Ömer İnanç Türeyen | Istanbul Technical University

UTILIZATION OF GEOTHERMAL ENERGY IN TÜRKIYE

Throughout history, geothermal energy in Türkiye has been used quite often dating back to Roman times. The geothermal fields of Türkiye are spread out throughout the country. However, the higher enthalpy and larger fields are concentrated in the Aegean region.

Over the past years, the utilization of geothermal energy has increased considerably in Türkiye. This is mostly due to the auctioning of geothermal licenses by the Mineral Research and Exploration Directorate (MTA) and the incentives taken by the government for using geothermal energy for power generation. Currently, the installed power capacity has almost reached 1.7 GWe and the installed capacity for direct use has reached 5 GWt. Direct use applications include district heating, greenhouse heating, thermal tourism and etc. All geothermal fields in Türkiye are liquid dominated fields with temperatures ranging between 30 – 250+ °C. Another common characteristics of the geothermal fields is that most of them contain some amount of dissolved carbon dioxide. The existence of significant levels of carbon dioxide provide unique production characteristics.

In this study, we provide an overview of geothermal energy in Türkiye along with the characteristics of the major fields. Furthermore, we also provide an update to various aspects of the utilization of geothermal energy.

Utilization of Geothermal Energy in Türkiye

Ömer İnanç Türeyen and Abdurrahman Satman

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History of ITU

- ITU was established in 1773.
- It has changed names a number of times over the years.
- Istanbul Technical University was established in 1944.
- ITU has 5 campuses.
- The German education system was adapted until 1974.

History of ITU

1795

1909

1944

2025

ITU Petroleum and Natural Gas Eng.

- The Petroleum and Natural Gas Engineering Department was established in 1961 by Prof. Ekrem Göksu
- Until 1972 the German education system was adapted. Afterwards, 4 BSc + 2 MSc + PhD system was adopted.
- In 1992 the name was changed from Petroleum Engineering to Petroleum and Natural Gas Engineering.
- In 2010 the undergraduate program adapted a 100% English curriculum.
- ABET accredited.
- The department has 8 full-time faculty with PhD's from ITU, Stanford, CSM, LSU, Penn State and New Mexico Tech. Also the department currently has 6 research assistants.
- One of the main research topic of the department is GEOTHERMAL.
- More than 1500 undergraduate, 200 Masters and 18 PhD's.

Outline

- History.
- Overall utilization.
- Characteristics of geothermal fields.
- Direct use.
- Power generation.
- Multiple license owners.
- Carbon Dioxide aspects.
- Summary.

History of Geothermal in Türkiye

- Geothermal energy has been utilized in Anatolia during the ancient times. Geothermal energy was used by almost all Anatolian civilizations through out the ages. Lydians, Hittites, Phrygians, Romans, Ottomans and etc. It was used mostly for public baths and heating (Picture from Sardes, capital of Lydia).
- MTA (General Directorate of Mineral Research and Exploration) started the geothermal exploration around 1962.
- First geothermal well is in Balçova İzmir (1963).
- Kızıldere geothermal field is discovered (1968).

Place in the World

Geothermal Heating & Cooling

in 88 countries

Total Installed (MWt)	Total Produced (TJ/y)
173,303.212	**1,476,312.020**

Top 5 Installed (MWt)

China	**100,219.800**
USA	**20,712.540**
Sweden	**7,280.000**
Germany	**5,381.300**
Turkey	**5,113.350**

Top 5 Produced (TJ/y)

China	**828,882.000**
USA	**152,809.500**
Turkey	**85,000.000**
Sweden	**67,680.000**
Iceland	**35,615.000**

Geothermal Power

in 30 countries

Total Installed (MW)	Total Generated (GWh)
16,211.384	**96,556.324**

Top 5 Installed (MW)

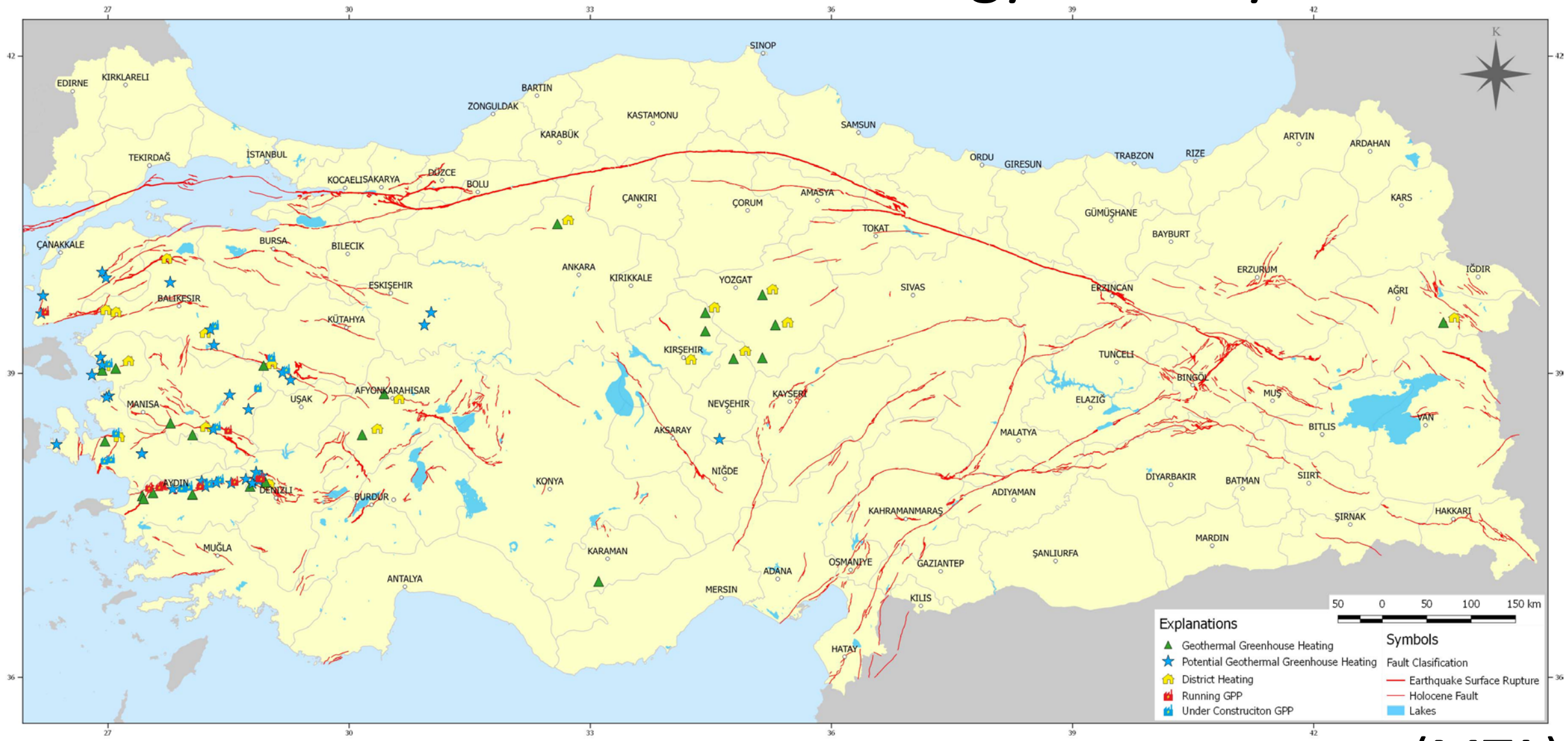
USA	**3,889.101**
Indonesia	**2,334.700**
Philippines	**1,951.760**
Turkey	**1,717.290**
New Zealand	**1,054.800**

Top 5 Generated (GWh)

USA	**18,702.200**
Indonesia	**16,592.407**
Philippines	**11,670.000**
Turkey	**10,840.000**
New Zealand	**7,820.000**

(IGA)

Utilization of Geothermal Energy in Türkiye



(MTA)

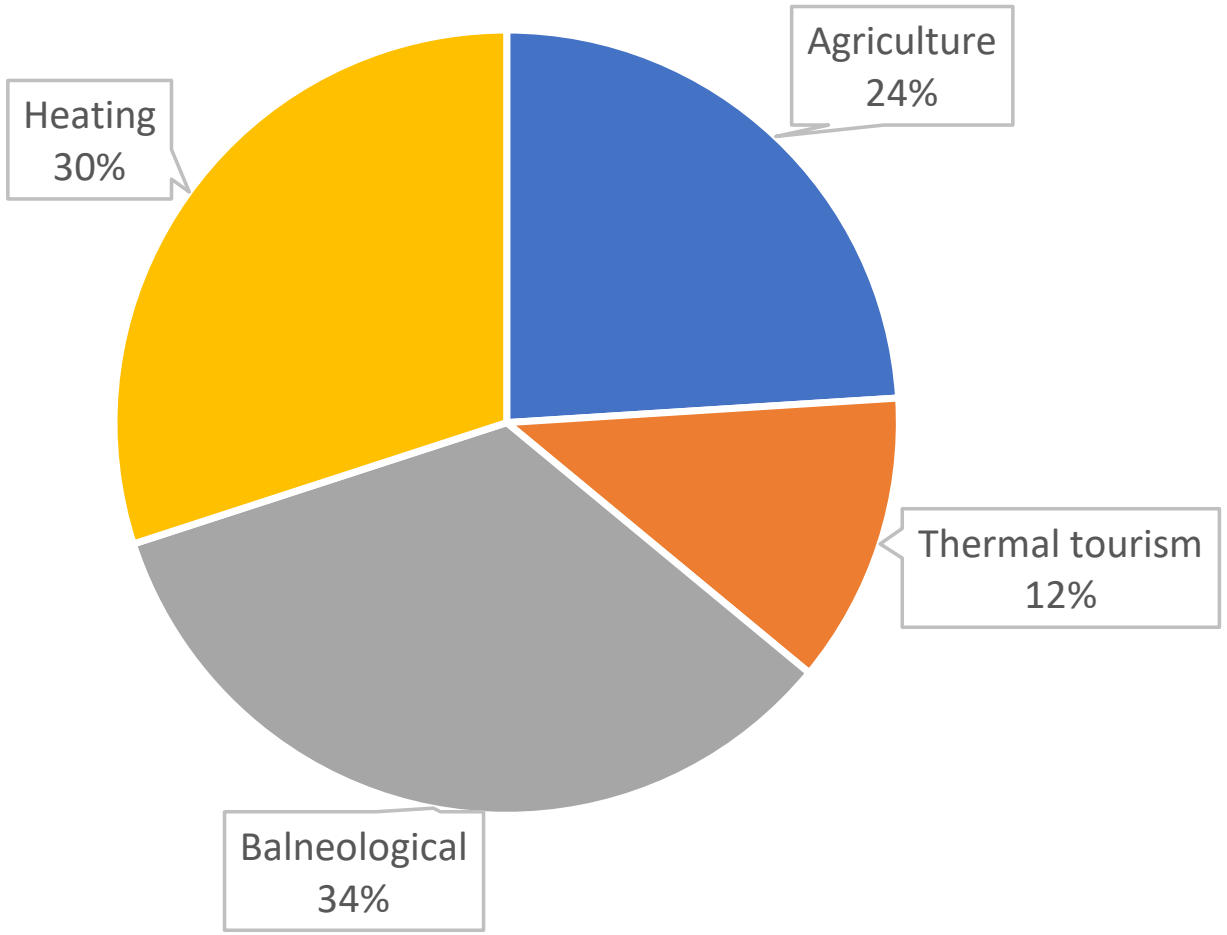
Current Status in Türkiye

- The MTA has held many auctions of geothermal licenses where exploration work has been done.
- As a result of government incentives, 55 power plants have been put in place.
- Currently the installed power capacity is around 1700+ Mw_e.
- Geothermal power generation in Türkiye is close to 11000 GWh which accounts for around 3.5% of generated power.
- The installed direct use capacity is around 5000 MW_t.

Characteristics of Geothermal Fields in Türkiye

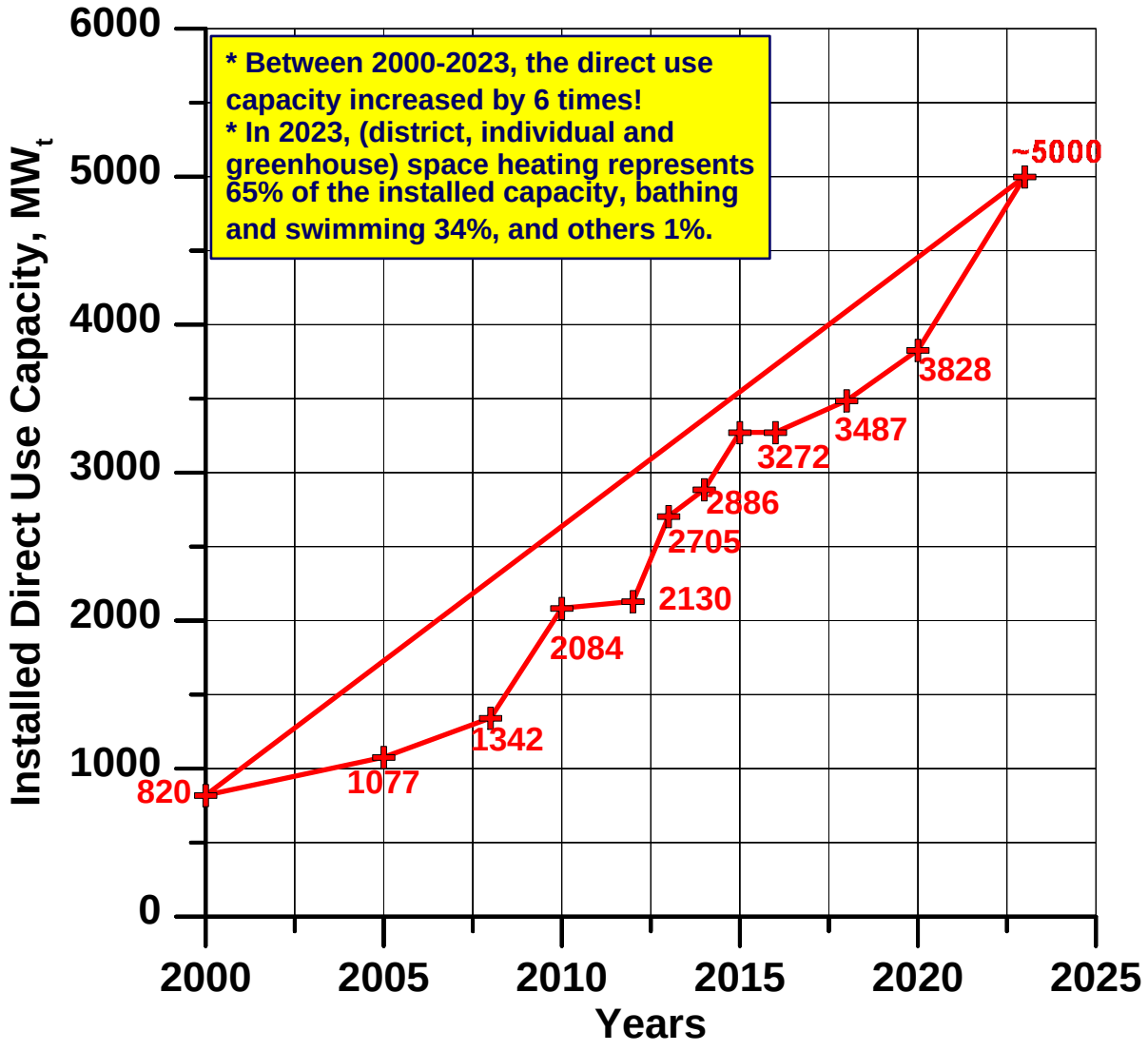
- All geothermal fields in Türkiye are liquid dominated.
- All geothermal fields are hydrothermal fields.
- Most of the fields contain some amount of dissolved carbon dioxide (could be as high as 9% by mass).
- Temperatures can vary depending on the field. Highest temperatures are observed in the fields located in the Menderes and Gediz Grabens. The deeper wells in the Kızıldere field have temperatures ranging between 200 °C-250 °C. A record temperature of 295 °C has been observed in Aksaray.

Direct Use



- There are few number of heat pumps also.

Direct Use



(Satman)

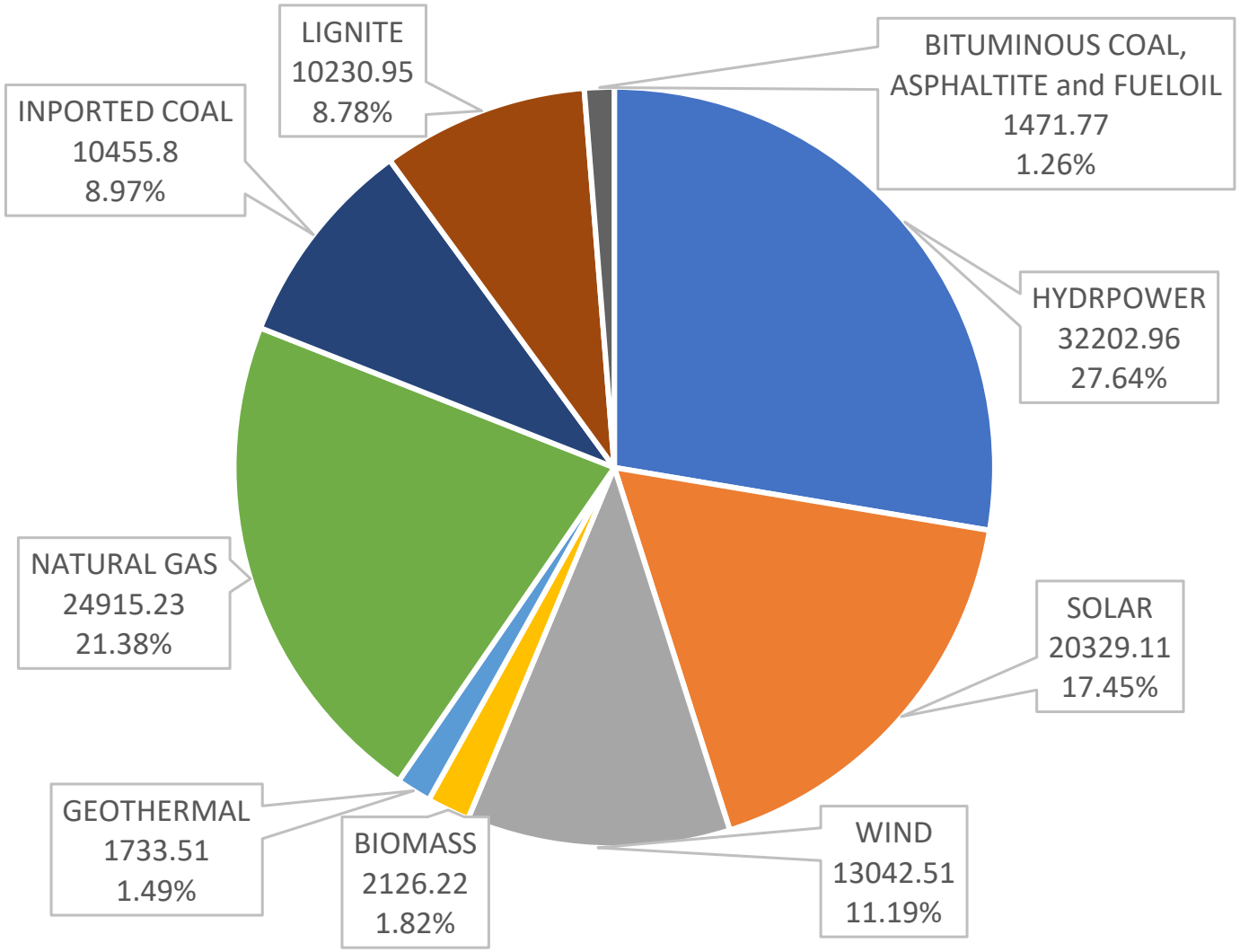
Power Generation, Geothermal Power Plants

- Most of the geothermal power plants are gathered in the Menderes and Gediz Grabens.

Common Characteristics of Power Plants

- The plants are usually flash type or binary or a combination.
- Inhibitors are used to avoid scaling. If not used, scaling could potentially completely block the well.
- Non condensable gasses are produced during operation. The dominant non condensable gas is carbon dioxide.
- Most of the advancements have been in a modular fashion.
- Reinjection is an important part of sustainability.

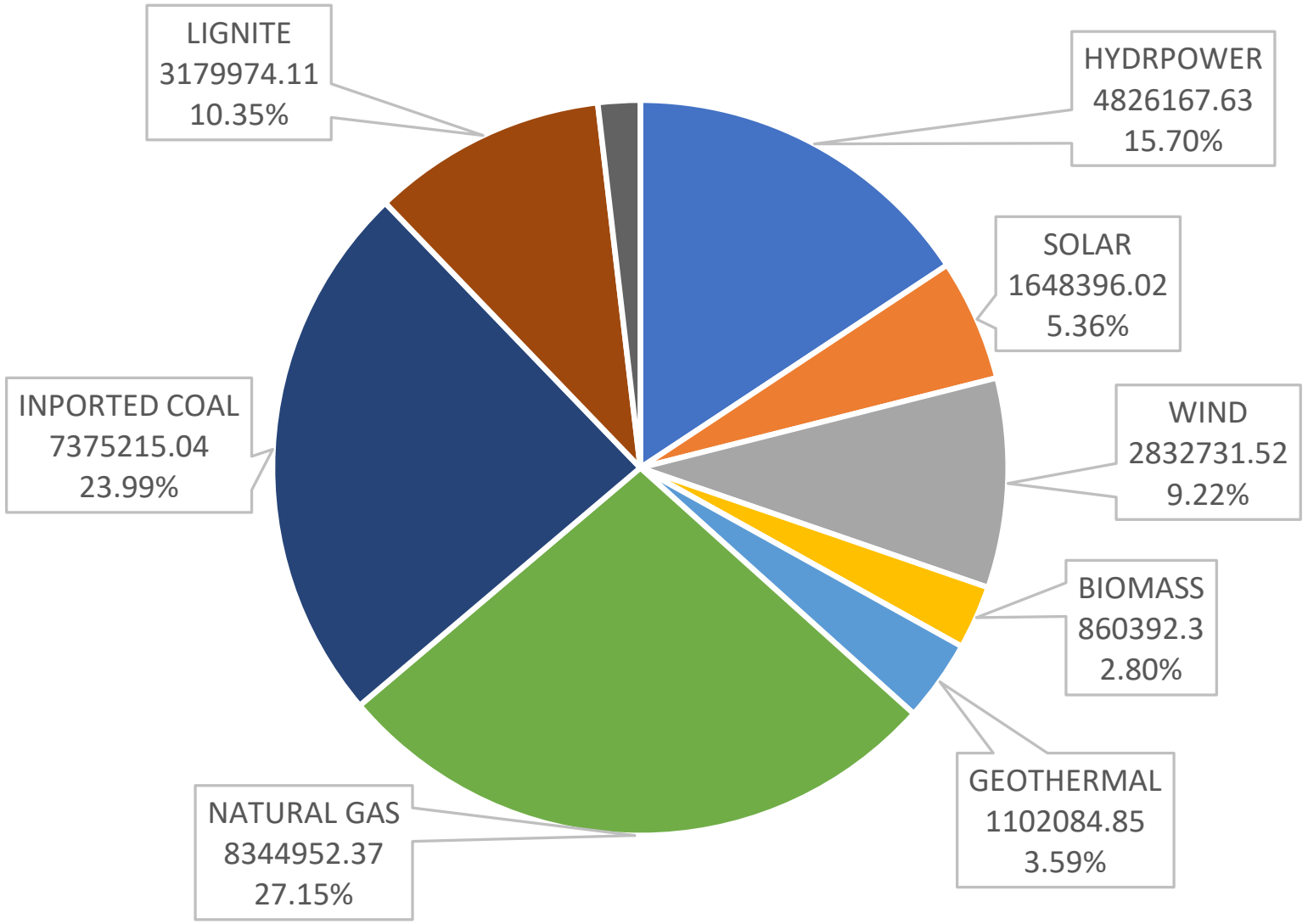
Power Generation, Installed Capacity, MW_e



- The share of renewables are close to 60%.
- Geothermal accounts for 1.49%.

EPDK

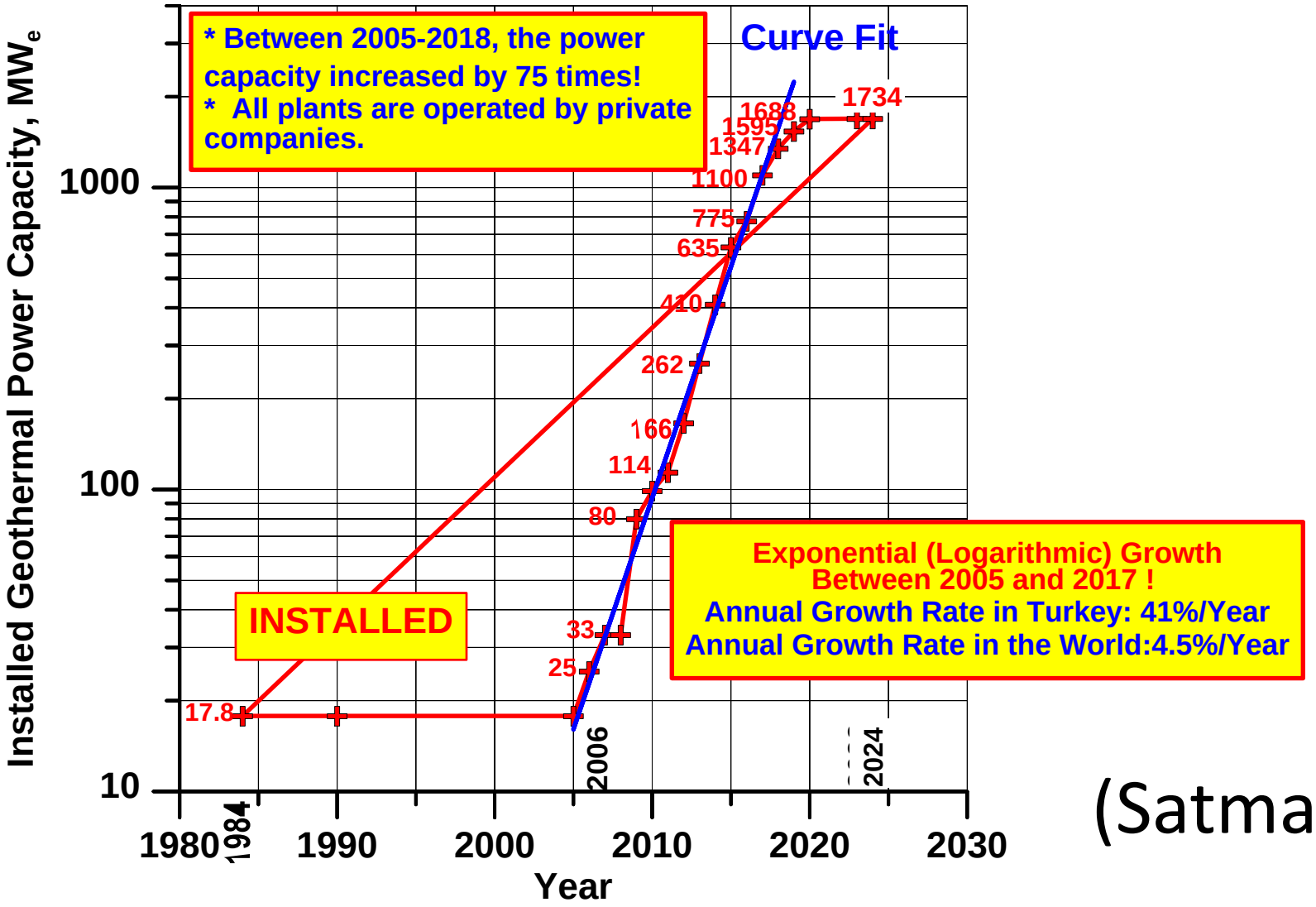
Power Generation, Power Production (MWh)



- The share of renewables are close to 37%.
- Geothermal accounts for 3.59%.

EPDK

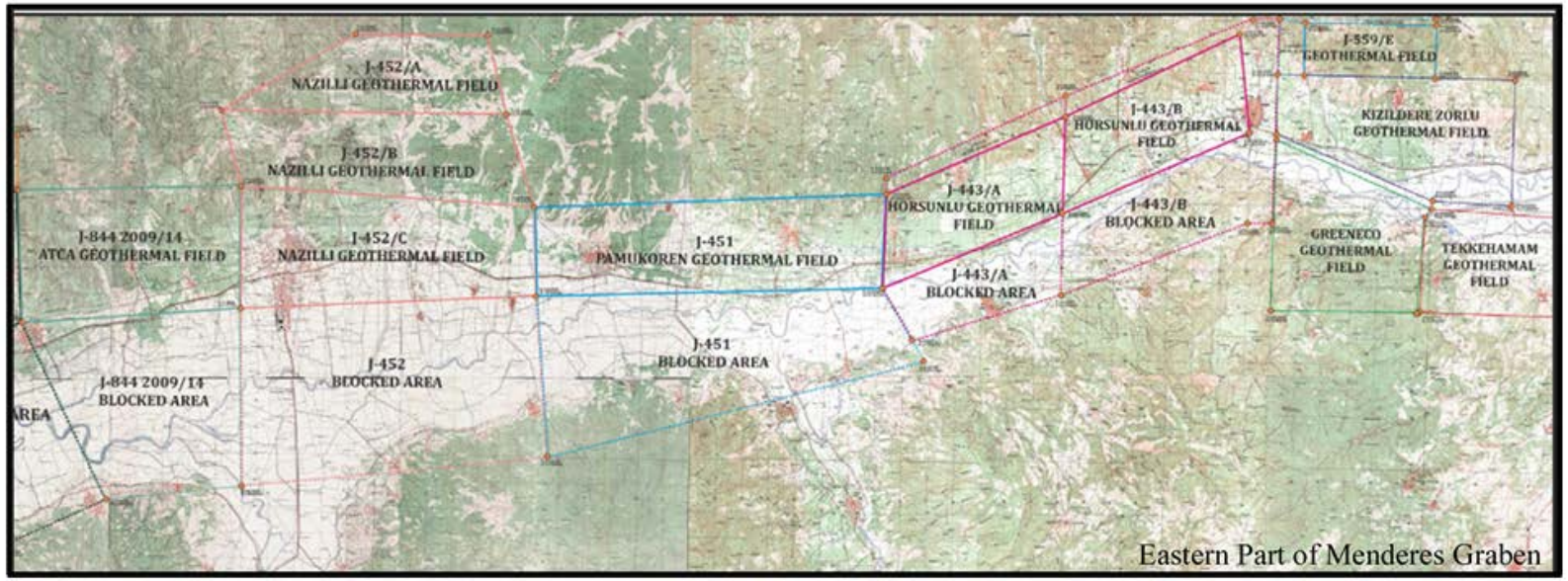
Power Generation. Installed Capacity, MW_e



- The exponential growth of installed capacity seems to have more or less flattened out.

(Satman)

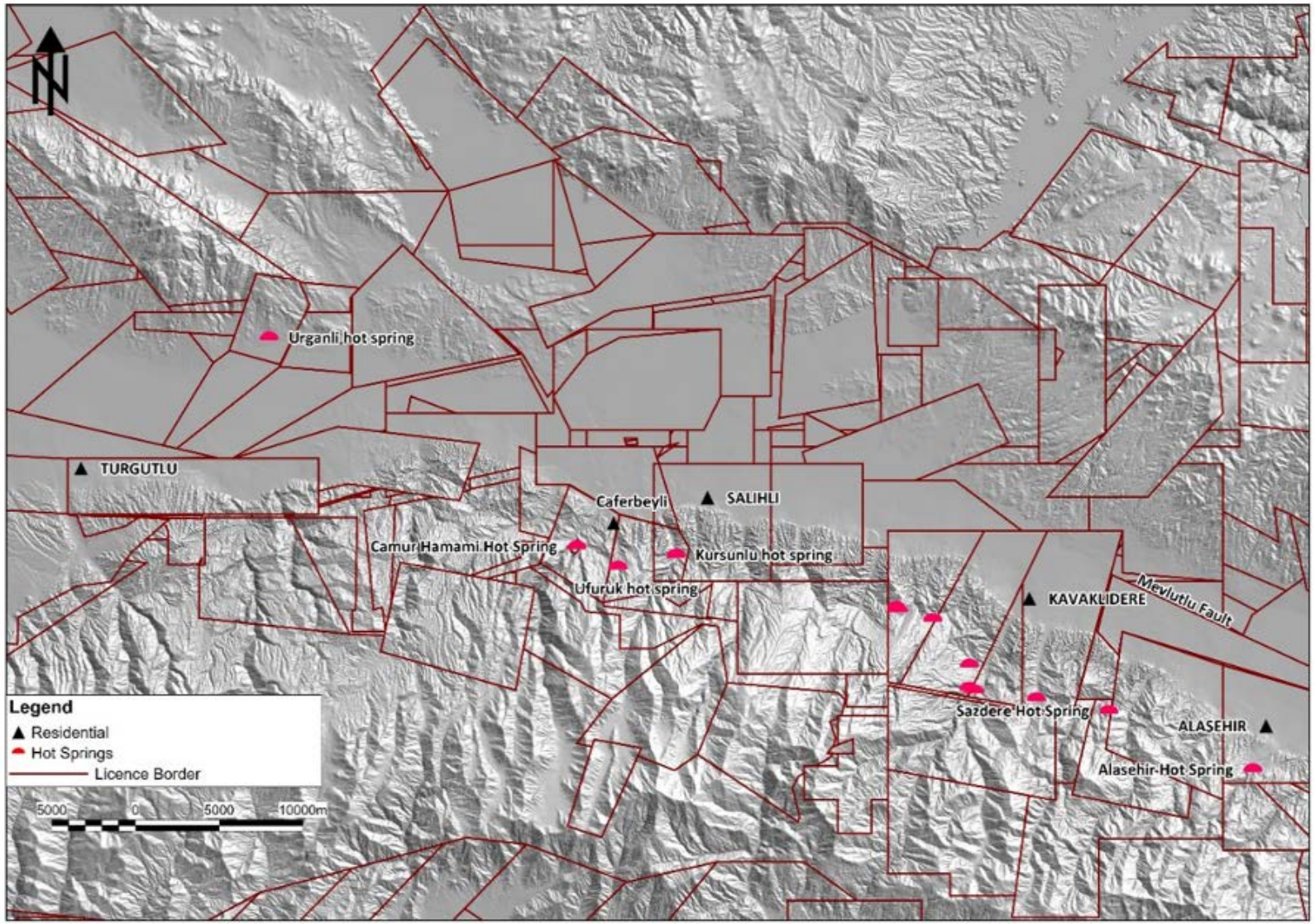
Multiple License Owners for the Same Reservoir



- Some of the licenses share the same reservoir.
- This has led to some unexpected pressure drops.

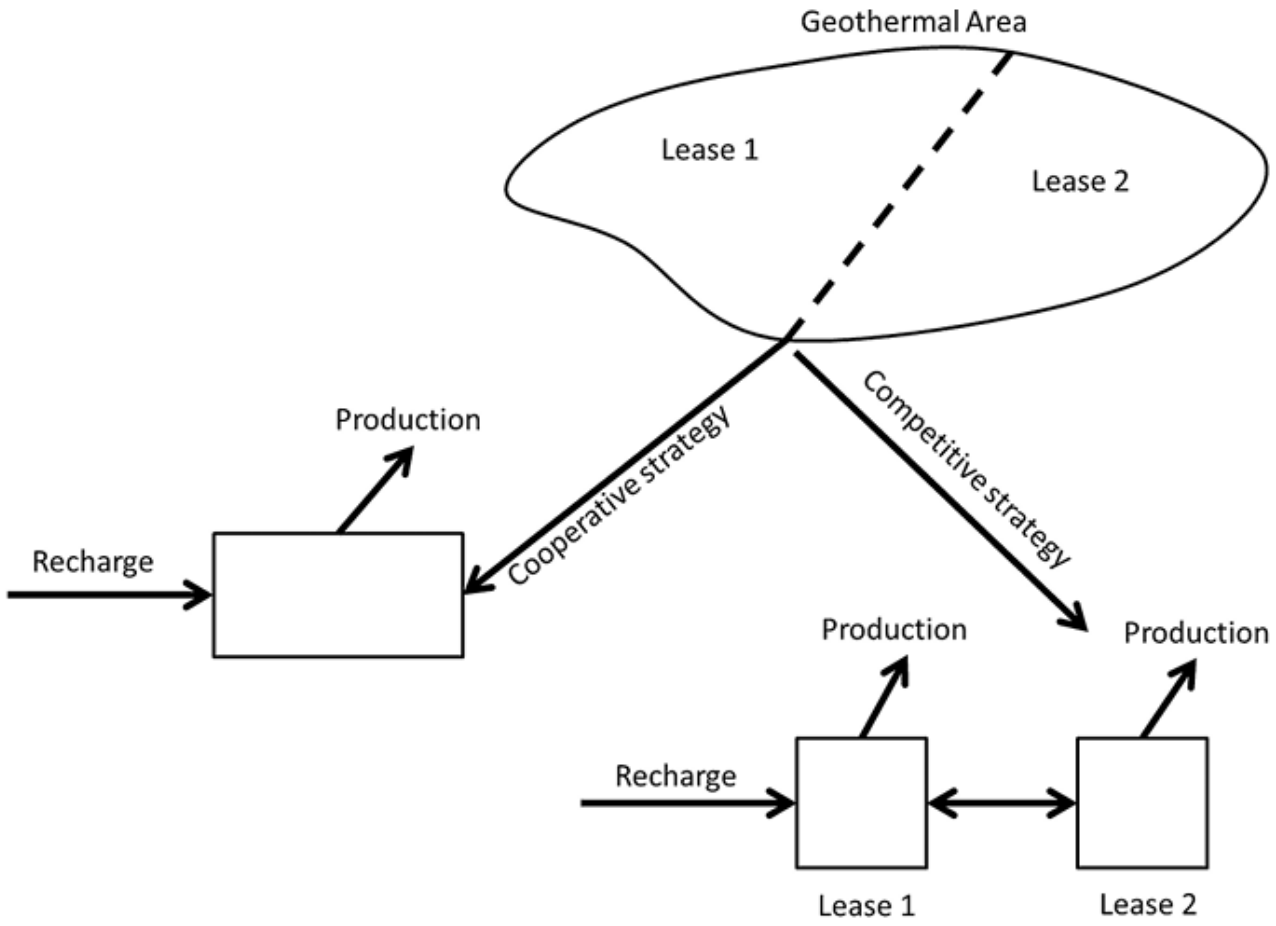
(Yamanlar et. al., 2020)

Multiple License Owners for the Same Reservoir



(Serpen et. al., 2022)

Modelling



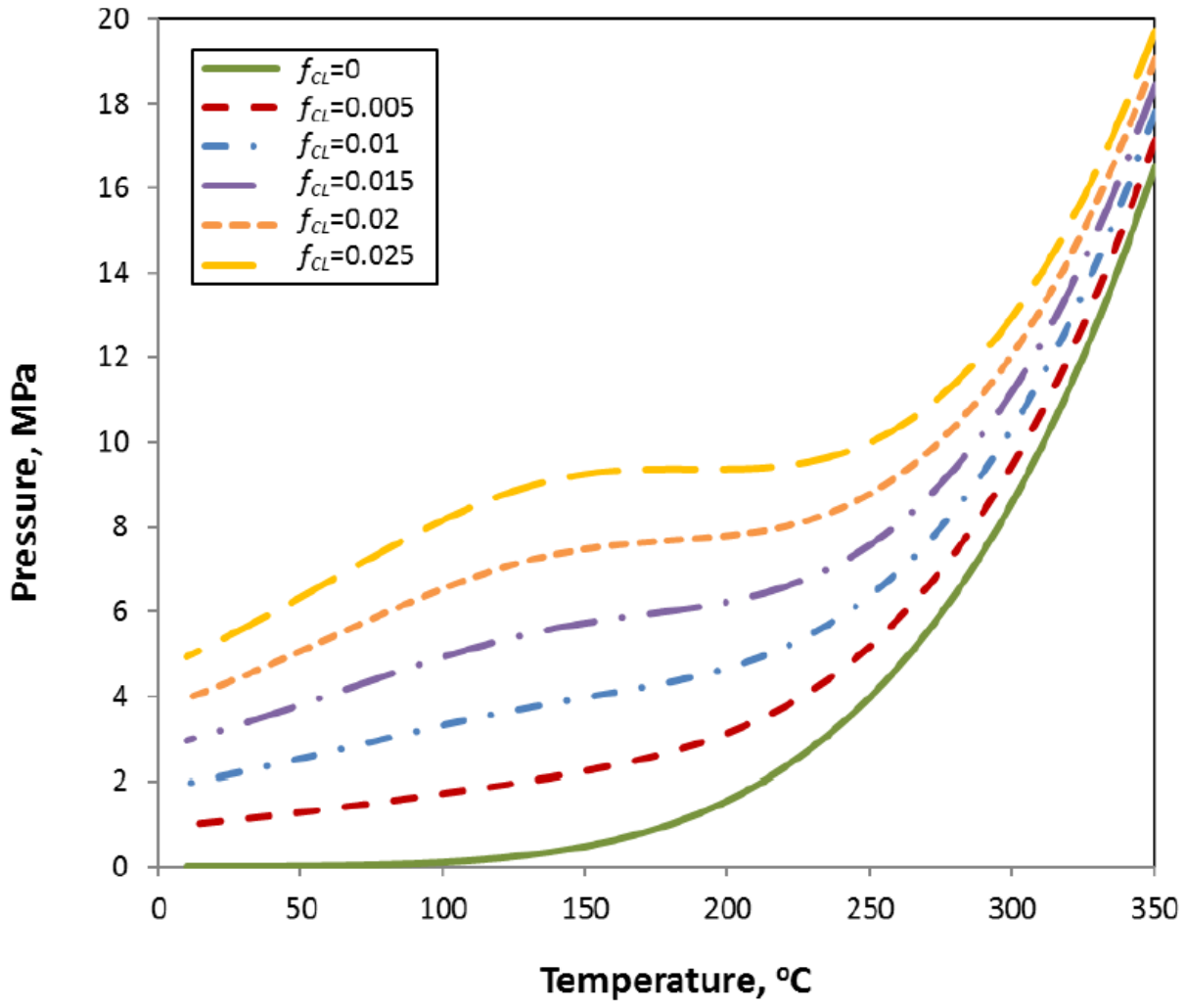
(Tureyen et. al., 2015)

- The need to form unit operations in the exploitation of geothermal resources is a matter of growing importance in Turkey.
- Modelling shows that the natural recharge has considerable effect on the reservoir. Who ever is closer to the recharge source has the upper advantage.
- Holding constant the characteristics of reservoirs, unitized production will result in a more sustainable total heat recovery that is greater than that derived from a non-unitized (competitive case) reservoir.

Aspects of Carbon Dioxide

- Most geothermal reservoirs contain non-condensable gasses such as H_2S, N_2, NH_3, CH_4 and CO_2.
- One of the most common non-condensable gasses is CO_2.
- The CO_2 content could be as high as 10% by mass.
- The CO_2 content is a function of pressure and temperature.
- The presence of CO_2 dissolved in water especially in liquid dominated geothermal reservoirs has a significant affect on the production performance of the field.

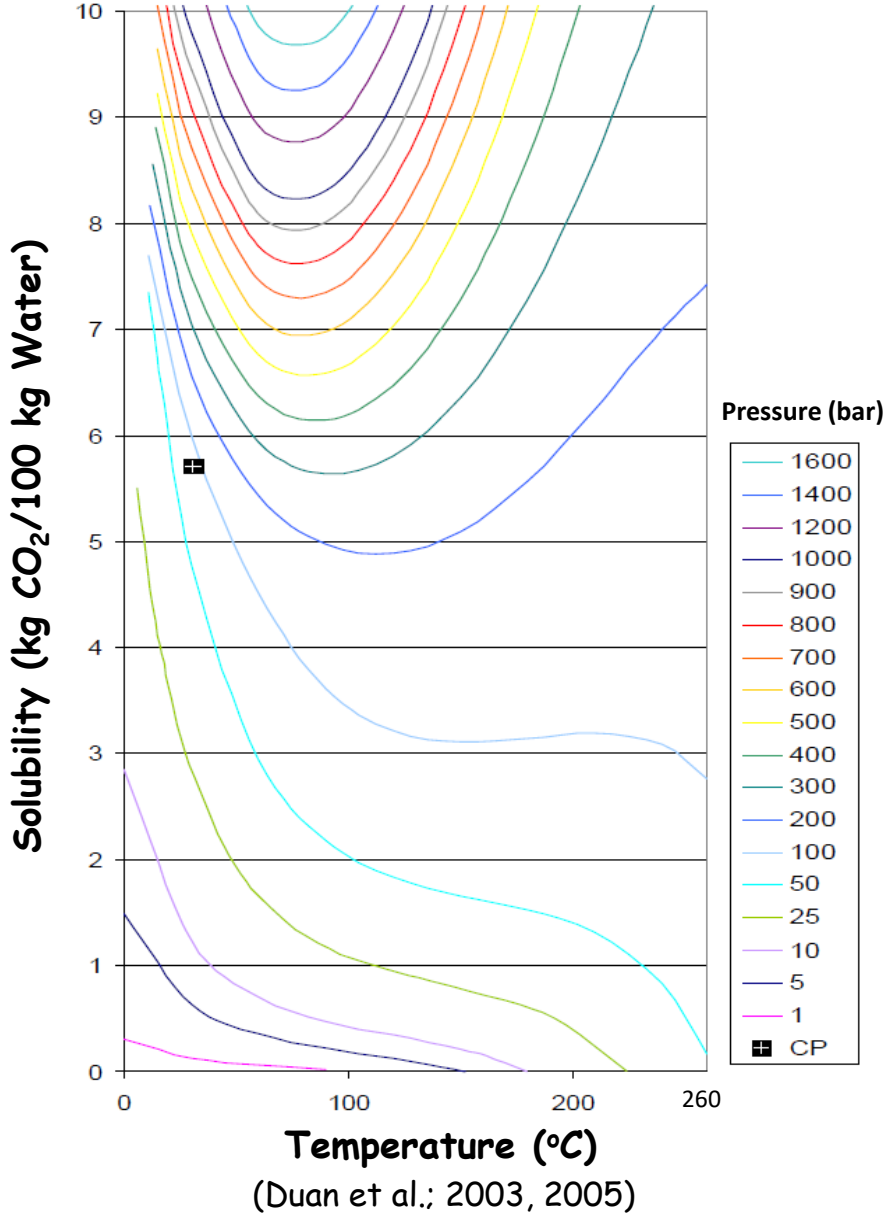
Aspects of Carbon Dioxide



- The presence of CO_2 in geothermal waters creates a phase envelope.
- The envelope becomes especially important around 150 °C.
- At higher temperatures the effect of CO_2 becomes less.

(Tureyen et. al., 2015)

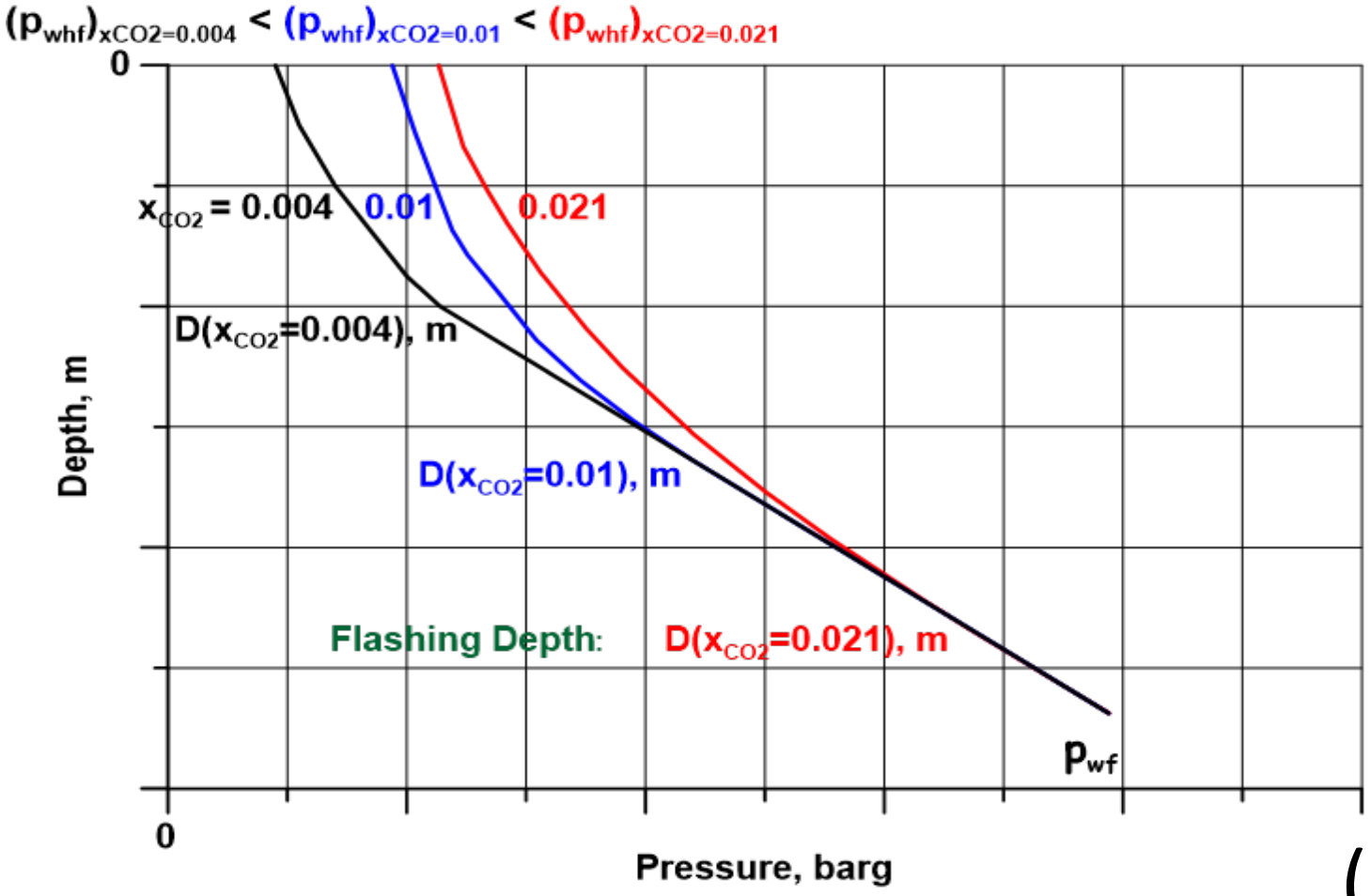
Aspects of Carbon Dioxide



(Duan et al.; 2003, 2005)

- The amount of CO_2 dissolved in water is a function of pressure and temperature.
- With increasing pressure more CO_2 can be dissolved in water.
- Hence, it is natural to find more CO_2 dissolved in water at deeper depths.

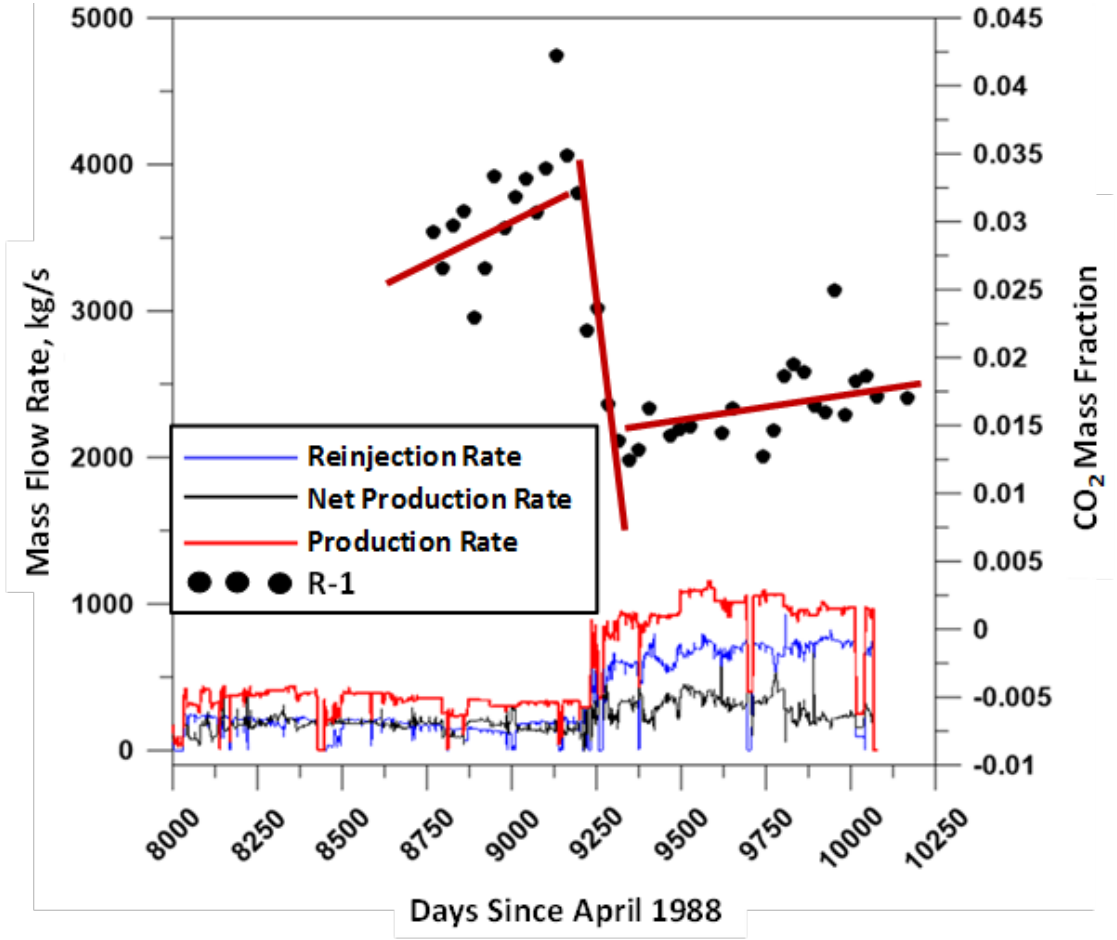
Aspects of Carbon Dioxide

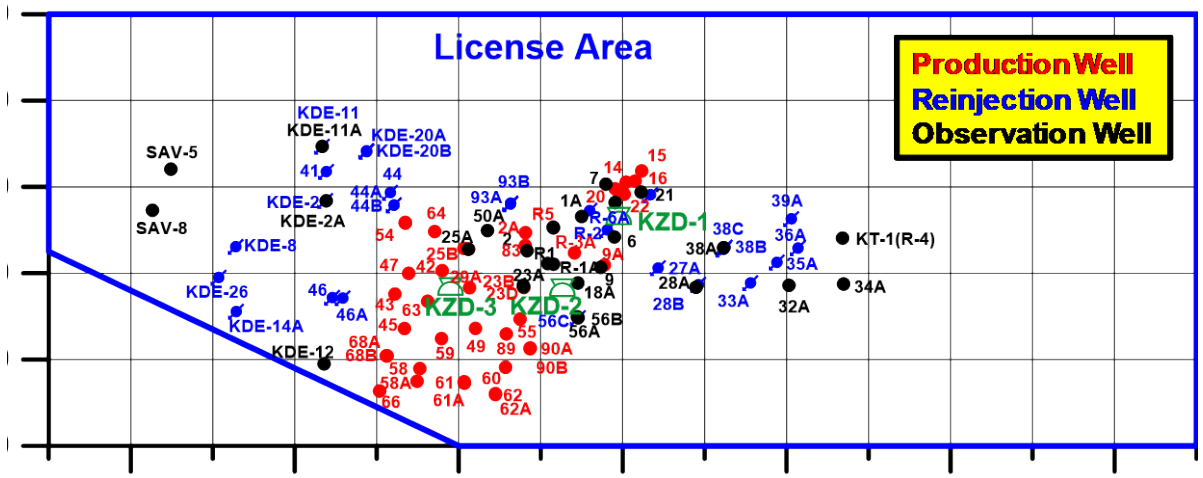


- Because of the high partial pressure of CO_2 , flashing can occur at deeper parts of the well during production.
- With increasing CO_2 content, flashing occurs deeper leading to higher well head flowing pressures

(Satman et. al., 2017)

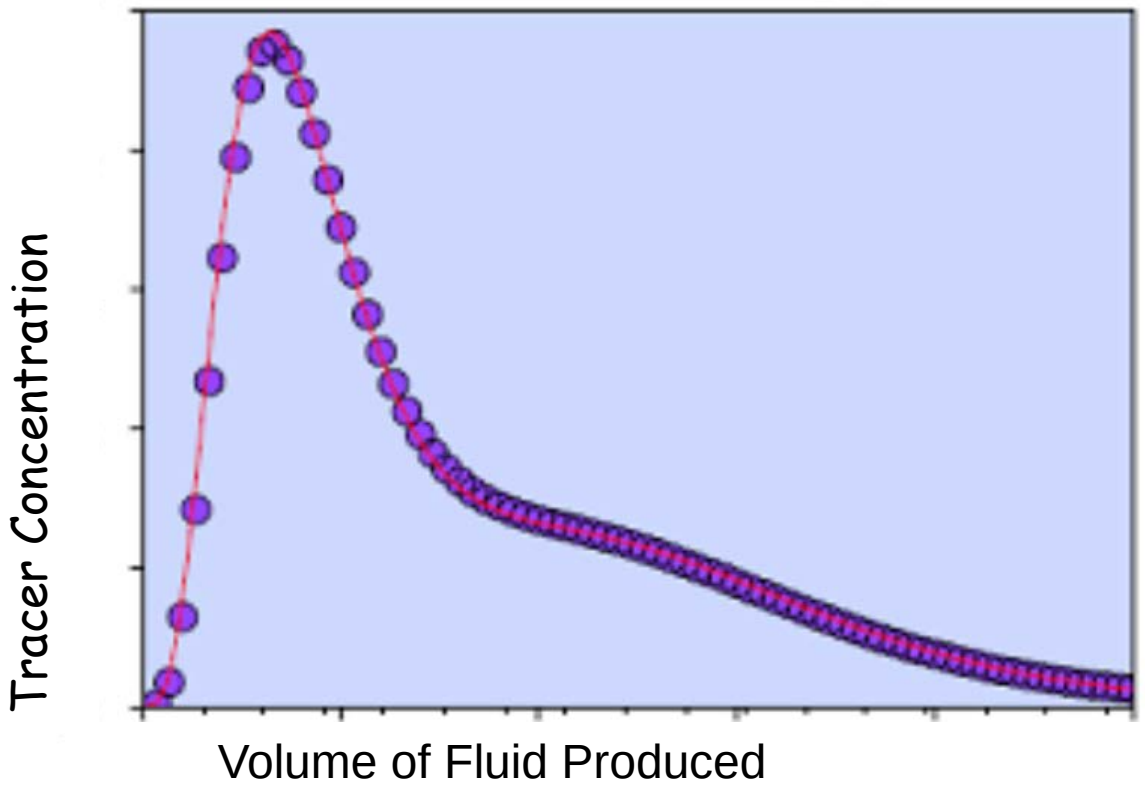
Aspects of Carbon Dioxide

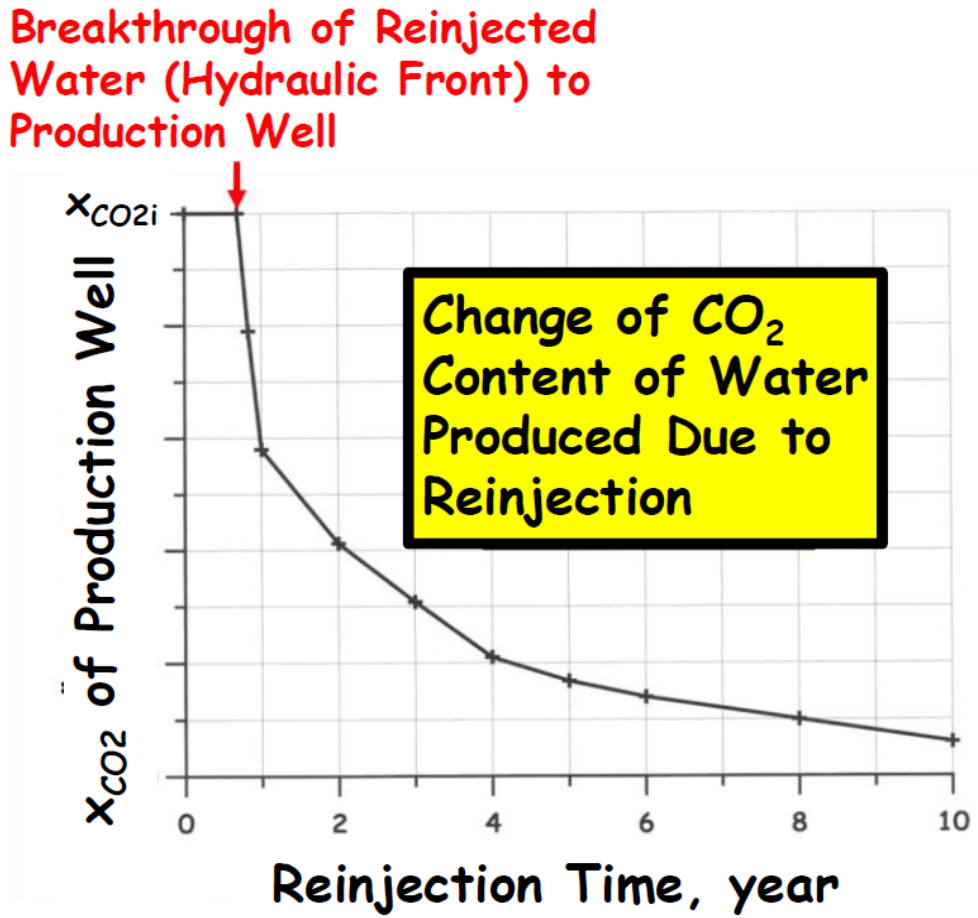




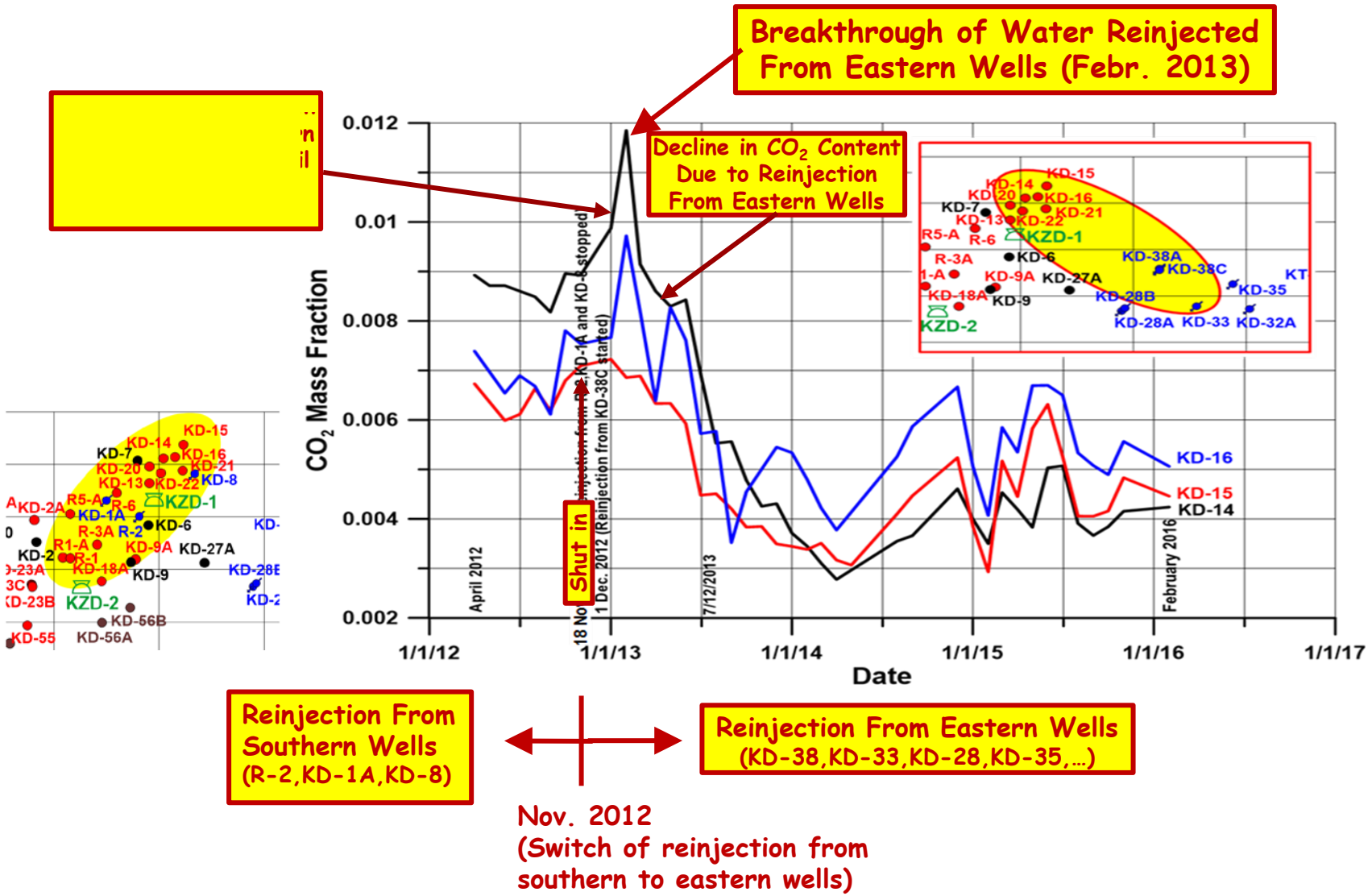
(Satman et. al., 2017)

Aspects of Carbon Dioxide



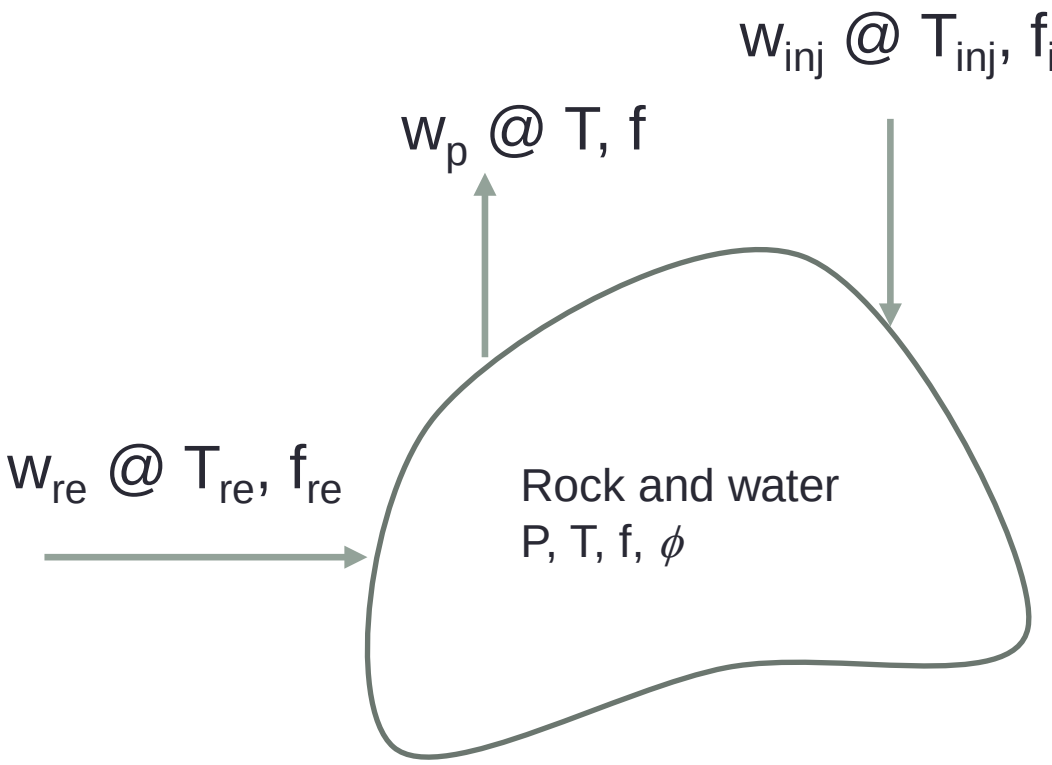


Aspects of Carbon Dioxide



(Satman et. al., 2017)

Aspects of Carbon Dioxide



$$f_{stabilized} = f_0(1 - RR)$$

$$w_{re} = \alpha(p_0 - p)$$

$$f(t) = f_0 e^{-\frac{w_p c_t}{\kappa}t} + \frac{w_{inj} f_{inj} + w_n f_{re}}{w_p} + \frac{w_n f_{re}}{w_p - \frac{\alpha}{c_t}} e^{-\frac{w_p c_t}{\kappa}t} - \frac{w_n f_{re}}{w_p - \frac{\alpha}{c_t}} e^{-\frac{\alpha}{\kappa}t}$$

$$- \frac{w_{inj} f_{inj} + w_n f_{re}}{w_p} e^{-\frac{w_p c_t}{\kappa}t}$$

$$\kappa = V_b \rho \phi c_t$$

$$f_{stabilized} = \frac{w_{inj} f_{inj} + w_n f_{re}}{w_p}$$

SUMMARY

- Since 2005, Türkiye has experienced a rapid expansion in the geothermal sector.
- Most of the activity is taking place in the Aegean region.
- As a result of this rapid expansion, Türkiye is now one of the top five countries that utilize geothermal energy for power generation and direct use.
- The expansion seems to have slowed down for power generation. The installed capacity has remained nearly constant over the last few years.
- Projects are underway for reinjecting the carbon dioxide.
- As ITU PNGE we are open to any collaboration for research.