors (thermal rehabilitation);- Development of sustainable public and private transports;- Promotion of mobility and encouraging non-motorized transport;- Increasing green spaces areas;- Sustainable waste management;- Educational and awareness programs regarding sustainable local development;- Ecological, sustainable agriculture;- Sustainable Planning and urban development;- Extension and modernization of public networks (streets, sewerage, network, electricity and gas)
Timisoara	329,554	20%	Our long-term vision is to develop a prosperous city, attractive for its inhabitants, an important growth pole, a regional economic, social and cultural center, in which economic development, competitiveness, protection of environment and sustainable development are priorities, in order to preserve the natural, cultural and built heritage in a clean and healthy environment for its inhabitants. In this context, Timisoara Municipality's mission is to increase energy efficiency, energy savings and the development of **renewable energy sources** in order to reduce greenhouse gas emissions and support sustainable development of the municipality.
Giroc	6,661	22%	Local Vision - ~Development and strengthening of a strong economic zones, stable and diversified, able to ensure prosperity and the improvement of the village~The vision of Giroc Town Hall is to assure energetic security both for public and private sector, with the clear orientation toward sustainable development of the town by creating a welbeing environment for the whole citizens. The priorities in setting their targets are to degrease the overall cost for energy consumption in town, to mitigate the public admininstration effort to sustain the local institutions ressource, by setting active measures in the building sector which consist mainly in insulation of all buildings and sustainable heating systems, encouraging sustainable consumption and production, implementation of renewable energy sources. The main objectives of the SEAP are to enhance the quality of life and energy comfort at the least

			cost to the citizens of the town by means of decentralized renewable energy supply/sustainable heating with a parallel implementation of energy efficiency measures. Giroc Town developed a policy of energy management at the local level, which covers energy consumption in municipal and residential buildings, street lighting, transport, awareness raising, training, waste management, green areas, covering a number of 38 actions. Objective 1. Reduction of energy consumption and C02 emissions in the private houses and public owened buildings; Objective 2. Reduced fuel consumption and C02 emissions and mobility; Objective 3. Encouraging the use of renewable energy sources. Objective 4: Education, training and raising awareness of citizens; Objective 5: Sustainable waste management Industrial sector has not been taken into account for the emission analysis, being outside of the competency and local public authority influence area. Therefore, no measures and actions have been committed to this sector.
Sînmihaiu Român	6,402	20%	The long term vision of Sînmihaiu Român Town public administration is to assure energetic security both for public and private sector, with the clear orientation toward sustainable development of the town by creating a welbeing environment for the whole citizens. Also, the vision of public administration of Sinmihaiu Roman Community aims "Sustainable development of Sag Community so as to ensure the transition to the next decade with reduced carbon emissions by 20%, as an example for smaller communities in western of Romania and Euroregion." This vision, from the perspective of Sustainable Energy Action Plan becomes a mission which requires a multisectoral approach, oriented towards energy efficiency in the community,in sectors where the local authority has authority or influence, and the use of renewable energy sources available at local level. Sînmihaiu Român Town developed a policy of energy management at the local level, which covers energy consumption in municipal and residential buildings, street lighting, transport, town planning, education/awareness raising, training, waste management, green areas, and agriculture, covering a number of actions. Objective 1. Reduction of energy consumption and C02 emissions in the private houses and public owened buildings; Objective 2. Reduced fuel consumption and C02 emissions and mobility; Objective 3. Spatial planning, green public procurement and local networking; Objective 4. Encouraging the use of renewable energy sources. Objective 5: Sustainable waste management and agriculture.Objective 6: Education, training and raising awarness of citizens; Industrial sector has not been taken into account for the emission analysis, being outside of the competency and local public authority influence area. Therefore, no measures and actions have been committed to this sector.

Şag	2,795	20%	The vision of Sag Town public administration is to assure energetic security both for public and private sector, with the clear orientation toward sustainable development of the town by creating a wellbeing environment for citizens. The priorities in setting their targets are to degrease the overall cost for energy consumption in town, to mittigate the public admininstration effort to sustain the local institutions ressource, by setting active measures in the building sector which consist mainly in insulation of all buildings and **sustainable heating systems**, encouraging sustainable consumption and production, implementation of renewable energy sources, and also creating a structure to provide biomass from sustainable forestration. The main objectives of the SEAP are to enhance the quality of life and energy comfort at the least cost to the citizens of the town by means of **decentralized renewable energy supply/sustainable heating** with a parallel implementation of energy efficiency measures. Şag Town developed a policy of energy management at the local level, which covers energy consumption in municipal and residential buildings, street lighting, transport, town planning, education/awareness raising, training, waste management, green areas, and agriculture, covering a number of 63 actions. Objective 1. Reduction of energy consumption and C02 emissions in the private houses and public owened buildings; Objective no.2. Reduced fuel consumption and C02 emissions and mobility; Objective no.3. Spatial planning, green public procurement and local networking; Objective no.4. Encouraging the use of renewable energy sources. Objective no.5: Sustainable waste management and agriculture. Objective no.6: Education, training and raising awarness of citizens;
Peciu Nou	5,158	20%	Ensure energetic security both for public and private sector, with the clear orientation toward sustainable development of the town by creating a wellbeing environment for the whole citizens. The priorities in setting their targets are to degrease the overall cost for energy consumption in town, to mitigate the public administration effort to sustain the local institutions resource, by setting active measures in the building sector which consist mainly in insulation of all buildings and sustainable heating systems, encouraging sustainable consumption and production, implementation of renewable energy sources, and also creating a structure to provide biomass from sustainable forestation.
Ghiroda	4,907	20%	Vision of public administration of Ghiroda Community aims "Sustainable development of Ghiroda Community so as to ensure the transition to the next decade with reduced carbon emissions by 20%, as an example for smaller communities in western of Romania and Timis County. This vision, from the perspective of Sustainable Energy Action Plan becomes a mission which requires a multisectoral approach, oriented towards energy efficiency in the

			community, in sectors where the local authority has authority or influence,and the use of renewable energy sources available at local level.

Annex 5: Settlements part of Convenant of Mayors in the DARLINGe territory of Slovenia, their CO2 emission targets and SEAP goals

Settlement	Population	CO2 emission target	Strategy (SEAP)
Kuzma	1,600	23%	n.a.
Cankova	1,900	20%	n.a.
Puconci	6,100	22%	n.a.
Odranci	1,700	21%	n.a.
Beltinci	8,333	20%	n.a.
Lendava	11,159	36%	Long-term vision for the local community by 2020 is to reduce the need for conventional transport, increasing interest in alternative transportation options, increasing the interest of local people to cycle, the introduction of measures to reduce the attractiveness of car travel, the implementation of local marketing campaign to promote the use of alternative means of transport and reduce emissions of cars owned by the municipal administration. In the field of energy consumption the municipality intends to improve the situation in the use of renewable energy, energy efficiency and district heating. Heating systems outside town of Lendava mainly use as an energy fuel oil, while **the town itself is heated by geothermal energy**. Renewable sources of energy with a little influence on the environment, facilitate the production of energy with a relatively small CO2 emissions. With the continued construction of biogas plants, cogeneration (production of electricity and heat) we hope to achieve very good results in protecting the environment of the local communities. District heating systems (geothermal) are planned to be implemented in future years because of the low environmental impact in the sense of CO2 emissions.
Ljutomer	12,275	21%	The building sector is the one that demands the local community in the future to give the highest priority. The proposals in the Action Plan (AP) are aimed primarily at energy-efficient construction and retrofitting of buildings. It also proposes district heating using biomass (BDH), a system for combined heat and power (CHP) from biomass and renewable energy in buildings. In the transport sector the local community will have to reduce the CO2 emissions of its own fleet purchasing vehicles with the low fuel consumption, and lower specific CO2 emissions, and hybrid and electric vehicles. Actions on public lighting are mostly aimed at replacing energy inefficient lamps and their control.
Rogašovci	3,200	21%	n.a.
Maribor	111,187	20%	Maribor City Council is in the frame of comprehensive

			vision of clean, green and connected city which included an innovative economy and sustainable neighborhoods and communities commit to achieve economic, social and environmental sustainable city. This is a long-term vision for the city of Maribor defined in ˝Development Strategy for Maribor 2030˝ and accompanied by the slogan˝ Maribor is creating and co-designing the future˝. An important part of 2030 Strategy represents sustainable energy use. Experts involved in the preparation of SEAP were identified activities and measures for climate protection at the local level. This task has been carried out taking into account the Baseline Emission Inventory. On the basis of data that has been collected and processed residential **buildings** and transport sector were identified as the Maribor´s **main sources of CO2 emissions.** Important saving potential represent also city administration. The overall aim of our SEAP is to have a positive impact on the environment through the reduction of CO2 emissions. Maribor´s priority areas of action are:- Energy renovation of existing buildings,- Intelligent energy use, especially in the field of public lighting, - improving public transport, - Changing behavior - promotional and educational events for different target public. As the initiator of climate protection City administration together with their public services set ambitious goals. In the frame of SEAP Maribor City administration will implement measures to reduce CO2 emissions in all areas under its control and management and this way it will act as good example for other sectors. Our aim is also to prepare more aggressive penetration of sustainable energy issues in private sector. The biggest challenge will be to achieve good results in the sectors that are not under direct control and management of municipality.
Moravske Toplice	6,000	21%	n.a.
Turnišče	3,400	22%	n.a.
Razkrižje	1,350	21%	n.a.