Working together for a green, competitive and inclusive Europe

This work was supported by a grant from the EEA Grants - Financial Mechanism 2014-2021, Projects of cooperation in university education" Education, Scholarships, Apprenticeship and Youth Entrepreneurship Program in Romania"

" Innovative Teaching methods for tomorrow's Renewable Energy Specialists"

19-COP-0025

The project is a cooperation between two partners: the Faculty of Physics at the University of Bucharest and the Iceland School of Energy at Reykjavik University

GEOTHERMAL ENERGY

Juliet Newson
Iceland School of Energy

Iceland School of Energy Geothermal Presentation 2 for the Green Program 2

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REYKJAVIK UNIVERSITY

Presentation Structure:

- How geothermal systems work
- Electricity generation process
- Challenges for geothermal electricity generation
- Worldwide geothermal generation & geothermal jobs

Desired outcome:

- Qualitative understandin

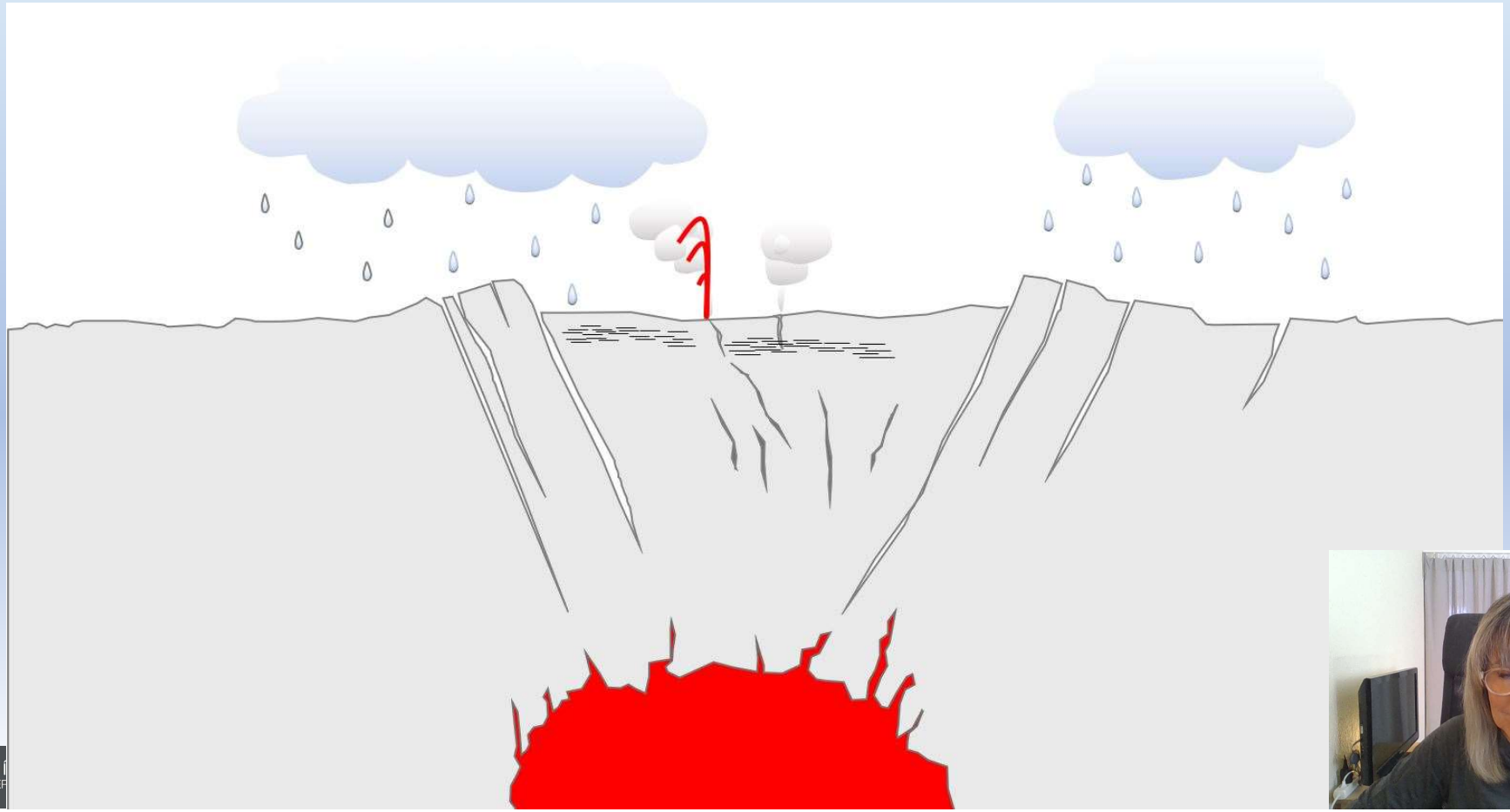
geothermal systems and elect

Understanding Geothermal Systems

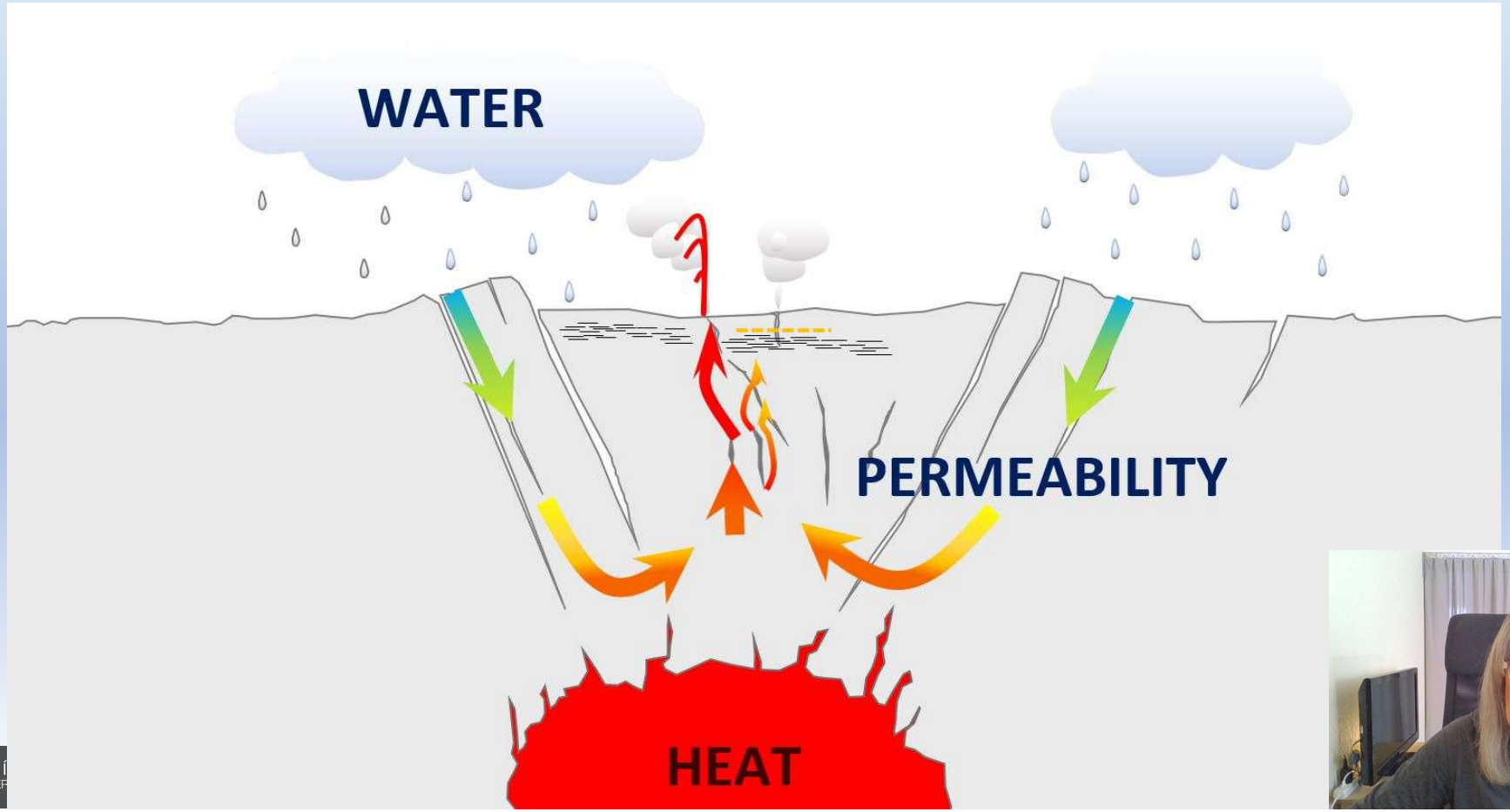
Approach is to look at a ‚typical' system.

- ‚Typical' system ⟶ simple ⟶ Only contains the important elements
- A simplified conceptual system is a starting point for understanding real systems which are much more complex

Conceptual model of a high temperature geothermal system

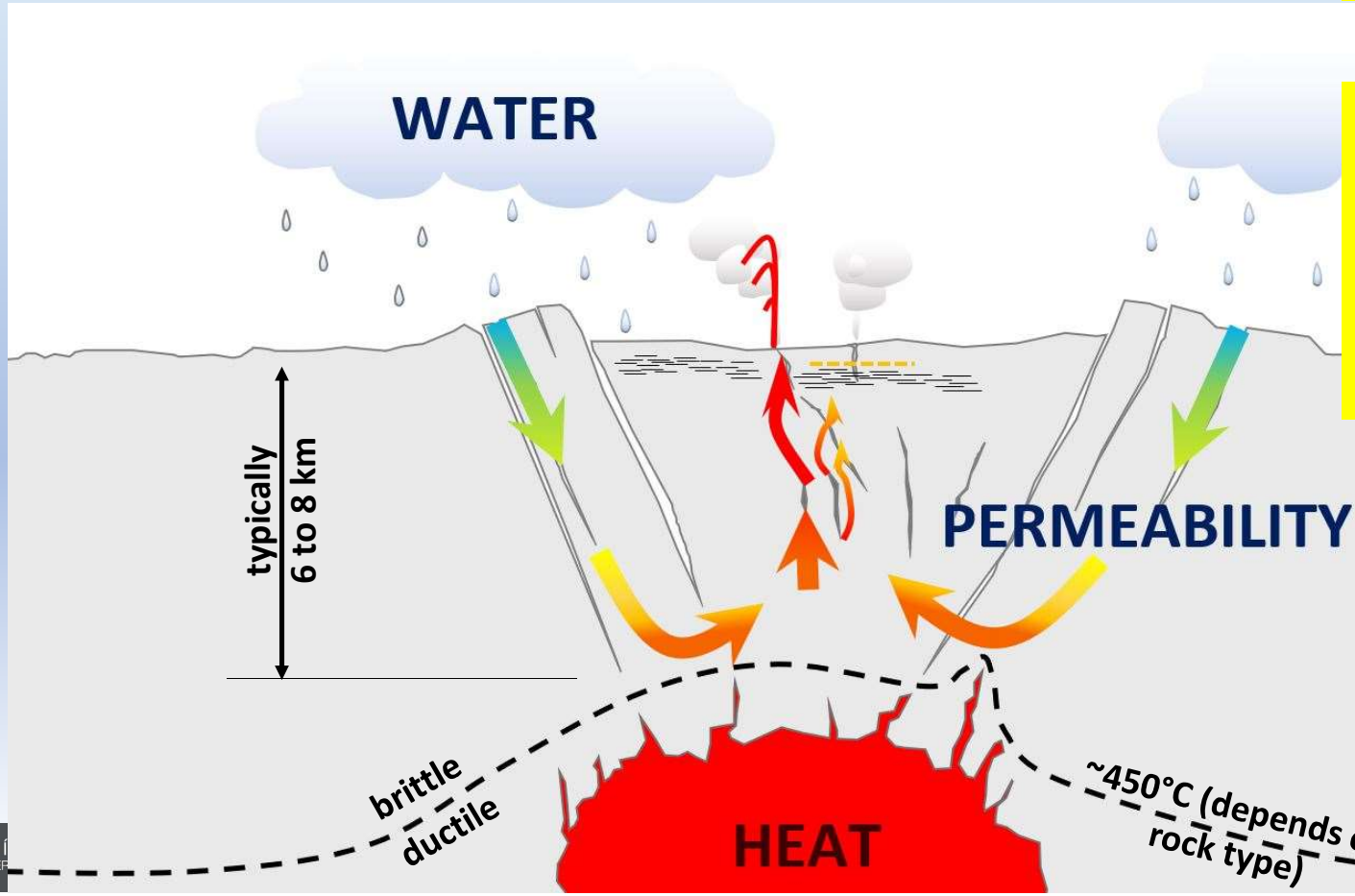


3 main factors



Fluid circulation

<u>Stable circulation system</u>. There are no changes over time.

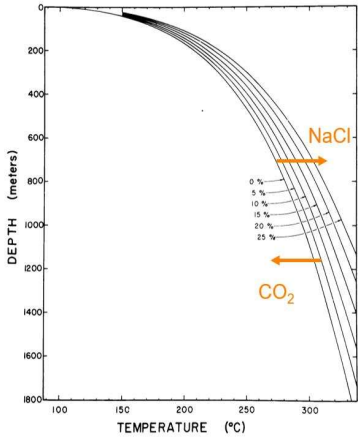


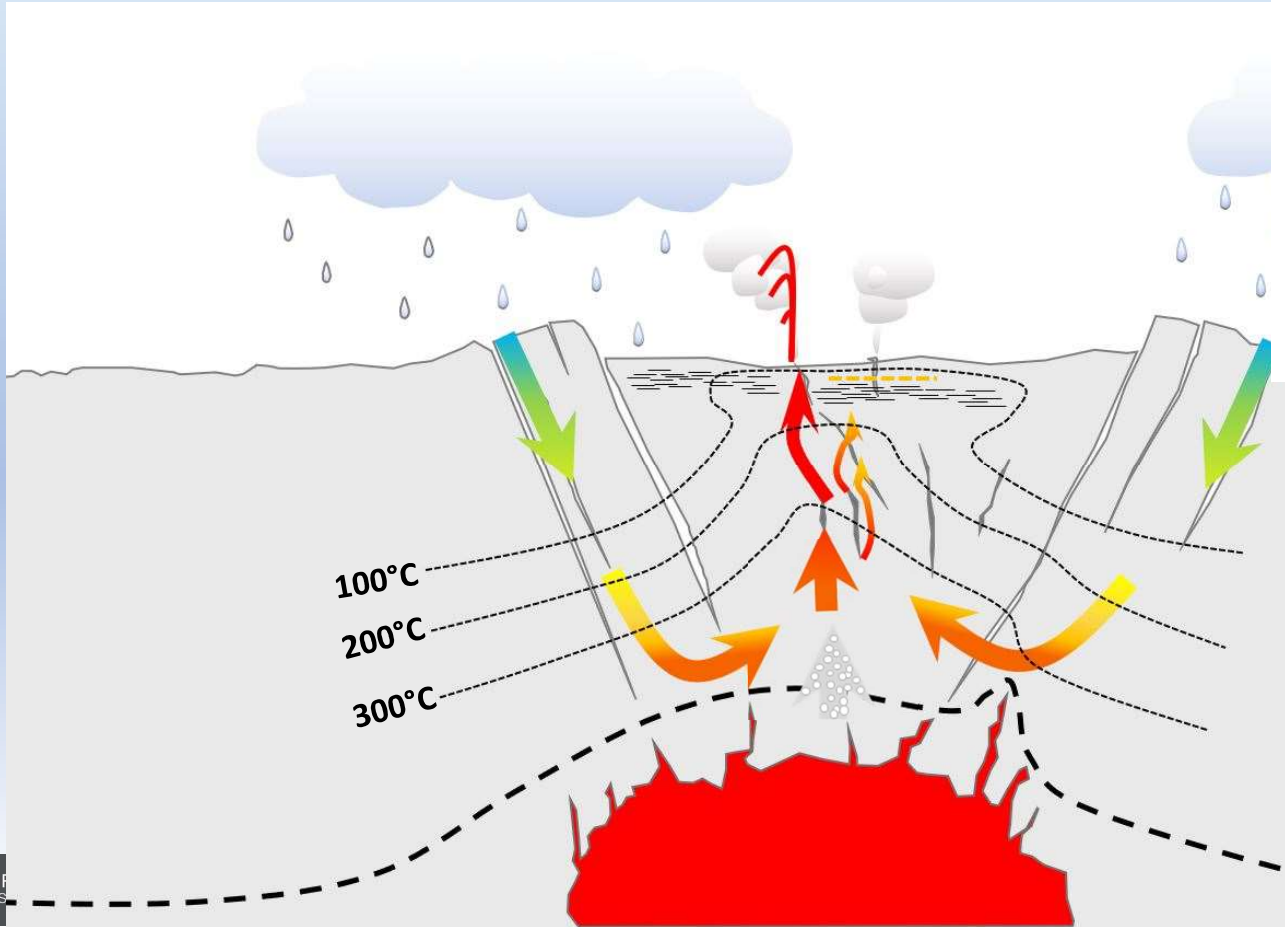
<u>Above</u> the brittle-ductile boundary: *Convective* heat transfer. The heat is carried in the water.
<u>Below</u> the brittle-ductile boundary: *Conductive* heat transfer

Isotherms

<u>Isotherms</u> Closely relate to the flow direction of the water.

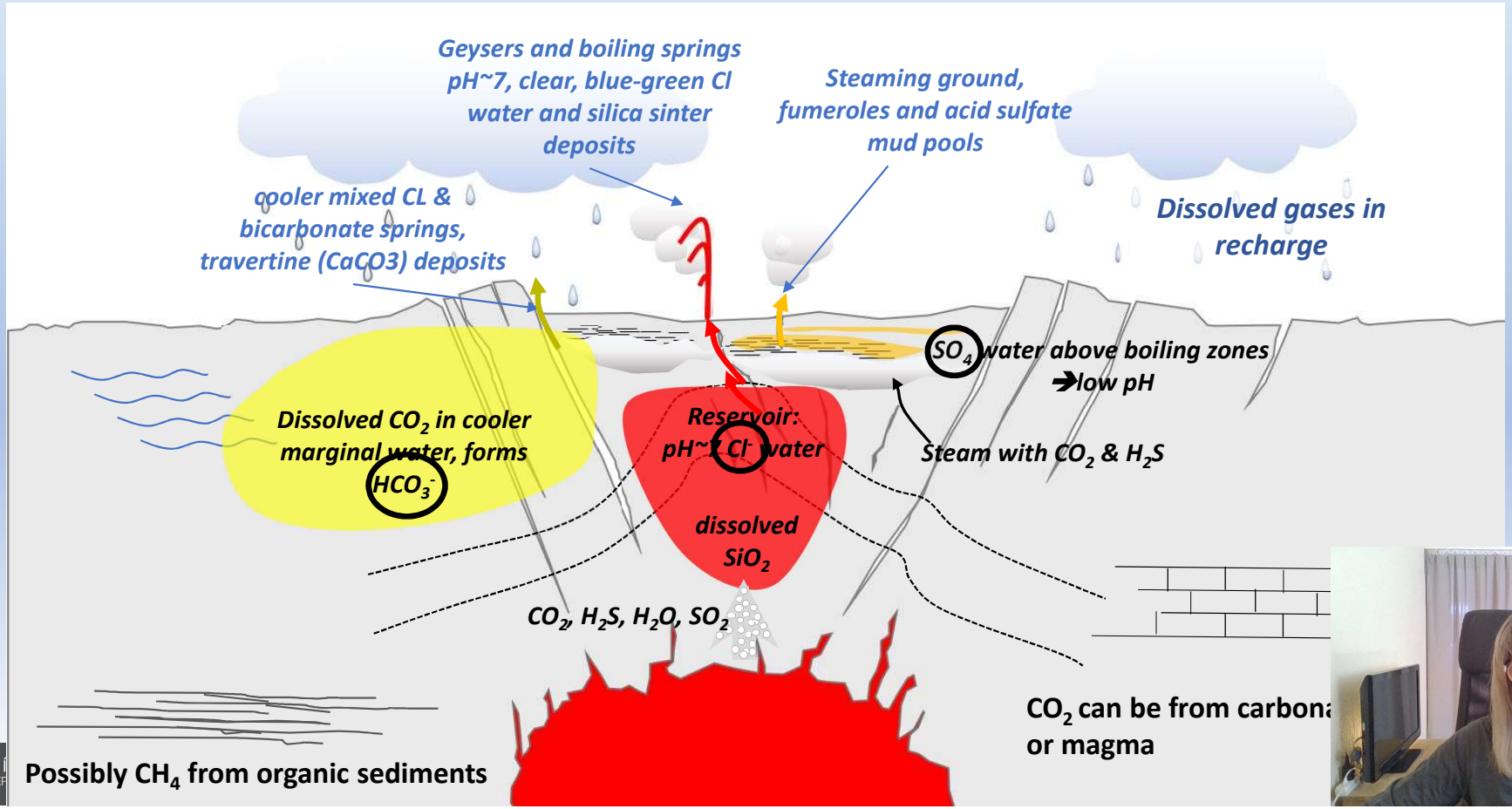
<u>Temperature is boiling point for depth</u>



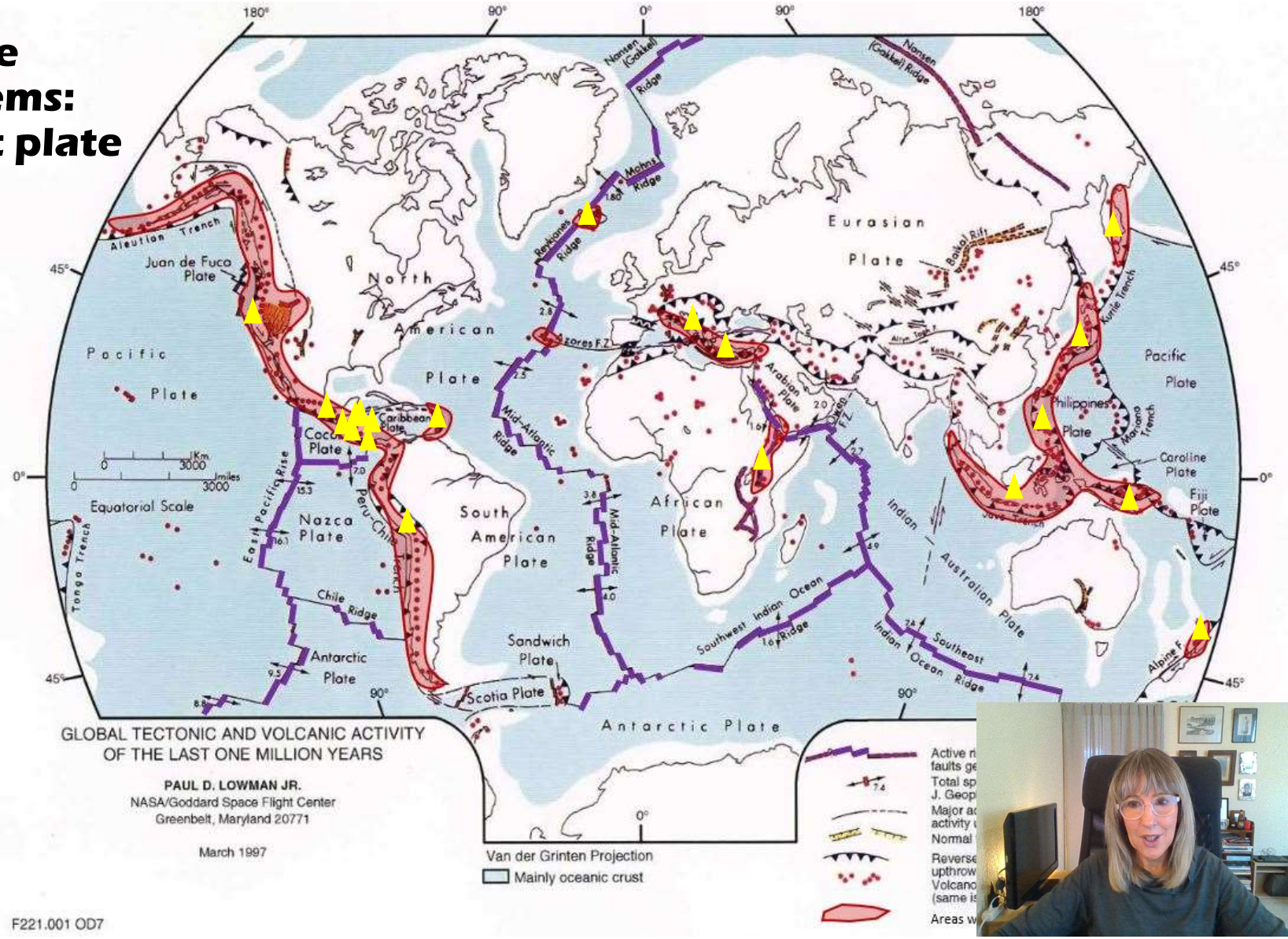


Constituents of geothermal water

Important processes contributing to chemistry of geothermal fluids:
magmatic fluids + meteoric fluids + fluid-rock interaction + mixing + boiling

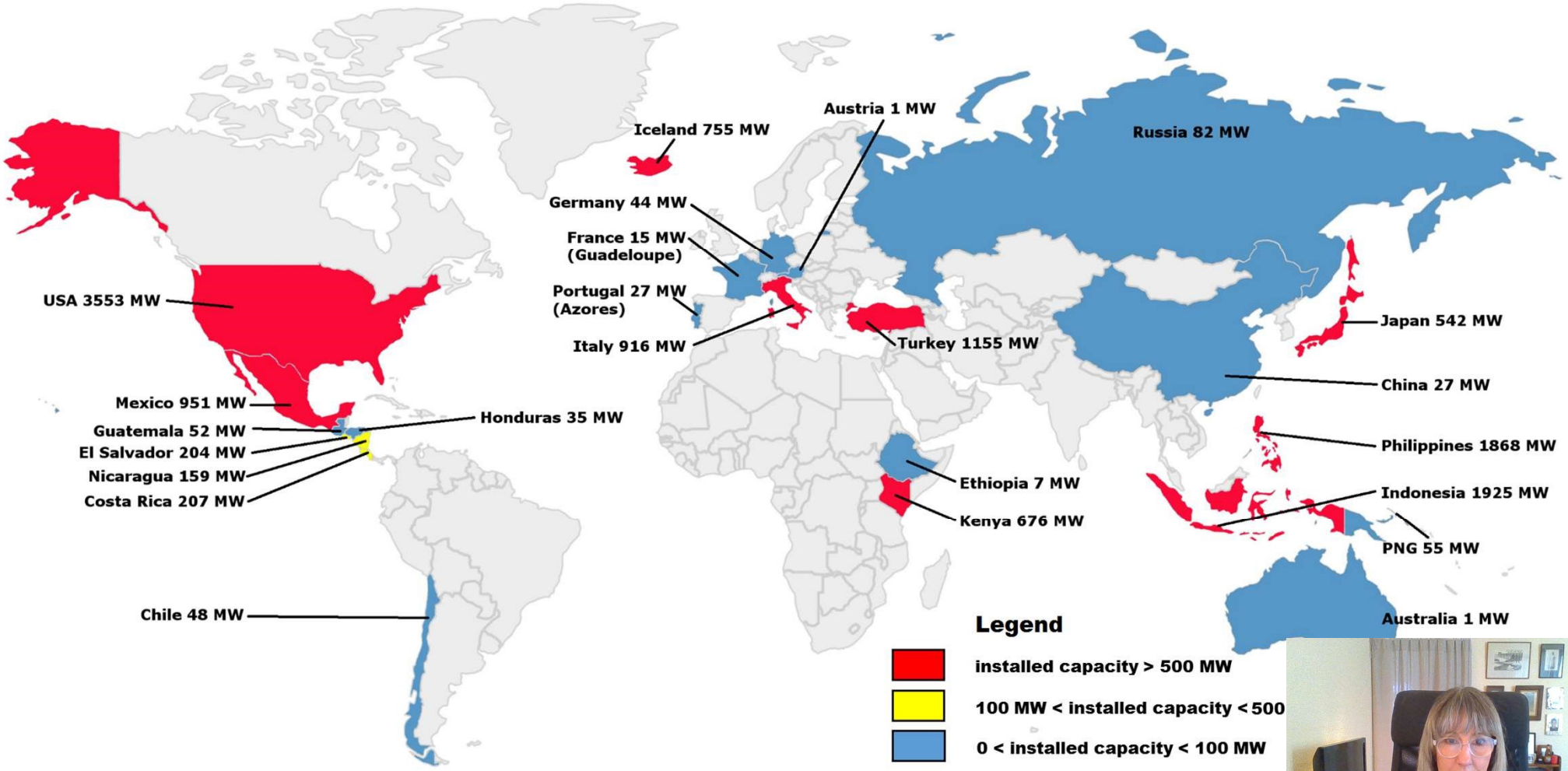


High temperature geothermal systems: mainly located at plate margins



A map of global tectonic and volcanic acti
over the last one million years, showing: a
ridges, continental extensions, transform
faults, ridge spreading rates and direction
continental rifts, subduction and overthru
zones, and generalized volcanic activity.
Illustration prepared by Paul D. Lowman J
NASA Goddard Space Flight Center. Van d
Grinten projection.

https://geology.com/plate-tectonics.shtml


Iceland 755 MW
Austria 1 MW
Russia 82 MW
Germany 44 MW
France 15 MW
(Guadeloupe)
Portugal 27 MW
(Azores)
Italy 916 MW
Turkey 1155 MW
USA 3553 MW
Japan 542 MW
China 27 MW
Mexico 951 MW
Honduras 35 MW
Guatemala 52 MW
El Salvador 204 MW
Nicaragua 159 MW
Costa Rica 207 MW
Philippines 1868 MW
Ethiopia 7 MW
Kenya 676 MW
Indonesia 1925 MW
PNG 55 MW
Chile 48 MW
Australia 1 MW
Legend
installed capacity > 500 MW
100 MW < installed capacity < 500
0 < installed capacity < 100 MW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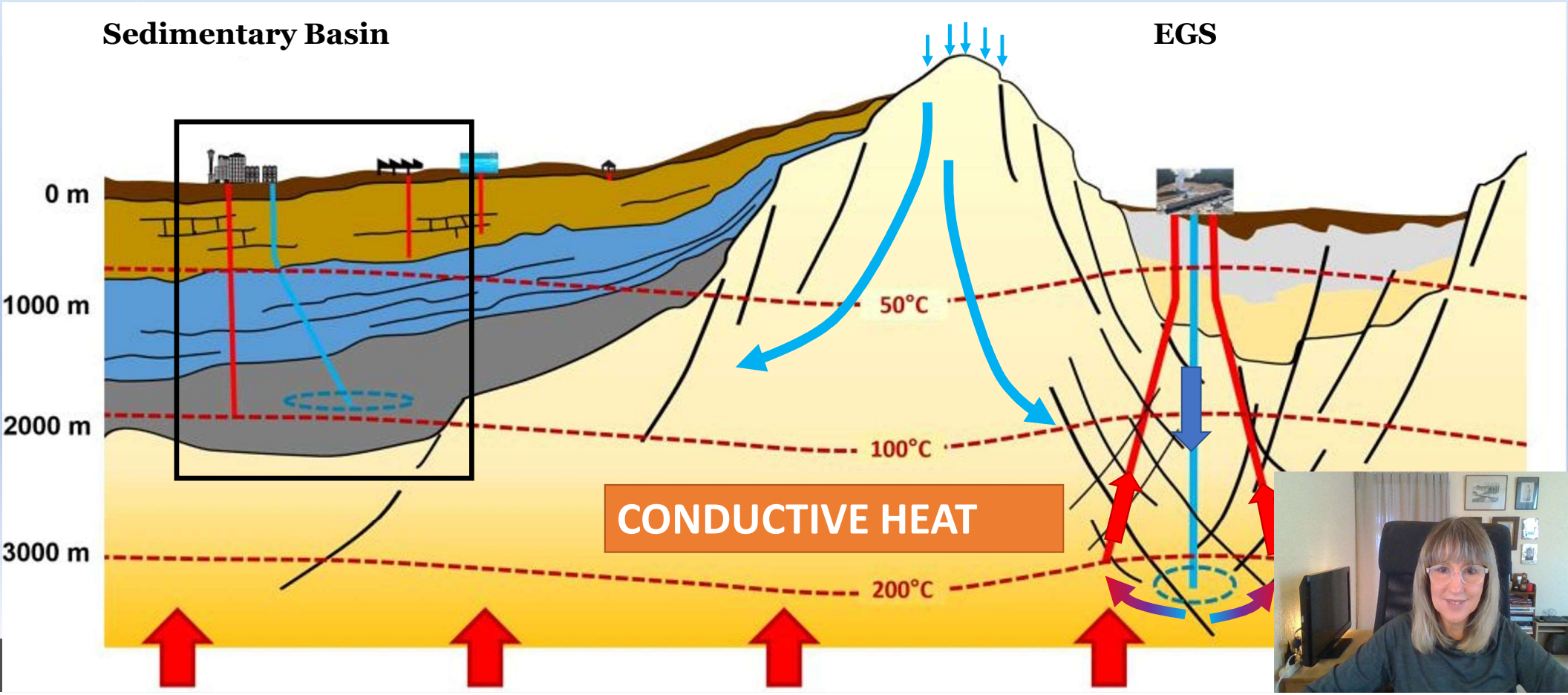
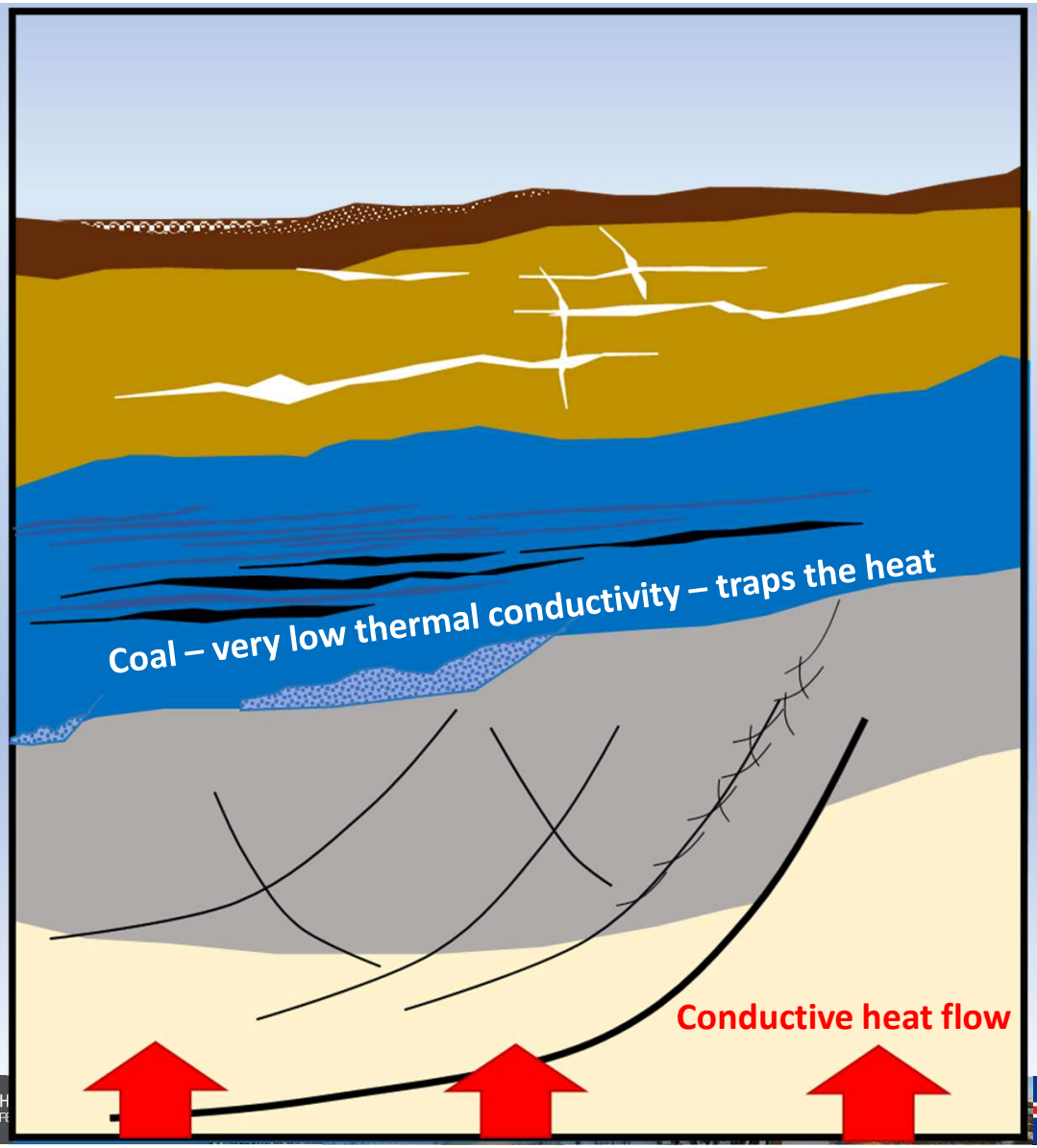
Sedimentary basin & Engineered Geothermal Systems (EGS)





Surficial rocks – soils, recent sediment and/or weathered rocks.

Will have an unsaturated zone, and may host the water table, or have perched aquifers.

Karst aquifers: carbonates with permeability due to dissolution. Highly permeable.

Clastic sedimentary aquifers. Permeability dependent on grain size, or fractures if the rock is cemented. Often permeability anisotropy with horizontal permeability ($k_{x,y}$) greater than vertical (k_z)

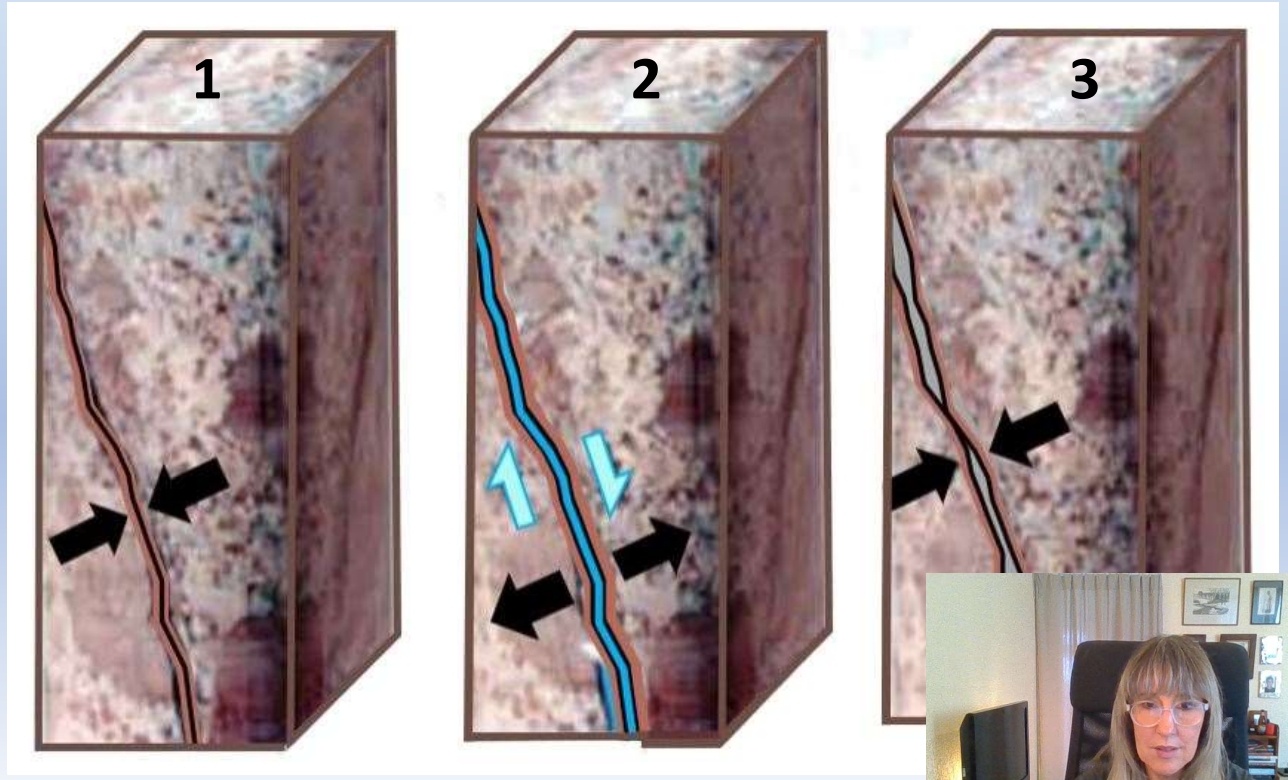
Older, indurated sediments (subject to higher pressure & temperature so harder, more fractured rock). Lower porosity, lower permeability except on fractures.

Crystalline basement, fracture p

Engineered Geothermal Systems

Rock permeability is improved by:

- Hydraulic stimulation
- Chemical dissolution



Hydraulic stimulation:

1. Closed fracture, compressive normal stress
2. Opened by water pressure removal of compressive normal stress allows shear movement
3. Relative movement means fracture faces do not 'fit', result is better permeability.

Surface features

- Fumarole (steam vent)
- Other types of geothermal pools
- Orakei Korako (silica sinter)
- Pamukkale (travertine)

Gunnuhver, Reykjanes, Iceland

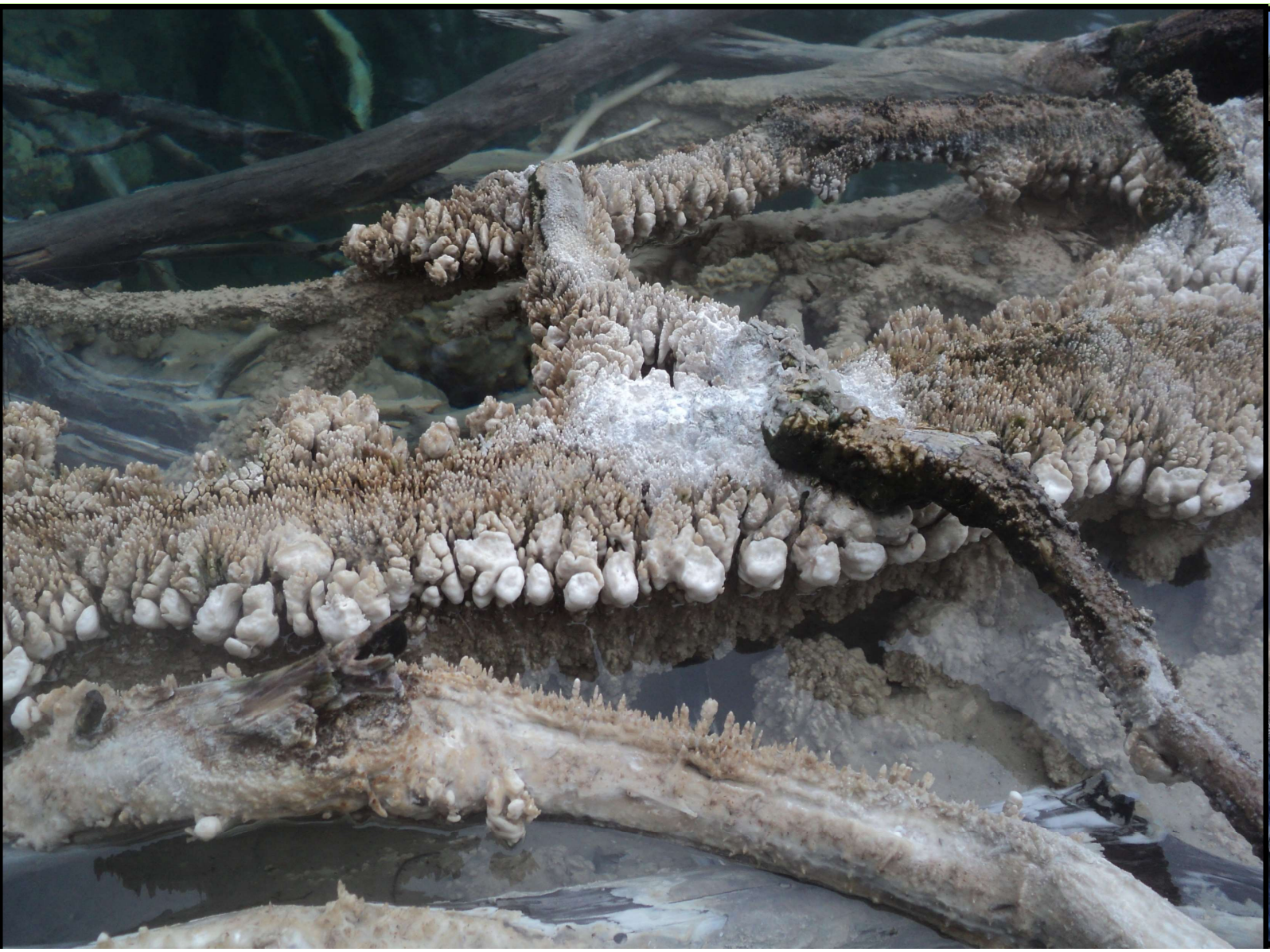
https://hiticeland.com/photos%20from%20iceland/reykjanes/gunnuhver

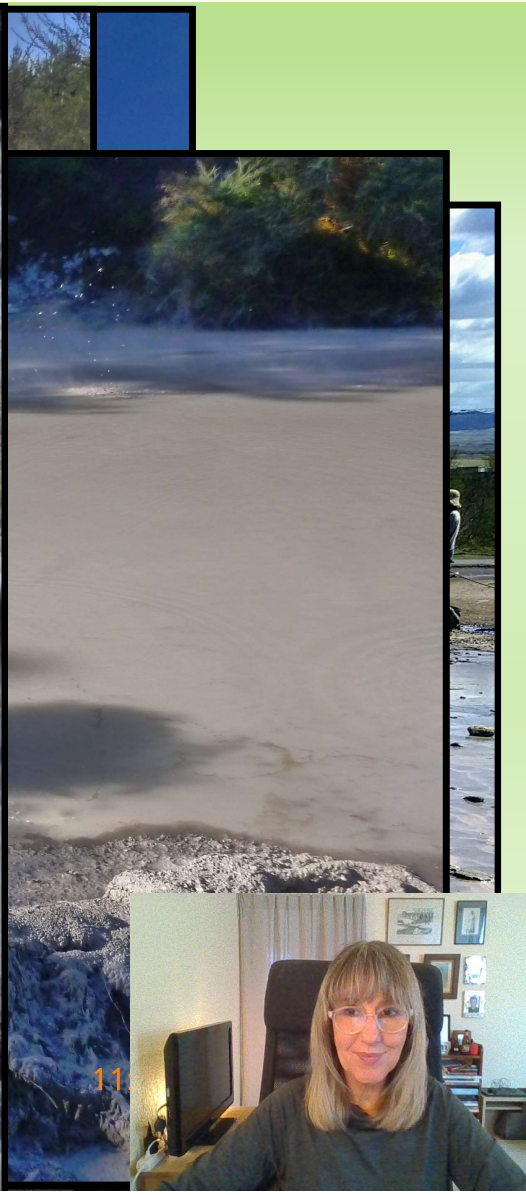
Gunnuhver, Reykjanes, Iceland

https://hiticeland.com/photos%20from%20iceland/reykjanes/gunnuhver

You will have to view this video as a separate file in the module.

The video is called 01_VidOfGunnuhver.mp4





Orakeikorako, New Zealand

https://www.orakeikorako.co.nz/

Pamukkale, Turkey

www.pamukkale.gov.tr/en

Summary of geothermal systems

Riley Newmann (ISE grad) at Waikite Thermal Valley, NZ.
Stream temperature 83 °C

We have covered:

- Large scale system structure
- Temperature stucture and heat transfer mechanisms
- Concepts of permeability & lithology
- High T geothermal systems
  - Chemistry
  - Types of surface expression

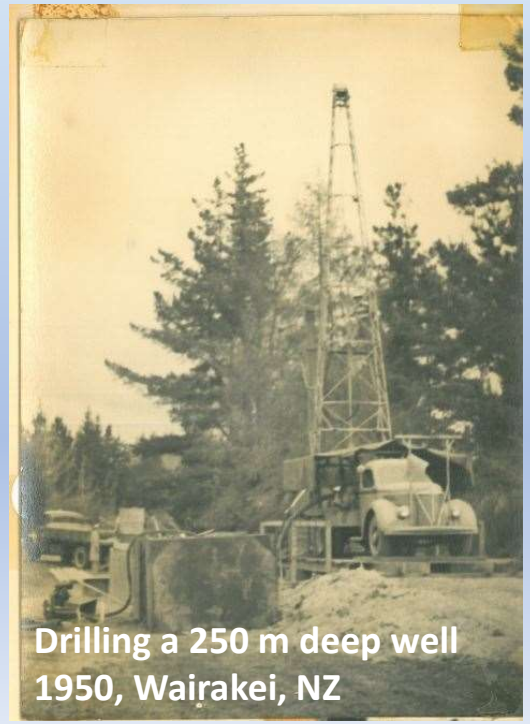
Geothermal Electricity Generation

- Accessing the resource
- The electricity generation process

A brief history of accessing the resource

1950's

Drill to <600 m deep



Drilling a 250 m deep well
1950, Wairakei, NZ

Drilling a 2700 m deep well
2013 Ohaaki, NZ

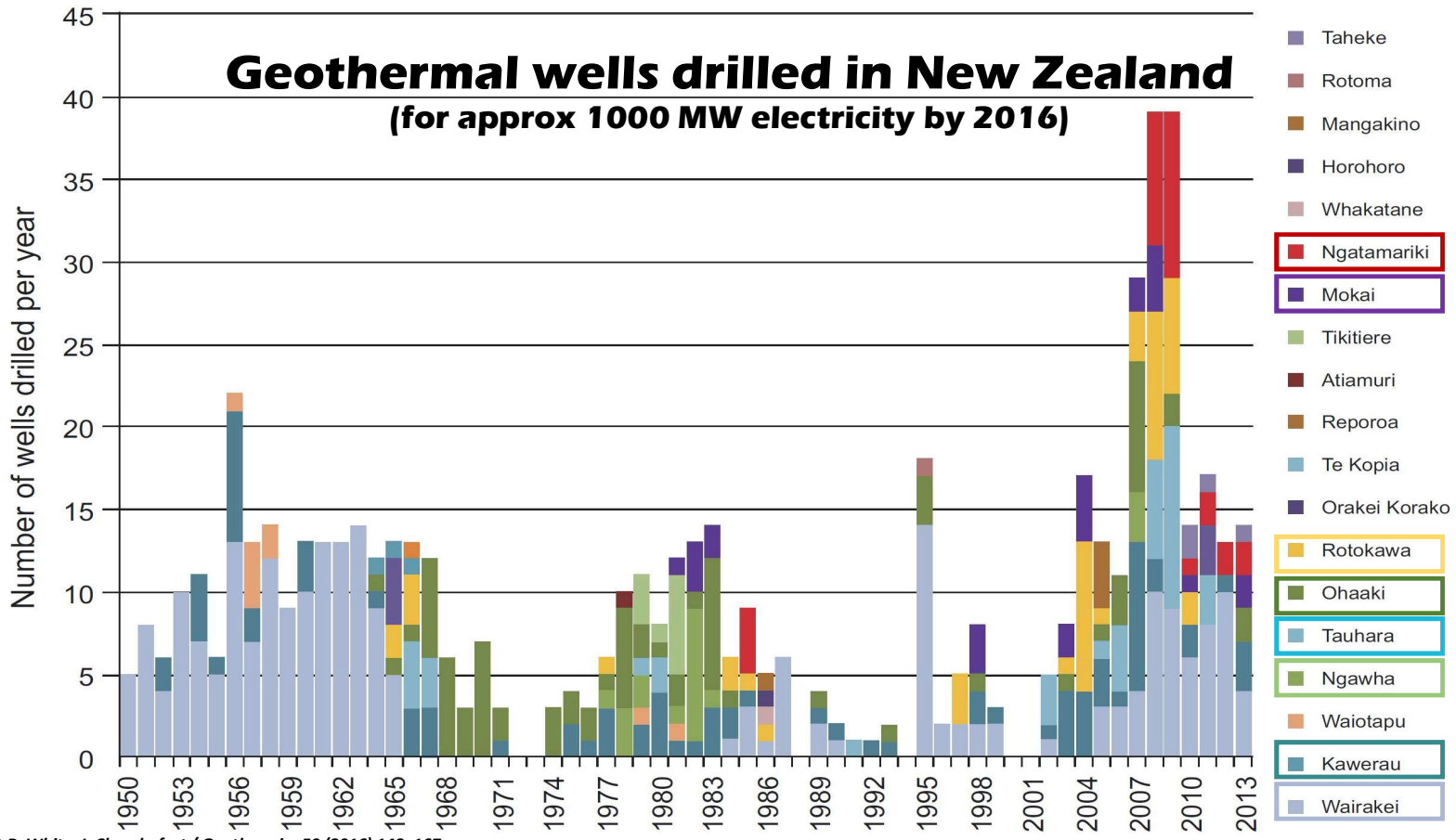
Usually now geothermal wells for electricity production are:

- 600 m to 3500 m deep,
- 240 to 320 ˚C, &
- cost $5 million to $10 million

Iceland has drilled IDDP1 and IDDP2, the hottest geothermal wells ever.

IDDP2, 4600 m deep
> 430 ˚C
2017 Iceland

How many wells might be needed?



B.R. White, I. Chambefort / Geothermics 59 (2016) 148–167

Includes:

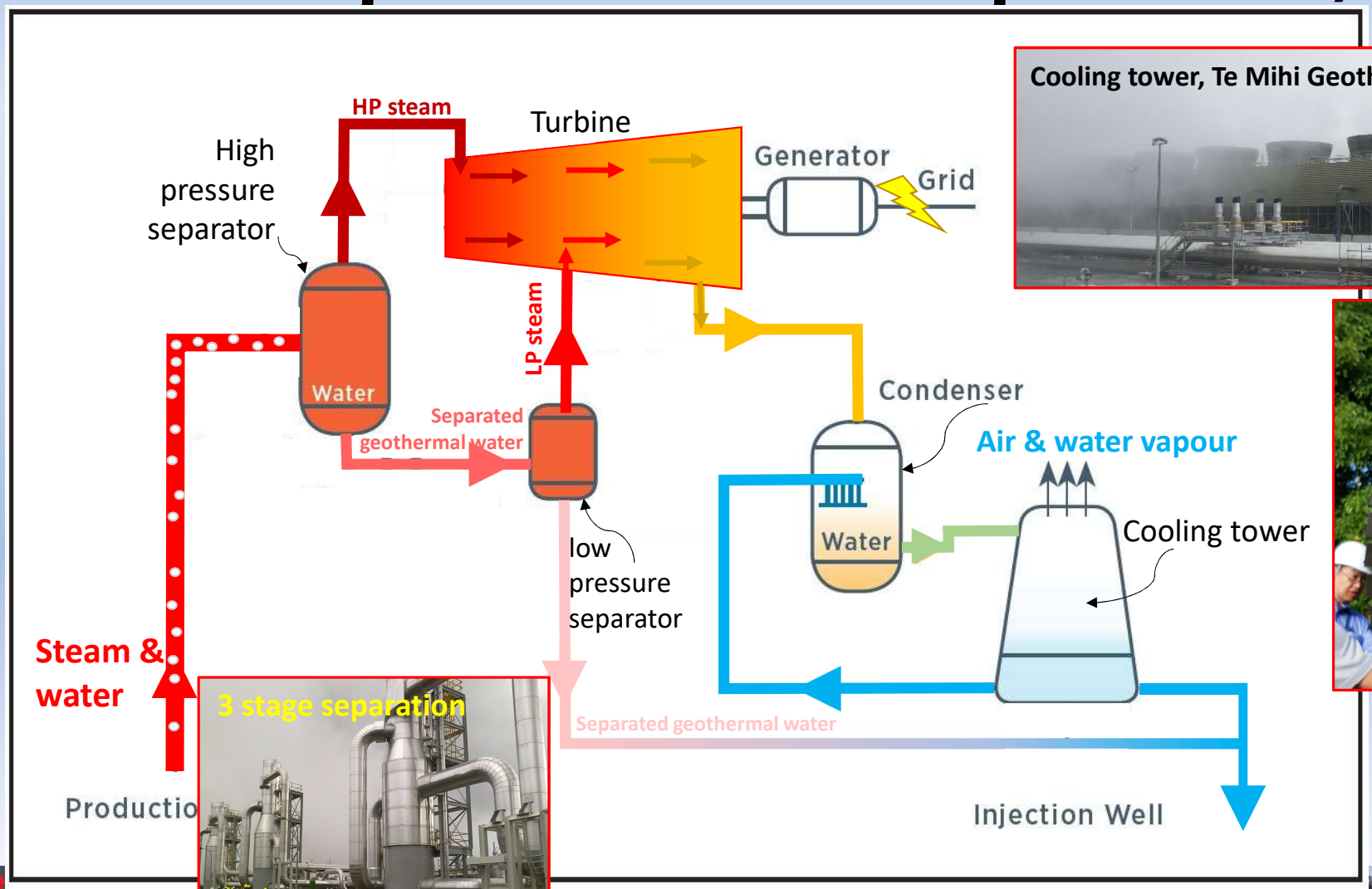
- **Exploration**
- **Production**
- **Injection**
- **Investigation**
- **Monitoring**
- **Many early wells now cemented (sealed) & abandoned**

No
us

WK254, Wairakei, New Zealand

You will need to view this as a separate file.
It is available in the module as 02_VWK254.avi

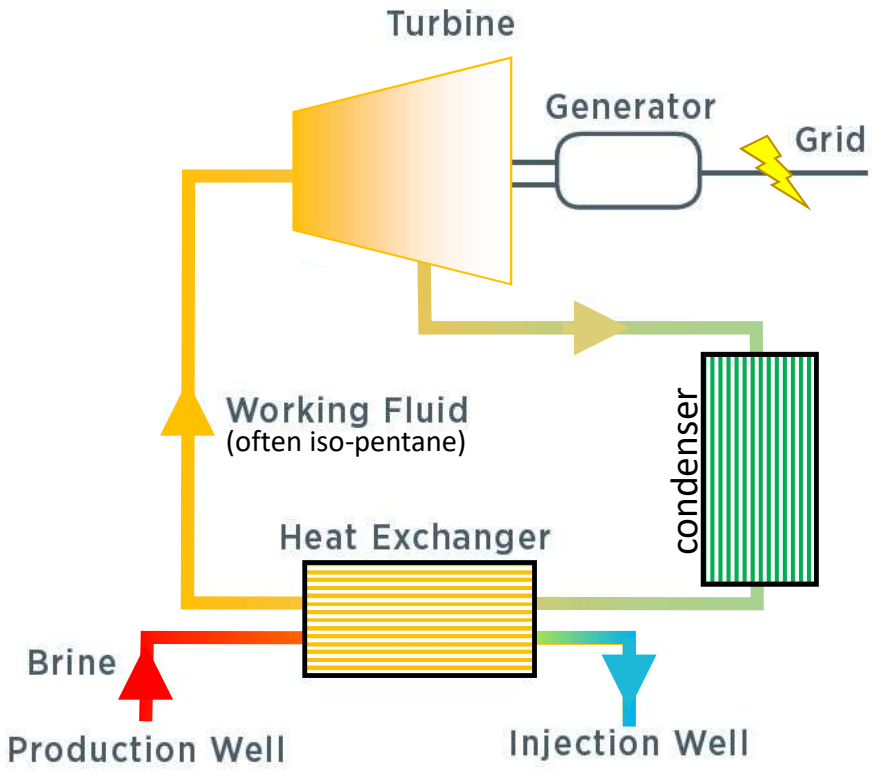
Geothermal power station with 2-phase wells, dual flash



Cooling tower, Te Mihi Geothermal Power Station, NZ

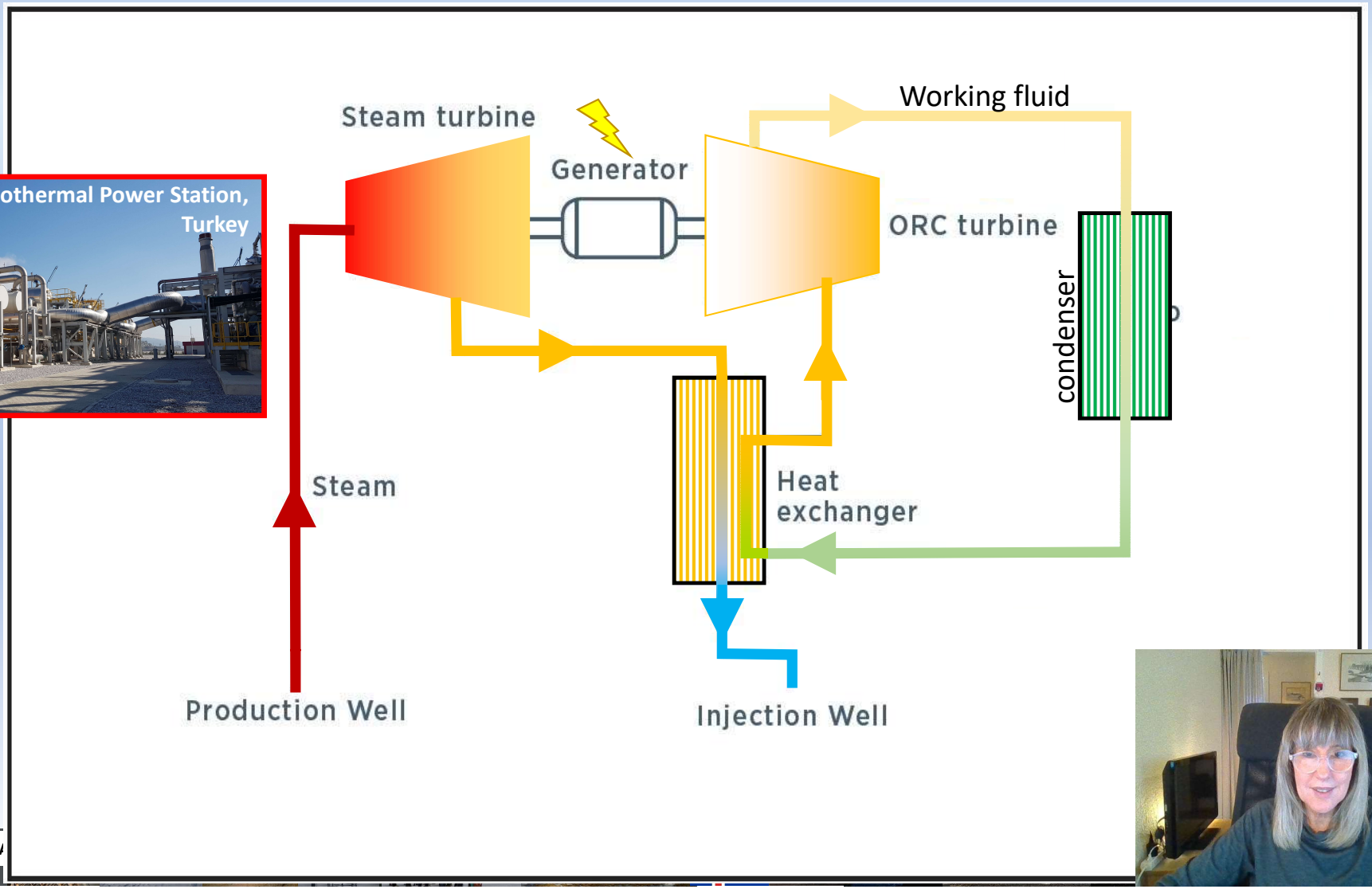
Adapted from: IRENA (2017), Geothermal Power: Technology Brief, International

Binary Power station geothermal fluid heats a secondary fluid with low boiling point




Condenser & cooling fans, Wairakei Binary Geothermal Power Station, NZ

Geothermal combined cycle: steam and binary

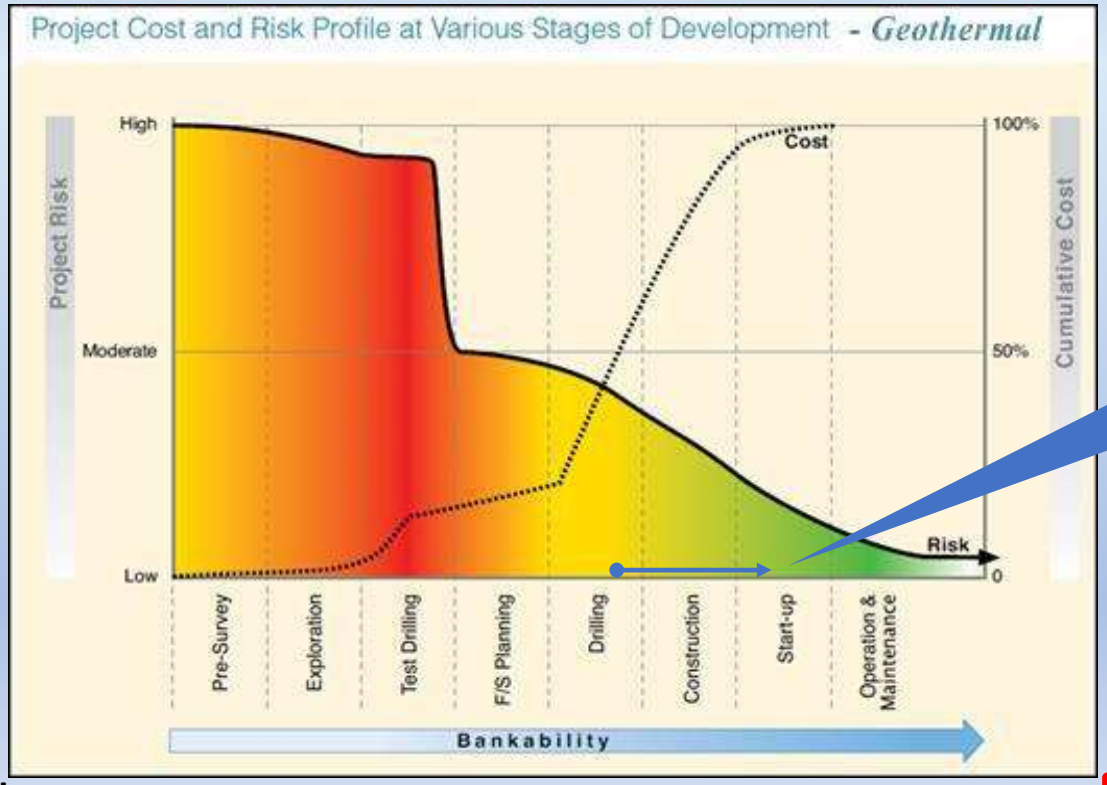


Challenges & Opportunities
of development & production

- Overcoming initial risk
- Policy, Regulation
- Geothermal System management
- Environmental (surface effects)
- Challenges for the future

Geothermal is a long-term strategy with high initial risk

From Geothermal Handbook: Planning and Financing Power Generation," World Bank, 2012



Steamfield & power station is >50 % of the total cost of the project

Many unknowns at start of project = high risk

Drilling and plant is expensive

Fuel –

Policy & Regulation

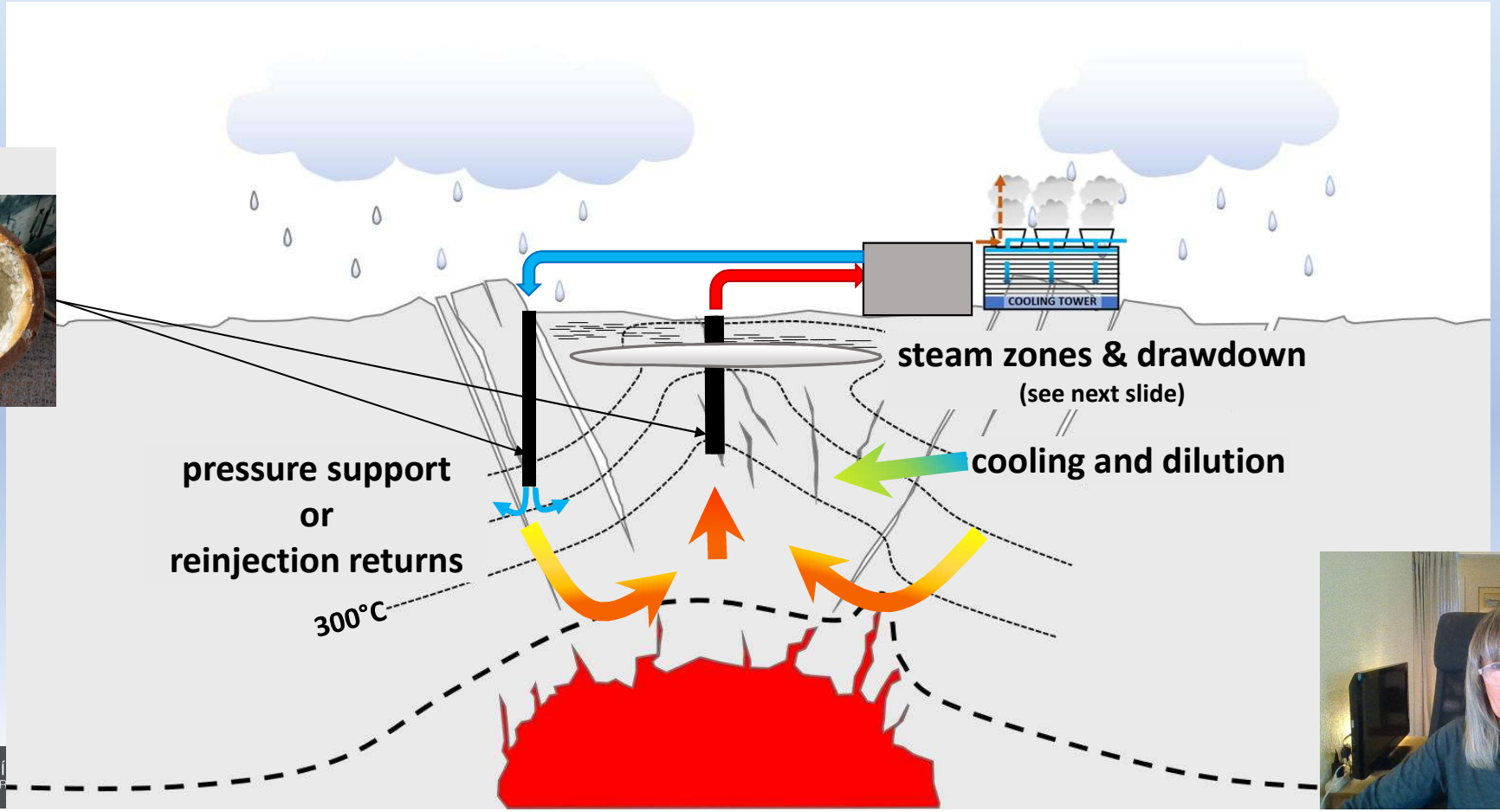
- Access to explore and utilize the resource →
  - Who controls access?
  - Speed of processing applications?
  - Is investment in exploration acknowledged?
  - Is there a long-term plan?

- Process for managing environmental concerns →
  - Monitoring surface effects/mitigation
  - Monitoring reservoir (resource) changes
  - Benefit for local people
  - Provision for ongoing dial

Geothermal System Management

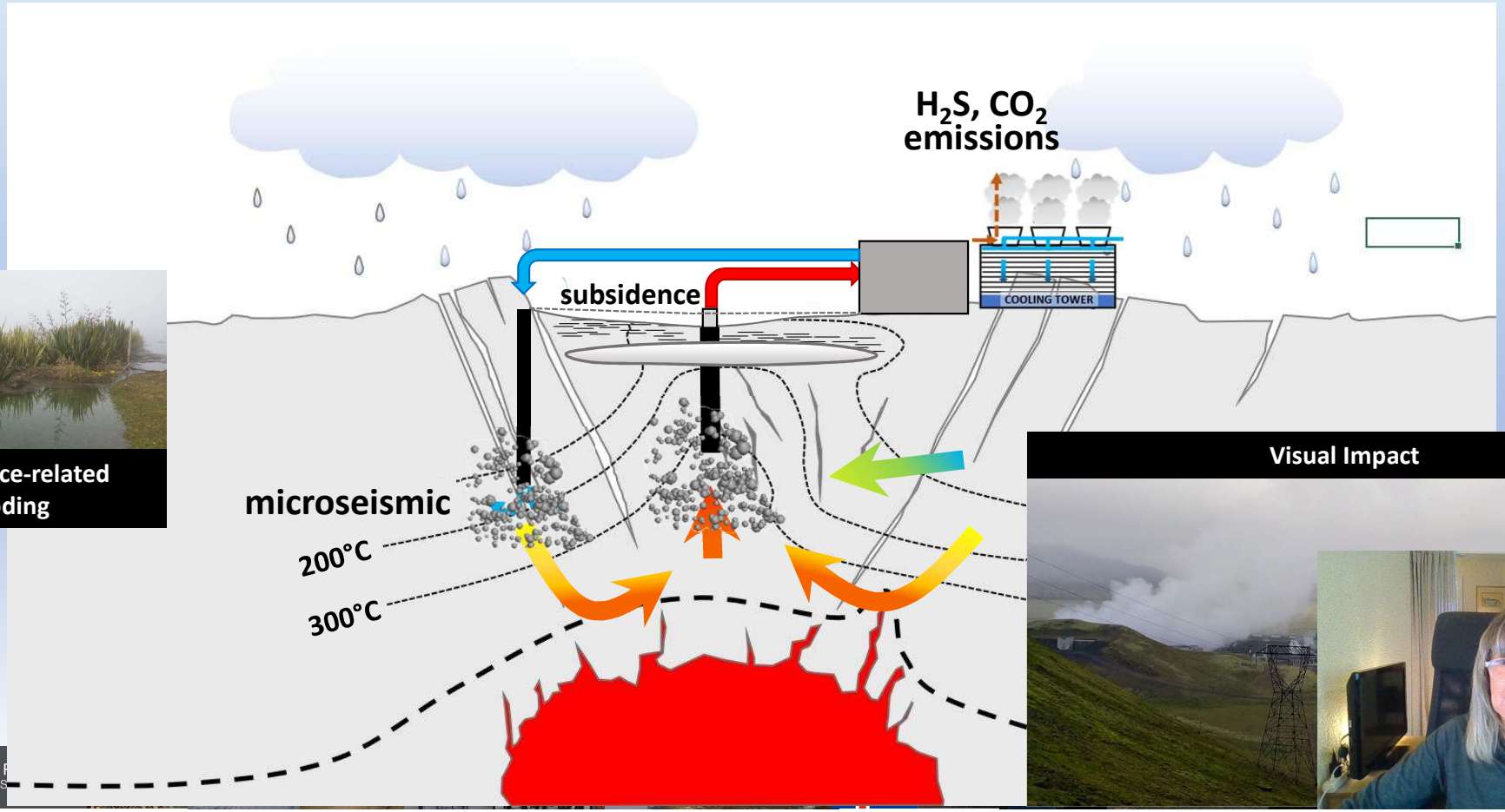
Subsurface issues that affect production

scale



Environmental Impacts and Social Acceptance

Surface & subsurface issues that affect production and public acceptance



Subsidence-related flooding

Visual Impact

Further challenges for the geothermal industry

Ex 1: Cascaded use: Blue Lagoon

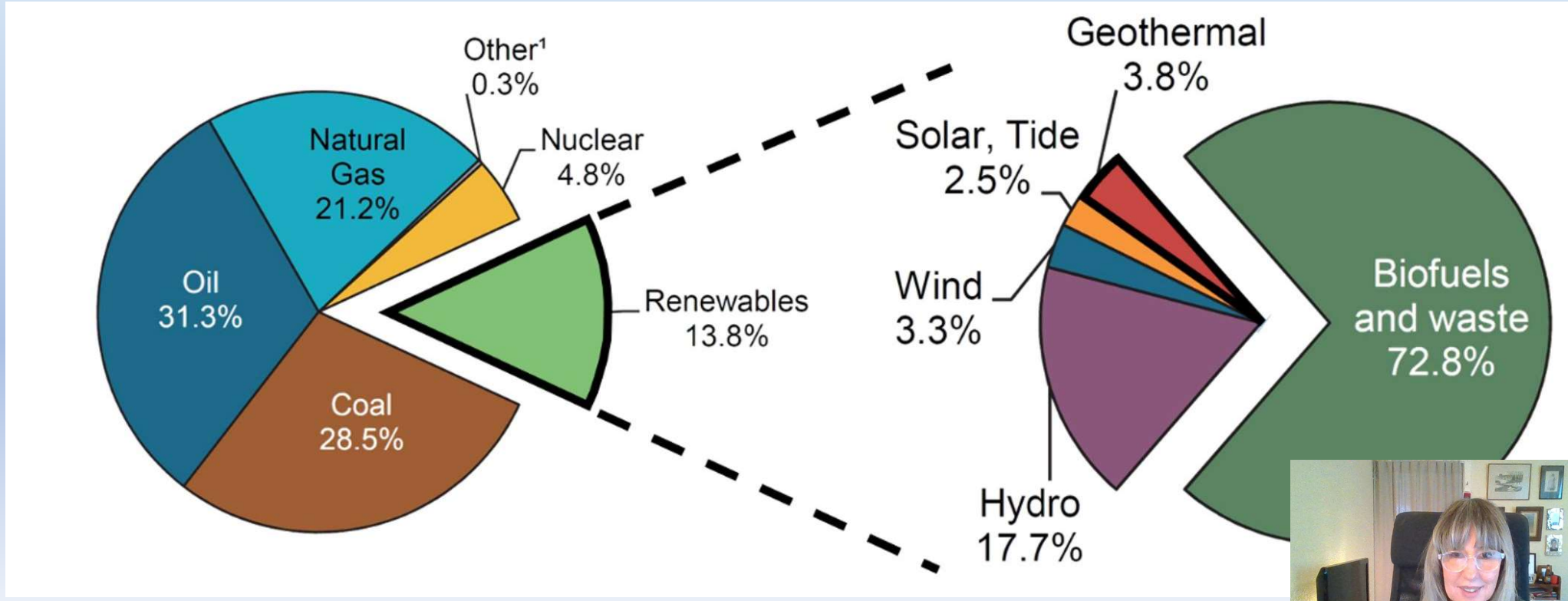
- Efficiency – making the most of the heat (i.e.cascading uses)
- Ensuring that project planning considers how to enrich the lives of local people

Ex 2: Cascaded use:

An article on the operational challenges for geothermal businesses in the time of coronavirus.

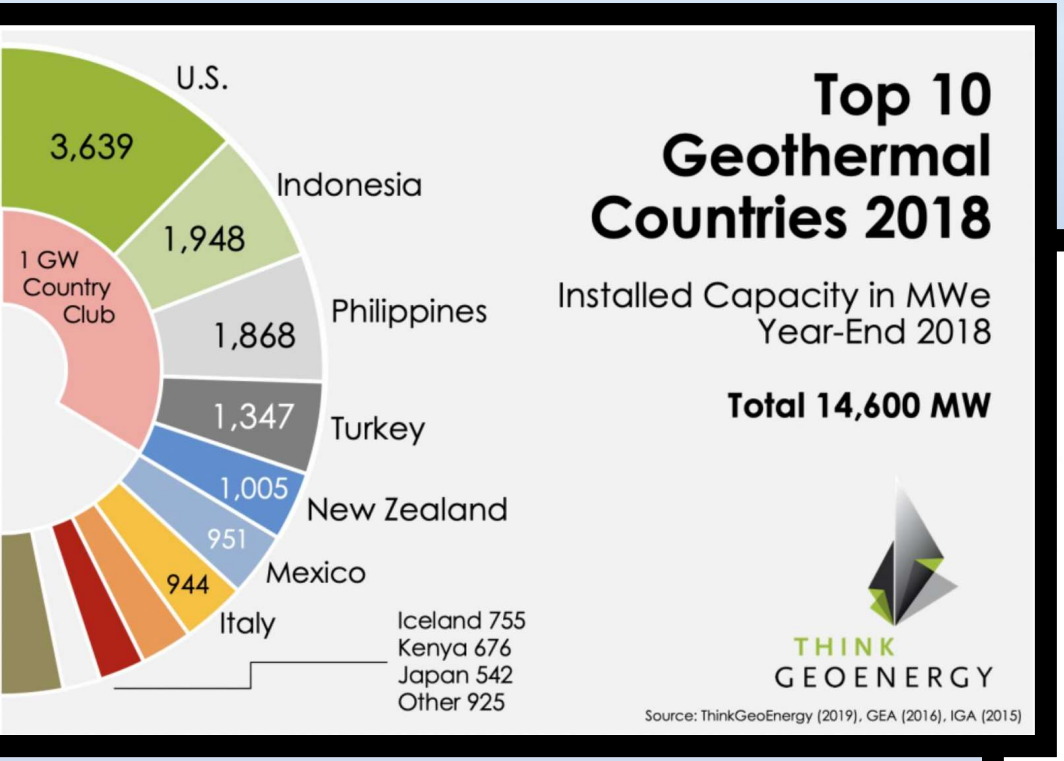
- In a time of lockdowns and social isolation, the energy business is particularly important to our society. In order to keep functioning at all, our towns and cities need electricity and heat/cooling.
- This article is about the steps that two geothermal companies are taking to ensure security of energy supply.
- Here is also an article on reducing regulatory risk for a Swiss geothermal project:
- https://www.thinkgeoenergy.com/more-legal-securi requested-for-geothermal-projects-in-switzerland/

Geothermal Energy worldwide
Slice of ‚Energy Pie'

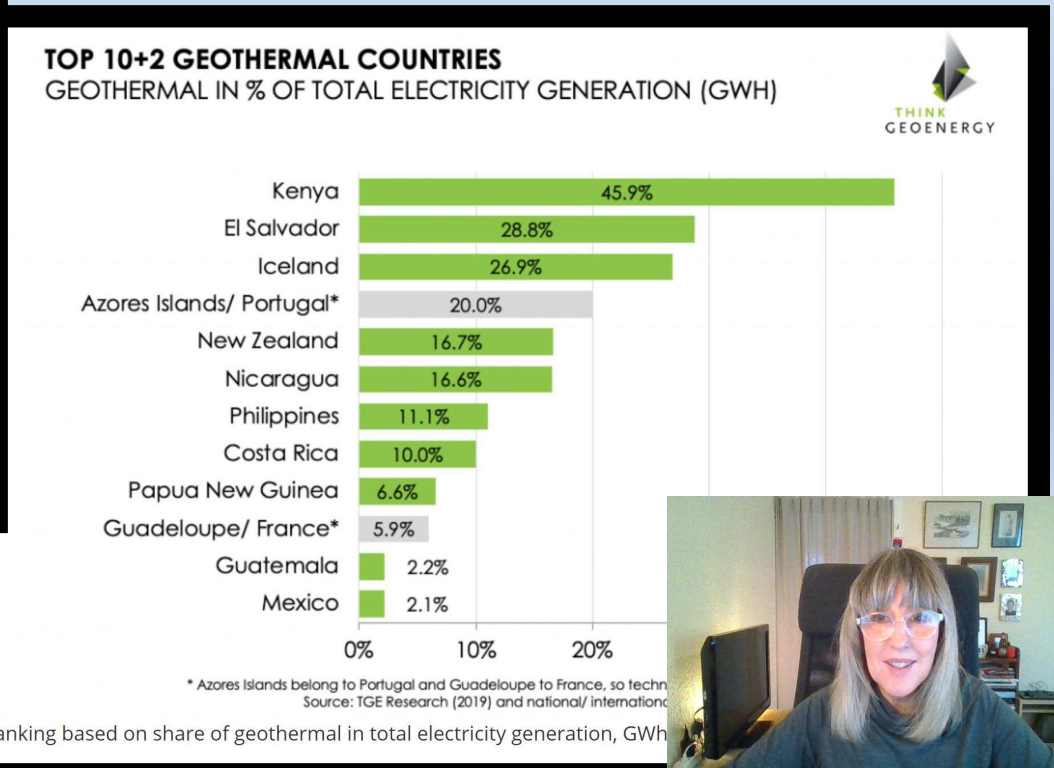


Utilization of geothermal energy in the international context of Total Primary Energy Supply. Adapted from IEA Renewables Inform

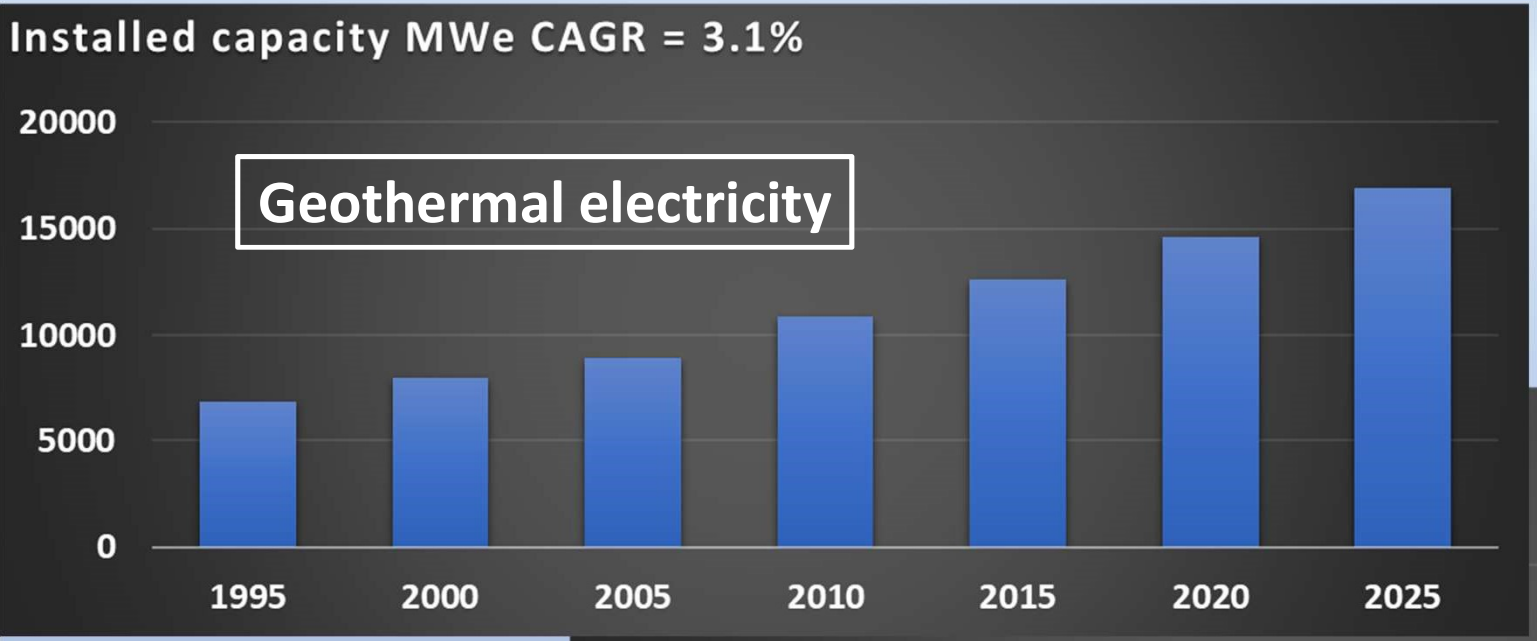
Geothermal electricity generation worldwide

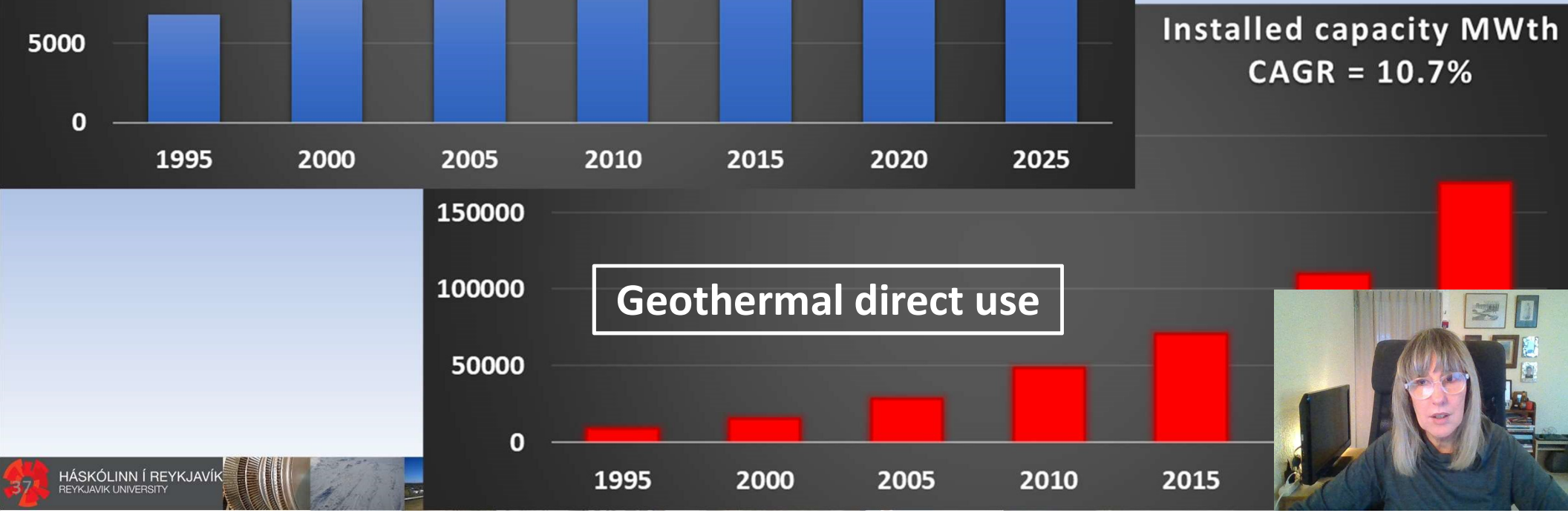


25 countries generate electricity
(82 countries with direct use of geothermal heat)



Industry Future?

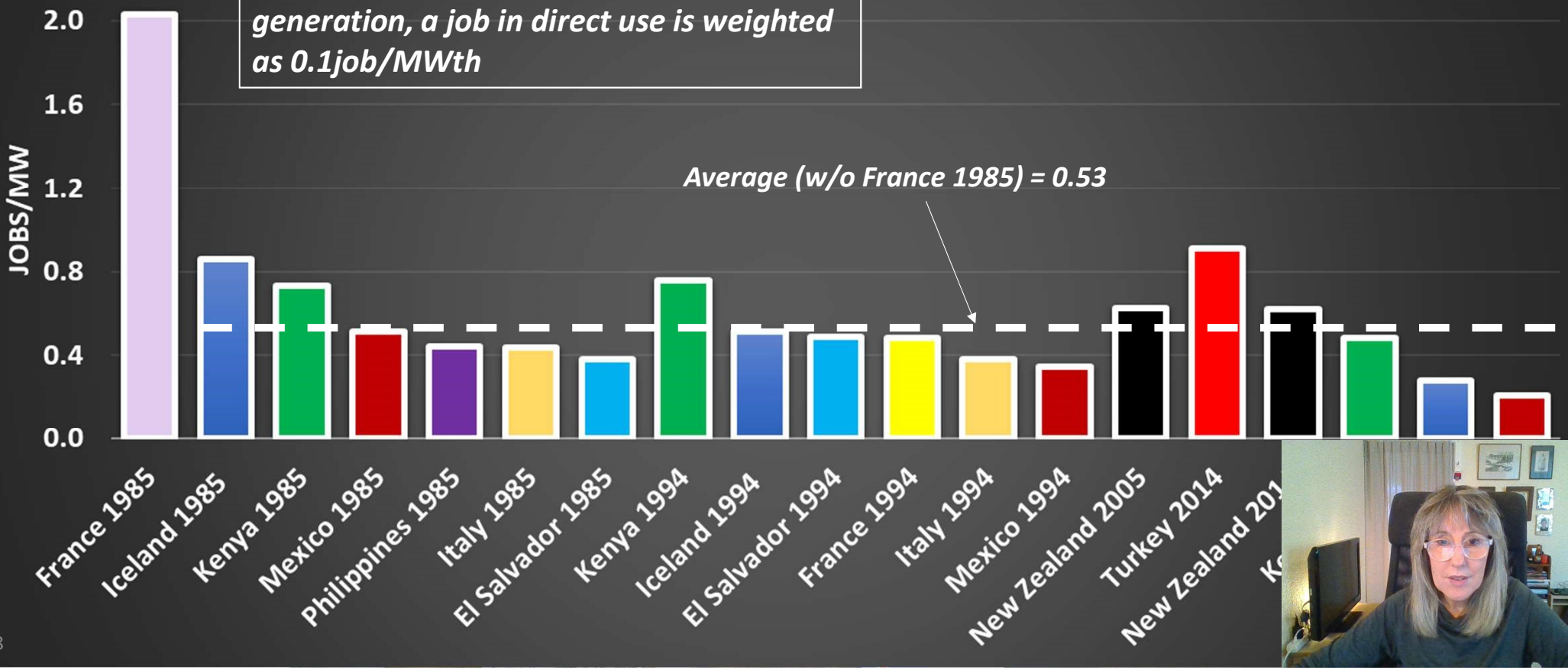




Reported ‚Professional Jobs/MW' over time

For every 1job/MWe in electricity generation, a job in direct use is weighted as 0.1job/MWth

Data from World Geothermal Congress country updates



Job prospects 2025?

2025

Worldwide capacity

33825

MWe + 0.1MWth

Average

jobs/MW:

0.53

There will be ~18000 professional j
in the geothermal industry

Geothermal Country Update Report of Turkey (2010-2015), Orhan Mertoglu, Sakir Simsek, Niigun Basarir. Proceedings World Geothermal Congress 2015 Melbourne, Australia, 19-25 April 2015

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Thank you

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