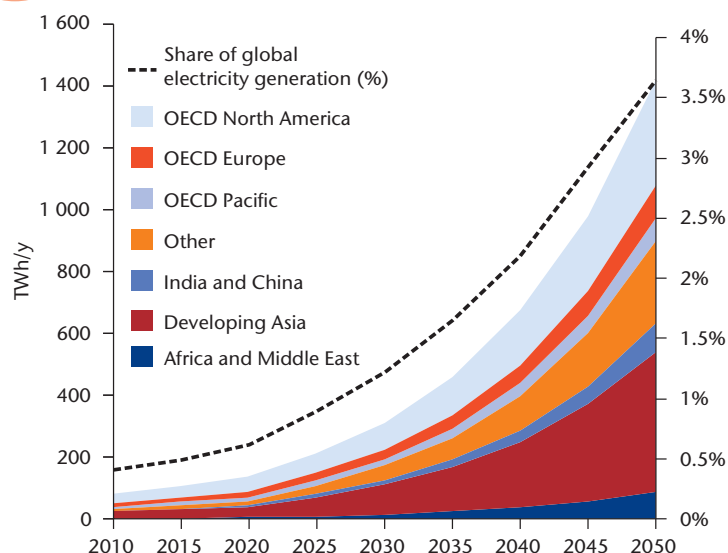
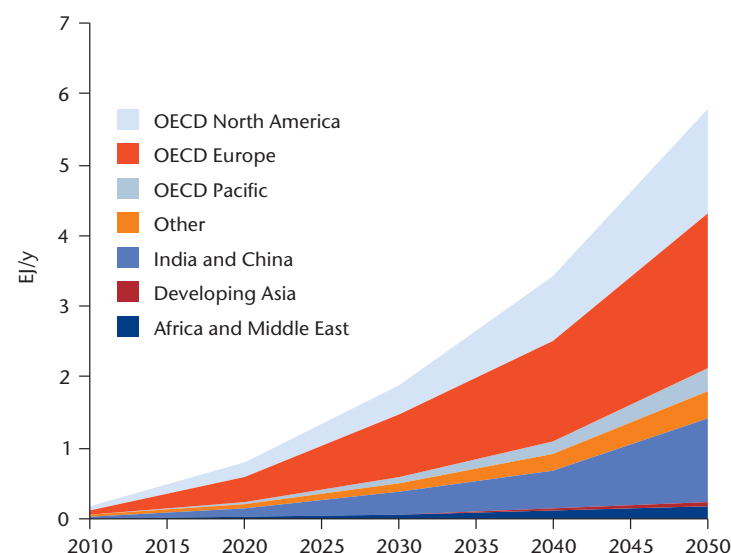


GEOHERMAL HEAT AND POWER ROADMAP

Roadmap vision of geothermal power production by region (TWh/y)



Roadmap vision of direct use of geothermal heat by region, excluding ground source heat pumps (EJ/y)



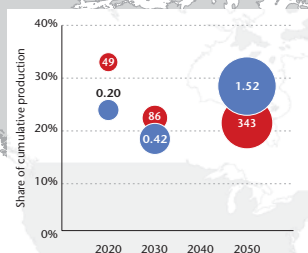
Key findings

- ▶ By 2050, geothermal electricity generation could reach 1 400 TWh per year, *i.e.* around 3.5% of global electricity production, avoiding almost 800 megatonnes (Mt) of CO₂ emissions per year.
- ▶ Geothermal heat¹ could contribute 5.8 EJ (1 600 TWh thermal energy) annually by 2050, *i.e.* 3.9% of projected final energy for heat.
- ▶ In the period to 2030, rapid expansion of geothermal electricity and heat production will be dominated by accelerated deployment of conventional high-temperature hydrothermal resources, driven by relatively attractive economics but limited to areas where such resources are available. Deployment of low- and medium-temperature hydrothermal resources in deep aquifers will also grow quickly, reflecting wider availability and increasing interest in their use for both heat and power.
- ▶ By 2050, more than half of the projected increase comes from exploitation of ubiquitously available hot rock resources, mainly via enhanced geothermal systems (EGS).² Substantially higher research, development and demonstration (RD&D) resources are needed in the next decades to ensure EGS becomes commercially viable by 2030.
- ▶ A holistic policy framework is needed that addresses technical barriers relating to resource assessment, accessing and engineering the resource, geothermal heat use and advanced geothermal technologies. Moreover, such a holistic framework needs to address barriers relating to economics, regulations, market facilitation and RD&D support.
- ▶ Policy makers, local authorities and utilities need to be more aware of the full range of geothermal resources available and of their possible applications in order to develop consistent policies accordingly. This is particularly true for geothermal heat, which can be used at varying temperatures for a wide variety of tasks.
- ▶ Important R&D priorities for geothermal energy include accelerating resource assessment, development of more competitive drilling technology and improving EGS technology as well as managing health, safety and environmental (HSE) concerns.
- ▶ Advanced technologies for offshore, geo-pressured and super-critical (or even magma) resources could unlock a huge additional resource base. Where reasonable, co-produced hot water from oil and gas wells can be turned into an economic asset.

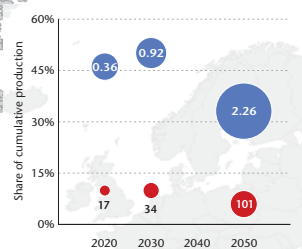
1. Ground source heat pump technology, also known as “shallow geothermal technology”, is not included in this roadmap.

2. Although the preferred wording of EGS is still being discussed, for this roadmap the IEA has chosen to use Enhanced Geothermal Systems, abbreviated as EGS.

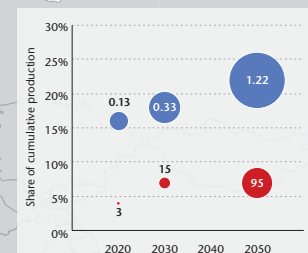
Regional geothermal heat and power production and shares of cumulative global production



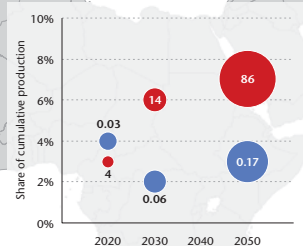
OECD North America



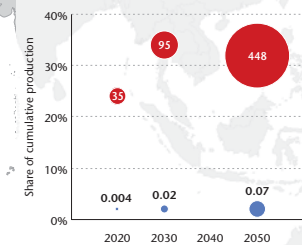
OECD Europe



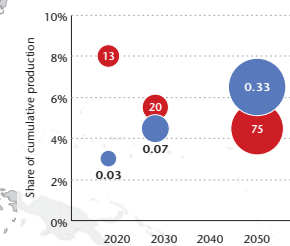
India and China



Africa and Middle East



Developing Asia

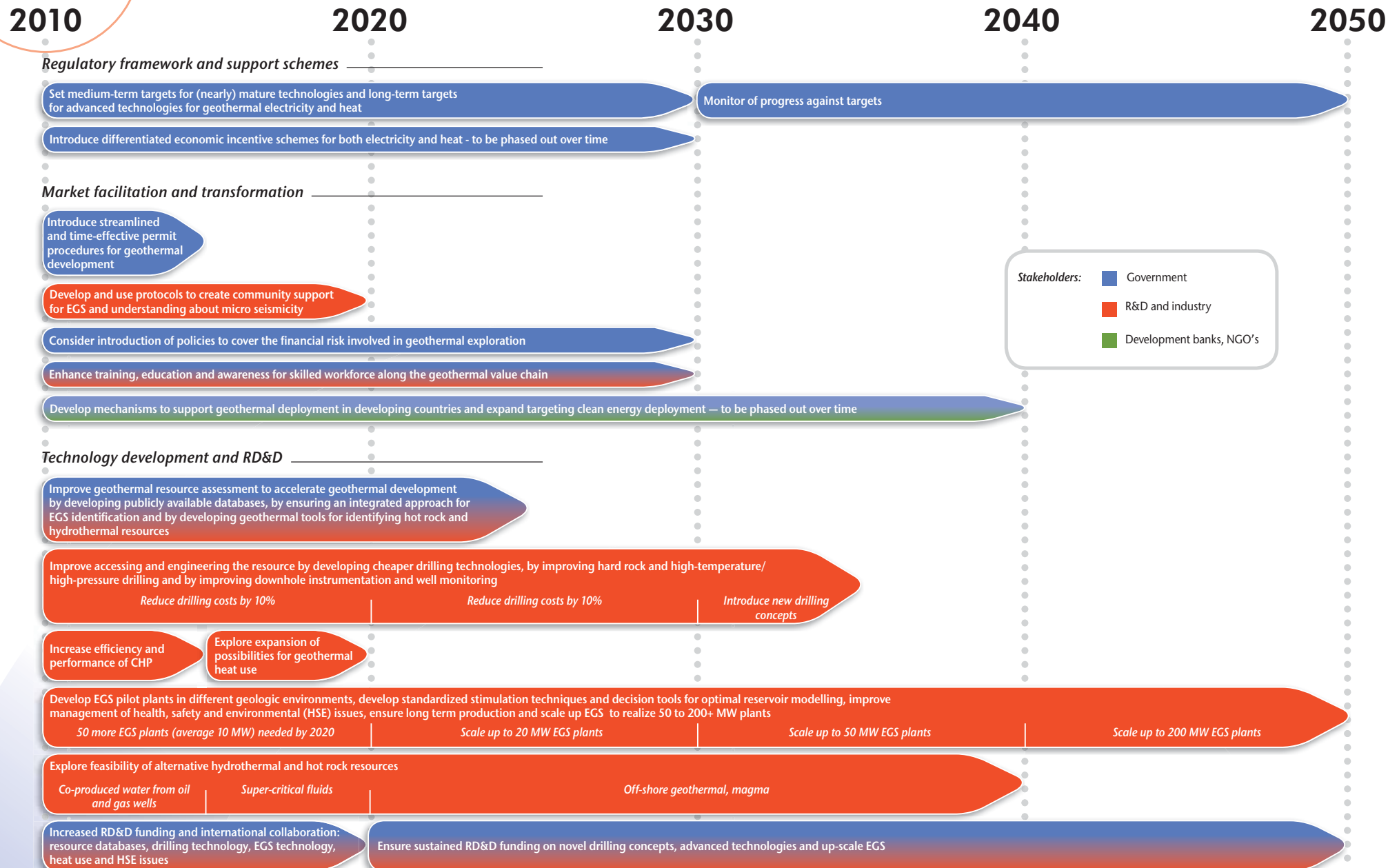


OECD Pacific

● TWh Total electricity production (TWh)

● EJ Total heat production (EJ)

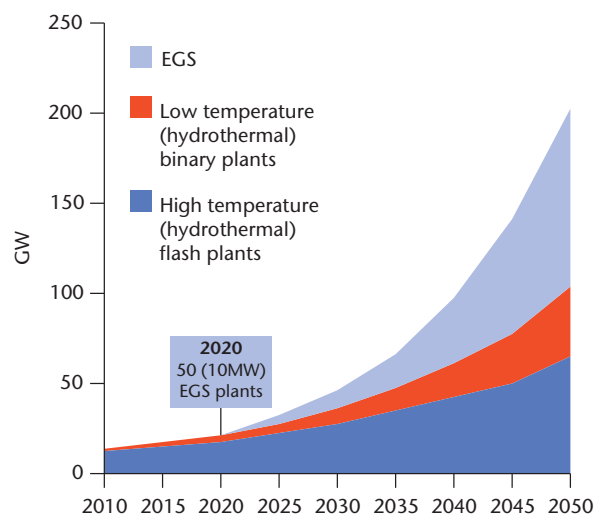
Geothermal heat and power roadmap milestones



Key actions over the next 10 years

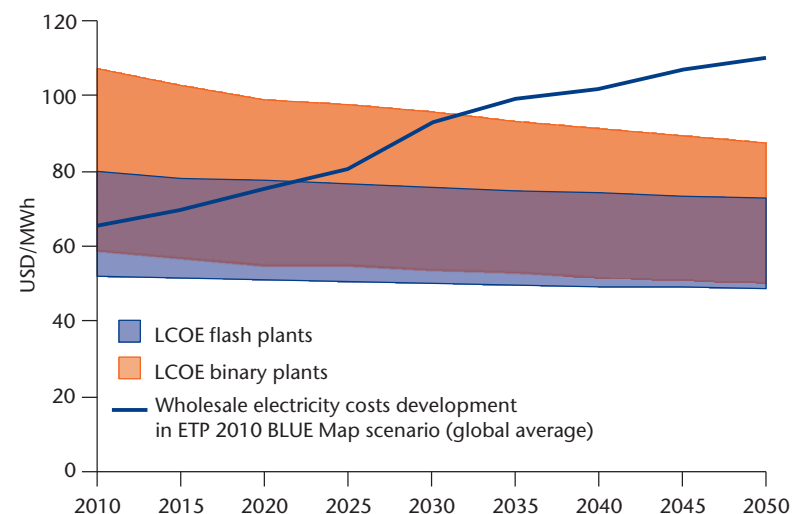
- Establish medium-term targets for mature and nearly mature technologies and long-term targets for advanced technologies, thereby increasing investor confidence and accelerating expansion of geothermal heat and power.
- Introduce differentiated economic incentive schemes for both geothermal heat (which has received less attention to date) and geothermal power, with incentives phasing out as technologies reach full competitiveness.
- Develop publicly available databases, protocols and tools for geothermal resource assessment and ongoing reservoir management to help spread expertise and accelerate development.
- Introduce streamlined and time-effective procedures for issuing permits for geothermal development.
- Provide sustained and substantially higher research, development and demonstration (RD&D) resources to plan and develop at least 50 more EGS pilot plants during the next 10 years.
- Expand and disseminate the knowledge of EGS technology to enhance production, resource sustainability and the management of health, safety and environmental (HSE) performance.
- In developing countries, expand the efforts of multilateral and bilateral aid organisations to develop rapidly the most attractive available hydrothermal resources, by addressing economic and non-economic barriers.

Growth of geothermal power capacities by technology (GW)



KEY MESSAGE: In addition to the 10 EGS plants currently under development, at least 50 more with an average capacity of 10 MW will be needed over the next 10 years to achieve the deployment levels envisaged in this roadmap.

Range of reduction of average levelised costs of electricity (LCOE) production in hydrothermal flash plants and binary plants



KEY MESSAGE: Costs of electricity production in flash plants, in many situations already competitive, are estimated to continue to fall at a moderate rate towards 2050. For binary (hydrothermal) plants, working with lower-temperature resources, costs will decrease to competitive levels as capacities increase.

Regional development geothermal power capacity 2020-2030-2050 (GW_e)

	Africa and Middle East	Developing Asia	India and China	OECD Pacific	OECD Europe	OECD North America	Other	World
2020	1	5	0	2	3	7	2	22
2030	2	14	2	3	5	13	7	46
2050	12	64	15	11	14	49	35	200

Regional development geothermal heat capacity (ground source heat pumps excluded) 2020-2030-2050 (GW_{th})

	Africa and Middle East	Developing Asia	India and China	OECD Pacific	OECD Europe	OECD North America	Other	World
2020	3	0	13	3	35	19	3	76
2030	6	1	32	7	90	41	7	184
2050	16	6	119	32	221	148	24	566