Decision-making process mapping

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GEOENVI

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Summary

In this report we analyse each of the GEOENVI national case study countries (Belgium, France, Iceland, Italy, Hungary, and Turkey) to gain a better overview of similarities and differences among national level geothermal environmental regulatory practice. After a general country overview, we analyse how the environmental regulations around deep geothermal energy are set-up in terms of definition, classification, and resource ownership. We find that definitions and rules for ownership are largely similar, but that classifications of different types of geothermal resources vary significantly. A mapping of permitting and licensing processes consequently addresses the type of permits required, permit durations, exclusivity arrangements etc. An interesting observation is the number of authorities involved in permitting that differs among countries. Moreover, Environmental Impact Assessment is present in each country, but the way it is incorporated in the overall permitting procedure differs.

Zooming in on environmental regulations, we provide an overview of international and EU regulations on the different environmental impacts identified under the work package on environmental concerns (WP2). Consequently, national level regulations in each of the GEOENVI case study countries are described in terms of applicable legislation, thresholds, required mitigation measures and arrangements for monitoring (see Appendices 1-6 for detailed country reports). Main observations are:

- Noise and vibration appear to be well regulated, as an industrial sector, both for workers and surrounding residents. Visual impacts and landscape are less strictly regulated, but generally treated in Environmental Impacts Assessments (EIAs), with the Tuscany region hosting the most developed regulations in this respect. Concerning dust and smell, various specific legislations and guidelines are in place.
- Possible degassing is related to air quality and is already generally well regulated by air quality regulation, often with reference to the relevant EU directives for EU member state countries. CO_2 emissions are subject to the EU Emissions Trading Scheme (ETS).
- Concerning the possibility of ground surface deformation and seismicity, guidelines for monitoring surface deformation are present in most countries and best practices are implemented by project developers and operators.

- Impacts on the underground fluid, as well as reservoir chemical modifications, appear generally well regulated as part of national legislation on ground water quality and thoroughly addressed in permitting processes. For aspects of pressure decline and thermal changes, apparently regulated is largely absent.
- Effects of surface operation have a variety of dimensions: energy consumption, water consumption, air emissions. The case of France illustrates how such impacts are regulated via, amongst others, reporting procedures and the voluntary compliance to ISO standards.
- Waste production appears generally well regulated as part of national waste legislation, including waste classifications, and special rules for dealing with hazardous waste.
- Leaks due to surface installations and operations is a specific topic treated in the EU Pressure Directive 2014/68/EU. Although in the scope of this report, limited national level legislation has been retrieved, the French case shows how the Pressure Directive is transposed to the national level, involving a variety of mitigation and monitoring measures, such as design requirements, risk assessment, and inspection protocols.
- Regarding liquid and solid surface waste from underground sources, national level legislation typically includes mitigating measures to prevent blow-out, also from the rationale of the safety of workers, as well as measures are in place to avoid the effusion of liquid chemical fluids and geothermal brine.
- General regulatory frameworks for radioactivity are in place in the different countries in the context of public health. Partly depending on the relevance of the issue of radioactivity in countries and regions, deep geothermal projects must comply to specific regulations concerning e.g. the characterization and treatment of possible radioactive waste.

The main value of this mapping exercise is as a starting point for more detailed analysis to address issues like:

- To what extent are national legislations consistent with EU legislation? On what aspects would harmonization be required?
- How strict are regulations? Are they sufficient for mitigating the impact at hand, or possibly too strictly applied? What are main regulatory gaps? Are these problematic?
- How are legislations applied in practice? Which informal aspects come into play?

- Which elements of national regulations and guidelines can be considered best practices that can be shared among countries?

To address those questions, the views of policy-makers, practitioners and other stakeholders will be included in the follow-up work of this WP4: engage with decision-makers, eventually leading to the formulation of recommendations on environmental regulations.

INTRODUCTION

The GEOENVI project addresses ways to tackle the environmental concerns for deploying deep geothermal energy in Europe. In previous reports a sound overview of possible environmental impacts has been provided (deliverable 2.1), as well as ways to avoid or minimise these impacts to the extent possible (deliverable 2.2). Furthermore, new ways of analysing the life cycle impacts of geothermal energy through Life Cycle Assessment (LCA) are being developed in work package 3: Harmonized methodology for environmental impact assessment with a life-cycle perspective for geothermal systems.

The current deliverable takes a policy perspective on environmental impacts. As described in Dumas et al. (2019), European energy policy concerning renewable energy at large has seen important developments over the past decades. This involves the recognition of the non-sustainability of the energy and transport sector based on fossil fuels and nuclear energy, the liberalisation of the energy markets in the 1990s, and the change of paradigm from a centralised system to a more decentralised system with increased importance of local and regional aspects. EU energy policy has developed greatly, with the 2020 energy package, the establishment of the European Energy Union in 2015, and the clean energy package of 2019 as main milestones.

Zooming in on environment regulation for geothermal energy, EU level policy provides guidelines for various regulatory aspects, such as (a) definition, classification, and resource ownership; (b) licensing and authorisations; and (c) sustainability and environmental impacts (see Dumas et al. 2019). However, the implementation on the national scale level often varies. For example, for the definition of geothermal energy, the RES Directive (Directive 2009/28/EC) provides a legally binding definition although in practice geothermal resources are still defined in a several ways. Moreover, different ways of classifying geothermal resources, and different rules of resource ownership exist. Adequate licensing and authorisation procedures are needed to guarantee that the project is performed in a safe and environmentally sound way. However, rules on exclusivity may not be consistent among member states, and the licensing process can in some countries be perceived by operators as unnecessarily long and complex (see Angelino et al. 2016). In the regard, the (2009) RES Directive (Art. 13) requires member states to streamline and rationalise the administrative procedures for RES projects, and to clearly define and coordinate the respective responsibilities of national, regional and local

administrative bodies. Concerning sustainability and environmental impacts, various directives exist[1] that set requirements for dealing with environmental impacts. Implementation and enforcement, however, depends largely on national and regional authorities, which may differ among member states.

In this report we therefore analyse each of the GEOENVI national case study countries (Belgium, France, Iceland, Italy, Hungary, and Turkey) to gain a better overview of similarities and differences among national level geothermal environmental regulatory practice. We analyse how the environmental regulations around deep geothermal energy are set-up, how permitting and licensing processes take place, and what specific regulations exist for specific environmental impacts. Thereby this report sets the stage for further research for finding ways to harmonize and improve existing environmental regulations of deep geothermal through the engagement of decision-makers and other stakeholders.

METHODOLOGY

Multi-level governance

The overarching theoretical framework of our analysis can be characterized as multi-level governance (Bache and Flinders 2004). In contrast to the traditional understanding of 'government', multi-level governance frames the policy process as a process driven by a variety of actors – from state, business and civil society – at multiple scale levels (e.g. EU, national, regional, local). It denotes a shifting balance from hierarchical to network forms of steering, from horizontal to vertical relations, and formal to informal structures. In its charter for multi-level governance in Europe[2], the EU Community of Regions also advocates multi-level governance as a policy principle. This implies "working in partnership between the different levels of government (local, regional, national and European) and applying a set of principles that should guide efficient policy-making, such as participation, cooperation, openness, transparency, inclusiveness and policy coherence, all of which are essential conditions to guarantee the success of public policies in the interest of the citizens."

[1] E.g. the EIA directive (Directive 2011/92/EU), the SEA directive (Directive 2001/42/EC), and Directive 2000/60/EC establishing a framework for Community action in the field of water policy.
[2] https://portal.cor.europa.eu/mlgcharter/objectives/Pages/default.aspx

In our research design, the principles of multi-level governance are important in the following ways. First, the multi-level element is apparent in the analysis of ways EU policy is transcribed on national levels and eventually involving various regional and local actors in its practical implementation. Second, it is reflected by the involvement of a range of stakeholders - ranging from 'regulation owners' (i.e. policy-makers) to civil society (e.g. citizen or environmental associations) and businesses (geothermal developers) with a clear interest in environmental regulations – in developing recommendations for regulatory improvements that will be the subject of follow-up reports.

Analysing environmental regulations

To analyse environmental regulations in the different case study countries, a descriptive template was developed. The template included first a general overview section comprising:

- General data on deep geothermal in the target country, including general data on the present situation of deep geothermal in the country such as the number of projects, the market importance, and recent policy developments.
- Institutional context, aiming to understand how countries are institutionally organized and how deep geothermal is embedded in this institutional organization (i.e. the main organization between levels of power, at federal and regional levels).
- Policies and policy visions that aimed to give an overview of the policies, visions, supporting measures and incentives undertaken to foster deep geothermal development in the country at the national and local level.

Following, the section on environmental regulations aimed to provide an in-depth country view on environmental regulations related to deep geothermal energy. Following Dumas (2019), it comprised three main dimensions:

- Definition, classification, and resource ownership, i.e. the way deep geothermal energy is defined as a basic entity, the way it is classified for example in terms of different depth or temperature levels, and specifics about resource ownership (e.g. state versus privately owned).
- Licencing and authorisations, i.e. the way the licensing process is organised in terms of the main permits required, main authorities involved, the way environmental impact

assessment is factored-in, as well as details on timing, duration, exclusivity regulations, royalties and specific requirements for obtaining permits.

- Sustainability and environmental impacts, i.e. any specific regulations on main environmental impacts in terms of applicable legislation, thresholds, required mitigation measures and arrangements for monitoring. Here the list of key environmental impacts developed under WP2 and displayed in Box 1 is taken as a reference.

Box 1 - Possible environmental risks, impacts or incidents of deep geothermal energy

- Effects of surface operations: energy and water consumption and emissions to the environments
- Waste production from surface operations
- Surface disturbance (vibration, noise, visual, land occupation, dust)
- Leaks due to surface installations and operations
- Liquid/solid effusion and waste
- Degassing
- Radioactivity
- Ground surface deformation
- Seismicity
- Interconnection of aquifers and disturbance of non-targeted aquifers
- Reservoir physical and chemical modifications

Source: GEOENVI deliverable 2.1 and 2.2

Country descriptions and comparative analysis

The template for environmental regulations and actor mapping aimed to provide a structured, but flexible way of describing the situations in the respective countries. It was used to develop individual country descriptions which are included as Appendices 1-6 in this report. The individual country descriptions are based on desk-top research and expert knowledge from the GEOENVI researchers involved. The country descriptions were consequently used to develop an overview and comparison among countries based on the different template categories. Data provided in the country reports were used to develop overview tables for each impact

considered, that were completed and refined through several feedback rounds with the projects' country experts.

COUNTRY OVERVIEW

General overview

The six countries in GEO-ENVI can be roughly divided into countries with a relatively long tradition in deep geothermal (Italy, Turkey, Iceland), and countries in which deep geothermal has been emerging over the past decades (France, Hungary, Belgium), see Figure 1. The former generally have a large installed capacity of geothermal electricity production ranging from 709 to 1131 MW in 2017. Turkey and especially Iceland combine this power capacity with a large share of geothermal district heating, with in Iceland most households connected to geothermal DH. In the emerging countries, current capacities are mostly based on heating. Belgium is currently the smallest player with 10MW capacity in 2017, followed (in increasing order) by Hungary (253 MW) and France (509MW).

Most countries have ambitions to further develop geothermal capacity as illustrated by current projects under development (EGEC, 2018) and expressed in national policy visions. For heating, Belgium aims to expand its (small) heating capacity manifold by 2030, whereas Hungary and France aim to expand on their already substantial geothermal heating capacity to further decarbonise the heating sector. For power production, it is mostly Turkey that aims to expand on its already significant power capacity, with Hungary and France seeking to build up new capacity. The Iceland energy system is already largely renewable based, but geothermal use is still predicted to increase to meet the growth of energy demand. Italian national policies foresee a growth of renewable energy sources, however, with only a minor role for additional geothermal DH and power production, albeit a significant projected increase of ground source heat pumps.

The governance approach to geothermal energy is roughly similar among the different countries. In each country, there is an important role for the national (or in Belgium the regional) government to set the framework for geothermal development, with an important role for the lower level governments (e.g. provinces, municipalities) with incorporating geothermal energy in regional and local land use and energy planning. Yet, specific procedures are markedly different. For example, in France there is an important role for the 'prefecture', a so-called

deconcentrated body - delegated by the national government to a centrally nominated representative in the territories (counties, regions) to regulate deep geothermal energy (authorization, follow-up of deep geothermal activities).. In Italy, larger municipalities (>50,000 inhabitants) are obliged to set up development plans for district heating and cooling consistent with provincial, regional and national legislation and planning. In Iceland, there is a central role for the periodic development of a Master plan to guide deep geothermal development and planning, and in which Ministers, parliament and local authorities participate. Different mechanisms of supporting geothermal energy have been in place in the different countries, as displayed in Table 1.

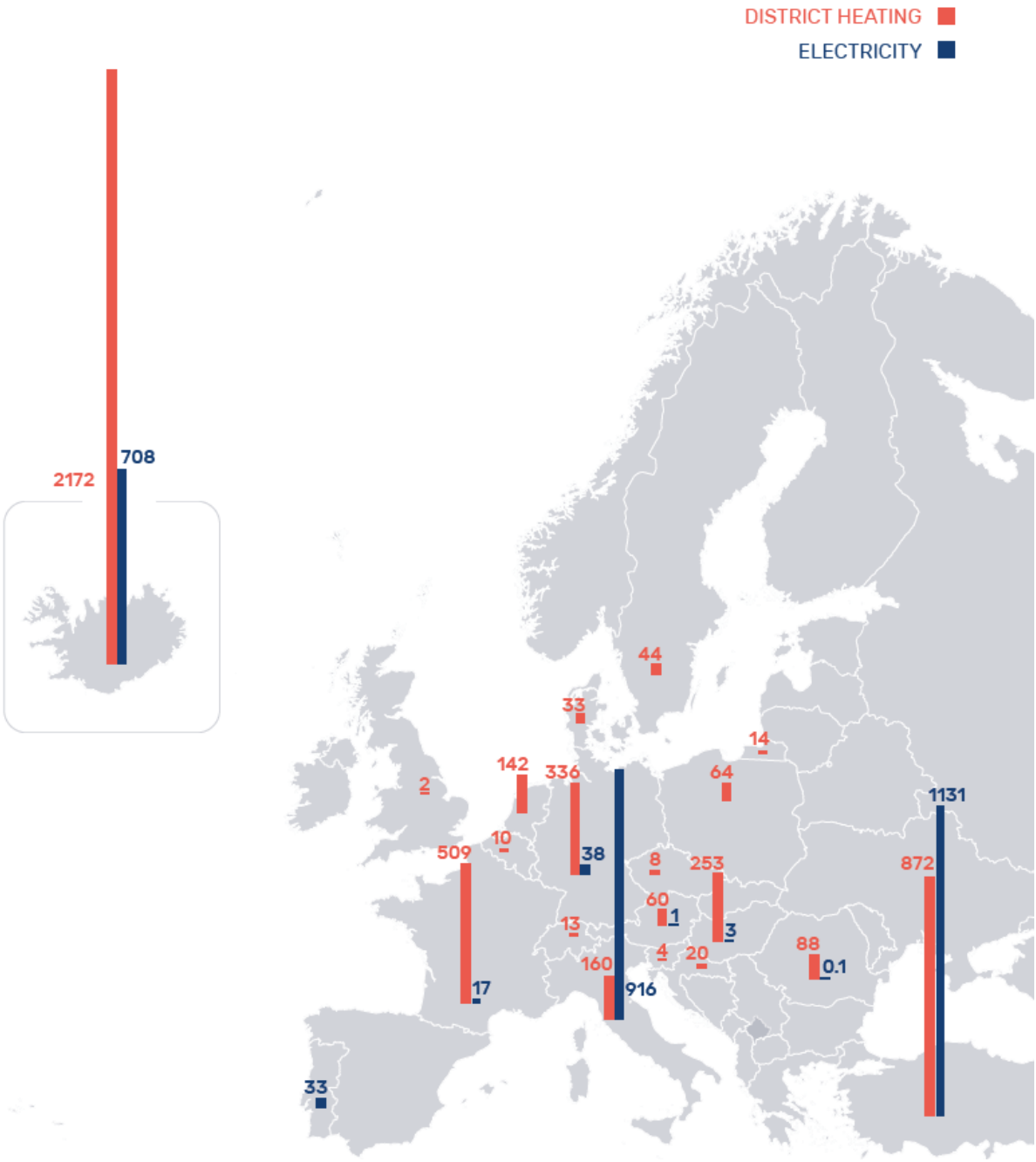

Figure 1: Installed capacity for geothermal electricity and district heating by country in 2017 (MW). Source: EGEC 2018.

	Belgium	France	Hungary	Iceland	Italy	Turkey
Capacity thermal (state 2017 / MW)	10	509	906	2172	160	872
Capacity electric (state 2017 / MW)	-	17	3	708	916	1131
Main policy vision on capacity development	Build-up heat	Expand heat Build-up power	Expand heat Build-up power	Meet growth of energy demand	Small growth	Expand power
Main support schemes	Investment support Insurance system	Feed-in tariff Heat fund Innovation support Guarantee fund	Feed-in tariff National RDI programs and funding Risk insurance scheme (under development)	Geothermal loans Investment support (e.g. Iceland Deep Drilling Project)	Premium and feed-in tariffs	Renewable energy certificates Land allocation incentives Grid connection priority Tax Incentives

Table 1: Overview of key features of the GEOENVI case study countries

In the following, each country is briefly described:

Belgium

The contribution of geothermal energy in the Belgian energy mix is still low. However, several deep Geothermal projects are currently in place in Flanders with a projected 164GWh capacity for 2020. The region of Flanders targets 594 GWh of green heat production through deep geothermal by the end of 2030, while Wallonia foresees the introduction of 233 GWh of geothermal energy in the 2030 renewable energy mix.

Belgium is a Federal State composed of a Federal Authority, and two types of 'federated entities' called Communities and Regions. There are three Regions (Flanders, Wallonia, and Brussels), and three Communities (Flemish, French and German-speaking). Deep geothermal falls mainly in the realm of Regional competences, and deep geothermal projects are regulated by separated actors and bodies of law (i.e. Flanders and Wallonia). Recent policy initiatives in Flanders (new decree on deep subsurface and the implementation of an insurance system) illustrate policy support. In Wallonia the legal framework should evolve in the same direction, with a new project decree for underground resources management and a similar insurance system being discussed.

France

In France, renewable energy sources (RES) represent approximately 10% of the primary energy consumption in 2017 and deep geothermal energy 1,3 % of the primary production of the renewable energies. The French geothermal district heating industry is well established and experienced, as many of the 74 existing installations have been installed since the 80s. Developments have increased again for the past 15 years, benefiting from the new ADEME Heat Fund. Geothermal installations currently supply heating and sanitary hot water to around 300,000 households, out of which 200,000 in the Paris area. In the Upper Rhine Graben (Alsace), building on the experience of Soultz-sous-Forêts power plant and Rittershoffen heat plant, several Enhanced Geothermal System (EGS) projects are under development to produce electricity and heat.

In France, regulating deep geothermal energy is a state competence: the central and so-called 'deconcentrated' bodies[3] hold most of the competences, specifying the conditions in which a geothermal project can be deployed from the exploration phase to the long-term exploitation. The territorial authorities[4] (communes, regions) play a key role showing (or not) the will to welcome deep geothermal energy on their territories and often participating in its funding. They are also the main contact with the local population, regarding the overall "acceptability" of geothermal projects. The 'Energy transition for green growth Act' provides the main legal framework of the French renewable energy policy, and the Multiannual Energy Planning

[3] Deconcentration corresponds to the delegation of policies and powers by the central Government to a centrally nominated representative in the territories.
[4] Decentralized bodies: elected by the local populations (≠ deconcentrated)

programme sets out specific targets for geothermal development. Current targets specify for electricity production a growth 8 MW (2018) to 24 MW (2023) of installed capacity; for heating consumption based on deep geothermal, a projection of 2,9 TWh for 2023 is planned. A variety of support schemes are in place to facilitate this growth via the Heat Fund, innovation support, a guarantee fund for geothermal district heating, and a feed-in tariff[5].

Hungary

Hungary's National Renewable Energy Action Plan targets a 17% share of geothermal in total RES by 2020, 4,47 PJ (direct use, deep geothermal and 57 MWe (power production) installed. Despite a delay in the implementation of the NREAP targets, especially in power production, the government expressed many times its strong intention to support geothermal energy in Hungary. With an expected installed capacity of geothermal energy for power production of 20 MW by 2030, and a 9 PJ share of deep geothermal energy in the heating and cooling sector, geothermal energy is foreseen to have a fundamental role in the decarbonisation of the district heating systems.

In Hungary all issues related to geothermal energy are organized at federal level. Main mining regulations are laid out in the Mining Act. As deep geothermal energy is exploited by the abstraction of thermal waters in Hungary, the other „branch" of legislation and institutional organization is related to the „water management" side. Recent legislation puts high priority on geothermal power production without water abstraction and improvement of reinjection technologies, and also addresses the mitigation of financial risks of geothermal investment.

Iceland

Iceland is one of the most tectonically active places on earth, with many volcanoes and hot springs and abundant geothermal resources. Today about nine out of ten households are heated with geothermal with the total use of geothermal energy amounted to 29 PJ in 2017. The country hosts 53 geothermal based heat utilities and over 100 auto-producing businesses. Electricity generation from geothermal power plants reached 6 TWh in 2018. The total use of geothermal energy for heating is estimated to increase to 34 PJ in year 2020. Geothermal use

[5] the feed-in tariff is currently under debate, see the Multi-annual Energy Planning proposal presented on 20 January 2020 (http://www.consultations-publiques.developpement-durable.gouv.fr/spip.php?page=article&id_article=2127)

is still predicted to increase considerably to 49 PJ in year 2050 in response to growth of various energy demand sectors (e.g. residential heating, fish farming).

Historically, the government has encouraged exploration and research for geothermal resources and applications. Geothermal electricity is today competitive with hydro in Iceland and is not subsidised. Space heating of residential buildings is subsidized only for those areas where geothermal based district heating systems are not reachable. The government uses the procedure of a 'Master Plan' to guide deep geothermal development and planning. The Minister for the Environment in co-operation with the Minister of Industry must, at least every four years propose a Master Plan to be confirmed by the parliament. This procedure entails public participation and various re-evaluation phases by municipalities, ultimately leading to a binding plan for all municipalities and is to be included in their general land use plans.

Italy

Italy has a long tradition of industrial use of geothermal resources. The abundant resources are mainly used for electricity generation and space heating by means of district heating. The 34 power plants currently in operation are in Tuscany with an installed capacity of 915.5 MWe in 2018, where also most (but certainly not all) of the geothermal district heating systems are located. At the end of 2017, the geothermal energy thermal use installed capacity exceeded 1400 MWt, with 119 MWt delivered from deep geothermal sources. UGI (2017) forecasts a steep increase of the aggregate installed capacity and production of the direct use of geothermal heat (including heat pumps) by 2050, passing from about 10500 TJ/yr in 2015 to values ranging between 53400 TJ/yr and 75350 TJ/yr, depending on the market and national support condition.

Specific administrative functions related to geothermal exploration and development as regulated by Italian law are allocated to different bodies (State, Regions, Provinces, Metropolitan Cities and Municipalities). For example, municipalities above 50,000 inhabitants are required to establish development plans for district heating and cooling, in cooperation with provincial authorities and coherently with the regional energy plans and national legislative frameworks. Geothermal electricity production is (as other renewables) incentivized through a system of premium and feed-in tariffs based on the plants installed capacity. A new incentive scheme is under development for geothermal plants demonstrating electrical power production with zero emissions and reduced environmental impact. RES in heating and cooling is

supported by a tax relief of 55% on RES technologies installation costs, and tax incentives for the benefit of users connected to district heating networks fed by geothermal sources. National energy policies (SEN and NECP) aims at increasing the use of heat from renewable sources and improvement of energy efficiency, however, envisaging a small growth of electricity from geothermal energy technologies.

Turkey

Turkey's geothermal history goes back to the 1960s. It has a large geothermal potential with 94% of the geothermal resources are low and medium heat, and suitable for direct applications (heating, thermal tourism, the output of minerals, etc.), while 6% are suitable for indirect applications such as the generation of electricity. Up to now, nearly a total of 1,200 geothermal exploratory, production and reinjection wells have been drilled, and nearly 80% of these wells have been drilled in the Western Anatolia of Turkey. With 1,347 MW installed capacity for power production Turkey is now a part of five countries that have more than 1 GW installed capacity, with a further target of 4,000 MW of capacity to be reached by 2030. Besides power production, Turkey exploits geothermal energy for district and greenhouse heating, taking second place within Europe with 872 MWth installed capacity following Iceland.

The Geothermal Energy Law in Turkey regulates geothermal resources along with natural mineral water resources and geothermal-related gases. It covers the procedures of usage rights, licences and their assignment or transfer. Relevant authorities are the Ministry of Energy and Natural Resources, the Provincial Special Administration in cities, the Investment Monitoring Coordination Department Head in metropolises and (for power production) the Energy Market Regulatory Authority. To support the uptake of deep geothermal various incentives are in place, including the Support Mechanism for Renewable Energy Sources based on renewable energy resource (RER) certificates, land allocation incentives, grid connection priority, and tax Incentives.

Definition, Classification, and Resource Ownership

The different ways of defining, classifying and regulating resource ownership are listed in Table 2. Definitions of geothermal energy appear broadly similar among the considered countries. A distinction can be made between the terms ‘geothermal energy’, ‘geothermal energy source’ and ‘water resource’ (c.f. examples of Hungary and France). Geothermal energy is the available energy per se, whereas the ‘geothermal energy sources’ is defined i.r.t. the medium via which energy can be extracted from it. This also differentiates a geothermal resource (for energy extraction) from a water resource (for other purposes). Classifications appear to vary significantly among the countries. There are case where no classifications are (yet) adopted (e.g. in Belgium, Hungary), and cases based on temperature and depth (Iceland), and cases where also potential production power is considered (Italy, France). Geothermal resources are mostly state owned, expect in Iceland where the ownership of ground resources is associated to land ownership.

	Definitions	Classifications	Ownership
Belgium	*In Flanders:* *Geothermal heat*: subsurface heat generated by natural means or by heat storage	Regulations on geothermal heat apply to the deep subsurface > 500 m depth. No further classifications are adopted.	The right of use subject to a license from the Flemish government.
	In Wallonia (foreseen decree): The geothermal resource is to be defined by the subsoil decree which is currently being validated by the Walloon Government.	The foreseen subsoil decree, currently under validation by the Walloon Government, will define deep subsoil > 500 meters in depth.	ND
France	*Geothermal resources*: subsurface resources for energy extraction *Water resources*: drinking water, balneology (not for energy extraction)	For exploitation: High vs. low primary thermal power >< 20 MW (used to be High vs. Low temperature resources: ><150°C) For exploration: choice of the petitioner Geothermal resources of minimal importance: <200m depth, < 25°C, using heat pumps < 500 kW	The right of use granted by the State or deconcentrated body (prefecture).
Hungary	*Thermal water*: all ground water >30 °C at outlet *Geothermal energy*: energy contained in the earth's crust *Geothermal energy sources*: physical materials (e.g. subsurface water, vapours) enabling utilizing geothermal heat	As the highest current production temperature is 105°C, no further classification (e.g. low/high temperature / enthalpy) are adopted.	*Thermal water*: exclusively state-owned *Geothermal energy*: state-owned
Iceland	See Resource Act	High vs. low temperature resources: >200°C above 1km depth (high) vs. < 150°C at depth of 1-3 km	Private land: ownership of ground resources associated to land ownership

			Public land: ground resources remain in public ownership Subject to licencing
Italy	*Geothermal energy:* the energy stored as heat under the Earth's crust; *Geothermal resources*: thermal energy from the Earth's, extractable through geothermal fluids; *Geothermal fluids*: fluids, with potential associated substances, coming from natural storage and heating processes and which are extracted in the form of steam, hot water, brine and hot gases, or deriving from artificial processes resulting from the introduction of fluids into the subsoil.	Deep geothermal resources are those found at more than 400 m Temperature based: High (>150°C); Medium (90° - 150°C); Low (<90°C) enthalpy sources Based on installable thermal capacity: National interest (>20 MWt); Local interest (2-20 MWt); Pilot plants (<5MWe, no emission, 100% reinjection), special case of a resource of national interest *Small local utilizations of geothermal heat* can be used in small plants (< 2MWt) and use shallower resources (< 400 m) for heat purposes and power generation (in binary plants only)	Deep geothermal resources (> 400 m) are ascribed to the class of "mines" and are considered as *unavailable heritage* of the State (resources of national interest), or of the regions (resources of local interest). The development of deep geothermal is subject to a license
Turkey	*Geothermal resources*: Locations that have temperatures constantly higher than the annual atmospheric average of the region with the effect of the temperature of the earth's crust that may contain melted material and gas.	Locations that have temperatures constantly higher than the annual average ambient temperature of the region with the effect of the temperature of the earth's crust depending on the geological structure, that may contain dissolved materials and gas in an amount higher than the surrounding water resources, where water, vapor and gas naturally erupt or are naturally extracted along with places where water, vapor and gas	Subsurface resources state owned subject to licensing

		are obtained via heating by the earth's crust or heated dry rocks through man-made structures underground, (Law on Geothermal Resources and Mineral Waters, Law No. 5686, year 2007)	

Table 2: Definition, classification and ownership

Licensing and Authorization

Different aspects of licensing and authorization are listed in Table 3. Concerning the **type of permits**, one typically exploration and exploitation permits or concessions are needed. Various other licenses may be required, such as an environmental permit, and permits for power plant construction and operation. The precise schemes may differ, for example in France the petitioner can choose its specific title for the exploration phase (Research authorization or Exclusive Research Permit) to facilitate the exploration in areas where the temperature is less predictable. In Italy there is a separate type of exploration license for pilot plants smaller than 5MWe, with no emission and 100% reinjection. **Permit durations** are broadly similar among the countries considered, with roughly 3-6 years for exploration, and from 30 up to 65 years for exploitation. **Exclusivity arrangements** are equally similar – with open competition for exploitation, after which the exploitation permit holder is granted exclusive rights for a certain time period – although different specific arrangement for dealing with land ownership and expropriation may apply. An interesting difference is the number of **authorities involved** in permitting. In Iceland this is strongly channelled to a single authority (Orkustofnun), whereas in other cases (c.f. Italy) a variety of authorities can be involved, also depending on the type of permit at hand. Stated **timing for permit applications** are broadly similar among countries, often taking some 200 days for exploration and exploitation, with similar duration to be added for environmental permits and EIA. Turkey seems to have a relatively rapid handling of permits, with reported durations of 5 and 15 days for exploration and exploitation license respectively, although the EIA may take up to 1 year. **Royalties** generally apply for concessions, but the beneficiaries of those royalties may differ: competent authorities, resource owner, or local municipalities for environmental compensation. Finally,

some form of **EIA** is present in each country, although the way it is incorporated in the overall permitting procedure differs. In some cases it is part of a separate environmental permit (c.f. Belgium, Hungary), whereas in other cases it is integrated in another I permit, such as the work permit in France. Another similar procedure among countries is the possibility to be exempted from a full EIA based on an Environmental Preliminary Study (EPS) or 'EIA screening'.

	Belgium	France	Hungary	Iceland	Italy	Turkey
Main regulatory frameworks	*Flanders* Decree on the deep subsurface Decree of Environmental Permitting VLAREM II Legislation on environmental quality *Wallonia* Foreseen subsoil decree in Wallonia, currently under validation by the regional government	Mining Code (*Geothermal resources*)	Mining Act (*Geothermal energy resources*) Water Management Act (*Thermal water*)	Resource Act Electricity Act	Royal Decree RD1927/1443 (*ore resources and subsurface energies*) Legislative Decree DL2010/22 (*rules on exploration and exploitation of geothermal resources*)	Geothermal law
Type of permits	*Flanders:* Exploration Production Environmental	Exploration: AR or PER based on petitioner's choice	Water license >2500 m Concession <2500 m Heating plant (e.g. DH license)	Research, Prospection, Utilisation (Resource Act) Power plant (Electricity Act)	Exploration Permit (EP) Mining lease / Concession Exploration (pilot plants)	Exploration Exploitation Generation Construction

	Wallonia: The foreseen subsoil decree defines the exclusive exploitation and exploration permit. Currently, unique permit is required.	Exploitation: Permit or Concession depending on primary thermal power Work permit (cf. drilling or Operation Permit)	Environmental permit			Various other licenses for power plant construction
Permit duration	*Flanders*: 5 years (exploration license) *Wallonia*: The foreseen subsoil decree defines 7 years exploration license.	Exploration 3 – 5 yrs Open	Water licence : 5 years Concession: 35 years	Varies between licenses. Up to 65 years.	Exploration: 4 +2 yrs Mining: 30 yrs (exception for titles 2010)	Exploration: 3 + 1 yrs Exploitation: 30+10 yrs
Exclusivity	*Flanders*: Yes (after 90 days fair competition – exploration license) *Wallonia*: The foreseen subsoil decree defines the terms and conditions of call	Exploration: competitive call Exploitation exclusive for exploration license holder if research authorization still valid	The licence holders have exclusive rights for exploration and production	Land ownership gives limited rights: Orkustofnun may initiate exploration Compensation / expropriation required	EP holder 6 month exclusive right to mining lease For competition: evaluation criteria in text	Exploitation exclusive during validity (6Ms) of exploration licence. Easement or compulsory land acquisition may be granted by related Authority

Authorities	*Flanders:* EIA office Environment department	Local deconcentrated Authority (Prefecture with local mining authorities (DREAL)) Central Authority (Ministry)	Regional Directorates for Disaster Management (Water license) Mining Authority (Concession) Environmental authority (involving relevant other authorities)	Orkustofnun (single actor)	EP: Competent Region (and the provincial authorities of Trento and Bolzano) EP-pilot: Ministry of Economic Development (MiSE) Ministry of Environment and Protection of Land and Sea (MATTM) Concession: Relevant regional administration (or MiSE in case of off-shore resources and pilot plants)	YİKOB (Investment Monitoring&Coordination Department EMRA (Electric Market Regulatory Authority; for power production) Environment Ministry, EIA Department
Timing of permit application	*Flanders:* Environmental permit: 150 days EIA: >100 days (subject to developing the EIA) Exploration permit: 90 + 120 days (subject to competition)	Exploration: - AR: 18 month administration, silence implies refusal - PER: 2 years administration, silence implies refusal	Water licensing: 45-60 days after submission of documents, Concession: 1-2 years	Licensing procedure takes 3-6 months depending on the situation.	EP: 240 days starting from the date of the submission (exc. time for EPS – 90 days) Mining: 220 days (exc. time for EIA - 150-330 days)	Exploration license: 5 days Exploitation license: 15 days Power generation pre license: 40 days EIA: 1 year

	Wallonia: The foreseen subsoil decree defines the timing.	Exploitation: Permit: 18 month administration, silence implies refusal Concession: 3 years administration, silence implies refusal				Power generation license: 70 days
Royalties	ND	ND	Water fee: proportional to the amount of produced thermal water Royalty: 2% of the value of the produced geothermal energy Concession fee	Yes, to resource owner	Yes, to the competent authority and municipalities for environmental compensation[6]	Deposits needed

[6] EP: annual fee of 325 euro (€) per km2 to the competent authority. Mining: 650 € per km2 to the Region / 0.13 cents of € per kWh to the local municipality / 0.195 cents of € per kWh to the regional government / 4% of the installation cost for environmental compensation to relevant municipalities.

Environmental Impact Assessment	Yes, to obtain Environmental permit	Formally, EIA for work permit and classified facilities for the protection of Environment. Exploration and exploitation titles require environmental impact statements.	Yes, EIA or Environmental Preliminary Study (EPS) to obtain environmental permit	Yes, for larger projects.	EP: EPS / EIA screening. If not considered sufficient, an EIA is required. Mining + EP pilots: full EIA	Yes, for exploitation permit: (within 3 months of permit, otherwise cancelled) Generation / construction: EIA Not Required Certificate may be obtained. Otherwise, EIA needed (exc. for GPP > 20MWe)
Remarks	Recently a financial insurance scheme was adopted	Tailormade regulations for exploitation possible Health Public Code may apply when geothermal energy is used in cascade with other applications (drinking water, balneology)	Monitoring requirements described (Water license / concession)		Sicily special legal status Local municipalities, communities and associations can raise objections (vis-à-vis local regulations and environmental compensation) during licensing, ultimately address the competent Administrative Court.	Annual monitoring for each license

Table 3: Licensing and authorization

SUSTAINABILITY AND ENVIRONMENTAL IMPACTS

This section aims to map current regulations in each case study country through the prism of the 11 environmental impacts and risks mapped in D2.2. We start with an overview of international and EU regulations on the different environmental impacts considered, and consequently map national regulations in each of the GEOENVI case study countries.

International environmental policy objectives and agreements

Much of the environmental regulatory framework at the European level directly translates higher level of international agreements on environmental protection objectives, setting thresholds and standards that reflect those recognised by the international community (often setting stricter limits). Beside the international agreements that are directly translated in the European environmental legislative framework, such as the Kigali agreement or the Montreal protocol, several international environmental objectives contribute to shape European environmental regulations and are often referred to in the justification of legislative texts. Many of the international agreements objectives, and more generally much of the various environmental policies adopted globally also strive to contribute to the implementation of the UN Sustainable Development Goals (SDGs). Among the UN SDGs, several are directly aligned with the benefits provided by the scaled-up deployment of geothermal energy technologies, in particular objectives on “Climate Action”, “Sustainable cities and communities” and “Affordable and Clean energy” among others, while some other goals inform environmental policies that geothermal projects should respect during the development phase. Table 4 provides an overview.

Topic	International Agreement[7]	Description and scope
Climate change, ozone layer	UNFCCC (1992)	United Nations Framework Convention on Climate Change: Source of international actions on climate change, including the Conference of Parties that yielded such agreement as the Paris Agreement in 2015. The UNFCCC is the origin for the adoption of the objective to limit the global increase of average temperatures to 2°C, aiming for 1.5°C.
	Kyoto Protocol (1997)	International treaty extending the UNFCCC, committing parties to greenhouse gas emissions reductions.
	Paris Agreement (2015)	Extends the UNFCCC, introducing an objective to limit temperature increases to 1.5°C. Sets requirements for parties to submit Nationally Determined Contribution to mitigating climate change.
	Vienna Convention for the protection of the Ozone Layer (1985)	Global convention setting objectives for international cooperation in mitigating the degrading of the ozone layer.
	Montreal Protocol (1987)	International agreement that successfully lead to the stopping of manufacturing ozone depleting chemicals CFCs.
Air pollution	Air Convention (1979)	International convention to reduce air pollution from all sectors.
Chemical emissions	Minamata Convention (2013)	International convention on reducing the anthropogenic emissions of mercury and limiting the impact of this metal on public health and the environment.
Civil protection	Helsinki convention on industrial accidents (1992)	International convention on the transboundary effects of industrial accidents, notably regarding to environmental degradation and impacts on public health.
Governance	Aarhus Convention (1998)	Convention on access to information, public participation in decision-making and access to justice in environmental matters and its Protocol on Pollutant Release and Transfer Registers.
	Espoo Convention (1991)	International convention on Environmental Impact assessment, setting requirements for the parties to assess the environmental impact for their planned activities.
Environmental protection	Convention on Biological Diversity (1992)	The convention aims at the preservation of the biodiversity, and the sustainable use of biological resources by parties. It is the origin of the Convention of Parties on biodiversity.
	Bern Convention on European Wildlife and Habitats (1979)	aims to conserve wild flora and fauna and their natural habitats, as well as to promote European co-operation in this field. The treaty also takes account of the impact that other policies may have on natural heritage and recognises the intrinsic value of wild flora and fauna, which needs to be preserved and passed to future generations.

Table 4: List of international agreements impacting European environmental regulations and policy relevant for the geothermal energy sector

[7] https://ec.europa.eu/environment/international_issues/agreements_en.htm

EU environmental regulations for deep geothermal

Table 5 gives an overview of main environmental themes for each environmental impact considered. One can distinguish cross-cutting themes - like water quality, air quality, waste and environmental liability - that apply to multiple environmental impacts, and themes that are specific to a particular impact (e.g. radioactivity). Each theme is covered by several EU directives as displayed in Table 6 and briefly described below.

Water quality

Water quality is treated in the Water Framework Directive 2000/60/EC (Annex X replaced by the text set out in Annex II of Directive 2008/105/EC). It concerns the protection of inland surface waters, transitional waters, coastal waters and groundwater and it is aimed at: i) preventing further deterioration and protects the status of aquatic ecosystems, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems; ii) promoting sustainable water use; iii) protecting and improving the aquatic environment, inter alia, through specific measures for the progressive reduction of discharges, emissions and losses of priority substances and the cessation or phasing-out of discharges, emissions and losses of the priority hazardous substances; iv) ensuring the progressive reduction of pollution of groundwater and preventing its further pollution; v) contributing to mitigating the effects of floods and droughts.

In particular, the Directive 2006/118/EC establishes specific measures as provided for in Article 17(1) and (2) of Directive 2000/60/EC in order to prevent and control groundwater pollution. These measures include in particular: i) criteria for the assessment of good groundwater chemical status; ii) criteria for the identification and reversal of significant and sustained upward trends and for the definition of starting points for trend reversals. This Directive also complements the provisions preventing or limiting inputs of pollutants into groundwater already contained in Directive 2000/60/EC and aims to prevent the deterioration of the status of all bodies of groundwater.

Directive 2013/39/EU amends Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. The list of priority substances, reported in the Annex X of Directive 2000/60/EC, is replaced by the text set out in Annex I to this Directive. Directive 2014/80/EU of the European Parliament and of the Council on the protection of groundwater

against pollution and deterioration, amended Annex II to Directive 2006/118/EC, concerning the threshold values for groundwater pollutants and indicators of pollution.

Air quality

The European Directive 2008/50/EC addresses ambient air quality and cleaner air for Europe. It assesses the concentrations of sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM10 and PM2.5), lead, benzene, carbon monoxide, and ozone and establishes: i) the requirements for assessment of concentrations in ambient air within a zone or agglomeration; ii) the minimum numbers of sampling points for fixed measurement of concentrations in ambient air; iii) the limit values for the protection of human health. The National Emission Ceilings Directive 2016/2284/EU requires annual information on emissions of a number of pollutants from EU Members States, with regard to the reduction of national emissions of some atmospheric pollutants, including sulphur dioxide (SO2), nitrogen oxides (NOx) and non-methane volatile organic compounds (NMVOC), with respect to those of the year 2005. Particular substances include (from Annex 1):

- the five main air pollutants NOx, NMVOCs, SO2, NH3 and PM2.5 as well as carbon monoxide (CO);
- in addition to PM2.5, also PM10 particulate matter and, if available, black carbon (BC) and total suspended particulate matter (TSP);
- heavy metals cadmium (Cd), lead (Pb) and mercury (Hg) and, if available, the additional heavy metals arsenic, chromium, copper, nickel, selenium and zinc);
- persistent organic pollutant

The European Directive 2004/107/EC establishes for a specific list of substances: i) target value for the concentration of arsenic, cadmium, nickel and benzo(a)pyrene in ambient air so as to avoid, prevent or reduce harmful effects on human health and the environment; ii) ensure, with respect these pollutants that ambient air quality is maintained where it is good and that it is improved in other cases; iii) determine common methods and criteria for the assessment of concentrations of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air as well as of the deposition of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons; iv) ensure that adequate information on concentrations of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air as well as on the deposition of arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons is obtained and ensure that it is made available to the public.

Finally, the ETS directive (2003/87/EC) is relevant as the basis for the EU Emissions Trading Scheme (ETS) to which deep geothermal power plants with CO_2 emissions from degassing must comply.

Waste

The European Directive 2008/98/EC is the base of the European waste regulation and was recently amended by Directive 2018/851. Wastes are codified according to Decision 2014/955/UE and 2000/532/EC. Some wastes are classified as Ordinary Industrial Wastes (OIW), such as paper, wood, and plastic. OIW are the most important in terms of quantity in the geothermal industry. Wastes classified as Hazardous Wastes can potentially be very damaging to both the environment and human health. The Directive stipulates that hazardous waste must be recorded, identified and kept separated from other types of hazardous and non-hazardous waste.

The European Directive 2018/850/EC, amending Directive 1999/31/EC, regulate landfill of waste (categories of waste, waste disposal and recovery operations). The aim of the Directive is to ensure a progressive reduction of landfilling of waste, in particular of waste that is suitable for recycling or other recovery, and by way of stringent operational and technical requirements on the waste and landfills, to provide for measures, procedures and guidelines to prevent or reduce as far as possible negative effects on the environment. The aim of the directive is to support the Union's transition to a circular economy and meeting the requirements of Directive 2008/98/EC.

Noise and vibration

The purpose of the European Directive 2000/14/EC is to harmonise the laws of the Member States relating to noise emission standards, conformity assessment procedures, marking, technical documentation and collection of data concerning the control of noise emission in the environment of equipment for use outdoors. European Directive 2002/49/EC concerning to the assessment and management of environmental noise, define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects due to exposure to environmental noise. The Directive, to that end, establishes the following actions: i) determining the exposure to environmental noise, through noise mapping, by methods of assessment common to the Member States; ii) ensuring that information on environmental

noise and its effects is made available to the public; iii) adopting the action plans by the Member States, based upon noise-mapping results, with a view to preventing and reducing environmental noise where necessary and particularly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality.

This Directive provide a basis for developing and completing the existing set of Community measures concerning noise emitted by the major sources (road and rail vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery), and for developing additional measures, in the short, medium and long term. According to Directive 2002/49/EC, the European Directive 2015/996/EC defines common assessment methods for the determination of the noise indicators (defined in the Annex to this Directive).

Landscape

The European Directive 2003/35/EC supports the involvement of the community in decisions concerning the landscape by providing for public participation in the preparation of plans and programmes relating to the environment.

Soil quality

On 22.9.2006 there has been a proposal for a Directive (COM(2006) 232) establishing a framework for the protection of soil and amending Directive 2004/35/EC. It sets out common principles for protecting soils from various threats (e.g. erosion, decline in organic matter, contamination, sealing, compaction, decline in biodiversity, salinisation, floods, landslides).

Concerning seismicity, to our knowledge no regulation measure exists at the European level. On the basis of many decades of experience on geo-energy production and results of many research and industrial projects (for geothermal cases see GEISER Project http://www.geiser-fp7.fr), the formulation of best practices for reducing impact of hazard associated with underground usage became effective. These practices help to assess, manage, and mitigate the potential seismic risk posed by some industrial activities, and represent a reference for establishing national, regional and federal regulation.

Pressure equipment

The Pressure Directive 2014/68/EU is relevant to the risk of leaks due to surface operations. According to this directive, each vessel is associated to a risk category as a function of fluid,

pressure, volume or diameter and vessel type. Each category of risk is then associated to inspection program necessary for the design, manufacturing and testing to be in conformity with the directive. For certain categories of risk, a notified body is required for approval of the different inspections and welding qualifications. Once pressure vessels are installed in a European country, operation of this equipment is regulated by national regulation. These national regulations specify that operators must establish and maintain an inspection plan for all pressure equipment on site. Purpose of this plan is to ensure that pressure vessels are still in good conditions to be operated in safety conditions for workers and the environment. The inspection plan indicates periodicity and method of inspection. Periodicity depends of several parameters, such nature of the fluid, type of pressure vessel and risk category. Method is a combination of visual inspection and non-destructive method, like thickness measurement and radiography.

Radioactivity

Thresholds for dynamic and cumulative radioactive doses are established at the European level by a European Directive that applies to any planned, existing or emergency exposure situation which involves a risk from exposure to ionizing radiation. Council Directive 2013/59/Euratom of 5 December 2013 laid down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealed Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. The European Directive is then translated into the national regulations. Depending on countries, the topic of radioactivity is often mentioned in the Public Health Code, the Labour Code, and the Environment Code and in some cases, in the Mining Code (as it's been now the case in France since 2018). In most European countries, the maximal cumulative dose for human exposure is fixed to 1 mSv (milli-Sievert) over 12 consecutive months. National recommendation on radioactivity may be part of the Environmental Impact Assessment procedure for permission to operate a geothermal plant, and necessary provision are established. They are usually based on the worst-case scenario. At the plants' level, recommendations and obligation regarding the management of radioactivity may be expressed in the local (region, county, and municipality) authorizations for utilization.

Environmental liability

The European Directive 2004/35/EC establishes a framework for environmental liability, based on the polluter-pays principle, for the prevention and remedying of environmental damage, for example from ground surface deformation or seismicity.

	Water quality	Air quality	Waste	Noise and vibration	Landscape	Soil quality	Radioactivity	Pressure equipment	Liability
Surface disturbance (vibration, noise, visual, land occupation, dust)		X		X	X				
Degassing		X							
Ground surface deformation						X			X
Seismicity						X			X
Interconnection of aquifers and disturbance of non-targeted aquifers	X								
Reservoir physical and chemical modifications	X								
Effects of surface operations	X	X							
Waste production from surface operations			X						
Leaks due to surface installations and operations								X	
Liquid/solid effusion and waste	X	X	X			X			
Radioactivity							X		

Table 5: Overview of main environmental themes for each environmental impact

Topic	EU legislation	Scope
Water quality	2000/60/EC 2008/105/EC	Water Framework directive: protection of inland surface waters, transitional waters, coastal waters and groundwater
	2006/118/EC	Specific measures to prevent and control groundwater pollution
	2013/39/EU	Priority substances in the field of water policy
	2014/80/EU	Threshold values for groundwater pollutants and indicators of pollution
Air quality	2008/50/EC	Air quality directive: Monitoring requirements and threshold values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter (PM10 and PM2.5), lead, benzene, carbon monoxide, and ozone
	2016/2284	National Emission Ceilings Directive: 2016/2284/EU requires annual information on emissions of a number of pollutants from EU Members States
	2004/107/EC	Target values, mitigation measures, monitoring and information requirements for a specific group of pollutants (arsenic, cadmium, mercury, nickel, benzo(a)pyrene and polycyclic aromatic hydrocarbons)
	2003/87/EC	ETS Directive: establishing a scheme for greenhouse gas emission allowance trading (ETS)
Waste	2008/98/EC ; 2018/851 ; Decision 2014/955/UE and 2000/532/EC	Classifies different types of waste, inc. Ordinary Industrial Waste (most applicable for deep geothermal) and hazardous waste and stipulates requirements for handling hazardous waste
	2018/850/EC	Regulates landfill of waste targeting a progressive reduction and mitigate possible negative effects on the environment in line with the ambitions of a circular economy.
Noise and vibration	2000/14/EC	Harmonises the laws of the Member States relating to (amongst others) noise emission standards and data collection concerning the control of noise emission by outdoor equipment
	2002/49/EC	Regulates the assessment and management of environmental noise intended to mitigate the exposure to environmental noise
	2015/996/EC	Defines common assessment methods for the determination of the noise indicators
Landscape	2003/35/EC	Supports the involvement of the community in decisions concerning the landscape by providing for public participation in the preparation of plans and programmes relating to the environment
Soil quality	COM(2006) 232	Sets out common principles for protecting soils from various threats (e.g. erosion, decline in organic matter, contamination, sealing, compaction, decline in biodiversity, salinisation, floods, landslides)
Radioactivity	2013/59/Euratom	Safety standards and thresholds for dynamic and cumulative radioactive doses for any planned, existing or emergency exposure situation which involves a risk from exposure to ionizing radiation.
Pressure equipment	2014/68/EU	Sets requirements for the design, manufacture and conformity assessment of pressure equipment and assemblies (pressure > 0,5 bar) including e.g. inspection programs for different risk categories.
Liability	2004/35/EC	Liability directive: establishes a framework for environmental liability, based on the polluter-pays principle, for the prevention and remedying of environmental damage

Table 6: Main EU directives and legislation for the environmental themes considered

National environmental regulations for deep geothermal in selected countries

Surface disturbance (vibration, noise, visual, land occupation, dust, smell)

Surface disturbance:

- **Visual impacts** on landscape, e.g. deforestation, deviation of rivers, visible industrial infrastructures
- **Land occupation**, e.g. due to the construction of roads and power plants, drill pad and other infrastructures on site
- **Noise and vibration** generated by e.g. exploration and drilling, enhanced road traffic, engines and pumps during the plant operations
- **Dust production** from trucks
- **Smell** in the (rare) case of strong degassing

Potential surface disturbance of deep geothermal plants, as for all industrial activity, covers different environmental themes, in particular noise and vibrations, visual impacts on landscape, and air quality issues including dust and smell (for relevant EU legislation see Table 5). National level legislation is summarized in Tables 7-9. Noise and vibration appear to be well regulated, as an industrial sector, both for workers and surrounding residents. Visual impacts and landscape are less strictly regulated, but generally treated in Environmental Impacts Assessments (EIAs), with the Tuscany region hosting the most developed regulations in this respect. National regulations on dust and smell follow general EU air quality regulations, with various dust and smell specific legislation and guidelines in place.

Country	Regulation	Scope	Thresholds	Mitigation & monitoring
Belgium	VLAREM II Section 2.2.1: Environmental quality norms and target values for noise in open air. Section 4.5: Noise pollution control Annex 4.5.1 Measuring methods and conditions for background noise.	Regional (Flanders) Environmental quality norms and target values for noise in open air. General guidelines (Section 2.2.1) and specifications / additional requirements for high risk activities (Section 4.5)	General threshold values given in Annex 2.2.1 for 10 land use categories and three time periods (day / evening / night), see (accessed Dec. 2019): https://navigator.emis.vito.be/mijn-navigator?woId=10069 For example, residential area: Day (45dB), Evening (40 dB), Night (35 dB)	Section 4.5: Requirements for using Best Available Techniques for minimizing noise pollution. Monitoring original background noise. Further specification of thresholds for 'specific noise' (i.e. the noise specific to the project/activity/…) and 'fluctuating sound' (e.g. occasional peaks) for high risk activities. Requirements for monitoring method (Annex 4.5.1)
	Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit	Regional (Wallonia) Noise	The threshold values are given according to three time frames per day (7-19h), transition period (6-7 & 19-22h), and night (22-6h), and different zones Day: btw 55 and 60 dBA Transition: btw 45 and 55 dBA Night btw 40 and 50 dBA.	Exceptions can be granted according to specific rules. Monitoring measures are foreseen in Section 3 of the Order.
France	Ministerial decree N°2006-1099 relative to neighborhood noise abatement	National Noise	Yes, and global noise emergence is limited to 5 dB(A) (day), and 3 dB(A) (night)	Monitored throughout the daytime (7h – 22h), during night (22h – 7h) time.
	The French Public Health Code	National	<30 dB	Fixes a spectral emergence in a certain octave band (article R 1334-34)

				Measurement of global and spectral emergence only if the background noise is up to 30 dB (article R 1334-32). DG: A day- and night-time noise measurements must be performed before any exploitation/drilling starts near the closest houses to determine the level of background noise. Must be done repeatedly and measures need to be taken to respect those general rules
	Ministerial decree of the 23rd of July 1986 about mechanical vibration emissions in the environment. NF E 90-0201 norm ISO 2631-2 norm ISO 2631 norm	National / vibration	three levels according to construction and frequency range	Applied during active seismic data acquisition during the exploration activity or during specific civil works for the construction of the drilling platform or the geothermal plant.
Hungary	284/2007 (X.29.) on protection against vibration and environmental noise Governmental decree 280/2004 (X.20) on the assessment and mitigation of environmental noise. KvVM.EüM Ministerial Decree 27/2008 (XII.3.) on environmental noise and vibration threshold values	National	In the case of construction in cities: 50-70 db (different values for night and daytime, also depending on the length of the construction work) Within buildings (various types): 40-50 db	Provisions on the measurement methods of noise and on the contents of the compulsory documentation (Annex 5 of the 284/2007 (X.29.) Gov. Decree) Assessment and handling of noise is the scope of the Governmental decree 280/2004 (X.20) – preparation of strategic noise maps, contents of the action plan, establishment and roles of a noise committee

Iceland	921/2006 Regulation on the prevention of stress due to noise at work. 724/2008 regulation on noise	Noise Ensure the safety and protection of health of workers. The aim is to prevent or reduce harmful effects caused by man-made noise	The noise level should be below 55 LAeq. In quiet areas, noise levels in urban areas should not exceed Lden 50 dB (A) and in rural areas not exceed Lden 40 dB (A).	The Occupational Safety and Health Administration has published the brochure Noise and Hearing Protection. The brochure is intended to provide managers and employees at work with information on noise hazards and ways to improve them. Companies are obligated to do everything in their power to prevent health damaging noise for the public.
	922/2006 Regulation on the prevention of stress due to mechanical vibration in the workplace.	Vibration Ensure safety and protect the health of workers at risk or at risk of mechanical vibration during their work.	Specific limit values given, e.g. daily limit values for eight hours reference period shall be 5 m / s², with the possibility of exceptions for peak exposure.	When operations are likely to involve risks due to mechanical vibration, the employer shall assess and, if necessary, determine the level of stress due to mechanical vibration of workers, cf. Article 65 a Act no. 46/1980, on working conditions, hygiene and safety at work, with subsequent amendments.
Italy	Law 447 of 26 October 1995 “Framework Law on noise pollution”. National framework law on noise pollution, modified thereafter to be harmonized with EU legislation (Dir. 2000/14/EC in particular)	National	ND	This law establishes the fundamental principles for the protection of the environment from noise pollution, in accordance with and for the purposes of Article 117 of the Constitution.

	Ministerial Decree of 11 December 1996, “Application of the differential criterion for plants with a continuous production cycle”.	National	ND	The decree defined the arithmetic difference between the noise measured with and without a specific source must not exceed a certain value (different during the day and night). For plants with a continuous production cycle the observance of the differential criterion is a necessary condition for the granting of the license.
	Decree of the President of the Council of Ministers of 14 November 1997 “Determination of limit values for noise sources”	National	Emission limit value (Leq in dB(A)): I - Protected areas (Day 45; Night 35) II - Residential areas (Day 50; Night 40) III - Mixed areas (Day 55; Night 45) IV - Areas of intense human activity (Day 60; Night 50) V - Mainly industrial areas (Day 65; Night 55) VI - Exclusively industrial areas (Day 65; Night 65) Intake level values (Leq in dB(A)): I - Protected areas (Day 50; Night 40) II - Residential areas (Day 55; Night 45) III - Mixed areas (Day 60; Night 50) IV - Areas of intense human activity (Day 65; Night 55)	Regulated according to the local area and its usage, and different levels are set for night-time (22:00 pm to 6:00 am) and day-time (6:00 am to 22:00 pm). Six classes of land use and related admissible noise level are established. For each class, noise emission limit values are given together with emission levels values and quality standard levels Each municipality must perform an acoustic characterization These limit values, applicable to permanent installations, such as geothermal power plants, are however not applicable to temporary sites, such as drilling rigs for research or cultivation

			V - Mainly industrial areas (Day 70; Night 60) VI - Exclusively industrial areas (Day 70; Night 70) Quality standard values (Leq in dB(A)): I - Protected areas (Day 47; Night 37) II - Residential areas (Day 52; Night 42) III - Mixed areas (Day 57; Night 47) IV - Areas of intense human activity (Day 62; Night 52) V - Mainly industrial areas (Day 67; Night 57) VI - Exclusively industrial areas (Day 70; Night 70)	wells geothermal energy. Authorizations for temporary activities that overcome the noise limits can be requested to local municipalities
	Ministerial Decree of 16 March 1998 "Detection and measurement of noise pollution"	National	ND	This decree establishes the techniques for detecting and measuring pollution from noise.
	Legislative Decree 262/2002. Implementation of Directive 2000/14/EC on the noise emission in the environment by equipment for use outdoors	National	ND	This decree regulates noise emission values, conformity assessment procedures, marking, technical documentation and noise data collection of the machines intended to be used outdoors, in order to protect both the environment and well-being and health of people

	D. Lgs. 194/2005 enforces the Directive 2002/49/EC, relating to the assessment and management of environmental noise.	National	ND	This decree, in order to avoid, prevent or reduce the harmful effects of exposure to environmental noise, including annoyance, defines the procedures for: (a) the preparation of noise maps and strategic noise maps; (b) the preparation and adoption of action plans to avoid and reduce environmental noise, in particular where exposure levels are likely to have harmful effects on human health; (c) ensuring public information and participation on environmental noise and its effects.
	Legislative Decree 42/2017. Requirements for the harmonization of national legislation on noise pollution	National	ND	This decree harmonizes the legislation on noise pollution and amends parts of Law 447/1995 and subsequent decrees)
Turkey	Regulation on the Assessment of Environmental Noise (04/06/2010 - 27601) Regulation on Protection of Employees from Noise Related Risks (23/07/2013-28721)	Noise National	ND	Noise assessment methods, acoustic report and environmental noise level evaluation report to protect physical and mental health. Determination the minimum requirements for the protection of

				employees from health and safety risks that may arise from exposure to noise.

Table 7: Regulations on noise and vibration

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	Decree general provisions for environmental policy (DABM) art. 4.3.1 Annex II bis	Regional (Flanders) The environmental impact assessment (f.e. the EIA for the Balmatt site) should comprise a description of the environmental impacts of a project/activity on land, spatial use, cultural heritage and landscape.	ND	Annex IIbis: In the environmental assessment, a description should be given of the planned measures to prevent, limit or – if possible – compensate the negative effects.
France	Drilling or exploitation authorization of each site	ND	ND	The operating company must take all possible measures to minimize the visual impact of facilities. The drilling site and the geothermal plant must be kept clean permanently.
Hungary	Not relevant for geothermal operations	ND	ND	ND

Iceland	660/2015 Regulation on environmental impact assessment.	General environmental impact assessment, including regulation and mitigation measures, and allow the public to comment and provide information before the Environmental Planning Agency's opinion on the environmental impact assessment is available.	Construction site information included in the assessment: description of site construction site locations: landscape, vegetation, wildlife and land use, an overview of protected areas and obligations, and land use restrictions, e.g. due to natural hazards.	ND
	90/2013 Planning regulations	General planning regulation concerning construction and building permits above and below the ground to be in accordance with the plans, cf. the provisions of the Planning Act, the Act on Structures and Regulations adopted thereunder.	ND	ND
Italy	Code of Cultural Heritage and the Landscape (BCP)	National	ND	The regional and local level programs must comply to BCP
	D. Lgs. 152/2006 Part II	National	ND	Regulates the landscape protection in the environmental impact assessment procedures.
	The regional Landscape Plan (PIT) (e.g. Tuscany)	Regional and local	ND	At the local level, it divides the Tuscany territory into 20 landscape areas (“Ambiti”), formulating specific quality

				objectives and relative discipline for each of them Established the need to further define the areas of the region in which the geothermal activities may be developed.
Turkey	ND	ND	ND	ND

Table 8: Regulations concerning visual impacts and landscape

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	Vision on sustainable policy concerning smell https://www.lne.be/beleid-geurhinder	Regional (Flanders) Smell In Flanders, policy concerning smell is limited to a vision document and some sectoral codes of good practice. These are not applicable to geothermal projects, as they are not considered to cause odour emissions.	ND	- Precautionary principle - In case of nuisance, BAT will be used to reduce to 'acceptable' levels. - Levels deemed acceptable depend on the environment and the frequency and duration of the odour.
	Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit, art. 12, 14, 17	Regional (Wallonia) Smell	ND	The operator must capture or if not, must limit the emissions and their transmission to the environment.
France	Exploitation authorization of each site	Local Smell, during plant operation	ND	Must be operated in such a way that they cannot be a source of olfactory nuisance or deterioration of the air

				quality, which may be a nuisance to the neighbourhood or harmful to the health of the neighbourhood
	The environmental code (Cf. articles R221-1 à R221-3) based on EU Directive 2008/50/EC of 21 May 2008 on ambient air quality and cleaner air for Europe. World Health Organization (WHO) recommendation.	Dust	For particles ''PM10'' quality objective is 30 µg/m³ of suspended particles in yearly average and 10 µg/m³ for ''PM2.5'' (WHO)	During exploration, drilling and operation phases, main source of suspended particles are vehicles. They must be in conformity with Euro norms. Operators must limit dust emissions during civil works by keeping the soil humid. Air quality measurement is performed by certified associations for monitoring air quality (e.g. Airparif in Paris area or Atmo Grand Est for the French Rhine Graben area)
Hungary	4/2011 (I. 14.) Ministerial Decree on the threshold values of air quality and point-source emissions 4/2011 (I. 14.)	Flue dust and their injurant substances	Flue dust 40 µg/m^3.(annually)	6/2011 (I.14) Ministerial Decree on the assessment and monitoring of emissions discusses the measurement and calculation methods.

Iceland	787/1999 Regulation on air quality	Dust/smell 2.1 This Regulation applies to air quality and the prevention of air pollution. The regulation applies in Iceland and in the pollution zone. The regulation applies to the activities of individuals as appropriate. 2.2. The provisions of Act no. 46/1980, on working conditions, hygiene and safety at work.	variable	5.1 Minimum air pollution shall be kept and the quality of clean and unpolluted air maintained. 5.2 Provision of operating permits for polluting business operations shall take appropriate measures to prevent air pollution and apply the best available technology. 5.3 The state's health protection or health committee, as appropriate, may make stricter requirements than this regulation states if air pollution in a particular area is particularly high or if the area is to receive special protection.
	920/2016 Regulation on air quality and information to the public.	National:. Sulfur dioxide, nitrogen dioxide and nitrogen oxide, benzene, carbon dioxide, particulate matter and lead in the atmosphere, ozone concentrations at the surface of the earth	Threshold variable for variable chemical compounds, the time exposure and how many times per year values may exceed the threshold.	Applies to monitoring, evaluation, measurement, limit values, information exchange and public notifications.
Italy	ND	ND	ND	ND
Turkey	Regulation on Odorous Emission Control (19/07/2013 – 28712)	Smell National	ND	Regulating administrative and technical procedures and principles for the control and reduction of emissions causing odor.

	Regulation on Industrial Air Pollution Control Directive (03/07/2009 – 27277)[8]	Dust National		Control emission in the from of dust that are released into the atmosphere as a result of the activity of industrial and power generation facilities

Table 9: Regulations on dust and smell

[8] Lastly amended by the OG – 20/12/2014 - 29211

Degassing

Degassing:

- The release of the non-condensable gas content of geothermal fluids into the atmosphere in some specific geothermal areas. Typically CO_2, but other gases such as H2S, CH4 and N2 could be present as well.

Possible degassing is exclusively related to air quality (for relevant EU legislation see Table 6). National level legislation is summarized in Table 10. The environmental impact is already generally well regulated by air quality regulation, often with reference to the relevant EU directives for EU member state countries. CO_2 emissions are subject to the EU Emissions Trading Scheme (ETS).

Country	Regulation	Scope	Thresholds	Mitigation & monitoring
Belgium	VLAREM II Section 2.5 Environmental quality norms and target values for air and the assessment and management of air quality. Section 4.4 Management of air pollution, target values and measuring methods for high risk activities.	Regional (Flanders) Environmental quality norms and threshold values for air. General guidelines (Section 2.5) and specifications / additional requirements for high risk activities (Section 4.4)	General threshold values given in Annex 2.5.1 for 6 gases (e.g. cadmium, chlorine) see (accessed Dec. 2019): https://navigator.emis.vito.be/mijn-navigator?woId=10078 General threshold values given in Annex 2.5.3 for sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter (PM10 and PM2.5), lead, benzene, carbon monoxide and ozone. https://navigator.emis.vito.be/mijn-navigator?woId=38570 General threshold values given in Annex 2.5.8 for arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons. https://navigator.emis.vito.be/mijn-navigator?woId=19906	Section 4.4 : Management of air pollution through installation requirements (Best Available Techniques), emission threshold values and measuring strategy. Annex 4.4.2 Emission threshold values, depending on the material and quantity of emissions of the source/installation Annex 4.4.3 Measuring frequency e.g. depending on the quantity and the material: every month, every 3 months, every 6 months. Annex 4.4.4 Control measuring scheme
	Order of the Walloon government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit, art. 12 to 17.	Regional (Wallonia) Generalities on air quality preservation	No	Defines the notions related to air, the formulas, and units of measurement Operator must capture emissions or limit their production and transmission.
	Order of the Walloon Government of 15 July 2010 related to the evaluation and the management of air quality,	Regional (Wallonia) General on ambient air quality	Yes, in appendices	Organizes the evaluation and management of air quality, based on

	transposes Directive 2008/50/CE, Directive 2004/107/CE, and Directive 2015/1480.			methods and criterium common to EU Ms. Includes target values for specific pollutants. Defines responsible authorities to evaluate and manage air quality.
France	Ministerial decree 80-331 on General Regulations on Extractive Industries, article 42 & 46	National, focus on DG, During drilling	ND	Monitoring through technology (degassing system) considering weather conditions. Exemption possible if safety is proven
	Articles RG29 and RG30 of the General Regulation on Extractive Industries	National, during drilling	> 10 ppm: trigger a visual and audible alert	Devices for H_2S detecting prior to drilling must be installed Site manager then applies the appropriate safety instructions.
	Exploitation permit of each site	Local, focus on DG, during plant operation	ND	Monitoring through physico-chemical parameters and chemical composition once a year
Hungary	4/2011 (I. 14.) Ministerial Decree on the threshold values of air quality and point-source emissions. Ministerial Decree 12/1997 (VIII.29) on the degasification of produced waters	National During thermal water abstraction with high gas content	•below the threshold of 0,8 l/m3 „A"; •between 0,8-10 l/m3 „B", •above 10 l/m3 „C". Degassifying unit is compulsory for category "C"	Accredited laboratories do measurements – in category "C" every 2 years
Iceland	Sanitary and Pollution Control Act on air quality. Regulations no. 787/1999 on Air Quality, no. 786/1999 on Pollution Control and	National. General air quality	Act no. 7/1998: The pollutant emission limit values shall apply at the point of discharge of the pollutants at the installation. When setting limit values,	That information on air pollution is obtained, that it is assessed in a consistent manner and that air quality is maintained or needs improvement. Part

	no. 785/1999 on operating licenses for business operations which may result in pollution. The air quality in Iceland is treated mostly in Act no. 7/1998 on hygiene and pollution prevention, but also Act no. 46/1980 on working conditions, hygiene and safety at work and Act no. 23/2006 on the right to information on environmental issues. 920/2016 Regulation on air quality and information to the public.	The common goal of the regulations is to reduce air pollution and bring it in prevent or reduce its harmful effects. SO2, NO2, NOx, CO, Benzene in the atmosphere (regl. 920/2016)	dilution that occurs prior to the release point shall not be taken into account.	of that is ensuring uniformity pollution control in the country. Act 7/1998 Monitoring of air pollutants shall take place in accordance with the provisions of a regulation issued by the Minister, cf. Paragraph 2 The installation and operation of automatic monitoring devices shall be subject to monitoring and annual monitoring tests. The Environment Agency determines the location of the sampling or measurement points to be used for emission monitoring.
Italy	Legislative Decree 152/2006 - Part V and subsequent amendments and integrations (Legislative Decree 128/2010) on air emissions.	National	Minimum and maximum emission values for wet gaseous effluents: -H_2S: 70-100 mg/Nm3 for a mass flow of 170 kg/h or more - As (as salts dissolved in the driving water): 1 – 1,5 mg/Nm3 for a mass flow of 5 g/h or more -Hg (as salts dissolved in the driving water): 0,2 - 0,4 mg/Nm3 for a mass flow of 1 g/h or more	Rules on air protection and reduction of atmospheric emissions. The Decree deals with the prevention and limitation of atmospheric emissions, through prescriptions and limits related to emissions generated by some activities, plants and fuels, reformulating the previous authorization regime
	Legislative Decree 155/2010 and subsequent amendments and	National	*Target values (*total content of PM10 fraction averaged over a calendar year)*:*	Contains definitions of limit value, target value, information and alert threshold,

	integrations (Legislative Decree 250/2012) implements Directive 2008/50/EC on air quality. This decree transposes Directive 2008/50/EC and replaces the provisions implementing Directive 2004/107/EC, establishing a single regulatory framework for the assessment and management of ambient air quality.		Arsenic (As): 6 ng/m^3 Cadmium (Cd): 5 ng/m^3 Nickel (Ni): 20 ng/m^3 Benzo(a)pirene (C20H12): 1 ng/m^3	critical levels, long-term objectives and target values. Mandatory monitoring for specific listed pollutants Describes the methods of transmission and the contents of information on the state of air quality, to be sent to the Ministry of the Environment, and competent authorities in assessing air
	Legislative Decree 81/2018. Transposition of Directive 2284/2016/EU.	National	ND	The decree establishes new national emission reduction commitments for SO2, NOx, NMVOCs, NH3 and PM2.5.
	DGRT 344/2010 “Guidelines for the containment of atmospheric emissions from geothermal power plants”	Regional - specific for geothermal power plants	-Emissions limits at stack; -max number of non-operational hours for abatement plants; -target emission values for new/revamped plants.	Obligation to install abatement systems for critical pollutants.Define the requirements for plants both as emission values and as technologies to be adopted for their containment.
	Regional Law RT 9/2010 “Regulation for the protection of ambient air quality”	Regional – specific for geothermal powerplants	ND	General law that assigns duties to the public administration and set the rules for the aims and approval of the regional air quality plan.
	DCR 72/2018 “PRQA, Regional air quality plan with new emission thresholds”	Regional	Annex 2: emission limit values and prescription for production activities	The Plan provided for by Regional Law 9/2010, is the act of government of the territory through which the Region of Tuscany pursues the progressive and constant improvement of air quality.

	Legislative Decree 81/2018. Implements Directive 2284/2016 on the reduction of national emissions of certain atmospheric pollutants.	National	ND	Established new national emission reduction commitments for sulphur dioxide (SO2), nitrogen oxides (NOx), non-methane volatile organic compounds (NMVOCs), ammonia (NH3) and fine particulate matter (PM2.5).
	Regional Law 7/2019 "Prescriptions about geothermal energy deployment – modification of the Regional Law 54/1997"	Regional – specific for geothermal powerplants	Emission limits allowed in Italian plants: -Outlet of the AMIS abatement plant (H2S kg/h 3; Hg g/h 2; SO2 g/h: 150) -Natural degassing without AMIS for plants ≤ 20 MW (H2S kg/h 10; Hg g/h 4) -Natural degassing without AMIS for plants > 20 MW (H2S kg/h 20; Hg g/h 8) -Forced degassing without AMIS for plants ≤ 20 MW (H2S kg/h 30; Hg g/h 10= -Forced degassing without AMIS for plants between 20 and 60 MW (H2S kg/h 60; Hg g/h 15) -Forced degassing without AMIS for plants > 60 MW (H2S kg/h 100; Hg g/h 20) Maximum hours per year of allowed plant stop in Italian plants:	Guidelines and prescriptions for: - authorising new geothermal plants / provide new authorisations to existing plants, - providing access to air quality and emissions data for the relevant public administration, - Guaranteeing the use of best available technologies and the recovery of waste heath and CO2. Partially modifies the emission limits stated in the previous legislation

			-Hours of overall non-operational plant (2% in 8760 hours / year) -Hours of operation of AMIS plants / overall operational time of the facility (≥98%)	
Turkey	Regulation on Industrial Air Pollution Control Directive (03/07/2009 – 27277)[9]	National	ND	Control emissions in the form of smoke, dust, gas, steam and aerosol;
	Regulation on Monitoring the Greenhouse Gaseous Emissions (17/05/2014 -29003)	National	ND	Regulating the procedures and principles for monitoring, reporting and verifying greenhouse gas emissions from activities listed in the regulation.

Table 10: Regulations on degassing

[9] Lastly amended by the OG – 20/12/2014 - 29211

Ground surface deformation

Ground surface deformation:

- Ground surface subsidence or uplift, generally in response to potential pressure and/or temperature changes within the geothermal reservoir.

In case of a ground surface deformation, it is mostly related to soil quality and environmental liability (for relevant EU legislation see Table 6). National level legislation is summarized in Table 11. Although it is difficult to specify specific threshold values for ground surface deformation, guidelines for monitoring surface deformation are present in most countries and best practices are implemented by project developers and operators.

Country	Regulation	Scope of application	Threshold	Mitigation & monitoring
Belgium	Decree Deep subsurface of the Flemish Government Decision Deep subsurface of the Flemish Government	Regional (Flanders, Wallonia NA) Covers the minimization of damage on the environment, the surface and the subsurface taken into account as a permitting criterium, and specifies financial responsibilities for the damages.	ND	Decree Section IV Obligations of the permit holder: The permit holder takes all necessary measures to prevent his activities from causing Environmental damage, Damages because of ground surface deformation Decision Section 3 Requesting a permit: The request for a permit must comprise a description of the environmental impact of the planned activity of the surface and subsurface and the means that will be used to limit those impacts to a minimum. Section 7 Measuring surface deformation sets requirements for measuring movement, set up a measuring plan etc.
	No regulation in Wallonia, specific conditions added in environmental permits	ND	ND	Monitoring by interferometry
France	ND	General	ND	Ground deformation evolution reported monthly to the Mining

				Authorities through mandatory geodetic station
Hungary	Not relevant	ND	ND	Has not been observed so far
Iceland	Yes but ND based on Resource Act (57/1998) regarding boreholes Guidelines	Specific to boreholes	ND	Public registry through ID number (www.map.is/OS) Rules on registration, design and permanent closure of boreholes, and the submission of information on boreholes to Orkustofnun to improve responsibility.
Italy	Law 183/1989, D.Lgs.152/200		ND	Ensuring the conservation and remediation of soil and subsoil, the hydrological restoration of the affected area through the prevention of instability phenomena, the safety of the risk situations, and combating desertification.
	Guidelines MISE-MATTM (2016)	General, during geothermal operation	ND	Describes procedures, protocol to monitor spatial-temporal surface deformation and the publication of data and results InSAR techniques complemented by GPS surveys during
Turkey	ND	ND	ND	ND

Table 11: Regulations on ground surface deformation

Seismicity

Seismicity:

- Induced seismic events as a result of a geothermal development in a specific environment, including often 'microseismicity' (detected vibrations, but not felt on the ground) and/or occasionally minor seismic events that can be felt.

Potential seismicity, like ground surface deformation, would be mostly related to soil quality and environmental liability (for relevant EU legislation see Table 6). National level legislation is summarized in Table 12. Similar to the case of ground surface deformation, a variety of guidelines for monitoring mitigation is present in most countries and geothermal operators use best available technologies and practices.

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	Decree Deep subsurface of the Flemish Government	Regional (Flanders, Wallonia NA) Ground movement is defined both on the long and short term, so as ground surface subsidence or uplift, but also as seismicity. The same regulations apply as under 'ground surface deformation', i.e. minimizing impacts on the subsurface, with financial liability of the exploitation permit owner.	ND	See 'Ground surface deformation'
	Not yet regulated in Wallonia	ND	ND	Monitoring by the Royal Observatory of Belgium (global seismicity)

France	Exploitation permit of each site	Local (e.g. relevant for Alsace but not the Paris area where seismicity is not an issue), seismological monitoring during drilling and exploitation	ND	– Information of the population about the hydraulic activities and the probability of induced seismicity; – Installation of a monitoring network (thoroughly described in the decree) at least 6 months before the start of drilling, in order to observe the local, natural seismicity.
			PGV ≥ 0.5 mm/s PGV ≥ 1.0 mm/s PGV ≥ 1.5 mm/s	Definition of Peak Ground Velocity (PGV), three scales with lead to specific procedures associated.
Hungary	ND	Not applicable because of no hydraulic fracturing	ND	ND
Iceland	Act No. 7/1998 on hygiene and pollution control rules on the preparation and execution of fluid injection into the ground via boreholes	National, Applicable when water injection is mandatory	ND	ND
	Rules on the preparation and execution of fluid injection into the ground via boreholes (OS-2016-R01-01) issued on January 21st of 2016	National, during operation	These rules apply to the preparation and implementation of ground liquid discharge through boreholes and earthquake risk preparedness when any of the following factors apply:	- Minimize the risk of bodily harm, damage to man-made structures and inconvenience due to earthquakes in connection with fluid injection to the ground via boreholes. - restrict and explain duties, roles and involvement of the licence holder, Orkustofnun and other parties

			Fluid discharge exeeds 5l/s annual average Fluid discharge exeeds 10 l/s average per hour As well as fluid release into active faults and fissures and if stimulation exceeds 6MPa pressure exceeding natural state	- provide information to applicants for production and utilization licences - establish a contingency plan for earthquakes or the risk of earthquakes due to ground discharge
Italy	Royal Decree 193/1909	National	ND	First normative reference identifying seismic areas on the national territory
	Law 64/1974	National	ND	Reference framework for the methods of seismic classification of the national territory, as well as the drafting of technical standards
	Guidelines for monitoring seismicity, soil deformation and pore pressures in the context of humans' activities 24/11/2014	National	ND	The guidelines, which referred to hydrocarbon exploitation, waste-water injection and CO2 storage, were updated, tailored for the geothermal case and embedded in the "Guidelines for the usage of medium and high enthalpy geothermal resources" (MISE-MATTM, 2016)
	Guidelines for the usage of medium and high enthalpy geothermal resources (MISE-MATTM, 2016).	National - Aims to ensure transparency and objectiveness of monitoring, with the full publication of data and results	Reinjection level of waste water depends on: Magnitude Peak ground velocity (PGV)	Detect variations in the monitored parameters (pore pressure, micro-seismicity and ground deformation),

		- Describes the governmental regulations, technical aspects of monitoring, and operative actions for a safe exploitation of the reservoir	Peak ground acceleration (PGA)	their correlation with the energy-activity carried out in the subsurface Undertake mitigation actions and launch proper actions for the safety of plant, people and involved environment The application of a four-stage traffic light protocol (actually applied exclusively for reinjection of waste water), depending on magnitude, Peak ground velocity (PGV) and peak ground acceleration (PGA).
	Regional Decree 298/2018 Seismometric monitoring in Tuscany Region	Regional	ND	Defines the monitoring protocol and the related technical details, such as number of monitoring station, data handling and communication with the population In case of damage to exposed value assets or population (e.g. evacuation), the support is handled by government and local authority emergency decree, that regulate the (public) funding expenditure
Turkey	ND	ND	ND	ND

Table 12: Regulations concerning seismicity

Impacts on the underground fluid

Impacts on the underground fluid:

- Accidental **interconnection of aquifers** via the wellbore
- Accidental **disturbance of non-targeted aquifers** with fluid intrusion (geothermal fluid, testing fluid, drilling mud, etc.)

Impacts on the underground fluid is mostly covered in the water framework directive and associated water quality legislation in particular for groundwater (for relevant EU legislation see Table 6). National level legislation is summarized in Table 13. This impact appears generally well regulated as part of national legislation on ground water quality and thoroughly addressed in permitting processes.

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	VLAREM II Sector-specific environmental conditions for high-risk activities Section 5.55 Drilling Annex 5.53 Code of good practice for drilling	Regional (Flanders) Regulates groundwater related impacts for drilling activities.	Every pollution of groundwater will be prevented, during constructions as well as during exploitation. It is prohibited to connect different aquifers.	The Code of good practice prescribes some measures to prevent 'contamination' of ground water. - The water used for drilling should be clean; - In case additives are necessary, biodegradables are recommended.

	Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit, art. 11	Regional (Wallonia), During exploitation	Annual average volume of the stream	General principle to preserve underground water quality the security of the persons, and the level of underground water.
	Order of the Walloon Government of 13 September 2012 determining the sectorial conditions related to drilling and equipment of wells destined to future underground water pumping, art. 3-4-7.	Regional (Wallonia) During drilling and operation		General prescriptions such as the prohibition to pump water from different underground waters, or prevention from disturbing the geological structure of neighbour area while drilling.
France	Mining code and drilling authorization of each site	National and local, during drilling		- Operators must take all possible measures or apply specific procedures in order to guarantee the underground water and minimize the risk of accidental pollution - Technical prescriptions on permeability of the well - Obligations to report from operators at the end of each casing and cementing operation
		National and local, during drilling, in case of drinkable aquifers		- Several casings can be imposed by the mining authority - The operator must also install a network of piezometers into shallow observation wells. - Water samples are monthly taken and analysed.
	Exploitation authorization of each site			- The operator must provide to the mining authority a program concerning wellbore integrity inspection (article 9 and 32). - Wellbore integrity control is performed using diameter, sonic or electromagnetic tools to assess casing integrity, cementation quality,

				deposit thickness and corrosion evolution (article 33). - According to exploitation authorization, wellbore inspections are required every 3 years in injection wells and every 5 (in Paris Basin) to 6 years (in French Rhine Graben area) in production wells.
Hungary	Act LIII of 1995 on the general rules of environmental protection Act LVII of 1995 on water management Governmental Decree 221/2004 (VII.21.) on certain rules of river basin management Governmental Decree 219/2004 (VII.21.) on the protection of groundwaters KvVM /Ministerial Decree 30/2004 (XII.30.) on certain rules of examination of groundwaters Governmental Decree 123/1997 (VII.18.) on the protection of water resources Governmental Decree 147/2010 (IV.29.) on the general regulations related to the activities and establishments serving the utilization, protection and mitigation of damages of waters Governmental Decree 220/2004 (VII. 21.) on the protection of surface waters KvVM /Ministerial Decree 28/2004. (XII. 25.) on the threshold values of water contaminating materials and on certain rules of their application	National / groundwater bodies as defined in the National River Basin Management Plans	Overall: to achieve and maintain the good quality and quantity status of groundwater bodies (for details see Appendix 3)	Operators, drilling companies, Directorate General for Disaster Management and its regional offices, General Directorate for Water Management (http://www.ovf.hu/en/) and its 12 regional offices (for details see Appendix 3)

Iceland	797/1999 Regulation on the prevention of groundwater pollution	National: Aims to prevent groundwater pollution from man-made water and limit the consequences of pollution that has already occurred on groundwater.	Emission limits are limits for allowable emissions that may not be exceeded during one or more periods. The limit can be specified as mass, volume, concentration or other parameters.	Prior to granting a permit to release material, the impact of the expected release on the environment must be investigated. Particular attention should be paid to cases where waste is landfilled or disposed of in other ways that could result in indirect emissions. The study should at least include an examination of the hydrogeological condition of the area concerned, possible soil and bedrock cleaning properties and the risk of contamination and changes in groundwater status due to the discharge, and shall verify the release of substances into the groundwater as a suitable solution
Italy	Legislative Decree. 152/2006 Part III National framework legislation, enforcing various EU directives included the Dir. 2000/60/CE and other directives (later modified by the Dir 2008/105/CE) as the dir. 84/156/CEE on Hg discharge, plus other relevant directives on wastewater treatment and discharge limits (Dir. 88/347/CEE, dir. 80/68/CEE). A number of subsequent decrees modified the framework legislation in order to include the European Directives	National	ND	Ensures the sustainable use of water resources and establishes the methods for water monitoring and use, as well as the procedures for obtaining permissions to discharge wastewater into sewers, groundwater and surface water.

	Legislative Decree 30/2009 Implementation of Directive 2006/118/EC aiming to prevent groundwater pollution and deterioration	National	ND	Measures to prevent or limit discharges of pollutants into groundwater
	Legislative Decree 172/2015 Implementation of Directive 2013/39/EU amending Directives 2000/60/EC.	National	ND	The Legislative decree regards priority substances in the field of water policy and identifying a list of pollutants and their environmental quality standards
	Ministerial Decree 6 July 2016 Transposition of Commission Directive 2014/80/EU amending Annex II to Directive 2006/118/EC.	National	ND	Ministerial Decree on the protection of groundwater against pollution and deterioration
	Legislative Decree 69/2013 converted with amendments by Law 98/2013	National	ND	Amendments to Legislative Decree 152/2006 (art. 104) related to the reinjection of groundwater into the same aquifer after treatment for the purposes of remediation"
	The guidelines from MISE-MATTM (2016)	National	-monitoring techniques -suitable locations for monitoring stations -frequency of controls	Defines instructions related to monitoring procedures
Turkey	Regulation on Urban Wastewater Treatment (08/01/2006 - 26047)	National	ND	Protecting environment by regulating collection, disposal and treatment of urban wastewater and protection against detrimental effects of wastewater disposal by some industries

	Regulation on Water Pollution Control (31/12/2004 - 25687)[10]	National	ND	Protecting surface waters and groundwater sources, facilitating use of water sources in a sustainable manner.
	Regulation on Protection of Underground Waters Against Pollution and Degradation (7/04/2012 – 28257)	National	ND	Preserving current conditions of groundwaters, preventing pollution and improving quality of groundwaters
	Regulation on Monitoring of Surface and Ground Water (11/02/2014 – 28910)	National	ND	Defines the basic surface/ground water quality parameters and monitoring implementations.

Table 13: Regulations concerning impacts on the underground fluid

[10] Lastly amended by the OG 25/3/2012 – 28244

Reservoir physical and chemical modifications

Physical and chemical modifications of the reservoir due to standard operations may include:

- **Pressure decline** after fluid withdrawal for geothermal production.
- **Thermal changes**, when production exceeds the natural long-term rate of recharge
- Change of **chemical composition** due to the different composition of the injected and resident fluids

Reservoir physical and chemical modifications, like the impacts on underground fluids, are mostly covered in the water framework directive and associated water quality legislation in particular for groundwater (for relevant EU legislation see Table 6). National level legislation is summarized in Table 14. Particularly the possible change of chemical composition of the underground fluid appears generally well regulated as part of national legislation on ground water quality and thoroughly addressed in permitting processes. For pressure decline and thermal changes, apparently regulated is largely absent.

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	VLAREM II Section 2.4 Environmental quality norms and target values for groundwater. Annex 2.4.1 Environmental quality norms and quantity criteria for groundwater	Regional (Flanders) Environmental quality norms for groundwater. Partial implementation of directive 2006/118/EG (section 2.4) target values and thresholds for the quality of groundwater (annex 2.4.1)	In the EIA for the Balmatt site 'changes in the chemical and biological quality of the groundwater during exploitation' are simulated in a numerical model.	The EIA for the Balmatt site describes monitoring as follows: "After realisation of the first well, a test will be performed to obtain more information on the chemical and hydrological characteristics of the relevant aquifer. Additionally,

				thermal and pressure changes in the subsurface will be evaluated.”
	Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit, art. 11	Regional, water pumping	ND	General principle to preserve the quality of the underground water when pumping.
	The Ministerial Order n°ESO/1/2007 destined to all operators of drinkable water pumping and all operators of non-drinkable water pumping,	Regional, during water pumping	ND	Includes the he methods to collect qualitative and quantitative data on water quality, including chemical components and data transfer procedure to the Administration.
	Water code, part II, integrated management of natural water cycle, appendix IV concerning surveillance of chemical state of underground water.	Regional, general rules	ND	Includes the quantitative and chemical monitoring procedures
France	Concession or exploitation permit of each site	Local, Chemical modification during exploitation	ND	- Establishes the scope of production - The operator must report and find solutions if occurrence of chemical modification or justify non responsibility of exploitation technical fault
Hungary	Determined case-by-case, as declared by the Governmental Decree 147/2010 (IV.29.) Note: Regulation whether reinjection is obligatory or not has been	Reinjection	ND	dischargeFor successful reinjection in porous media: effective porosity should be more than 20%, permeability more than 500 mD, and filtered thickness should be above 20

	changing several times over the last decades, currently it is not compulsory			m to avoid sudden starts and stops of the flow. Mitigation recommendation: - building an accumulation tank so as to provide an injection flow rate which is as constant as possible. - shut-down at least once a year so that their static water level can be measured and the surface piping system can be cleaned - in case the pressure in the exploitation system starts increasing, the following interventions are necessary: filter cleaning with a compressor, hourly water sampling and visual inspections; sterilization of the piping system; backwashing of the reinjection well with hourly water sampling; bottom-hole cleaning of the well, incorporating packer tests; layer cleaning involving acid treatment.
Iceland	Utilization licenses and OS-2016-R01-01 on reaction to earthquake hazard due to the release of spent fluid into the ground via boreholes. Here the 797/1999 Regulation on the prevention of groundwater pollution	National: reduce the risk of physical damage, damage to structures and earthquake discomfort during fluid discharge in boreholes	Utilization license stipulates maximum drawdown in licenses for intense production.	To monitor and stick within the utilization limits

	could also fit for chemical modifications.			
Italy	Part Three, Section II (Environmental regulations - Soil protection and the fight against desertification, protection of waters against pollution and management of water resources) of D. Lgs. 152/2006 implement Directive 2000/60/CE	National, Discharge of water and Chemical modification	ND	- regulations aim to ensure the sustainable use of water resources and establishes the methods for water monitoring and use, as well as the procedures for obtaining permission to discharge into sewers, groundwater and surface waste. - monitors and classifies the water quality, and makes regional authorities responsible for planning and monitoring of surface and underground water quality and quantity. - Containment and treatment of meteoric water falling in the perimeter of the drilling pad to avoid potential damage to the environment.
	The guidelines from MISE-MATTM (2016).	National, Chemical modification	ND	monitoring techniques, suitable locations for monitoring stations, and the frequency of controls.
Turkey	Regulation on Urban Wastewater Treatment (08/01/2006 - 26047)	National	ND	Protecting environment by regulating collection, disposal and treatment of urban wastewater and protection against detrimental effects of wastewater disposal by some industries

	Regulation on Water Pollution Control (31/12/2004 - 25687)[11]	National	ND	Protecting surface waters and groundwater sources, facilitating use of water sources in a sustainable manner.
	Regulation on Protection of Underground Waters Against Pollution and Degradation (7/04/2012 – 28257)	.National, Chemical modification	ND	Preserving current conditions of groundwaters, preventing pollution and improving quality of groundwaters
	Regulation on Monitoring of Surface and Ground Water (11/02/2014 – 28910)	National	ND	Defines the basic surface/ground water quality parameters and monitoring implementations.

Table 14: Regulations on reservoir physical and chemical modifications

[11] Lastly amended by the OG 25/3/2012 – 28244

Effects of surface operations: energy and water consumption and emissions to the environment

Effects of surface operations as an industrial project:

- **Energy consumption** resulting from the use of engines and **emissions** in the atmosphere caused by the fuels that they burn (so excluding emissions from degassing). Relevant engines include vehicular traffic for everyday business, machines used during the plant operation or decommissioning phases, drilling machinery and machinery for road making.
- **Water consumption** in the drilling phase (e.g. produce the mud and cement) and during the plant operation (e.g. to minimize scaling and for cooling).

Effects of surface operation has a variety of dimensions: energy consumption, water consumption, air emissions. Relevant EU regulations consequently include the water framework directive and air quality directives (for relevant EU legislation see Table 5). National level legislation is summarized in Table 15. The case of France shows how these impacts are regulated via, amongst others, reporting procedures and the voluntary compliance to ISO standards.

Country	Regulation	Scope of application	Threshold	Mitigation & monitoring
Belgium	Emissions to the environment are covered in VLAREM II	Regional (Flanders)	ND	ND

France	Drilling authorization of each site	Local Energy and water consumption	ND	Daily report sent to the local mining authority on the monitoring on energy, ground/tape water and chemicals consumption, as well as volume of brine produced, during the drilling and well testing phase.
	Exploitation authorization of each site	Local Energy and water consumption	ND	Record by operators of, energy and resources consumption during plant operation. Monthly reporting and monitoring sent out to the local deconcentrated authorities on electrical, water and chemical treatment consumption and volume of brine produced.
	Ministerial decree of the exploration License of each site	Local Energy and water consumption	ND	Above mentioned reporting completed by a monthly report on energy extracted from the geothermal reservoir.

	ISO standard 9001 - Quality Management, 14001 - Environmental Management and 50001 - Energy Management Systems - Voluntary procedure		ND	Can be completed with a detailed monitoring following ISO standards. Operators applying these ISO standards must monitor energy and resource consumption according to a dedicated management system approved by an external party and check every year.
	French environmental code, local health regulations and drilling or exploitation authorization.	National Emissions to the environment	ND	Domestic sewage must be collected, treated and released according to the local health regulations. Treated by a sceptic tank and then by an oil separator.
	Drilling or exploitation authorization for Industrial and storm sewage	Local Emissions to the environment	- Total Suspended Solid: 35 mg/l - Temperature: 30°C - Chemical oxygen demand: 125 mg - Total hydrocarbons: 10 mg/l	Must conform with the thresholds. Sewages mostly treated first by a sand filter and then by an oil separator.

	Directive 97/68/EC of 16 December 1997, Directive of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery; Commission Directive 2012/46/EU of 6 December 2012 amending Directive 97/68/EC	National Emissions to air resulting from fuel burned in engines during surface operations	ND	Drilling rig diesel engine emissions are regulated by two EU Directives
Hungary	emissions: Governmental Decree 306/2010 (XII.23.) on the protection of air 4/2011 (I. 14.) Ministerial Decree on the threshold values of air quality and point-source emissions LVIII Act of 1995 on water	National Air emissions (rig engine emissions) Water consumption during drilling	ND	ND
Iceland	Electricity act 65/2003	National: The purpose of this Act is to promote efficient electricity systems and thus strengthen the economy and population in the country. 1. Establish conditions for competition in the generation and trading of electricity, with the restrictions necessary for the security of electricity supply and other public interests.	ND	ND

		2. Promote the efficiency and efficiency of electricity transmission and distribution. 3. Ensure the safety of the electricity system and the interests of consumers. [4. Promote the utilization of renewable energy sources. 5. Take environmental considerations into account.		
Italy	ND	ND	ND	ND
Turkey	ND	ND	ND	ND

Table 15: Regulations on the effects of surface operations: energy and water consumption and emissions to the environment

Waste production from surface operations

Waste production of surface operations:

- **Waste** resulting from drilling wells and the construction, operation and maintenance of the plant (e.g. building materials, chemical waste, excavated earth), including urban waste from the personnel

Waste production from surface operation is covered by the EU directives on waste regulation (for relevant EU legislation see Table 5). National level legislation is summarized in Table 16. The issue of waste appears generally well regulated as part of national waste legislation, including waste classifications, and special rules for dealing with hazardous waste.

Country	Regulation	Scope of application	Threshold	Mitigation & monitoring
Belgium	VLAREMA	Regional (Flanders)	ND	ND
France	Order n° 2010-1579 of 17 December 2010 on diverse matters of law adaptation of the EU law in the domain of waste Directive 2008/98/EC of 19 November 2008 on waste, repealing other Directives Drilling and exploitation authorization of each site	National	ND	Classification of waste according to EU directives. Operator's responsibility for its own waste, from production to final treatment. Operators must ensure that a subcontractor has the ability to do the job. CERFA 12571 form used by operators for dangerous wastes to be followed by

				operators from the transport to the final treatment. Quantity of wastes on site must be as low as possible according to authorizations
	Code de l'environnement, livre V, titre IV relatif à l'élimination des déchets et à la récupération des matériaux	National	ND	ND
	ISO certification 14001 - voluntary		ND	Waste management system that can be followed by operators.
Hungary	Act CLXXXV of 2012 on wastes	National	ND	Provisions on waste management should be followed by companies, operators
Iceland	737/2013 regulation on waste management 1014/2016 Regulation on the list of waste and assessment of hazardous waste properties.	National	ND	ND
Italy	D. Lgs. 152/06 Part IV Framework legislation on waste management – (does not include yet EU directive 2018/851)	National	ND	Part four of this decree regulates the management of waste and the remediation of polluted sites also in implementation of EU directives on waste.
	Law 12/2019	National	ND	Defines waste management traceability system

	Decree of the President of the Republic DPR 120/2017	National Regulates the management of rocks and excavated earth produced during the wells drilling and the construction of facilities.	Waste is classified: -according to their origin in urban or industrial waste; -according to the specific activity that originated it and/or their composition in “non-hazardous” - treated similarly to urban waste - or “hazardous”.	Hazardous and non-hazardous waste cannot be mixed. The waste must be disposed of or recovered at least quarterly, regardless of the volume, or whenever a volume: - 20 m3 of non-hazardous waste - 10 m3 of hazardous waste, is reached. In any case, waste cannot be stored for more than one year. Excavated earth and rocks from drilling and construction can be reused or disposed depending on the content of polluting substances and the feasibility of their effective reuse.
Turkey	Regulation on Landfilling of Waste (26.03.2010 – 27533)	National	ND	Regulating landfilling and disposal of wastes in order to minimize negative impacts of leakage and landfill gas on soil, air, groundwater and surface water.
	Regulation on using domestic and urban wastewater sludge in soil (03/08/2010 - 27661)	National	ND	Determining the principles of taking necessary precautions in the use of sewage sludge in soil in accordance with sustainable development targets.
	Regulation on Waste Management (02/05/2015 – 29314)	National	ND	Management of wastes from cradle to grave in order to protect environment and human health. Natural resources preservation by Reduction, Re-use, Recycling and Recovery of wastes

	Regulation on the Control of Packaging Waste (24/08/2011 - 28035)	National	ND	Producing environmentally friendly packaging. Prevention of packaging waste generation and disposal directly to receiving bodies.

Table 16: Regulations on waste production from surface operations

Leaks due to surface installations and operations

Leaks due to surface installations and operations:

- Accidental escape of highly mineralized or polluted fluids from waste storage tanks or from a hole or crack in the surface pipe circuits

Leaks due to surface installations and operations is a specific topic treated in the Pressure Directive 2014/68/EU (see Table 6). National level legislation is summarized in Table 16. Although in the scope of this report, limited national level legislation has been retrieved, the French case shows how the Pressure Directive is transposed to the national level, involving a variety of mitigation and monitoring measures, such as design requirements, risk assessment, and inspection protocols.

Country	Regulation	Scope of application	Threshold	Mitigation & monitoring
Belgium	ND	ND	ND	ND
France	Decree n° 2015-799 of 1st July 2015 transposing the European Pressure Directive 2014/68/EU	National	ND	Design requirements for pressure vessel, including pipes and equipment. Categorization of the risk according to fluid, pressure, volume or diameter and vessel type. Each category of risk is then associated to inspection program necessary for the design, manufacturing and testing to be in conformity with the directive.

				For certain categories of risk, a notified body is required for approval of the different inspections and welding qualifications. This European Pressure Directive is a first step in the management of surface installation leakage
	Ministerial decree of the 20th of November 2017	National		Operation of these equipment Operators must establish and maintain an inspection plan for all pressure equipment on site
	Exploitation authorization of each site	Local		Example: Inspection plan must be approved by a certified body and transmitted to the mining authority Operators ensure that contamination of surface water is not possible in case of leakage of geothermal brine or process fluid. operators must: • Provide to the mining authority all geothermal pipes inspection and a risk analysis on geothermal pipes; • Report all fluid leakages to the mining authority in the annual operation report;

				• Report the annual corrosion rate.
Hungary	1995 LIII Act on the environment	National	ND	ND
Iceland	ND	ND	ND	ND
Italy	ND	ND	ND	ND
Turkey	ND	ND	ND	ND

Table 17: Regulations concerning leaks due to surface installations and operations

Liquid/solid effusion and waste

Effusion of liquid / solid waste:

- Liquid and solid materials at surface, resulting from drilling wells and the construction, operation and maintenance of the plant, which may accidentally effuse in the environment
- Main focus is liquids, e.g. drilling mud, drilling fluid additives, diesel and lubricant, cleaning fluid waste and geothermal brine

Regarding liquid and solid surface waste from underground sources, the regulations principally concern water protection, e.g. Article 11 of the European Directive 2000/60/EC (Water Framework Directive), waste management, and soil protection (for relevant EU legislation see Table 6). National level legislation is summarized in Table 17. Reported national level legislation includes various mitigating measures to prevent blow-out, also from the rationale of the safety of workers. Also measures are in place to avoid the effusion of liquid chemical fluids and geothermal brine.

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	VLAREM II Code of good practice for drilling	Regional (Flanders)	ND	Installing suitable sealing systems, e.g. blow out preventers
France	Drilling and exploitation authorization, of each site	Local Requirements for the retention of waste water	Retention capacity - 100% of the capacity of the largest tank; - 50% of the capacity of the associated tanks.	Example: Liquid chemical fluid effusion - Operators must provide a soil analysis in case of leakage in the environment of geothermal or process fluid - All chemicals, such as mud chemicals, inhibitors, lubricants…

				that could generate contamination of soil or surface water must be stored in proper condition on retention capacity. - In case of accidental effusion out of retention system: the operator must immediately take all possible measures to interrupt or at least limit it. - Waste water management to prevent contamination through design of drilling platform and geothermal plant.
	Exploitation authorization of each site	Local Requirements for avoiding geothermal brine effusion	ND	Example: Geothermal brine effusion: Equipment of geothermal pipes of sensors In case of rupture of a pipe, this sensor must immediately interrupt geothermal flow by • stopping the production pump; • closing the valves closest to the place of rupture; • closing wellhead valves. This sensor must be checked periodically.

	Drilling authorization of each site and article 41 of the ministerial decree 80-331 about General Regulation on Extractive Industries.	Local Requirements for avoiding blow-out and mitigate it's impacts		Example: Blowout: Equipment of wellheads during all the drilling operations with a suitable sealing system to prevent a gas or geothermal water eruption. A flexible pipe also has to be connected on the wellhead to neutralise, if necessary, the eruption by injection of brine. Salt must be available on the site in sufficient quantity. A fictitious gas lift exercise must be planned at the beginning of the drilling in order to check the functioning of the sealing systems and the procedures. A test of the sealing system is then asked every 3 weeks.
Hungary	Act CLXXXV of 2012 on wastes	National	ND	ND
Iceland	530/2014 Regulation on power options in the protection and energy efficiency plan	National. The following data and information shall always be accompanied by requests for consideration of the activation of high-temperature areas: 1) goals for the sustainability of the power plant, ie the interaction of utilization and service life,	ND	ND

		2) plans for re-injection and disposal of waste water and possible impacts on groundwater bodies; 3) plans to acquire and dispose of cooling water, 4) targets for the release of hydrogen sulphide and its local maximum concentration in the atmosphere.		
Italy	ND	ND	ND	ND
Turkey	Regulation on Soil Pollution Control and Pointed Source Polluted Areas (08/06/2010 - 27065)	National	ND	Defines the basic soil quality parameters and pollution parameters based on different sectors.
	Regulation on the Protection of Employees against the Hazard of Explosive Environments (30/05/2013 - 28633)	ND	ND	Example blow-out: Regulating the procedures and principles regarding the precautions to be taken in order to protect the employees from the hazards of explosive environments that may occur in the workplace in terms of health and safety.

Table 18: Regulation on the effusion of liquid / solid waste

Radioactivity

Possible radioactivity:

- Radioactive contamination at surface, in specific areas, due to the transfer of naturally radioactive fluids and rocks from the subsurface (i.e. through radionuclides such as Uranium 238, Thorium 232, Potassium 40 and the products of their decay chain).

Thresholds for dynamic and cumulative radioactive doses are established at the European level by a European Directive that applies to any planned, existing or emergency exposure situation which involves a risk from exposure to ionizing radiation (for relevant EU legislation see Table 6). National level legislation is summarized in Table 19. In most countries, general regulatory frameworks for radioactivity are in place in the context of public health. Partly depending on the relevance of the issue of radioactivity in countries and regions, deep geothermal projects must comply to specific regulations concerning e.g. the characterization and treatment of possible radioactive waste.

Country	Regulation	Scope	Threshold	Mitigation & monitoring
Belgium	Royal Order of 20-04-2001 concerning general regulations for the protection of the population, employees and the environment to the hazards of ionizing radiation (ARBIS)	National	ND	- Risk of NORM to be evaluated in the EIA - NORM -file issued to the Federal Agency of Nuclear Control (FANC) - Regular consultation with FANC during project duration - Risk detected needs to be reported to the FANC - Mitigation measures reported in a file on how to: - treat the pumped water

				- Prevent scaling in surface installations - Procedures to prevent employees from direct contact with radiations
	Order of the Flemish government of 28-10-2019	Regional (Flanders)	ND	- Includes the liability of the operator, but monitoring is not obligatory to the operator. - Yearly reporting required
France	Mining code and Decree 2006-649	National	ND	Radioactive wastes must be characterized and have to be collected and treated by the ANDRA (French national agency for nuclear waste management). Protection against ionizing rays
	Drilling and exploitation authorization of each site	Local - relevant for Alsace but not the Paris area where radioactivity is not an issue	ND	Radiological characterization of solid, liquid, gaseous effluent. Operating company at least performs measurements to check the level of radiation on the facilities and to monitor its evolution
	Mining Code	National	ND	Protection of the environment, and populations Defines mandatory measures for the operating company. Radiological characterization of solid, liquid, gaseous effluent
	Public health regulation, Labor code	National	Maximal cumulative dose that can be received by workers and population over 12	Measures and procedures that must be followed by employers for the protection of workers. The level of radiation has to be measured and the potential exposure of workers should be calculated.

			consecutive months is 1 mSv (one milli-Sievert).	
Hungary	CXVI Act of 1996 on Nuclear Energy Governmental decree 487/2015 (XII.30) on the protection against radiation and related licensing, reporting and monitoring obligations	National	Not relevant for geothermal	ND
Iceland	1290/2015 Regulation on the maximum levels of radiation for workers and the public due to radiation-using activities.	This Regulation applies to radiation exposure limits caused by workers and the general public activities using ionizing radiation as well as the maximum radiation available to the public for because of the use of non-ionizing radiation. The regulation also applies to classification employees and work areas, as well as the supervision of employees' radiation load.	Variable between groups, size and the maximum of annual radiation	The National Radiation Protection Authority supervises the radiation load of personnel in accordance with paragraph 3. Paragraph 1 Article 5 fix no. 44/2002 on Radiation Protection.
Italy	ND	ND	ND	ND
Turkey	ND	ND	ND	ND

Table 19: Regulation on radioactivity

CONCLUSION AND OUTLOOK

The mapping of environmental regulations in this deliverable provides a wealth of information on environmental regulations in the six GEOENVI countries in the context of current EU regulatory frameworks. It illustrates that for many of the environmental impacts related to deep geothermal associated for example with water quality, and noise, energy regulations are well established. Other impacts like visual impacts on the landscape, or pressure and temperature decline at the production site, are less well regulated, although generally included in EIAs required for obtaining permits.

The main value of the current mapping exercise is as a starting point for more detailed analysis. Country descriptions provide rather factual descriptions of the current 'formal' status of regulations and actors in the respective countries. This is intended as a first preparatory step towards a more in-depth understanding of regulatory process – including informal aspects and practices. For a select set of environmental impacts the following issues need to be addressed in more detail:

- To what extent are national legislations consistent with EU legislation? On what aspects would harmonization be required?
- How strict are regulations? Are they sufficient for mitigating the impact at hand, or possibly too strictly applied? What are main regulatory gaps? Are these problematic?
- How are legislations applied in practice? Which informal aspects come into play?
- Which elements of national regulations and guidelines can be considered best practices that can be shared among countries?

To address those questions, the views of policy-makers, practitioners and other stakeholders is needed. In follow-up work, stakeholder engaged will therefore play an important role in working towards formulation and adoption of recommendations on environmental regulations.

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APPENDIX 1: BELGIUM

This appendix provides the institutional framework, policies and the state of the regulatory affairs on the Environmental Impacts studied in the framework of GEOENVI regarding deep geothermal in Belgium, more specifically in the two main regions, Flanders and Wallonia.

General overview

General data on deep geothermal in Belgium.

The contribution of geothermal energy in the Belgian energy mix is still low. However, for deep geothermal development in Flanders, important initiatives were taken by the Flemish government in previous years: a new decree on deep subsurface including deep geothermal projects and the implementation of an insurance system to cover geological risks. In Wallonia the legal framework should evolve in the same direction in 2019, with a new decree for underground resources management and a similar insurance system. Two deep geothermal projects are in production or under development: (1) 3 heating networks using existing unique deep wells in the Hainaut basin and (2) a pilot project in the Campine Basin consisting of 3 deep wells (the Balmatt project) to deliver heat to company buildings in 2019 (Lagrou et al. 2019).

Institutional context

Belgium is a Federal State composed of a Federal Authority, and two types of 'federated entities' called Communities and Regions. There are three Regions (Flanders, Wallonia, and Brussels), and three Communities (Flemish, French and German-speaking). The Regions are competent in 'territorial' matters such as spatial planning, some segments of the energy policy, environment, agriculture, industry and transport. The Communities have competences in 'personal' matters such as health, education, culture or sports. The Federal Authority holds competences in the areas of foreign affairs, national defense, justice, finance, social security, important parts of national health and domestic affairs.

The democratic process of the country is thus shared between the Federal Authority, the Communities and the Regions, which are equal from a legal point of view, but who independently exercise their authority within their domains[12]. Consequently, the energy policy is spread between the Federal Authority and the federated entities. For example, the nuclear power is a competence of the Federal Authority, whereas the promotion of renewable energy is a competence of the Regions[13]. The domain of Environment and Deep Subsurface resides under the regional competences. Therefore, deep geothermal falls mainly in the realm of Regional competences, and deep geothermal projects are regulated by separated actors and bodies of law. In that sense, to give the overview of Belgian deep geothermal policy and environmental regulations, this case study will focus on the two regions where deep geothermal can be further enabled: Flanders and Wallonia. Brussels does not fall within the scope of this study as the Region focuses on the development of shallow geothermal.

[12] Accelerating and Rescaling Transitions to Sustainability project, D2.3 p. 113
[13] Art 6, §1, VII, f de la loi spéciale de réformes institutionnelles du 8/08/1980.

Policies and policy vision

Flanders

In 2015, the Flemish government approved a policy framework for deep geothermal heat and amended the Energy Decree so that the heat plants and networks related to deep geothermal could receive support. Meanwhile, two projects were approved through project call on green heat, Vito's Balmatt project in Mol, and Janssen Pharmaceutica project in Beerse.

In 2017, the Heat Plan 2020 (Vlaams parlement, 2017) was published by the Flemish government inscribing deep geothermal at heart of its energy policy and giving further precisions on the green heat targets by 2020. It foresees an addition of 57 GWh of deep geothermal energy capacity between 2019 and 2020, increasing from 107 to 164 GWh, based on the two research projects. The Heat plan proposes to examine how the energy efficiency and primary energy savings can be optimized for deep geothermal. It also foresees the reduction of the threshold for power production to receive support and a stimulation of investments. It establishes a guarantee system that secures return on investment for project developers when the economic return is less than expected due to geological risks and heat source. An accounting method legal framework will be developed in order to include deep geothermal energy in Energy Performance of Buildings (EPB) regulation.

The recent National Energy and Climate Plan (NECP 2021-2030) provides further insights and adaptations needed throughout 2020. It foresees 95GWh in 2020 but targets 594 GWh of green heat production through deep geothermal by the end of 2030. The plan recalls that the future supply of green heat via deep geothermal remains uncertain, but nevertheless keeps the target as it is as the government will evaluate, as agreed in the governmental agreement, the two ongoing deep geothermal research projects[14].

Geraamde trajecten per technologie – groene warmteproductie

Productie (GWh)	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Zon	193	200	208	216	224	233	243	253	264	276	287
Warmtepompen	610	655	707	765	831	905	997	1.098	1.208	1.327	1.455
Geothermie	95	145	195	245	295	345	394	444	494	544	594
Biomassa huishoudens	3.850	3.660	3.470	3.280	3.090	2.900	2.710	2.520	2.330	2.140	1.950
Biomassa andere	3.841	3.997	4.153	4.309	4.465	4.621	4.777	4.933	5.089	5.245	5.401
Totaal	**8.589**	**8.657**	**8.732**	**8.815**	**8.905**	**9.004**	**9.122**	**9.249**	**9.386**	**9.532**	**9.688**

Table A1.1: 2030 Targets for renewable heat in Flanders (Solar panels, heat pumps, deep geothermal, and biomass). Source: Belgian National Energy and Climate Plan (2021-3030), pp. 78-80.

Wallonia

Deep geothermal in Wallonia is rather at its infancy stage. In 2010, the Department of Energy and Sustainable building of the Walloon Public Service (SPW- DGO4) commanded two studies on deep geothermal, as the need to develop new non-pollutant and renewable energy sources for the future was felt (Ecorem & al., 2011; Petitclerc & Vanbrabant 2011). Those studies emerged in the context of the Directive 2009/28/CE on the promotion of renewable energies. The first study aimed at creating a platform to map the potential of deep geothermal in

[14] Belgian National Energy and Climate Plan (2021-3030), pp. 78-80. Retrieved from: https://www.plannationalenergieclimat.be/admin/storage/nekp/pnec-plan-definitif.pdf

Wallonia, through the geological study of the sub-soil (Ecorem & al., 2011, p. 12). The report concludes that the potential for geothermal implementation can cover a large portion of the Walloon territory. The second report was commanded at the same period to determine the obstacles of the deep geothermal development in Wallonia, and to propose solutions to tackle those. Those two reports aimed to serve as a basis to draft further propositions of law. In 2011, the government adopted a strategy that focused on the development of deep geothermal energy through two pilot projects. One low temperature deep geothermal project was granted to IDEA in the Hainaut bassin, destined to feed the heating needs of the urban area. The other one was a middle temperature deep geothermal project granted to Earth Solution to assess the potential to produce electricity[15]. The willingness to develop geothermal energy and deep geothermal was reiterated in 2014, in the Regional Air Energy and Climate Plan, the 'Plan Air-Energie-Climat' (2016-2022), underlying its insufficient development. In the actions to be taken, the plan foresees to "conceive a legal framework, and when appropriate, an adequate financial framework for the development of deep geothermal in Wallonia, on the basis of objective evaluation, support the development of exploitation projects" (AWAC, 2016, p.24).

Further policy developments were made since 2014. In Wallonia, a regional geothermal guarantee system for sub-soil exploration draft project decree was adopted on 24 January 2019 by the Walloon government in first reading. The draft decree has two parts: 1) The regional geothermal guarantee scheme: the region covers the risk, based on the opinion of a technical committee and compensates if necessary. According to this scheme, the cost is linked to the first drilling of the doublet and covers almost all the investment before knowing if the resource reaches the expected level. 2) The creation of a "geothermal guarantee" section in the Kyoto Fund, with a specific budget (to be provided during budget programming) used for compensation. To benefit from the compensation, investors contribute to the fund by paying a premium proportional to the cost of a project.

The legal framework of the deep geothermal energy is currently evolving with the foreseen adoption of a new decree for the underground resources management. This framework will consider deep geothermal energy as a strategic resource, such as fossil fuels and metallic substances. By this way, the achievement of this new policy should stimulate industrial investment in deep geothermal energy in Wallonia.

The National Energy and Climate plan (2021-2030) foresees for Wallonia the introduction of geothermal energy in the 2030 renewable energy mix and assesses the investment needs, see the table below. For deep geothermal, to reach the objective to have a production of 233 GWh by 2030, an investment of 438 million euros between 2020 and 2030 is estimated, with an over-cost of 97 million euros (p.149).

[15] https://www.renouvelle.be/fr/actualite-belgique/avec-geothermia-la-geothermie-wallonne-refait-surface

	Objectif 2030 p/r 2020 (GWh)	Coût d'investissement 2030 p/r 2020 (M€)	Surcoût (M€)
Solaire thermique	84	160	91
Pompes à chaleur	1.507	1.140	282
Géothermie profonde	233	438	97
Biomasse	2.285	1.003	657
Cogénération (biomasse)	1.225	441	95

Table A1.2: Investment needs in Wallonia by 2030 in comparison to 2020, with an over-cost per technology.

Environmental regulation mapping

Definition, Classification, and Resource Ownership

In Flanders, the Flemish Decree of 8 May 2009 defines geothermal heat as subsurface heat generated by natural means or by heat storage, with the deep subsoil being defined as at least deeper than 500 meters. In Wallonia, no definition of deep geothermal can be found until today. Regarding the resource ownership, deep geothermal projects in Flanders are classified as projects with a regional character (Order of the Flemish Government 13-02-2015). In Wallonia, the Territorial Development Code in Wallonia, defines geothermal energy as an “act and work related to the energy production exclusively destined to the collectivity” (Art. D.IV.22, CoDT).

Licensing and Authorization

Flanders - Environmental permitting

Applicable legislation

The Flemish Decree of 8 May 2009 concerning the deep subsurface regulates the licensing for deep,i.e. deeper than 500 m, geothermal projects. It follows a two steps procedure with exploration and production licenses. Since the end of 2018 also an insurance system for geological risk is in place.

Applicants for an exploration licence need to submit a complete application covering the necessary data and information, including a thorough geological study. The application is opened for fair competition during 90 days. The permit grants the exclusive right for a well-defined 3D-volume at depth to explore in detail how much heat might be produced and what are the boundary conditions. During the validity period of the exploration permit (default 5 years), a production plan is set up based on detailed reservoir data. This production plan needs to be validated before a production permit can be granted. Apart from the exploration / production permit, also an environmental permit is needed.

To stimulate the investments in geothermal energy, which is characterized by high initial investment cost and high uncertainty risk, the Flemish government provides an insurance system for geological risk (VPO 2019). This covers the exploration risk, i.e. the short-term geological (uncertainty) risk. Long-term performance, technical fails and geohazards are not covered in the insurance. The maximum amount per project that can be covered is 18,7 MEUR. Only 85% of the eligible costs can be insured. A participation fee of 7% on this amount must be paid. The applicant has to validate the expected thermal power (P90 value) by a set method and perform adequate testing to prove the outcome.

In Flanders geothermal projects targeting reservoirs deeper than 500m below mean sea level (local reference is TAW) are on the list of projects with a regional character, as published in the Order of the Flemish government of 13-02-2015. Therefore an environmental permit is to be provided by the Flemish government or the Flemish minister of Environment.

The environmental permitting system is rather new in Flanders. Since 27-11-2015, when the Order of the Flemish government was published implementing the new Decree of Environmental Permitting of 25-04-2014, it combines both the old system of building permits as well as environmental permits, focusing on classified activities with a possible impact on the environment.

The list of classified activities is documented as Appendix 1 to the Order of the Flemish government of 01-06-1995 handling the general and sectoral stipulations concerning environmental hygiene (VLAREM II). In this list the following activities, related to a geothermal project, are found:

- 53: pumping of ground water
- 54: replenishment of ground water
- 55.2: drilling of wells deeper than 500m

The section 53 on pumping of groundwater contains several subtypes of pumping for different purposes including the reinjection of treated or non-treated water. It has to be mentioned however that up-to-date no specific activity describes the pumping of ground water in hydrothermal systems, in which the cooled down water is reinjected in the same layer. Therefore the section 54 is often also applicable to a geothermal project. It is expected that a subtype in section 53 with respect to hydrothermal systems is added in the near future.

Specifically for the drilling of ground water wells Appendix 5.53.1 to the aforementioned Order stipulates the requirements.

Timings and procedures

The application for an environmental permit has to be done using an online desk (www.omgevingsloketvlaanderen.be) . It is advised to have several preparatory meetings with the authorities before submitting the application. As indicated in the time table below a normal procedure takes some 150 days before a final decision is made. Filing a project EIA at the same time as the environmental permit application has the risk of

some further delays. Therefore, it is advised to first perform the EIA-discussions with the EIA office including the possibility for a motivated request for exemption of a full EIA study.

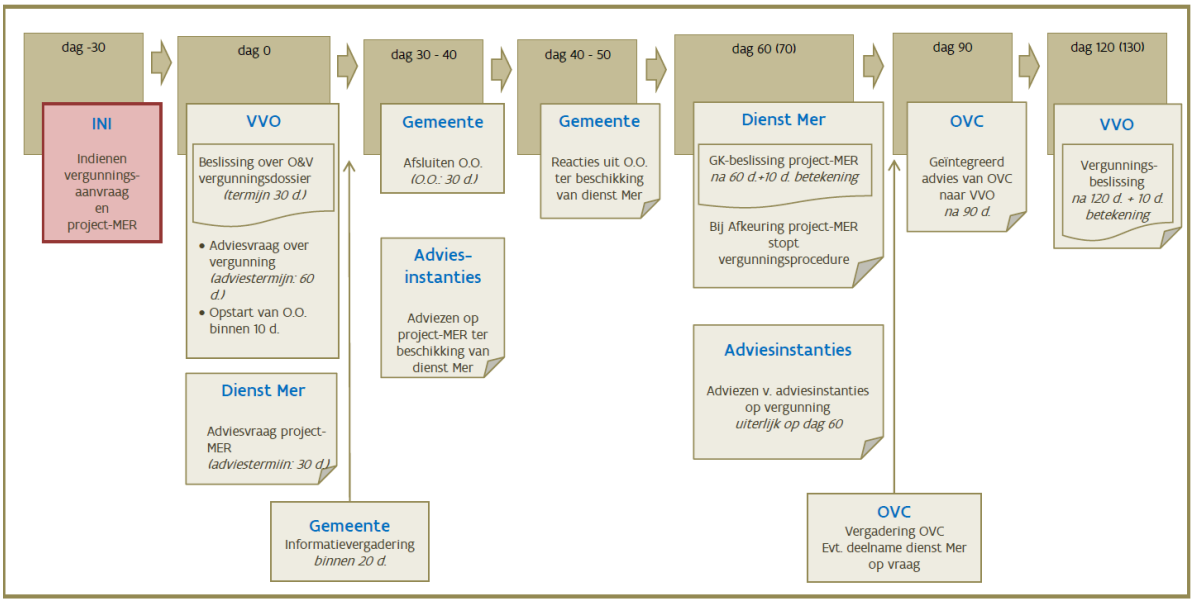

Figure A1.1: Steps and timings for acquiring an environmental permit

Environmental Impact Assessment (EIA)

According to the Order of the Flemish government of 10-12-2004 determining the category of projects subject to Environmental Impact Assessment, geothermal wells deeper than 500m, should perform an Environmental Impact Assessment for the whole project or provide a motivated request for an exemption to this assessment. In practice, the permit granting authority is not the same as the EIA office. This means that before submitting an application for an environmental permit, several meetings with EIA office are required to discuss the degree of detail for the site specific EIA. As indicated in the timing table below, for a provisional acceptance of the project by the EIA office, a duration of >100 days is to be foreseen.

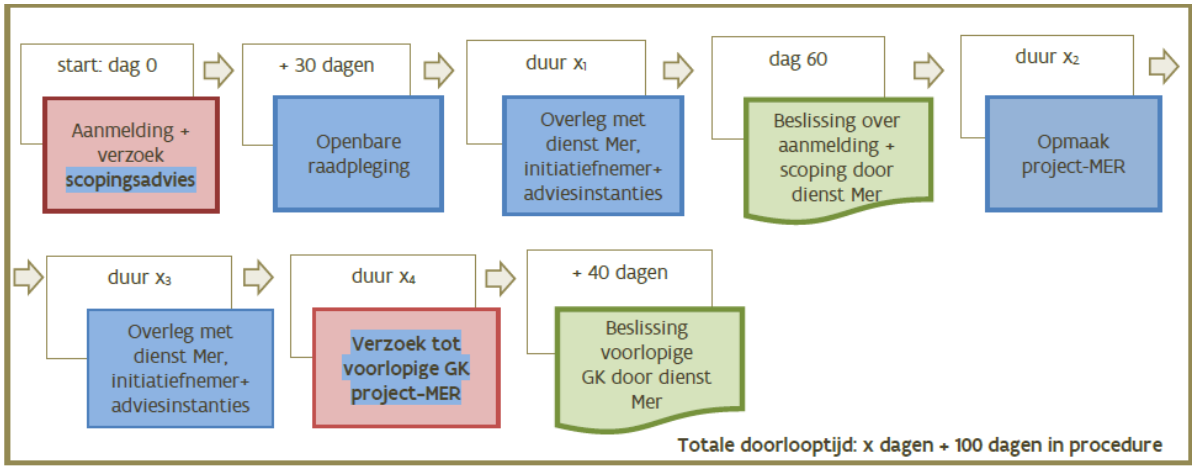

Figure A1.2: Steps to be taken to get approval by EIA office

Flanders - Exploration/Exploitation permitting

Applicable legislation

In order to organize the different valorizations of the (deep) subsurface a Decree was made in 209 (28-05-2009). This Decree includes since 25-03-2016 a chapter on the exploration and exploitation of geothermal. The Order of the Flemish government of 28-10-2016 stipulates the further details on the application procedures for an exploration license/permit.

Governmental (Exploration) Insurance Scheme

Since 12-01-2018 the Decree on the Deep Subsurface includes a chapter on the exploration insurance of geothermal wells (doublets). The Order of the Flemish government of 23-05-2018 stipulates the further details on the application procedures for an exploration insurance.

Timing and procedures

Applications for an exploration license have to be submitted to the same department of Environment as with the environmental permitting, although it is evaluated by a different unit of the department. Furthermore, for this type of application no online desk is present yet. For the application for the insurance, specific documents can be downloaded from the following website: https://www.lne.be/waarborgregeling-voor-aardwarmteprojecten

For an exploration permitting, timings depend on the submission of competing offers. Standard timings are 90 days for the confirmation of completeness of the submission and 120 extra days for the decision on the granting of the permit by the Flemish ministers of Environment and Energy. In case competing offers are submitted, timings will shift accordingly.

Wallonia - Environmental permitting

Applicable Legislation

The legislations supporting the environmental permitting of deep geothermal are fragmented in Wallonia. The legal framework is spread across the Environmental code, the Water Code, the Urbanism code (CoDT), and the Housing code (Ecorem & al., 2011). In that sense, deep geothermal installations and activities in Wallonia are not subject to their own body of law yet and deep geothermal is not mentioned per se in the law, but can be mapped because of its several features.

Though ongoing legislative processes attempt to harmonize the regulations, the starting point as a project developer to know if he/she can build and operate a DG plant is the Decree of 11 March 1999 related to the environmental permit which organizes the conditions under which installations and activities, called ‘establishments’, that can have an impact on the environment and human health can be exploited. Those ‘establishments’ are classified into three classes. Class 1 and 2 ‘establishments’ are subject to an environmental permit, whereas class 3 only needs a declaration to be submitted to the municipality. Class 1 and 2 environmental permits can have a validity of maximum

20 years (Article 1, Decree of 11March 1999 related to the environmental permit)[16]. When the installation requires the construction of an installation or the transformation of landscape for example, an urbanism permit needs to be demanded (Article 1, 11-003-1999). This joint demand of an environmental and an urbanism permit is called the unique permit, because of its mixed features and is explained in the Chapter XI of the Decree of 11 March 1999 related to the environmental permit (Article 1, 11-03-1999). A deep geothermal plant requires a unique permit.

The permit is complemented by general conditions, sectorial and integral conditions fixed by the Government. The general conditions are defined in the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation of establishments included in the decree of 11 March 1999 related to the environmental permit and, apply to all installations and activities. The sectorial conditions apply to an economic, territorial sector or in a sector where a specific risk can appear (Article 5, §1, 11-03-1999). Sectorial conditions are mandatory and have a regulatory value. The general and sectorial conditions are determined based on the best available technical knowledge (Art 8, 11-03-1999)

The Order of the Walloon Government of 4 July 2002 defines the list of projects subject to impact assessment and of classified installations and activities. Since deep geothermal is not mentioned per se, it can nevertheless be mapped through its activities. Ecorem & al. (2011) did the exercise and concluded that the main activities concerning the implementation of a deep geothermal project which are drilling, reservoir stimulation, water extraction, water injection, rejection of water to the surface, electricity and heat production, as well as electricity and heat distribution are included in the list of activities(Ecorem & al., 2011). Only the stimulation of the geothermal field is not part to the list of installations and activities (Ecorem & al., 2011). The section on EIA below explains further which activities are subject to EIA.

Timings and procedures

The demand for a unique permit must be introduced to the local authority called the municipality college. The public servants designated by the Government within the administration of land management, urbanism and the administration of environment (DGO3 and DGO4), are also jointly competent to receive the demands for the unique permit. Only the technical officer and the delegated officer at the department of permits and authorization of the Public Service of Wallonia (DGO3), are competent to deliver the permit for geothermal projects because of their exclusive collective end (Art. D.IV.22, CoDT). The decision to grant the permit is taken within 90 days for a class 2 'establishment', and 150 for a class 1 'establishment'. Those officers also explain to the exploiters the conditions of exploitations to be followed[17].

The Order of the Walloon government of 4 July 2002 related to the procedures and diverse execution measures of the decree of 11 March 1999 related to the environmental permit organizes the different procedures for the diverse activities of deep geothermal. The forms related to the demand for a unique permit can be found on the Regional portal (https://www.wallonie.be/demarches/20520-demander-un-permis-d-environnement-ou-un-permis-unique-

[16] https://www.wallonie.be/demarches/20520-demander-un-permis-d-environnement-ou-un-permis-unique-pour-un-etablissement-de-classe-1-ou-2
[17] http://etat.environnement.wallonie.be/contents/indicatorsheets/TRANSV%202.html

pour-un-etablissement-de-classe-1-ou-2), as well as the appendixes related to specific activities related to deep geothermal such as e.g.:

- The drilling permit procedure can be found in Appendix XVIII, “drilling and sounding operations”
- The water extraction procedure in Appendix III “document related to water extraction”.
- The water injection procedure permit is the Appendix VIII “document related to artificial recharge of groundwater”.

Applicable since September 2019, a new portal is offered to submit permit requests: http://permis-environnement.spw.wallonie.be/fr

Environmental Impact Assessment (EIA)

All permit applicants must submit an Environmental Impact Assessment attached to the permit demand. The Order of the Walloon Government of 4 July 2002 defining the list of projects subject to impact assessment and of classified installations and activities, classify the diverse installations or activities, into three classes. Class 1 installations and activities requires an environmental impact assessment. Class 2 installations and activities requires an environmental notice and it is left to the appreciation of the authorities to demand an environmental impact assessment. Class 3 activities are not subject to environmental assessment.

EIAs determine the short, medium, and long term indirect or direct effects of the project on the fauna and flora, soil, water, air, climate and landscape, material goods and cultural heritage and the interactions between them (Title II, Art 8, §1, 11-03-1999), but also all the necessary data related to the project and solutions brought to minimize environmental impact (Art. 9, §3, 11-03-1999). The government accredits specific moral or physical person allowed to perform the EIA, based on criteria that he defines (Title II, Art 11, 11-03-1999). The EIA can receive the advice of the Walloon Environment Council for Sustainable development, which became the Environment pole in 2017, a branch included in the Economic, Social and Environmental Council of Wallonia[18].

Each activity related to deep geothermal projects is classified, but not all of them are subject to mandatory environmental impact assessment. Only water injection to groundwater is subject to a thorough Environmental impact assessment (Ecorem & al., 2011). In the fragmented legislation, overall a deep geothermal project with water injection is classified as a class 1 establishment whereas a deep geothermal project without water injection is classified in class 2 establishment. (Ecorem & al., 2011)

Conclusion

In conclusion, in order to exploit an establishment, an environmental permitting and an urbanism permit are required, under the name of the unique permit in Wallonia. However, the current legislative landscape concerning deep geothermal is currently evolving and a decree on the sub-soil is being validated by the Walloon government.

[18] Decree related to the rationalization of the consultative function: http://www.etaamb.be/fr/decret-du-16-fevrier-2017_n2017201834.html ; https://www.cesewallonie.be/

Moreover, a pre-project of decree establishing the Code of sub-soil resource management is under discussion as well, including deep geothermal[19].

Wallonia - Exploration/Exploitation permitting

As mentioned above, the current legislative framework is currently under discussion at the parliament level. Nevertheless, the foreseen subsoil decree will define the exclusive exploitation and exploration permit.

Sustainability and Environmental Impacts

Surface disturbance (including vibration, noise, visual, landscape, dust and smell)

Noise

Noise in Flanders is regulated in VLAREM II. Section 2.2.1 on environmental quality norms and target values for noise in open air provides the general guidelines. The related Annex 2.2.1 provides the general thresholds values according to 10 land use categories in three time period (day/evening/night).[20]

The specifications and additional requirements are provided in section 4.5 concerning high risk activities. Concerning the monitoring and mitigation measures of those high risk activities, the law foresees the use of the best available techniques to minimize noise pollution, the monitoring of background noise, and the further specifications for thresholds for specific noise (e.g. noise specific to the project or activity.), and the 'fluctuating sound' (e.g. occasional peaks) (Section 4.5 and annex 4.5.4 and 4.5.5).

In Wallonia, the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit provides the conditions under which an operator must operate regarding noise in its article 18 to 37 [21]. It includes thresholds limit values that can be summarized into three time categories: day (7-19h), transition (6-7h & 19-22h), and night (22h-6h), and four different zones.

Monitoring measures are foreseen in Section 3 of the Order.

Emission zones in which measures are performed		Limit values (dBA)		
		Day 7h-19h	Transition 6h-7h 19h-22h	Night 22h-6h
I	All zones, when the measure point is located at less than 500m of the extraction zone, dependence of extraction, industrial economic activity, specific economic activity, or to less than 200 m of the mixed economic zone of activity, in which the establishment is located.	55	50	45

[19] Parlement Wallon (2019). Projet de décret instituant le code de la gestion des ressources du sous-sol. Retrieved from : http://nautilus.parlement-wallon.be/Archives/2018_2019/DECRET/1335_1.pdf
[20] https://navigator.emis.vito.be/mijn-navigator?woId=10069. Accessed January 2020.
[21] http://environnement.wallonie.be/legis/pe/pe004.htm

	Under peculiar conditions	60	55	50
II	Habitat zone, zone of municipal interest, rural habitat	50	45	40
	Under special conditions	55	50	45
III	Agricultural zones, forestry, green space, natural, parks	50	45	40
	Under peculiar conditions	55	50	45
IV	Leisure zones, public service zones, community equipment.	55	50	45
	Under peculiar conditions	60	55	50

Table A1.3: General limit values of noise level applicable to a classified installation Source: Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit.

Vibration

Vibration is not foreseen by VLAREM II regulation in Flanders. Vibration in Wallonia is monitored by the Royal Observatory of Belgium (global seismicity), hence no regulation applies but well the DIN 4150 norm.

Smell

In Flanders, policy concerning smell is limited to a vision document[22] and some sectoral codes of good practice. These are not applicable to geothermal projects, as they are not considered to cause odorous emissions.

In Wallonia, the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit provides the conditions under which an operator must operate concerning smell in its article 12 and 14 [23]. It includes the formula called the smell level, and the smell emissions are measured according to the smell debit. The operator must take the necessary measures, if he cannot capture those emissions, to limit the production of emissions and their transmission to their environment (art. 17).

Dust

Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit provides the general precautionary principle to avoid inflammable dust.

Visual and landscape

In Flanders, the Decree general provisions for environmental policy (DABM) stipulates that the environmental impact assessment should comprise a description of the environmental impacts of a project/activity on land, spatial use, cultural heritage and landscape. With respect to monitoring, Annex IIbis further specifies that the environmental assessment should describe the planned measures to prevent, limit or – if possible – compensate the detrimental

[22] https://www.lne.be/beleid-geurhinder
[23] http://environnement.wallonie.be/legis/pe/pe004.htm

effects. Also, possible monitoring measures should be described. In the EIA for the geothermal project in Mol, a specific chapter is dedicated to the analysis of the impact on landscape and cultural heritage.
More generally, in Flanders as in Wallonia, activities that have an impact on landscape are subject to an urban or building permit.

Degassing

In Flanders, air quality and pollution is regulated through VLAREM II. Section 2.5 on environmental quality norms and target values for air, and the assessment and management of air quality provides the general guidelines and the section 4.4 on management of air pollution target values and measuring methods for high risk activities provides the additional requirement for high risk activities.

The general threshold values can be found in annex 2.5.1 for 6 gases (e.g. cadmium, chlorine)[24]. The general threshold values given in Annex 2.5.3 for sulphur dioxide, nitrogen dioxide and nitrogen oxides, particulate matter (PM10 and PM2.5), lead, benzene, carbon monoxide and ozone[25]. General threshold values given in Annex 2.5.8 for arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons[26]. Concerning the mitigation and monitoring measures, Section 4.4 foresees the management of air pollution through installation requirements (Best Available Techniques), emission threshold values and measuring strategy. Annex 4.4.2, 4.4.3 and 4.4.4 include respectively the emission threshold values, depending on the material and quantity of emissions of the source/installation, the measuring of frequency e.g. depending on the quantity and the material: every month, every 3 months, every 6 months., and the control measuring scheme.

In the Walloon Region, the rules related to degassing can be linked to air quality and emission regulations. No specificities in the case of deep geothermal energy are foreseen. Order of the Walloon government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit foresees the framework related to air emissions in its article 12 to 17 [27]. It defines the notions related to air, formulas and the units of measurement. The operator must take the necessary measures, if he cannot capture those emissions, to limit the production of emissions and their transmission to their environment (art. 17).

The Order of the Walloon Government of 15 July 2010 related to the evaluation and the management of ambient air quality transposes the Directive 2008/50/CE and the Directive 2004/107/CE concerning arsenic, cadmium, mercury le nickel and polycyclic aromatic hydrocarbons in ambient air, and the directive 2015/1480 [28]. It organizes the evaluation and management of ambient air quality, defines and sets targets to preserve air quality concerning specific pollutants (such as sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particles, lead benzene and carbon monoxide, ozone, arsenic, cadmium, nickel, benzo(a)pyrene, mercury, polycyclic aromatic hydrocarbons),

[24] https://navigator.emis.vito.be/mijn-navigator?woId=10078
[25] https://navigator.emis.vito.be/mijn-navigator?woId=38570
[26] https://navigator.emis.vito.be/mijn-navigator?woId=19906
[27] http://environnement.wallonie.be/legis/pe/pe004.htm
[28] http://environnement.wallonie.be/legis/air/air063.htm

based on methods and criterium common to EU MS. The decree identifies the competent authorities to evaluate and manage the air quality. The Agence Wallonne de l'Air et du Climat is the responsible body to, among other missions, evaluate ambient air quality, defines action programs, and data exploitation, performs the inventories on emissions, evaluate the forecastable evolutions (art.32). The Institut scientifique de service publique, makes sure that the network of ambient quality measurement work properly, controls the quality according to EU norms, and participates to the reporting on the Inter-regional cell on Environment (CELINE-IRCEL- http://www.irceline.be/fr) This order is a reference for the development of Deep geothermal as it includes the respective bodies measuring air quality and sets the framework for limit values to be respected.

Ground surface deformation

In Flanders this is regulated through the Decree on Deep Subsurface (9 may 2008) and the Decision on Deep Subsurface (15 July 2011). The decree stipulates that the impact of the planned activity (i.e. deep geothermal) on the environment, the surface and the subsurface is taken into account as a permitting criterium, as well as the means that will be used to limit those impacts to a minimum. Furthermore, the owner of an exploitation permit can be held financially responsible for the damages that are deemed to have been the result of ground movement caused by the exploitation.

With respect to monitoring and mitigation, the decree foresees an obligation for the permit holder to take all necessary measures to prevent his activities from causing environmental damage and damages because of ground surface deformation

The decision provides further details: the request for a permit must comprise a description of the environmental impact of the planned activity of the surface and subsurface, together with a description of the means that will be used to limit those impacts to a minimum. A special section is dedicated to measuring surface deformation (i.e. how to measure movement, how to set up a measuring plan.)

There is no regulation in Wallonia, specific conditions are added in the environmental permit. The monitoring of ground surface deformation is performed by interferometry.

Seismicity

In Flanders, seismicity (effect on short term) and ground surface deformation (effect on longer term) are both considered as 'ground movement' and therefore are covered by the same regulations as described above. The risk on seismic events, related to the (exploration and) exploitation of a geothermal project and related liability of the operator, is captured in the Order of the Flemish government of 28-10-2019. However, the monitoring of seismicity is not obligatory to the operator. Although risks on seismicity related to geothermal operation is one of the effects that can be investigated as part of the Environmental Impact Assessment as a step in acquiring the environmental permit, the same risk evaluation is not required for acquiring an exploration permit. It can be requested as an extra condition in the latter permit to perform seismic monitoring. Furthermore, a yearly reporting is required in which an overview of seismic events related to the geothermal operations, is given.

In Wallonia, seismicity is not regulated, but well monitored by the Royal Observatory of Belgium for global seismicity. Nevertheless, a legislative framework should see the light in the coming legislature (2019-2024), as a project of decree related to the management of underground is in current discussion. It will include the management of seismological risks prior to drilling, including a public information campaign and the installation of a seismological surveillance network which will operate throughout the testing and operation of DG plant. The sharing of seismological and geodesic data will be in partnership with the Royal Observatory of Belgium[29].

Interconnection of aquifers and disturbance of non-targeted aquifers

In Flanders, interconnecting aquifers and the disturbance of non-targeted aquifers is explicitly mentioned in Section 5.55 of VLAREM II, holding sector-specific environmental conditions for high-risk activities such as drilling: Every pollution of groundwater will be prevented, during constructions as well as during exploitation. Further, it is prohibited to connect different aquifers.

Also in Annex 5.53 the code of good practice for drilling some measures are described to prevent 'contamination' of ground water. For example, the water used for drilling should be clean, and in case additives are necessary, biodegradables are recommended.

In Wallonia, the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit foresees the preservation of water quality linked to underground water pumping in its article 11. The water pumping must preserve underground water quality. The total quantity of water pumped cannot exceed the annual average volume of the natural stream. The security of the people and goods cannot be affected by the modification of the underground water.

The Order of the Walloon Government of 13 September 2012 determining the sectorial conditions related to drilling and equipment of wells destined to future underground water pumping, and modifying the Order of the Walloon Government of July 4 2002 related to the procedure and the diverse measures of execution of the decree of 11 March 1999 related to environmental permit, foresees that the wells must be located in such a way that they prevent all risks of alteration of water quality by migration of surface or underground pollutants, or by mix of different underground waters in its article 3, 2°. During drilling operations, the drilling must be performed such as it does not alter the neighbor geological structure and the qualitative state of underground water (art. 4). When several underground waters are separated by a poor permeable frontier, one well cannot in any way allow the pumping of water from several underground waters (art. 7)[30].

Reservoir physical and chemical modifications

In Flanders, reservoir physical and chemical modification is regulated through VLAREM II. Section 2.4 sets environmental quality norms and target values for groundwater, linked to annex 2.4.1 that sets thresholds for groundwater quality and quantity criteria. In the EIA for the Balmatt site 'changes in the chemical and biological

[29] https://www.parlement-wallonie.be/pwpages?p=interp-questions-voir&type=28&iddoc=91291
[30] http://environnement.wallonie.be/legis/pe/pesect063.html

quality of the groundwater during exploitation' are simulated in a numerical model. Monitoring will be carried out through a test after realization of the first well. This test will result in more information on the chemical and hydrological characteristics of the relevant aquifer. Additionally, thermal and pressure changes in the subsurface will be evaluated.

In Wallonia, the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit foresees the preservation of water quality related to underground water pumping in its article 11. The water pumping must preserve underground water quality. The total quantity of water pumped cannot exceed the annual average volume of the natural stream. The security of the people and goods cannot be affected by the modification of the underground water.
The Ministerial Order n°ESO/1/2007 destined to all operators of drinkable water pumping and all operators of non-drinkable water pumping, located in the Walloon Region (MB. 17.01.2018) foresees the monitoring of environmental data on underground waters in application of the European Directive on water (2000/60/CE)[31]. The order describes the methods to collect qualitative and quantitative data on water quality, including chemical components. It organizes the monitoring and the transmission of environmental data to the Administration Direction of underground waters in the defined time frame. This monitoring is completed by the Water code part II, integrated management of natural water cycle, appendix IV, concerning surveillance of chemical state of underground water, and completes the environmental permit[32]

Effects of surface operations: energy and water consumption and emissions to the environment
In Fanders, the emissions to the environment are covered in VLAREM II. At this stage of our research, no data is available for Wallonia.

Waste production from surface operations
In flanders, the waste production from surface operation can be found VLAREMA for Flanders. In Wallonia safety measures related to waste production are captured in the Order of the Walloon government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit.

Leaks due to surface installations and operations
Concerning leaks due to suface installation and operation, we do not have data for Flanders and Wallonia at this stage of our research.

Liquid/solid effusion and waste
In Flanders, the VLAREMII establishes the code of good practice for drilling. As mitigation and monitoring measures technical solutions are proposed such as installing suitable sealing systems, e.g. blow out preventers. In Wallonia, at this stage of our research we do not dispose of data.

Radioactivity

[31] http://environnement.wallonie.be/legis/eau/eanitr006.htm
[32] http://environnement.wallonie.be/legis/Codeenvironnement/codeeaucoordonneR.html

The presence of Naturally Occurring Radioactive Material (NORM) in the reservoir fluid to be pumped to the surface, is one of the risks to be evaluated in the Environmental Impact Assessment. However, in the environmental permitting procedure the national authority charged with the evaluation of radioactivity and the risks on the environment (FANC), is not commonly involved.

Nevertheless, recently geothermal projects are added to the list of professional activities in which there is a risk of natural radiation. Such activities are obliged to have a NORM-file issued to the Federal Agency of Nuclear Control (FANC) in accordance with the Royal Order of 20-04-2001 concerning general regulations for the protection of the population, employees and the environment to the hazards of ionizing radiation (ARBIS). This regulation is not regional and is therefore not directly linked to the first two (regional) permitting systems.

The following procedures apply. As soon as the risk on pumping reservoir fluids containing naturally occurring radioactive material is defined, he Federal Agency for Nuclear Control (FANC) has to be contacted. Next, a file has to be prepared containing ways to handle/treat the pumped water from a production test phase, ways to prevent scaling in surface installations and procedures to prevent employees to be in direct contact with radiation. Regular consultation and reporting to FANC is required during the whole project duration in Flanders. At this stage of the research, we do not dispose of data to draw conclusions on how NORM is regulated and mitigated in Wallonia.

Conclusion

This first exercise on policy and environmental regulation mapping in the framework of GEOENVI provides a good starting point to develop a more detailed analysis in the course of the project. At this stage we can already conclude that the Belgian landscape for the development of deep geothermal is marked by its institutional complexity. It evolves at the regional level, in the Flemish Region and in the Walloon Region, competent for the promotion of renewable energy, deep surface and environment, thus is subject to respective regional policies, and bodies of law. Deep geothermal is emerging in Belgium, as its contribution in the energy mix is currently low and mainly in the demonstration phase. Though representing a minor contribution in the overall RES mix in the National Energy and Climate plan (2021-2030) the target for the end of 2020 in Flanders is to reach 164 GWh and an investment plan to reach 233GWh by 2030 for Wallonia has been accessed. In that sense, though it remains at an early development stage and subject to uncertainty, deep geothermal is considered a viable and serious option from the policy makers in both Regions.

When looking at the overarching legal framework for deep geothermal energy, it has developed quite well since 2009 in Flanders, including the procedures for the exploration and production licenses, the environmental permitting, and provides legal certainty for developers thanks to the implementation of a guarantee system securing return on investment since 2018. In Wallonia, the current legal framework is quite complex and spread across different bodies of law, but the main activities related to deep geothermal development and operations are regulated, through the environmental permit, and through general and sectorial conditions of exploitations. Moreover, a political willingness to develop a harmonized legal framework for deep geothermal is witnessed thanks to the project decree for underground resources management currently being validated by the Walloon Government, including the exploration and production licensing framework, and the project decree establishing a guarantee system for sub-soil exploration for project developers.

A deep geothermal project is defined as at least deeper than 500 meters in Flanders, whereas of today no definition is found for Wallonia. Concerning the classification/ownership, deep geothermal projects are respectively projects “with a regional character” in Flanders, and “destined to the collectivity” in Wallonia. In that sense those projects are destined to public ends in both Regions.

The environmental permitting processes are quite similar in both Regions, consisting of an urban or building permit and an environmental permit listing the classified activities with a possible impact on the environment. Both Regions use an online desk to apply for permits. Interestingly, in Flanders the list of projects subject to an Environmental Impact Assessment includes geothermal wells deeper than 500m as an activity and an EIA is needed for the whole project, whereas in Wallonia, a systematic mapping of deep geothermal activities is needed to understand which activities are subject to an environmental impact assessment or not given their classification.

To have the environmental permit granted, the approval by the EIA and the public permit authority are needed in Flanders whereas the technical officer and the delegated officers at the department of permit and authorization of the Public service are the person delivering the permit in Wallonia.

Concerning the environmental impacts studied in the framework of the GEOENVI research project we can conclude for:

- Noise. It is similarly regulated in both Regions, with three time periods per day, and according to different land use categories with thresholds per time frame. It can be found in the VLAREM II and in the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit in Wallonia.
- Vibration. It is neither regulated by the environmental legislation in Flanders, nor in Wallonia, but well mitigated by the Royal Observatory of Belgium.
- Smell. The mitigation of smell follows a code of good practices in Flanders which not applicable to DG since they do not emit odor and is generally regulated in Wallonia according to the general sectorial conditions of exploitations.
- Visual and landscape. They are mitigated in both Region through the environmental permit’s conditions and EIA.
- Degassing is regulated by the general air quality and emissions legislation in both Region. It is covered in the environmental code VLAREM II under air quality and pollution, and in the Order of the Walloon Government of 15 July 2010 related to the evaluation and the management of ambient air quality. They both includes the thresholds according to the type of molecule.
- Ground surface deformation is regulated by the Decree on Deep surface of 9 May 2008 in Flanders and in the Decision on Deep surface, providing the necessary requirements to mitigate, whereas it is not yet regulated in Wallonia.
- Seismicity is regulated in the Order of the Flemish government of 28-10-2019 and argues that it is in the liability of the operator though not mandatory to the operator. In Wallonia it is not regulated but well monitored by the Royal Observatory of Belgium.
- Interconnection of aquifers and disturbance of non-targeted aquifers are captured respectively in VLAREM II in Flanders and in the Order of the Walloon Government of 4 July 2002 fixing the general conditions of

exploitation related to the environmental permit in Wallonia. Both legislation advocate for the preservation of underground water.

- Reservoir physical and chemical modification is regulated in VLAREM II for Flanders, and in the Order of the Walloon Government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit and the Ministerial Order n°ESO/1/2007 in Wallonia. Both VLAREM II and the Ministerial Order set thresholds to preserve the water quality.
- Radioactivity is regulated at the federal level in the Royal order of 20-04-2001 and is monitored through the Federal Agency for Nuclear Control (FANC). The FANC is consulted at the Flemish level., but no conclusion can be drawn concerning the Walloon Region.
- Waste production from surface operation is regulated in VLAREM II for Flanders and in the Order of the Walloon government of 4 July 2002 fixing the general conditions of exploitation related to the environmental permit provides general safety measures.

VLAREM II includes elements concerning effects of surface operation and liquid/solid effusion and waste for Flanders. Nevertheless no such data is available at this stage of our research for Wallonia. The same comment stands for both Regions concerning leaks due to surface installation and operations. Those elements will be subject to further attention in the next stages of this research project, and a more in-depth analysis of the overall environmental impacts will be developed in the later stages of the project.

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APPENDIX 2: FRANCE

General overview[33]

General data on deep geothermal in France.

In France, renewable energy sources (RES) represent approximately 10% of the primary energy consumption in 2017 and deep geothermal energy 1,3 % of the primary production of the renewable energies (SDES, Chiffres clés des énergies renouvelables, Editions 2019[34]). Table A2.1 presents the actual features of geothermal energy in France.

Deep Geother-mal for Heating & Cooling capacity (GeoDH)	Number of GeoDH systems installed	Geothermal electricity capacity	Number of Geothermal power plants
586 MWth	74	17 MWe	2

*Table A2.1: Actual geothermal capacity in France (From EGEC **Country fiches on geothermal energy market potential to 2030[35])***

The power plants are located in Soultz-sous-Forêt (1,5 MWe) in Alsace and Bouillante (15MWe) in Guadeloupe.

The French geothermal district heating industry is well established and experienced, as many of the 74 existing installations have been installed since the 80s. Developments have increased again for the past 15 years, benefiting from the new ADEME Heat Fund. Geothermal installations supply heating and sanitary hot water to around 300,000 households. In the Paris area, around 200,000 households are currently supplied by geothermal heat, which amounts to more than 240 000 tons of CO_2 avoided annually. Despite this installed capacity in GeoDH, France has been slowly caught up by other European countries, and on current trends, is likely to be passed by Germany in the role of first EU country in terms of installed geothermal district heating capacity.

In the Upper Rhine Graben (Alsace), building on the experience of Soultz-sous-Forêts power plant and Rittershoffen heat plant, several Enhanced Geothermal System (EGS) projects are under development to produce electricity and heat. 18 Research Permits - in France mainland and overseas territories - were valid in 2018 (see the map here[36]). In Vendenheim and Illkirch (Alsace), drilling operations are ongoing.

[33] Some of the information presented here are extracted from the EGEC Country fiches on geothermal energy market potential to 2030
[34] https://www.statistiques.developpement-durable.gouv.fr/sites/default/files/2019-05/datalab-53-chiffres-cles-des-energies-renouvelables-edition-2019-mai2019.pdf
[35] https://www.egec.org/policy-documents/necps-country-fiches-on-geothermal-energy-market-potential-to-2030/
[36] https://umap.openstreetmap.fr/fr/map/perimetres-des-titres-miniers-de-gites-geothermiqu_158171#6/45.737/2.725

For deep geothermal, the French market in 2018 represented 120 million € expenditures and 650 jobs (Boissavy and al., 2019). The market is notably carried by the large French energy groups and their subsidiaries, but several smaller companies and SMEs play also a key role in geothermal development. In addition, the role of specific financial institutions, most notably the "Caisse des Dépôts et Consignations", should be underlined as they highly contributed to allow some recent developments in innovative technologies.

Institutional context

The French Republic is a unitary semi-presidential representative democratic republic. The executive branch itself has two leaders: the President of the Republic and the Government, led by the Prime Minister. The legislative branch, namely The French Parliament is a bicameral system comprising a National Assembly (*Assemblée nationale*) and a Senate.

France implements "**territorial decentralization**", which corresponds to *the transfer* of power, responsibilities and resources to a given territorial authority in a defined domain. The citizens of those territories elect their representatives. This is different from "deconcentration", which corresponds to *the delegation* of policies and powers by the central Government to a centrally nominated representative in the territories: the Prefect (*Préfet*), who is responsible before the central Government.

Currently, the French decentralized administration is divided in four different layers of administrative and political structures:

- The *Commune*, with around 36 000 municipalities.
- The *Inter-communale* structures where several *Communes* can unite to implement special fields of public policies.
- The *Département,* with 101 in mainland France and overseas.
- The 18 Regions.

Decentralization means that more and more policies have a national framework and their design and implementation are done at a decentralized level. For instance, the guidelines regarding the energy transition are framed in the energy transition for a green growth act[37] (2015) that gives the legal framework. The Government is in charge of the global planning tools (taking into account international and Europeans guidelines), especially the multiannual energy planning. The territorial authorities, in charge of major investments (economics, infrastructures, buildings, transportations…) and through their policies (urban and spatial planning policies, environmental policies…) have a lot of impact. They – especially at the regional level - are in charge of some planning tools dedicated to Climate – Air – Energy issues (SRADDET, PPA, PCAET, schéma directeur des réseaux de chaleur ou de froid), or other impactful sectoral themes (SCoT, PLUi, PLH, PDU).

In France, deep geothermal energy is a centralized activity: the central and deconcentrated bodies hold most of the competences, as they are responsible for the safety of the activity, regarding population and environment. They specify the conditions in which a geothermal project can be deployed from the exploration

[37]https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000031044385&dateTexte=&categorieLien=id

phase to the long-term exploitation, often at a local scale (deconcentrated bodies: prefecture and its technical bodies the DREAL/DRIEE/DEAL) to take into account the territorial specificities. The territorial authorities (communes, regions) play a key role showing (or not) the will to welcome/develop deep geothermal energy on their territories and often participating in its funding. They are also the main contact with the local population, regarding the overall "acceptability" of geothermal projects.

Policies and policy visions

Legislative framework

The Energy transition for green growth Act (see above), provides the main legal framework of the French renewable energy policy[38], setting the objective of 23% RES by 2020 and 32% by 2030. In 2030 renewable energy sources should account for 40% of total electricity generation and 38% of final heat consumption.

The Multiannual Energy Planning (*Programmation Pluriannuelle de l'Energie* or PPE), to be adopted by the end of 2019[39], sets out specific targets for geothermal development:

- for electricity production, the previous Multiannual energy planning, adopted in 2016 indicated a target of the 8 MW of installed capacity in 2018. In the project under study, the target for 2023 is 24 MW.
- for heating consumption based on deep geothermal, a projection of 2,9 TWh for 2023 is planned.

Support schemes

France has implemented several supportive instruments to promote geothermal energy development and utilization for electricity and heating and to stimulate R&D in the geothermal sector.

Electricity

Geothermal energy mostly benefits from the new feed-in tariff introduced in 2016, consisting of a premium paid to the producers of RES electricity to top up the revenues they receive from the sale of their electricity directly on the market.

However, this operational support to geothermal electricity production (246€/MW) is not secured for the coming years. It should be re-discussed at governmental level in the frame of the new "Multiannual Energy Planning" by the end of 2019[40].

Heating and cooling

[38] France submitted a project of "National Energy and Climate Plan" to the European Commission based on the temporary versions of the multiannual energy plan and the low carbon national strategy.
[39] A new Multiannual Energy Planning proposal was submitted to consultation on 20 January 2020.
[40] The feed-in tariff for geothermal electricity disappeared from the MEP proposal presented on 20 January 2020.

Geothermal heating and cooling are mostly financed by the Heat Fund through regional aids or specific call for projects, while the SAF environment fund insures investors against the geological risks related to high-investments projects.

Innovation

Regarding Innovation and R&D, the "Investments of the Future"[41] program is the main financial instrument for the geothermal sector, increasing the potential of exploitable geothermal resources for heat and electricity.

Guarantee

SAF Environment Fund is a guarantee fund for geothermal district heating which covers geological risk and protects operators against the risk faced during the exploration and exploitation phases of geothermal projects.

It could be completed with another Guarantee in 2019: Geodeep SAS (dedicated to "EGS" and "volcanic" projects). After the green light given by the European Commission, the fund, based on public/private financing, will aim at mitigating the geological risk of geothermal resource deployment in France. It will compensate the operator in case of exploration drillings failures. This Fund lowers the financial risk to secure developers and industrials in their investment commitment.

Environmental regulation mapping

Definition, Classification, and Resource Ownership[42]

In France, geothermal resources are classified as "mines" and their exploration and exploitation are regulated by the Mining Code[43]. Their definition in the Mining Code is as follow: "resources enclosed within the earth from which energy can be extracted through the production of hot waters and vapors".

There is a distinction between geothermal resources and water resources. On a first approximation, it is related to the use of the resources whatever their temperature:

- If the purpose is energy extraction, it is considered as geothermal resources whatever the temperature;

[41] https://www.caissedesdepots.fr/en/investments-future
[42] Some of the information presented here are extracted from Traineau and al., 2018 and updated.
[43] And its application decree : Décret n°78-498 du 28 mars 1978 relatif aux titres de recherches et d'exploitation de géothermie
Décret n°2006-648 du 2 juin 2006 relatif aux titres miniers et aux titres de stockage souterrain.
Décret n°2006-649 du 2 juin 2006 relatif aux travaux miniers, aux travaux de stockage souterrain et à la police des mines et des stockages souterrains.
Décret n°80-331 du 07/05/1980 modifié portant règlement général des industries extractives
Décret n°2016-1303 du 4 octobre 2016 relatif aux travaux de recherches par forage et d'exploitation par puits de substances minières.

- If not, it is considered as water resources. In this category, there is a distinction between drinking water and water used for balneology purposes.

Originally, the Mining Code considered two types of geothermal resources according to the fluid temperature measured at the wellhead during the production tests of the exploration boreholes:

- *High temperature resources* if the temperature is higher than 150°C;
- *Low temperature resources* if the temperature is equal or lower than 150°C.

In 2015, the Mining Code was updated in order to take into account a third type of geothermal resource: it corresponds to shallow aquifers above 200m, with temperature less than 25°C, which are used for heating or cooling by using heat pumps under 500 kW. These geothermal resources are called "Ressources géothermales de minime importance" or "***Geothermal resources of minimal importance***".

In 2019[44], the 150°C criterion between low and high temperature resource has been changed, especially because:

- it was established when it corresponded to the minimum temperature needed to produce electricity which is no longer the case with recent ORC plants;
- to facilitate geothermal development in areas where the subsoil is less known and its temperature less predictable.

This criterion has been partly replaced by 20 MW "primary power" ("puissance primaire") for the exploitation phase. For the exploration phase, the petitioner chooses the most adequate mining title (see below).

The right of use of a geothermal resource is granted by the State or its deconcentrated bodies (prefecture).

Licensing and Authorization[45]

Under the mining code

As mentioned previously**, geothermal resources are regulated by the mining legislation (Mining Code)**. Its key objectives are:

- To optimize the exploitation of the sub-surface mining resources which are the property of the State. For geothermal resources, their sustainability has to be preserved;
- To minimize the risks and pollutions associated with exploration and exploitation of mining resources both for the natural and human environment;

[44] Ordonnance n ° 2019-784 du 24 juillet 2019 modifiant les dispositions du code minier relatives à l'octroi et à la prolongation des titres d'exploration et d'exploitation des gîtes géothermiques, JO du 26 juillet 2019, textes n° 20 et 21. And Décret n° 2019-1518 du 30 décembre 2019 relatif aux titres d'exploration et d'exploitation des gîtes géothermiques, JO n°0303 du 31 décembre 2019 texte n° 37.

[45] Some specificities exist for the Overseas territories and are not described here

- To guarantee the safety and health of workers.

It distinguishes 2 phases:

- The exploration (1);
- The exploitation (2).

The ordonnance, adopted in July 2019, should facilitate deep geothermal development. To encourage projects in less geologically known aquifers (Trias or Lusitanien in Île-de-France, aquifers in the Aquitain basin or in Alsace, Hauts de France, Provence- Alpes-Côte d'Azur region), **the petitioner can now choose under which regime he wants to do the exploration phase** (1 -Research authorization or Exclusive Research Permit, see below). Before this change, there was a threshold criterion : 150°C[46] that complicated the exploration in areas where the temperature was less predictable.

For the **exploitation phase (2), the temperature criterion has been replaced by the "Primary thermal power" (20 MW) which should reflect better the resource valuable potential**[47].

The procedures can be summed up as follows[48] (Table A2.2):

Mining titles required for **EXPLORATION**		
	The petitioner chooses:	
Mining Title in French (English Translation)	Autorisation de Recherches (AR) *(Research Authorization)*	Permis Exclusif de Recherche (PER) *(Exclusive Research Permit)*
Delivered by	Local deconcentrated Authority (Prefecture)	Central Authority (Ministry)
Competitive call	Yes	Yes
Public Enquiry	Yes	No public enquiry but an electronic consultation
Initial Duration	3 years	3 to 5 years
Extension of the Duration	No	Yes - Can be extended twice for 5 years each time, without competition[49]. The holder must have fulfilled its obligations, and

[46] décret n°78-498 du 28 mars 1978
[47] Décret n° 2019-1518 du 30 décembre 2019 relatif aux titres d'exploration et d'exploitation des gîtes géothermiques, JO n°0303 du 31 décembre 2019 texte n° 37.
[48] As presented in the ordonnance n ° 2019-784 du 24 july 2019
[49] With a perimeter reduction

		must subscribe a financial commitment at least equal to the previous financial commitment.
Mining titles required for **EXPLOITATION**		
	Primary power <20 MW	Primary power >20 MW
Mining Title in French (English Translation)	Permis d'Exploitation (PE) *(Exploitation Permit)*	Concession *(Concession)*
Delivered by	Local deconcentrated Authority (Prefecture)	Conseil d'Etat
Competitive call	No – can be delivered only to the holder of the Research Authorization or Exclusive Research Permit during its duration.	No – if requested during the validity of the Exclusive Research Permit or Research Authorization Yes – if the Exclusive Research Permit or the Research Authorization has expired
Public Enquiry	Yes, except if the Research Authorization is valid	Yes
Initial Duration	Open	Open[50]
Extension of the Duration	Yes – for periods up to 15 years each	Yes – for periods up to 25 years each

Table A2.2: Mining titles required for exploration and exploitation of deep geothermal resources in France.

The exploitation titles (Exploitation Permit or Concession) are completed by prefectural decrees (work permit, see below), established in collaboration with local mining authorities (DREAL). Those texts explicitly define the operator's obligations in terms of general exploitation conditions, definitive cessation of exploitation, safety on the facilities, prevention against pollution and nuisances, seismological monitoring, boreholes and pipes monitoring, relationships with and information to local mining authorities, regional and national administrative authorities. It means that within a common framework, some specific guidelines can be defined for each site. Those "tailor made" guidelines imply a strong adaptation potential, to the geological, geographical, even sociological context.

In addition to the Mining Titles - which gives rights to explore or to exploit mines - the Mining Code enforces a strict control on mining work by imposing the obligation to obtain a Work Authorization (or Work Permit).

[50] "La durée de la concession est arrêtée de manière à permettre au titulaire d'atteindre des conditions de rentabilité économique équilibrée pour un investisseur avisé, en prenant en compte les coûts de recherches et d'exploitation mentionnés à l'article 8-1 et au I de l'article 8-2 du présent décret et les risques associés au projet. Elle doit permettre l'amortissement des investissements réalisés pour la recherche du gîte géothermique, pour l'exploitation du gîte, y compris le cas échéant des substances connexes, dans le respect des conditions prévues à l'article L. 161-2 du code minier, et pour l'amélioration de la connaissance de la ressource, avec un retour sur les capitaux investis » art. 9.9 Décret n° 2019-1518 du 30 décembre 2019

For geothermal resources, it corresponds mainly to the drilling operations and to the plant exploitation (for heat direct uses or electricity generation). A company or operator who is willing to implement these activities during the exploration or exploitation phases of geothermal resources is required to submit ***an application for requesting a Work Permit***. This application is called DAOTM (Demande d'Autorisation d'Ouverture de Travaux Miniers). Referring to the foreign mining legislation, these authorizations would correspond to the Drilling Permit or to the Operation Permit. This Work Permit doesn't substitute for Mining Titles.

During the exploration phase or the exploitation phase, an application for new Work Permit has to be submitted each time the operator is implementing a new operation which represents a significant change compare to the initial state (new drilling for example, or addition of a new unit). For implementing operations of minor extent (like well cleaning or repair, well logging, plant maintenance…), the operator needs only to inform the local authority (Declaration).

The way to prepare and to submit applications for a Work Permit is governed by the Decree n°2006-649 of 2 June 2006, updated on 11 October 2018.

Concerning the environmental risks and impacts, it is of importance to note that within the items needed for the application are:

The impact study as defined in article R. 122 - 5 of the Environmental Code;

- A report featuring the health and safety policy during the work;
- A document stating the terms of the abandonment of the exploration or exploitation work and its estimated cost;
- A document assessing the potential impacts of the exploration or exploitation activities on the water resources and the mitigating measures envisaged if necessary;
- A document featuring the main risks induced by the project on the public safety.

Under other regulations

Other French regulations that may apply to the exploration and exploitation of geothermal resources are:

- The Environmental Code and the Water Act;
- The Health Public Code;
- The Labour Code.

The Environmental Code and the Water Act

The exploration and exploitation of geothermal resources must comply also with the requirements of the Environmental Code and Water Act. However, in order to facilitate the implementation of geothermal projects, the legislator has established some links between the Mining Code and the Environmental Code. For example, the drilling permit and the exploitation permit for geothermal resources - which are relevant to the Mining Code - are also in compliance with the requirements of the Environmental Code and the Water Act.

In some cases, the exploitation of geothermal resources can be also regulated by the Environmental Code and Water Act. It is the case when projects involve large capacity heat pumps and binary plants which are using large content of organic gases such as pentane or ammoniac which present a main risk for the natural and human environment. In the French nomenclature, these facilities are termed as ***Classified Installations for the Protection of the Environment*** (ICPE).

The ICPE procedure includes a public enquiry and a consultation process in which the environmental authority is consulted. The préfet delivers the authorization. The application for requesting an exploitation permit must be accompanied with specific Environmental Impact Assessment and Risk assessment.

The content of the environmental impact assessment is proportionate to the environmental and activity context and evaluated by the administration "case by case". The risk assessment justifies the fact that the project, in acceptable economic conditions, reaches the lowest possible level of risks. Its content is related to the risks importance and includes a presentation of the potential accidents' probability and kinetics and the organization of the emergency services.

The Health Public code

The use of geothermal resources has to be in compliance with the Health Public Code in special cases when they are used in cascade. For example, they are used first for energy extraction purpose (i.e. heating with or without heat pump) and then for human consumption (drinkable water) or for balneology[51].

Low volume withdrawals (family uses) are subject to declaration to the municipality only. Other withdrawals for distribution by public or private networks are subject to a request for authorization.

Another example of a specific case when the mining regulation must comply with the Health Public Code deals with the protection of workers and population if they can be exposed to ionizing radiations caused by the presence of naturally radioactive material on the geothermal installation.

The summary of the regulations applying to geothermal resources in France can be presented as follow (Figure A2.1, inspired from Traineau et al., 2018, updated with the last regulation evolutions):

[51] In France, there are two examples of a geothermal resources which are used first for district heating and then for supplying thermal water to a spa. The first one is in Jonzac. The geothermal reservoir is 1700-1900 m deep and 65°C. There is no reinjection. The fluid has a very low salinity and it is discharged into a cooling pond and then in the local river without significant environmental impact. The second example is in Bourbon Lancy where the water first heats a hospital and then is used for thermal purposes.

Geothermal Resources		Water resources for mineral waters and Spa
Mining Code		Environmental Code
Exploration		Depends on groundwater withdrawal volume
The petitioner chooses:		
AR Research Authorization (3 years) Environmental Impact Statement	PER Exclusive Research Permit (5 years & renewable) Environmental Impact Statement	D Declaration if less than 200 000m^3/y A Authorization if more than 200 000m^3/y
Exploitation		Public Health Code
Primary power < 20 MW	Primary power > 20 MW	A authorization for operating source of natural mineral water for conditioning, therapeutic use in a thermal establishment or distribution in a public refreshment bar A Definition of regulatory protection perimeter for the wells
PEX Exploitation permit 30 years Environmental Impact Statement	Concession 50 years Environmental Impact Statement	
Environmental Code ↓ ICPE (Classified Facilities for the protection of Environment) (ORC cycle and Large Heat Pump) Declaration or Authorization depending on		
Work permit		
DAOTM Authorization to Open Mining Works Impact study		

Figure A2.1: Main French regulations covering the exploration and exploitation of geothermal resources.

The local authorities are formally consulted for the work permits, which comes at the end of the process. The public is consulted about the geothermal energy projects (public enquiry). The way the consultations are hold, their timing and perimeters could be improved (Chavot et al. 2016).

Sustainability and Environmental Impacts

The previous section highlights the fact that there are national regulations concerning deep geothermal energy (mainly the mining code and decrees) but the main detailed regulation tools are specific to each installation (AR or PER, PEX or concession, DAOTM) adopted by the central authority (Ministry or Conseil d'Etat) or deconcentred bodies (Préfecture). It allows adaptation because deep geothermal installations can differ depending on:

- **Their purpose (producing heat, electricity, both), equipment and operating. It will determine if they are ICPE (classified Facilities for the protection of Environment) or not - which implies a more protective regime,**
- **Their context, especially geological context. For instance, in the Paris Basin, special attention will be given to potential corrosion and aquifer pollution whereas induced seismicity and radioactivity are not an issue as it is the case in the Rhine Graben area.**

While reviewing the impacts and risks as identified in the GEOENVI project and the regulations that address them, the examples of geothermal plants operated by ES-Géothermie (Soultz-sous-Forêt and Rittershoffen) will be taken to illustrate in practice.

Effect of surface operations: energy and water consumption and emissions to the environment

The framework for this item is established by the local or central mining authorities, in the mining titles and decrees, specific to each installation. It means that it is tailor made.

The management energy and resource consumption and emissions to the environment from surface operations is mainly based on monitoring and reporting.

Drilling

Drilling authorization[52] given by the local deconcentrated authorities asks for a detailed daily monitoring on energy, ground/tape water and chemicals consumption, as well as volume of brine produced, during the drilling and well testing phase. This daily report is sent to the local mining authority.

Operation

During plant operation, energy and resources consumption are recorded by operators. Exploitation authorization[53] given by the local deconcentrated authorities asks for a specific monitoring and reporting on a monthly electrical, water and chemical treatment consumption and volume of brine produced. According to the ministerial decree of

[52] Example : Article 14 of the drilling authorization of Illkirch
[53] Example : Article 45 of Soultz-sous-Forêts and Rittershoffen exploitation authorization

the exploration License[54], this reporting is completed by a monthly report on energy extracted from the geothermal reservoir. These monthly reports are summarized for the local and national authorities in annual reports of operation.

This monitoring can also be completed with a detailed monitoring according to ISO standard 9001 - Quality Management, 14001 - Environmental Management and 50001 - Energy Management Systems. Operators applying these ISO standards must monitor energy and resource consumption according to a dedicated management system approved by an external party and check every year. However, these ISO certifications are not imposed by French authorities for geothermal power plant operation.

Emissions to the environment from surface operations

Emission to the environment from surface operations are regulated by the French environmental code, local health regulations and drilling or exploitation authorization.

Regarding the emissions to air resulting from fuel burned in engines during surface operations, drilling rig diesel engine emissions are regulated by two EU Directives:

- Directive 97/68/EC of 16 December 1997, Directive of gaseous and particulate pollutants from internal combustion engines to be installed in non-road mobile machinery;
- Commission Directive 2012/46/EU of 6 December 2012 amending Directive 97/68/EC.

In France, air quality measurement is performed by certified associations for monitoring air quality, like Airparif in Paris area or Atmo Grand Est for the French Rhine Graben area.

Domestic sewage must be collected, treated and released according to the local health regulations. Most of the time it is treated first by a sceptic tank and then by an oil separator.

A specific regulation is provided in drilling or exploitation authorization[55] for Industrial and storm sewage. These specific kinds of sewages must be in conformity with following limits:

- Total Suspended Solid: 35 mg/l
- Temperature: 30°C
- Chemical oxygen demand: 125 mg
- Total hydrocarbons: 10 mg/l

Most of the time these sewages are treated first by a sand filter and then by an oil separator.

[54] Example : article 3 of the ministerial decree of the 22th September 2015, according the concession of geothermal resource to the GEIE “Exploitation Minière de la Chaleur”, owner of the Soultz-sous-Forêts power plant

[55] Example: article 23 of Soultz-sous-Forêts and Rittershoffen exploitation authorization

Surface wastes production

The framework for this item is established in the Directive 2008/98/EC of 19 November 2008 on waste, repealing other Directives, and is the base of the French regulation[56]. Wastes are classified and codified according to this directive. As wastes producers have the responsibility of their own wastes from production to final treatment, they must ensure that a subcontractor has the ability to do the job. For wastes classified as dangerous, French wastes producers use an official national form (Cf. CERFA 12571) to follow the different steps from the transport to the final treatment. This form is part of the wastes management that French geothermal operators must apply according to their Drilling or Exploitation authorization[57]. Quantity of wastes on site must be as low as possible according to authorizations. Moreover, radioactive wastes must be characterized and have to be collected and treated by the ANDRA (French national agency for nuclear waste management). Some additional elements about radioactive wastes are detailed in the section on Radioactivity below.

Waste management can also be completed by French operators with a more detailed wastes management system according to ISO certification 14001, on a voluntary basis.

Surface disturbance, including vibration, noise, visual, dust and land occupation

Vibration

Vibration emissions are regulated in France by ministerial decree of the 23rd of July 1986 about mechanical vibration emissions in the environment. It limits vibration emissions according to type of construction and frequency range. Figure A2.2 presents the different limits.

[56] Ordonnance n° 2010-1579 du 17 décembre 2010 portant diverses dispositions d'adaptation au droit de l'Union européenne dans le domaine des déchets Code de l'environnement, livre V, titre IV relatif à l'élimination des déchets et à la récupération des matériaux
[57] Example : Article 28 of Soultz-sous-Forêts and Rittershoffen exploitation authorization

TABLEAU 1

VIBRATIONS CONTINUES OU ASSIMILÉES

Valeurs limites de la vitesse particulaire en fonction de la fréquence observée

Méthode de mesure de classe « Contrôle »

Ces valeurs limites sont valables pour chacune des trois composantes du mouvement.

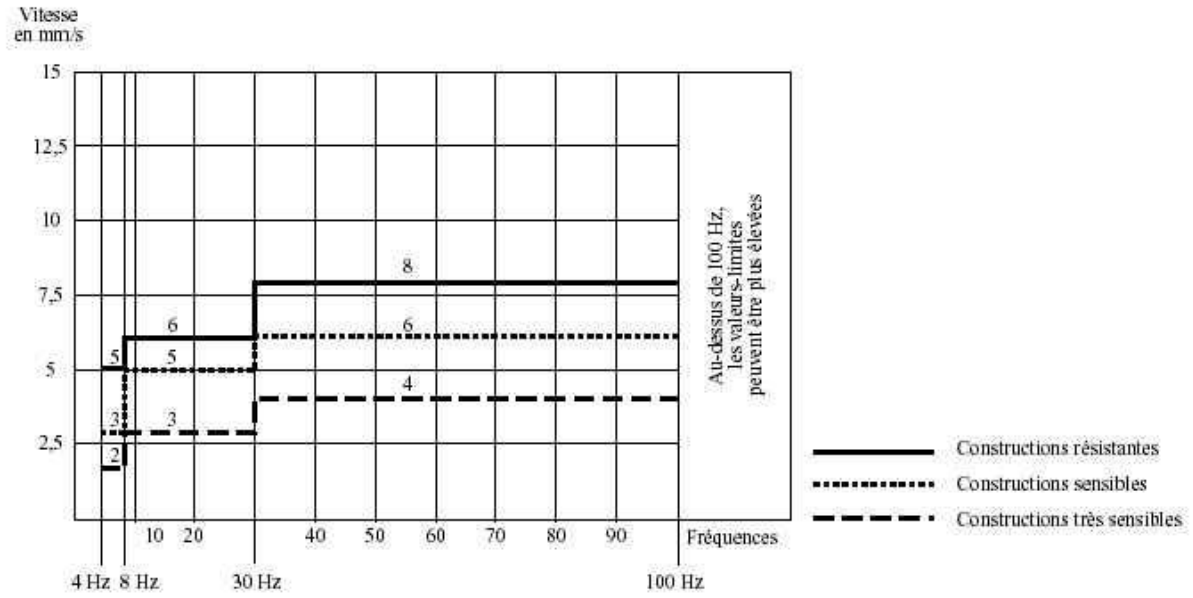

Figure A2.2. Limits as function of type of construction and range frequency. Plain lines: Resistant constructions, Doted lines: Sensitive constructions, Dashed lines: Highly sensitive constructions.

NF E 90-0201 norm and ISO 2631-2 norms are used by the third party in charge of the vibration measurement. According to ISO 2631, human vibration perception starts from 0.18 mm/s in a building.

This regulation is particularly applied during active seismic data acquisition during the exploration activity or during specific civil works for the construction of the drilling platform or the geothermal plant.

Smell

- During drilling

Prior to starting drilling activities, devices for H_2S detecting any H_2S gas emissions must be installed on the drilling rig. The installation should consider the site's configuration and the extent of the specific danger zone in accordance with Articles RG29 and RG30 of the General Regulation on Extractive Industries. These detectors trigger a visual and audible alert beyond the threshold of 10 ppm. The site manager then applies the appropriate safety instructions.

- During plant operation

According to exploitation authorization, geothermal plants must be operated in such a way that they cannot be a source of olfactory nuisance or deterioration of the air quality, which may be a nuisance to the neighbourhood or harmful to the health of the neighbourhood[58].

Noise

Noise emission are regulated in France by the ministerial decree N°2006-1099[59] relative to neighborhood noise abatement. According to this decree, global noise emergence is limited to 5 dB(A) during the daytime (7h – 22h), and 3 dB(A) during night-time (22h – 7h). A corrective term is also applied in function of the daily cumulative duration:

Daily duration T	Emergence corrective term
T ≤ 1 min	6 dB(A)
1 < T ≤ 5 min	5 dB(A)
5 < T ≤ 20 min	4 dB(A)
20 < T ≤ 2 h min	3 dB(A)
2 h < T ≤ 4 h	2 dB(A)
4 h < T ≤ 8 h	1 dB(A)
T > 8 h	0 dB(A)

Table A2.3: Example of emergence corrective term as function of the noise emission's duration.

The French Public Health Code also fixes a spectral emergence in a certain octave band (Cf. article R 1334-34). However global and spectral emergence are measured only if the background noise is up to 30 dB(A) (Cf. article R 1334-32).

Exploitation and drilling works must be performed according to the previous regulation. A day- and night-time noise measurements must be performed before any exploitation/drilling starts near the closest houses to determine the level of background noise. Those measurements must be repeated several times during the exploitation/drilling, to check if noise emissions exceed the regulatory levels of emergence (that is, above the determined background noise). In that case, it is mandatory for the operating company to take measures or establish procedures to decrease the level of generated noise. In particular, during the drilling phase, any loud operation is forbidden during the night-time (22h – 7h). Figure A2.3 presents an example of locations where noise measurements are regularly performed around the Soultz-sous-Forêts power plant.

[58] Example: article 25 of Soultz-sous-Forêts and Rittershoffen exploitation authorization
[59] Arrêté du 23 janvier 1997 relatif à la limitation des bruits émis dans l'environnement par les installations classées pour la protection de l'environnement

Figure A2.3. Location of places around the Soultz-sous-Forêts power plant, where noise emissions are repeatedly measured (OTE, 2017, courtesy of GEIE Exploitation Minière de la Chaleur). A and B are located at the plant; the other spots (1, 2, 3, 4) are located near the closest habitations.

Visual

The operating company must take all possible measures to minimize the visual impact of facilities according to drilling or exploitation authorization (Cf. article 5). Moreover, the drilling site and the geothermal plant must be kept clean permanently.

Dust

French criteria of air quality are defined in the environmental code (Cf. articles R221-1 à R221-3) and are based on EU Directive 2008/50/EC of 21 May 2008 on ambient air quality and cleaner air for Europe. For particles ''PM10'' quality objective is 30 µg/m³ of suspended particles in yearly average and 10 µg/m³ for ''PM2.5'', according to World Health Organization (WHO) recommendation.

Suspended particles can be of natural or anthropic origin. During exploration, drilling and operation phases, main source of suspended particles are:

- circulation of vehicles and construction equipment on the access roads and drilling platform;
- civil works required for the drilling or power plant site;
- diesel engine, such drilling rig generator (see 3.3.1).

Thus, vehicles must be in conformity with Euro norms. Operators must limit dust emissions during civil works by keeping the soil humid[60].

In France, air quality measurement is performed by certified associations for monitoring air quality, like Airparif in Paris area or Atmo Grand Est for the French Rhine Graben area.

Leaks due to surface installations/operations

Pressure vessel, including pipes and equipment like heat exchangers or liquid/gas separator, must be designed according to European Pressure Directive 2014/68/EU. According to this directive, each vessel is associated to a risk category as a function of fluid, pressure, volume or diameter and vessel type. Each category of risk is then associated to inspection program necessary for the design, manufacturing and testing to be in conformity with the directive. For certain categories of risk, a notified body is required for approval of the different inspections and welding qualifications. This European Pressure Directive is a first step in the management of surface installation leakage.

Once pressure vessels are in installed in France, operation of these equipment is regulated by the ministerial decree of the 20th of November 2017. This French regulation specify that operators must establish and maintain an inspection plan for all pressure equipment on site. Purpose of this plan is to ensure that pressure vessels are still in good conditions to be operated in safety conditions for workers and the environment. Inspection plan must be approved by a certified body and transmitted to the mining authority[61] . This French regulation is a second step in the management of surface installation leakage.

Exploitation authorization (article 24 for Soultz-sous-forêt and Rittershoffen) and legislation about classified installation for the environment also ask operators to ensure that contamination of surface water is not possible in case of leakage of geothermal brine or process fluid. Thus, water management must be a key point of geothermal plant design (Ravier et al., 2016). It is recommended to collect all rain sewage of geothermal plant in a specific retention system. When the retention system is filled with rainwater, an operator can check different parameters of the fluid, like conductivity, to decide if the fluid is not contaminated and can be released, or if the fluid is contaminated by geothermal fluid or process fluid. An example of the water management system of the Rittershoffen plant is given in Figure A2.4.

[60] Example : article 10 of Illkirch drilling authorization
[61] Article 9 of Soultz-sous-Forêts and Rittershoffen exploitation authorization

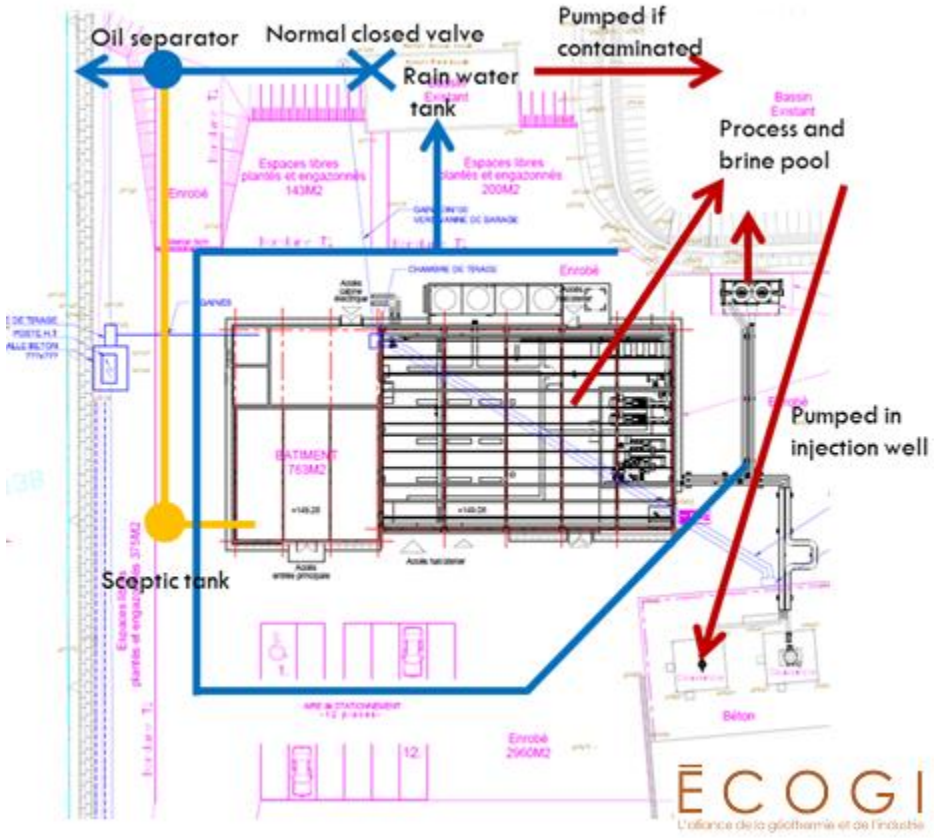

Figure A2.4. Example of the water management at the Rittershoffen geothermal plant to prevent any contamination of surface water with geothermal brine or process fluid.

In addition, according to exploitation authorization[62], operators must:

- Provide to the mining authority all geothermal pipes inspection (article 39) and a risk analysis on geothermal pipes (article 40);
- Report all fluid leakages to the mining authority in the annual operation report (article 45);
- Report the annual corrosion rate (article 45).

Liquid / solid effusion and wastes

According to drilling and exploitation authorization, operators must provide a soil analysis in case of leakage in the environment of geothermal or process fluid (article 46).

[62] Soultz-sous-Forêts and Rittershoffen exploitation authorization

Liquid chemical fluid effusion

According to drilling or exploitation authorization, all chemicals, such as mud chemicals, inhibitors, lubricants… that could generate contamination of soil or surface water must be stored in proper condition on retention capacity (article 21). Retention capacity is at least equal to the greater of the following two values:

- 100% of the capacity of the largest tank;
- 50% of the capacity of the associated tanks.

In case of accidental effusion out of retention system, whatever the cause is, the operator must immediately take all possible measures to interrupt or at least limit it (article 24). Products recovered after the incident must be reused or disposed as waste. In addition, design of the drilling platform or the geothermal plant must contain and prevent any contamination of surface water from this kind of event thanks to a proper waste water management.

Geothermal brine effusion

According to exploitation authorisation, geothermal pipes must be equipped with a pressure sensor, implanted immediately downstream of the wellhead and detecting any pipe rupture (article 42). In case of rupture of a pipe, this sensor must immediately interrupt geothermal flow by

- stopping the production pump;
- closing the valves closest to the place of rupture;
- closing wellhead valves.

This sensor must be checked periodically.

Blowout

This topic is regulated by the drilling authorisation and article 41 of the ministerial decree 80-331 about General Regulation on Extractive Industries.

During all the drilling operations, wellheads must be equipped with a suitable sealing system to prevent a gas or geothermal water eruption. A flexible pipe also has to be connected on the wellhead to neutralise, if necessary, the eruption by injection of brine. Thus, salt must be available on the site in sufficient quantity.

A fictitious gas lift exercise must be planned at the beginning of the drilling in order to check the functioning of the sealing systems and the procedures. A test of the sealing system is then asked every 3 weeks.

Degassing

During drilling

This topic is regulated by article 42 and 46 of the ministerial decree 80-331 about General Regulation on Extractive Industries. The drilling rig must be equipped with a degassing system and a torch judiciously placed, considering

dominant wind direction, and designed with an automatic or remote ignition device. The operator can be exempted from this obligation if it can be demonstrated in the safety document that danger due to gas does not exist.

During plant operation

In the Paris Basin[63], the prefectural decree asks, once a year, for a monitoring of physico-chemical parameters and chemical composition (liquid and gas, especially N_2, CH_2, H_4, H_2S, CO_2).

Radioactivity

In the case of geothermal plants exploiting a reservoir containing natural radionuclides, the probability exists that some of the radionuclides could be washed out by the circulation of the geothermal fluid and then trapped during the formation of scales in the plant's surface equipment. This type of slightly radioactive scales is called "NORM" (Naturally Occurring Radioactive Material). Typically, the geothermal plants developed in the Rhine Graben have to face this issue. It is not the case for instance in the Paris basin.

Thus, the drilling and exploitation authorizations – taken by territorial based authorities - require, in the Grand-Est region, that the operating company at least performs measurements to check the level of radiation on the facilities and to monitor its evolution. Last year, the French Mining Code was modified to take into account the problem of NORM: a new chapter was added, mainly dedicated to the protection of the environment and the populations. It defines the measurements that are mandatory for the operating company. Radiological characterization is asked for all kinds of solid, liquid and gaseous effluents, to be sure that no radioactive material could be spread into the environment and could be harmful for the surrounding population. In addition, in France, the regulation regarding radioactivity is defined in the Labour Code and the Public Health Regulation, which defines the measures and procedures that must be followed by employers for the protection of workers. The basic principle of radiation protection states that every exposure to radiation, even the lowest, could have potential, harmful effects on human's health. Thus, the regulation imposes that at least, the level of radiation has to be measured and the potential exposure of workers should be calculated. Depending on the results, radiation protection measures have to be implemented, in order to respect the following principal law: the maximal cumulative dose that can be received by workers and population over 12 consecutive months is 1 mSv (one milli-Sievert).

As an example, are listed some of the measures that are applied on the geothermal plants of Soultz-sous-Forêts and Rittershoffen in Example 1.

Ground surface deformation

[63] Prefectorial decree no 2017 -0451 d21 February 2017 giving to the Syndicat d'Equipement et d'Aménagement des Pays de France et de l'Aulnoye (SEAPFA) an exploitation permit in Le Blanc Mesnil

The evolution of surface ground deformation is reported monthly to the Mining Authorities, as asked in the exploitation authorization. To allow that, the specifications of the Mining Authorities ask for the installation of a geodetic station on each platform. Example 2 shows the case of Soultz-sous-Forêts and Rittershoffen.

Seismicity

The seismic hazard depends on geological and operative factors. Its probability is therefore more important in some areas (like the Rhine Graben), where the natural seismic hazard can be significant, than in others (the Paris Basin).

The regulation of the seismic risk linked to deep geothermal activity is defined by local mining authorities in the exploitation authorizations.

The monitoring of induced seismicity associated with geothermal energy started very early in France through the development of the Soultz-sous-Forêts EGS project. However, for a very long time, the seismological monitoring has only been performed for research and development purpose, without any legal framework. The first mention of seismological monitoring in the regulation appeared in the drilling authorization of the Rittershoffen boreholes, which also covered the well testing, stimulation tests and inter-well circulation tests in December 2011.

The occurrence of a series of induced earthquakes that were felt by the population in Soultz-sous-Forêts (M=2.6 in 2000, M=2.9 in 2003, Cuenot et al., 2008, Charléty et al., 2007, Dorbath et al., 2009), in Basel ($3 \leq M \leq 3.4$, Häring et al., 2008) and in Landau (M=2.7) contributed to make induced seismicity the major environmental concern associated with the development of EGS projects. This also led the mining authorities to include the seismological monitoring and the procedures to be followed in case of earthquakes into the drilling and exploitation authorization.

Seismological monitoring has been included in both the prefectural decrees authorizing drilling (article 12) and exploitation (article 27). They impose the following:

- Information of the population about the hydraulic activities and the probability of induced seismicity;
- Installation of a monitoring network at least 6 months before the start of drilling, in order to observe the local, natural seismicity. For the first time, a detailed description of the characteristics of the required network is given:
    - At least, 4 short period seismometers;
    - 1 “multi-sensor” station including a broad-band seismometer, an accelerometer, a GNSS receiver and a corner-coin reflector for InSAR studies. All data from this station should be transmitted to and archived by RéNaSS[64] (French National Seismological Network, hosted at EOST[65], Strasbourg University). The RéNaSS is in charge of publishing online the data from this station, which are freely accessible by the public; a convention was signed in 2016 between EOST,

[64] RéNaSS : Réseau National de Surveillance Sismologique

[65] EOST : École et Observatoire des Sciences de la Terre, Department of Strasbourg University

Strasbourg University and geothermal operators to regulate this topic, under the control of Mining Authorities.

- Definition of Peak Ground Velocity (PGV) thresholds and associated procedures:
  - **PGV ≥ 0.5 mm/s**: an event reaching this threshold triggers the "vigilance threshold". The operator must continuously follow the seismicity in order to check if a further event reaches the threshold and eventually adapt the operating conditions of the plant;
  - **PGV ≥ 1.0 mm/s**: this value triggers the "increased vigilance threshold". The operator must follow the seismicity in order to check if a further event reaches the threshold. All the seismological data from the 4 short period stations must be sent to the RéNaSS, within 24 h after the event and this, for a period covering 7 days before the event. The RéNaSS is then in charge of precisely characterizing the event. In the same time, the operator must take the appropriate measures in terms of operating conditions in order to avoid the occurrence of a further similar event.
  - **PGV ≥ 1.5 mm/s**: an event reaching this value triggers the mandatory, gradual shutdown of the plant. All the seismological data from the 4 short period stations must be sent to the RéNaSS, within 24 h after the event and this, for a period covering 7 days before the event. The RéNaSS is then in charge of precisely characterizing the event. The Mining Authorities must be immediately informed about the event and the plant's shutdown. Depending on the results of the event's analysis, the Mining Authorities will authorize or not the restart of the plant.

The examples of application of regulation to the current seismological and geodetical monitoring of the Soultz-sous-Forêts and Rittershoffen plants are reported in Example 3.

Interconnection of aquifers and disturbance of non-targeted aquifers

The general principle states[66] that operators must take all possible measures or apply specific procedures in order to guarantee the underground water and minimize the risk of accidental pollution.

During drilling

According to drilling authorisation, wells' completion must guarantee the protection of potential permeable layers. Casings put in place during the drilling progress, and the quality of the cementations of the annular spaces between the casings and the grounds must guarantee protection of permeable levels. Cementation shall be carried out under pressure from bottom to top and a suitable drying time shall be observed before the checks and the continuation of the operations. At the end of each casing and cementing operation, the operator must:

- Perform a pressure test;
- Carry out casing inspection and cement bound log (CBL);
- Report casing and cement log results to the mining authority.

[66] In the prefectural exploitation/drilling authorization, source in the mining code L 161-1

In case of presence of groundwater potable aquifer, several casings can be imposed by the mining authority. The operator must also install a network of piezometers into shallow observation wells. At least, one piezometer must be installed upstream from the facilities and 2 piezometers downstream of the facilities. Regular measurements of the groundwater table's level, conductivity, temperature, pH, reduction potential must be performed. In addition, water samples are monthly taken and analysed. The concentration in main anions, cations, metallic species, pollutants and the radiological activity of main natural radionuclides are then characterized. All these measurements aim at detecting any pollution of the groundwater table by geothermal fluid. The location of the shallow observation boreholes around the Illkirch drilling platform, as well as the installation of piezometric sensors are shown on Figure A2.5.

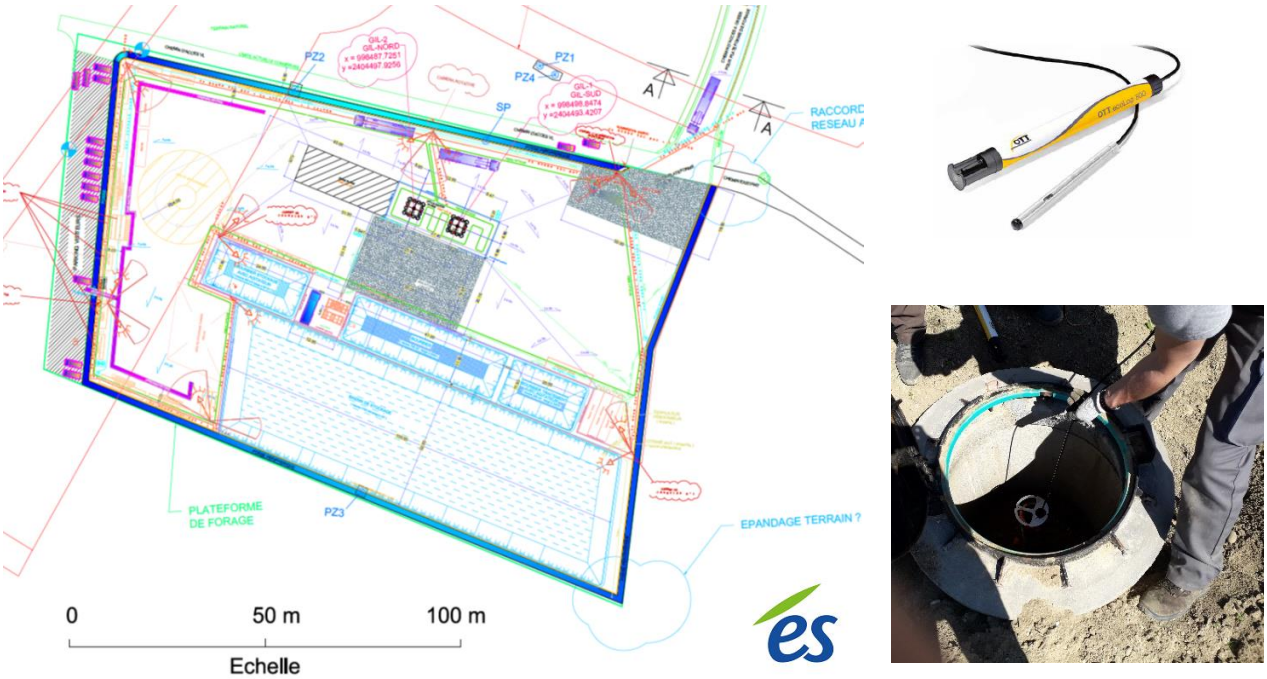

Figure A2.5. Left: Location of the shallow observation wells around the drilling platform at Illkirch (PZ1, PZ2, PZ3, PZ4); Right: piezometric sensor (top) and installation of the sensor (bottom)

During plant operation

According to exploitation authorization, the operator must provide to the mining authority a program concerning wellbore integrity inspection (article 9 and 32). Wellbore integrity control is performed using diameter, sonic or electromagnetic tools to assess casing integrity, cementation quality, deposit thickness and corrosion evolution (article 33). According to exploitation authorization, wellbore inspections are required every 3 years in injection wells and every 5 (in Paris Basin) to 6 years (in French Rhine Graben area) in production wells.

Reservoir physical and chemical modifications

The concession or exploitation permit establishes the production conditions (flow rate…) and their reporting measures. Therefore, if physical or chemical modifications of the initial parameters occur, the operator must report them and find the solutions to respect his engagements or justify the fact that they are not the consequences of exploitation technical faults.

Conclusion

One of the main issues regarding the development of deep geothermal in France is the competition with conventional energies. Developing efficient life cycle assessment methodologies that allow comparisons with fossil and other renewable energies is therefore relevant and will also help the sector improving its practices. The ecosystem around deep geothermal energy, politico-administrative players, professionals, scientific actors, is smoothly working.

The French market in 2018 represented 120 million € expenditures and 650 jobs.

The regulation framework is improving (new regulation of July 2019 that needs to be comforted). Framing deep geothermal energy is a state activity in France: the central and deconcentrated bodies hold most of the competences, as they are responsible for the safety of the activity, regarding the population and the environment.

The action of the deconcentrated authorities in the framing of the environmental impacts of deep geothermal energy allows tailor made solutions, taking into account the dialogue with the industrials and local stakeholders and the territory specificities.

The local authorities – if they are formally marginally associated - play an active role in directly developing or not (for geothermal energy direct use) or supporting or not, politically and financially, deep geothermal energy.

In November 2019, deep geothermal energy is at a turning point in France. The final version of the “multiannual energy planning” is still awaited. If there is no question about the ambition regarding conventional direct use of geothermal energy, the future of deep geothermal energy for electricity production in France mainland will probably be less supported by the feed in tariff[67].

The possibility of co-exploiting lithium will probably help to maintain the support of the public authorities, as it represents a new integrated way of development for deep geothermal energy. On the other hand, on November 12th, a 3.1 magnitude seismic event was felt in Strasbourg. The question about its potential relationship with a deep geothermal project nearby was officially raised and is under investigation by experts. This is actually a test for the sector and could be significant for the image of deep geothermal energy.

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[67] As mentioned before the feed-in tariff for geothermal electricity disappeared from the Multi-annual Energy Planning proposal presented on 20 January 2020.

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Example 1: Radioactivity, measures applied on the geothermal plants of Soultz-sous-Forêts and Rittershoffen

"NORM" (Naturally Occurring Radioactive Material) is an issue that needs to be faced in the Rhine Graben. : the geothermal fluid circulates in granite, a rock containing small amounts of radionuclides, for instance Uranium 238, Thorium 232, Potassium 40 and the products of their decay chain. On the surface, enhanced concentration of Radium 226, Radium 228 and Lead 210 can be found in sulfates and sulfides scales, as shown on Figure A2.6 (Cuenot et al., 2013, 2015; Scheiber et al., 2012; Eggeling et al., 2013; Mouchot et al., 2018).

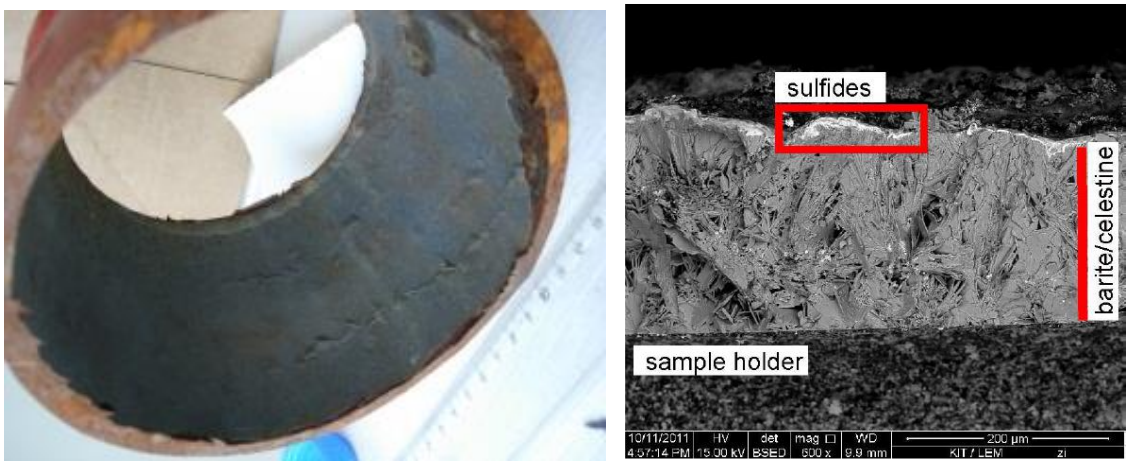

Figure A2.6. Left: Barite scaling covering the inner surface of a pipe (Scheiber et al., 2012); Right: Electron microscopy of the cross-section of a scaling layer showing sulfide and sulfate scaling (Scheiber et al., 2012)

Monitoring

- Quarterly measurement survey: every three months, ambient and contact dose rate measurements (Figure A2.7, left) are performed on several tens of locations over the plants' surface equipment. This allows to accurately monitor the evolution of radioactivity, which has to be reported to the Mining Authorities.
- Characterization: regular sampling of geothermal fluid and scaling is performed. Samples are then fully analysed in terms of geochemical content and radiological characterization. This is explicitly asked by the regulation, at least once per year.
- Aerial emission: quantification of Radon emission on the plant, but also, in the environment around the plant (typically, near the closest habitations) is mandatory, as well as radiological measurements on the dusts that can be emitted on the plant (Figure A2.7, right). It has to be done once per year and reported to the Mining Authorities
- Effluents: sampling and radiological analysis of liquid and solid effluents that can be released into the environment or stored on site (for example, rainwater, mud, …) must be performed once per year. In addition, if some effluents are released in the environment, soils, flora and fauna located near the discharge place must also be sampled and analysed to check for the presence of radionuclides.

Figure A2.7. Left: Dose rate contact measurements on a pipe; Right: Planned radon measurements around the Rittershoffen plant (Bosia et al., 2020).

Radiation protection (only if radiations have been measured on site)

- Appointment of a radiation protection expert: the expert will be in charge of the monitoring described above, but also to all actions related to radiation protection
- Estimate of individual exposure: from the list of all possible works that employees are likely to perform on the plant, duration of each work and dose rate measurements on facilities, a calculation of the possible received dose for each worker has to be made and compared to the maximal permitted dose over 12 consecutive months (1 mSv).
- Workers' dosimetry: each worker must wear a passive dosimeter during its working time if he works on the plant's facilities. The dosimeters are analysed every three months to check the value of the cumulative dose (Figure 8, left).
- Installation zoning: if the measured ambient dose rates exceed given thresholds, it is required to proceed to a zoning of the installation (Figure A2.8, right), according to the procedure defined in the regulation. It has to be noticed that, as soon as an area is determined and reported, workers must compulsorily wear their passive dosimeter when entering the zone. It is applicable even for the first zone defined in the regulation ("blue" or "supervised" area).

Figure A2.8. Left: Personal, passive dosimeters worn by employees; Right: Blue or supervised area defined on the Soultz-sous-Forêts power plant (Cuenot et al., 2013)

- Work procedures and authorization: specific work procedures have to be defined for the work in supervised or controlled area (including the access authorization), or for work where the risk of exposure is higher (for example, when opening a contaminated equipment implying a risk of contact with radioactive material). A particular attention should be paid to the collective and individual protective equipment that is required regarding the type of operation (Figure A2.9).
- Employee's training: each employee who is likely to be exposed to radiations must be trained, or at least informed, about radioactivity in general, but especially about all related issues in its framework.

Figure A2.9. Example of individual protective equipment worn for the opening of a heat exchanger

Waste management

- Scaling residues: the radioactive scales, coming from filters or equipment cleaning are first stored in a dedicated, isolated place. The Mining Authorities require that these wastes cannot stay on site for a long time. In France, all radioactive wastes have to be collected by ANDRA (French national agency for nuclear waste management) for a long-term storage (depending on the type of radionuclides). This process is, by the way, very expensive for the operator.
- Contaminated equipment: other contaminated equipment (heat exchanger, pipes, valves,…) should normally be also collected by ANDRA. Due to the large weight of these metallic components and consequently, very high costs associated with their management by ANDRA, several research projects are currently running to develop decontamination processes in order to reduce the costs.

Example 2: Surface ground deformation measures applied on the geothermal plants of Soultz-sous-Forêts and Rittershoffen

A geodetic station was installed on the platforms: in July 2013 for GPK-1 (Soultz-sous-Forêts), and in April 2014 on GPK-2, GPK-3, GPK-4 and GRT-1 and GRT-2 platform (Rittershoffen). The geodetic stations on Soultz-sous-Forêts and Rittershoffen platforms are respectively named GPK1/GPK2, and ECOG.

The evolution of the relative position of the station ECOG and GPK2 is presented in the Figure A2.10, in the horizontal and vertical directions, as well as the baseline, which is the distance in 3D between both stations. It shows that the relative position varies of about ±2.5 cm in the Northern and Eastern direction and ±1.0 cm in the vertical direction. The baseline oscillates between ±0.5 cm on a mean distance of 6 435.210 m between the two stations. The year 2015 was taken as a reference, as both plants were under construction and no hydraulic activities were performed. The comparison with the reference shows that no significant vertical and horizontal ground motions can be observed at the surface of each plant.

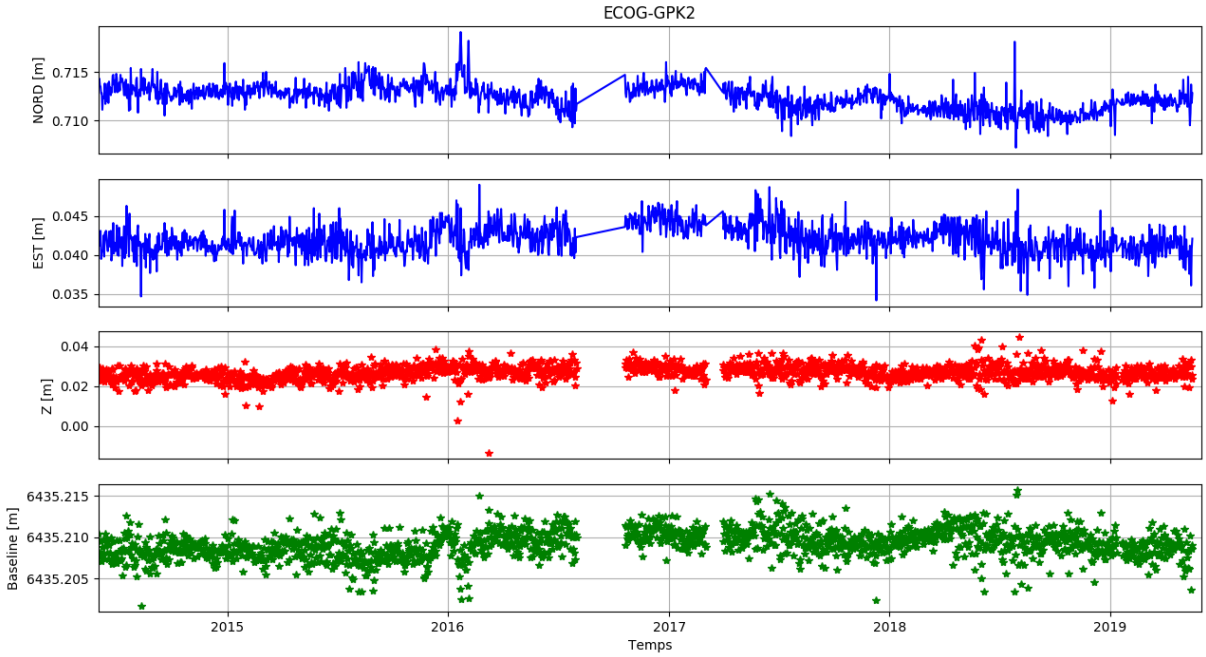

Figure A2.10. Position of the ECOG station (Rittershoffen plant) relative to the GPK2 station (Soultz-sous-Forêts plant). Results are shown horizontally (blue lines), vertically (red dots) and in baseline (green dots)

Example 3: Examples of application of regulation to the current seismological and geodetical monitoring of the Soultz-sous-Forêts and Rittershoffen plants

As seen before, the regulation gives the operators several guidelines to be respected. Nevertheless, it is often necessary for operators to translate these guidelines into proper and efficient working and monitoring procedures. The seismological monitoring of the Soultz-sous-Forêts and Rittershoffen plants is regulated by the latter decree described above. Following are examples of what has been done so far to fit with the regulation.

Seismological networks and data processing

Figure A2.11 presents the permanent seismological networks installed around the Soultz-sous-Forêts and Rittershoffen plants since 2002 and 2012 respectively (Maurer et al., 2020).

Originally composed of 9 surface stations, the Soultz network (in blue on Figure A2.11) currently consists of 7 stations:

- Four 3 components short period (1 Hz) velocimeters
- Two 1 component short period (1 Hz) velocimeters
- One 3 component broad-band (120 s) velocimeter
- One 3 component accelerometer (2 g), located at the same place as the broad-band sensor

The sampling rate for all stations is set at 200 Hz.

The multi-sensors public station is the one called “OPS” located with a blue star on Figure A2.11.

The Rittershoffen network was initially composed of 4 stations. The station named “KUHL” was recently transferred from the Soultz network to the Rittershoffen network comprising today 5 stations.

- Four 3 components short period (1 Hz) velocimeters
- One 3 component broad-band (120 s) velocimeter
- One 3 component accelerometer (2 g), located at the same place as the broad-band sensor

The characteristics of the sensors and the sampling rate are the same as the Soultz network. The multi-sensors station is the one called “BETS”, marked with a red star on Figure A2.11.

In case of specific operations such as chemical and/or hydraulic stimulations, the permanent networks are densified by temporary stations (Maurer et al., 2015).

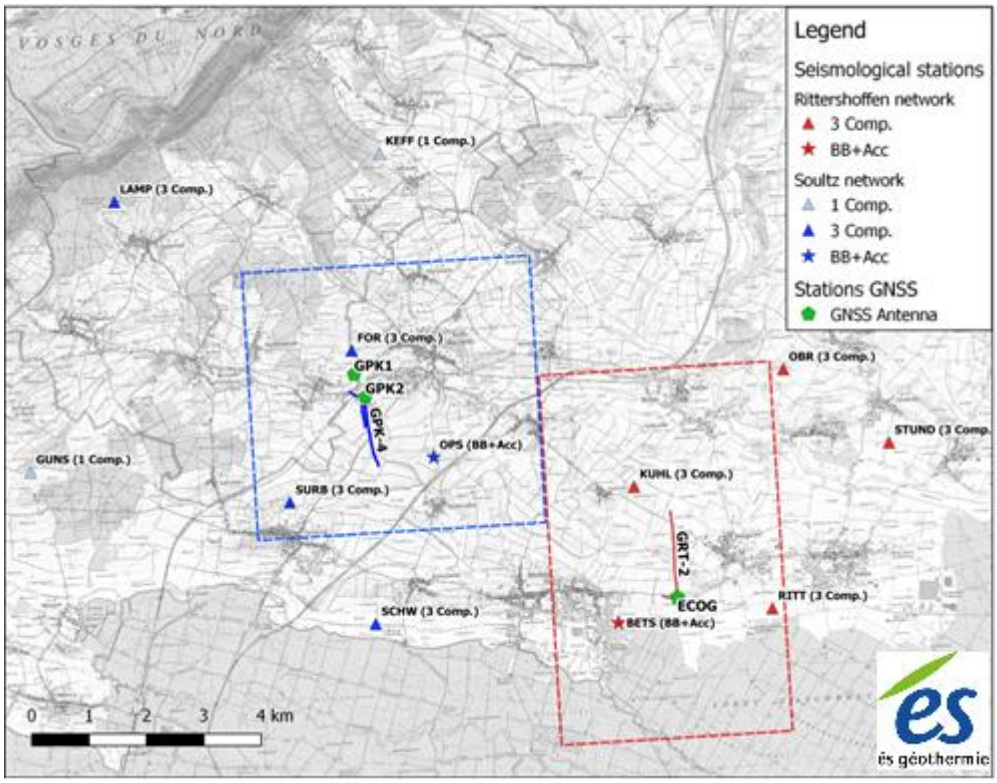

Figure A2.11. Seismic networks of Soultz-sous-Forêts (in blue) and of Rittershoffen (in red) and geodetic network (in green). Trajectories of wells are also displayed. Dashed rectangle shows Soultz-sous-Forêts (in blue) and Rittershoffen (in red) exploitation license (concession)

For both networks, the data from the individual stations are transmitted in real-time by radio or WiFi link to a central acquisition place, where the data are compiled and stored. From this place, the data from all stations are transmitted through an ADSL connection to a server hosting the archiving and processing software. A view of a station is given on Figure A2.12.

Figure A2.12. View of a permanent station from the Rittershoffen network

The detection, phase picking, location and magnitude estimate are processed automatically. Then a seismologist manually reprocesses the detected events to improve the accuracy of location and magnitude. The detection magnitude is close to 0, depending on the overall background noise. In case of a detected seismic crisis, it is often necessary to manually review all the waveforms as the automatic detection system may have missed some of the weakest events.

The seismological observations are monthly reported to the Mining Authorities, together with the monthly exploitation report.

Alert system

To be able to quickly:

- manage the occurrence of an event, exceeding one of the thresholds defined in the regulation,
- meet all legal obligations demanded by the regulation,
- avoid any further event,

an alert system together with a decisional chart has been set up. In the case of an automatically detected event, reaching or exceeding a magnitude of 1.7, an automatic alert e-mail and phone call is sent to the on-call duty person (in the frame of the plants' exploitation, there is permanently an on-call duty person, 7 days a week, 24h/24), who may contact if necessary a seismologist. Then the event is manually reprocessed and the PGVs at each station estimated. If the first threshold is reached on at least two stations, then the procedure described on Figure A2.13 is launched.

This procedure aims at translating the main, general obligations defined in the regulation, into practical decisions and actions to be followed. For example, it was decided to:

- re-evaluate the periods of vigilance and increased vigilance every 6h, as no time frame for the vigilance is defined in the regulation;
- in case of reaching the second PGV threshold, it was decided to decrease the flowrate by iterative steps of 20 m^3/h, as "an appropriate measure in terms of operating conditions in order to avoid the occurrence of a further similar event", which is stated in the regulation.

This procedure has never been launched since the commissioning of both geothermal plants, as no event has been felt nor reached the first PGV threshold on more than one station.

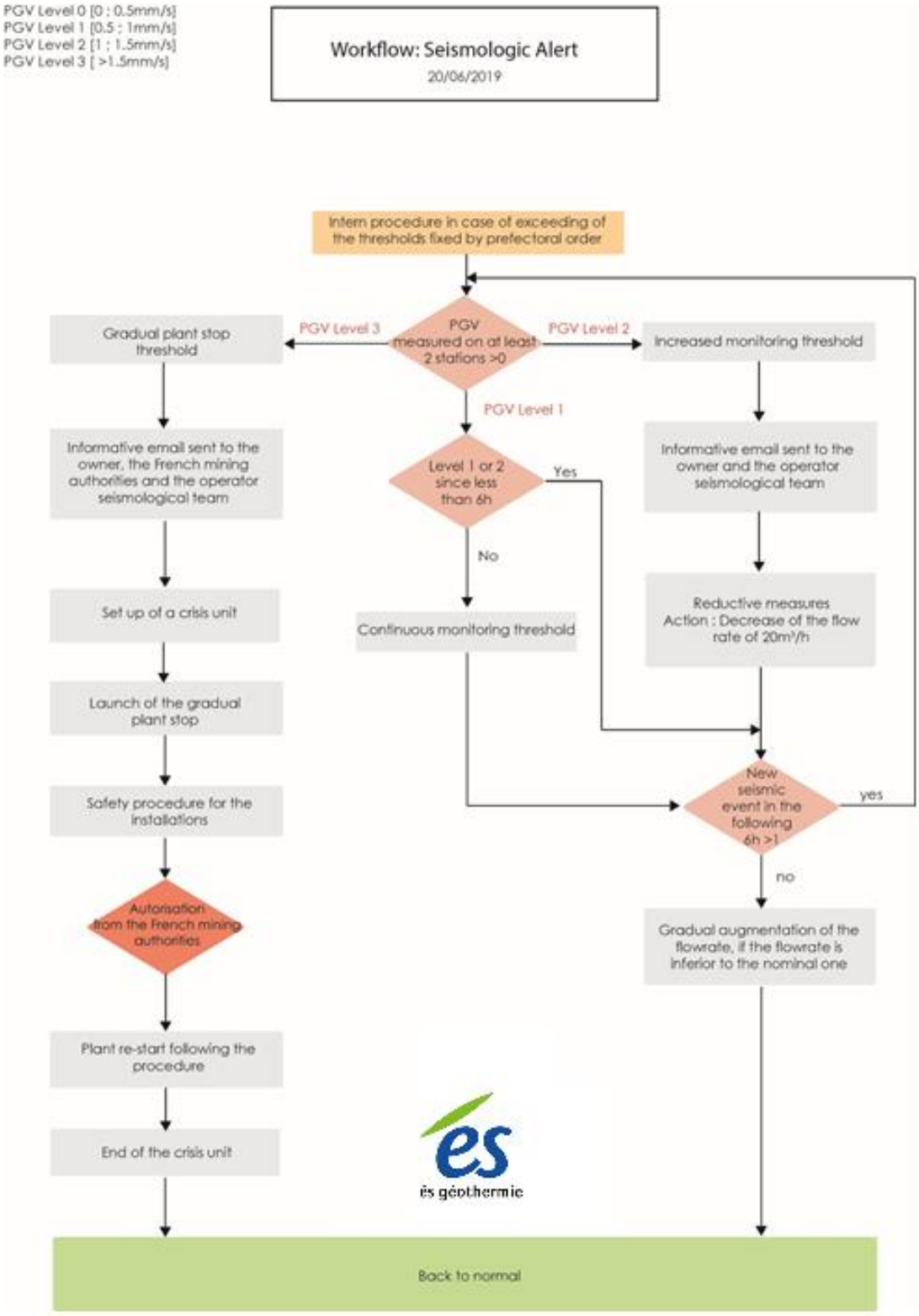

Figure A2.13. Decisional chart designed by operators in case of occurrence of induced micro-seismic activity, based on French mining authorities regulation

Results of the seismological monitoring

Since 2016, the geothermal plants of Soultz-sous-Forêts and Rittershoffen have been almost continuously operating, with an availability higher than 90%. The micro-seismic activity has been carefully monitored in real–time since the beginning of the production. Since then, a couple of thousands of induced low magnitude earthquakes were detected (maximal reached magnitude M_L = 1.7), all located in the vicinity of the injection wells, GRT-1 for Rittershoffen and GPK-4 for Soultz-sous-Forêts (Maurer et al., 2020).

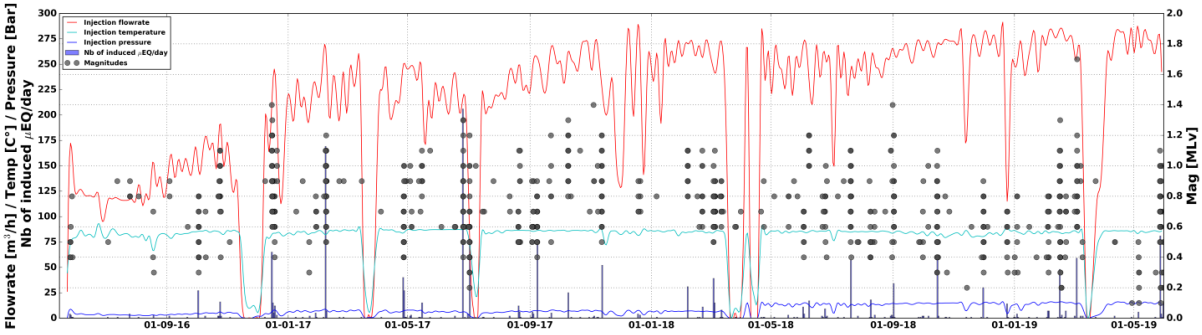

Figure A2.14. Induced seismicity associated with the injection parameters since the commissioning of the Rittershoffen plant (Maurer et al., 2020)

For the Rittershoffen plant, since the commissioning of the plant, a total of 1680 microseismic events have been automatically detected and located in the direct vicinity of the project by the local seismic network (Figure A2.14). All events have been then manually relocated. Most events are located within a radius of 1 km around the open-hole section of the injection well GRT-1 (Figure 15). The maximum recorded local magnitude M_L was 1.7 for an event occurred on the 04th of March 2018. The maximum PGV recorded for this event was 0.506 mm/s. No induced seismic event has been felt by the local population around the Rittershoffen plant since operation has started. The lowest PGV threshold value (0.5 mm/s) was only reached once, but only on one single station, so that the alert procedure has not been launched. The induced microseismic activity during exploitation is shown in Figure A2.15.

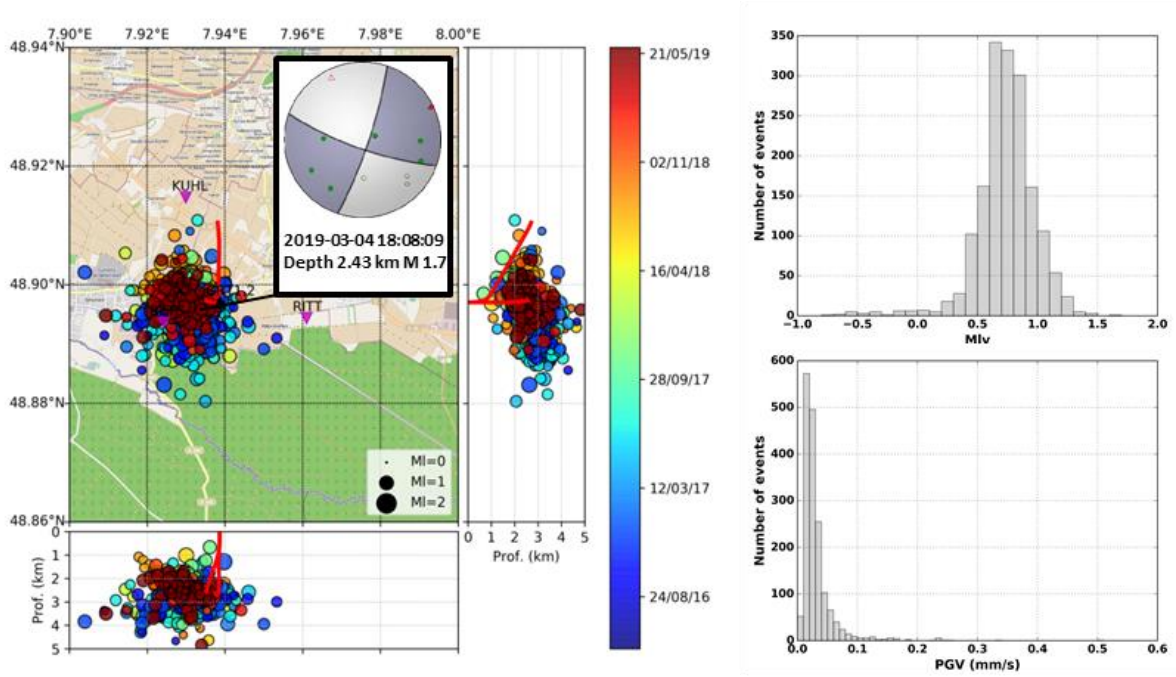

Figure A2.15. Induced seismicity during geothermal exploitation located around GRT-1 since the commissioning of the Rittershoffen plant (Maurer et al., 2020)

In Soultz-sous-Forêts, induced seismicity has been observed since injection has started in GPK4 (Figure A2.16). A total of 156 events could be located in the vicinity of the project since the commissioning of the plant in July 2016. The maximum local magnitude M_L was 1.7. The maximum PGV recorded for this event was 0.173 mm/s. The lowest PGV threshold value (0.5 mm/s) was never reached and no induced seismic event has been felt by the local population around Soultz-sous-Forêts since operation has started in 2016. The generated micro-seismic activity during exploitation is shown in Figure A2.17.

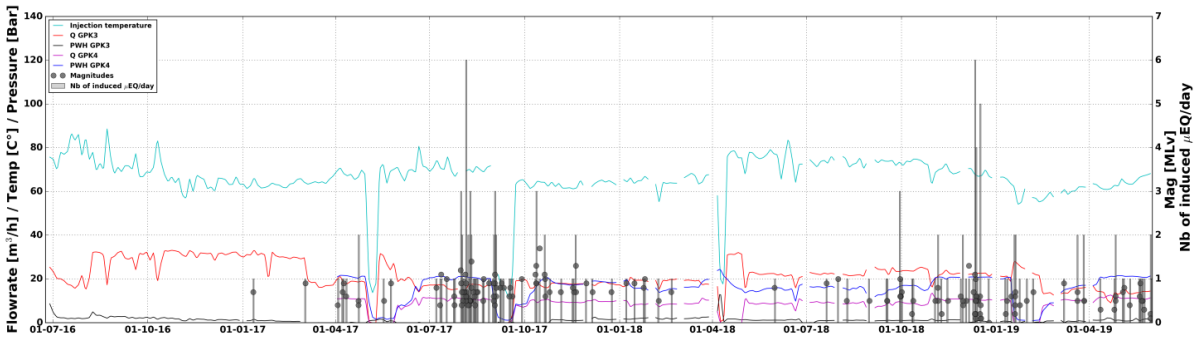

Figure A2.16. Induced seismicity associated with the injection parameters since the commissioning of the Soultz-sous-Forêts plant (Maurer et al., 2020)

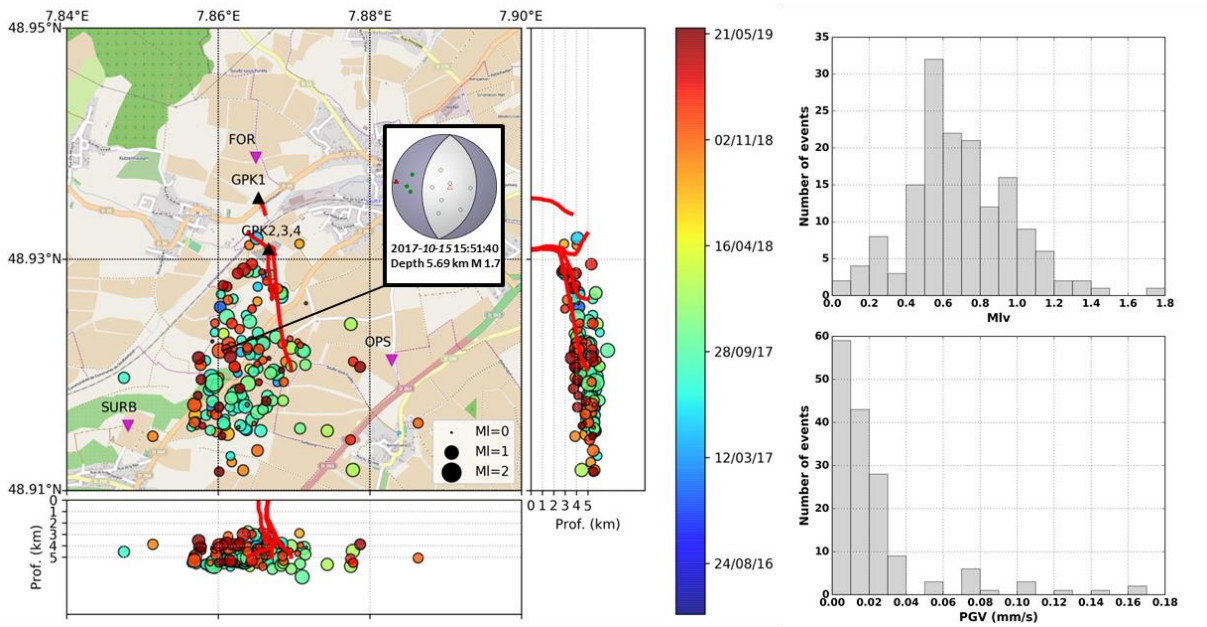

Figure A2.17: Induced seismicity during geothermal exploitation located around GPK-4 since the commissioning of the Soultz-sous-Forêts plant (Maurer et al., 2020)

APPENDIX 3: HUNGARY

General overview

General data on deep geothermal in Hungary

Hungary lies in the central part of the Pannonian basin, which is one of the European areas with a well-known positive geothermal anomaly, where the rich geothermal resources have been utilized mainly for direct use purposes for a long time (Nádor et al. 2019). In Hungary, geothermal district-heating and thermal-water heating cascade systems represent a major part of direct use available in 23 towns representing about 223 MWth installed capacity and 636 GWhth/y annual production. However geothermal represents only an appr. 2,5 % share of the total district heating capacity of Hungary (7635 MWth). In geothermal district heating (geo-DH) systems, geothermal energy supplies the already existing district heating infrastructure (operated otherwise by gas) with a 30 to 100% share of geothermal, whereas the rest remains fossil-fuel based. Such systems operate in the cities of Makó, Csongrád, Hódmezővásárhely, Szentes, Vasvár, Szentlőrinc, Miskolc, and Győr. The cities of Miskolc and Győr are the 2 largest projects (with 55MWth and 52 MWth installed capacity respectively. In Szeged, a city of nearly 163,000 habitants at the Hungarian-Serbian-Romanian border, an ambitious project recently began, with the aim of introducing geothermal energy into the district heating network. Presently, two triplets are operating with 4,4 and 4,5 MWth capacity. Another nine triplets, with similar layout and a capacity of 3 – 5 MWth each are under development: 4 triplets already have licenses; the other 5 triplets are under permitting.

The other (and more widespread) type of geothermal heating is represented by the so called “thermal water heating cascade systems”, typically in settlements without a district heating infrastructure, where the gas-based heating of some public buildings (town halls, libraries, schools, hospitals, etc) is replaced by geothermal, and which are sequentially linked along the geothermal loop according to their decreasing heat demand. Other nearby buildings (private houses) may also eventually connect to the newly established thermal water pipelines. These systems supply heat only to a separate part of the settlement through a heat supply centre (this is the case in Kistelek, Veresegyház, Bóly, Mórahalom, Gárdony, Mezőberény, Szarvas, Szeged, Barcs, Cserkeszőlő, Szolnok, Szigetvár, Törökszentmiklós, and Tamási). These local systems are commissioned on the basis of a water license and are often run by local municipalities, or municipality-owned service providers. This contrasts with the district-heating systems, where heat is provided by a trading company on a contract basis, regulated by the Hungarian Energy and Public Utility Regulatory Authority.

Individual space heating (mostly associated with spas) is available at nearly 40 locations representing an estimated installed capacity of about 77,2 MWth and 83,1 GWhth/yr production.

The agriculture sector is still a key player in direct use, especially in the S-ern part of the Hungary, where heating of greenhouses and plastic tents have long traditions. These account for about 358 MWth installed capacity and 803 GWhth/yr production. The major users are Árpád-Agrár Zrt in Szentes, Flóratom and Bauforg Ltd-s. in Szeged, Bokrosi Ltd. in Csongrád and Primőr-Profit Ltd in Szegvár, but there are many others, especially in SE-Hungary.

Balneology – i.e. bathing in natural mineral waters for health and wellness - has historical traditions in Hungary, more than 250 wells yield thermal water, sometimes medicinal waters which represent a total installed capacity of 249,5 MWth with an annual use of about 745,5 GWhth/yr. The outflow temperature typically ranges between 30 and 50 °C. The hottest ones are at Zalaegerszeg (SW-Transdanubia - 95 °C) and at Gyula (SE Hungary at the Romanian border - 89 °C).

Thus the total installed capacity for direct use is 908,06 MW (Nádor et al. 2019).

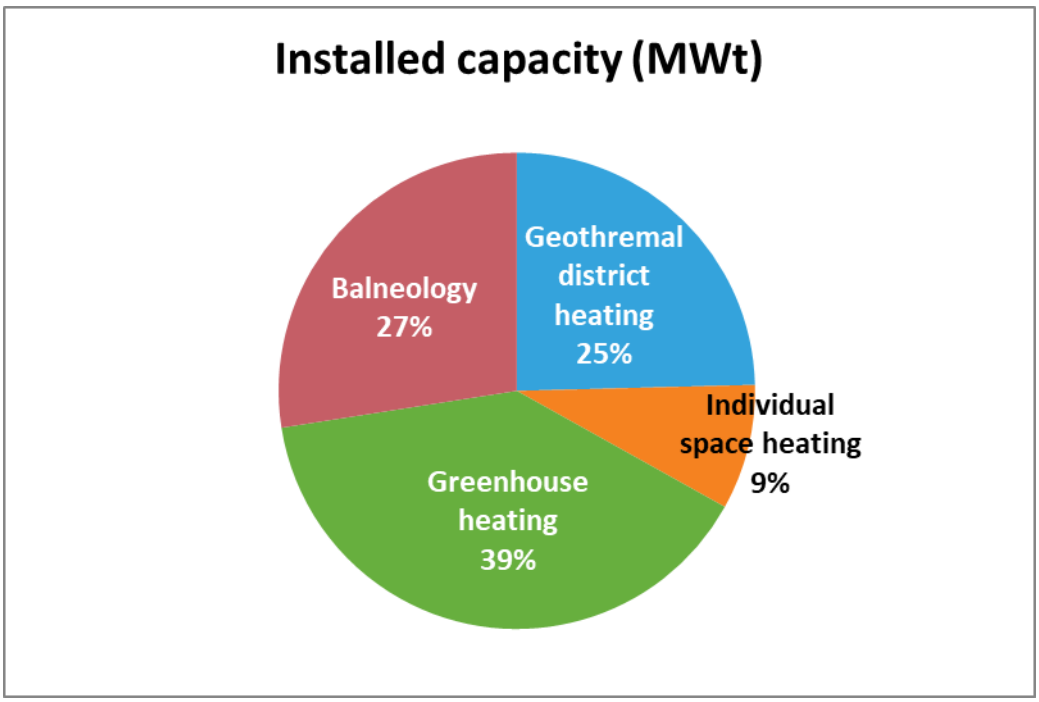

Figure A3.1: Share of the different uses of the deep geothermal energy resources of Hungary

The first Hungarian geothermal power plant project has been implemented in Tura, NE from Budapest. This project is located in a well-explored former hydrocarbon block. The project aimed to achieve a 3.0 MWe capacity. Actual gross electricity production is however only 2.3 MWe, of which nearly 1 MWe is the electricity demand of the power plant. Thus, it is capable of 1.3 MWe net. An 11-hectare greenhouse complex is also planned to use the remaining heat.

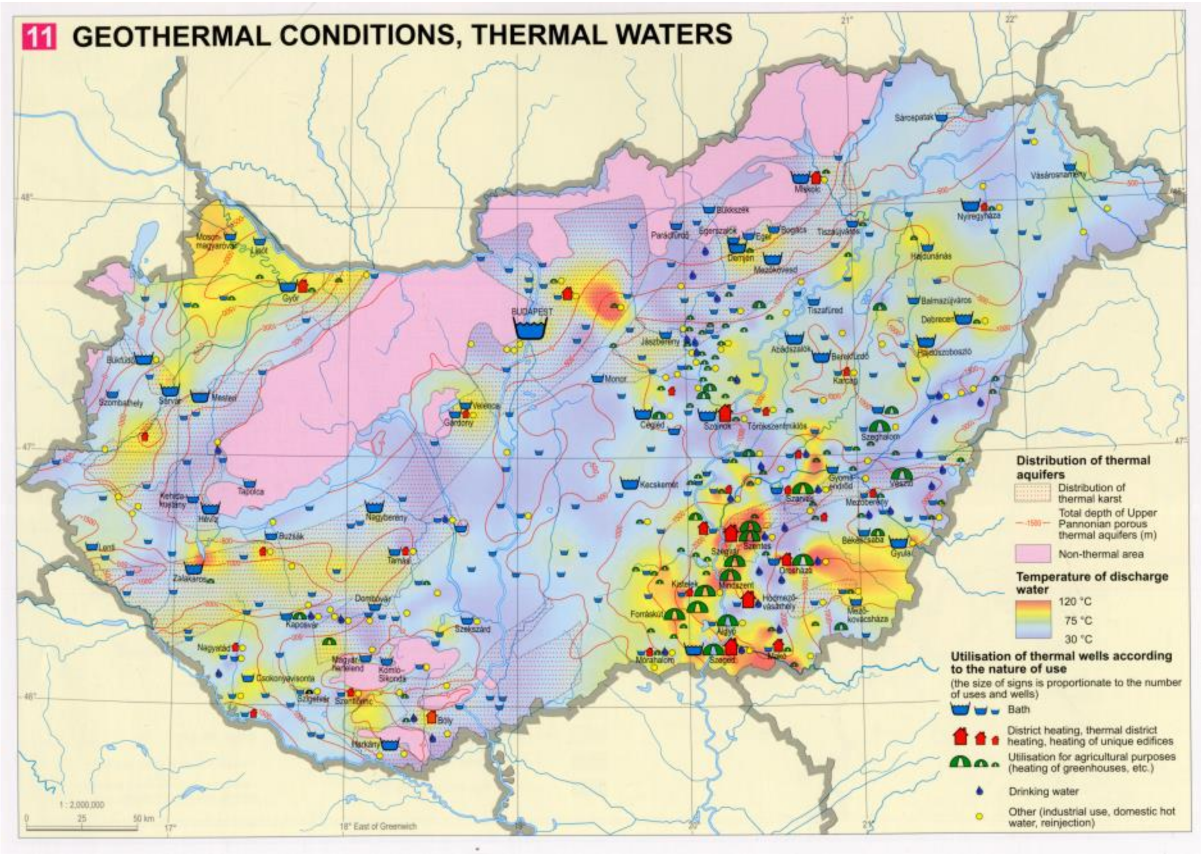

Figure A3.2: Main thermal water utilisation types and sites in Hungary

Institutional context

In Hungary all issues related to geothermal energy (including all utilization types discussed in 1.1) are organized at federal level.

The responsible ministry for energy policy is the **Ministry of Innovation and Technology**, and within that the State Secretariat for Climate and Energy Policy https://www.kormany.hu/en/ministry-for-innovation-and-technology. One of its key areas is the renewable energy, currently responsible for the preparation of the Renewable Climate and Energy Action Plan of Hungary 2030 (see also under chapter 3).

The **Hungarian Energy and Public Utility Regulatory Authority** (HEA) http://www.mekh.hu/introduction is an independent regulatory body of the energy and public utility market, supervising the national economy's sectors of strategic importance, such as electricity, natural gas, district heating. As geothermal energy plays an important role in the heating sector (there are several geoDH systems operating), especially the division dealing with district heating is interested in geothermal. As a member of the official statistical service, HEA also performs the tasks related to single national energy statistics, including renewables (and geothermal).

The **Mining and Geological Survey of Hungary** (https://mbfsz.gov.hu/en) is a central governmental body, performing all state activities related to mining and geology. As a research institute it performs various tasks related to the exploration of geothermal energy (3D geological models, numerical flow and heat transport models, various

geophysical measurements and interpretations) and based on all these data it develops integrated databases, web-map services, partly available to the public. The Survey also performs authority tasks, such as collection of mining royalty paid after geothermal energy use (based on self-declaration), keeping updated the register of geothermal energy users, as well as preparing the so called preliminary vulnerability and impact assessments necessary for the concessional tendering (see more details in chapter 2). These tasks are all prescribed for the Survey in the Mining Act. Furthermore, based on the Ministerial Decree 101/2007. (XII.23) KvVM the Department of Hydrogeology is responsible to issue Hydrogeological log-book of new wells, to maintain the National Well Cadastre and to operate the National Hydrogeological Data Store. These databases store data of more than 1000 thermal water wells in Hungary.

As deep geothermal energy is exploited by the abstraction of thermal waters in Hungary, the other „branch" of legislation and institutional organization is related to the „water management" side. Following a major reorganisation of the water management sector in Hungary, currently all authority tasks related to (thermal) groundwater are supervised by the **Ministry of Interior**, and within the **Directorate General for Disaster Management and its regional offices (**http://www.katasztrofavedelem.hu/index2.php?pageid=szervezet_intro&lang=eng). They issue all licences e.g. for thermal water drilling, operation, etc. The other main organization also supervised by the Ministry of Interior is the **General Directorate for Water Management (**http://www.ovf.hu/en/) **and its 12 regional offices,** however they do not perform authority tasks, but mainly do expert work to support water policy in general (e.g. make the regular updates of the River Basin Management Plans, manage national groundwater monitoring systems, etc).

Policies and policy visions

Hungary's National Renewable Energy Action Plan target is 14,65% RES by 2020 with a 17% share of geothermal in total RES. The geothermal target numbers by 2020 are 4,47 PJ (direct use – deep geothermal) and 57 MW_e (power production). There has been a delay in the implementation of the NREAP especially in power production.

The EU2030 targets, including the 32% RES proportion at EU level, are also taken into consideration in the recently launched (January 2020) National Climate and Energy Action Plan and the new Energy Strategy 2030, in which Hungary has committed itself to increase the share of RES in the final energy consumption to 20% by 2030. These documents emphasizes the importance of geothermal energy especially in the heating and cooling sector, first of all in switching the fossil fuel (gas) based district heating systems.

The share of deep geothermal energy in the heating and cooling sector is expected to be as much as 9 PJ by 2030. Although the share of geothermal in this sector is expected to grow by 58 % by 2030, its total share within the RES will be only 5%. The expected installed capacity of geothermal energy for power production is 20 MW by 2030, and 59 MW by 2040.

A new feed-in tariff system has been issued. This system follows the related EU regulations and ensures a competitive operation for geothermal power plants.

The 1345/2018. (VII. 26.) Governmental Decision on the Action Plan of the Utilization and Management of Energetic Mineral Resources is an important piece of recent legislation as it sets up concrete tasks with deadlines and responsible ministries concerning deep geothermal energy. It states that during the development of national RDI

programs and funding schemes, geothermal power production without water abstraction and reinjection technologies should be treated as priorities. The other important point is that it addresses geothermal risk mitigation: it calls on the Minister for Innovation and Technology and the Minister for Finances to make a joint proposal on introducing financial tools for the mitigation of high upfront risks for geothermal projects (i.e. a risk insurance scheme) by June 2019.

Environmental regulation mapping

Definition, Classification, and Resource Ownership

Since the in the licensing of geothermal projects both the water management and the mining sectors are involved, there are separate definitions for geothermal energy/thermal water. In Hungarian legislation, the definitions of "thermal water" and "geothermal energy" are differentiated. While thermal water is a term of water management related rights, the geothermal energy is regulated by mining law.

The Act LVII. of 1995. on Water Management Annex 1. gives a definition to thermal water, „ all ground water (derived from aquifer) with an outlet temperature (surface temperature) of 30 °C or higher".

The definition of geothermal energy is given by the Act XLVIII. of 1993 on Mining 49. §, „ the internal heat energy of the earth crust". Also, the law gives a definition to geothermal energy sources, „in application of the present Act, the materials in different physical states (e.g. subsurface water, vapours) which make possible the utilization of the internal heat energy of the earth crust for different purposes or with the application of other technologies."

The Act LVII. of 1995. on Water Management 6. § (6) declares that all the groundwater, and natural aquifers of groundwater are exclusively state-owned.

According to the Act XLVIII. of 1993. on Mining 3. § (1), "The […] geothermal energy is state-owned in their natural place of occurrence. The […] geothermal energy obtained for energy purposes shall be the property of the mining entrepreneur with the utilization."

Licensing and Authorization

The Hungarian law clearly defines that the geothermal energy and thermal water is state-owned and only the state can give license to access geothermal energy / thermal groundwater (carrying medium of geothermal energy). Private parties and persons can have right to use the geothermal resources after obtaining the necessary licenses and contracts, but they cannot hold ownership.

The Hungarian regulation distinguishes **open and closed areas** for geothermal resources, however this is related only for licensing, and not for other (e.g. environmental) legislation. The Act XLVIII. of 1993. on Mining 49. § defines these definitions:

"24. Closed area: the area to be designated for a concession contract [….] With respect to geothermal energy, the layer below 2500m measured from the natural surface shall be considered as a closed area throughout the country."

"20. Open area: every area not considered as a closed area in relation to the defined mineral raw material."

In open areas (above 2,5 km depths) the wells (i.e. prospection and utilization of thermal waters) are licensed by the Regional Directorates for Disaster Management (as competent authorities for water management) The closed areas (below 2,5 km depths) are under concession obligatory and wells are licensed by the Mining Authority. The Act XLVIII. of 1993. on Mining 5. § (1) defines that "Mining supervision shall license prospecting, […] g) exploitation and utilization of geothermal energy, if the activity doesn't require water license." (i.e. in areas below 2500 m)

Obtaining licenses

Content of licenses is prescribed by the relevant regulation of each licensing authorities. The structure of licenses is very similar, the following main chapters shall be appeared:

- Identification data about the licensee (e.g. name, address, tax number)
- Duration/expiry date of the license
- Licensed technical data (e.g. location, authorized quantities, equipment)
- Official and Authority requirements (concerning the construction in a permit for construction / concerning the operation in a permit for operation)
- Reporting obligation (if any)
- Explanation
- Final clause (legal basis of procedures and prescriptions, right of appeal)

For thermal water wells above -2500 m there are different consecutive steps for licensing, described in detail in the **Governmental Decree of 72/1996 (V.22.) on the tasks of the water management authorities.** Water permits have different types. *The planning (preliminary) permit* describes the general water management objectives and basic technical parameters of the planned activity and determines the amount of water to be used in the future (which is registered as reserved water resource and is considered during new applications), but it does not authorize for drilling of a well, or any kind of water utilization. This is valid for 1 year. *The construction permit* is necessary for drilling, reconstruction, or abandonment of a well, which is valid for 2 years. Only *the operation permit* authorizes for the execution of water use, which is valid for 5 years. These are all licensed by the Regional Directorates for Disaster Management (i.e. water management authority).

District heating production license

District heating production license is needed only in case the produced heat sold out on free market – if the heat utilized by the licensee itself, this license is useless. District heating production license for construction request document shall contain:

- technical data of the heat plant
- economical and technical data about the heat production
- business plan for 5 years
- P&ID of energetic equipment
- previous permits in connection with the subject matter of the application

Also, in addition to those listed above, the District heating production license for operation need to contain:

- description of quality assurance system, including troubleshooting of breakdowns and maintenance rules
- presentation of the availability of the energy sources for the medium-term district heating demand

- contract with the Heat supplier

Royalties, fees

The **mining royalty** for geothermal energy (irrespective of production depth) is 2% of the value of the produced energy, as set in 54/2008 (III.20) Governmental Decree Annex 2 Point 2

The users have to measure temperature and produced amount and calculate the produced energy in GJ. The value of produced geothermal energy is set as 2000 HUF/GJ (6 euro/GJ)

In case of **concession**, the mining entrepreneur has to pay the following fees.

- 1 500 000 HUF (4545 euro) + VAT participation fee (to get the tender materials)
- concession fee (this varies on the basis of the size, properties of the area, to be determined case-by-case). For the last tender for the Gádoros concessional area of 419,4 km2, it was 21 000 000 Ft (63 636 euro) + VAT
- tendering security deposits: 15 000 000 HUF (45 445 euro)

Water fee (in case of thermal water production) to be paid after the used amount., as determined in the 43/1999 (XII.26) KHVM Ministerial Decree. Water fee= produced amount (m^3) x basic fee (HUF/m^3)* x m** x g***

*basic fee: 4,5 HUF (0,01 euro) / m^3, in case the produced amount is 10% more than the licensed: 9 HUF (0,02 euro) / m^3, in case of production without license: 28,9 HUF (0,08 euro) /m^3.

**m: measured amount: 1, calculated amount: 2

***g: based on the utilization type, in case of thermal waters:

medicinal use: 1

public use: 1

drinking: 3

fish farming: 5

renewable energy use: 2

balneology: 3

other: 7,5

No water fee to be paid after the reinjected amount of thermal water.

Monitoring

Generally, the regulatory authorities surveille the licensed activities with regards to permanent reporting duties and occasionally on-site visits. The frequency of on-site visits depends on the possible environmental effects of the licensed activity (type of facility, influenced water management system, depths, gas content etc).

The reporting duties are strict, an operational log needs to be written with the information of monthly measured water meter position, daily measured water flow, pressure of wellhead, yearly measured water quality results, gas content results, four years periodic measurements results, the maintenance operations of the equipment, deviation from normal operation events.

The reporting duties, and the frequency of on-site visits are determined in the permits.

Above 2500 m

In case of water licensing based objects, the licensing authority surveille the construction very rarely, although the authority has access to the electric construction log.

The water management authority classifies the water facilities and water utilizations during the water licensing procedure of operation and defines the supervision procedure, based on legal prescriptions (72/1996 (V.22.) on exercising the authority of water management, with attention to the type of facility and to the role of the regional water management. Important objects (with relatively high influence on water management) controlled once a year by authority during operation, lesser important controlled with a lower frequency (every second or fifth year), or just occasionally.

In some cases, the drilled wells enrolled to the national groundwater monitoring system, then additional data shall be sent to the authority on yearly basis.

Generally, an operation log must be written gathering the most relevant data (quantity, quality, water level, etc), and sent to the authority in every year.

Below 2500 m

In case of mining licensing based objects, the surveillance mostly based on self-detection of mining entrepreneur, although mining authority has the right to supervise both construction and operation on site. The technical operation plan shall be reviewed annually by the entrepreneur and be obliged to apply for the modification of the technical operation plan if any circumstances have changed (Governmental decree 203/1998 (XII.19.) implementing the Act XLVIII. of 1993. on mining, 14. § (3)).

The mining entrepreneur shall declare mining royalty quarterly to the Mining Authority, as well as to be paid to the accounts of the central budget separated for such a purpose (Governmental decree 203/1998 (XII.19.) implementing the Act XLVIII. of 1993. on mining, 4. § (5)).

Environmental licensing / legislation

The main piece of environmental legislation is the LIII Act on Environment (1995).

Environmental licensing is the first step of project development, exploration and construction licensing could be started only in possessing (if necessary) an environmental license.

During environmental preliminary licensing process, the environmental authority involves special authorities (directorate for water management, directorate for disaster management, land- and soil protection authority, public health and medical officer, notaries, etc) to make decisions on their relevant fields. Starting of licensing procedure and other relevant data are published on the website of the environmental authority, the study itself also shall be available via internet for the public. All those, whose property is affected by the calculated impact area are involved into the licensing process as a client and has the right to access licensing document and express their views. Those NGOs (mainly nature protection organizations) whose operational area are under the impact assessment or the activity itself are considered as clients also.

During environmental impact assessment (see below) similar rules takes places as above. Additionally, a so called public consultation shall be organized, where the population under the impact area shall have the possibility to be informed about the planned activity, its effects, and the planned effect/risk mitigation procedures. Environmental authority prepares a report about the consultation, and the results have to be considered in the license.

In the case of closed areas for future concession (i.e,. below 2500 m), a so called a ”**Complex vulnerability and impact assessment” (Governmental Decree 103/2011 (VI.29.)** has to be done with the aim to determine those areas, where future mining activity cannot be performed due to environmental- and nature protection, water management and protection of water resources, protection of cultural heritage, - agriculture, public health, national defense, land-use, transportation issues, as well as mineral resource management.. The detailed content of the study is listed in Appendix 2 of the decree. It includes the geographical location of the area, description of land-use, geological, hydrogeological, tectonic characterization and status of previous exploration, protected areas related to the water management plans, status of the surface- and subsurface (ground)water bodies, their monitoring, rate of groundwater abstraction, other valid licenses for exploration and exploitation. The study also summarizes data related to the geological environment of geothermal energy, expected amount to be exploited, foreseen exploration and exploitation methods, introduction of the energy concept, duration of activity and forecast of environmental impacts with a special regard to surface and subsurface (ground)water bodies, drinking water resources, areas of natural protection (Natura 2000), and possible transboundary effects.

According to article 4, The Hungarian Office for Mining and Geology (who is responsible for the compilation of the study) sends the report to the public authorities listed in Appendix 1 for comments and supplement with further specific data. These authorities determine those areas where mining activity cannot be performed, or only with certain restrictions.

Activities requesting an **Environmental Impact Assessment** are listed in **Governmental decree of 314/2005 (XII.25)** Annex 3. According to this an EIA is compulsory for geothermal plants (power or heat) if (a) capacity is above 20 MW, (b) it is within the protection zone of mineral-, medicinal- or drinking water resource, (c) it is within a Nature 2000 area. An EIA is also compulsory if thermal water abstraction exceeds 500 m^3/day from thermal karstwater, or 2000 m^3/day from thermal groundwater (porous) resource.

During impact assessment all relevant effects related to the subsurface (with a special attention on groundwater resources), air quality, noise and wastes are evaluated considering the thresholds identified in separate legislations for each media. These are the following:

Groundwaters

The Acts on the general rules of environmental protection (Act LIII of 1995) and on water management (Act LVII of 1995) and related governmental decrees provide a general framework for protection of waters (including groundwater) in line with the Water Framework Directive (2000/60/EC) and the Directive on the protection of groundwater against pollution and deterioration (2006/118/EC). All provisions in the Hungarian legislation (i.e. thresholds, their determination, etc.) are in line with the EU legislation. There are hardly, if any articles that are specifically phrased for thermal waters. Therefore environmental protection and water management-related legislation associated with the utilization of thermal waters (for energetic or balneological purposes) are encompassed in these laws.

Basic principles regarding the protection of waters are given in articles 18-21 of the **Act LIII of 1995 on the general rules of environmental protection** and in article 15 of the **Act LVII of 1995 on water management**. According to these the protection of water in general encompasses the protection of surface and groundwaters, their reserves, *quality* (including temperature conditions) and *quantity,* their natural aquifers (such including thermal water reservoirs). Groundwater resources can be utilized only to that extent that the dynamic equilibrium of recharge and abstraction is maintained without quality deterioration, and targets related to the good status of waters phrased in the Water Framework Directive are achieved. The actions to achieve the good status (both in terms of quality and quantity) have to be determined in the river basin management plans, which details are regulated in the **Governmental Decree 221/2004 (VII.21.) on certain rules of river basin management**.

The aim of the **Governmental Decree 219/2004 (VII.21.) on the protection of groundwaters** is to regulate tasks, rights and obligations associated with ensuring and maintaining the good status of groundwater, progressive reduction and prevention of their pollution, a sustainable water use based on the long-term protection of available groundwater resources and the remediation of the geological medium. In terms of thermal groundwater, their *quantitative status* has been primarily investigated, as due to overexploitation drops in groundwater level / hydraulic head is registered at many places. According to the decree, a groundwater body is in good quantitative status if the long-term (min. 6 years) annual abstraction rate does not exceed the available groundwater resource, abstraction does not cause a permanent decrease in groundwater level or hydraulic head, and ecological or chemical status of associated surface waters are not threatened by any deterioration in the coupled groundwaters. Further criteria are that no alterations in the subsurface flow directions take place which could cause significant changes in the chemical or physical status of the groundwater body and no groundwater-dependant terrestrial ecosystems are damaged.

According to article 9, in order to achieve the good quality status, water abstraction cannot exceed the so called “abstraction limit value (Mi)” which would ensure that abstractions do not cause permanent drop in the groundwater table / hydraulic head and do not result the mixture of other surface or subsurface waters causing unfavourable changes in quality. However the determination of the Mi values for the groundwater bodies still has not happened.

A groundwater body is in good *qualitative (chemical) status* if its monitoring proves no contamination, measured values do not exceed the threshold values, or the natural background values (if it is higher than the threshold value), or individual contamination limit values, water quality does not hinder to achieve the environmental objectives of associated surface waters, and no groundwater-dependant terrestrial ecosystems are damaged. Furthermore a groundwater body is in good qualitative status if it has good chemical status and its temperature does not decrease to such extent which may cause changes in its chemical or qualitative status, or flow paths and does not disturb utilization.

The natural background and threshold values have been determined in the National River Basin Management Plan, following the guidance of the 2006/118 EC Directive (art 3 and Appendices I and II) which are the following for the different thermal groundwater bodies:

Groundwater body	Nitrate			Ammonium		Conductivity		Sulphate		Chloride		Arsenic		Cadmium		Lead		Mercury	
	B	Tecol	T drink	B	T	B	T	B	T	B	T	B	T	B	T	B	T	B	T
name	mg/l			mg/l		µS/cm		mg/l		mg/l		µg/l		µg/l		µg/l		µg/l	
Észak-dunántúli termálkarszt	<1	N	N	16,7	N	5097	N	266,0	N	627,0	N	24*	N	0,1*	N	3,42*	N	0,5*	N
Budapest környéki termálkarszt	<1	25	50	0,86	N	1720	N	371,0	N	196,0	N	16,8	N	0,09	N	2,7	N	0,07	N
Visegrád-Veresegyháza termálkarszt	<1	N	N	0,39	N	3239	N	138,0	N	107,0	N	13,9	N	0,02	N	3	N	0,5*	N
Nógrádi termálkarszt	<1	N	N	0,99	N	2850*	N	126,0	N	121,0	N	24*	N	0,1*	N	3,42*	N	0,5*	N
Szabadbattyáni termálkarszt	<1	N	N	2,2	N	2904	N	637,0	N	462,0	N	20,8	N	0,21	N	3,6	N	0,48	N
Közép-dunántúli termálkarszt	<1	N	N	15,9	N	11805	N	48,4	N	5098,0	N	34,9	N	0,13	N	1	N	0,5*	N
Mecseki termálkarszt	<1	N	N	5,6	N	1560	N	519,0	N	1271,0	N	155,0	N	0,06	N	1,8	N	0,16	N
Dél-Baranya, Bácska termálkarszt	<1	N	N	7,4	N	2460	N	38,4	N	456,0	N	6,8	N	0,1*	N	3,42*	N	0,5*	N
Sárvári termálkarszt	<1	N	N	7,1*	N	2850*	N	1160,0	N	23991,0	N	24*	N	0,1*	N	3,42*	N	0,5*	N
Bükki termálkarszt	<1	N	N	16	N	6761	N	271,0	N	1127,0	N	1,6	N	0,17	N	2,9	N	0,5*	N
Bükki termálkarszt	1,1	25	50	4,2	N	2038	N	64,4	N	246,0	N	60,0	N	0,06	N	0,9	N	0,5	N
Sárospataki termálkarszt	<1	N	N	0,19	N	2850*	N	601,0	N	95,9	N	24*	N	0,1*	N	3,42*	N	0,5*	N
Recsk-Bükkszék termálkarszt	<1	N	N	12,1	N	19501	N	373,0	N	2580,0	N	11,2	N	0,16	N	3,42*	N	0,5*	N
Harkány és környezete termálkarszt	<1	N	N	2,3	N	1448	N	27,7	N	113,0	N	1,3	N	0,1*	N	3,42*	N	0,5*	N
Nyugat-dunántúli termálkarszt	1,0	25	50	0,77	N	854	N	107,0	N	50,7	N	1,2	N	0,07	N	4	N	0,11	N
Északnyugat-Dunántúl	<1	N	N	28,4	N	6846	N	87,8	N	1640,0	N	35,2	N	0,12	N	2,3	N	0,11	N
Nyugat-Alföld	<1	N	N	25,2	N	8624	N	27,2	N	3391,0	N	13,9	N	0,1	N	6	N	0,45	N
Dél-Alföld	<1	N	N	14	N	3055	N	32,0	N	96,2	N	28,2	N	0,1	N	2	N	0,03	N
Észak-Alföld	<1	N	N	11,7	N	3134	N	25,0	N	500,0	N	49,2	N	0,24	N	5,1	N	0,32	N
Délkelet-Alföld	<1	N	N	16,1	N	3279	N	56,7	N	271,0	N	98,0	N	0,23	N	3,3	N	0,28	N
Északkelet-Alföld	<1	N	N	11,5	N	9430	N	28,2	N	2197,0	N	43,0	N	0,11	N	2,5	N	0,48	N
Északi-középhegység medencéi	<1	N	N	5,2	N	5778	N	137,0	N	1651,0	N	1,4	N	0,16	N	3,07*	N	0,23*	N
Délnyugat-Dunántúl	<1	N	N	12,1	N	3212	N	42,4	N	1192,0	N	8,1	N	0,1	N	2,4	N	0,1	N

B: background value, T: threshold value, N: no threshold value

General values: trichlor etilen: 10 µg/l, tetrachlor etilen: 10 µg/l, AOX: 20 µg/l, total pesticides: 0,5 µg/l

The different contamination threshold values for groundwaters are determined in Annex II of the Ministerial Decree 6/2009 (IV.14) in the following groups: (metals, inorganic components, aliphatic hydrocarbons, benzols and alkil-benzols, phenols, polycyclic aromatic hydrocarbons, halogenated aromatic hydrocarbons, halogenated aliphatic hydrocarbons, chlor-phenols, polychlorinated biphenyls, polychlorinated dibenzo-dioxines, pesticides, pH, others.

KvVM /Ministerial Decree 30/2004 (XII.30.) on certain rules of examination of groundwaters applies to the designation, characterization, status assessment, monitoring of groundwater bodies, as well as the collection, processing and reporting of data necessary for the execution of these tasks.

According to article 3, water bodies should be designated on the type and occurrence of the aquifer, such as karstic formations, non-karstic and porous formations of basin areas, and formations of non-karstic mountainous areas. Based on the outflow temperature, the 2 main categories are cold waters with a temperature below 30 °C, and thermal groundwaters with temperature exceeding 30 °C.

According to article 9, the status of groundwater bodies has to be evaluated and assessed according to Appendix 2. During the quantity status assessment the relationship of the contents of the application form and its annexes to be submitted for granting the water permits − determined in the Governmental Decree 221/2004 (VII.21.) on certain rules of river basin management − and real load (amount of exploited water) has to be investigated by the followings tests: water budget test (ratio of recharge and abstraction), surface water test (effects on related surface water body), ecosystem test (effects on related terrestrial ecosystems), flow pattern test (admixture of saline, or other chemical types of waters).

During quality status assessment the following tests have to be performed: general water quality test (to determine spatial distribution of contamination), surface water test (contamination effects on related surface water body),

ecosystem test (contamination effects on related terrestrial ecosystems), drinking water test (contamination effects on drinking water reserves), temperature test.

For the chemical status assessment the background concentration of natural components has to be determined.

In addition to the above summarized sets of laws approaching the protection of groundwater reserves (such including thermal waters) from a river basin management / groundwater body quantity/quality status point of view in line with the Water Framework Directive, article 14 of the Act LVII of 1995 on water management introduces the terminology of *protection zones,* also related to mineral and medicinal waters, which is regulated in details under **Governmental Decree 123/1997 (VII.18.) on the protection of water resources**. According to article 2, the protection of such groundwater resources means the delineation and maintenance of protection blocks and zones, which have to be divided into inner-, outer- and hydrogeological protection zones. The boundaries of these zones have to be outlined on the basis of hydrogeological conditions, the actual, or potential water exploitation of the water resource, and details provided in Appendix 2.

According to article 3, the task of the inner protection zone is the technical protection of the well itself and the protection of the water resource from direct contamination. The outer protection zone should safeguard the water resources from other degrading and bacterial contaminations, while the hydrogeological protection zone should protect the resources from non-degrading contamination which has to be outlined for parts, or for the entire recharge area.

According to article 4, the dimensioning of the protection zones is based on the travel times, calculated from permanent groundwater flow velocity (i.e. the time necessary for a pollutant, or water particle to reach the abstraction site).

Article 8 summarizes the main aspects of delineation of the different protection zones, such as the targeted depth interval, the amounts of water with abstraction permits, brief geological, characterization of the aquifers of the protected water resources, restrictions in land-use, necessary measures and monitoring and their assessment.

According to article 10, only those activities can be performed in the different protection zones, which do not endanger the quality or quantity of the water to be abstracted. Article 11 regulates and gives restrictions for activities to be performed in the inner protection zone, article 12 for the outer protection zone and article 13 for the hydrogeological protection zones. Such activities are potential pollutions from agriculture, animal farming, industry, etc. The detailed list of the prohibited activities in the different zones is listed in Appendix 5.

At last, but not at least, in addition to the above outlined two major approaches on environmental objectives (groundwater body status assessment and protections zones of groundwater resources), the third major set of laws is really specific to the sustainable utilization of thermal groundwaters and is associated with *re-injection.*

According to article 21 of the Act LVII of 1995 on water management the utilization of water, their load, the input of used and wastewaters into water bodies − after a necessary treatment − can happen only in a way that does not threat the natural processes and the quality and quantity renewal of the water reserves. Article 15 explicitly states, that thermal water abstracted solely for geothermal energy utilization has to be re-injected. Further general provisions of re-injection are given in Governmental Decree 219/2004 (VII.21.) on the protection of groundwaters

(article 10: to prevent re-injection of contaminating materials into groundwaters and to limit those activities which would cause the deterioration of the good chemical status of the water body, or would permanently increase the concentration of contaminating materials, article 13: the re-injected groundwater does not contain any materials different from the originally abstracted water, and thus does not cause the deterioration of water quality).

Governmental Decree 147/2010 (IV.29.) on the general regulations related to the activities and establishments serving the utilization, protection and mitigation of damages of waters comprises the most important regulations concerned re-injection of thermal groundwater.

According to article 10, waterworks (wells) aiming water production solely for energetic purposes have to be planned in a way, that their operation does not affect unfavourably the discharge and temperature of thermal karstic springs. The thermal groundwater abstracted for energetic purposes may be reinjected to the same aquifer after utilization, but surface disposal/discharge is also allowed considering the amount and quality of the used thermal water, its impacts on the environment, the capacity of the surface recipient.

According to article 11, thermal groundwater can be utilized for medicinal and other health purposes, as drinking – and mineral water, for balneology, warm water supply in households, heat production and generation of electricity. During the planning of utilization, a multi-purpose (cascade system) operation and economic water use should be targeted. The utilization of accompanying gases should be also considered. During the construction of a waterworks using thermal groundwater, the safe disposal of utilized water, especially their reinjection has to be taken care of. Throughout the selection of a potential surface reservoir, environmental aspects and natural recharge processes have to be considered. Thermal water for household warm water supply can be delivered to the pipeline system only if the water meets the quality requirements of drinking water. If the thermal water is a certified mineral-, or medicinal water, than water treatment has to be designed on the basis of individual analyses. Medicinal waters can be treated only by a technology that does not weaken its healing effect.

Article 28 summarizes the provisions for disposal and cleaning of used thermal waters (in case they are not re-injected). It says that if any of the components of the used thermal water are above the threshold values, then the thermal water has to be discharged into an artificial lake. In case the used thermal water and the cleaned wastewater of the settlement have no harmful interactions, they should be drained together.

In relation to reinjection, the provisions of this decree have to applied in licensing procedures starting after the decree comes into force, except for those activities, which preliminary water permit was already issued before (78§). Operational water permits applied for after December 22, 2012 and their prolongation are under the scope of this decree.

Governmental Decree 220/2004 (VII. 21.) on the protection of surface waters is relevant when discussing of releasing used thermal water (without re-injection) into surface waters, which may contaminate them, as thermal waters may contain natural components (e.g. remnants of hydrocarbons, some metal compounds) listed as ‘hazardous materials’ for surface waters in the Appendix 1. The Decree discusses in detail the waste water fine and Appendix 2 provides its detailed calculation method.

KvVM /Ministerial Decree 28/2004. (XII. 25.) on the threshold values of water contaminating materials and on certain rules of their application contains provisions on the thresholds values of various contaminating materials in different fields. Chapter 34 specifies threshold values for thermal water discharge into surface recipients

(e.g. rivers, streams) in 3 categories: medicinal, balneological, and energetic. The highest allowable threshold values are provided for the medicinal utilization (5000 mg/l) thus appreciating its economic and public health value, while lower values are allowed for balneological (2000 mgIl) and energetic (3000 mg/l) utilization (. The allowed heat load is 30 °C in all 3 categories (i.e. this is the maximum allowed temperature at which thermal water can be released at the surface).

Air quality

The general provisions on the protection of air are in the Governmental Decree 306/2010 (XII.23.)

Air quality is regulated by the **4/2011 (I. 14.) Ministerial Decree on the threshold values of air quality and point-source emissions** It determines the hourly, daily and annual threshold values in µg/m^3 for the flue dust (for PM10 and PM 2,5), as well as the injurant substances within, identified by their CAS numbers. It also determines the threshold values for information and alarm. It also specifies threshold values for certain industrial processes, but nothing specific for geothermal. **The 6/2011 (I.14) Ministerial Decree on the assessment and monitoring of emissions** discusses the measurement and calculation methods.

Pollutant	**Annual threshold value (**µg/m^3)
SO_2	50
NO_2	40
CO	3000
flue dust	40
Pb	0,3
Hg	1
bensol	5
As	0,01
Cd	0,005
Ni	0,025
Cr	0,05
Be	0,05
Buta-dyen	2,25
Dioxynes	10^{-6}
Tetrachlor-etylen	60
Trichlor-etylen	23

Vinil-chlorid	5

Table A3.1: Threshold values for a number of pollutants

Waste

The produced waste (e.g. drilling mud, drilling devices) has to be handled according to the provisions of the Act CLXXXV of 2012 on wastes. It does not comprise radioactive wastes, and air pollutants which are regulated separately.

Sustainability and Environmental Impacts

Noise

This is regulated by the Governmental decree **284/2007 (X.29.) on protection against vibration and environmental noise,** and the **Governmental decree 280/2004 (X.20) on the assessment and mitigation of environmental noise**. This latter encompasses provisions on the preparation of strategic noise maps, contents of the action plan, establishment and roles of a noise committee. Threshold values are determined in the **KvVM.EüM Ministerial Decree 27/2008 (XII.3.)** for different types of activities (geothermal falls under the category "construction"), different parts of the day (day and night), depending also on the duration of the construction activity. Various threshold values (typically between 50-70 db) determined for various types of builidings (e.g. residential, hotel room, public building, hospital, etc.)

In geothermal context noise is relevant while using high-capacity pumps (rarely near to habited areas), or drilling noise. This latter is the case at the moment in the city of Szeged (3rd largest townof Hungary), where the drilling of new triplets is happening in the middle of the city. The noise of the drilling has caused a lot of complain from the inhabitants.

Drilling of a new geothermal well in downtown Szeged

Visual / land occupation

Thermal water use has long lasting (more than 50 years) traditions in Hungary with nearly 1000 thermal water wells in the country, so these are “part of the culture” and the landscape. The wellheads are normally well maintained, occupy small land.

Typical thermal water wellhead in Hungary (Zalakaros K-11, with the automatic production control unit)

Dust and smell

See under 2.3.2 Air quality

Degassing

Degassing is a common environmental issue in Hungary. At many locations the natural gas reservoirs and the geothermal aquifers – both accommodated in the thick porous basin fill sedimentary sequence of the Pannoninan Basin – are in hydraulic connections resulting in a high ratio (often close to 1:1.) of the produced thermal water and the gas (most often CO2 and methane). As most of the individual utilization sites for various direct use purposes (mostly heating of greenhouses) are relatively small, the volumes of the produced gas content is not of commercial interest, furthermore there is no penalty incurred, when it is released to the atmosphere, if it is in category “A” of the 12/1997 Ministerial Decree. (Otherwise degasification is compulsory.) Therefore the methane content is utilized rarely at present in auxiliary equipment.

The **Ministerial Decree 12/1997 (VIII.29) on the degasification of produced waters** classifies waters into 3 categories according to their measured gas content at 1013 millibar pressure and at 20 °C temperature, such as the following:

- below the threshold of 0,8 l/m^3 „A”;
- between 0,8-10 l/m^3 „B”,
- above 10 l/m^3 „C”.

The Decree describes in detail the procedure of analyses, which can be done only by nationally accredited laboratories. The analyses are pre-requisite to get an operational license for water wells. Degasification is compulsory in water falling into ”C” category applying a MSZ-10-226 certificated degasifying unit. In “B” category the degasification has to be done under the normal operational circumstances, while in category “A” it is not required. The degasification has to be done in a way that it does not cause the deterioration of water quality.

The gas content has to be regularly monitored with repeated analyses: in category “A” – every 5 years, in category “B” – every 3 years, in category “C” – every 2 years.

Ground surface deformation

Although there is a significant amount of thermal groundwater abstraction in Hungary (appr. 60million m3/year), ground surface deformation (sinking) has not been observed so far.

Seismicity

As there are no geothermal projects using hydraulic fracturing in Hungary, this is not relevant. However it has to be mentioned, that the some oil companies use hydrofracturing during the exploitation of unconventional hydrocarbons in some deep basins (4000 m or deeper) with detailed and strict monitoring of induced seismicity, but such unfavorable effects have not been registered yet (mostly due to the soothing effect of the thick overlying “soft” sedimentary clayey succession and the high geothermal gradient which makes sediments ductile).

Interconnection of aquifers and disturbance of non-targeted aquifers

The adverse environmental effect to accidentally connect aquifers via the wellbore, or disturb non-targeted aquifers with fluid intrusion (geothermal fluid, testing fluid, drilling mud, etc.) is a case specific issue, which is regulated through the **Ministerial decree 101/2007. (XII. 23.) on the requirements of drilling water wells and intervention into water reserves**. Art. 4 states about the technical details of using casings / cementing during drilling in order to avoid contamination of non-targeted aquifers, Art 5 says that well-logging is compulsory after the drilling is completed (details in Annex I), the gas content has to be measured according to the provisions of the 12/1997 Ministerial Decree, and thermal water wells and related surface pipelines have to be constructed from materials resistant to corrosion and in a way that scaling could be removed. Art 7 emphasizes that when drilling is completed, the finalization of the well has to be done in a way that the produced water des not contaminate any surface,or subsurface waters. These are all the responsibilities of the drilling company. Art 10 and 11 list the special provisions of thermal water wells and geothermal installations: these include that the wellhead (both the production and the reinjections well) has to be equipped with a flow-meter, regular (daily) measurements should include discharge, pressure, temperature and water level.

Reservoir and surface recipient physical and chemical modifications

The prevailing, historical use of geothermal energy has been based on the irreversible extraction of thermal water. This is unfortunately still the practice in many regions in Hungary, where the energy-depleted (cooled) waste thermal water is usually emitted to a surface recipient such as a lake, a river, or a channel. The possible consequences of such discharge can be:

- Salinisation – increased chemical load of the recipient surface waters
- Thermal pollution – increased thermal load of surface waters

- The increased chemical load of the atmosphere – in some cases methane and carbon-dioxide are emitted as free gases
- Depletion of geothermal resources – usually first reflected as a significant decrease of the water level and/or pressure in production wells, but sometimes indicated in changes in temperature and the chemical composition of thermal water
- Depletion of produced energy over time, given that most heat is stored in the rock and not in the water

While reinjection is successfully applied to many fractured reservoirs and the large geothermal district heating systems of Hungary (e.g. Miskolc and Győr) operate based on a 100% reinjection, it is still a challenge in porous geothermal aquifers (Szanyi et al. 2015), which are very common in the Pannonian basin. These geothermal aquifers are usually composed of an alternation of sandy/loose sandstone, and silty and clayey layers of variable thickness. The most common challenges refer to the damage caused to the formation due to drilling and well activities (and even the injection process itself) which result in a deterioration of the permeability of the rocks. Clogging is mainly caused by the migration of fine particles among larger grains in the reservoir, near the well, or in the screens. Moreover, reduction of permeability may also be a result of: (a) swelling of clays, silica, or carbonate scaling in the piping, well or reservoir, (b) biofilm growth, and/or (c) corrosion particles originating from the surface pipelines.

The specific location of a well plays a key role in porous aquifers since it has a major influence on the productivity and lifetime of a well. The depth of the reinjection well and its distance from the production zone will affect the aquifer pressure and timing of the possible thermal breakthrough. The optimal location of a reinjection well is a place where the pressure supply and injected water quantity are as great as possible, the probability of thermal breakthrough is minimal, and the investment costs are as low as possible. In order to achieve these conditions, the fulfilment of several physical parameters are advised based on the Hungarian experience: effective porosity should be more than 20%, permeability more than 500 mD, and filtered thickness should be above 20 m (Szanyi et 2015). Successful prevention of such damage requires comprehensive knowledge about the processes involved. The primary aim here is to avoid sudden starts and stops of the flow. Therefore, it is advised that an accumulation tank should be built in the vicinity of the reinjection well so as to provide an injection flow rate which is as constant as possible.

In any case, completion of the wells by under-reaming and gravel pack is essential, as is the provision of an overground micro-filtering system. The latter removes the suspended solids from the water prior to injection in the well. It is also advised (Szanyi et al. 2015) that all wells are shut-down at least once a year so that their static water level can be measured and the surface piping system can be cleaned. If the pressure in the exploitation system starts increasing, the following interventions are necessary:

- filter cleaning with a compressor, hourly water sampling and visual inspections,
- sterilization of the piping system,
- backwashing of the reinjection well with hourly water sampling,
- bottom-hole cleaning of the well, incorporating packer tests,
- layer cleaning involving acid treatment.

Reinjection has been generating the most heating discussions in Hungary among geothermal energy users (especially those of the agriculture sector, who do not have reinjection wells, but represent a significant proportion of the direct use) and authorities. Regulation whether reinjection is obligatory or not has been changing several times over the last decades, at the moment it is not compulsory, but is determined case-by-case, as declared by the **Governmental Decree 147/2010 (IV.29.)**
According to article 10, the thermal groundwater abstracted for energetic purposes may be reinjected to the same aquifer after utilization, but surface disposal/discharge is also allowed considering the amount and quality of the used thermal water, its impacts on the environment, the capacity of the surface recipient.

Effects of surface operations (energy consumption, emissions and water consumption)

Emissions of drilling rigd is not a major impact, for related regulations see 'Air quality' above.

Water consumption during drilling phase is not a major impact either, general provisions of the LVIII Act of 1995 on water are valid. As there is no (except for one small-scale pilot project) geothermal power production, i.e. no lartge cooling tanks are necessary, there is no water consumption for the operational phase.

Waste

See under 'Waste' above.

Radioactivity

Some thermal waters have reasonable radioactivity in Hungary (see Table A3.2), especially those yielding from the thermal karst system of the Buda hills, however these are considered and used as medicinal waters with no environmental impact.

Type of water	Activity Bq/l
Drinking water (pipelines) – for reference	2-3
Marget island (Budaspest)	7
Miskolctapolca	11
Lukács bath (Budapest)	20
Császár bath (Budapest)	30
Püspökfürdő (Eger)	80
Mátyás spring, Rudas spa (Budapest)	246

Attila spring (Budapest)	440
Diana spring , Rudas spa (Budapest)	840

Table A3.2: Radioactivity levels of some thermal waters

The relevant legislations are the CXVI Act of 1996 on Nuclear Energy and the Governmental decree 487/2015 (XII.30) on the protection against radiation and related licensing, reporting and monitoring obligations. The latter identifies the exploitation of geothermal energy as a potential activity, however no further specifications are provided.

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APPENDIX 4: ICELAND

General overview

General data on deep geothermal in Iceland

Iceland is a young country geologically, started forming above the ocean surface about 16-18 Ma. The island lies astride one of the earth's major fault lines, the Mid-Atlantic ridge, which is the boundary between the North American and Eurasian tectonic plates, that are moving apart at a rate of about 2 cm per year. Iceland is an anomalous part of the ridge where deep mantle material wells up and creates a hot spot of unusually great volcanic productivity. The spreading tectonic plates along with the mantle plume makes Iceland one of the few places on earth where one can see an active spreading ridge above sea level.

As a result of its location, Iceland is one of the most tectonically active places on earth, with many volcanoes and hot springs. More than 200 volcanoes are located within the active volcanic zone stretching through the country from the southwest to the northeast, and at least 30 of them have erupted since the country was settled.

In the volcanic zone there are at least 20 high-temperature areas containing steam fields with underground temperatures reaching 250°C within 1,000 m depth. These areas are directly linked to the active volcanic systems.

About 250 separate low-temperature areas with temperatures not exceeding 150°C in the uppermost 1,000 m are found mostly in the areas flanking the active zone Figure A4.1.

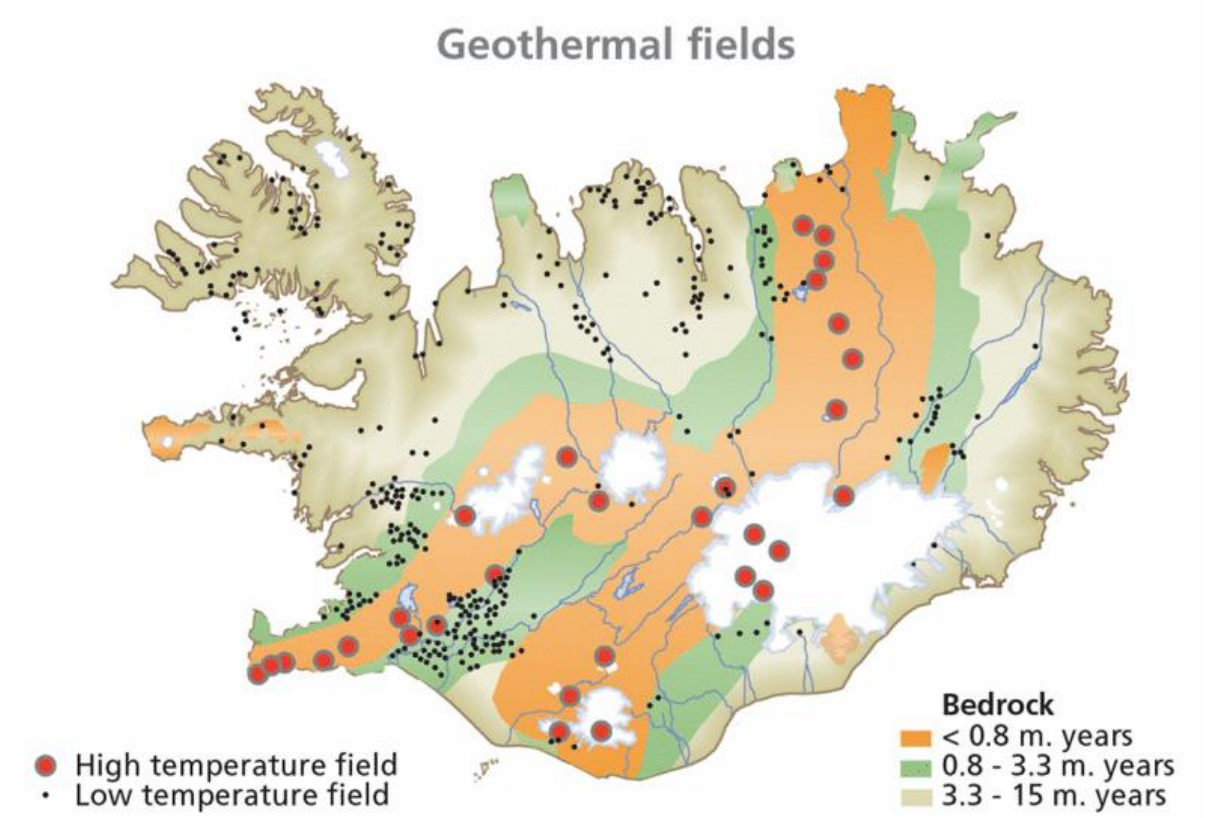

Figure A4.1: High and low temperature geothermal systems in Iceland, where the high temperature systems are found within the active volcanic zones.

During the 20th century Iceland emerged from being a nation dependent upon imported oil and coal, to a country where practically all stationary energy, and 86% of primary energy, is derived from domestic renewable sources with near carbon-free electricity production in year 2018. This is the result of an effective policy in making renewable energy a long-term priority in Iceland. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply.

Already in the 1940s, the State Electricity Authority promoted geothermal development and carried out regional surveys of geothermal areas suitable for space heating and explored promising fields with exploratory drilling. The capital Reykjavik obtained by law a monopoly to operate a geothermal heating service in the town and took the initiative in production drilling and establishment of the first large geothermal district heating system. The State guaranteed loans for the construction of the system. In 1950 about 25% of families in the country enjoyed geothermal heating services, while 40% used coal and 20% oil for heating. The low cost geothermal heating was attractive and intensified the flux of people from rural areas to the capital. To balance that, the Parliament approved an Act in 1953 on geothermal heating services in communities outside Reykjavik which permitted the State to guarantee loans up to 80% of the total drilling and construction cost of heating services. Further, to encourage the development, the State established a Geothermal Fund in 1961. The fund gave grants for surveying and exploratory drilling carried out by the Geothermal Department of the State Electricity Authority and offered loans to communities and farmers for exploratory and appraisal drilling covering up to 60% of the drilling cost. If the drilling was successful, the loans were to be paid back at the highest allowed interest rate within 5 years of exploitation commencement. If the drilling failed to yield exploitable hot water, the loan was converted to a grant and not paid back. In this way the fund encouraged exploration and shared the risk. Within the next 10 years many villages used this support and succeeded in finding geothermal water. In 1967 the fund was merged with the Electricity Fund and named the Energy Fund. The Electricity Fund had since the 1940s supported electrification and transmission in rural areas. Over 350 geothermal loans have been issued since the beginning that has led to the widespread use of geothermal across Iceland.

When the oil crisis struck in the early 1970s, fuelled by the Arab-Israeli War, the world market price for crude oil rose by 70%. At about the same time, close to 90,000 people enjoyed geothermal heating in Iceland, or about 43% of the population. Heat from oil served over 50% of the population, the remainder using electricity. In order to reduce the effect of rising oil prices, Iceland began subsidising those who used oil for space heating. The oil crises in 1973 and 1979 (Iranian Revolution) caused Iceland to change its policy, reducing oil use and turning to domestic energy resources; hydropower and geothermal heat. This policy meant exploring for new geothermal resources and building distribution networks. It also meant constructing transmission pipelines (commonly 10–20 km) from geothermal fields to towns, villages and individual farms, as well as converting household heating systems from electricity or oil to geothermal heat. However, despite the reduction in the use of oil for space heating from 53% to 7% from 1970 to 1982, the share of oil still remained about 50% to 60% of the total heating cost due to rising oil prices. Today about nine out of ten households are heated with geothermal. Total use of geothermal energy amounted to 29 PJ in year 2017. From an economical perspective, the present value of the estimated savings of house heating with geothermal instead of oil between 1914 and 2013, using 2% real interest rate over the cost price index, is estimated at 2,500 billion ISK (132 ISK/US$). In 2014 the estimated savings of that year amounted to

about 5.5% of the GDP of Iceland or 2,300 US$ per capita only for 2014. Beside the economic impact of high energy security and avoided cost of importing energy to the country, there are also environmental benefits for reducing greenhouse gas emissions by using geothermal energy compared to conventional fossil fuel-based technologies. In 2014, geothermal utilization reduced the anthropogenic release of CO_2 by 5.0 million tonnes for geothermal based electricity generation and 3.4 million tonnes for geothermal based heat use compared to coal. This has also considerably improved air quality in populated areas over the decades since the time Icelanders used to heat their houses with coal and later oil.

Geothermal utilization amounted to 29 PJ in 2017 using both IGA and IEA final use categories. Detailed monitoring of geothermal utilization has been set up in Iceland by Orkustofnun with data from over 53 geothermal based heat utilities (where geothermal energy production is the main business activity) and over 100 auto-producers (where geothermal energy is produced mainly for own use in support of some business) of geothermal energy using a web portal for authentication. The data is accumulated and analysed annually by Orkustofnun with 19 categories of utilization in order to be able to fully disseminate information to the public in accordance with the legal role of the institution and international requirements.

Within the geothermal industry, Orkustofnun participates in several associations and partnerships and collaborates with many others like the Implementation Agreement within the IEA (IEA Geothermal), International Geothermal Association (IGA), European Geothermal Energy Council (EGEC), Geothermal ERA NET and now Geothermica, GeoEnvi and the International Partnership for Geothermal Technologies (IPGT) to name a few.

The information Orkustofnun disseminates is based on the accounting system of the heat utilities after extensive review and collaboration over recent years which still is ongoing to ensure the reliability of the information. For the first time, categorization of space heating for residential and commercial and public services is possible. Verification of the information is through comparison of data from Registers Iceland and Iceland Met Office. That being said, the focus of this paper is not to give a detailed account of statistics in Iceland. The point is to examine Icelandic policy in respect of geothermal energy, both research and utilisation, and at the same time observe how official monitoring of both geothermal research and utilisation manifests itself in Icelandic legislation and amendments from a previous review in year 2015 (Ketilsson et al., 2010).

Institutional context

There are only two levels in Iceland, ie. e. State and municipalities. Legislation, licensing and control over utilization are the responsibility of the state. Local authorities do not do so, but grant operating licenses for drilling, district heating and power plants, and monitor pollution due to geothermal utilization of T. D. I groundwater. However, the Environment Agency (state) also supervises such as gas emissions, etc.

Policies and policy visions

The Icelandic National Renewable Energy Action Plan (NREAP) was published in year 2012 in accordance with Directive 2009/28/EC which outlines the strategy for 2020 and goals of geothermal utilization amongst other renewable energy sources. Promotion of the use of energy from renewable sources was further stipulated by

changing law no. 30/2008 for promotion of electricity generation with renewable resources taking into consideration Directive 2009/28/EC. The total use of geothermal energy for heating is estimated to increase to 34 PJ in year 2020. Electricity generation from geothermal power plants was expected to increase to 5.8 TWh in year 2020 according to the NREAP but reached 6 TWh in year 2018. The predicted overall share of renewable energy of final energy use in Iceland of 72% as a binding target has already been achieved in year 2014.

Carbon dioxide capturing from geothermal power plants can be a source for alternative fuel by converting it to methanol, e.g. Carbon Recycling Ltd. is running a plant at Svartsengi power plant for this purpose with promising results. ON Power has successfully illustrated that it is possible to also turn CO_2 and H_2S into rock. Until now, Iceland has been an island not only geographically but also economically to a greater extent than many of its neighbours in Europe (Björnsson, 1995).

The Geothermal Working Group, under the Icelandic Energy Forecast Committee, has regularly developed a multi decade forecast for geothermal utilization in Iceland based on assumptions concerning the development of Icelandic society. The base assumptions are stipulated by the Energy Forecast Committee and are common to all energy forecasts for Iceland. Orkustofnun compiles the energy statistics data, which in turn is important for all studies on future geothermal utilization that are used for the forecast. A new geothermal forecast until 2050 is now being developed. It will describe the assumptions used and the predicted effect geothermal utilization will have on the renewable energy sector in Iceland. Statistics Iceland predict a population growth of 36% until 2050 so geothermal utilization, e.g. residential and commercial services, is expected to increase considerably over the next decades. The energy forecast committee has predicted the total cubic meters of heated buildings to increase by 50% until 2050 from the current value of 60 million cubic meters to close to 90 million cubic meters. In total geothermal use is predicted to increase from to 49 PJ in year 2050 (see Figure A4.2). Fish farming is expected to increase considerably relative to other sectors.

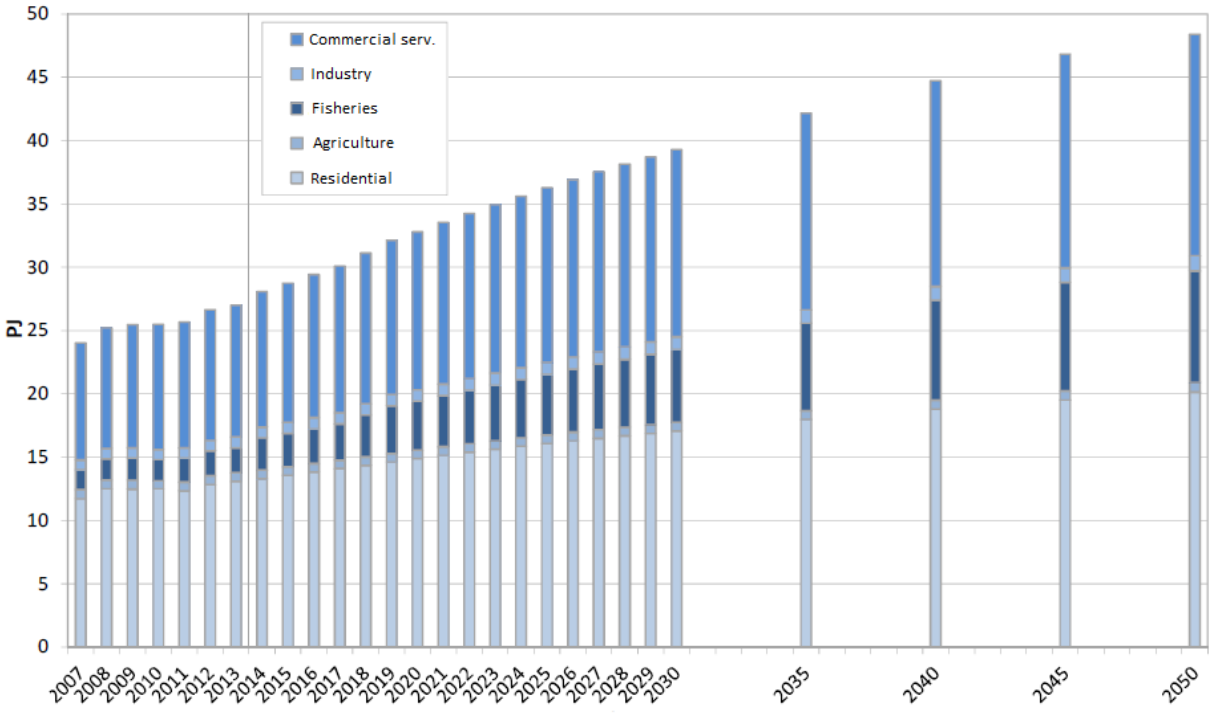

Figure A4.2: Geothermal utilization in [PJ] plotted against time until 2050 (Orkustofnun, 2019).

The government has encouraged exploration for geothermal resources, as well as research into the various ways geothermal energy can be utilised. As stated earlier, this work began in the 1940s at The State Electricity Authority, and was later in the hands of its successor, Orkustofnun, established in 1967. The aim has been to acquire general knowledge about geothermal resources and make the utilization of this resource profitable for the national economy. This work has led to great achievements, especially in finding alternative resources for heating homes. Since the electricity market was liberalized with adaption to EC Directive in year 2003 Orkustofnun only contracts research for exploration of domestic resources. According to a new *Energy Act* in 2003, the Energy Fund is now under Orkustofnun.

Geothermal electricity is today competitive with hydro in Iceland and is not subsidised; providing reliable base load, small surface footprint, green energy and favourable prices. Transmission and distribution costs are high in Iceland due to low population density. For cost of residential heating see **Error! Reference source not found.**. In recent y ears geothermal has become cost-competitive for electricity which was not the case a few decades ago (Bjornsson, 1995) when geothermal was not competitive with hydro on a major scale.

Space heating of residential buildings is subsidized by the state as shown in Figure A4.3 for those areas where geothermal based district heating systems are not reachable. The lump sum of this state subsidization for 8 years has been available to support home owners to transform to renewable heating (Act No. 78/2002). This has recently been increased by 50% to be equivalent of 12 years lump sum. In addition, if the project receives other grants it will not affect in any way this lump sum payment. This has stimulated new geothermal based district heating systems to be installed like in the town of Skagastrond, operated by RARIK in year 2013.

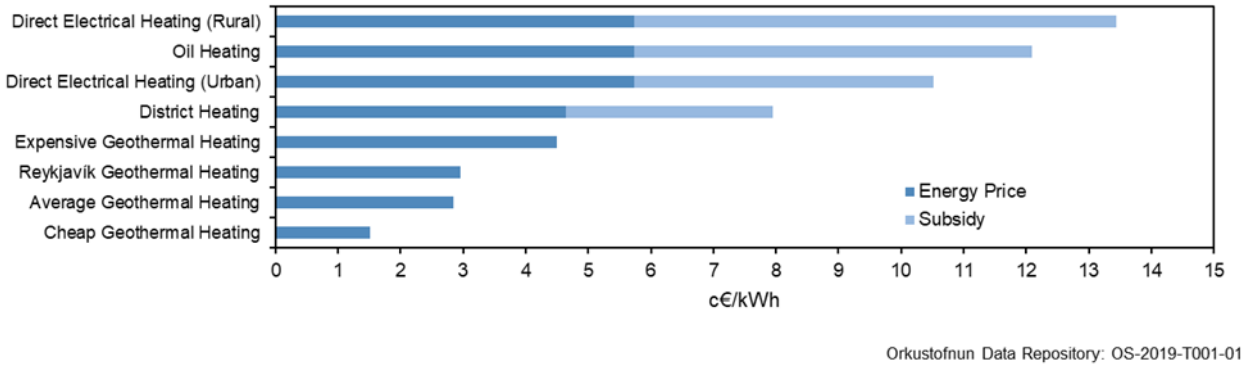

Figure A4.3: Comparison of energy prices for residential heating in September 2018 in €-cents per kWh of heat.

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

The Government supports the Iceland Deep Drilling Project (IDDP) with 342 million ISK. If successful, this project could start a new era in geothermal development. The main purpose is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. The first well drilled yielded superheated steam after drilling into magma at roughly 2 km depth. The second well was completed in Reykjanes geothermal field in January 2017 when an existing well was deepened and reached supercritical conditions at a depth of 4,5 km. Based on measurements the bottom hole temperature is estimated to be about 535°C. Currently the development of a well head and flow testing is underway, and plans are being made for a third well in the Hellisheiði geothermal field.

Drilling success has been on average 74% in Iceland into high temperature systems for electricity generation (Sveinbjörnsson, 2014). In total 105 wells were used in year 2019 to generate electricity and hence the average well is contributing 6.3 MW of electric power and generating 50 GWh of electricity. The average high temperature well is 1866 m deep, cased down to 1585 m. For low temperature systems in total 173 wells are used and 9 hot springs with an average depth of 1055 m, cased down to 223 m (Oddsdóttir and Ketilsson, 2012). For wells drilled for production of hot water for district heating systems, 93% were productive and 88% had a discharge temperature of over 60°C. The average age of production wells currently in use is 33 years, and the oldest well currently in use was drilled in 1946 (Sveinbjörnsson, 2018).

As reviewed in more depth in Johannesson et al. (2020) the three largest Icelandic Power Companies and two Governmental Agencies formed a Working Group in year 2016 for the development of an assessment tool to measure geothermal sustainability performance; Geothermal Sustainability Assessment Protocol, GSAP. At the initiative of the International Hydropower Association, IHA, a multi stakeholder Sustainability Assessment Protocol, HSAP, was prepared in the period 2008 to 2010. Representatives from IHA, Governments, Finance Institutions and NGOs prepared the Protocol. HSAP is now applied worldwide, to assess key sustainability factors of projects; social, environmental and economic. The aim is to measure, guide and improve performance for sustainability topics. Iceland actively participated in the preparation of HSAP. The GSAP Working Group took on to transform this widely accepted HSAP tool to geothermal application. As the stakeholders are in principle more or less the same, modifications are kept to a minimum to maintain as possible the existing consensus on HSAP. A Draft GSAP is now prepared and successfully tested for the Preparation Stage of *Theistareykir 90 MWe* and the Operation Stage of *Hellisheidi 300 MWe/130 MWth*.

Earlier energy developments in Iceland were focused on meeting the basic energy needs of the society for space heating and electricity for the general market. Through the years it has become more and more evident that utilisation of energy resources (as other development) must consider not only the energy needs and the economic aspects of the development, but also a range of other interests as well. This includes other land use and the impact of development on the environment and the cultural heritage. The first step towards such an evaluation was undertaken by a collaboration committee of specialists from the Ministry of Industry, the National Power Company, Orkustofnun and the Nature Conservation Council. This committee was active during the 1970's to the 1990's. It discussed plans for various electrical power plants with special emphasis on the natural conservation aspects of the projects. A general view on the energy policy and the nature conservation policy was needed for the country. This became even more important by 1994 when the Parliament of Iceland passed the first *Act on Environmental Impact Assessment*. The Icelandic Government published a white paper on sustainability in the Icelandic society in 1997. There the need of the development of a long-term Master Plan for energy use in Iceland was once again

stressed. All proposed projects, with installed capacity above 10 MWe or 50 MWth, should be evaluated and categorized on the basis of energy efficiency and economics, as well as, on the basis of the impact that the power developments would have on the environment.

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

The Master Plan aims to identify power projects that rank high from an economical point of view, have a minimum negative impact on the environment, and a positive impact on the society. Such a score card for the energy projects helps decision makers to filter out which of the proposed projects are likely to become controversial and disputed and which ones not. It also directs attention to those project areas that might have protection value and should be left untouched by human development.

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

Possible electricity production of proposed power development sites by part of country in the third phase of the Master Plan is shown in Figure A4.4, which is currently under consideration by the parliament. As can be seen the majority of the proposed production is in the South, Southwestern and Northern part of Iceland, the regions which currently have the most power production. Meanwhile, regions such as the Western fjords that need further electricity infrastructure, do not have much proposed production, further highlighting their need. Figure A4.4 shows proposed sites of power plant development. After the steering committee has decided that resources in a designated area should be harnessed, protected or further studied, the projects themselves can be re-evaluated and hence subject to review again by the Master Plan until the municipalities have adjusted their regional plans. The municipalities could also take the initiative to designate a certain area for protection and another area for re-evaluation. This process of re-evaluation is necessary because with increased understanding on the effects of these projects and with technological advancements, assumptions can change. This re-evaluation is relative until either the area has been formally protected or licenses for the power plant have been issued. Administrative bodies can grant licenses relating to projects that are categorized for utilisation and all research that does not require licensing can be carried out. Administrative bodies cannot grant licenses for projects that await further research if the intended work requires assessment of environmental impact. Research that does not require licensing can be carried out in

these areas with the same restriction. Administrative bodies cannot grant any licenses for projects that are in areas categorized for protection except for a limited research license for prospecting on surface without affecting the environment. The projects in question are approved by Orkustofnun before submittal to the Steering Committee and can both be state owned and privately owned. Before presenting the proposal to Parliament the Steering Committee of the Master Plan must ask for both written comments and publicise the draft proposal. After the confirmation of the Parliament, the Master Plan is valid and binding for all parties for up to four years, unless the Parliament changes its resolution. The municipalities are required to adjust their regional plans accordingly within 15 years from the decision of the Parliament. The Master Plan only covers projects that have the potential of at least 10 MW electric or at least a thermal potential of 50 MW. The plan is binding for all municipalities and is to be included in their general land use plans.

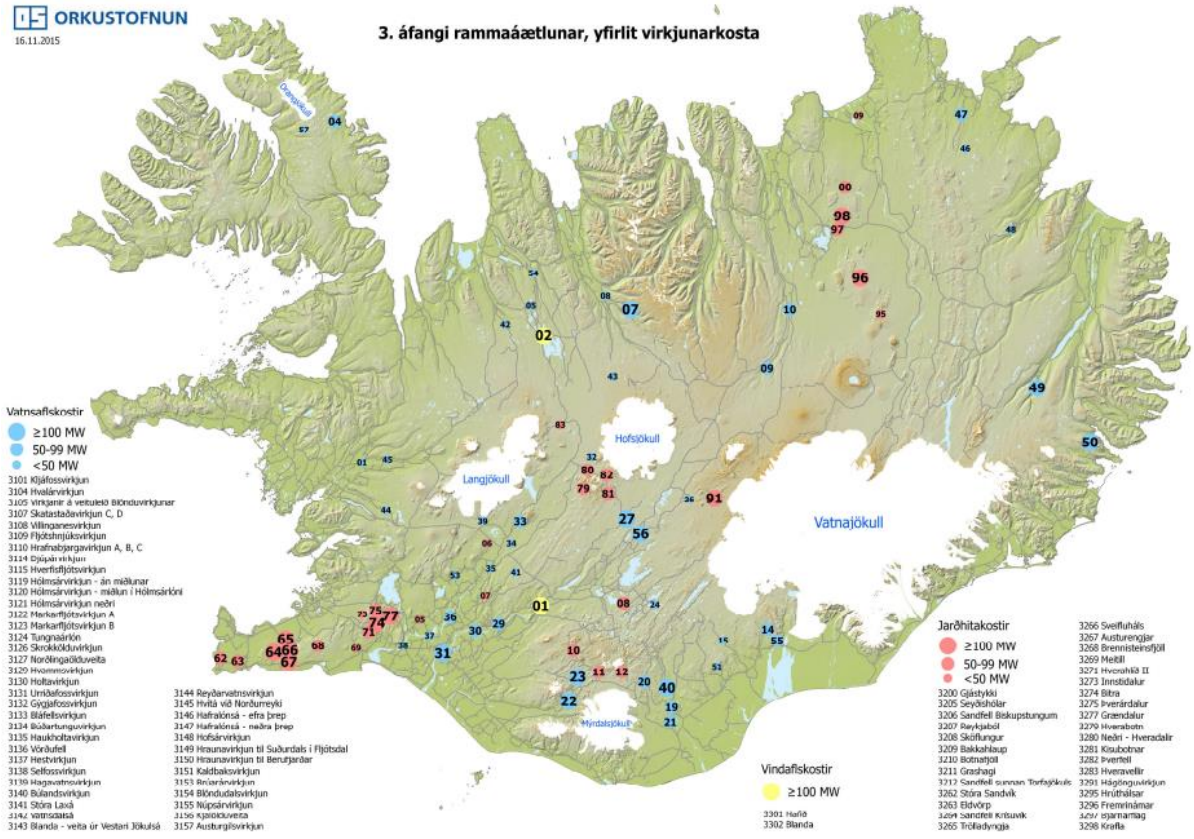

Figure A4.4: Proposed hydro (blue), geothermal (red) and wind (yellow) areas by Orkustofnun for consideration for the next Master Plan phase.

Environmental regulation mapping

Definition, Classification, and Resource Ownership

The ownership of resources in the ground is associated to the ownership of private land, while on public land, resources in the ground have to remain in public ownership, unless others can prove their right of ownership. Even though the ownership of resources is based on the ownership of land, research and utilisation is subject to licensing

according to the *Act on Survey and Utilisation of Ground Resources*, No. 57/1998 (*Resource Act*) and the *Electricity Act*, No. 65/2003. Survey, utilisation and other development pursuant to these Acts are also subject to the *Nature Conservation Act, Planning and Building Act, Environmental Impact Assessment Act* and other Acts relating to the survey and utilisation of land and land benefits.

The Ministry of Industries and Innovation is the head organisation of energy matters in Iceland. The Ministry has today two ministers, Minister of Industry and Commerce and Minister of Fisheries and Agriculture. The Ministry has authority of the *Resource Act* and the *Electricity Act* which are the two main legal acts that geothermal energy exploration and utilisation is based on in Iceland.

Orkustofnun is a government agency under the Ministry of Industries and Innovation. Orkustofnun works on the basis of the *Act on Orkustofnun* no. 87/2003. The main responsibilities have been to advise the government of Iceland on energy issues and related topics, promote energy research and administer development and exploitation of the energy resources. Orkustofnun is also responsible for gathering, guarding and mediating information on energy resources and their exploitation. It has been responsible for the regulation of the fore mentioned Acts, among other Acts such as the *Act on Prospecting, Exploration and Production of Hydrocarbons*, the *Water Act*, No. 15/1923 and the *Act on the Ownership of the Icelandic State of the Resources of the Sea Floor, No. 73/1990*. More recently Orkustofnun has received the responsibility of granting licenses for exploration and exploitation of natural resources as well as all licenses according to the *Electricity Act*, thus acquiring full independence regarding the granting of licenses based on the Acts regulated by Orkustofnun. Figure A4.5 gives an overview of the role of Orkustofnun and the two ruling committees that decisions of Orkustofnun can be appealed to.

In 2008 the Parliament decided to prevent any further sale of water resources, including geothermal energy, to private entities. All-natural resources that were not privately owned were guaranteed to remain in the possession of the State or municipalities or entities owned by them. As described previously the State can grant licenses for utilisation, for up to 65 years, according to the *Resource Act*. As of that same year Parliament also decided to implement into the Act a clause stating that the Minister of Industry could delegate the power to grant licenses to Orkustofnun.

Prior to that time, the Minister granted such licenses. The decisions made by Orkustofnun, derived from the newly granted power, could be appealed to the Ministry for revision. In that way, civilians had the possibility to have a decision revised in the administrative sector, without having to turn to the courts. Another amendment that same year (2008) dictates that combined heating and power plants are obliged to keep separate accounts for heat and power production to prevent cross subsidisation of electricity. Producers of electricity compete in an open market in Iceland whereas the heat is sold based on a natural monopoly license to sell heat within a certain area, hence, it is necessary to keep financial records separate in relation to e.g. the *Administrative Act*, No. 37/1993 as well as Art. 65 of the *Icelandic Constitution*.

In 2012, Parliament decided to move that same license granting power to Orkustofnun by amending the law, making Orkustofnun fully independent in its decision making. Such decisions can today be appealed to the *Appeals Committee for Environmental and Resource Matters* as previously mentioned (A4.5).

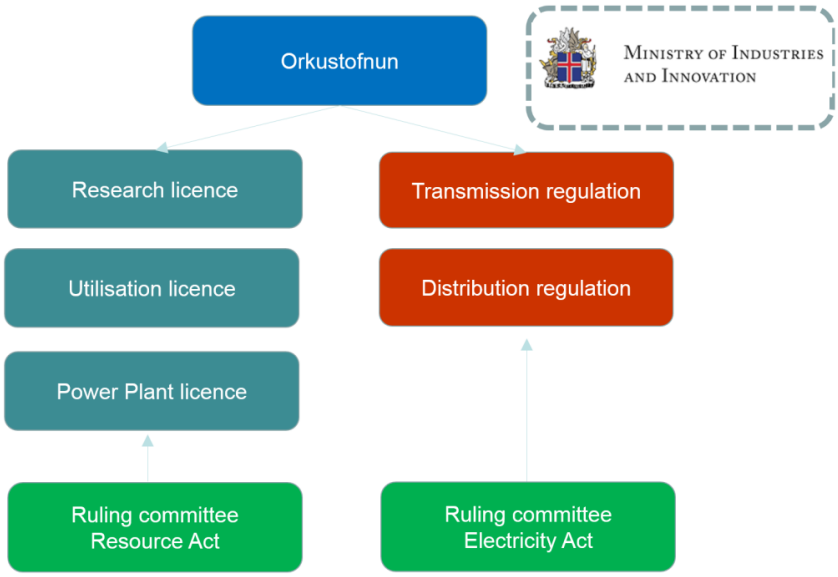

Figure A4.5: Role of Orkustofnun as a licensing authority and the two ruling committees that can be appealed to.

Licensing and Authorization

Orkustofnun has been working towards making applications for licences easy and accessible. A template has been made as a guide for applicants to sufficiently submit an application with the needed information. The template can be accessed on the Orkustofnun website to make application preparation easier for applicants. In addition, an internal procedure has been set up to systematically evaluate applications divided into five phases. In the first phase, a specialist begins by reviewing the application and by making sure the information is sufficient. In the second phase, a lawyer will look at the application from a legal point of view. Formal requirements are examined according to the Resource Act. In the third phase, the application is sent to legal entities and individuals for review and the feedback is taken into consideration in phase four and five after receiving a response from the applicant which includes the final stages of the licencing process. After an overview of the application and with input from geothermal energy specialists, the application is either granted or rejected. The decision of Orkustofnun can be appealed to the Appeals Committee for Environmental and Resource Matters, cf. Act. No. 130/2011 on the appeals committee.

Licences granted by Orkustofnun can be found in the OS Licensing Registry which is a search engine of licences issued by Orkustofnun from the year 2008. In total 46 licenses issued since 2008 of which 25 are utilisation licences, 15 research licences and 5 power plant licences. In Ketilsson and Bromley (2020) these licenses are further reviewed and in total 12 dilemmas defined that were encountered during the licensing procedure. The tools developed to overcome these barriers are described and analysed based on new governance approach further described in the paper. In addition, leadership roles applicable to these dilemmas are suggested and the Principal Challenge for Iceland identified as being the Transition Challenge (Ketilsson and Bromley, 2020).

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

According to the Act, Orkustofnun is permitted to take the initiative in and/or give instructions on surveying and prospecting for resources in the ground anywhere in the country, regardless of whether the owner of the land has himself or herself begun such surveying or prospecting or permitted others such surveying or prospecting, unless the party in question holds a valid prospecting licence pursuant to the Act. In the same way, Orkustofnun may permit others to survey or prospect, in which case a prospecting licence shall be issued to them. A prospecting licence confers the right to search for the resource in question within a specific area during the term of the licence, survey extent, quantity and potential yield and to observe in other respects the terms which are laid down in the Act and which Orkustofnun considers necessary.

The utilisation of resources in the ground is subject to a licence from Orkustofnun, whether it involves utilisation on private land or public land, with the exceptions provided for in the Act. A landowner does not have priority to a utilisation licence for resources on his or her land, unless such an owner has previously been issued a prospecting licence. A utilisation licence permits the licence holder to extract and use the resource in question during the term of the licence to the extent and on the terms laid down in the Act and regarded necessary by Orkustofnun. Before the holder of a utilisation licence begins extraction on private land the holder needs to reach an agreement with the landowner on compensation for the resource or obtain permission for expropriation and request assessment. In the event that neither an agreement is made on compensation nor expropriation requested within 60 days immediately following the date of issue of a utilisation licence, the licence shall be cancelled. The same applies if utilisation on the basis of the licence has not started within three years of the issuance of the licence. This also applies to the utilisation of resources on public land.

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

According to the *Electricity Act* a licence issued by Orkustofnun is required to construct and operate a power plant. However, such a licence is not required for power plants with a rated capacity of less than 1 MW, unless the energy produced is delivered into the distribution system of a distribution system operator or into the national transmission grid. Power plants with installed capacity less than 100 kW are exempt from this requirement. The owners of power plants with a rated capacity of 30–1000 kW shall submit technical details of the plant to Orkustofnun. Also, Orkustofnun shall be informed annually of the total generation of power plants with a rated capacity of over 100 kW. Figure A4.6 illustrates the executive power of public authorities according to Icelandic law.

Sustainability and Environmental Impacts

Ground surface deformation- Rules concerning boreholes

Orkustofnun and its predecessors have kept a registry of the boreholes drilled in Iceland for many decades. At the start of 2019 the registry had over 14.000 boreholes, with the oldest dating back to 1904. Just over 4.500 of these are related to geothermal activity, either research or production boreholes. Each borehole has an ID number by which information about it is identified. This includes the location of the borehole, its depth, casing depth, when it was drilled, purpose of drilling, the drilling contractor in charge and what drill rig was used. In recent years,

considerable improvements have been made to the registry, such as assigning every well in the registry a location, scanning older drilling reports and making them available online and developing a new web portal for Orkustofnun where the registry can be accessed more easily (www.map.is/OS). By law, Orkustofnun shall be notified when a borehole is drilled and receive a report once drilling is concluded. However, this is often not the case leading to boreholes not being reported and therefore not included in the registry. Another problem that has emerged is the uncertainty regarding the ownership and responsibility of a number of boreholes, leading to some unused boreholes becoming hazardous due to low maintenance and inadequate closure.

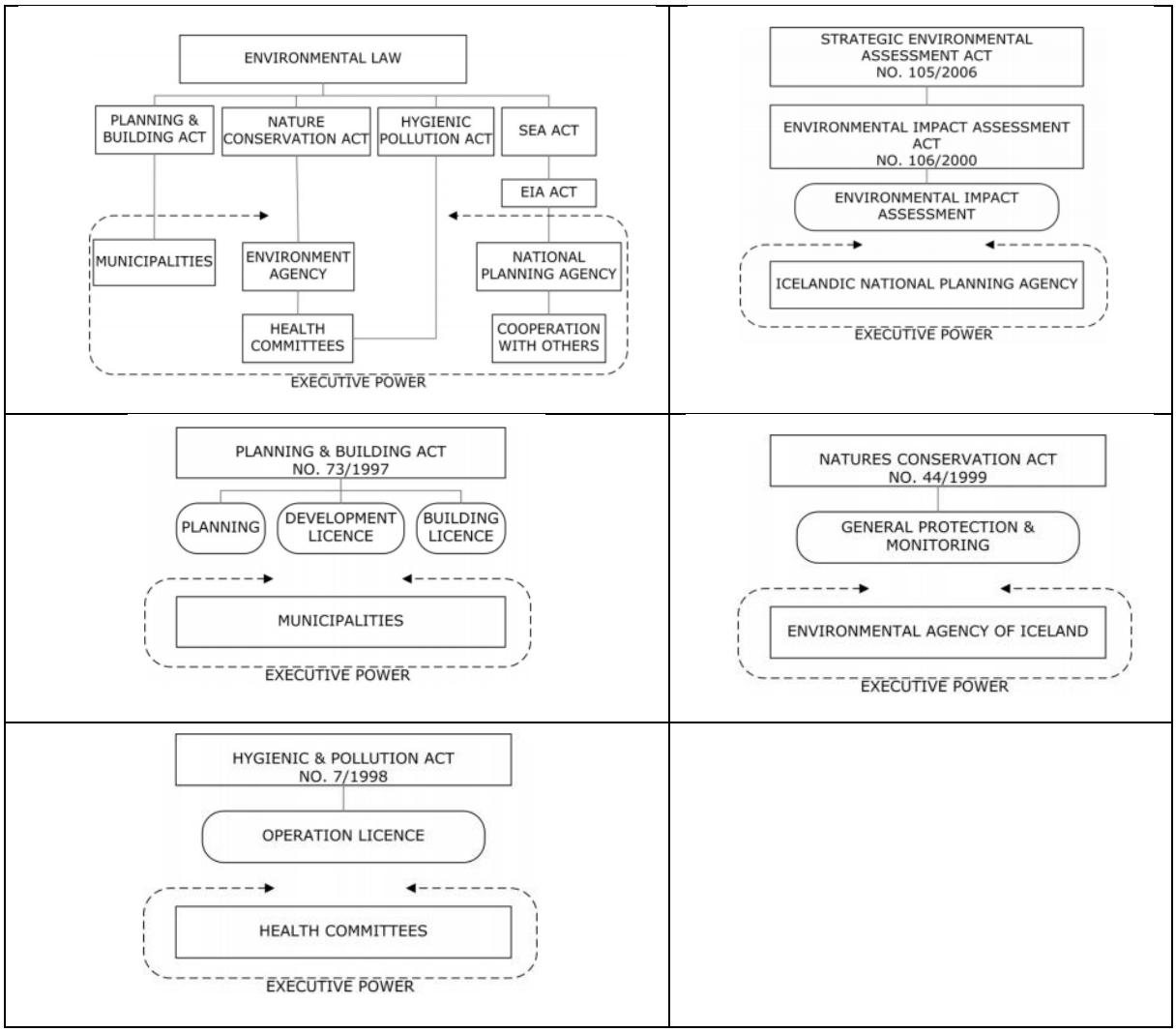

Figure A4.5 The executive power of public authorities according to Icelandic law as presented by (Steinsdóttir er al., 2009., Ketilsson et al., 2010).

In order to improve this, Orkustofnun has developed rules on the registration, design and permanent closure of boreholes, and the submission of information on boreholes to Orkustofnun. The purpose is to clarify the obligations placed on those who drill boreholes and the intended result will be increased regulating and more complete data on boreholes. During the development of these rules stakeholders were consulted, resulting in valuable feedback and dialogue. The rules outline the relevant articles of the Resource Act regarding boreholes, and what is required of Orkustofnun as well as owners of boreholes and other stakeholders by law. In order to streamline the data collection, three forms have been made for borehole owners to fill out and send to Orkustofnun. One is to be filled out before drilling, fulfilling the legal requirement of notifying Orkustofnun of drilling activities; the second form is to be filled out after drilling, describing the drilling process, the borehole depth, casings, geology etc.; and a third to be filled out when a borehole has been permanently closed. Additionally, guidelines will also be published to explain the purpose and execution of the borehole rules to stakeholders.

The desired outcome of the implementation of these rules is an organized and systematic data collection, resulting in a complete borehole registry that is available to the public on an accessible online portal which is valuable to drilling contractors and other entities that are considering drilling, as well as professionals, academics, students and the general public. This is in line with Orkustofnun's policy of public data dissemination which has been valuable for the geothermal development in Iceland for the last few decades. Another outcome of the implementation of these rules would be to clarify the ownership of boreholes, which increases the security of the general public and tourists traveling in Iceland.

Seismicity - Rules regarding preparedness and reactions to seismic hazards due to fluid injection into the ground via boreholes

Geothermal areas are geologically active and such areas are likely to experience seismic activity. Fluid withdrawal and fluid injection into the ground accompanying geothermal utilization causes changes in the stress field of the Earth. Research on fluid injection into the ground in geothermal areas has shown that in active geothermal areas in Iceland it may stimulate some microearthquake activity. On the one hand there are microearthquakes as a response to this change in the stress, but on the other hand it may bring forward earthquakes that would inevitably take place later. The most common reason is change in injection rate, e.g. if injection is for some reason temporarily stopped, the probability of microearthquake activity is increased. In general, these earthquakes are not felt at the surface but in specific cases there is a considerable probability that increased fluid pressure due to release has triggered larger earthquakes.

The injection of geothermal fluids into the ground is an important part of the utilization of geothermal energy on the one hand to dispose of fluids, but on the other to counteract pressure decline in geothermal systems. In some cases, injection is mandatory in accordance with a utilisation licence and/or an operation licence according to Act No. 7/1998 on hygiene and pollution control and is practiced from the start of operations. In other cases, it has been initiated after some time of operation. Geothermal energy is however widely harnessed without injection into the ground.

The extent of fluid injection into the ground with the utilization of geothermal energy is steadily increasing. With reference to the risks described here Orkustofnun issued rules on the preparation and execution of fluid injection into the ground via boreholes (OS-2016-R01-01) the rules were issued on January 21st of 2016. The objective of the rules is to minimize the risk of bodily harm, damage to man-made structures and inconvenience due to earthquakes in connection with fluid injection to the ground via boreholes. Furthermore, they are intended to restrict and explain duties, roles and involvement of the licence holder, Orkustofnun and other parties as applicable in each instance, and to promote the proper emphasis during the preparation and execution of the injection.

The chief objective is to provide information to applicants for production licences according to the Electricity Act and utilization licences according to the Resource Act, due to power production or other utilization of geothermal energy, regarding the requirements considered upon the publication and revision of these licences with reference to the provisos of Item 7, Article 18 of the Resources Act and Item 4, Paragraph 1, Article 6 of the Electricity Act.

Surface disturbance

Potential surface disturbance of deep geothermal plants, as for all industrial activity, covers different environmental themes, in particular noise and vibrations, visual impacts on landscape, and air quality issues including dust and smell. In Iceland there are several regulations on these matters. For noise and vibration: 921/2006 Regulation on the prevention of stress due to noise at work, 724/2008 regulation on noise, 922/2006 Regulation on the prevention of stress due to mechanical vibration in the workplace. For visual impacts and landscape: 660/2015 Regulation on environmental impact assessment and 90/2013 Planning regulations. For dust and smell: 787/1999 regulation on air quality and regulation on air quality and information to the public.

Degassing

For degassing Iceland has the Sanitary and Pollution Control Act on air quality. Regulation no. 787/1999 on air quality, no. 786/1999 on Pollution control and no. 785/1999 on operations which may result in pollution. The air quality in Iceland is mostly treated in Act no. 7/1998 on hygiene and pollution prevention, but also Act. No 46/1980 on working conditions, hygiene and safety at work as well as Act no. 23/2006 on the right information on environmental issues. Regulation 920/2016 is about air quality and information to the public.

Impacts on the underground fluid

By impacts on the underground fluid the definition is: Accidental interconnection of aquifers via the wellbore and accidental disturbance of non-targeted aquifers with fluid intrusion.

In Iceland there is a Regulation no. 797/1999 on the prevention of groundwater pollution, partly covering impacts on the underground fluid.

Reservoir physical and chemical modifications

Physical and chemical modifications of the reservoir due to standard operations may include: Pressure decline due to fluid withdrawal, thermal changes, when production exceeds natural long-term rate of recharge and change of chemical composition due to the different composition of the injected and resident fluids.

In Iceland utilization license has to be published. OS-2016-R01-01 on reaction to earthquake hazard due to the relese of spent fluid into the ground via boreholes. Here the 797/1999 Regulation on the prevention of groundwater pollution is also a fit for chemical modifications of the reservoir.

Effects of surface operations: Energy and water consumption and emissions to the environment.

Effects of surface operation has a variety of dimensions: energy consumption, water consumption, air emissions. Iceland has an Electricity act 65/2003 with the purpose to promote efficient electricity systems and thus strengthen the economy and population in the country.

Waste production from surface operations

Waste resulting from drilling of wells and the construction, operation and maintenance of the plant. On this there is a regulation on waste management in Iceland (737/2013) and Regulation on the list of waste and assessment of hazardous waste properties (1014/2016).

Liquid/solid effusions and waste

This chapter is on liquid and solid surface waste from underground sources. Iceland has a Regulation on power options in the protection and energy efficiency plan (530/2014): The following data and information shall always be accompanied by requests for consideration of the activation of high-temperature areas:

1) goals for the sustainability of the power plant, ie the interaction of utilization and service life,

2) plans for re-injection and disposal of waste water and possible impacts on groundwater bodies;

3) plans to acquire and dispose of cooling water,

4) targets for the release of hydrogen sulphide and its local maximum concentration in the atmosphere.

Radioactivity

Radioactive contamination at surface due to hazardous transfer of naturally radioactive fluids and rocks from the subsurface. Iceland has little to no radioactivity due to its geological conditions. The only regulation about radioactivity is regulation on the maximum levels of radiation for workers and the public due to radiation-using activities (1290/2015).

Monitoring

In June 1999 the Icelandic Parliament passed *Act on Official Monitoring* no. 27/1999 in order to promote efficient yet beneficial monitoring practice. The objective of this act is to ensure that official monitoring is conducted in the most economical way possible, both for the State and for those the monitoring is aimed at. The official monitoring rules have to be effective in order for it to serve its aims. According to Act. 2, the objective of the Act is also to ensure that official monitoring rules promote the welfare of the Nation, safety and public health, safety of property, environmental protection, normal business practices and consumer protection. The *Official Monitoring Act* requires authorities to conduct an economic evaluation before new monitoring rules are passed as law, to ensure that the extent of the monitoring is reasonable in proportion to the objectives aimed for. The monitoring should not be more extensive or more complex in execution than is required to achieve the distinctive objectives.

The official monitoring of utilisation of geothermal resources in Iceland is rather extensive and is the responsibility of different public authorities[68]. The objective of the monitoring for each sector is different, respectively: to protect

[68] It will be discussed in the further sections.

the environment, to prevent overexploitation of the resource, and to secure occupational safety and safety of delivery at the power plants as outlined in the following sections.

Environmental monitoring

The objective of official monitoring of the environment surrounding geothermal projects in Iceland is reflected in the stated aims of Art. 1 of the *Nature Protection Act* no. 60/2013. The objective is to regulate the interaction of man with his environment so that it harms neither the biosphere nor the geosphere, nor pollutes the air, sea or water. The ultimate aim is to ensure that the Icelandic ecosystem can develop according to its own laws and to ensure the conservation of its exceptional or historical aspects. An important pillar in environmental protection according to Icelandic legislation is *Act on Environmental Impact Assessment* no. 106/2000 (*EIA*) as previously mentioned. The objective of the EIA is to gauge the effects a project may have on the environment and to minimize as far as possible the negative environmental impact of projects. Furthermore, when resource utilisation and power plant licenses are issued, environmental factors should be taken into consideration. Surveying, utilisation and power plant licenses may be bound by specific conditions in order to safeguard environmental requirements, according to the *Resources Act*, Art. 17 and the *Electricity Act*, Art. 5. With the *Strategic Environmental Assessment Act* no. 105/2006 (*SEA*), Iceland adopted Directive 2001/42/EC from the European Parliament and the Council as previously mentioned. The objective of the Directive is to protect the environment and to encourage sustainable development by conducting an environmental assessment of plans which are likely to have an impact on the environment. In the Directive it is assumed that the impact of plans and programmes on the environment are assessed before they are passed and executed.

The Health Committees of municipalities are responsible for official monitoring of the operation license. These committees derive their power from the *Hygienic & Pollution Act* no. 7/1998. The Act divides Iceland into ten regulatory zones and each zone has one committee. The operation licenses for power plants are issued by these health committees. The objective of these licenses is to prevent pollution from e.g. run-off water and to promote a clean environment. The operation license is equipped with conditions and the health committees oversee that these conditions are met. Failure to do so can result in official warnings, daily penalties and termination of the license.

Resource monitoring

Another objective of official monitoring of utilisation of geothermal resources is to ensure that the most efficient exploitation of the resource is adopted in the long run and that extraction of geothermal fluid does not exceed levels deemed necessary, according to Art. 25 of the *Resource Act*. One way to ensure this is to have effective official monitoring of the utilisation taking place at every geothermal project. Besides efficient monitoring it is also important that relevant institutions, municipalities and developers are aware of the fact that utilisation of geothermal energy in Iceland is to be conducted as stipulated in Art. 25 of the *Resource Act*. Some natural resources are exhaustible; therefore, it has been considered necessary to apply rules to manage their utilisation, in order to ensure natural resources are protected and maintained for future generations.

Orkustofnun has the responsibility to monitor geothermal areas being researched or utilised, according to the *Resource Act.* Orkustofnun is also responsible for the official monitoring stipulated in the *Electricity Act*.

Appendices within utilization licenses and power plant licenses stipulate what detailed information a developer shall present annually to Orkustofnun. The information required is as follows:

- The amount of fluid extracted or reinjected into each well in the geothermal field, each month.
- The temperature of the water reinjected into the geothermal reservoir each month.
- Results of water level measurements in wells where the water level can be measured and are within the geothermal field.
- The pressure changes or drawdown determined in the geothermal reservoir.
- The results of measurements of the enthalpy of the fluid from every production well in the geothermal field.
- Chemical analysis of the geothermal water (and steam, if appropriate).
- Results from simulations of the geothermal reservoir.
- Results of measurements made to monitor changes in the geothermal reservoir.
- Information on drilling in the industrial area.
- A resume of improved understanding of the physical characteristics of the geothermal reservoir based on the results of latest drilling.

The abovementioned items should provide all the necessary information for the monitoring authority to monitor the utilisation of the resource. Furthermore, Orkustofnun has stipulated certain limits on drawdown within the geothermal systems of the last three utilisation licenses for geothermal power plants. This is done to maintain long term balance of water in place, in order to secure the possibility of continuing carrying heat in place to the surface using water as the carrier. In addition to limitation of drawdown there are also limitations in terms of annual reduction in steam supply to be no more than 3%. If those limits are reached ON Power is required to take the necessary steps in mitigating the effects by calibrating the reservoir model and predicting again whether the geothermal system can sustain enough yield through the lifetime of the power plant. The prediction is given with a calculated probability margin taking uncertainty into account. If the drawdown goes beyond the error margin the license holder needs to re-evaluate the reservoir model, change the extraction levels within the area or increase reinjection into the same geological formation to maintain long-term water balance.

Safety and management

The objective of monitoring utilisation of geothermal energy does not only entail monitoring of the surrounding environment and the resource. The third objective of monitoring of geothermal projects is to ensure the safe and responsible management of power plants which generate electricity from geothermal energy. Monitoring of a power plant starts before construction of the plant begins. First, the municipal authority in the area where the power plant is to be built issues a development license or a building license, according to the *Planning and Building Act* no. 73/1997. According to Paragr. 2 in Art. 38 it is the local authority's responsibility to monitor power plant development and its surroundings, according to the terms of the development or building license that it has issued for the power plant. The council is to make sure that all buildings are built according to the development plan, rules and regulations. Second, a power plant license is required in order to build and operate a power plant, according to Art. 4 of the *Electricity Act*. Orkustofnun is responsible for official monitoring of the conditions stipulated in the relevant license. The objective of monitoring after generation of electricity at the power plant has begun is to ensure that

operations are conducted according to the requirements of the Act. On-site monitoring at the power plant, quality of electricity, security of supply of electricity and accounting should be as stipulated in the *Electricity Act.*

Reaching the objectives

According to the *Official Monitoring Act* the objective is to ensure that official monitoring rules promote the welfare of the Nation, safety and public health, safety of property, environmental protection, normal business practices and consumer protection. In para. 4 of Art. 9 of the derivative Regulation of the *Official Monitoring Act* it is stipulated that the requirements of individual official monitoring authorities are to be harmonised and the monitoring implemented by one and the same party to the greatest possible extent.

The objectives formulated in the legislation concerning the arrangements for official monitoring of utilisation are in general being reached, especially with regard to the preparation phase for utilisation, environmental protection and the construction phase.

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APPENDIX 5: ITALY

General overview

General data on deep geothermal in Italy.

Italy has a long tradition of industrial use of geothermal resources. The resources are abundant, thanks to geological favourable conditions. Nowadays they are mainly used for electricity generation and space heating by means of district heating.

Italy, in 1904, was the first country in the world to produce electrical power (power from now on) from hot geothermal fluids, and power generation has been continuous since the first power plant, built on 1913 (Figure A5.1). The 34 power plants currently in operation are located in Tuscany, in the two "historical" areas of Larderello-Travale and Mt. Amiata (Figure A5.2). In the year 2018 the gross electricity generation reached 6.1 TWh, with an installed capacity of 915.5 MWe (MW of electricity). Taking into account the real operating conditions of the plants in the different areas (pressure, temperature, non- condensable gas content in the steam), the total running capacity (Reference Net Capacity) is 761.2 MWe (Manzella et al., 2019).

Since 2010, year of the liberalization of geothermal resource development, several new players tried to enter the market, with about 120 new applications for new research permits in geothermal resources suitable for power generation, cogeneration and district heating. After this initial rush, only a few proposed projects completed the surface exploration and, in most cases, the Environmental Impact Assessment (EIA) procedure required for the mining lease is still ongoing. Based on available data from the Ministry of Economic Development online services (in July 2019), 34 Geothermal Research Permits have been released: two of them are applying for the concession; seven are currently applying for the authorization to realize exploratory wells; one has obtained the authorization to realize two exploratory wells. All the other Requests are still in the investigation phase, and other twenty Permit Requests are still waiting for the final notice for the awarding.

Figure A5.1: Historical trend of electricity generation from geothermal resources in Italy

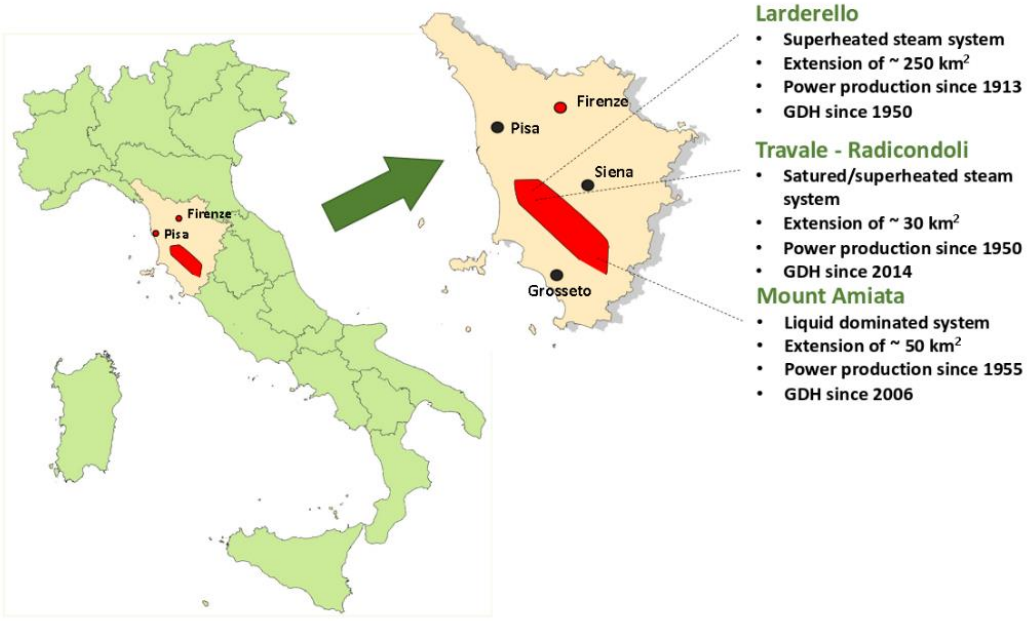

Figure A5.2: "Traditional" geothermal areas in Italy, where electricity is produced from geothermal high temperature resources, and where the most productive geothermal district heating (GDH) networks are located.

Direct uses of geothermal heat are widespread developed, well beyond the geothermal areas of Tuscany, where, however, most of the geothermal district heating systems are located.

At the end of 2017, the geothermal energy thermal use installed capacity exceeds 1400 MWt (MW thermal), for a corresponding total energy use of 10915 TJ/yr (Table 1). The main sector of utilization is the space heating - DH networks and individual systems - which holds 42% and 52% of the total energy use and installed capacity (namely, 4566 TJ/yr and 739 MWt) (Manzella et al., 2019; Bargiacchi et al., 2019).

The heat delivered in 2017 by geothermal district heating systems from deep geothermal resources was 795 TJ, generating 119 MWt (data from GSE (2018) and AIRU (2019)).

Sector of application	Capacity (MWt)			Energy (TJ/yr)		
	Total	**GSHPs**	**DHs**	**Total**	**GSHPs**	**DHs**
Space heating	739	515	149	4566	3.165	853
From deep geothermal			**119**			**795**
Thermal balneology	456	-	-	3.501	-	-
Agriculture uses	80	13	-	656	75	-
Fish farming	130	-	-	2.019	-	-
Industrial process heat + minor uses	20	4	1	174	25	10
TOTAL	**739**	**515**	**149**	**10.915**	**3.265**	**863**

Table A5.1: Summary table of geothermal thermal uses as of 31 December 2017 in Italy

The last national assessment of deep, hydrothermal resources in Italy was carried out at the end of the 1980s with the completion of the Inventory of the Italian Geothermal Resources (Cataldi et al., 1995). In the assessment, Italy was divided and ranked in seven categories on the basis of the presence of a regional aquifer of up to 3 km depth and on the fluid temperature range. More recently, geothermal potential was computed at local scale, especially for mining lease requests of power production projects, but the potential at a national scale has been only roughly estimated. On the basis of the temperature distribution, the Italian Geothermal Association (UGI) esteems a potential total production from geothermal resources within 5 km depth of 21 Exajoule (Buonasorte et al., 2011). Two third of them have temperature below 150°C. Resources at temperature >80-90°C at relatively shallow depth can be found in many areas, i.e. those showing a high surface heat flow. In particular, low temperature resources can be found almost everywhere in Italy, and they could be efficiently used for thermal applications, also in combination with by GHSP technologies.

Waiting for modern resource assessment at national level, various assessments have been carried out at regional level, using diversified methodologies. The most comprehensive assessment of geothermal resources has been carried out by the National Research Council in four regions of southern Italy. The provided maps show the location of geothermal resources that can be developed with the current technologies, including district heating, both in heating and heating/cooling (H&C) mode, and open- and closed-loop GSHP systems (Manzella et al., 2017 and ref. therein).

UGI (2017) forecasts a step increase of the aggregate installed capacity and production of the direct use of geothermal heat by 2050, passing from about 10500 TJ/yr in 2015 to values ranging between 53400 TJ/yr and 75350 TJ/yr, depending on the market and national support condition (Fig. A5.3).

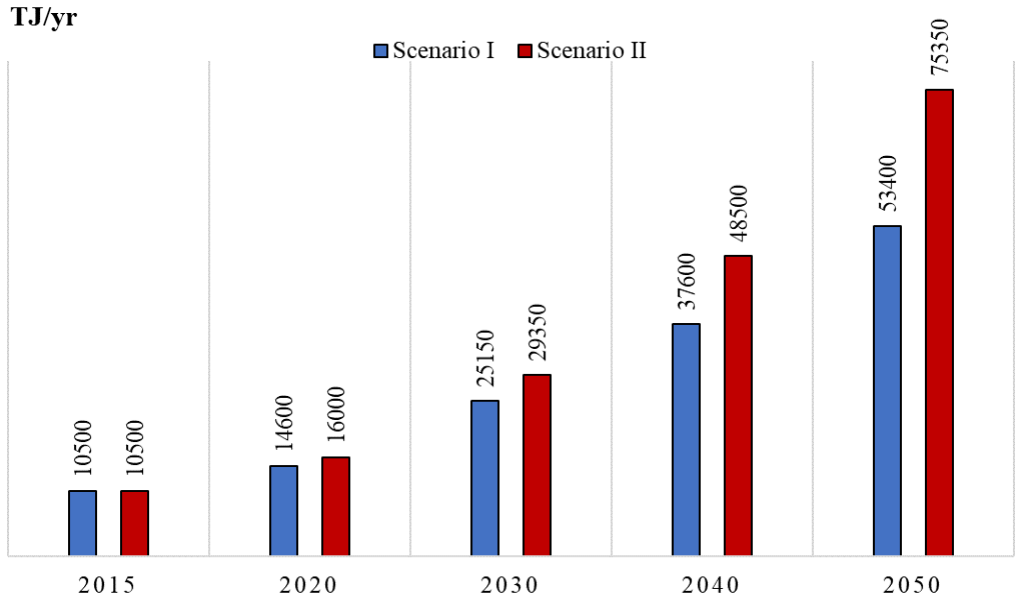

Figure A5.3. Development of direct uses, including heat pumps, 2015-2050, as forecasted by UGI (2017).

Institutional context

Italy' s public administration structure is made up, in descending order of size, of the State, Regions, Provinces, Metropolitan Cities and Municipalities. Each of these has specific administrative functions related to geothermal exploration and development as regulated by Italian law, deriving from the more general laws concerning the attribution of powers among the several administrative bodies.

Policies and policy visions

Energy in Italy

Since Second World War, the energy demand in Italy constantly increased and peaked in 2008, when the economic and financial crisis abruptly interrupted this growth. In the first two decades after the war, the Italian energy production was mainly based on fossil fuels and a first tentative diversification of energy provision was made in the 1970's after the oil crisis. In the late 1970's Italy fostered nuclear power plants development and import from other Countries also increased, but few years later, in 1987, after the Chernobyl disaster, the Italian citizens opted out from nuclear energy in a referendum (the permanent dismissal of the nuclear program was definitely established after a second public consultation in the referendum of 2011). In 1999 the Italian energy market was liberalised by

a governmental decree, the oil resources used for thermoelectric production were progressively substituted by natural gas (mainly introduced from Russia, Algeria and Libia) and the import of energy was further increased.

Italy is an industrialized country, and has a very high energy-dependence rate: almost 77 % in 2017, following EUROSTAT, with the main share of gross energy consumption for thermal uses, in particular space conditioning for building. In the year 2017, the most recent year for which official and robust data are available at the date of this report, the final energy consumption in Italy amounted to 121 Mtoe (Tonnes of oil equivalent) ($5 \cdot 10^6$ TJ).

Italy has historically paid great attention to renewable sources, energy efficiency and energy saving as tools to reduce dependence and mitigate the environmental and climatic effects of the energy cycle. In 2010, Italy has adopted the Renewable Energy Action Plan in order to reach the target described under the terms of the European directive 2009/28/EC. The target was to achieve 17% of final energy consumption from renewable sources by 2020 and Italy reached its goal before the final term. In 2017 the share of Renewable Energy Sources (RES) in gross final energy consumption was 18.3%. 10% of the EU's annual turnover in the renewable energy sector is generated by Italy.

The main share of gross energy consumption in Italy is for thermal uses, in particular space conditioning for building. As to the main electricity consumption sectors, in 2018 42% of the Country general electricity consumption were spent by the industrial sector, 35% by services, 21% by domestic consumption and 2% by agriculture (Terna, 2019).

The contribution of geothermal electricity generation is 2.0% of the whole Italian generation, and over 30% of the electricity needs in Tuscany.

Although the contribution of geothermal energy appears small if compared to the high country energy demand, Italy is one of the most renowned country worldwide in the geothermal sector. It isranked among the top 10 countries for electricity generation (Bertani, 2016) and among the first 20 for thermal applications (Lund and Boyd, 2016).

Energy policy and visions

The development of geothermal resources is one of the topic addressed by the National Energy Strategy (SEN) adopted by the Italian government in 2017 (MISE, 2017). Italy's National Energy Strategy 2017 is a ten–year plan to anticipate and manage the change of the national energy system, to make it more competitive, more sustainable, and more secure. It lays down the targets that must be achieved by 2030, in accordance with the long–term scenario drawn up in the EU Energy Roadmap. The core targets are:

- reducing national energy consumption by a total of 10 Mtoe by 2030;
- reaching a 28% share of renewables in total energy consumption by 2030, and a 55% share of renewables in electricity consumption by 2030;
- strengthening supply security;
- narrowing the energy price gap;
- furthering sustainable public mobility and eco–friendly fuels;
- phasing out the use of coal in electricity generation by 2025.

As required by the Regulation of the European Parliament and of the Council 2016/0375 on the governance of the Energy Union, Italy had time until 31 December 2018 to deposit its proposal for the Integrated National Energy and

Climate Plan (NECP), a ten-year strategy on energy efficiency and environmental sustainability (MISE, 2018). The proposed Italian NECP provides guidelines on the development policies for the Italian national energy system and updated Italy's National Energy Strategy (SEN) goals, taking advantage of a system focused on using renewable sources and becoming more sustainable. This strategy is developed on five parallel levels: decarbonisation, energy efficiency, energy security, internal energy market and research/innovation and competitiveness.

Both SEN and NECP documents forecast an increase of energy production from Renewable Energy Sources (RES) in Italy, an increasing use of heat from renewable sources and improvement of energy efficiency. They, however, envisage a small growth of electricity from geothermal energy technologies. Regarding thermal applications, they forecast an increasing role played by district heating (DH). NECP in particular forecasts a very large contribution from heat pumps. They do not establish, however, any specific action in relation to geothermal DH and HP.

Support measures

The **electricity** generated from renewable energy sources, including geothermal, is incentivized in Italy through a system of premium and feed-in tariffs based on the plants installed capacity.

In 2018 the value of the GRIN (Gestione Riconoscimento Incentivo, i.e. Management of the Incentive Recognition, which replaced in 2016 the Green Certificates) tariff for the plants that have access to this type of incentive was 9.9 Eurocent/kWh in addition to the average market price of electricity. This value is reduced by a “Base Incentive Fee”, a percentage due to the auction reduction, resulting in: 13.4 Eurocent/kWh (under 1 MW_e installed Capacity), 9.8 Eurocent/kWh (for plants between 1 MW_e and 5 MW_e) and 8.4 Eurocent/kWh (over 5 MW_e installed Capacity). All these tariffs are already inclusive of the average market price of electricity, which in 2018 was 6.191 Eurocent/kWh (GSE, 2019). The incentives apply only if the geothermal power plant is enrolled in the register/auction roll managed by the GSE and when, after the completion of the works, is admitted by the GSE, upon specific request, to such incentives.

A new incentive scheme for energy produced through renewable energy sources (RES), the so called FER1, has been issued on 2019 and provides for specific incentives for the 3-year period 2019-2021. It reintroduced an overall average annual cost for incentives, equal to 5.8 bn Euro applicable to photovoltaic (which were excluded from incentives on 2012), onshore wind, hydroelectric plants fuelled by landfill gas and by gas residues from purification processes. New geothermal power plants were excluded from the possibility to participate in the bids for incentive schemes offered by FER1 to RES power plants.

The government is preparing a new incentive scheme for to RES power plants using innovative and environmental friendly technologies (the so called FER2), and has declared the wish to establish a support scheme for geothermal plants demonstrating electrical power production with zero emissions and reduced environmental impact.

The promotion of the use of RES in **heating and cooling** is achieved in Italy by the so-called “Conto Termico” (i.e. Thermal Account), a reimbursement up to a maximum of 65% of expenses incurred to essentially install and purchase small RES-H plants (i.e. geothermal heat pumps) and energy efficiency solutions, which is part of a wider measure to promote energy savings in the building sector. Other measures to promote energy savings the use of RES heat, consist of:

1) the obligation to cover a quota (50%) of the energy needs for domestic hot water with renewable sources for new buildings which are not yet fully operational;
2) the possibility of deducting up to 65% of costs incurred for energy retrofit operations, connection to DH networks, or installation of heat pumps from personal income tax (IRPEF) or corporate income tax (IRES) obligations (so-called “Ecobonus” for existing buildings);
3) reduction of VAT to 10% on expenses in buildings for residential purposes for energy efficiency, energy consumptions and connection works to a DH network;
4) National Fund for Energy Efficiency, to support interventions aimed at ensuring the achievement of national energy efficiency targets, through guarantees funds and subsidized financing;
5) GSE (the national manager of energy services) carried out a survey to assess in 2016 the potential to develop highly efficient CHP systems and DHC networks, as stated by the transposition of Directive 2012/27/UE in 2014.
6) White Certificates, corresponding to the saving of energy (Toe) in industrial sector, as in particular in grid and network infrastructures.

The district heating and cooling networks are managed at local level. National legislation provides only the framework legislation, with an obligation for all municipalities above 50,000 inhabitants to establish, in cooperation with provincial authorities and coherently with the regional energy plans, development plans for district heating and cooling networks with the aim to increase usage of the energy produced also from RES. Municipalities below 50,000 inhabitants can also develop such plans, however there is no obligation in place.

Environmental regulation mapping

Definition, Classification, and Resource Ownership

Legislation regarding geothermal energy in Italy began with the Royal Decree No. 1443 of 29 July 1927 (RD1927/1443), which regulates the activities concerning ore resources and subsurface energies. The geothermal resource, ascribed to the class of “mines”, does not belong to the owner of the land, but is an asset of the State, whose development is subject to a license.

In 1986, the first specific law for the geothermal sector was issued, Law No. 896 of 9 December 1986 (L1986/896) (now abrogated). This geothermal law stipulated the obligations, authorization procedures and the first classification of geothermal resources in national, local and small local utilizations, based on the installable capacity. In addition, a monopoly was established for geothermal resources located in the most promising Italy provinces, as the national power company was the only possible operator. With the introduction of Presidential Decree No. 395 of 27 May 1991 (DP1991/395) and No. 485 of 18 April 1994 (DP1994/485), procedures to request and manage the exploration permits and mining leases were defined. A major change in the authorization process was achieved with the “*administrative decentralization*”, introduced by Legislative Decree No. 112 of 31 March 1998 (DL1998/112), transferring some functions from the State to the Regions. The responsibility for authorizing the development of geothermal resources on the mainland was delegated to the Regions, in compliance with the national policy guidelines and national development programs.

Legislative Decree No. 22 of 11 February 2010 (DL2010/22) is the main reference for legislation currently in force in the field of geothermal resources, which completely abrogated the previous L1986/896. This decree simplifies the authorization and operational activities by enabling local authorities to grant and control mining titles.

Subsequently, the introduction of "*pilot projects*" for the development of "*pilot plants*" with nominal installed capacity not exceeding 5 MW, total reinjection of geothermal fluids in the same reservoir, and with zero emissions, was established by Legislative Decree No. 28 of 3 March 2011 (DL2011/28). Finally, Law No. 98 of 9 August 2013 (L2013/98), which converted, with amendments, the Decree Law No. 69 of 21 June 2013 into Law, and contained urgent provisions for boosting the economy, disposed the State authority for the exploration and testing of *pilot plants*.

Law No. 134 of 7 August 2012 (L2012/134) provided for the inclusion of geothermal energy among the strategic energy sources.

Other norms governing the geothermal exploration and development in Italy are the Presidential Decree No. 327/2001, which regulates the expropriation procedures in case of resources qualified as of public utility; the resolution of the Italian Regulatory Authority for Electricity, Gas and Water No. 111/2006 and the Resolution No. 444/2016, which regulate the main aspects of the Power Purchase Agreements (PPA); the Presidential Decree No 395/1991, which regulates other licenses (for geophysical survey, fluid injection, etc.).

According to Italian legislation introduced on 2010, two main classifications of geothermal resources have been established, based on the temperature or the size (installable capacity). The temperature classification includes:

- high-enthalpy resources, for temperatures higher than 150°C;
- medium enthalpy resources, for temperatures ranging from 90° to 150° C;
- low enthalpy resources, for temperatures lower than 90°C.

Based on the installable thermal capacity, the legislation classifies the resources as follow:

- national interest;
- local interest;
- small local utilizations (essentially related to shallow geothermal, and not further described).

High enthalpy geothermal resources, or those that are considered to be economically viable for running a geothermal project ensuring an overall thermal capacity of at least 20 MWt, are considered of **national interest**, and part of the national heritage. Medium and low enthalpy geothermal resources suitable for running a geothermal project with a thermal capacity up to 20 MWt, are considered of **local interest**. The regional administration (or delegated bodies) in whose territory the project is located is the competent authority for the release of mining titles, both for national or local interest resources. In the case of the off-shore discovery of geothermal resources, authorization is granted by the Ministry of Economic Development (MiSE) in agreement with the Ministry of Environment and Protection of Land and Sea (MATTM).

In 1998 it was established a special case of development of resources of national interest, under state jurisdiction, named "Research for geothermal resources finalized to the test of Pilot Plants" (*pilot plants* in the following). They are required to produce with zero gas emissions and total reinjection of the fluids, and to have installed power

capacity up to 5 MWe. The MiSE is responsible for managing exploration permit for *pilot plants*, in agreement with the MATTM and with the relevant regional governments.

Geothermal resource classification and relevant authorities for granting authorization to development are summarized in Table A5.2.

Type	Size	Relevant authorities granting authorization to development
Resources of national interest on mainland	Above 20 MWt	Regions or their delegated bodies
Resources of local interest on mainland	2-20 MWt	Regions or their delegated bodies
Resources developed by innovative technologies (Pilot Plants)	Up to 5 MWe	Ministry of Economic Development (MiSE) in agreement with the Ministry of Environment and Protection of Land and Sea (MATTM) and the relevant regional governments
Off-shore resources	Any size	Ministry of Economic Development (MiSE) in agreement with the Ministry of Environment and Protection of Land and Sea (MATTM)

Table A5.2 - Resources and relevant authorities for authorization in summary.

Licensing and Authorization

Titles and regulations

Italian law provides two kinds of titles for the exploration, use and development of geothermal resources of national and local interest: an exploration permit and a *"mining"* lease.

The *exploration license* or *permit* gives the license holder exclusive rights to explore for geothermal resources within a designed area and for a definite time, but it does not permit development nor guarantee a mining lease will be granted. The *mining lease* or *concession* is the legal contract for the right to extract geothermal fluids and develop the resource, under prescribed conditions of time, price and royalties. Note that *pilot plants* and off-shore resources have a national relevance, whereas the other titles related to mainland resources regards the whole of Italy except for Sicily. This Region, which has its own special legal status, provides for two geothermal titles, which are, however, quite very similar to the national ones.

Tables A5.3-5 summarize the main information about the management of the mining titles.

The exploration permit

The exploration permit is an exclusive license for the geothermal exploration, which allows the licence-holder to perform, on an exclusive basis, all those operations involved in verifying the existence of geothermal resources.

The application for the exploration permit and the documentation required must be submitted to the Region/s in charge. Several documents are required in the application form:

i) the company data,
ii) the topographic maps;
iii) the work program;
iv) the technical report supporting the work program; and
v) an assessment of any environmental changes that might be caused by the exploration (Preliminary Environmental Study).

If the company does not already possess other geothermal mining titles in Italy, it must present a technical report demonstrating technical experience in geothermal exploration in addition to a report on the company finances.

The technical report *(iv)* must contain a study of the geographic and geo-structural aspects of the exploration area. This report is a "pre-feasibility" study, which deals with the geological, geo-morphological, tectonic, hydrogeological, geochemical frame of the area. The type of power plant that is expected to be installed must be specified and the work program must contain a description of the whole set of studies and operations that the applicant intends to carry out in order to assess the existence and the potential use of these fluids.

For each type of proposed prospect, the work program must detail the tools and techniques to be used, as well as the cartographic location of sampling and measurements points. There must be a business plan detailing the budget and the time schedule for the entire duration of the permit.

Regarding the procedures for preparing the preliminary study of environmental changes *(v)*, the following must be included:

- a report with cartographic indications of geomorphological, hydrographic, urbanistic, landscaping and land use characteristics as well as legal restrictions imposed by national and regional laws (hydrogeological, forestry, landscape, naturalistic, historical, artistic, archaeological, architectural, urban and civic use) in force in the area;
- a qualitative and quantitative definition of the waste and emissions that may be produced during the planned activities;
- a preliminary description of the geophysical and drilling activities,
- a description of the environmental changes that could be produced in relation to the type of work planned,
- a description of the measures that will be put in place to avoid and reduce environmental impacts;
- a study of the environmental recovery work expected as a result of exploratory activities, with reference to the accommodation and maintenance of service areas, the surrounding areas and the infrastructure related to planned activities.

The permit is provided to an industrial operator, or more than one in co-ownership, with adequate technical and economic capacity. It is issued by the authority in charge simultaneously with the approval of the work program. In case the preliminary Environmental Study included in the work program is not considered sufficient, an Environmental Impact Assessment (EIA, see 2.3 for details) more detailed studies on the environmental impacts and risk mitigation is also required.

The permit is subject to the presentation of a bank or insurance guaranty commensurate with the value of the environmental recovery works. The exploration permit can cover a maximum area of 300 km^2, can be awarded for up to four years and can be extended for another two years. The same licence holder may be granted several licences, as long as the total area does not exceed 5000 km^2 nationwide or 1000 km^2 within the limits of the same Region. The licence holder must pay an annual fee of 325 euro (€) per km^2 to the competent authority. The holder of an exploration permit who identifies geothermal fluid, must immediately inform the competent authority, which will then establish the level of national or local interest of the discovered resource. Immediate public notice will be given in the Regional Official Gazette (BUR, Bollettino Ufficiale Regionale) or similar bulletins as seen fit by the region itself (or in the Official Bulletin for Hydrocarbons and Geothermal Resources, BUIG, if the notice is given by the MiSE). The permit holder has the right to submit the application for a mining lease within six months from the granting of national or local interest of the resource by the competent authority. At the end of this period the mining lease for the explored area can be requested in competition with other operators.

The main features of the exploration permit in Italy are summarised in Table A5.3.

Exploration permit	
What is	Exclusive licence for geothermal exploration
Which documents (for the application)	Application form and additional documents in accordance with DL2010/22 and DP1991/395: • company data; • topographic maps; • work program; • technical report supporting the work program; • assessment report of any environmental changes likely to be caused by the project (Preliminary Environmental Study).
Who (competent body)	Competent Region (and the provincial authorities of Trento and Bolzano)
Deadline (duration of the authorization procedure)	240 days starting from the date of the submission of the application (excluding the time for environmental assessment, see section 2.3 for details)
How many km^2	300 km^2 (maximum size)
How long	4 years (with a possible 2 years extension)
Annual fee	€325 per km^2

Table A5.3 – The exploration permit in summary.

A special case of ***exploration permit*** is the one ***for innovative geothermal pilot plants***, set out to promote research and development for low impact geothermal technologies, in particular using technologies for total

reinjection of the geothermal fluid in the same productive formation, and in any case with zero emissions. Each exploration permit is granted for an installed power not exceeding 5 MWe, for a total commitment nationwide not exceeding 50 MWe. No more than three installations, each with a rated capacity not exceeding 5 MWe, may be authorised for each applicant. The exploration permit in this case covers a maximum area of 300 km^2 and is awarded for up to four years, extendable for other two years.

Since the research activities consist solely of a test of a zero-emission *pilot plant*, the industrial operator can propose to carry out the testing only if the geothermal resource is already known. From a technical point of view, therefore, the exploration permit for *pilot plant* testing differs considerably from a conventional exploration permit. Those applications related to areas in which licenses (exploration permit and mining lease) already exist are not accepted because they refer to the same resource.

The exploration permit for *pilot plants* is not subject to the payment of fees. Within its duration, which is the same as for conventional exploration permits, the *pilot plant* activities, i.e. the installation, the commissioning of the power plant and the start of the testing, must be completed.

The MiSE firstly checks the admissibility of an operator's instance in 30 days. The admitted application is published in the BUIG. Within 120 days from the opening of the procedure, the MiSE informs the involved Region and the MATTM. The instance for this form of permit is examined by the CIRM (Hydrocarbons & Mining Resources Committee). Instances are judged on: *i)* knowledge of geological structures, freshwater aquifers, and potential of the geothermal resource; *ii)* quantitative characterization of the geothermal reservoir; *iii)* work program and technological characteristics of the pilot plant with zero emissions. Upon the favourable outcome of the CIRM, the environmental compatibility of the project is assessed (see Section 2.3 for details). Within 30 days from the publication of the environmental outcome, a Conference of Services (a decision planning meeting of relevant authorities) is then hold. Eventually, the MiSE decides regarding the exploration permit together with the MATTM and in agreement with the relevant Region, taking into account the preliminary activity, the outcome of the CIRM and the recommendations of the Conference of Services.

The permissions to test the *pilot plant* is published in the Official Bulletin for Hydrocarbons and Geothermal Resources (BUIG). If the plant is tested successfully, the holder may submit a request for a mining lease in accordance with the procedures set out by the relevant regional authorities and the MiSE.

The main features of the exploration permit for testing *pilot plant* technologies in Italy are summarised in Table A5.4.

The mining lease

The mining lease authorizes the drilling of the wells, the construction of facilities and infrastructures, and the industrial development of national and local interest geothermal resources. The mining lease is issued by the competent authority for a period of thirty years. The geothermal leases that were ongoing in 2010, when the geothermal market was liberalised, will end by 2024.

To obtain a mining lease, the applicant has to provide a bank or insurance guarantee commensurate with the value of the works for environmental recovery. If a competition procedure is necessary, the evaluation criteria are based on: *i)* completeness and rationality of the work program, with particular reference to the long-term sustainability, safety and mitigation of impacts and environmental protection; *ii)* know-how of the applicant.

Exploration permit for testing of Pilot Plant	
What is	Permit for testing pilot plants. Upon acceptance and positive testing, it is followed by a mining lease.
Which documents (for the application)	Application form and additional documents in accordance with DL2011/28: • technical-financial programme of planned work and technical-geological report of the area; • topographic maps; • document to be attached to the topographical map (name of the applicant company; denomination; Region(s), Province(s), Municipality(s); Area (km^2); number of sheet(s) of the IGM; geographical coordinates; date; signature; • Environmental Impact Assessment
Who (competent body)	Ministry of Economic Development, in agreement with the Ministry of Environment and Protection of Land and Sea and with the relevant regional governments
Deadline (duration of the authorization procedure)	240 days starting from the date of submission of application (excluding the time for environmental assessment, see section 2.3 for details)
How many km^2	300 km^2 (maximum size)
How long	4 years (can be renewed for a further 2 years)
Annual fee	None

Table A5.4 – The exploration permit for pilot plants in summary.

The following documents must to be submitted for requesting a mining lease for geothermal resources:

i) *a* technical work program, including further exploration under the mining lease,
ii) a technical report to demonstrate experiences in geothermal development and management;
iii) a preliminary study of the environmental changes associated with the mining lease activities;
iv) a *geothermal project* including a business plan the economic development geothermal resources and any associated substances.

The work program *(i)* must specify the deadline for starting the development of geothermal resources, including a detailed technical description along with the costs of the operations (e.g. injection and reinjection wells, plants and infrastructures). The geothermal project *(iv)* must provide a detailed study of the plants both for electricity conversion or direct uses of geothermal heat and the use of the associated mineral resources. The preliminary study of environmental changes *(iii)* must contain:

- a detailed description of the plant as well as of the alternatives to be taken into account for environmental purposes;

- a detailed report of existing restricted areas (e.g. national parks),
- an environmental framing of the area and the state of quality of the environment (atmosphere, ground water, subsoil, ecosystems, public health and cultural heritage);
- an assessment of the socio - economic impact induced by the introduction of mining lease;
- an analysis of any environmental changes that may possibly be caused by the mining activities;
- a description of the actions planned to limit the environmental impacts.

Eventually, a detailed recovery plan of the areas affected by the work must be presented at least one year before the expiration of the lease. The granting of a mining lease is published in the Regional Official Gazette (BUR).

The holder is required to pay an annual fee of 650 euro (€) per square kilometre of land under mining license. In the case of power generation by means of plants with an installed capacity greater than 3 MW, the following fees must be paid:

- 0.13 cents of Euro per kWh of energy produced in the geothermal field, to the municipalities where the power plants are located, in proportion to the area covered by the mining lease;
- 0.195 cents of Euro per kWh of energy produced in the geothermal field, to the relevant regional governments, in proportion to the area defined by the mining title.

The holder is also required to pay to the relevant municipalities up to the 4% of the cost of the plants, for environmental compensation.

To guarantee the environmental sustainability of the field, the relevant authority requires to the applicant to demonstrate up-to-date technical and economic capacity, by describing the effects of development with particular reference to the distance between production and injection wells and the maintenance of the thermal regime in the reservoir. Additionally, by the twentieth day of each month, the holder must provide the data on the production of fluids, the energy obtained and their use as well as the data relating to the production of other extracted associated substances. The drilling of wells is permitted, upon request, by the relevant authorities, which evaluate the submitted documentation, including for example the location of the well, the depth to be reached, the facilities to be used and the pipe-laying programs. The reinjection of the fluids in the productive formations or other aquifers has to be authorized.

The main features of the mining lease in Italy are summarised in Table A5.5.

Mining lease	
What is	Mining title for the drilling of the wells, the construction of facilities and infrastructures, and the industrial development of national and local interest resources.
Which documents (for the application)	Documents mentioned in DP1991/395: • technical work program; • technical report to demonstrate experiences in geothermal mining; • preliminary study of the environmental changes associated with the mining lease activities; • geothermal project indicating the economic development plan of geothermal resources and any associated substances; • a detailed recovery plan of the areas affected by the work, to be presented at least one year before the title expires.
Who (authorizing body)	Relevant regional administration (or MiSE in case of off-shore resources and *pilot plants*)
Deadline (duration of the authorization procedure)	220 days (excluding the time for environmental assessment, see section 2.3 for details)
Candidate	The holder of exploration permit or other operators (6 months after the resource interest have been granted by the relevant authority)
When (time to request authorization)	Within 6 months of the authorities granting national or local interest of the resource.
How long	30 years (except those titles ongoing in 2010, which expire by 2024, according to art. 16, par. 10 of DL2010/22)
Annual fee	650 € per km^2 to the Region F*or power production >3MWe:* • 0.13 cents of Euro per kWh to the local municipality (in proportion to the size of the field) • 0.195 cents of Euro per kWh to the regional government (in proportion to the size of the field) A fee equivalent to 4% of the cost of the installations for environmental compensation to relevant municipalities.

Table A5.5 – The mining lease in summary

Authorization in the Tuscany Region

The recent "geothermal law" (Tuscany Region Law L.R. 7/2019 "Disposizioni in materia di geotermia"- "Provisions about geothermal energy") approved by the Regional Council of Tuscany, establishes that the authorization of mining leases for new power production plants in old or new concession areas is subordinated to (further details below):

- the use of the Best Available Technologies to mitigate degassing and to reduce the maximum hours per year of allowed plant stop to 2% of the total plant working (production) hours;
- monitoring of air quality, and in particular hydrogen sulphide (H_2S) (continuously), and mercury, arsenic, boron, ammonia (seasonally), and establishing the emission limits for such pollutants;
- providing air quality data in real time to the regional environmental agency (Agenzia Regionale per la Protezione Ambientale della Toscana, ARPAT);
- providing for compatibility with landscape;
- guaranteeing the best possible economic, social and environmental benefit, including the obligation to use at least 50% of the residual energy from electricity production for heat applications, the use of at least 10% of produced CO_2, and to provide the produced CO_2 for free in case of request.

Environmental regulations

The main current regulatory reference in Italy in the environmental field (Environmental Regulations) was set up in 2006 (D. Lgs. 152/2006), modified and supplemented in 2017 by the D. Lgs. 104/2017, and provides the framework for the "Valutazione di Impatto Ambientale, VIA" (Environmental Impact Assessment, EIA). The EIA is defined as the assessment of plans, programs and projects to ensure that human activities are compatible with the conditions for sustainable development, in accordance with the regenerative capacity of ecosystems and resources, the preservation of biodiversity, and a development in which the benefits are shared by all. It describes and assesses the direct and indirect impacts that a project could have on humans, flora and fauna; on the soil, water, air and climate; on the cultural heritage and on the interaction between these factors.

In the geothermal case, the Environmental Regulations are used for detecting, describing and assessing the environmental effects produced by the activities of a geothermal project, and are applied by the competent authorities (ministries or regions) for the exploration permit and mining lease. Two types of environmental procedures are provided for geothermal projects: Environmental Impact Assessment Screening (Verifica di Assoggettabilità a VIA) and Environmental Impact Assessment (EIA).

The *EIA screening* consists of a preliminary assessment of whether a project could have a significant impact on the environment. If the project is assumed to have no significant environmental impacts, the competent authority excludes the project from the EIA procedure.

The *EIA* procedure requires the applicant to send a "preliminary environmental study", and a copy of the payment of a fee to the competent authority. The preliminary environmental study is published immediately on the website of the competent authority and notified to all administrations and local authorities potentially involved in the project. The applicant has to notify the request in the Italian Republic's Official Gazette "Gazzetta Ufficiale" for the relevant

State projects, in the Regional Official Gazette for projects of regional relevance, and in the official book “Albo Pretorio” of the municipalities involved.

Level	#/year	Description
EU	Directive 2011/92/EU	'Environmental Impact Assessment' – framework EIA Directive as amended in 2014 by the Directive 2014/52/EU (https://ec.europa.eu/environment/eia/eia-legalcontext.htm)
National	D. Lgs. 152/2006 Part II	PROCEDURE PER LA VALUTAZIONE AMBIENTALE STRATEGICA (VAS), PER LA VALUTAZIONE D'IMPATTO AMBIENTALE (VIA) E PER L'AUTORIZZAZIONE AMBIENTALE INTEGRATA (IPPC) Framework national legislation, modified by the Legislative Decree (D. Lgs.) 104/2017, which transposes into the Italian Legislation the changes enforced by the Directive 2014/52/EU
Regional	L.R. 10/2010	Norme in materia di valutazione ambientale strategica “VAS”, di valutazione di impatto ambientale “VIA”, di autorizzazione integrata ambientale “AIA” e di autorizzazione unica ambientale “AUA” Framework regional legislation (Tuscany), modified by the R.L. 25/05/2018 n. 25 in order to adapt it to the above-mentioned national D. Lgs. 104/2017

Table A5.6 – The EIA regulation at EU, national and regional level in summary

In the subsequent 45 days, the competent authority has to check whether the project has any significant negative effects on the environment and, by that deadline, gives its opinion on the proceedings, taking into account the comments received. The decision is published by the competent authority, in the official media.

If allowed to proceed, the applicant sends to the competent authority the final project, the environmental impact study, a non-technical summary, a copy of the press releases, the list of permissions, agreements, concessions, licenses, opinions, and consents acquired or to be acquired and an electronic copy of the documents submitted.

The *environmental impact study* is drawn up following the instructions provided by regulation, periodically updated and in accordance with the outcome of the consultation with the competent authorities and the relevant stakeholders on the environment. The environmental impact study must contain the following information:

i) characteristics, location and size of the project;
ii) description of the measures envisaged to prevent and/or reduce significant adverse effects;
iii) identify and assess the main impacts of all phases of the project on the environment and the cultural heritage;
iv) a description and rationale of the alternatives studied, including the so-called 'zero' option (the possibility of not starting the project), explaining the choices;

v) a monitoring plan of potential environmental impacts arising from the project, including the responsibilities and resources necessary for the implementation and monitoring;

vi) any additional information relating to the specific characteristics of the project or type of project and the environmental factors likely to be affected.

Within 15 days, the competent authority has to check the completeness of the documentation and the payment of fees. If the application is judged incomplete, the competent authority may require the applicant to submit the additional documentation within 30 days. Within a 60-day period from the publication of the project, anyone who is interested can examine the project and submit their comments. The competent authority has to express its opinion on the environmental impact assessment within 90 days of the deadline for submitting comments.

Within 150 days (extendable up to 330 in particularly complex cases) of the submission of the complete application, the competent authority has to take a motivated decision on the environmental compatibility of the plant. A report with the final decision on the environmental impact assessment is published in the Official Gazette of the Italian Republic for projects under state jurisdiction, and in the Regional Official Gazette (BUR), for projects of regional competence. The report contains the rationale underlying the decision of the competent authority, a summary of the results of the consultation and the environmental conditions, i.e.: *i)* the requirements for the construction, operation and decommissioning of the installation; *ii)* the measures to avoid, prevent and reduce environmental impacts; *iii)* the monitoring measures.

The geothermal resources are subject to the EIA Screening for exploration permit and EIA for mining lease under the responsibility of the regional authorities (or the provincial authorities in the case of Trentino Alto Adige region). Moreover, deep well drilling and exploration permit in the case of negative EIA Screening are subject to the EIA procedure.

The geothermal *pilot plants* are subject to the EIA under the responsibility of the MATTM.

The main features of the two environmental procedures are summarised in Table A5.7.

Title	**Exploration permit**	**Exploration permit of pilot plants**	**Mining lease**
Type	EIA Screening	EIA	EIA
Timing	90 days	150-330 days	150-330 days
Responsibility	Regional authorities (Provincial authorities in the Trentino Alto Adige region)	Ministry of Environment and Protection of Land and Sea (MATTM)	Regional authorities (provinces in the Trentino Alto Adige region)

Table A5.7: The environmental procedures in summary.

Regulatory guarantees

The granting of exploration permit and mining lease is subject to bank guarantee, whose value is proportional to the entity of environmental recovery works, reclaiming of decommissioned areas. This is aimed at ensuring the duly and timing execution of the project and the restoration of the areas at the end of the works.

During the environmental impact assessment procedure, local municipalities, local communities and associations representing indigenous people can rise objections in order to protect local interests and local values. They submit documents, opinions, authorisations, in order to ascertain whether the project meets local regulations and, as the case may be, to benefit from environmental compensation measures. These documents are taken into account by the competent authorities in assuming their final decision. In any case, if local communities and associations believe that their interests have not been adequately protected, they are entitled to challenge the granted license before the competent Administrative Court.

Sustainability and Environmental Impacts

Environmental aspects in Italy are regulated by European, national and regional legislation. Here we focus on national legislation, in particular those rules that further enforce and detail the European legislation.

The Italian regulation of reference in the case of geothermal plants is mainly focussed on the protection of air, water, soil, public health and aimed at the prevention of pollution, seismic risk, noise and visual disturbances.

In an attempt to address environmental concerns, the Italian Government also edited the “Guidelines for the use of medium and high enthalpy resources”, which describes the best practices for a sustainable and ecocompatible management of geothermal fields, with a focus on monitoring (MiSE-MATTM, 2016). The document focuses on: i) a preliminary survey to identify a potential industrially exploitable geothermal reservoir; ii) the methodologies for the safe drilling of geological formations and measures to eliminate the risk of contamination of the surface aquifers between the ground and the rock reservoir; iii) the water, soil and air monitoring techniques for the early detection of any contamination of the environment; iv) the methodologies for the monitoring and control of seismicity, subsidence and pore pressures.

Italian regional governments are supported, by law, by regional environmental agencies for environmental protection (Agenzia Regionale per la Protezione Ambientale, ARPA) aimed at enforcing environmental legislation, according to the guidance of the regional authority.

Waste management

Level	#/year	Description
EU	Directive 2008/98/EC	New framework EU legislation
	Directive 2018/850/EC and Directive 2018/851/EU	Enforces measures for the circular economy. Directive amending Directive 2008/98/EC on waste.
National	D. Lgs. 152/06 Part IV	Framework legislation on waste management – (does not include yet EU directive 2018/851)
	L. 12/2019	Waste management traceability system
	D.P.R. 120/2017	Management of rocks and excavated earth waste

Table A5.8 – The waste management regulation at EU and national level in summary

In Italy, waste management is regulated by the Part IV of the Legislative Decree 152/2006, and subsequent amendments and integrations, which enforces in Italy the EU directives on waste management, and in particular of the directive 2008/98/CE; the new EU directive 2018/851, issued on May 30, 2018, which partially modifies the directive 2008/98/CE, has not been enforced yet in the Italian legislation.

The Law 12/2019 defines the waste management traceability system. The Decree of the President of the Republic DPR 120/2017 regulates the management of rocks and excavated earth produced during the wells drilling and the construction of facilities.

Waste is classified into urban or industrial waste according to their origin and are classified as “non-hazardous” (treated similarly to urban waste) or “hazardous” according to the specific activity that originated it and/or their composition. Temporary storage of waste is allowed in an area within the production site, before disposal or recovery. Temporary storage does not require any authorization, but the waste must be disposed of or recovered at least quarterly, regardless of the volume, or whenever a volume of 20 m3 of non-hazardous waste, or 10 m3 of hazardous waste, is reached. In any case, waste cannot be stored for more than one year.

Hazardous and non-hazardous waste cannot be mixed. Waste disposal must be registered, and a return form duly filled must accompany disposed waste during transportation. Excavated earth and rocks from drilling and construction can be reused or disposed depending on the content of polluting substances and the feasibility of their effective reuse.

Water quality, discharge of water

Level	#/year	Description
EU	Directive 2000/60/EC	Water framework directive, partially modified by subsequent directives
	Directive2006/118/EC, modified by the Directive 2014/80/EU	Protection of groundwater resources
	Directive 2008/105/EC	Water quality standards, also modifying the Directive. 2000/60/EC
	Directive 2013/39/EU	Priority water pollutants, including Hg
National	Legislative Decree. 152/2006 Part III	National framework legislation, enforcing various EU directives included the Dir. 2000/60/CE and other directives (later modified by the Dir 2008/105/CE) as the dir. 84/156/CEE on Hg discharge, plus other relevant directives on wastewater treatment and discharge limits (Dir. 88/347/CEE, dir. 80/68/CEE). A number of subsequent decrees modified the framework legislation in order to include the European Directives

	Legislative Decree 30/2009	Implementation of Directive 2006/118/EC aiming to prevent groundwater pollution and deterioration
	Legislative Decree 172/2015	Implementation of Directive 2013/39/EU amending Directives 2000/60/EC as regards priority substances in the field of water policy and identifying a list of pollutants and their environmental quality standards
	Ministerial Decree 6 July 2016	Transposition of Commission Directive 2014/80/EU amending Annex II to Directive 2006/118/EC on the protection of groundwater against pollution and deterioration
	Legislative Decree 69/2013 converted with amendments by Law 98/2013	Amendments to Legislative Decree 152/2006 (art. 104) related to the reinjection of groundwater into the same aquifer after treatment for the purposes of remediation"
	"Guidelines for the use of medium and high enthalpy resources" (MiSE-MATTM, 2016).	This document, among other things, is focused on the water, soil and air monitoring techniques for the early detection of any contamination of the environment.

Table A5.9 – The regulation related to water quality and management at EU and national level in summary

The reference law for the protection of water in Italy is Part Three, Section II (Environmental regulations - Soil protection and the fight against desertification, protection of waters against pollution and management of water resources) of D. Lgs. 152/2006 and subsequent amendments. This section of the regulation aims to ensure the sustainable use of water resources and establishes the methods for water monitoring and use, as well as the procedures for obtaining permissions to discharge wastewater into sewers, groundwater and surface water. The part three of the D. Lgs. 152/2006 implements the European Directive 2000/60 for monitoring and classifying the water quality, and makes regional authorities responsible for planning and monitoring of surface and underground water quality and quantity. It requires also that meteoric water falling in the perimeter of the drilling pad and plant facilities are contained and treated, to avoid potential damage to the environment. A number of subsequent decrees modified the framework legislation in order to include the European Directives mentioned in Table A5.9.

Further instructions related to monitoring procedures in Italy are defined in the guidelines from MISE-MATTM (2016). They include monitoring techniques, suitable locations for monitoring stations, and the frequency of controls.
3.2 Surface disturbance

Landscape

Level	#/year	Description
EU	Directive 2003/35/CE	General framework on the participation of the public to planning procedures for environmental protection
	Directive 2006/12/EC	Adoption of measures to ensure that waste is recovered or disposed of without damaging the landscape transposed into Italian law by Legislative Decree No 152 of 3 April 2006

National	D. Lgs. 42/2004	Code of Cultural Heritage and the Landscape
	D. Lgs. 152/2006 Part II	Regarding EIA and SEIA: landscape must be preserved when designing new plans and facilities

Table A5.10 – The landscape protection regulation at EU and national level in summary

The Code of Cultural Heritage and the Landscape (BCP) (D. Lgs. 42/2004, Codice dei beni culturali e del paesaggio) is the most important plan to which the regional and local level programs must comply. We describe here the case of Tuscany, where all national geothermal power plants are located and actions aimed at improvement of the environmental compatibility of geothermal activities are ongoing.

Also, the D. Lgs. 152/2006 Part II, regulates the landscape protection in the environmental impact assessment procedures.

In Tuscany, the regional Landscape Plan (PIT - *Piano di indirizzo territoriale con valenza di piano paesaggistico*, Plan of territorial address, with status of Landscape Plan) recognizes aspects, peculiar features and landscape characteristics of the regional territory, and define specific use regulations and appropriate quality targets. The Landscape Plan is organized on two levels, the regional and the local one: at regional level it regulates the transformation of the territory (geomorphological and hydrogeological features, natural, semi-natural and human ecosystems, etc.), and the "landscape assets", formally recognized as such (natural parks and reserves, peculiar natural emergences, archaeological sites, cultural heritages places, etc.); at the local level, it divides the Tuscany territory into 20 landscape areas ("*Ambiti*"), formulating specific quality objectives and relative discipline for each of them. On various occasions, the most recent being the Geothermal Law (L. R. 7/2019), moreover, it established the need to further define the areas of the region in which the geothermal activities may be developed.

Noise

Level	#/year	Description
EU	Directive 2000/14/EC	Framework directive – harmonisation of emission standards, methods, etc
	Directive 2002/49/EC	Assessment and management of environmental noise
	Directive 2015/996/EU	Directive establishing common noise assessment methods according to Directive 2002/49/EC
National	Law 447/1995	National framework law on noise pollution, modified thereafter to be harmonised with EU legislation (Dir. 2000/14/EC in particular)
	Ministerial Decree of 11 December 1996	Application of the differential criterion for plants with a continuous production cycle
	Decree of the President of the Council of Ministers of 14 November 1997	Determination of limit values for noise sources
	Ministerial Decree of 16 March 1998	Detection and measurement of noise pollution

	Legislative Decree 262/2002	Implementation of Directive 2000/14/EC on the noise emission in the environment by equipment for use outdoors
	D. Lgs. 194/2005	Enforces the EU Dir. 2002/49/CE
	Legislative Decree 42/2017	Requirements for the harmonisation of national legislation on noise pollution (amending of parts of Law 447/1995

Table A5.11 – The noise regulation at EU and national level in summary

Noise production is classified as a form of pollution by the Italian law which defines the maximum allowed noise levels, how to handle acoustic pollution, the evaluation of sound sources etc. The Italian legislation is composed by a framework law (L. 447/95) and a number of ministerial decrees for its implementation, defining noise limits and technical rules on specific aspects, and by the D/ Lgs. 194/2005, enforcing the EU directive 2002/49/CE on noise mapping and emissions management plans of local to be enforced by local authorities.

The level of noise allowed is regulated according to the local area and its usage, and different levels are set for night-time (22:00 pm to 6:00 am) and day-time (6:00 am to 22:00 pm). Six classes of land use and related admissible noise level are established. For each class, noise emission limit values are given together with emission levels values and quality standard levels as summarized in Table A5.12.

Territory classification		**Emission Level Values dB(A)**		**Intake Level Values dB(A)**		**Quality Standard Values dB(A)**	
CLASS		Day	Night	Day	Night	Day	Night
I	Areas with special protection: hospitals, schools, rural residential sites, parks etc.	45	35	50	40	47	37
II	Mainly residential areas, with commercial and industrial activities	50	40	55	45	52	42
III	Mixed residential and non-industrial production activities areas	55	45	60	50	57	47
IV	Intensively inhabited areas	60	50	65	55	62	52
V	Mostly industrial areas, scarcely inhabited	65	55	70	60	67	57
VI	Exclusively industrial areas	65	65	70	70	70	70

Table A5.12 - Noise Limit Values in the environment (dB(A)) according to the sites' land use

By law, each municipality must perform an acoustic characterization, i.e. mapping and ranking, of its local area according to the classification in Table A5.12.

These limit values, applicable to permanent installations, such as geothermal power plants, are however not applicable to temporary sites, such as drilling rigs for research or cultivation wells geothermal energy. Authorizations for temporary activities that overcome the noise limits can be requested to local municipalities.

Air emissions and quality

Level	#/year	Description
EU	Directive 2004/107/EC	Air quality of As, Hg, Cd, Ni and PAH (Fourth Daughter Directive)
	Directive 2008/50/EC	Framework directive on air quality
	Directive 2016/2284/EU	Reduction of national emissions of certain atmospheric pollutants (SO2, NOx, CONVNM, NH3 fine particulate matter (PM2,5)
National	D. Lgs. 152/2006 Part V	Prevention and limitation of atmospheric emissions
	D. Lgs. 155/2010	Air quality regulation, enforcing the EU directives 2008/50/CE and 2004/107/CE
	Legislative Decree 81/2018	Transposition of Directive 2284/2016/EU establishing new national emission reduction commitments for SO2, NOx, NMVOCs, NH3 and PM2.5.
Regional	DGRT 344/2010; Tuscany Region Law 9/2010; DDGRT 1743/2014	The regional legislation establishes specific limits and measures for target pollutants from geothermal plants, which take over on the less specific national legislation.
	DCR n. 72/2018	Air quality planning
	Tuscany Region Law L. R. 7/2019	Requirements for geothermal plants, modifying some emission limits of the previous regional legislation

Table A5.13 – The air emission and quality regulation at EU national and regional level in summary

The Italian legislation on air quality and emissions transposes European legislation and provides guidelines as well as air quality and emission limits from plants. The two main laws regarding, respectively, regulations of emissions and air quality, transposed from the European directives:

- **Legislative Decree 152/2006** and subsequent amendments and integrations (Legislative Decree 128/2010) rules on air protection and reduction of atmospheric emissions. The Decree deals with the prevention and limitation of atmospheric emissions, through prescriptions and limits related to emissions generated by some activities, plants and fuels. Limit values are established.

However, the national limits do not apply for geothermal plants, where the regional specific legislation is enforced, by posing limits according to the best available technologies for the abatement of geothermal emissions.

- **Legislative Decree 155/2010** and subsequent amendments and integrations (Legislative Decree 250/2012), implements the Directive 2008/50/EC and 2004/107/CE on Cd, Hg, As, Ni and PAH, and establishes a single regulatory framework for the assessment and management of ambient air quality. It contains definitions of limit value, target value, information and alert threshold, critical levels, long-term

objectives and target values . The Decree identifies the list of pollutants for which monitoring is mandatory (NO2, NOx, SO2, CO, O3, PM10, PM2.5, Benzene, Benzo(a)pyrene, Lead, Arsenic, Cadmium, Nickel, Mercury, ozone precursors). The Decree also establishes the methods of transmission and the contents of information on the state of air quality, to be sent to the Ministry of the Environment. The decree identifies the Regions as the competent authorities for assessing air quality and drawing up air quality restoration plans in areas where the limit values have been exceeded.

Such decrees are relevant to geothermal plants as they define the general framework for regulating emissions and air quality, defining the permitting authorities and procedures and the framework for establishing air quality regional plans, which include air quality standards, monitoring procedures and methods.

The national guidelines (MISE-MATTM, 2016) stipulate that authorizations for new plants are subordinated to the definition of predictive models for emission effects and the planning of monitoring and abatement measures.

The Tuscany Region prescribes, by regional laws, specific emissions limits to be imposed to the geothermal powerplants and, due to such limits, there is an obligation to install abatement system for critical pollutants as H_2S, Hg. Such regional decrees and laws (DGRT 344/2010, Tuscany Region Law 9/2010, DDGRT 1743/2014, Tuscany Region Law 7/2019, DCR n. 72/2018 (approval of the Regional air quality plan) define the requirements for plants both as emission values and as technologies to be adopted for their containment, and procedures for sampling and analysis of geothermal emissions. Such specific requirements are summarised in Tables A5.14-16.

Decree / law	Title	Prescriptions relevant for geothermal plants
Tuscany Region Law 7/2019	Prescriptions about geothermal energy deployment – modification of the Regional Law 54/1997	This law sets the general guidelines and prescriptions for: - authorising new geothermal plants / provide new authorisations to existing plants, - providing access to air quality and emissions data for the relevant public administration, - Guaranteeing the use of best available technologies and the recovery of waste heath and CO_2.
DCR 72/2018	Regional ambient air quality plan – approval according to the RL 65/2014	This regional plan confirms the prescriptions from the Resolution of the Tuscany Region government n. 344 / 2010: - Emissions limits at stack; - max number of non-operational hours for abatement plants; - target emission values for new/revamped plants
Resolution of the Tuscany Region government n. 344 / 2010	Resolution of the Regional Council No. 344 of March 22, 2010 "Guidelines for the containment of atmospheric emissions from geothermal power plants".	- Emissions limits at stack; - max number of non-operational hours for abatement plants; - target emission values for new/revamped plants

Regional Law RT 9/2010	Regulation for the protection of ambient air quality	General law that assigns duties to the public administration and set the rules for the aims and approval of the regional air quality plan.

Table A5.14 - Main contents of the Italian Tuscany Region legislation on air emissions and air quality relevant for geothermal plants.

Equipment	H_2S kg/h	Hg g/h	SO_2 g/h
Outlet of the AMIS abatement plant	3	2	150
Natural degassing without AMIS for plants ≤ 20 MW	10	4	
Natural degassing without AMIS for plants > 20 MW	20	8	
Forced degassing without AMIS for plants ≤ 20 MW	30	10	
Forced degassing without AMIS for plants between 20 and 60 MW	60	15	
Forced degassing without AMIS for plants > 60 MW	100	20	

Table A5.15 - Emission limits allowed in Italian plants, enforced by the Tuscany Region legislation relevant for geothermal plants (L.R. 7/2019).

Type of stop	limit
Hours of overall non-operational plant	2% in 8760 hours / year
Hours of operation of AMIS plants / overall operational time of the facility	≥ 98%

Table A5.16 - Maximum hours per year of allowed plant stop in Italian plants, enforced by the Tuscany Region legislation relevant for geothermal plants (L.R. 7/2019).

Ground deformation

The first reference in Italian law related to mitigation of land subsidence phenomena is Law 183/1989. Today, the main reference is the D. Lgs.152/2006 and subsequent amendments to Part Three, aimed at ensuring the conservation and safeguarding of soil and subsoil, the hydrological restoration of the affected area through the prevention of instability phenomena, the safety of the risk situations, and combating desertification.

The guidelines from MISE-MATTM (2016) describe procedures and protocols for monitoring and analysing the spatial-temporal evolution of surface deformation and the publication of data and results. They require the use of InSAR techniques complemented by GPS surveys during geothermal operations.

Seismicity

Level	#/year	Description
National	Royal Decree 193/1909	First normative reference identifying seismic areas on the national territory
	Law 64/1974	Reference framework for the methods of seismic classification of the national territory, as well as the drafting of technical standards
	Guidelines for monitoring seismicity, soil deformation and pore pressures in the context of humans' activities 24/11/2014	The guidelines, which referred to hydrocarbon exploitation, waste-water injection and CO2 storage, were updated, tailored for the geothermal case and embedded in the "Guidelines for the usage of medium and high enthalpy geothermal resources" (MISE-MATTM, 2016)
Regional	DGRT 298/2018	Seismometric monitoring in Tuscany Region

Table A5.17 – The seismicity regulation at national and regional level in summary

The "Italian Guidelines for monitoring the seismicity, underground deformation and pore pressure in subsurface industrial activities" were issued on 2014 by the Ministry of Economic Development and developed within the Commission on Hydrocarbon and Mining Resources (CIRM) (CIRM, 2014). The guidelines, which referred to hydrocarbon exploitation, waste-water injection and CO_2 storage, were updated, tailored for the geothermal case and embedded in the "Guidelines for the usage of medium and high enthalpy geothermal resources" (MISE-MATTM, 2016). The Guidelines are thought to ensure the highest transparency and objectiveness of monitoring, with the full publication of data and results. They describe the governmental regulations, technical aspects of monitoring, and operative actions for a safe exploitation of the reservoir. The purpose is to detect variations in the monitored parameters (pore pressure, micro-seismicity and ground deformation), their correlation with the energy-activity carried out in the subsurface, to undertake mitigation actions and launch proper actions for the safety of plant, people and involved environment. The Guidelines direct the application of a four-stage traffic light protocol (actually applied exclusively for reinjection of waste water), depending on magnitude, Peak ground velocity (PGV) and peak ground acceleration (PGA).

By regional decree N°298 26/03/2018A a further agreement between Regione Toscana and the geothermal operator is mandatory in Tuscany and defines the monitoring protocol and the related technical details, such as number of monitoring station, data handling and communication with the population.

In case of damage to exposed value assets or population (e.g. evacuation), the support is handled by government and local authority emergency decree, that regulate the (public) funding expenditure.

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APPENDIX 6: TURKEY

General overview

General data on deep geothermal in Turkey.

Turkey has the highest rate of growing energy demand among OECD countries over the last 15 years. To keep energy import dependency in control an attention to utilising domestic sources has become an energy strategy of the Country. Concerning renewable energy sources, the Law on the Utilization of Renewable Energy Sources for the Purposes of Generating Electricity has been adopted in 2005 for promoting electricity production from the renewable energy sources in liberalized energy markets.

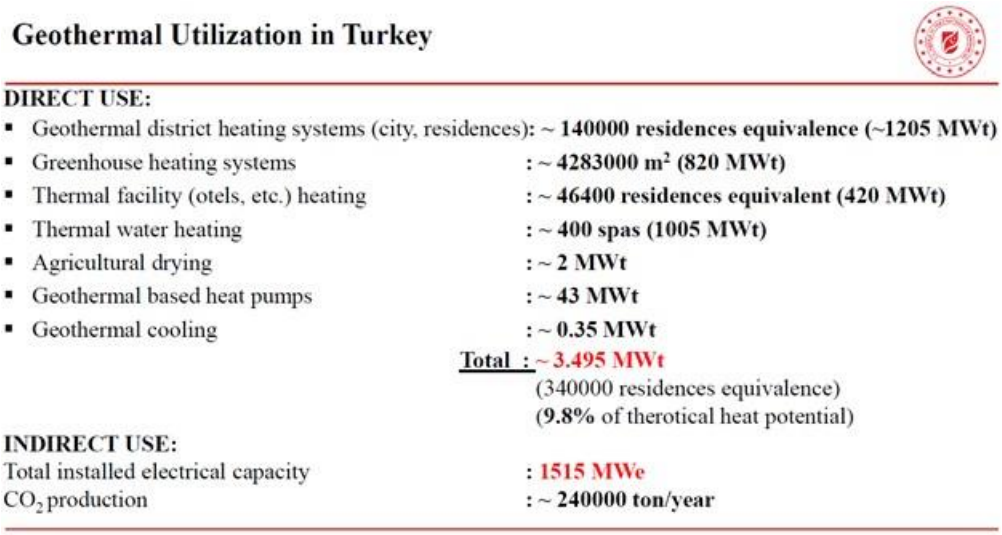
Figure A6.1: Electricity installed capacity development. Source: TR Ministry of Energy and Natural Resources

Geothermal energy as published on Official Gazette on3rd of June, 2007, is regulated by the Law numbered 5686, Law on Geothermal and Mineral Resources (Geothermal Energy Law) along with the Geothermal and Mineral Resources Law Implementation Regulation numbered 26727 (Regulation).

Turkey's geothermal history goes back to the 1960s thanks to studies from the General Directorate of Mineral Research and Exploration (MTA) and its discovery in Kızıldere field

Up to now, nearly a total of 1,200 geothermal exploratory, production and reinjection wells have been drilled, and nearly 80% of these wells have been drilled in the Western Anatolia of Turkey.

As presented on the 2014 dated National Renewable Energy Action Plan of Turkey forecasted installed capacity of geothermal resources for electricity production was 1,000 MW for year 2023. Today with 1,515 MW installed capacity Turkey is now a part of five countries that have more than 1 GW installed capacity. With the 2023 target already reached today, Turkey has set itself a new target of 4,000 MW of capacity to be reached by 2030.



Geothermal Utilization in Turkey

DIRECT USE:

- Geothermal district heating systems (city, residences): ~ **140000 residences equivalence (~1205 MWt)**
- Greenhouse heating systems : ~ **4283000 m² (820 MWt)**
- Thermal facility (otels, etc.) heating : ~ **46400 residences equivalent (420 MWt)**
- Thermal water heating : ~ **400 spas (1005 MWt)**
- Agricultural drying : ~ **2 MWt**
- Geothermal based heat pumps : ~ **43 MWt**
- Geothermal cooling : ~ **0.35 MWt**

Total : ~ **3.495 MWt**
(340000 residences equivalence)
(**9.8%** of therotical heat potential)

INDIRECT USE:

Total installed electrical capacity : **1515 MWe**
CO_2 production : ~ **240000 ton/year**

Figure A6.2: Geothermal utilization in Turkey. Source: TR Ministry of Energy and Natural Resources; December 2019

Besides power production Turkey exploits geothermal energy for district and greenhouse heating and other direct usage areas.

The key drivers of the significant growth in a relatively short period can be based on (i) Government's incentive tariff mechanism; (ii) passion, ambitious and entrepreneurship of domestic investors; (iii) strong collaboration between Government instutions, universities and operators; and (iv) access to project financing.

Institutional context

5686 numbered Geothermal Energy Law in Republic of Turkey regulates geothermal resources along with natural mineral water resources and geothermal-related gases. It covers the procedures of usage rights, licences and their assignment or transfer which is approved by Grand National Assembly of Turkey and implemented by related ministries and their organs. The relevant authority is the Ministry of Energy and Natural Resources (MENR) and the relevant head state entity is the Provincial Special Administration (Administration) in cities; and Investment Monitoring Coordination Department Head (YİKOB) (Administration) in metropoles. Relevant authority for power production from geothermal resources is Energy Market Regulatory Authority (EMRA).

Policies and policy visions

The energy demand of Turkey, by being one of the fastest growing economies, are at rates of 4.5% to 7% per year and almost 75% of energy demand is met by imported natural gas, followed by coal and petroleum. The main electricity generation source is conventional fuels such as natural gas and coal. Since currently, Turkey is able to meet only around 25 % of its total energy demand from its own domestic resources Authorities has been focused on alternative energy sources to balance increasing energy demand and import dependency.

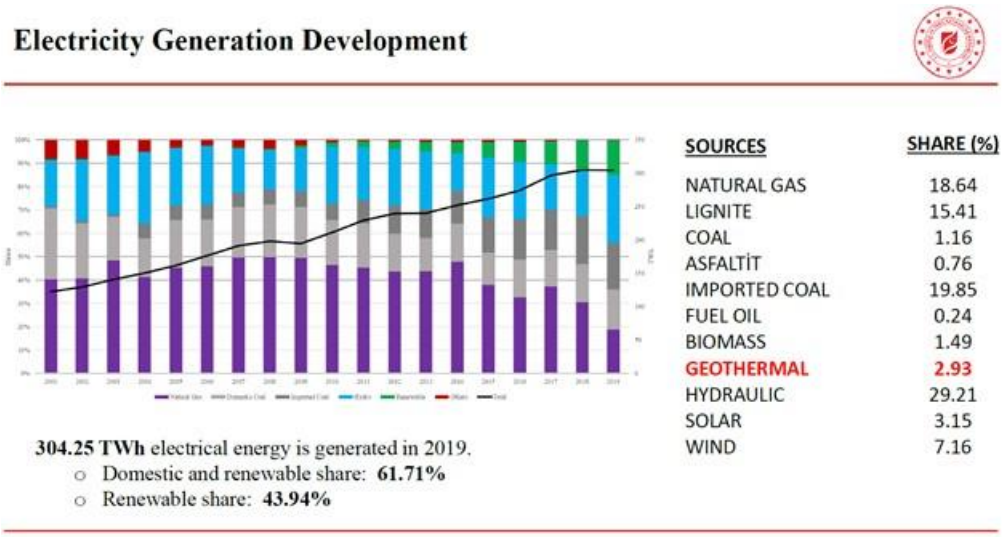


Figure A6.3: Electricity generation development. Source: TR Ministry of Energy and Natural Resources

The Turkish Government's announced strategic plan for the years 2015 to 2019 has been based on:

- Good governance and shareholder interaction;
- Regional and international effectiveness;
- Technology, R&D (research and development) and innovation applications; and,
- Improvement of the investment environment in the field of energy and natural resources.

In accordance with above detailed plan to improve and support the investment environment in the power generation sector, the Government has taken substantial steps especially by taking in force legislative amendments.

In order to benefit from the incentives under the Renewables Law, a renewable energy generation facility must hold a renewable energy resource certificate (the RER Certificate), which is issued by EMRA. The RER Certificate will be valid for the term of the generation license of the relevant generation company.

The first step in the process of liberalization of the energy market in Turkey started by the 6446 numbered Electricity Market Law published on Official Gazette dated 20th of February 2011. This law has aimed to provide adequate, high quality, continuous, low cost and environmentally friendly usage of electricity to consumers and predicate to increase of the shares of private market in electricity production. Based on energy politics of the Government it was preferential to initiate utilizing domestic sources to decrease energy dependency.

Estimated geothermal potential of the country has increased to 60,000 MWt. 79% of the areas with a potential are situated in Western Anatolia, 8,5% in Central Anatolia, 7,5% in the Marmara Region, 4,5% in Eastern Anatolia and 0,5% in the other regions. 94% of the geothermal resources are low and medium heat, and suitable for direct applications (heating, thermal tourism, the output of minerals, etc.), while 6% are suitable for indirect applications

such as the generation of electricity energy. On the other hand, some new findings and results of deep geothermal wells states an undiscovered potential in mid-Anatolia and there are still areas to be explored in eastern part of the Country that can increase foreseen potential.

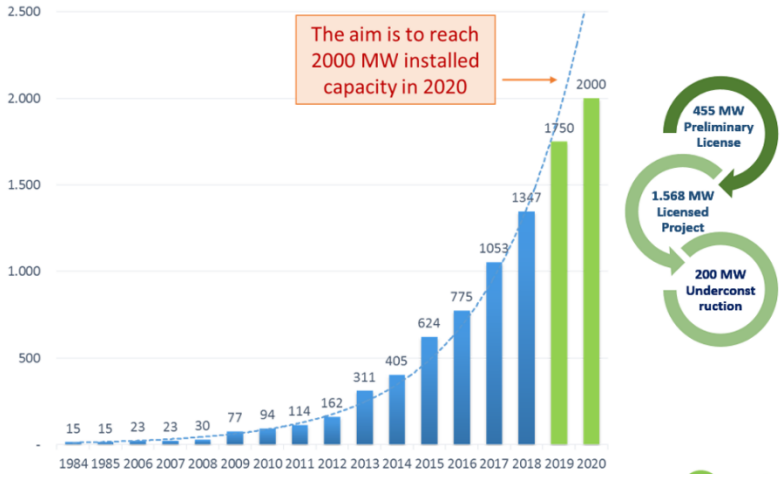


Figure A6.4: Installed capacity

Studies have identified more than 227 geothermal fields which can be useful at the economic scale and about 2,000 hot and mineral water resources (spring and well discharge and reservoir temperature) which have the temperatures ranging from 20 to 295°C.

Support Mechanism for Renewable Energy Sources (YEKDEM)

Through mentioned liberalisation period a need of determination of incentive mechanism has emerged in order to increase the efficiency of private sector in electricity generation. In May 2005, 5346 numbered Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy came in force and has defined YEKDEM (Support Mechanism for Renewable Energy Sources). However, investors did not show any interest to join to mechanism since the tariff was around the value being defined by EMRA over total sale price level (4 – 4.5 Euro/cent); and was under balancing market values. In July 2011, YEKDEM was updated and revised mechanism introduce a sector-specific incentive scheme independent from spot market values.

Type of Production Facility Based on Renewable Energy Resources	Prices Applicable (USD cent/kWh)
Hydroelectric production facility	7.3
Wind power based production facility	7.3
Geothermal power based production facility	10.5

Biomass based production facility	13.3
Solar power based production facility	13.3

Table A6.1: YEKDEM applicable prices

Revised regulation also defined an additional incentive to be provided in case of using domestic components in the power generation process aiming to trigger the development in domestic manufacturing.

Type of Facility	Domestic Production	Domestic Contribution (US Dollar cent/kWh)
Geothermal power based production facility	Steam or gas turbine	1.3
	Generator and power electronics	0.7
	Steam injector or vacuum compressor	0.7

Table A6.2: Domestic production contribution bonus

As a result of the revision, today 60% of the components are being provided by domestic market.

Land Allocation Incentives

Leasing and establishing easements or usage rights on, or grant authorisation for the land around the facility and any related access roads to be used for transmission lines up to the network connection point, if a renewable generation facility is established on forest or state-owned land. If the relevant land is a feeding ground, pasture or shelter, the land will be changed and registered to the Treasury. The Ministry of Finance can then lease and establish easements over these lands in exchange for consideration. (This incentive is not directly applicable for drilling locations.)

Applying an 85% discount for the right to use land under the ownership of the Treasury or under the control or disposal of the state during the investment period and for the first ten years of the operation period (provided that the power plant is commissioned by the end of 2020). No forest villagers' development revenue or erosion control revenue will be applied to renewable energy licence holders.

Grid Connection Priority

Priority in connecting to the national grid (to the transmission and/or distribution systems) is provided by The Turkish Electricity Transmission Company and/or holders of distribution licences for the facilities generating electricity from renewable energy resources.

Tax Incentives

Effective as of January 1, 2012, the new investment incentives system has been comprised of four different schemes. Local and foreign investors have equal access to (i) general; (ii) regional; (iii) large scale; and (iv) strategic investment incentives scheemes. The modelling of the scheme has divided Turkey into six regions with different support mechanisms.

Major investment incentive instruments that are aslo applicable for geothermal projects are (i) exemption from custom duties on equipment imports; (ii) VAT exemption for imported or domestically purchased machinery and equipment for projects with an investment incentive certificate; and. (iii) exemption from WHT on documents and transactions.

Environmental regulation mapping

Definition, Classification, and Resource Ownership

- Geothermal resources are generally located between 1,500m and 2000 m in western part of Turkey. These are the resources with capable characteristics for power production, heating or cooling systems. In general Turkey uses “deep geothermal” term related to power generation activities only.
- No matter the resources below surface, it belongs to the state, current developers in the market (for power generation) is dominated by Turkish investors. Prior to the Geothermal Law, MTA (Mining Authority) was in charge of exploration of the resource.

Ownership

Pursuant to Article 4 of the Geothermal Energy Law, ownership of above-mentioned resources is deemed to belong to the State rather than to private property-owners where the resources are located. Any activity relating to the resources will be subject to parties first obtaining the necessary licenses set out into the same law. Turkish citizens or legal entities duly incorporated under Turkish Law are entitled to apply for the related licences.

Licensing and Authorization

There are two types of licences; exploration licence and exploitation licence. Exploration license enables its holder to carry out prospecting activities in a specific area based on the project notified to the Administration; and the exploitation license enables its holder to produce geothermal fluid (water, gas and/or steam) for power generation, heating or for industrial purposes, etc.

Exploration Licence

Pursuant to Article 5 of the Geothermal Energy Law and Article 6 and 7 of the Regulation, the applicant may apply to the Administration for the licence with the prospecting project, stating the plate name and its coordinates drawn to a scale of 1/25000, with 5,000 acres limitation. In case of more than one application for the same location, the

first one will normally have priority over others. However, in the event that there is more than one application at the same time, the Administration may give priority to another project with a more suitable project proposal. The duration of an exploration licence is 3 years, commencing as of the date of the registration of the licence and may be extended up to 1 year on the condition that the revised project is satisfactory to the Administration. As long as the activities are not hazardous to the environment, production may be operated with a trial purpose during the licence term.

Exploitation Licence

Under Article 6 of the Geothermal Energy Law and Article 9 of the Regulation, the exploration licence holder may apply with a project to the Administration for an exploitation licence before the expiration date of the exploration licence. Concession holder must specify a deadline to initiate the operation. The failure to start the operation before the specified term may give rise to the cancellation of the licences and the guarantee deposited will be recorded as revenue by the Administration. The concession holder cannot make any amendment with regard to the project without the consent of the Administration. The duration of the licence is 30 years, commencing as of the date of the registration of the licence and may be extended up to further 10 years. After receiving the exploitation licence, the holder should obtain / apply for other required permits, including the Environment Assessment Report within 3 months, otherwise the licence may be cancelled.

As per Article 10 of the Regulation, the operation must be conducted under the supervision of an engineer from a related field as a technical responsible person. In the absence of such engineer during the operation, the amount deposited as a guarantee will be deemed to be recorded as revenue by the Administration and the operation will be suspended.

Moreover, the technical responsible person must prepare operating and prospecting report to be submitted annually to the Administration until the end of March and every other consecutive year. In the event that the report is not submitted in time, the amount deposited as a guarantee will be again deemed to be recorded as revenue by the Administration and an extension for the submission will be granted, provided that a deposit equal to twice the amount is deposited as guarantee. Otherwise, the exploitation licence may be cancelled. Furthermore, all activities regarding to licences are also annually monitored by the Administration. If the licence holder does not meet the criteria under the related law, the licence may be suspended or even cancelled.

Assignment, Transfer and Easements

Pursuant to Article 14 of the Regulation both the exploration and exploitation licences can be assigned. In order to track the record relating to the assignment, the Administration is required to have a registry in place under Article 10-b of Geothermal Energy Law. According to Article 15 of the Regulation, obligations and rights as a whole are transferred to inheritors and cannot be divided into parts without their consents. In the event that there is dispute among inheritors, the issue may be resolved by the court, whereby the licence may be sold via tender.

If either the exploration or development activity requires the licence holder to have access to a private property, the required permission may be obtained from the owner. If the owner withholds his consent, the licence holder may

apply to the Administration for easement or compulsory acquisition by related Authority, whichever is most appropriate and such application is being determined within three months.

Permits

For any geothermal activity the very first licenses needs to be granted are the exploration and exploitation licenses (explained in 3.2 and 3.3 sections of this report). For developers whom are interested in establishing a power plant via geothermal energy ressources the main permit need is the generation licence issued by the Energy Market Regulation Authority (EMRA) according to 6446 numbered Turkish Electricity Market Law; entered into force on 30th of March, 2013; and followed by Electricity Market License Regulation published on 2nd of November, 2013.

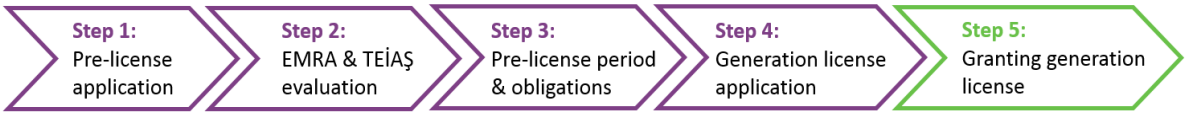


Figure A6.5: The permitting process

The following issues are covered:

- Land utilisation rights
- Approval of zoning permit
- Preliminary project approval
- Application for the system connection agreement and system utilisation agreement with TEİAŞ or the relevant distribution company;
- Opinions regarding Regulation on Military Forbidden Zones and Security Zones from the Turkish Armed Forces Chief of Staff;
- Environmental Impact Assessment Decision: Applications must be submitted to the relevant authorities within 90 days following the granting of the pre-license. Under the EIA Regulation, the GPP (Geothermal Power Plant) projects are subject to a "selection and elimination" process, after which it is decided whether preparation of an EIA Report is necessary or not. If the authority in charge decides that the report is not needed, an EIA Not Required Certificate is issued. If the relevant project falls within the scope of the EIA Regulation, either EIA approval or a "not required" certificate must be issued before the construction permit and generation licence can be secured. No matter regulation is applicable for GPPs's with a capacity equal to or over 20 MW wohole proccess is implemented to receive "not required" certificate.

There might be other permits and licences needed to construct a power plant that vary according to the place of the facility.

- Regulation on great plains (Büyük Ovalar) conservation area: 141 great plains located in the borders of 49 cities are anounced to have taken under protection and any activities within this areas will require a specific permit from Ministry of Food, Agriculture and Livestock. Some of the protected Great Plains are also located surrounding of geothermal concession areas.
- Regulation on activities on agricultural land: Under the "Soil Protection Project" activities on agricultural lands are forbidden. However, an exemption is defined for geothermal activities. Geothermal energy exploration activities will be granted a temporary permit for exploration activities; in case absence of any

alternative locations. This permit will be extended a maximum of one more year in the direction of justified demand. A recycling project related to the exploration activities will be prepared and a notarized undertaking will be provided to related commission ensuring that the land to be searched will be restored and the agricultural production losses in the vicinity will be compensated.

- Archeological zones are divided into three sections in terms of permitting. First degree archeological zones are protected areas that are preserved except for scientific studies. In these areas, absolutely no construction is allowed besides limited excavation for scientific excavations. Areas are determined as a protected area to be preserved in zoning plans. Second degree archeological zones are protected sites that are preserved, except for scientific studies. Such sites are subjected to the permission of Cultural and Natural Heritage Conversation Boards. In and around third degree archeological zones new arrangements can be allowed in the direction of protection - use decisions by Cultural and Natural Heritage Conversation Boards.

Sustainability and Environmental Impacts

EIA is not regulated in Turkey by means of law, but through a decree put into force on the basis of the relevant provision of the Environmental Law. The Environmental Impact Assessment (EIA) System, which embodies the “prevention principle” of the environmental law, is an important tool for environmental protection. This tool has a private importance for Turkey since it is a developing country, and it entered the Turkish law in 1983 with the Environmental Law. Besides, the EIA Regulation, which shows the application principles, became effective in 1993. Because Turkey is a candidate for European Union (EU), the EIA Regulation has been changed due to the EU compliance procedure, and its latest version became valid in 2017.

Pursuant to current regulations, certain kinds of projects are subject to certain requirements which the project owner shall apply for an "EIA Positive" decision whereas some other projects are subject to "Selection and Elimination Criteria". Accordingly, the Ministry shall decide whether "EIA Not Required" or "EIA Positive" decision shall be obtained.

During the EIA process, not only Environmental Law (with secondary legislation) but also protection of nature, protection of cultural heritage, etc. other regulations, such as In addition, the legislation specific to other geothermal energy projects with an impact on design studies will be taken into consideration in the EIA Process.

The list of national legislation is a dynamic document, so during the EIA studies, updated / revised versions of this legislation will be taken into account.

Geothermal resource utilization projects, EIA Directive 2011/92 / EU (last amendment 2014/52 / EU): Annex I (2-a) - Thermal power plants with thermal power of 300 MW and above, Annex II (3-a) - Electricity , industrial facilities producing steam and hot water (not included in Annex 1) and Annex II (2-d (i)) - are evaluated within the scope of geothermal drilling.

For dust / PM emissions, PM2.5: 25 µg / m3 (1-year), PM10: 50/40 µg / m3, (24-hour / 1-hour) 23 Emission reduction commitments under the Paris Agreement (Renewable Energy Directive 2018/2001 / EU), Emissions from combustion of fuels Limit values are defined for (Midsize Combustion Plant Directive 2015/2193 / EU).

Law/Directive	Main Subject
TURKISH NATIONAL LEGISLATION	
Environmental Law	
Environmental Law No: 2872 dated 09/08/1983	Main law on protection and preservation of the environment in a sustainable manner.
Wastewater management sector	
Regulation on Urban Wastewater Treatment (08/01/2006 - 26047)	Protecting environment by regulating collection, disposal and treatment of urban wastewater and protection against detrimental effects of wastewater disposal by some industries
Regulation on Water Pollution Control (31/12/2004 - 25687)[69]	Protecting surface waters and groundwater sources, facilitating use of water sources in a sustainable manner.
Regulation on Protection of Underground Waters Against Pollution and Degradation (7/04/2012 – 28257)	Preserving current conditions of groundwaters, preventing pollution and improving quality of groundwaters.
Regulation on Monitoring of Surface and Ground Water (11/02/2014 – 28910)	Defines the basic surface/ground water quality parameters and monitoring implementations.
Waste management sector	
Regulation on Waste Management (02/05/2015 – 29314)[70]	Management of wastes from cradle to grave in order to protect environment and human health. Natural resources preservation by Reduction, Re-use, Recycling and Recovery of wastes
Regulation on the Control of Packaging Waste (24/08/2011 - 28035)	Producing environmentally friendly packaging. Prevention of packaging waste generation and disposal directly to receiving bodies.
Regulation on Landfilling of Waste (26.03.2010 - 27533)[71]	Regulating landfilling and disposal of wastes in order to minimize negative impacts of leakage and landfill gas on soil, air, groundwater and surface water.
Regulation on Medical Wastes Control (25/01/2017 - 29959)	Regulating medical wastes from cradle to grave in order to prevent disposal to receiving body thus protecting environment and human health. Stating principles on segregation of wastes at source, temporary storage and transportation to medical waste processing plant
Waste Oil Control Regulation (30/07/2008 - 26952)	Preventing waste industrial oils to be disposed directly to receiving body. Stating principles on temporary storage, transportation and disposal of waste oils.
Regulation on using domestic and urban wastewater sludge in soil (03/08/2010 - 27661)	Determining the principles of taking necessary precautions in the use of sewage sludge in soil in accordance with sustainable development targets.
Regulation on Soil Pollution Control and Pointed Source Polluted Areas (08/06/2010 - 27065)	Defines the basic soil quality parameters and pollution parameters based on different sectors.
Noise sector	
Regulation on the Assessment of Environmental	Protecting physical and mental health of the people as a

[69] Lastly amended by the OG 25/3/2012 – 28244
[70] Amended on 23.03.2017 – 30016)
[71] Amended by the OG 11/03/2015 - 29292

Noise (04/06/2010 - 27601)	result of exposure to environmental noise and determination of environmental noise exposure levels by using noise assessment methods, acoustic report and environmental noise level evaluation report
Air sector	
Regulation on Industrial Air Pollution Control Directive (03/07/2009 – 27277)[72]	Control emissions in the form of smoke, dust, gas, steam and aerosol that are released into the atmosphere as a result of the activity of industrial and power generation facilities; preventing the negative effects that cause significant damages to public and neighborhood relations due to air pollution
Regulation on Odorous Emission Control (19/07/2013 – 28712)	Regulating administrative and technical procedures and principles for the control and reduction of emissions causing odor.
Regulation on Monitoring the Greenhouse Gaseous Emissions (17/05/2014 -29003)[73]	Regulating the procedures and principles for monitoring, reporting and verifying greenhouse gas emissions from activities listed in the regulation.
Permit/License Policy	
Regulation on Environmental Permits and Licenses (10/09/2014 - 29115)	Regulating the procedures and principles to be followed in the process of environmental permits and licenses to be obtained in accordance with the Environmental Law No. 2872.
Regulation on Environmental Audit (21/11/2008 – 27061)[74]	The procedures and principles of environmental audit for protection of the environment; to regulate the qualifications and obligations of the audit personnel, environmental management unit / environmental officer and the companies authorized for environmental service
Environmental Impact Assessment - EIA sector	
Environmental Impact Assessment Regulation (25/11/2014 – 29186)[75]	Defining the administrative and technical procedures and principles to be followed during the Environmental Impact Assessment (EIA) process.
Regulation on Strategic Environmental Assessment (08.04.2017 - 30032)	In order to ensure the protection of the environment, in line with the principle of sustainable development, to regulate the administrative and technical procedures and principles to be followed in the process of Strategic Environmental Assessment
Chemical sector	
Regulation on the Classification, Labeling and Packaging of Materials and Mixtures (11/12/2013 - 28848)	Regulating the administrative and technical procedures and principles for the classification, labeling and packaging of substances, mixtures and certain goods placed on the market
Regulation on Registration, Evaluation, Permission and Limitation of Chemicals (23.06.2017 - 30105)	Ensuring the high level of protection of human health and the environment, to encourage alternative methods for the assessment of damages of substances, to improve competition and innovation, the registration, evaluation,

[72] Lastly amended by the OG – 20/12/2014 - 29211
[73] Lastly ameded by the OG31/05/2017 - 30082
[74] Lastly amended by the OG 16/8/2011-28027
[75] Lastly amended by the OG 14.06.2018 - 30451

	authorization and restriction of chemicals to regulate administrative and technical procedures and principles.
Health and Safety Sector	
Labor Law No. 4857 (10/06/2003 - 25134)	Regulating the rights and responsibilities of workers employed on the basis of an employment contract with employers regarding the working conditions and working environment.
Occupational Health and Safety Law (Law No: 6331 – 30/06/2012- 28339)[76]	Regulating the duties, authorities, responsibilities, rights and obligations of employers and employees in order to ensure occupational health and safety in the workplaces and to improve the existing health and safety conditions.
Occupational Health and Safety Regulation for Construction Works (05/10/2013 -28786)	The purpose of this regulation is to determine the minimum occupational health and safety requirements for construction works.
Regulation on the Protection of Employees against the Hazard of Explosive Environments (30/05/2013 - 28633)	Regulating the procedures and principles regarding the precautions to be taken in order to protect the employees from the hazards of explosive environments that may occur in the workplace in terms of health and safety.
Regulation on Protection of Employees from Noise Related Risks (23/07/2013- 28721)	Determination the minimum requirements for the protection of employees from health and safety risks that may arise from exposure to noise.
Regulation on Health and Safety Conditions for Use of Work Equipment (25/04/2013 - 28628)	Determination the minimum requirements to be complied with in terms of health and safety requirements regarding the use of work equipment in the workplace.
Occupational Health and Safety Services Regulation (29/12/2012 – 28512)[77]	Regulating the establishment of workplace health and safety units to be established to carry out health and safety services, the authorization of joint health and safety units, cancellation of authorization documents, duties, powers and responsibilities and working procedures and principles.
Occupational Health and Safety Risk Assessment Regulation (29/12/2012- 28512)	Regulating the principles and procedures of risk assessment in terms of occupational health and safety in workplaces.
Regulation on Emergency Situations in Workplaces (18/06/2013 - 28681)	Preparation emergency plans in the workplace, prevention, protection, evacuation, firefighting, first aid issues and managing emergency situations safely.
Energy Sector	
The Electricity Market Law (Law No: 6446, 30/03/2013 - 28603)[78]	Establishing a financially strong, stable and transparent electricity market operating in accordance with the provisions of private law in order to make electricity available to consumers in an adequate, quality, continuous, low-cost and environmentally compatible manner and
Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy (Law no: 5346 -18/05/2005 – 25819)[79]	Expanding the use of renewable energy resources for the purpose of generating electricity, bringing these resources to the economy in a reliable, economic and

[76] Lastly amended by the Law no:7033 dated 18/06/2017
[77] Amended by OG 18/12/2014 - 29209
[78] Lastly amended by the OG 09.07.2018 - 30473
[79] Amended on 10/05/2005-5346, on 04/07/2012-6353, and on 17/06/2016-5346

	high quality manner, increasing resource diversity, reducing greenhouse gas emissions, evaluating wastes, protecting the environment and developing the manufacturing sector needed to achieve these objectives.
The Electricity Market Licensing Regulation: (05/042011 - 27896)[80]	Determination of rights and obligations of license holders and procedures and principles related to associate and licensing applications in the electricity market.
Law on Geothermal Sources and Natural Mineral Waters (Law number 5686- 02/062007).	Regulating the procedures and principles regarding the efficient exploration, development, production, protection of natural resources, geothermal and natural mineral water resources, ownership of these resources and transfer of rights
Regulation on Implementation of Geothermal Sources and Natural Mineral Waters Law (11/12/2007 - 26727)	
Agricultural Sector	
Soil Preservation and Land Use (Law No: 6537)	Soil protection, development, classification of agricultural land, determination of minimum agricultural land and agricultural land with sufficient income and prevention of division,
Biodiversity	
Law on Fisheries (No.1380)	This Law regulate the issues related to protection, production and control of fishery products.
Cultural Heritage	
Cultural and Natural Heritage Protection Law (No: 2863)	Regulating the operations and activities to be carried out in order to protect cultural and natural heritage, to determine the establishment and duties of the organization that will take the necessary principles and implementation decisions in this regard.

Conclusion

Turkey's geothermal history for power production from geothermal resources goes back 1960s by studies of General Directorate of Mineral Research and Exploration (MTA) and its discovery in Kızıldere field. However the Law on the Utilization of Renewable Energy Sources for the Purposes of Generating Electricity has been adopted in 2005 for promoting electricity production from the renewable energy sources in liberalized energy markets.

Following invoivement of private sector, development of power generation from geothermal resources significantly increased. Today, Turkey's installed capacity got power generation is over 1 GW. Besides power generation, Turkey took second place within Europe with 872 MWth installed capacity following Iceland as of 2018.

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[80] Lastly amended by the OG 30/12/2018 - 30641

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