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Geothermal Developments and Projections in Turkey

Presented by: Prof. h. Orhan MERTOGLU

- President , Turkish Geothermal Association
- IGA-International Geothermal Association (Iceland-Germany), Vice President (2003-2007), European Chairman (2007-2010), Honorary Board Member of European Branch (2010-….),
- GRC-Geothermal Resources Council Member of Board, USA (1999-2001)
- EGEC-European Geothermal Energy Council (Belgium), Vice President (1999-2004)
- Turkish Republic Ministry of Development 10th Development Plan (2014-2018) Chairman of Geothermal Working Groups
- WGC'2005 World Geothermal Congress Vice President and Turkish National Com. Chairman
-Worldbank – IFC Geothermal Consultant
- TUBİTAK (The Scientific and Technological Research Council of Turkey) and Ministry of Agriculture - Geothermal Greenhouse Technical Committee Member
- Jeotermal Araştırma ve Tesisler A.Ş. (Geothermal Exploration and Facilities Inc.) V.President
- China, Shaanxi Institute Of Geological Survey, Senior Technical Geothermal Consultant

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As it has been declared according to WGC2020 country updates,

Turkey is ranked :

-as the 1st country in geothermal electricity power plant increase

- as the 1st country in geothermal greenhouse applications

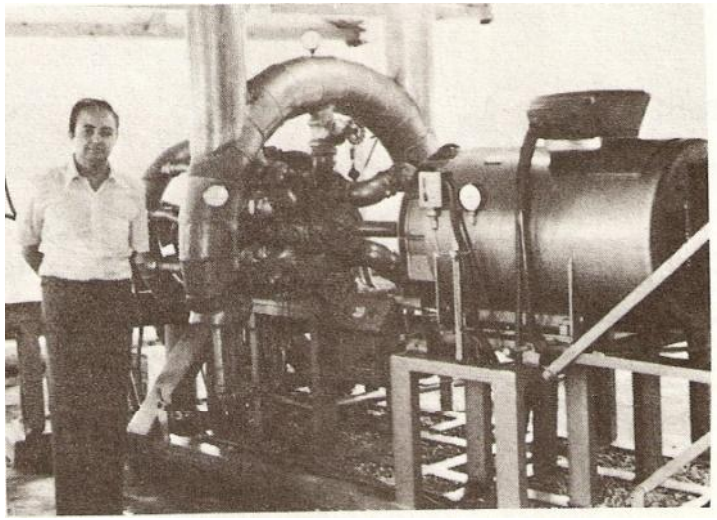
- as the 4th country (USA; Indonesia; Philipines; Turkey; Kenya) in geothermal electricity production

- as the 2nd-4th in geothermal non-electric applications (China; USA; Sweden; Turkey; Japan) (it differs according to the application)


10 4 2001
WORLD GEOTHERMAL CONGRESS 2005
ANTALYA - TURKEY
24-29 Nisan 2005
ANTALYA-TÜRKİYE

Turkey has achieved important geothermal developments since 2015. Since the 1960’s, about 460 geothermal fields have been discovered in Turkey until yet.

Geothermal electricity production installed capacity is **1678 MWe** (about 1278 MWe binary cycle and about 400 MWe flash steam geothermal power plants) as of September 2020.



AS A NOSTALGY:

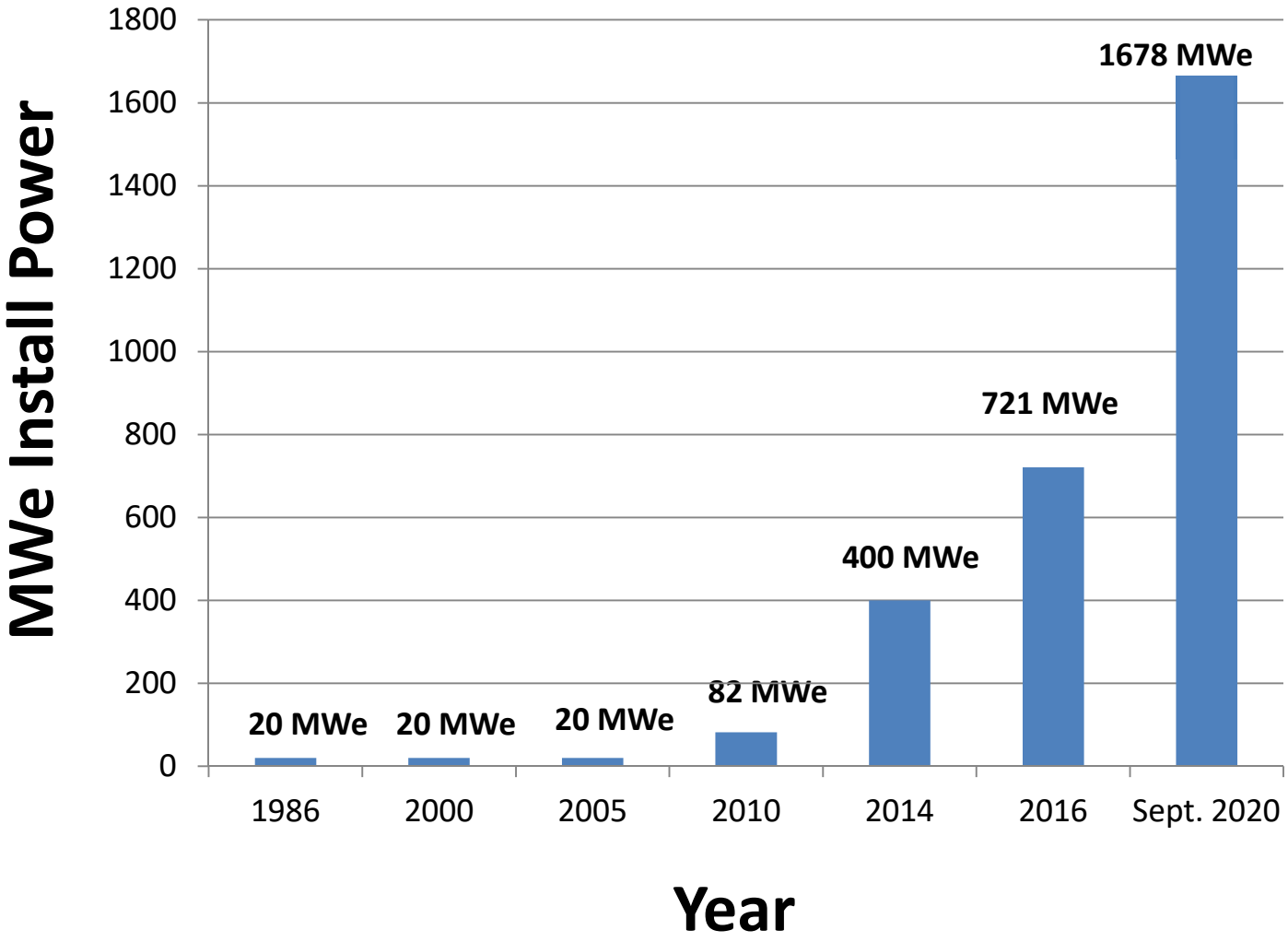
The first geothermal power plant of Turkey has been designed by Orhan Mertoglu in 1975, with 0,5 Mwe capacity in Kizildere-Turkey

Liquid carbon dioxide and dry ice production factories, greenhouse heating are integrated to the Denizli Kizildere and Aydin geothermal power plants. Deep reservoir explorations are going on for electricity production purposes. For his reason deep drilling targets have reached up to 4800 m. The increase of directional drillings and coil tubing operation applications are other important developments for the geothermal fields in Turkey.

EXISTING GEOTHERMAL DIRECT USE AND ELECTRICITY PRODUCTION IN TURKEY

UTILIZATION	CAPACITY
GEOTHERMAL DISTRICT HEATING (CITY, RESIDENCES)	126.000 RESIDENCES EQUIVALENCE (1122 MWt)
GREENHOUSE HEATING	4,4 Million m^2 (840 MWt)
HEATING OF THERMAL FACILITIES, SPAS, THERMAL HOTELS AND TIME SHARE FACILITIES	46.400 residences equivalence (420 MWt)
HEAT ENERGY OF THERMAL WATER USE IN HOTELS, SPAS AND AND TIME SHARE FACILITIES	520 GEOTHERMAL SPA (1405 MWt) (about 23 Million guests/annual)
AGRICULTURAL DRYING	4,5 MWt
GEOTHERMAL COOLING	0,3 MWt
GSHP-Ground Source Heat Pumps	8,5 MWt
TOTAL HEAT USE	**3800 MWt** **(366.000 Residences Equivalence)**
TOTAL ELECTRICTY PRODUCTION	**1678 MWe** (Aydın, Denizli, Manisa, Çanakkale, Afyon)
CARBONDIOXITE PRODUCTION (Food grade Liquid CO_2)	400.000 Tons/year

Geothermal electricity production install capacities in Turkey



(From Jeotermal Araştırma A.Ş.)

GEOTHERMAL POWER PLANTS IN TURKEY (September 2020)

Locality	Power Plant Name	Year Com-missioned	Total Installed Capacity MWe
Denizli (Zorlu)	Kizildere 3		165,00
Aydin (Guris)	Efeler	2009-2018	162,50
Denizli (Zorlu)	Kizildere 2		80,00
Aydin (Celikler)	Pamukoren	2015	68,00
Aydin (Guris)	Galip Hoca Germencik	2009	47,40
Manisa (Zorlu)	Alasehir	2015	45,00
Aydin (Kipas)	Maren		44,00
Aydin (MB)	Dora 3	2013	34,00
Aydin (Kipas)	Melih		33,00
Denizli (Greeneco)	Greeneco	2016-2018	51,20
Manisa (Enerjeo)	Kemaliye	2016	25,00
Aydin (Kipas)	Mehmethan		25,00
Aydin (Kipas)	Deniz		24,00
Aydin (Kipas)	Ken Kipas		24,00
Aydin (Kipas)	Kerem		24,00
Aydin (Cevik)	Kubilay		24,00
Manisa (Turkerler)	Alasehir - 1	2014	24,00
Manisa (Turkerler)	Alasehir - 2		24,00
Manisa (Turkerler)	Alasehir - 3		100,00
Manisa (Ozmen-Sis)	Ozmen 1		23,52
Manisa Akça	Baklacı	2018	19,4
Aydin (Celikler)	Pamukoren 2		23,00
Aydin (Celikler)	Pamukoren 3		23,00
Aydin (Celikler)	Pamukoren 4		32,00
Aydin (Turcas)	Kuyucak	2018	18,00

Aydin (MB)	Dora 4		17,00
Denizli (Zorlu)	Kizildere	1984	15,00
Manisa (Sanko)	Sanko	2018	15,00
Aydin (Celikler)	Sultanhisar	2018	14,00
Aydin (BM)	Gumuskoy	2014	13,00
Manisa (Sanko)	Sanko	2018	15,00
Aydin (Celikler)	Sultanhisar	2018	14,00
Aydin (BM)	Gumuskoy	2014	13,00
Aydin (Karadeniz)	Karkey Umurlu	2016	12,00
Aydin (Karadeniz)	Karkey Umurlu-2	2018	12,00
Manisa (Maspo)	ALA-1	2018	10,00
Aydin (Kipas)	Ken-3		24,80
Aydin (MB)	Dora-2		9,50
Canakkale (MTN)	Babadere	2016	8,00
Aydin (MB)	Dora-1	2006	7,95
Canakkale (Enda)	Tuzla	2010	7,50
Denizli (Bereket)	Kizildere	2007	6,85
Denizli (Akca)	Tosunlar	2015	3,81
Afyonkarahisar (Afjet)	Afjet	2018	2,76
Aydin (3S Kale)	3S Kale	2018	25,00
Denizli (Limgaz)	Buharkent	2018	13,80
Denizli (Jeoden)	Saraykoy	2014	2,52
Manisa (Soyak)	Mis-1	2018	12,30
Manisa (Zorlu)	Alasehir-2	2019	24,90
Aydin (Greeneco)	jes5	2019	28,05
Manisa (Soyak)	Mis-3	2019	48,00
Manisa (Maspo)	Ala-2	2019	30,00
Aydin	Kiper		10,00
Manisa (Sanko)	Salihli JES2&3		55,00
Manisa (Sis)	Özmen 3		19,00

2025 Geothermal Utilization Targets

Geothermal Application	**2025 approximate targets**	**Additional investment cost (USD) (from 2020 to 2025)**
Electricity Production	2500 MWe (16 Billion kWh)	4 Billion US$
Heating (residences, hotel, Thermal Facilities etc.9	4000 MWt (400.000 Res. Equi.)	800 Million US$
Greenhouse heating	4500 MWt (12.000.000 m2)	1 Billion US$
Drying and others	200 MWt (250.000 ton/h)	150 Million US$
Thermal Tourism	1650 MWt Total 500 spa, balneological facilities	2,2 Billion USD$
Cooling	400 MWt (20.000 Res. Equi.)	200 Million US$
Fish Farming and others	400 MWt	150 Million US$
Total Investment		**8.500.000.000 US$**

Natural gas equivalent of the previous applications	**4 Million US$**
In case if the 2025 targets in geothermal electricity production, heating (residences, thermal facilities etc.), thermal tourism, greenhouse heating, drying, fish farming and other applications are achieved the economical activity created	**About 16 Billion US$**
Direct and indirect employment created	**300.000 people**

As the Turkish Geothermal Association we have calculated the

geothermal heat potential of Turkey: **60.000 MWt**

which equals to

= 10 Million Residences equivalence heating

or

= 300 Million m2 greenhouse heating

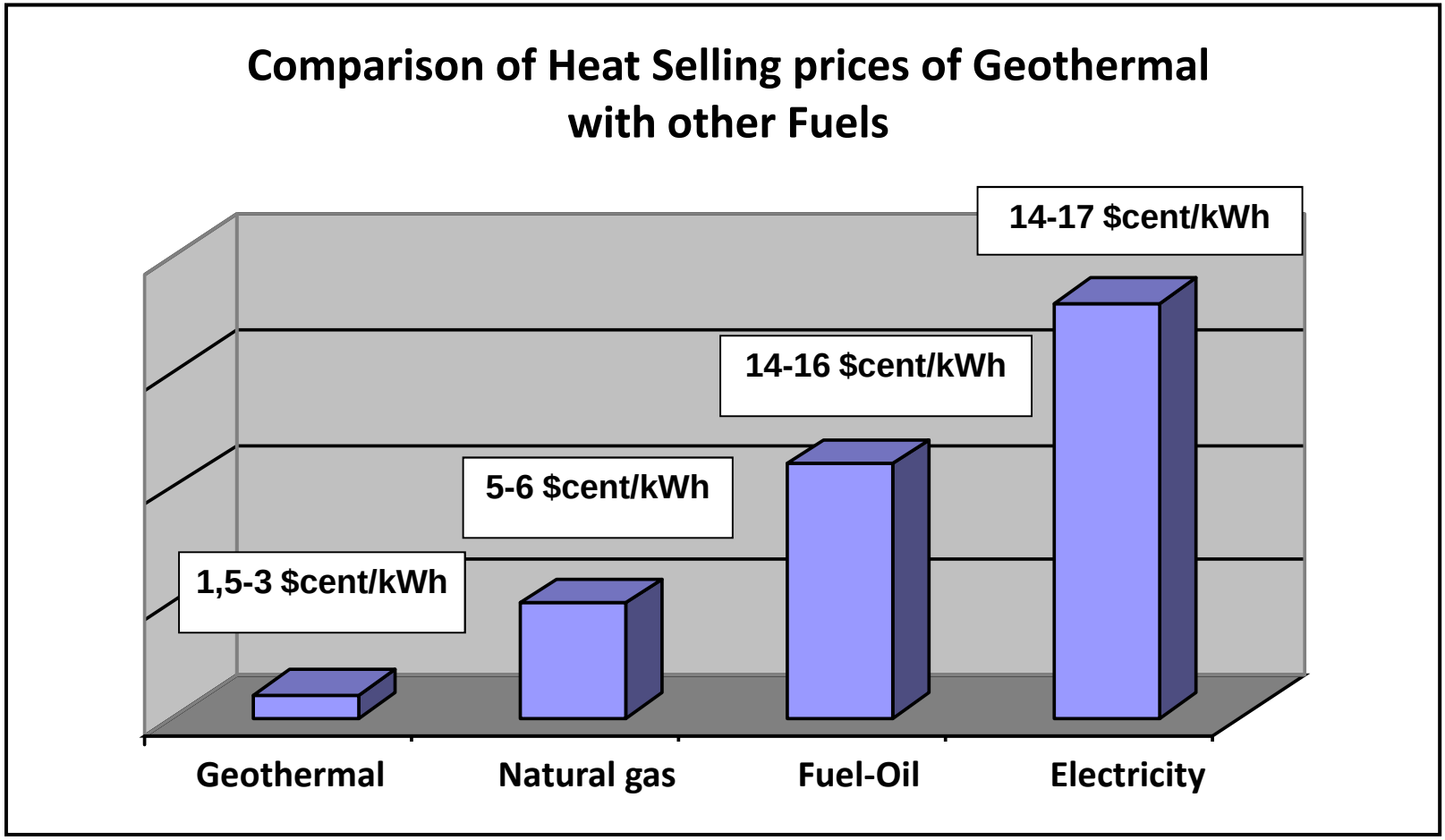
= over 1 Million thermal facility bed capacity

= 60 Billion m3 /year natural gas equivalent

The economical activity created from the present geothermal applications in Turkey is about 8,1 Billion US$.

Direct and indirect employment created is 210.000 people.

The natuıral gas equivalent of all the present geothermal applications in Turkey is about 2,4 Billion US$.


Comparison of Heat Selling prices of Geothermal with other Fuels
14-17 $cent/kWh
14-16 $cent/kWh
5-6 $cent/kWh
1,5-3 $cent/kWh
Geothermal
Natural gas
Fuel-Oil
Electricity

The issued geothermal law and incentives contributed to the increase in geothermal electricity production investments within Turkish private sector. Beside of the hydrothermal system utilization, Turkey shall give emphasize on EGS systems for future projections. The Turkish Geothermal Association are giving emphasize and advise on the continuing of the feed in tariff which will end at the end of 2020.

With big probability it would continue after that date for increase the renewable energy portion in total energy production.

Geothermal Potential of Turkey

The total hydrothermal possible theoretical geothermal heat potential is 60.000 MWt according to heat flow maps, measured well depth temperatures and calculations made for 4 km depth. Turkey's total geothermal electricity production potential (hydrothermal, 0-4 km) can be estimated as 4500 MWe with existing 10,5 USDcent/kWh incentive and 10 years purchase guarantee. The technical and economical EGS geothermal electricity production potential has been projected as 15.000 MWe if the 15 USDcent/kWh incentive with minimum 15 year purchase guarantee would be possible.

We estimated the EGS-Enhanced Geothermal System Electricity Production Technical Potential of Turkey (3–5 km) as 400,000 MWe.

It is known that the CO_2 in the geothermal fields in Turkey, are formed mostly by the marble and carbonated reservoir rocks due to the effect of the water and heat. CO_2 is emitting naturally towards the atmosphere at ground surface from the reservoir. It is a natural discharge of CO_2 and is independent to the existence of geothermal power plants. For this reason, 50-70 % decreament in the CO_2 amount in 10 years in the geothermal fields in Turkey has been obtained. The decreament continues. The reasons of the decline will be explained in the paper.

As a natural result of CO_2 decrease in the geothermal fields; The downhole pump (Lineshaft and ESP Electrical Submersible Pump) usage in the geothermal fields will be increased. Existing CO_2 in the geothermal fluid is the advantage for the artesian well flow but it is a disadvantage for the power plant electricity generation.

Today 17 cities are heated partly with geothermal in Turkey. These geothermal district heating systems have been constructed since 1987 and many developments have been achieved in technical and economical aspects.

The first geothermal cooling application has been realized in Izmir - Balcova by Izmir Jeotermal Inc. In 2018, for cooling of 1900 m^2 indoor area by lithium bromide absorption and 90/85°C geothermal temperature regime by supplying 6/9 °C clean cold water to the coolers in the buildings.

The 2025 target of Turkey about geothermal direct use including mainly geothermal heating like district heating and local cooling (as air-conditioning), greenhouse heating, thermal facilities heating and cooling and balneological use has been estimated as 11.150 MWt.

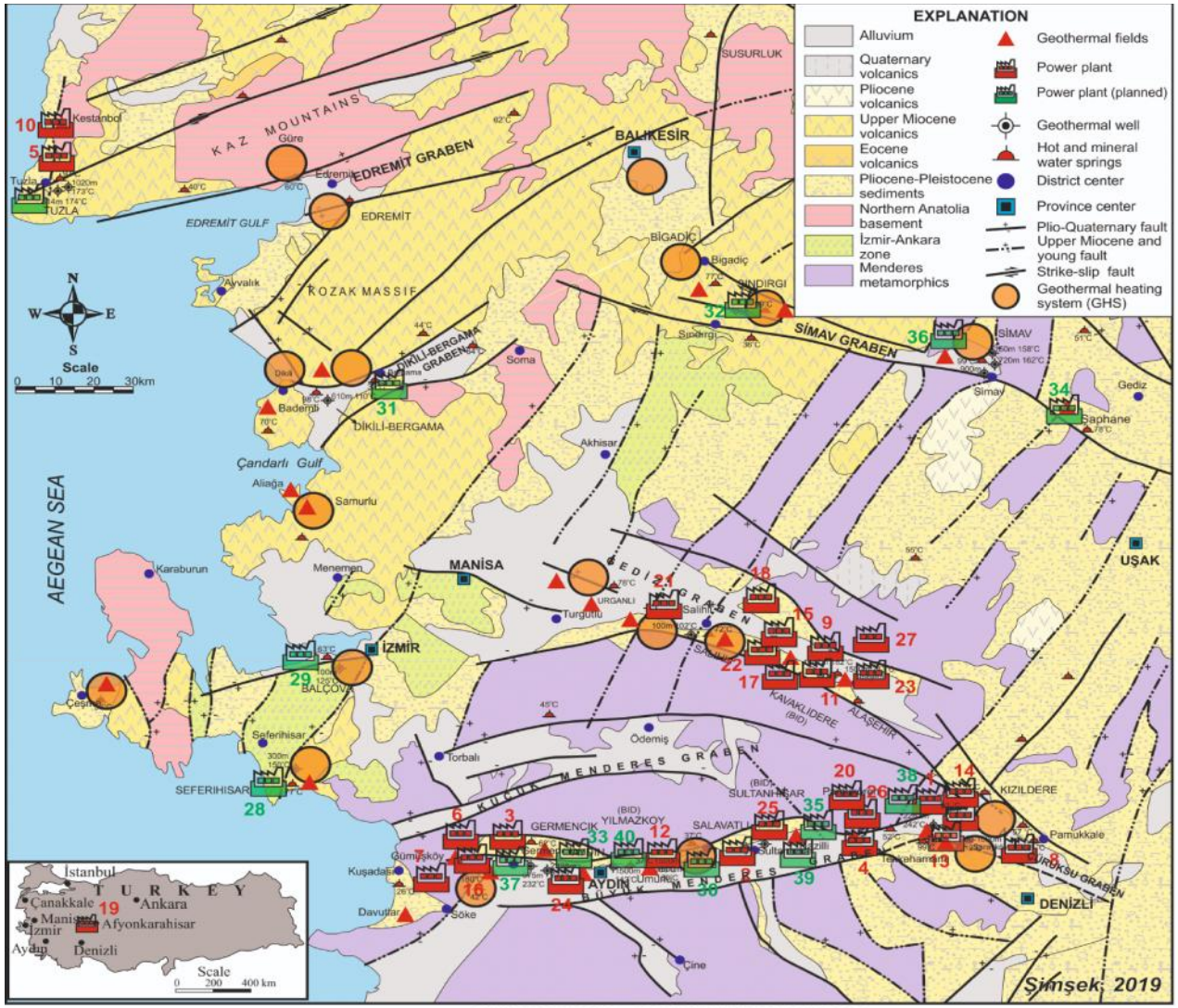
About 12 % of Turkey’s geothermal potential is utilized so far in direct use and electricity production in Turkey.

Turkey is an area of complex geology with active tectonics and high geothermal potential (hydrothermal and EGS). Faults accommodating the deep circulation of hydrothermal fluids of mostly meteoric origin are the primary means by which of geothermal systems are controlled. Most important geothermal systems of western Turkey are located in the major grabens of the Menderes Metamorphic Massif, while those that are associated with local volcanism are more common in the central and eastern parts of the country. Simav, Gediz, Küçük and Büyük Menderes Graben systems are the most high temperature geothermal systems located in Western Anatolia.

Hydrothermal and EGS potential is distributed in whole Turkey with different temperature intervals. Due to the effect of extensional tectonism, the western part of Turkey has the most abundant geothermal activity with highest temperatures (up to 287 °C in Manisa -Alasehir in Gediz Graben and 295 °C at 4800 m depth at Nigde province).

Geothermal exploration studies are comprising geothermal geology, hydrogeology, geochemistry and geophysical studies (Vertical Electrical Sounding (VES), MagnetoTellurics, AMT-AudiomagnetoTelluric, CSAMT-Controlled Source Audio-frequency Magneto- Tellurics, SP, Seismic (2D;3D) studies, gravity, magnetic), gas measurements (CO2) and radon measurements in Turkey.

Main geothermal fields of Western Anatolia



MAIN GEOTHERMAL FIELDS OF WESTERN ANATOLIA

Installed GEP Field

1-Denizli-Kızıldere (200-245°C) (Zorlu) Denizli-Kızıldere (140°C) (Bereket)
2-Aydın-Salavatlı (171°C) (MeGe)
3-Aydın-Germencik (276°C) (Gürmat)
4-Aydın-Pamukören (188°C) (Çelikler)
5-Çanakkale-Tuzla (174°C)(Enda)
6-Aydın-Hıdırbeyli (180°C) (Maren)
7-Aydın-Gümüşköy (180°C) (BM)
8-Denizli-Gerali (124°C) (Değirmenci)
9-Manisa-Alaşehir (185°C) (Türkerler)
10-Çanakkale-Ayvacık (160°C) (MTN)
11-Manisa-Alaşehir-Alkan (193°C) (Zorlu)
12-Aydın-Umurlu (155°C) (Kar-Key)
13-Denizli-Tekkehamam (241°C) (Greeneco)
14-Denizli-Tosunlar (103°C) (Akça)
15-Manisa-Alaşehir-Kemaliye (160°C) (Enerjeo)
16-Aydın-Germencik-Ortaklar (180°C) (Karizma)
17-Manisa-Alaşehir (180°C) (Sis)
18-Manisa-Alaşehir (287°C) (MASPO)
19-Afyonkarahisar (125°C) Afjet
20-Denizli-Kuyucak-Yöre (200°C) (Turkas)
21-Manisa-Salihli-Caferbeyli (168°C) (SANKO)
22-Manisa-Alaşehir (180°C) (Mis Enerji)
23-Manisa-Alaşehir-Baklacı (250°C) (Akça)
24-Aydın-İncirliova (180°C) (3SKale)
25-Aydın-Sultanhisar (180°C) (Çelikler)
26-Aydın-Buharkent (146°C) (Limak)
27-Manisa-Alaşehir (180°C) (Soyak)

Project Phase

28-İzmir-Seferihisar (153°C)
29-İzmir-Balçova (142°C)
30-Aydın-Atça (124°C)
31-İzmir-Dikili-Bergama (130°C)
32-Balıkesir-Sındırgı (107°C)
33-Aydın (≅100°C)
34-Kütahya-Şaphane (188°C)
35-Aydın-Nazilli (168°C)
36-Kütahya-Simav (164°C)
37-Aydın-Germencik (239°C)
38-Denizli-Kızıldere (245°C)
39-Aydın-Sultanhisar (180°C)
40-Aydın-Yılmazköy (142°C)

Main Geothermal Heating System

- İzmir-Balçova (JMS+SR)
- Balıkesir-Edremit (JMS+SR)
- Denizli-Sarayköy (JMS+SR)
- Manisa-Salihli (JMS+SR)
- Kütahya-Simav (JMS+SR)
- İzmir-Dikili (JMS+SR)
- Balıkesir-Bigadiç (JMS)
- Manisa-Turgutlu (SR)
- Manisa-Salihli-Lider (SR)
- Denizli-Agro Pekdemir (SR)
- Denizl-AKÇA (SR)
- İzmir-Çeşme (JIS)
- Balıkesir-Pamukçu (SR)

GEP: Geothermal Electric Power Plant
GDHS: Geothermal District Heating System
GH: Greenhouse Heating

SOME NEW GEOTHERMAL RESEARCHES AND PROJECTS

1. We have CO_2 injection projects for the protection of the environment and the sustainability of the reservoir. After some trials and studies in one of the projects in one well we have recorded increase in artesian production after CO_2 injection by means of reinjection well. It is a successful application.

2. For the abatement of the little amount of H_2S discharged from the Binary ORC plants, we are investigating the practical, economical and easy applicable new methods . I am personaly leading this project.

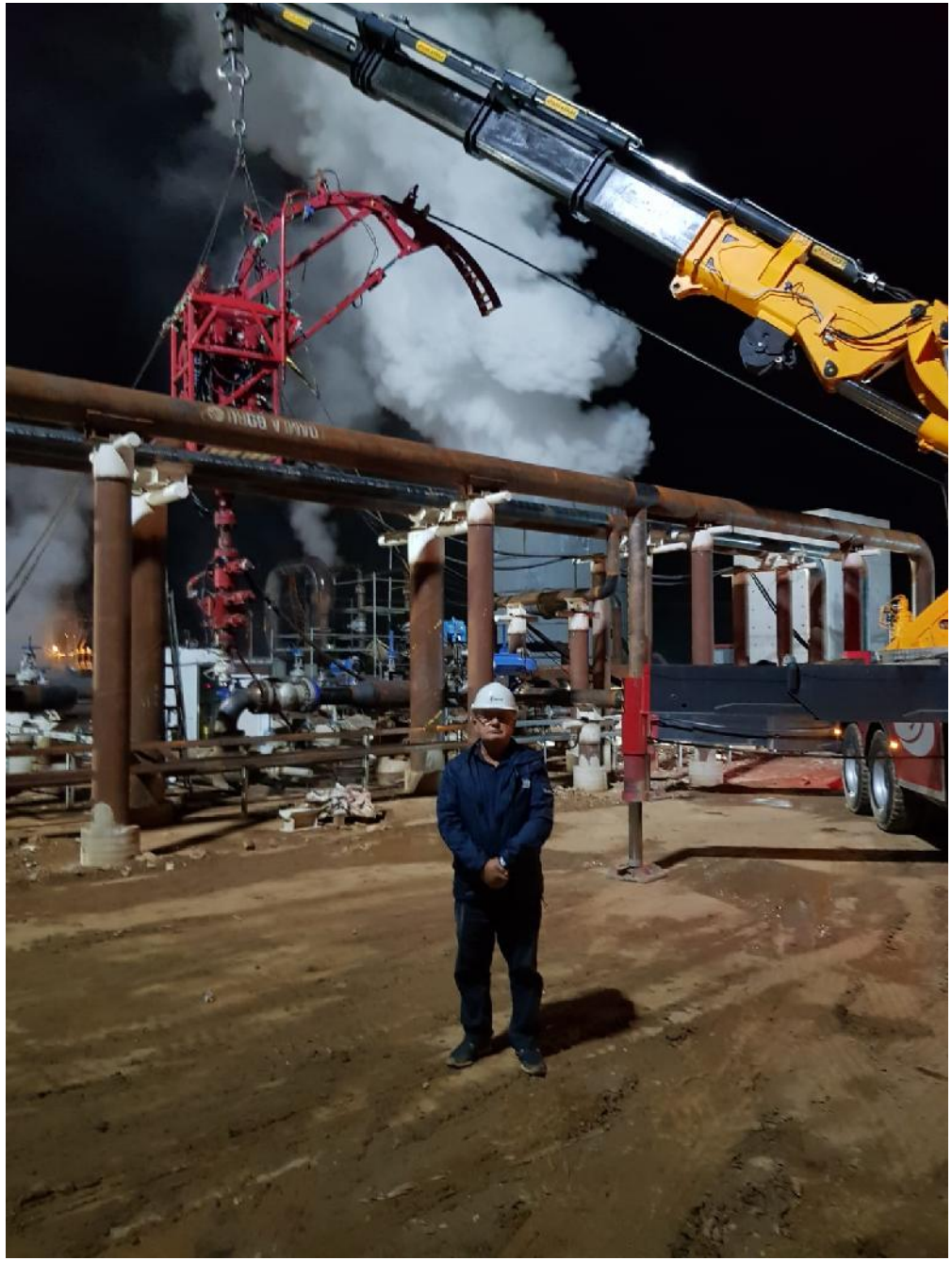
3. Geothermal greenhouse heating applications are very popular in Turkey and are increasing to meet the nourishment, exportation and employment needs. For this reason we are developing new ways to integrate the geothermal greenhouse applications to geothermal power plants and geothermal district heating systems. Some ways proposed by myself are:

a) to use the high temperature reinjection brine of geothermal power plants with 3-5 °C difference for greenhouse heating during winter season.

b) Since, the thermodynamic efficiency of Binary ORC geothermal power plants is about 15% and about 80% of the heat energy is discharged to the atmosphere; by using a special heat exchanger before the air cooled condenser at the binary plants, it would be possible to obtain cyclic 30-50 °C clean hot water for geothermal greenhouse heating purposes.

c) Due to the decrease of the wellhead pressure, in some geothermal fields, the steam is discharged to the atmosphere from the seperator. By condensing this waste steam, it is technical and economical possible to realize geothermal greenhouse heating.

d) The reinjection temperature of geothermal district heating systems in Turkey is about 55-60 °C. In case we evaluate this heat for greenhouse heating with 35-50 °C cyclic temperatures we will obtain additional minimum 5 million m^2 geothermal greenhouse heating in Turkey.



NEW PROJECTIONS AND TARGETS

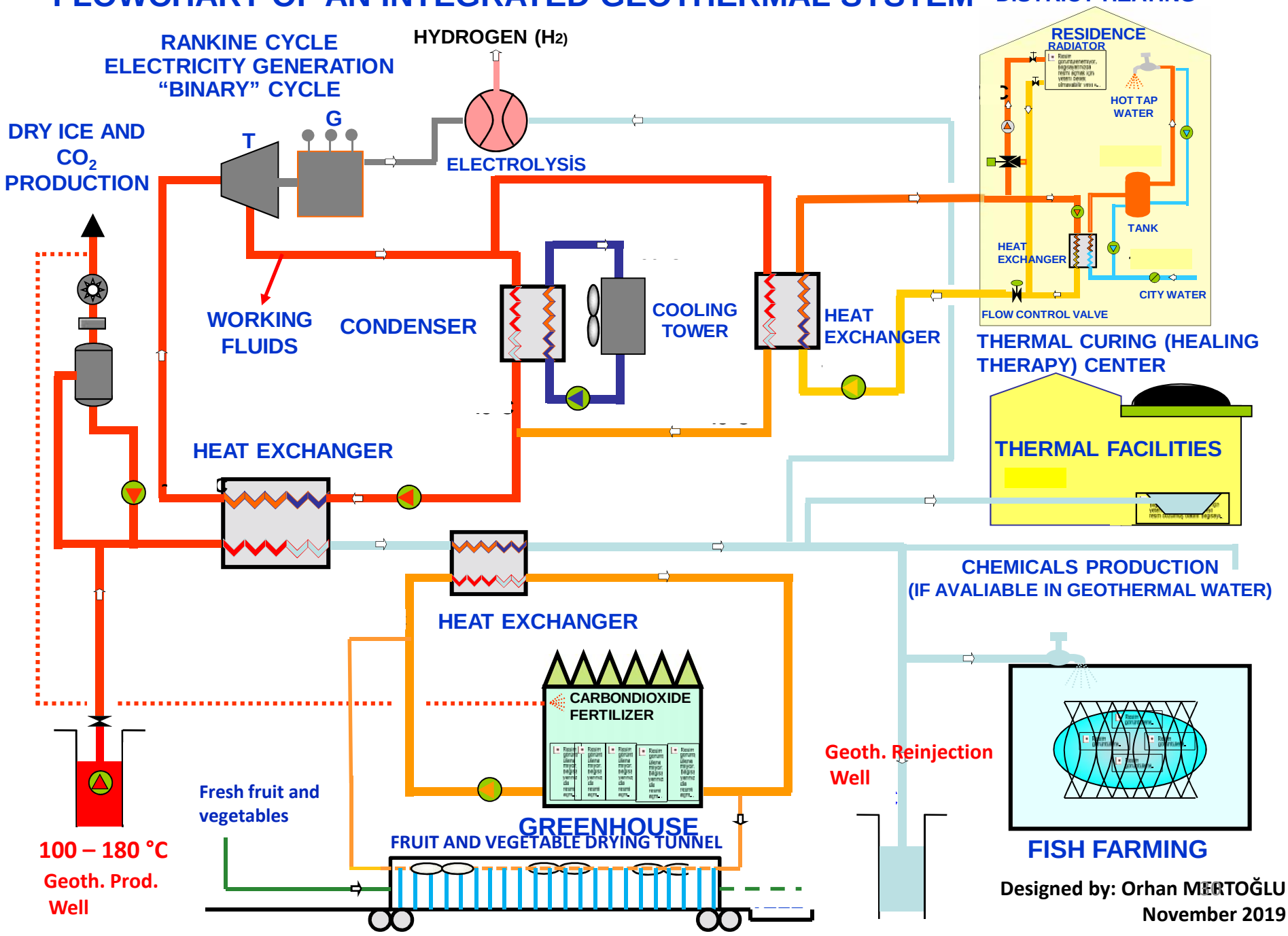
1) Deep reservoir explorations are going on for electricity production purposes. For his reason deep drilling targets have reached up to 4800m with 295°C measured.

2) The increase of directional drillings and coil tubing operation applications are very important for developments of geothermal reservoirs in Turkey.

3) Today, as low as 40-45°C temperature geothermal waters are also used for space heating in Turkey without heat pumps.

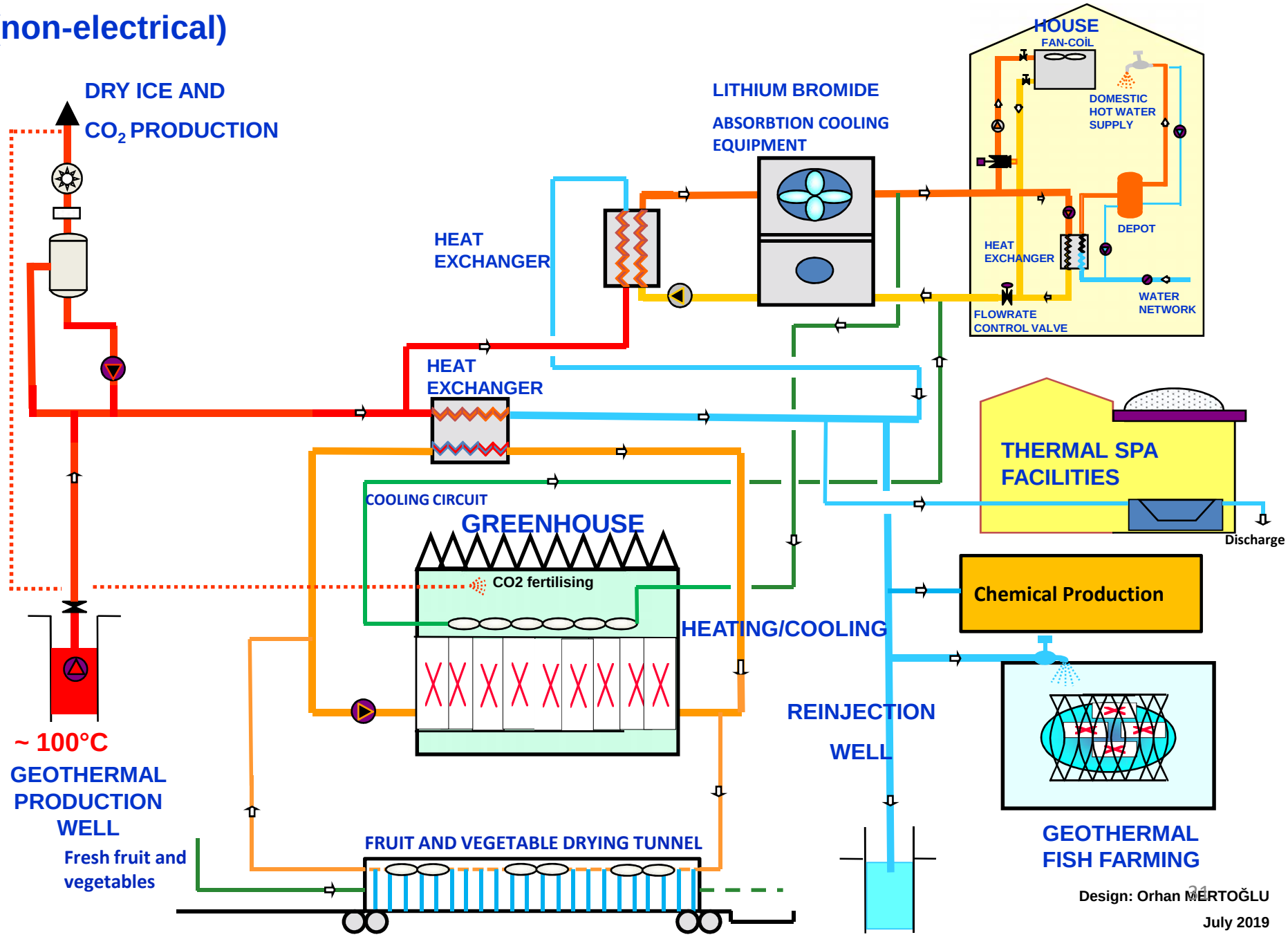
Ground source heat pump (GSHP) applications in Turkey started in 2000’s for residential single family houses with a total installed capacity of 586 kWt. Today, 90 GSHP applications are closed systems with installed capacity of 8,5 MWt. In recent years, as a new source waste heat from balneological use is recovered.

FLOWCHART OF AN INTEGRATED GEOTHERMAL SYSTEM



Designed by: Orhan MERTOĞLU
November 2019

GEOTHERMAL CASCADE USE (non-electrical)



Design: Orhan MERTOĞLU

July 2019

By coming to the end, I would like to thank very much to Prof. Dr. Keyan Zheng for his kind invitation to this valuable event.

I would like to congratulate for this excellent organisation.

I would like to congratulate you for the next World Geothermal Congress 2023 which will be held in China. Which I believe it will be a big success.
As you will remember the WGC2005 was held in Antalya – Turkey.

With believe and wishes of many fruitful
cooperations , joint-ventures, technical and know-how exchanges which would be beneficial for both countries.

THANK YOU FOR YOUR ATTENTION !....

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