ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ
UNIVERSITY OF PIRAEUS

University of Piraeus
Department of European and International Studies

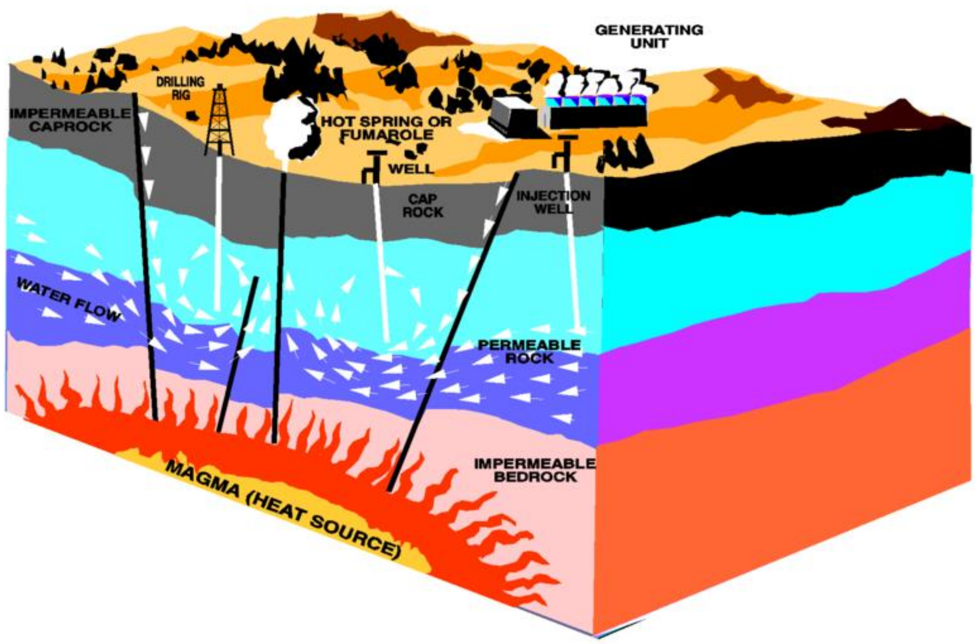
Renewable Energy Sources (RES) in Global Politics

GEOTHERMAL ENERGY

Vasileios Papakostas
va.papakostas@gmail.com

What is geothermal energy?

- Geothermal energy is the thermal energy in the Earth's crust which originates from the formation of the planet and from radioactive decay of materials
- The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in parts of the mantle convecting upward since it is lighter than the surrounding rock.



What is geothermal energy?

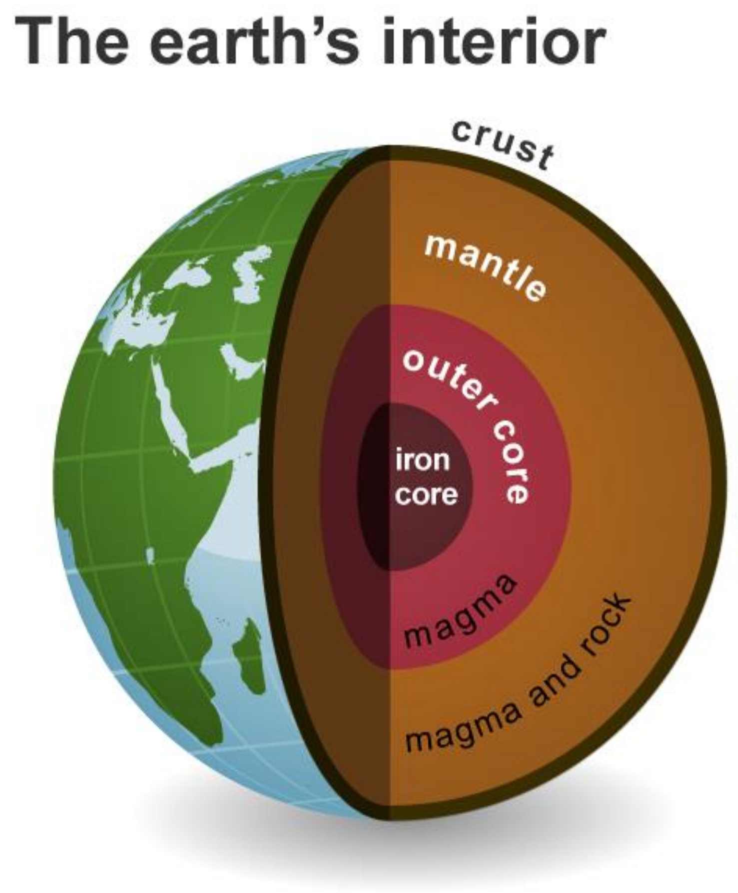
- Geothermal energy is that part of the total heat energy stored within the Earth's interior that is available for human use. That means practically that it is related to the heat energy stored in the upper layers (crust) of the earth.

- Although the earth's stored heat is theoretically finite, its large amount (12.6 x 1024 MJ) makes geothermal energy practically a renewable energy that can theoretically sustain the energy needs of mankind many times.

- Geothermics is the science that deals with the theoretical study of the thermal regime of the earth as well as the engineering aspects to use the earth's heat for heating / cooling and electric power generations.

The source of geothermal energy

- The earth's crust is broken into pieces called tectonic plates. Magma comes close to the earth's surface near the edges of these plates, which is where many volcanoes occur.
- Rocks and water absorb heat from magma deep underground.



The source of geothermal energy

- The Earth's internal thermal energy flows to the surface by conduction at a rate of 44.2 TW, and is replenished by radioactive decay of minerals at a rate of 30 TW.
- These power rates are more than double humanity's current energy consumption from all primary sources, but most of this energy flow is not recoverable.

Geothermal Resources

- The thermal efficiency and profitability of electricity generation is particularly sensitive to temperature.
- Hot Springs
- Wells into hot aquifers.
- Hot Dry Rock or Enhanced Geothermal Systems (EGS).

Geothermal energy uses

- Balneology (Hot spring and spa)
- Agriculture (Greenhouse and soil warming
- Aquaculture (Fish farming)
- Industrial uses
- Residential and District heating
- Electricity generation

Historical facts about geothermal energy

- Hot springs have been used for bathing at least since Paleolithic times.
- The world's oldest geothermal district heating system in Chaudes-Aigues, France, has been operating since the 15th century
- The earliest industrial exploitation began in 1827 with the use of geyser steam to extract boric acid from volcanic mud in Larderello, Italy
- 1911, the world's first commercial geothermal power plant was built in the same area

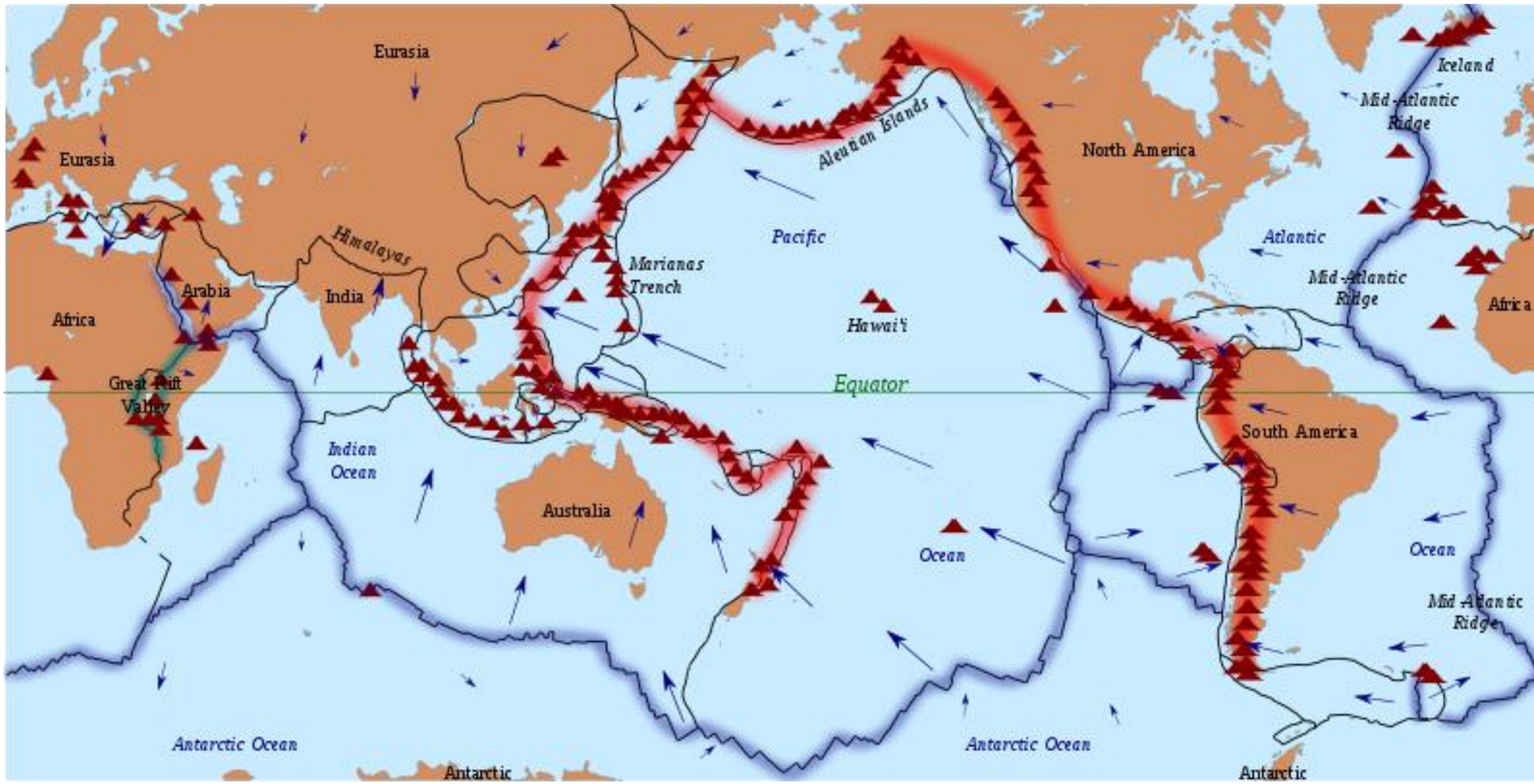
Facts About geothermal energy

- Worldwide availability limited by:
  - Geothermal gradient (France 4C/100m, Iceland 30C/100m)
  - Permeability of the rocks, which determines the rate of flowing heat to the surface.
- Geothermal has a big advantage compared to wind and solar energy (which is that?).

What is geothermal power?

- Geothermal power is electrical power generated from geothermal energy.
- Geothermal electricity generation is currently used in 26 countries, while geothermal heating is in use in 70 countries.
- Geothermal power is considered to be a sustainable, renewable source of energy because the heat extraction is small compared with the Earth's heat content.
- The greenhouse gas emissions of geothermal electric stations are on average 45 grams of carbon dioxide per kilowatt-hour of electricity, or less than 5 percent of that of conventional coal-fired plants.
- As a source of renewable energy for both power and heating, geothermal has the potential to meet 3-5% of global demand by 2050. With economic incentives, it is estimated that by 2100 it will be possible to meet 10% of global demand.

Where we find geothermal energy?



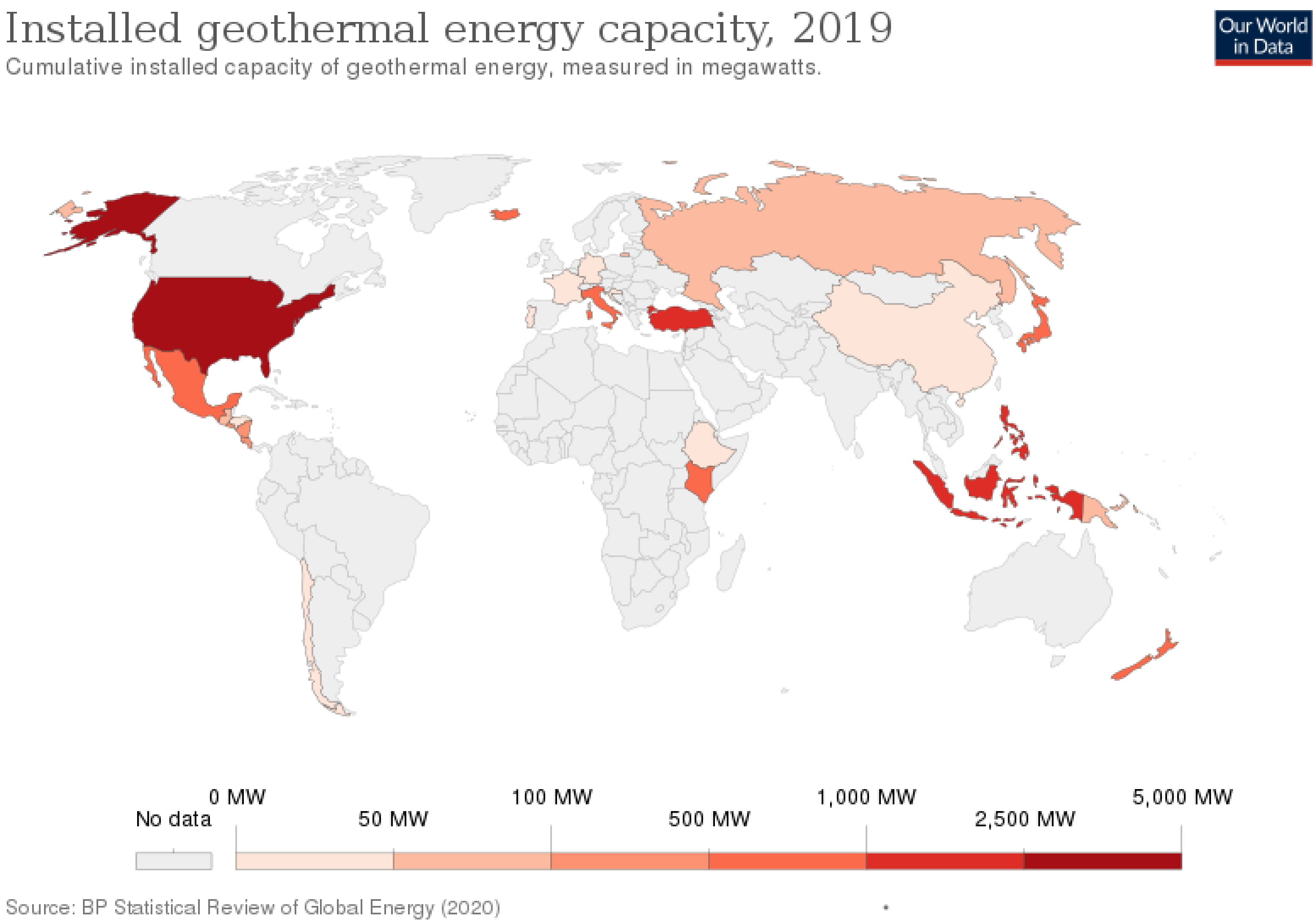
Benefits of Geothermal power

- Provides clean and safe energy with minimum land use
- Renewable and sustainable
- Continuous generation
- Conserves fossil fuels and diversifies energy sources
- Benefits local economies
- Perfect solution for remote sites (e.g. islands)

Geothermal installed capacity

- Worldwide, 13,900 megawatts (MW) of geothermal power was available in 2019.
- An additional 28 gigawatts of direct geothermal heating capacity is installed for district heating, space heating, spas, industrial processes, desalination and agricultural applications as of 2010.

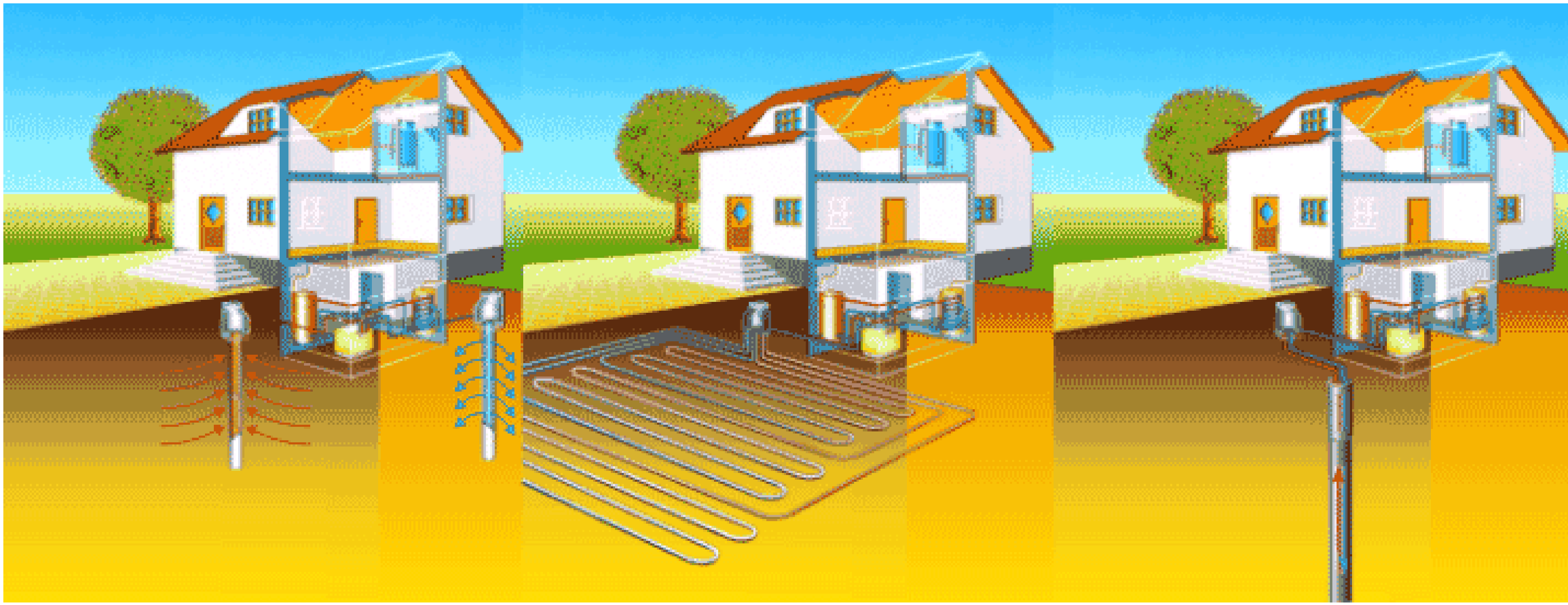
Geothermal energy installed capacity



Potential electricity production

- 0.035 to 2TW depending on the scale of investments.
- Upper estimates of geothermal resources assume enhanced geothermal wells as deep as 10 km.
- Existing geothermal wells are rarely more than 3 kilometres deep.

Surface use of geothermal energy with heat pumps

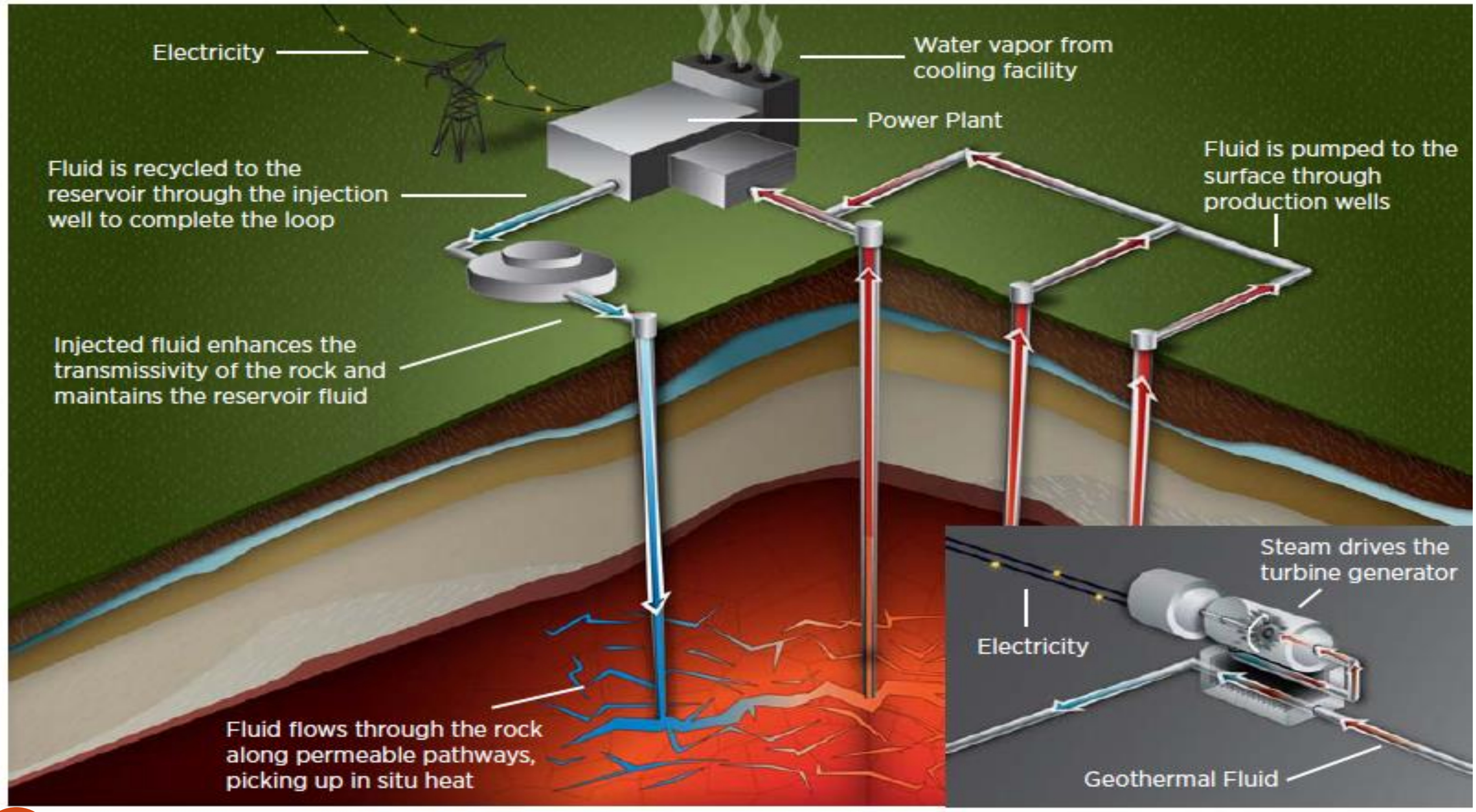


Open dublett system | horizontal ground loops | vertical U-tube loop (most common)

Geothermal Exploration Surveys

- Satellite imagery and aerial photography
- Volcanological studies
- Geologic and structural mapping
- Geochemical surveys
- Geophysical surveys
- Temperature gradient hole drilling

Geothermal energy principles

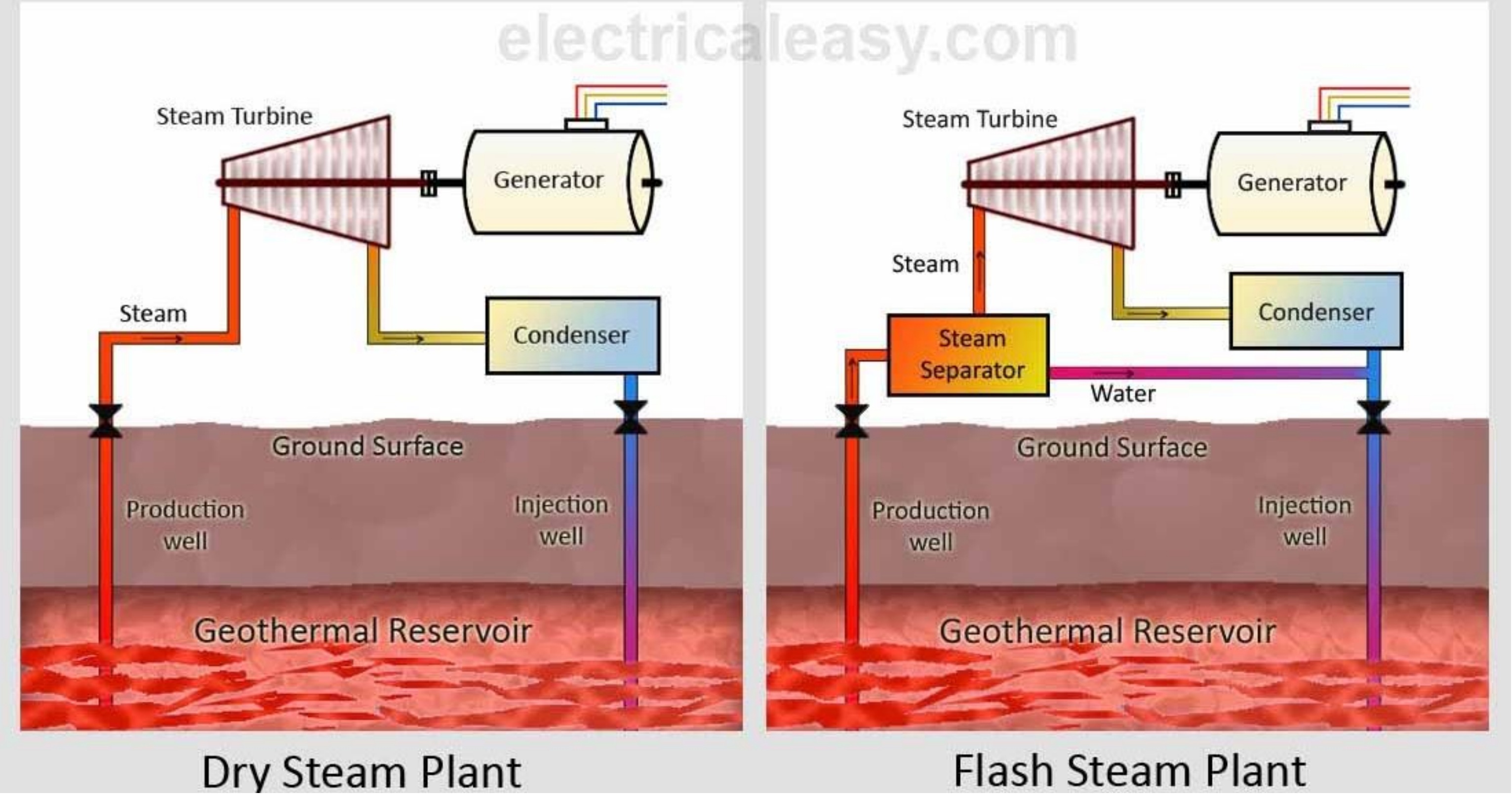


Geothermal plants

- Geothermal electric plants were traditionally built exclusively on the edges of tectonic plates (why?)
- The development of binary cycle power plants and improvements in drilling and extraction technology enable enhanced geothermal systems over a much greater geographical range.
- Demonstration projects are operational in Landau-Pfalz, Germany, and Soultz-sous-Forêts, France, while an earlier effort in Basel, Switzerland, was shut down after it triggered earthquakes.

Types of geothermal plants

- Geothermal energy comes in either vapor-dominated or liquid-dominated forms.



Liquid-dominated plants

- Liquid-dominated reservoirs (LDRs) are more common with temperatures greater than 200 °C (392 °F) and are found near young volcanoes surrounding the Pacific Ocean and in rift zones and hot spots. Flash plants are the common way to generate electricity from these sources. Pumps are generally not required, powered instead when the water turns to steam. Most wells generate 2–10 MW of electricity.
- Lower-temperature LDRs (120–200 °C) require pumping. They are common in extensional terrains, where heating takes place via deep circulation along faults, such as in the Western US and Turkey. Water passes through a heat exchanger in a Rankine cycle binary plant. The water vaporizes an organic working fluid that drives a turbine. These binary plants originated in the Soviet Union in the late 1960s and predominate in new US plants. Binary plants have no emissions.

Enhanced geothermal systems

- An enhanced geothermal system (EGS) generates geothermal electricity without the need for natural convective hydrothermal resources. Until recently, geothermal power systems have exploited only resources where naturally occurring heat, water, and rock permeability are sufficient to allow energy extraction.[
- Enhanced geothermal systems (EGS) actively inject water into wells to be heated and pumped back out. The water is injected under high pressure to expand existing rock fissures to enable the water to freely flow in and out.. Drillers can employ directional drilling to expand the size of the reservoir.
- Small-scale EGS have been installed in the Rhine Graben at Soultz-sous-Forêts in France and at Landau and Insheim in Germany.

HORIZON 2020

- Horizon 2020 is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over 7 years (2014 to 2020) – in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.

Horizon 2020
European Union Funding
for Research & Innovation

ORCHYD

- Innovative Drilling Technologies for Deep Geothermal Systems
- ORCHYD's new drilling technology will increase hard rock drilling rates from the current range of 1-2m/h to up to 4-10 m/h. The novelty is to combine two, previously separate, mature technologies: High Pressure Water Jetting (HPWJ) and Percussive Drilling, in a system customized for hard rock geothermal reservoirs to depths of 6 km.
- More information at https://www.orchyd.eu/

ORCHYD partners

- FRANCE: Association pour la Recherche et le Développement des Méthodes et Processus Industriels (ARMINES)
- FRANCE: MINES ParisTech (MINES PARISTECH)
- UNITED KINGDOM: Imperial College of Science Technology and Medicine (ICL)
- NORWAY: SINTEF AS (SINTEF)
- FRANCE: Drillstar Industries (DRILLSTAR)
- GREECE: University of Piraeus Research Center (UPRC)
- CHINA: University of Petroleum – East China (UPC)

ORCHYD environmental impact assessment - Lithosphere

- Subsistence
- Seismicity
- Soil profile
- Groundwater
- Liquid and solid waste
- Land use
- Visual intrusion

ORCHYD environmental impact assessment - hydrosphere

- Water quantity and quality
- Wastewater

ORCHYD environmental impact assessment - Atmosphere

- Greenhouse gas emissions
- Local air pollution
- Odors
- Noise

ORCHYD environmental impact assessment - biosphere

- Ecosystems
- Health impacts
- Socioeconomic impacts
- Energy security
- Energy consumption
- Material use

Characterization of environmental impacts

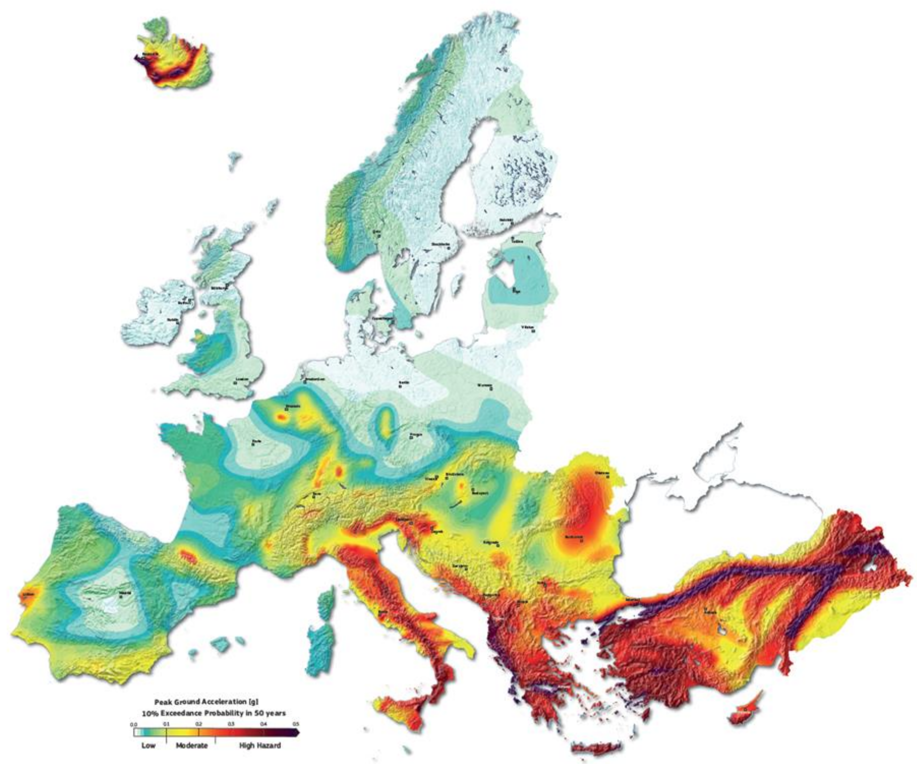
- Impact types may be characterized as follows:
  - Positive/negative (type): favorable or unfavorable to the environment (including the viability of species, habitats and communities);
  - Temporary/long term (duration): according to the time of recovery to pre-impact levels, with the cutoff value to be determined, e.g. 3 or 5 years;
  - Reversible/irreversible (nature): depending on whether the impacted species and communities will recover (on their own) or that (special) mitigation measures (to be proposed) will be required;
  - Direct/indirect (nature): referring to the source/origin of the impact and whether it acts directly or indirectly on the environmental target;
  - Not likely/potential/certain (likelihood): with probability cutoffs to be determined, e.g. up to 10%, 10 to 70%, over 70%;
  - Local/regional/national/international (scale): characterizing geographical restrictions to specific habitats, communities and regions.

Quantification of environmental impacts

- Risk Analysis (RA) ~ risk acceptability (criteria), (semi) quantitative and qualitative techniques, interfacing with energy experts
- Life Cycle Analysis or Assessment (LCA) ~ raw materials and energy; manufacturing; distribution (transportation); use/consumption; recycling; and (final) disposal
- Carbon Footprint (CF) ~ equivalent greenhouse gas emissions, often selected as the functional unit of LCA
- Ecological Footprint Analysis (EFA) ~ resource consumption and waste generation = ecological assets (bioproductive land and sea requirements)

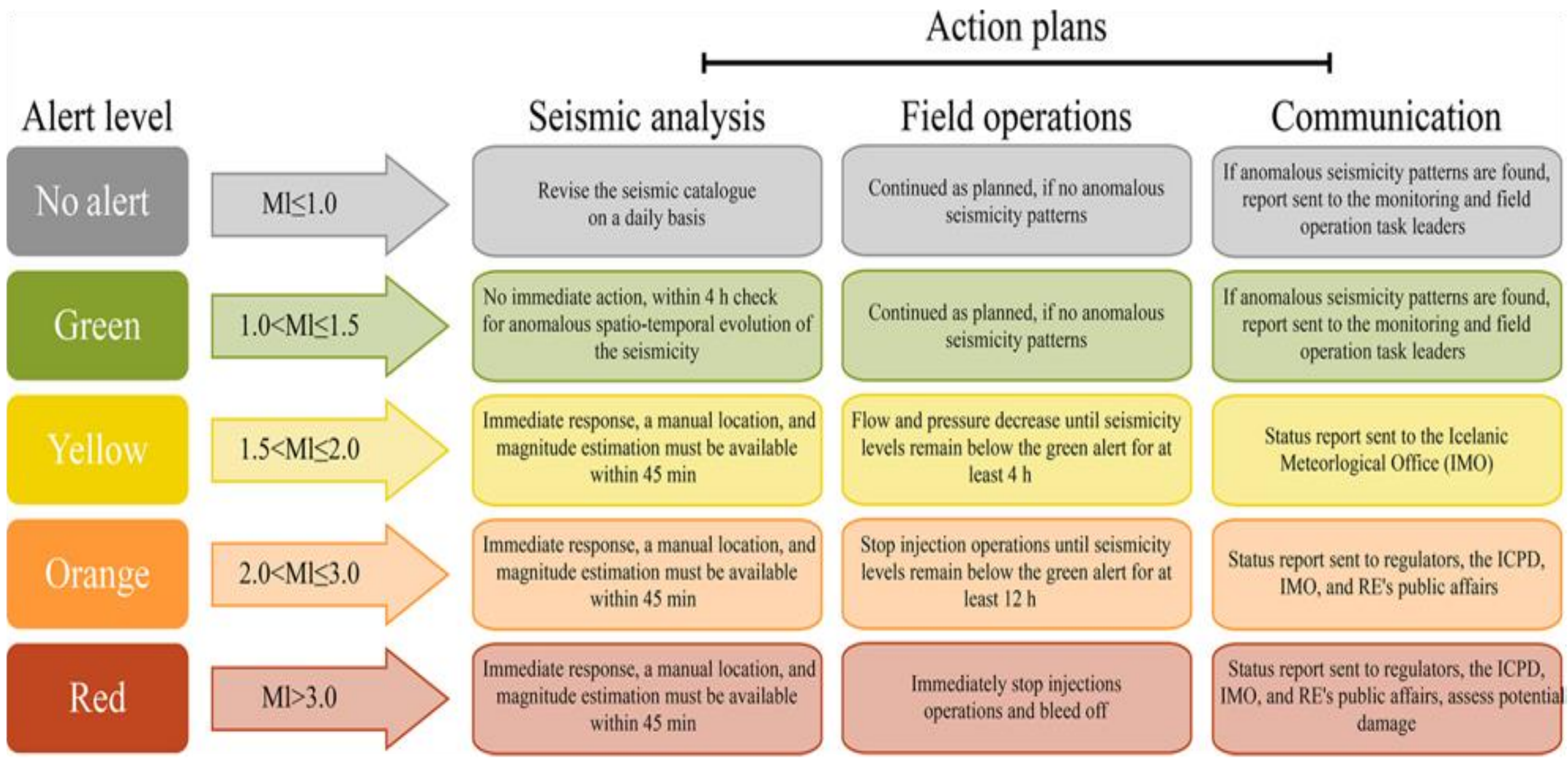
Induced seismicity

- Seismic risk can be defined as the likelihood or probability of different levels of undesirable consequences due to the occurrence of earthquakes. Such consequences may include loss of life, injury, damage and collapse of buildings, economic costs, and business interruption, among others,

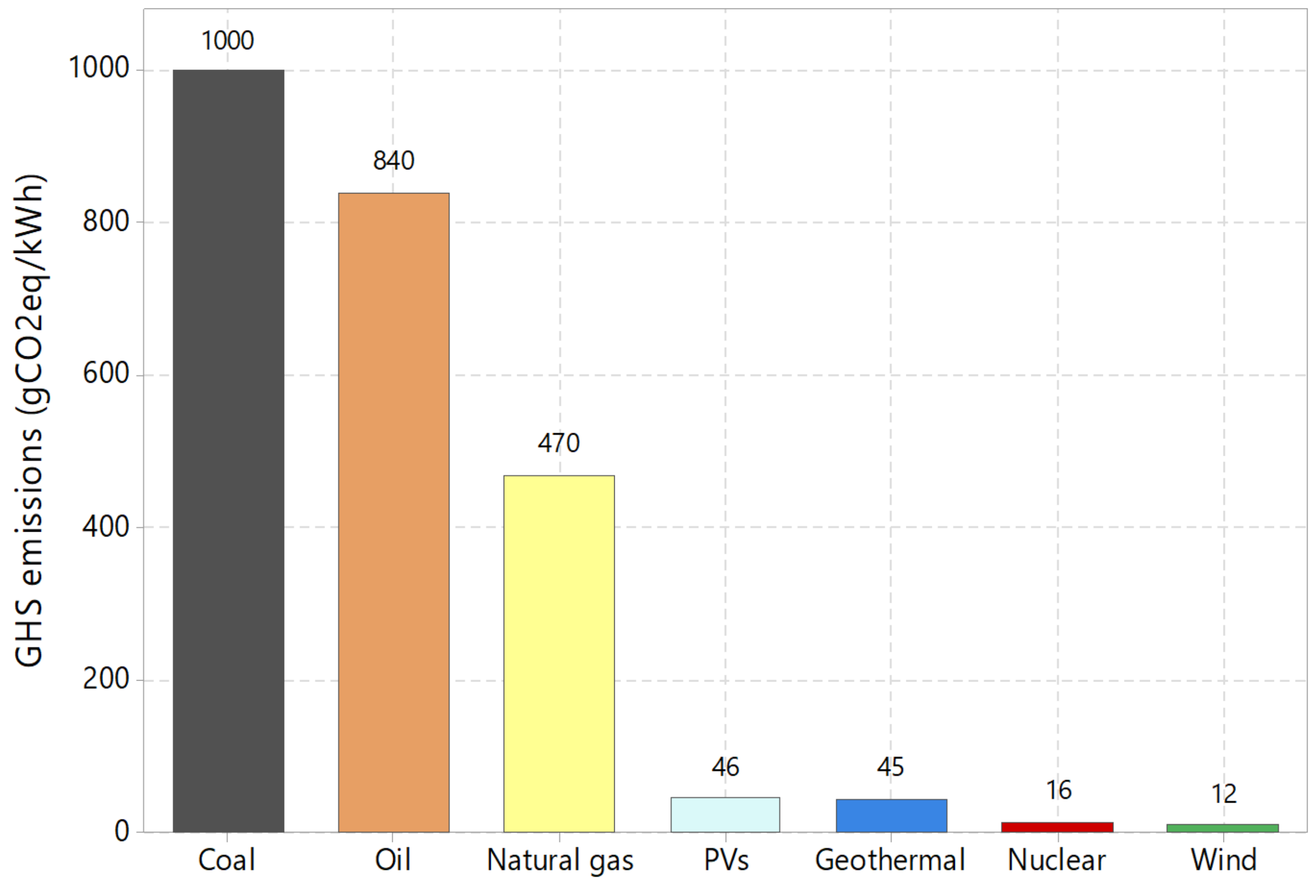


Induced seismicity risk assessment

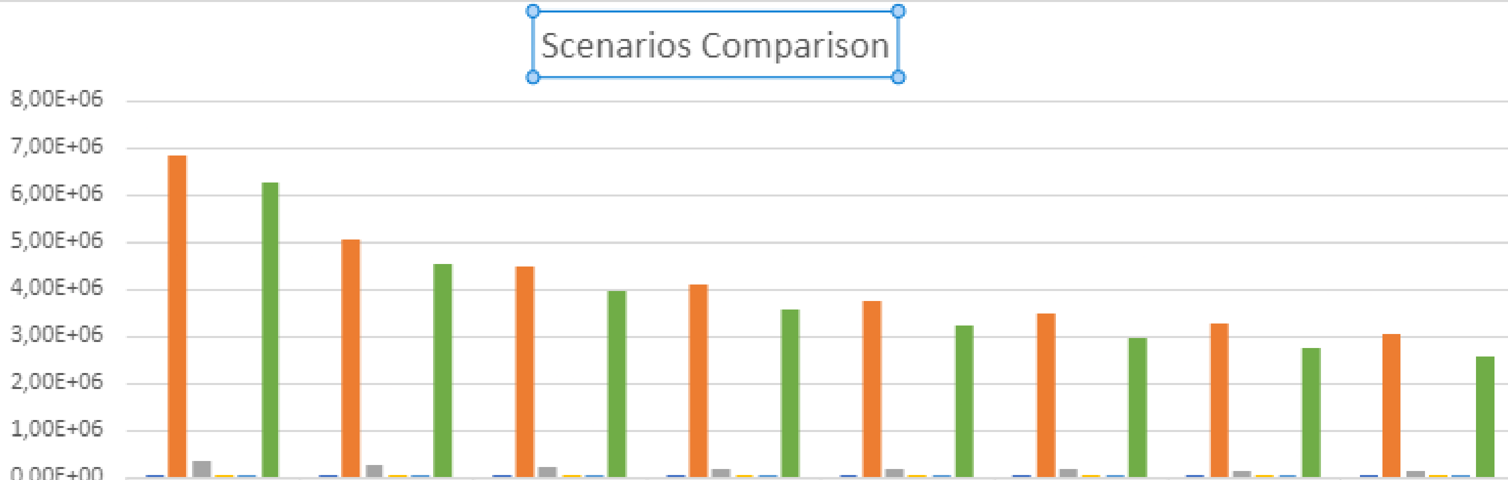
- Traffic Lights System (TLS)



Life Cycle Assesment (LCA)



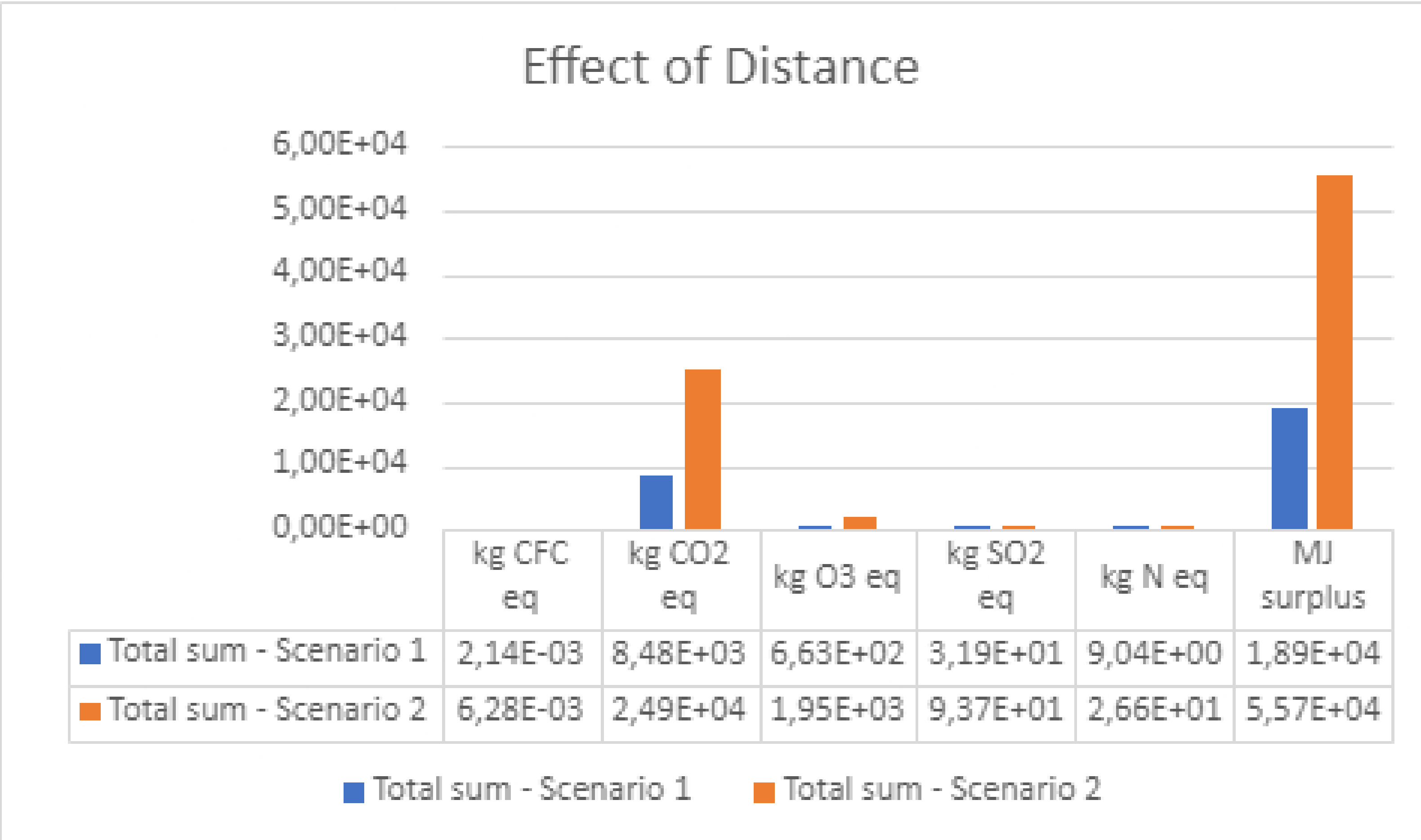
Life cycle assessment (LCA)



	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8
Total kg CFC eq	1,30E+01	1,28E+01	1,28E+01	1,28E+01	1,27E+01	1,27E+01	1,27E+01	1,27E+01
Total kg CO2 eq	6,84E+06	5,06E+06	4,52E+06	4,10E+06	3,76E+06	3,49E+06	3,27E+06	3,08E+06
Total kg O3 eq	3,55E+05	2,61E+05	2,32E+05	2,10E+05	1,92E+05	1,78E+05	1,66E+05	1,56E+05
Total kg SO2 eq	3,26E+04	2,38E+04	2,11E+04	1,91E+04	1,74E+04	1,61E+04	1,50E+04	1,40E+04
Total kg N eq	2,79E+04	2,03E+04	1,80E+04	1,63E+04	1,49E+04	1,37E+04	1,28E+04	1,20E+04
Total MJ surplus	6,28E+06	4,53E+06	3,99E+06	3,57E+06	3,24E+06	2,98E+06	2,75E+06	2,56E+06

Total kg CFC eq · Total kg CO2 eq · Total kg O3 eq · Total kg SO2 eq · Total kg N eq · Total MJ surplus

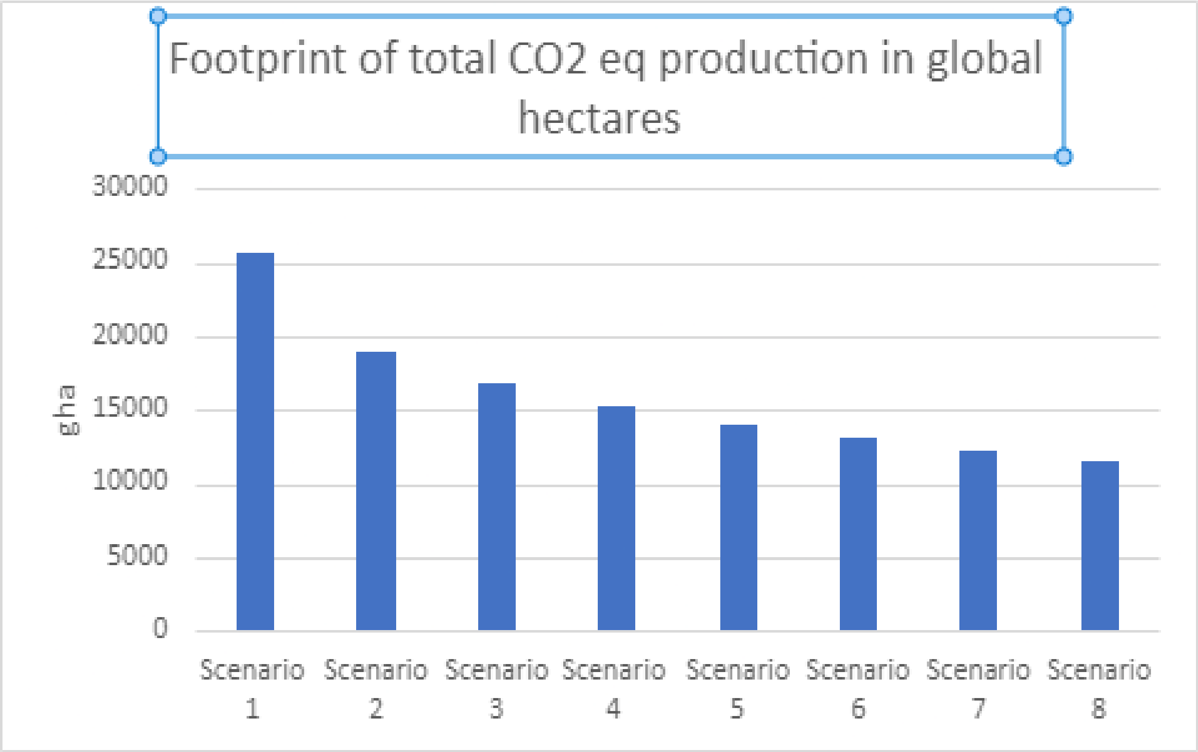
Life Cycle Assessment (LCA)



	kg CFC eq	kg CO2 eq	kg O3 eq	kg SO2 eq	kg N eq	MJ surplus
Total sum - Scenario 1	2,14E-03	8,48E+03	6,63E+02	3,19E+01	9,04E+00	1,89E+04
Total sum - Scenario 2	6,28E-03	2,49E+04	1,95E+03	9,37E+01	2,66E+01	5,57E+04

Ecological Footprint Assessment (EFA)

- EFA was developed during 90s by Wackernagel and Rees in Columbia University



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