Decarbonization Wedges Exercise

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GEOTHERMAL ENERGY

1. State of the art and current development

Technology 1: Conventional high-temperature geothermal energy (for electricity production)

Geothermal energy involves drawing energy from wells in hydrothermal reservoirs which produce hot water or vapor to run an electricity generating plant. The considered depths are generally moderate (< 2 km) and in relationship with volcanic contexts.
This template will not assess coproduction from oil and gas wells and geo-pressurized reservoirs in sedimentary formations (sandstone or shales).

Technology 2: Deep non-conventional geothermal energy, Engineered Geothermal System (EGS) (for electricity and heat production)

This technology involves specific techniques for using resources (medium to high temperatures) that are hard to harness generally at great depth (2 to 6 km) in various geological contexts. This energy is operated either to produce electricity (binary plants) either for direct use of heat for industrial purposes or heating).

Technology 3: Low to medium temperature geothermal energy (for heat and electricity production)

The well-known low-temperature geothermal energy technology is mainly located in sedimentary basins and is essentially used by district heating networks and other direct uses (industrial processes, agriculture...), by mean of direct use of heat. Low to medium-temperature geothermal energy exploits about the same geological depths as high-temperature geothermal energy, but due to a significantly lower geothermal gradient than in volcanic environments, it is only possible to pump relatively hot water from aquifers. Medium temperatures resources can be exploited for power generation (binary plants).

Technology 4: Very low-temperature geothermal energy (heat production)

The very low-temperature geothermal technologies aim at providing thermal comfort and/or sanitary hot water in individual, collective and tertiary buildings. Heat pumps are usually required for heating and cooling purposes, but direct cooling may be possible when refrigeration is not imperative.
This template will not assess cooling production

2. Maturity level and technological perspectives

Maturity of elementary technologies associated with geothermal energy

	2015	2020	2030	2040	2050
Conventional high-temperature geothermal energy	5	5	5	5	5
Deep non-conventional geothermal energy	3	3	4	4	5
Low to medium-temperature geothermal energy	5	5	5	5	5
Very low-temperature geothermal energy	5	5	5	5	5

Conventional high-temperature geothermal energy is a well-developed technology, indeed commercial-sized plants have been operating for half a century around the world.

Deep non-conventional technology is experiencing its first demonstrations. This technology needs to reach the next maturity level in order to be present among other geothermal energies in the future. By 2030 EGS technology will mainly develop for applications to heat production and to cogeneration, which will reduce the impacts on electricity generation. EGS should reach full maturity by 2050.

Low to medium temperature geothermal energy is a mature technology. Its deployment is expected to grow rapidly due to increased interest in their use to generate heat and combined electricity / heat in countries with high heat demand (heating systems renovation in Northern and Central Europe ...). In perspective of electricity production, these medium temperature resources should be used mainly as electricity in hot countries

Very-low temperature geothermal energy - with heat pumps or open-loop heat exchangers - is mature but not deployed yet.

Potential development of technologies related to geothermal energy

	2020	2030	2040	2050
Electricity production	1	1	1	2
Heat production	0-1	1	1-2	2
Electricity and heat production	1	1-2	2-3	4

Geothermal energy will contribute to a 3 % reduction of CO_2 emissions by 2050. As soon as heat grids and facilities for heat production are present in the technological landscape, applications for heat production will probably produce more energy than applications for electricity distribution which is currently quite developed already in naturally favourable areas. The wide deployment will depend on the successful development of non-conventional technologies.

3. Technological, economic and social bottlenecks

Technology		Research & technological bottlenecks	Economy and Financial bottlenecks (investment, risks)	Regulation & institutional environment	Resources & environmental impacts (including scarcity of raw materials, water, land, climate)	Safety & security (impacts on health, people and security assets)	Socio-technical feasibility
Conventional high-temperature geothermal energy	Rank	3	6	5	2	1	4
	Key-words	Exploration	Drilling costs High-risk projects	Long delays and complicated licenses	Water consumption for cooling H_2S emissions	Subsidence Phreatic eruption	Qualified personnel Acceptability
Deep non-conventional geothermal energy	Rank	4	6	3	2	1	5
	Key-words	Exploration Drilling Development of underground heat exchangers	Drilling costs Very high-risk projects	Long delays and complicated licenses Specific regulation	Water consumption for cooling	Working fluids Radioactive materials	Acceptability (induced seismicity) Qualified personnel
Low to medium-temperature geothermal energy	Rank	5	6	2	3	1	4
	Key-words	Knowledge of deep aquifers	Investment costs	Proven application (Paris area)	Cooling	Drilling and corrosion treatment	Local demand
Very low-temperature geothermal energy	Rank	4	6	2	3	1	5
	Key-words	No energy structures for heat networks	ROI for buildings	Specific new regulation	Conflicting uses Water reinjection	Drilling quality	Lack of structure for the sector

All 4 technologies involve high costs. Lack of specifically trained personal and long delays for operating licenses also hinder the development of these technologies.

Development of technology 1 will be mainly linked to a research to improve methods of exploration and high temperature equipments. The possibility of induced seismicity should be mentioned as well as it can occur during reservoir stimulation -though only for EGS (i.e. technology 2). For technologies 3 and 4, bottlenecks pertain to conflicting uses of subsurface underground space. These bottlenecks depend on the development of management strategies integrating regulations and economic constraints and on the involvement of social actors. The socio-technical feasibility of the technology 3 concerns mainly, for heat networks in dense urban areas, to the requirements about the land needed for the installing drilling platforms. Finally developing geothermal energy is conditioned by the deployment of thermal energy networks.

As there is no regulatory framework for technology 4, manufacturers are reluctant to incorporate use of geothermal energy in their new buildings because they will not get any "performance guarantee". They are even more reluctant as investment is very high in comparison with the expected ROI[1]. Research programs must be carried on closed-loop heat exchangers integrated to collective housings.

4. Potential radical and incremental innovations

Technology		**Research & technological innovations**	**Economy and Financial innovations** (investment, risk)	**Regulation & institutional environment**	**Resources & environmental impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and security assets)	**Socio-technical feasibility**
Conventional high-temperature geothermal energy	I or R	R/I	I	I	I	-	R
	Key-words	Drilling Exploration	Guarantee fund	Long delays Homogenization	Fluid reinjection Hybrid cooling systems		Specific trainings Awareness raising
Deep non-conventional geothermal energy	I or R	R	R	R	I	I	R
	Key-words	Techniques Drilling Alternative stimulation methods	Guarantee fund Carbon price	No standards	Hybrid cooling systems	Safety measures (induced seismicity)	Protocols and codes of conduct Awareness raising
Low to medium-temperature geothermal energy	I or R	R	I	I	I	I	I
	Key-words	Knowledge of deep aquifers	Perennity of assistive devices and guarantees	Revision of the mining code	Continuous improvement of techniques and equipments	Continuous improvement of techniques and equipments	Better consideration of feedback
Very low-temperature geothermal energy	I or R	I/R	R	I	I	I	I
	Key-words	No energy structures for heat networks Inefficient heat-carrying fluids	Financial tools Carbon tax	Cooling	Conflicting uses	Coulis	Trainings Sizing tools Awareness raising

For all geothermal technologies: better highlighting the general structure of costs (initial investment is largely offset by limited operating costs) and combining geothermal techniques with other heat- or electricity-producing technologies. Career pathways must be created for geothermal energy and these pathways must also be made attractive compared to other energy careers.

In terms of social acceptability for technologies 1 and 2, it is crucial to raise awareness concerning the perceived dangers - i.e. induced seismicity and subsidence.

For technologies 1, 2 and 3, new business models will have to be developed in the exploration phase to counterweight high investment risks and costs - because of the uncertain resource availability. The regulatory framework needs to speed-up procedures, to homogenize regulations for some countries - e.g. regulations are not homogenized between U.S.A. states-, etc. Standards for clean energy production must also be established in order to encourage investments and secure a market.

For technology 4, markets need to adapt to geothermal energy -new low-energy buildings, positive-energy buildings etc. - and to use underground soil as reservoirs of energy in urban areas in link with energy storage and hybridization modes.

[1] ROI: Return on Investment