IADC™

GEOTHERMAL COMMITTEE

General Meeting

November 2024
Hybrid Event – Dubai

AGENDA – MENA Focus

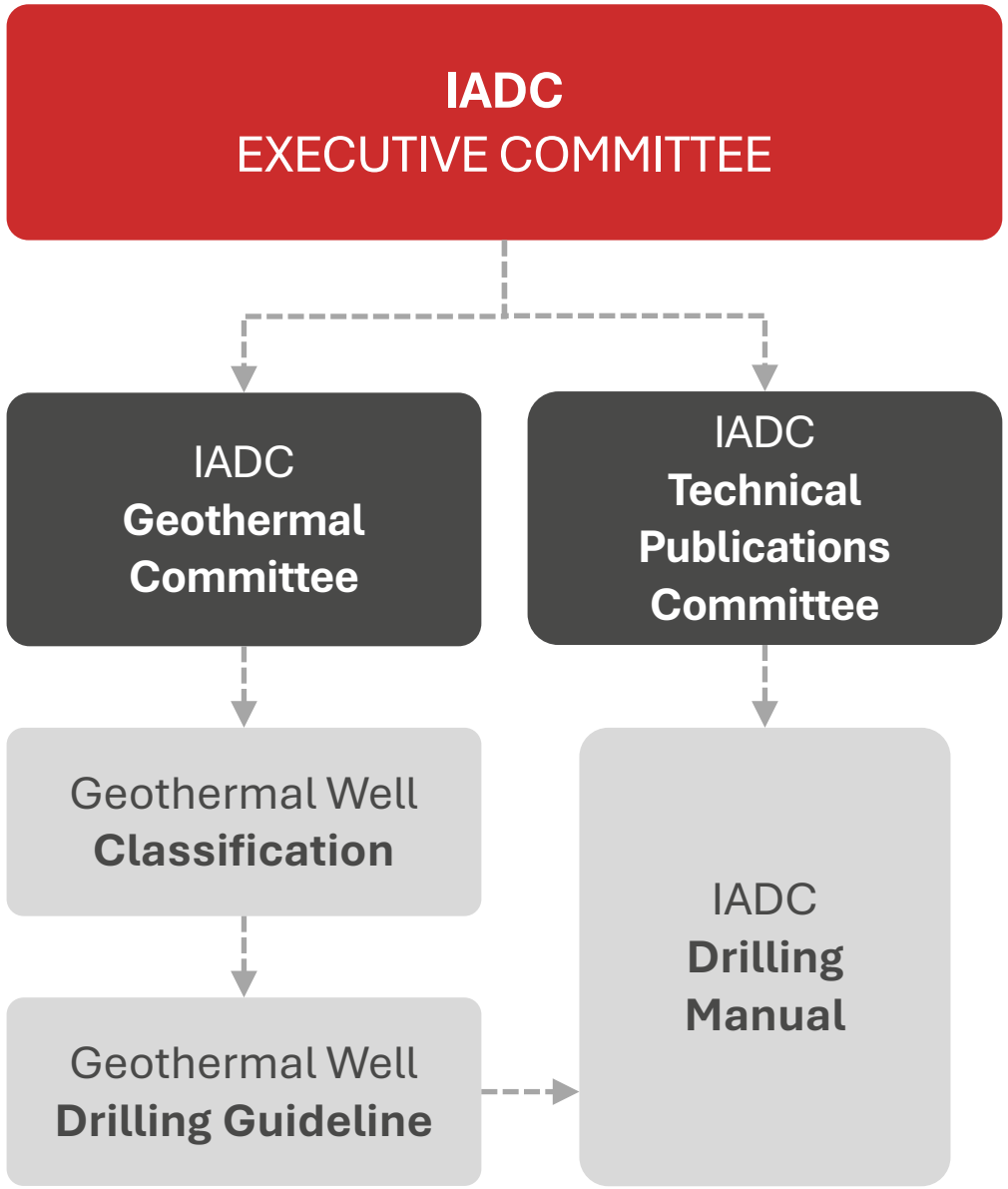
- 09:30 Welcome
- 09:40 Geothermal Market Overview with MENA Focus – Aditya Saraswat, Rystad
- 10:00 Geothermal Energy and Regional Projects – Jack Kiruja, WSP
- 10:20 ENOWA Project Overview – Jon Jonsson, NEOM
- 10:40 Overview from TAQA – Marije Van Koolwijk, TAQA
- 11:00 Deep Geothermal Energy for Decarbonizing the City of Vienna – Alex Heger, OMV
- 11:10 Questions/Comments
- 11:30 Adjourn

The Geothermal Committee aims to enhance the pivotal role of the drilling industry in expediting geothermal energy development.

Serving as a forum and bridge for industry practitioners, it seeks to ensure a safe, sustainable, and efficient model of well construction for the geothermal sector to provide renewable, stable and affordable energy anywhere in the world.

IADC Geothermal Well Classification

Provide an international coding system for **geothermal well construction** that reflects the practicalities of "**putting a hole in the ground**", the risks associated with drilling operations, and the long-term operation of the well.



IADC Geothermal Well Classification

Project Level

Well Level

Reservoir Dependency	Asset Purpose	Location Sensitivity	Design	Construction	Rig Capacity	Drilling Complexity	Well Control
Reservoir Dependent	**Heat Production**	**Rural**	Re-Entry	Circulating Temp	**Superlight**	Predominant UCS	**Liquid**
Reservoir Independent	**Power Production**	**Industrial**	**TRUE/FALSE**	**Low**	**Light**	**Low**	**Two-Phase**
	Mineral Extraction	**Urban**	Function	**Medium**	**Medium**	**Medium**	**Vapour**
		Offshore	**Select**	**High**	**Heavy**	**High**	**Hydrocarbons**
		Residential	Well Geometry	Pressure Regime	**Superheavy**	**Very High**	**Toxic Gases**
		Sensitive	**Final Hole Ø**	**Sub-Hydrostatic**		**Interbedded**	**Supercritical**
			No. of Sections	**Hydrostatic**		DDI	
			Total Depth	**Over Pressured**		**Low**	
			Design Parameters	**UBO & MPD**		**Medium**	
			Max Temp			**High**	
			Max Pressure			**Very High**	
			Stimulation			**Multilateral**	
			Scaling			**Interception**	
			Corrosion				

THANK YOU FOR YOUR ATTENTION

IADC™

GEOTHERMAL COMMITTEE

https://iadc.org/committees/geothermal/

Geothermal Energy

Key Drivers and Opportunities

Jack Kiruja

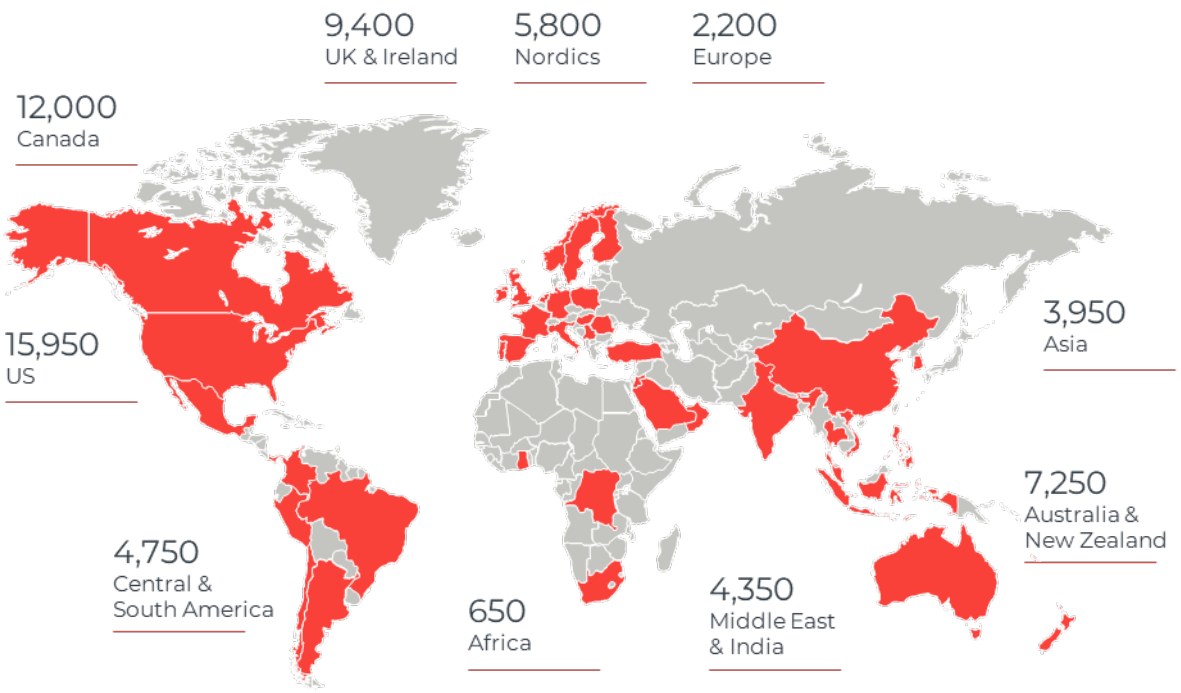
Energy Policy and Strategy, WSP Middle East

About WSP

WSP is a leading global advisory, engineering, and environmental sciences consultancy providing end-to-end client services from project inception to preliminary design, planning, detailed design, and construction management.

138 Years	52 Years
Globally	Middle East

International Agility



52 Years
In the UAE

49 Years
In KSA

15 Years
In Oman

31 Years
In Kuwait

Number 1
International Design Firm (ENR 2021 and 2022)

Over 66,300 Experts
Advisors, designers, engineers, scientists and project managers

550+ offices
Centres of design excellence, specialists and project offices

40+ Countries
Global coverage across all major continents

Our Business Units

- Property and Buildings
- Project Management
- Transport and Infrastructure
- Advisory Services

WSP Geothermal Services

GEOTHERMAL DEVELOPMENT DRIVERS

- Energy transition, Net Zero vison and global climate change commitments
- Energy security and diversification
- Sustainable heating and cooling
- Technology advancement
- Widespread availability of low and medium temperature resources

WHAT WSP CAN OFFER

- Geothermal policies, strategies, licensing procedures
- Geothermal resource assessment
- Reservoir and Geological modelling
- Geothermal well testing
- Feasibility studies
- Engineering design
- Carbon Capture and Storage
- Environmental baseline studies, impact assessments and monitoring
- Planning and permitting support
- Environment, health and safety guidelines for geothermal power generation

VALUE PROPOSITION

- One stop shop for geothermal value chain services
- Global team with experience in different geothermal systems
- Deep understanding of global geothermal markets and best practices
- Regional presence and experience

WSP Geothermal Projects

Work in 8 countries with installed capacity of over 9 GWe, representing around 60% of installed geothermal capacity globally

Projects

1. Hydrothermal systems
2. Enhanced Geothermal Systems
3. Carbon Capture and Storage

Countries

1. Indonesia
2. Hungary
3. New Zealand
4. Philippines
5. Spain
6. Switzerland
7. United Kingdom
8. United States

Geysers geothermal Reservoir Modelling, California, USA

WSP developed and validated a fully coupled, heat and mass flow, stress-strain model for The Geysers geothermal reservoir.

WSP analysed site data and production records to develop and calibrate a reservoir model which was used to assess specific environmental impacts of the production of geothermal fluids.

Geothermal Resource Assessment, Pannonian Basin, Hungary

Since 2008 WSP has been carrying out a geothermal project at Battonya in the Pannonian Basin, Hungary.

The initial phase is to assess the feasibility of a groundwater abstraction/recharge system for direct heating purposes from a formation of conglomerate and sandstone overlying the granitic bedrock.

Downhole In Situ Stress Measurements for Geothermal Exploration, British Geological Survey, UK

A series of in situ stress measurements were undertaken by WSP as part of the British Geological Survey's geothermal exploration programme.

The stress measurements were undertaken using in situ hydraulic fracture methods and at depth of approximately 300 m in exploration borehole drilled into Carboniferous strata.

Karaha 30MW Geo Power Plant Project EPC Engineering, Indonesia, PGE

WSP was engaged in steam field Feasibility Study and Front-End Engineering Design, sizing and optimisation of equipment and pipelines, produced steam field Heat and

Mass Balance, PFDs and P&IDs, preliminary layout drawings, bills of materials and equipment specifications for project costings

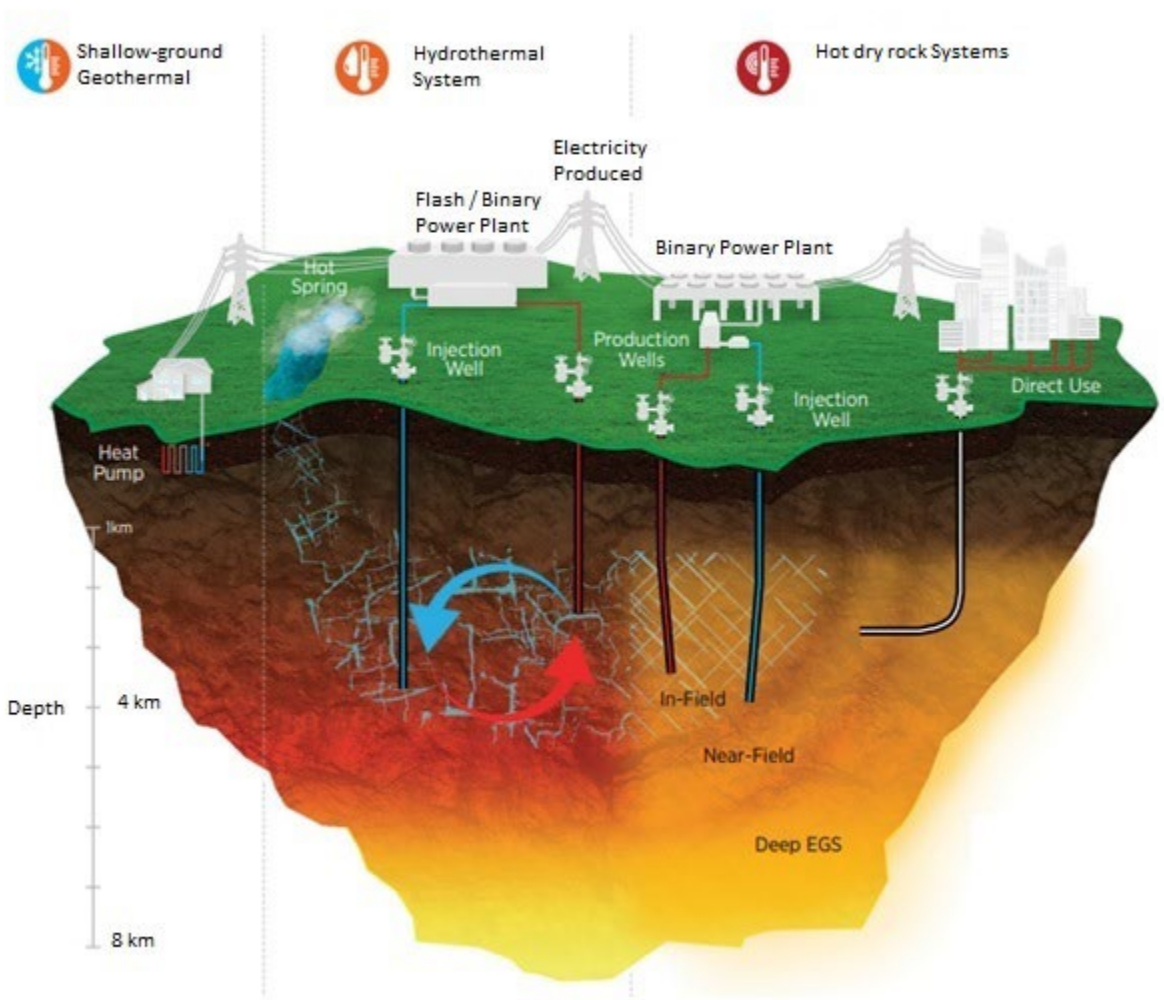
Geothermal Resource Assessment for the Pacific Northwest, USA

WSP carried out extensive geological and hydrogeological research to assess the potential of geothermal sites throughout the states of Washington and Oregon

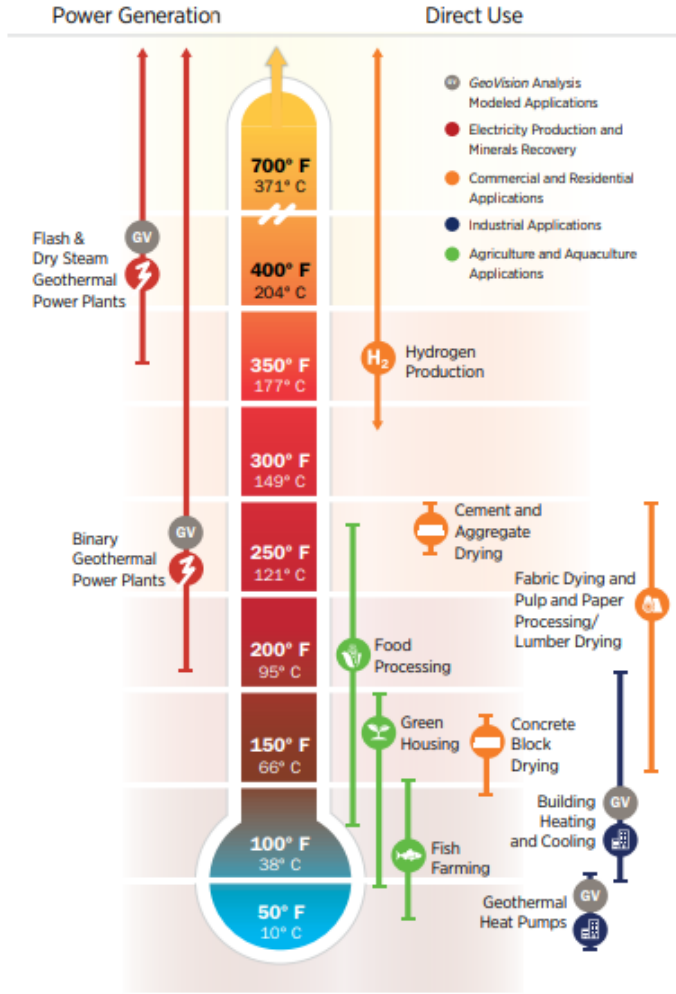
Many other projects:

- Hot Dry Rock Geothermal Energy Cornwall, **UK**
- Lawrence Berkeley National Laboratory- Geologic Characterisation for Carbon Dioxide Sequestration
- New Northern Negros 5MW Front End Engineering Design (Feed), **Philippines**, EDC.
- Reservoir production and subsidence modelling, **New Zealand**
- Te Mihi Geothermal Power Station, **New Zealand**
- Hydraulic Testing to Evaluate the Potential use of Geothermal Energy In Zurich, **Switzerland**
- Permitting of geothermal projects, **Spain**

Geothermal Occurrence and Utilisation



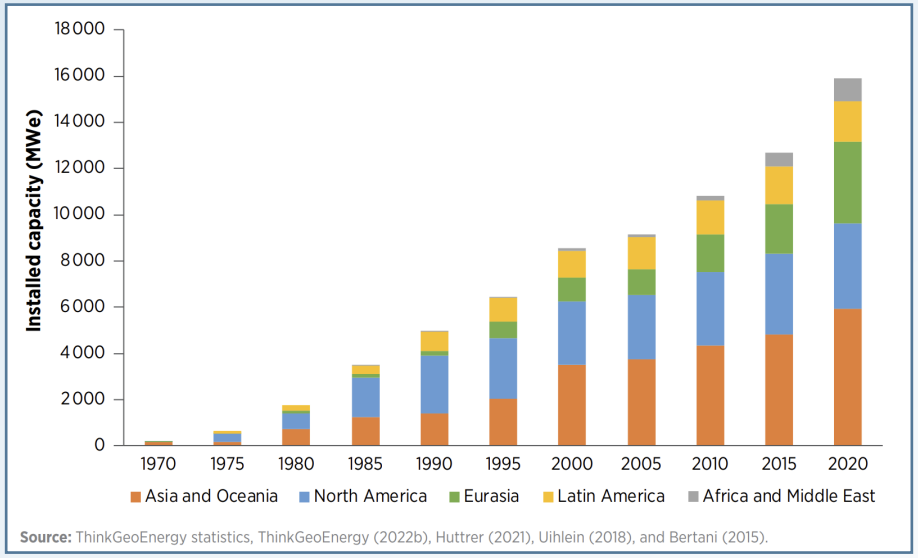
Geovision (DoE), 2019



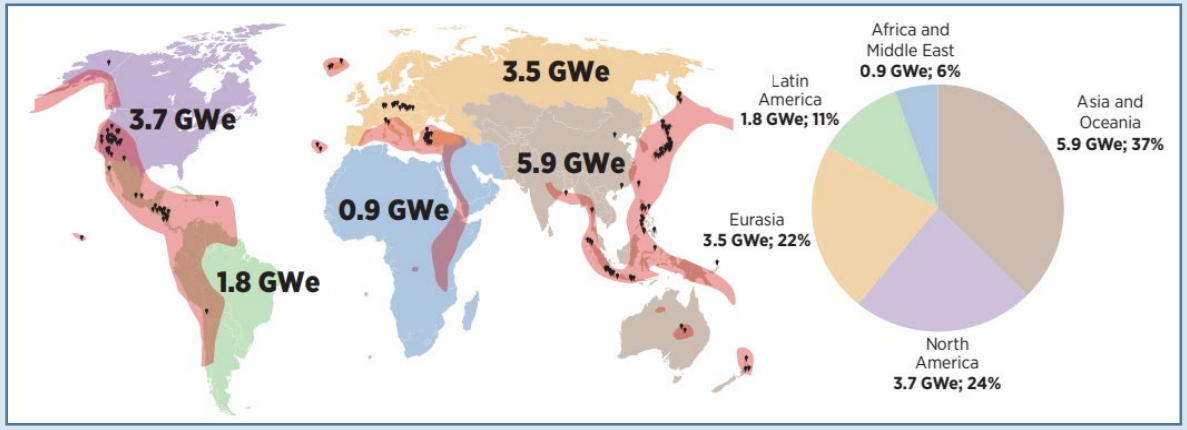
Geovision (DoE), 2019

Expansion of Geothermal Electricity Capacity

- Global installed capacity: **16.36 GWe** (2023).
  - Increase of **281 MWe** in 2023
  - **0.5%** share in global RE capacity
- Average annual growth rate:
  - **3.5%** between 2000 and 2021
  - **3.6%** between 2015 – 2020
  - **4%** between 2020- 2023



Source: ThinkGeoEnergy statistics, ThinkGeoEnergy (2022b), Huttrer (2021), Uihlein (2018), and Bertani (2015).

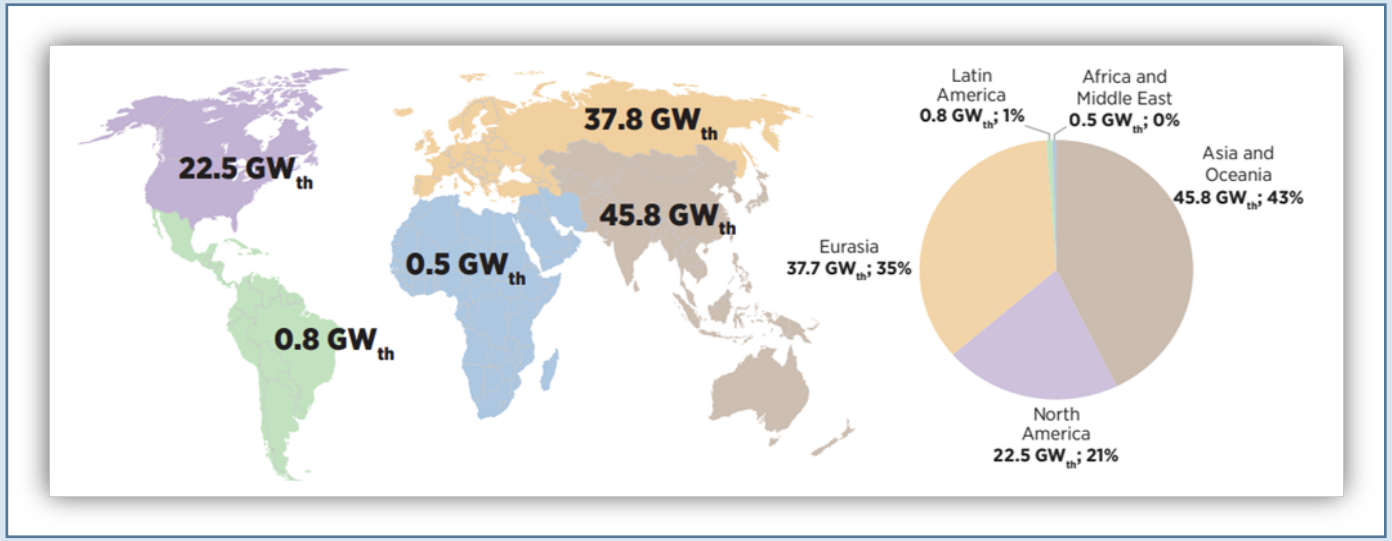


Source: IRENA, IGA (2022)

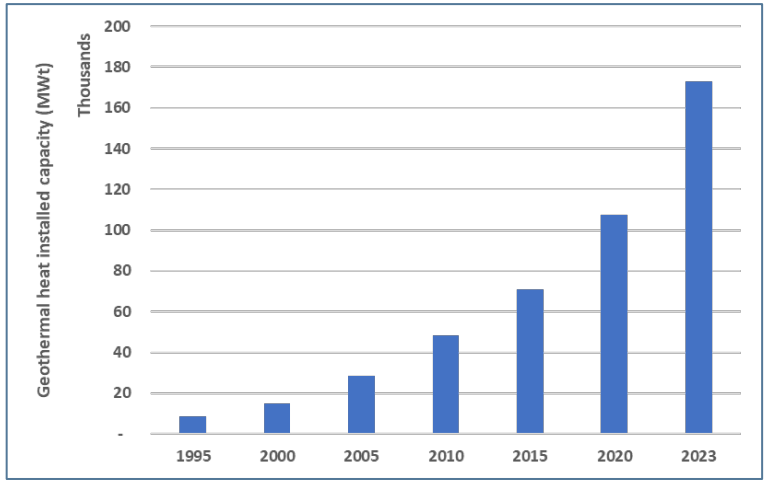
- Around **31** countries across the world **(3,700 wells)**
- USA **(3.90 GWe),** Indonesia **(2.42GWe)**, Philippines **(1.95GWe)**, Turkiye **(1.69GWe)**, NZ **(1.04)**
- Kenya **(0.99 GWe)**, Mexico **(0.98GWe)**, Italy **(0.92GWe)**, Iceland **(0.75GWe)**, Japan **(0.58GWe)**
- Growth driven by Turkiye, Indonesia, Kenya, NZ, USA.

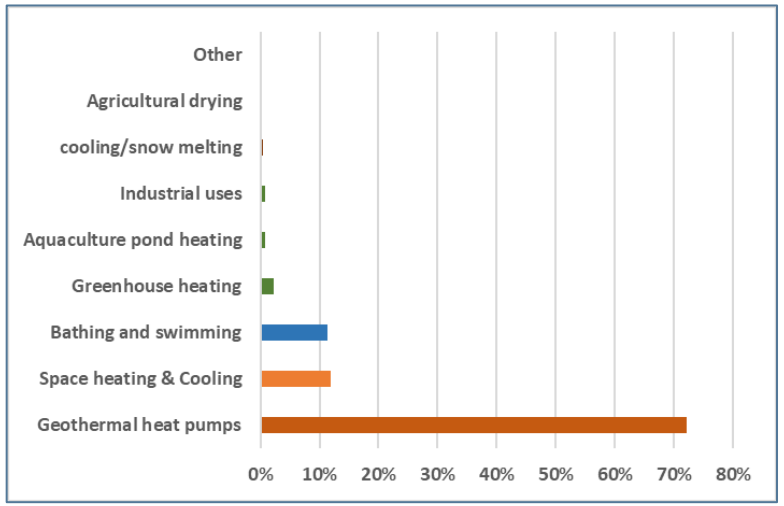
Geothermal Heating and Cooling Market

- **173 GWth** installed capacity in 2023
  - Growth of **66 GWth** since 2020
  - Only **0.3%** of installed heat capacity
- Average annual growth rate:
  - **10.3%** between 2000 and 2020
  - **8.9%** between 2015 – 2020
  - **17%** between 2020 - 2023
- Over **88 countries** with heat installations (**2,500 wells**)



Source: IRENA, IGA (2022)





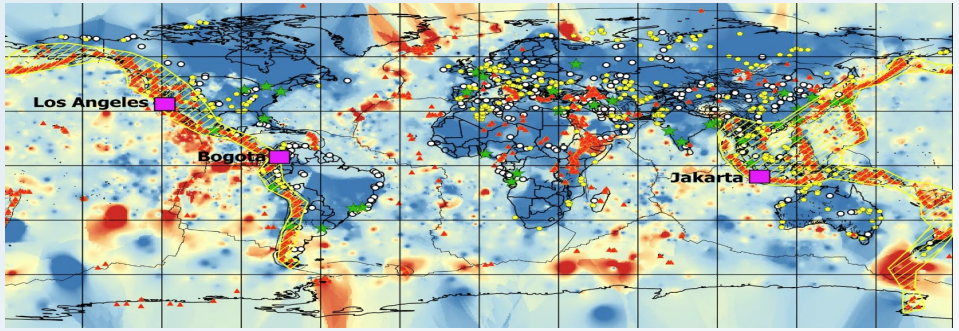
Geothermal Development Continue to Face Challenges

Country specific market conditions

- Inadequate policies and regulatory frameworks (complex and lengthy)
- Inadequate financial and risk mitigation instruments
- Remote mountainous locations
- Small and remote island with limited demand
- Country risks

Socio-environmental

- Limited awareness
- Public resistance
- Ecological sensitivity



Technical challenges

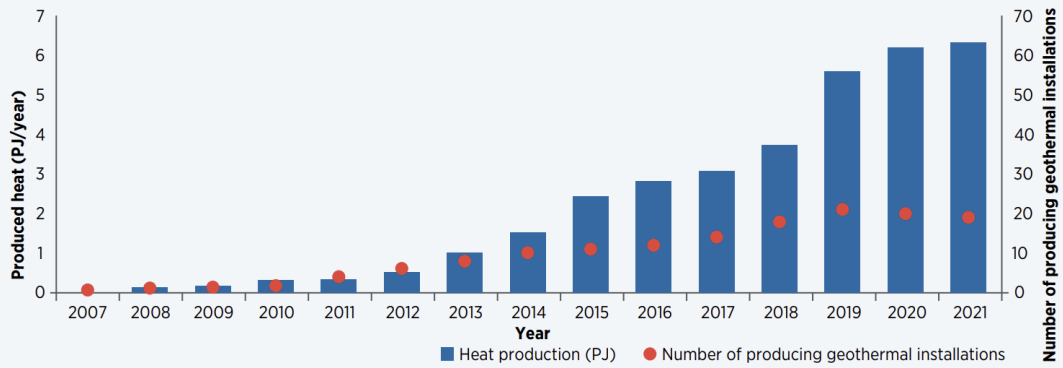
- Data availability limitations
- Inadequate technical expertise
- Challenging geological conditions

Policy, Regulations and Risk Mitigation Instruments Enable Geothermal Growth

Legal and Regulatory Frameworks

- Clear, transparent and simplified permitting procedures
  - Dedicated laws and regulations
  - Geothermal reserved for the public sectors
- Environmental regulations: Reservoir, biodiversity & pollution management
- Scale and type of utilisation: Electricity or direct use
- By-products: Minerals, heat, brine

Figure 9 Geothermal heat produced and number of geothermal installations in the Netherlands, 2007-2021



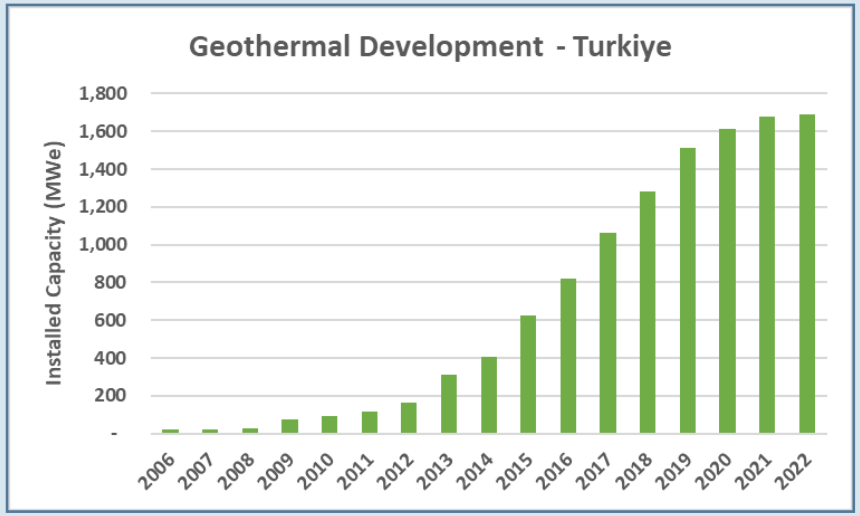
Source: Ministerie van Economische Zaken en Klimaat (2022).

Risk Mitigation instrument

- Public risk mitigation scheme
- Risk sharing schemes
- Insurance based risk mitigation schemes

Policy Instruments

- National and local climate and RE plans and strategies
- Incentives: Tax credits & Subsidies (CFD's)
- Pricing: Feed-in-tariffs and Power Purchase Agreements
- R&D Support and grants



Source: ThinkGeoEnergy (2022)

Deepening Energy Transition– Fostering Cross-industry Collaboration

Oil and Gas

Projects

- Las Maracas, Colombia
- Swan hills, Alberta
- Geothermal Energy from Oil and Gas Demonstrated Engineering (GEODE)
- Sinopec (RE Strategy)

Synergy

- Similar technologies & expertise
- Investment & scalability
- Data sharing

Critical Mineral

Projects

- Salton Sea, USA
- Cornwall, UK
- Upper Rhine Valley, Germany, France

Synergy

- Production of mineral water in geothermal system

Green Hydrogen

Projects

- Oita, Kyushu, Japan
- Mokai, New Zealand
- Svartsengi, Iceland
- Kamojang, Indonesia

Synergy

- Clean baseload electricity
- Higher efficiency due to elevated temperatures

CCUS

Projects

- Ngawha Geothermal Power Station, New Zealand
- Hellisheidi, Iceland (Carbfix, Orca)

Synergy

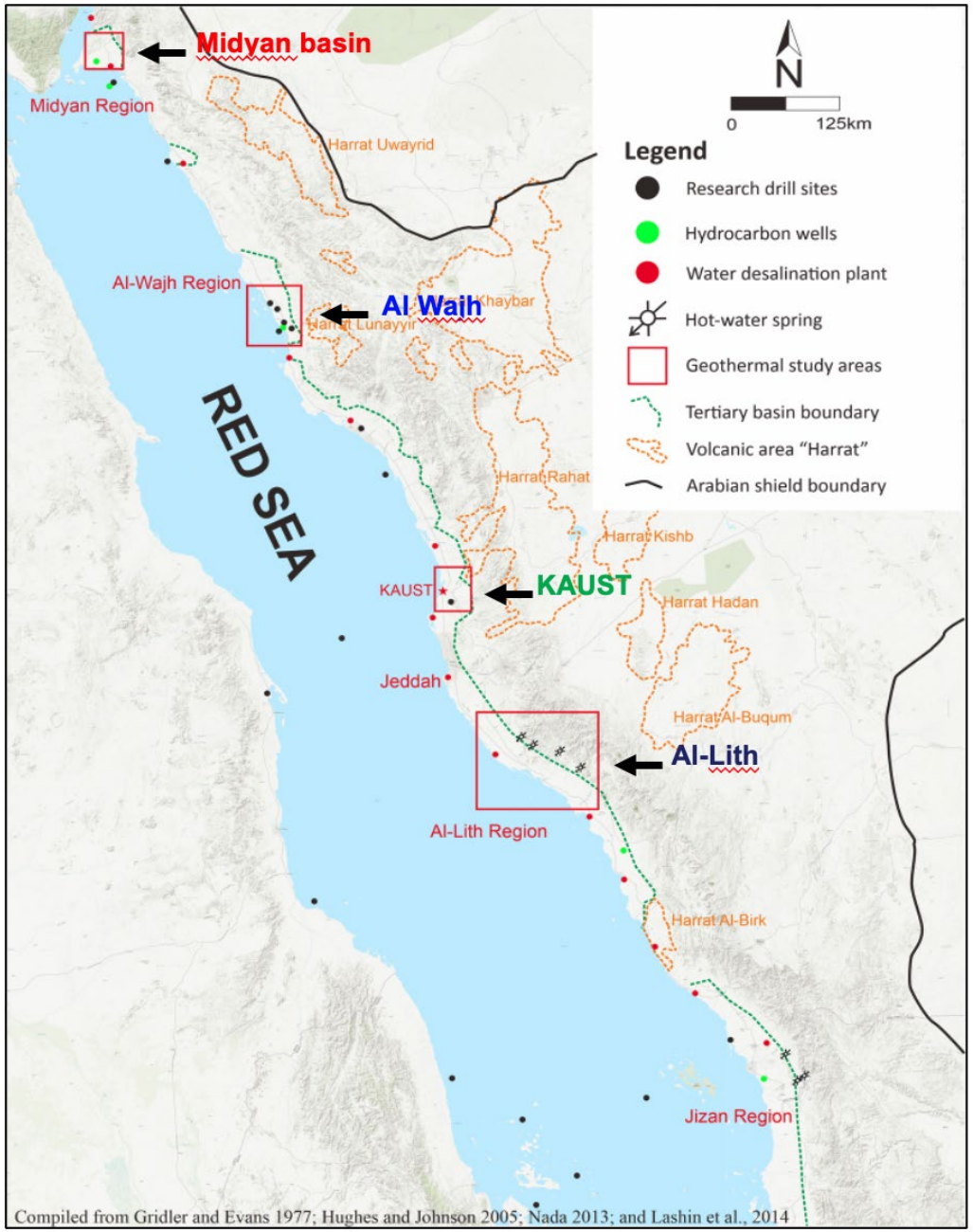
- Rocks that readily react with CO_2 to permanently store it

Geothermal Energy in The Middle East

- Exploration of geothermal resources for power generation, district cooling and water desalination in both sedimentary and volcanic settings (UAE, KSA)
- Assessing oil and gas data to map potential geothermal project areas – may include cogeneration and repurposing old wells (Oman)
- Explore potential to use geothermal rock formation to permanently store carbon dioxide through mineralisation (KSA)
- Explore the techno-economic feasibility of geothermal district cooling and heat pump installation in the gulf region (UAE, KSA)

Early-stage development; low-medium temperature resources

GEOTHERMAL IN KSA



Geothermal exploration programmes

- In Jan 2023, the Ministry of Energy of Saudi Arabia and the Saudi Geological Survey (SGS) signed a memorandum of understanding to start the exploration of geothermal resources in the country.
- SGS since 2020 investigated Saudi Arabia's geothermal energy reservoirs under funding from the National Industry Development and Logistics Program (NIDLP) at the Ministry of Industry and Mining.
- Collaboration between TAQA Geothermal and KAUST to drill shallow wells at the campus to study geothermal energy potential

Geothermal Mineralisation project

- A CO_2 mineralisation demonstration project close to the Jazan Economic City to capture CO_2 from Jazan Economic City and use water from the Red Sea to demonstrate the potential of this technology (in collaboration with Saudi Aramco)

KAUST Circular Carbon Initiative

- The Geo-Solutions Thrust explores and quantifies the potential of geological storage and geothermal energy in the context of the Circular Carbon Economy. It aims to identify the most feasible locations in Saudi Arabia for geothermal energy generation and for CO_2 storage in non-well-based settings.

Key Initiatives - UAE & Oman

United Arab Emirates

1. Geothermal well drilling
    - Two geothermal well drilled in Masdar in 2010 to a depth of 3,000m producing 90°C water with a flow rate of 100 kg/s

2. Geothermal District Cooling (G2COOL plant)
    - Collaboration between ADNOC and Tabreed to develop the regions 1st geothermal district cooling project in Masdar City
    - Supported by ADNOC's initial $15 billion (AED 55 billion) allocation towards low carbon solutions to support its decarbonization plan and net zero goals by 2045
    - Provides 10% of Masdar City's cooling needs using absorption cooling technology

Oman

1. Development of a National Strategy to Develop Geothermal Resources in Oman
    - An initiative of the Oman's Ministry of Energy and Minerals and the Oman Investment Authority.
    - Evaluation of data from the Oman Oil & Gas Data Repository (OGDR) to identify geothermal prospects in the country.
    - Data from more than 7000 oil, gas, and water wells evaluated
    - ⇨ assessment of the economic feasibility of developing these prospects

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Our experts include engineers, advisors, technicians, scientists, architects, planners, surveyors and environmental specialists, as well as other design, program and construction management professionals.

With over 60,000 talented people globally, we are uniquely positioned to deliver successful and sustainable projects, wherever our clients need us.

Thank you.

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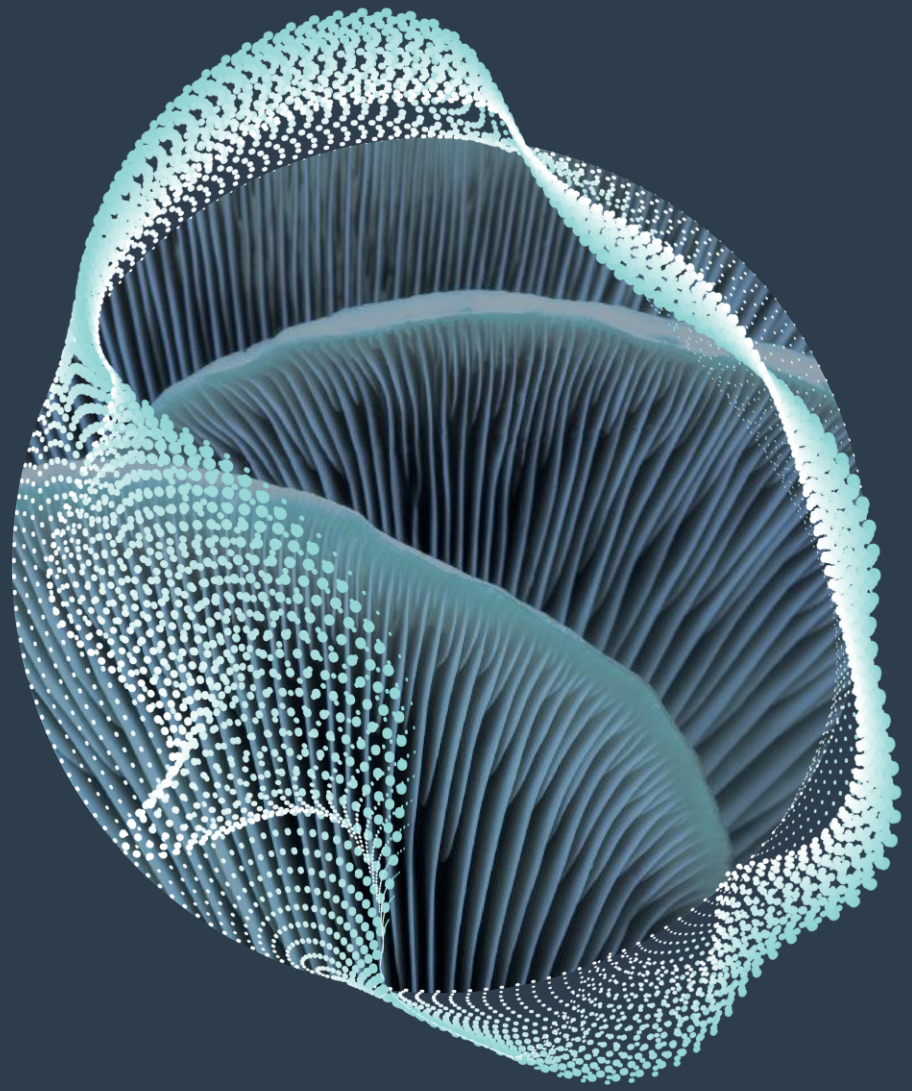
ENOWA.
NEOM

GEOTHERMAL VALUE PROPOSITION

NOVEMBER 2024



Executive Summary

WHY GEOTHERMAL: Geothermal is a scalable baseload renewable energy solution that offers reliable and flexible energy with a small environmental footprint at a competitive cost compared to conventional technologies.

WHAT IS GEOTHERMAL: Geothermal energy harnesses heat from within the earth's crust, using conventional, enhanced, or advanced systems to generate electricity or provide direct heating.

HOW TO LEVERAGE GEOTHERMAL ENERGY: NEOM's Geothermal available temperature ranges from 100°C to 150°C supporting diverse applications such as district heating/cooling, power generation, grid support, and desalination.

WHERE: NEOM Features five geothermal sites, indicating substantial potential for harnessing geothermal energy that can be strategically utilized.

Investing in Geothermal is not an option, it’s a necessity

NEOM requires geothermal as a core energy source for 3 reasons:

Renewable Baseload Power

NEOM has no other continuous renewable energy supply which can provide baseload power and balance intermittent solar/wind resources.

More Bang for NEOM’s Buck

Investing in a single project will enable multiple applications (power, industrial heating, district cooling) via a cascaded arrangement, unique to Geothermal.

It Fits Like a Glove

Resource is close to demand sinks (off-grid projects possible); Skills for extraction readily available (can fully leverage O&G experience); Real opportunity for KSA to set a new technology standard.

ENOWA. NEOM

Confidential External

Geothermal is a scalable baseload RE solution that offers reliable and flexible energy with a small environmental footprint at a competitive cost

Reliability

- Steady baseload renewable energy 24/7
- Geothermal mitigates intermittent power generation profile and acts as supplementary reserve
- Can have an off-grid option.

Flexibility

- Power solutions: baseload, load following, complementing LDES
- Thermal solutions: efficient district cooling and heating, heating for industrial processes and agriculture.
- Desalination solutions: reliable heat for efficient desalination.

Small Environmental Footprint

- Uses 4 to 35 times less land compared to wind/solar + LDES development[1]
- Minimal surface disruption as infra. can be located underground, preserving natural landscape
- Low water consumption as water can be recycled

Economic Viability

- Competitive LCOE
- LCOC and LCOH is ~10-20x lower compared to conventional RES
- Projects can generate annual revenue and operate for 30+ years with minimal decline in energy output

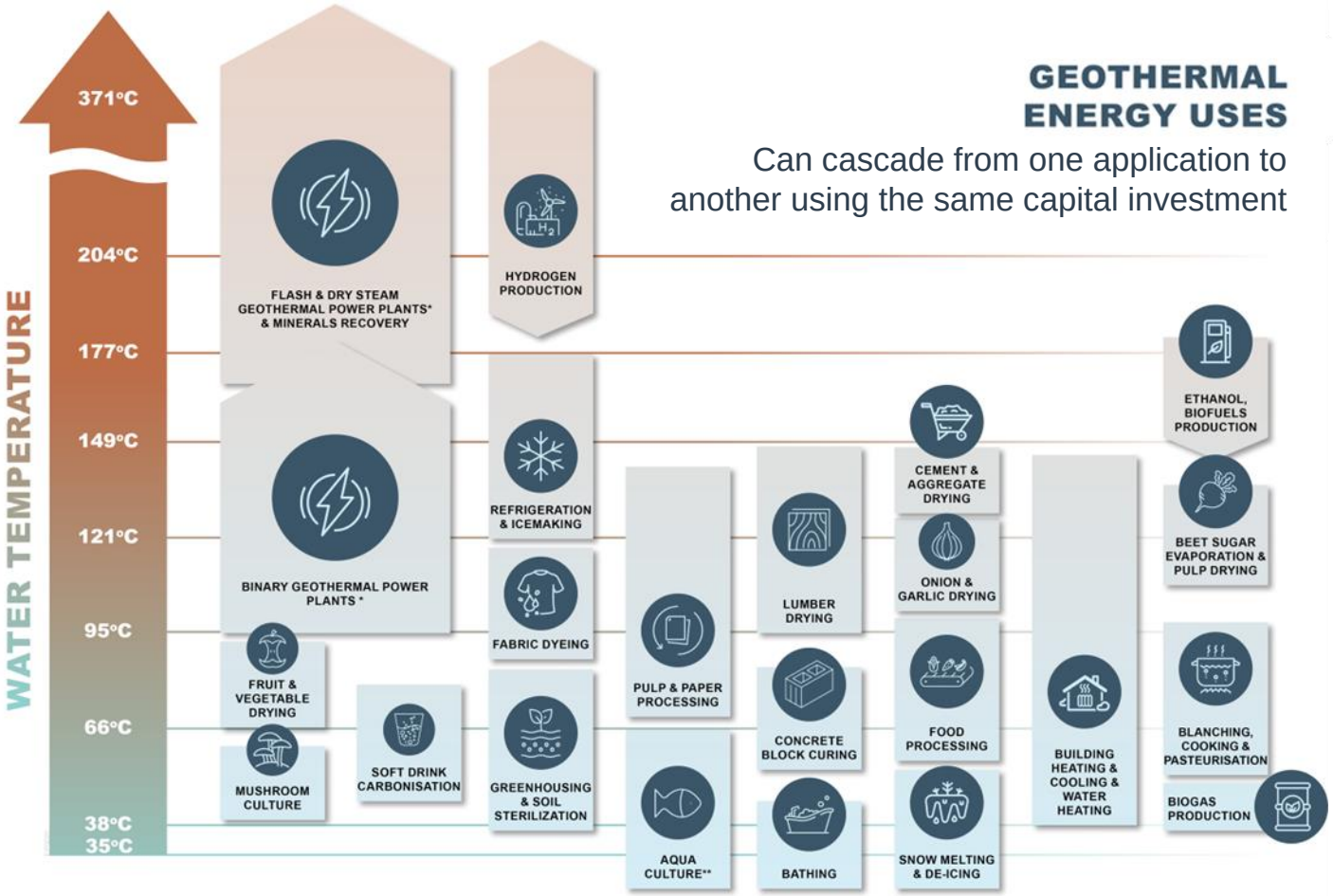
Deployment

- Proximity to the demand center
- Locally available
- New advanced technologies enable faster & cheaper development

ENOWA. NEOM

- Acronyms: Renewable Energy Solutions (RES), Long Duration Energy Storage (LDES), Levelized Cost (LC) of Electricity (LCOE), LC of Cooling (LCOC), LC of Heating (LCOH)
- References: [1] ENOWA power BI and DiPippo, 2016

NEOM's geothermal available temperature ranges from 75°C to 175°C supporting diverse applications



NEOM specific applications:

District heating and cooling 100°C to 70°C

Used directly for heating and cooling applications

Geothermal power generation 150°C to 115°C

Used to generate reliable, baseload electricity

Grid services

Support grid reliability, buffer supply fluctuations and stabilize grid frequency

Thermal desalination 115°C to 70°C

Heating saline water to create steam, then condensing to produce fresh water

ENOWA. NEOM

NEOM's geology bestows geothermal potentials

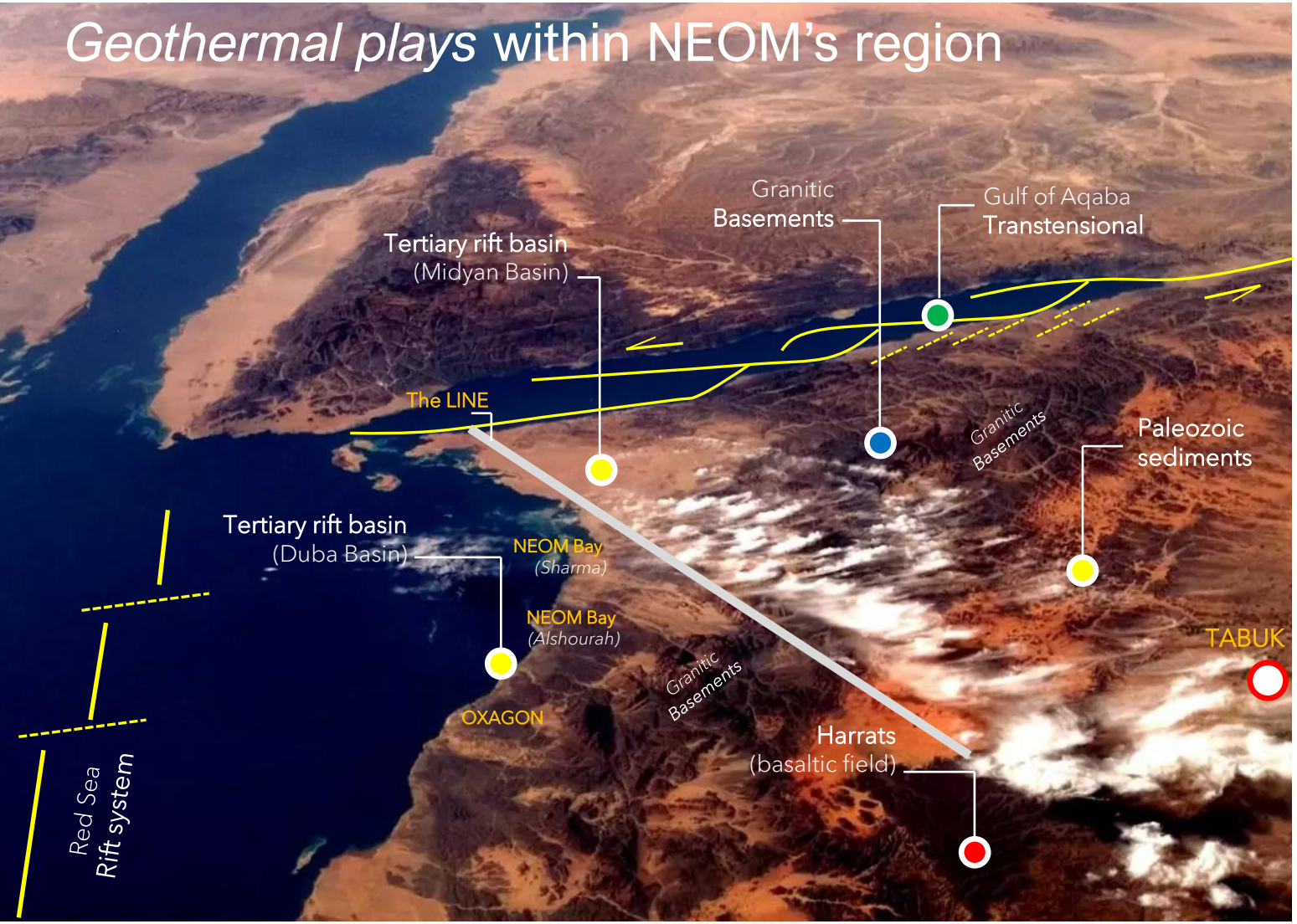


Image credit: http://city.jsc.nasa.gov/scripts/sseop/photo.pl?mission=ISS016&roll=E&frame=8810

1 Red Sea **Rifting**

- Crustal thinning, creates elevated heat flow
- Tertiary rift basins, with porous and permeable sediments
- **Hot sedimentary aquifer (HSA)** geothermal play
- Cambrian *Sandstones* may also host HSA resources

2 **Gulf of Aqaba Transtensional**

- **Active faulting, creates permeable structures**
- **Overlain by porous Quaternary deposits**
- **Fault-controlled convective geothermal play (FCS)**

3 Pleistocene **Basaltic Volcanism**

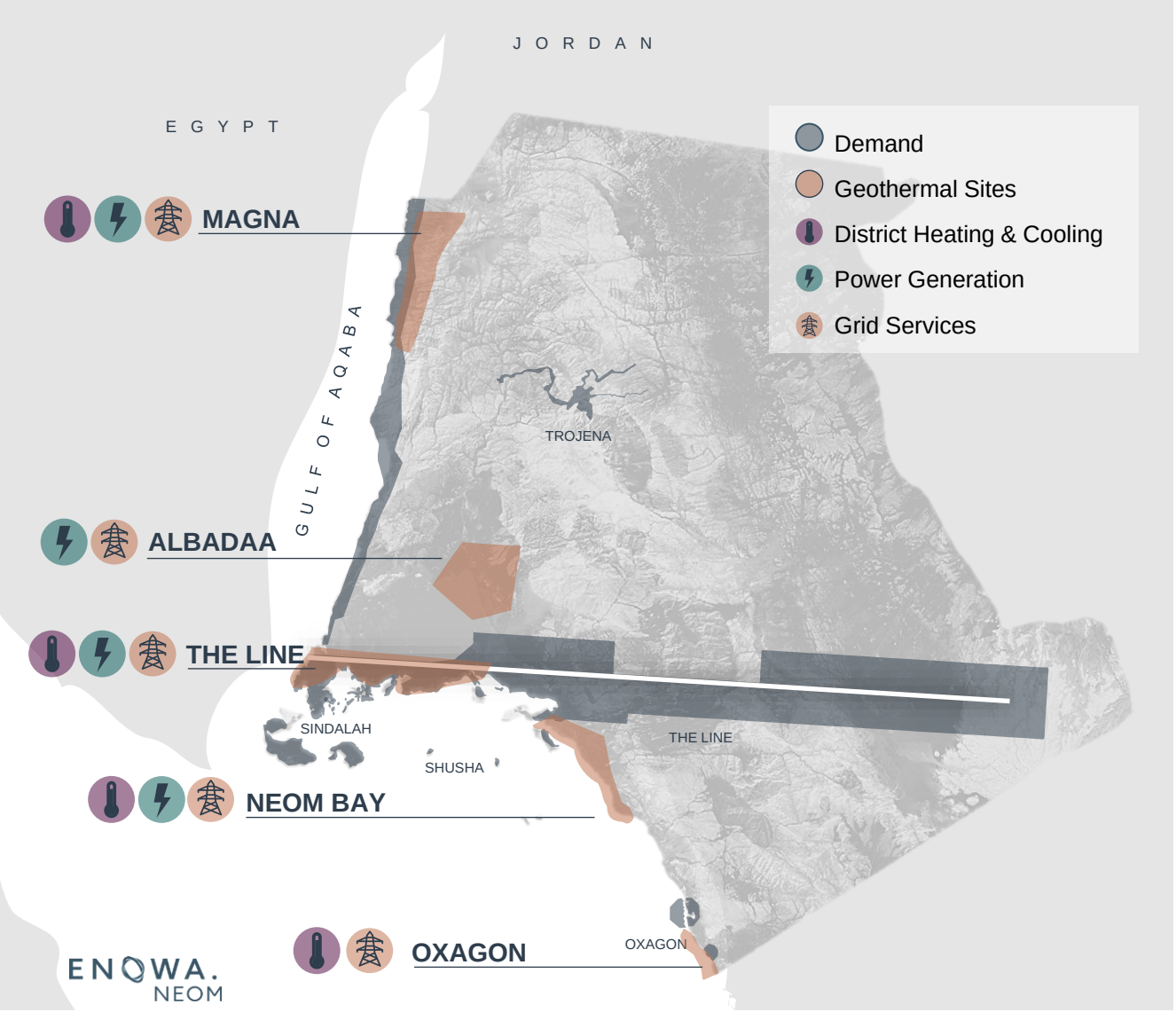
- Cooling intrusions as potential heat sources
- Convective hydrothermal system; med-high enthalpy geothermal resources

4 Proterozoic **Granitic Basements**

- Elevated heat flow from radiogenic heat generation
- Permeability assoc. with fracture systems
- Enhance / Advance geothermal system (E / AGS)

ENOWA. NEOM

WHERE: NEOM features five geothermal sites, indicating substantial potential for harnessing geothermal energy that can be strategically utilized.



We've identified five locations for harnessing geothermal energy: THE LINE, OXAGON, MAGNA, ALBADAA and NEOM BAY. More details on some projects are below:

- **THE LINE**, a strategic site, will leverage geothermal for heating & cooling, baseload power generation, and other applications including grid services.
- **OXAGON**, will leverage geothermal for industrial processes, heating & cooling, baseload power generation, and grid services.
- **Other projects**, including NEOM Bay Airport, MAGNA, and TOPIAN Fish Company. Geothermal energy will be utilized for industrial processes, heating & cooling, baseload power generation, and grid services.

Note: All baseload power generation can have an off-grid option.

Relevant global example: Binary Cycle projects in Turkey's Aegean Region

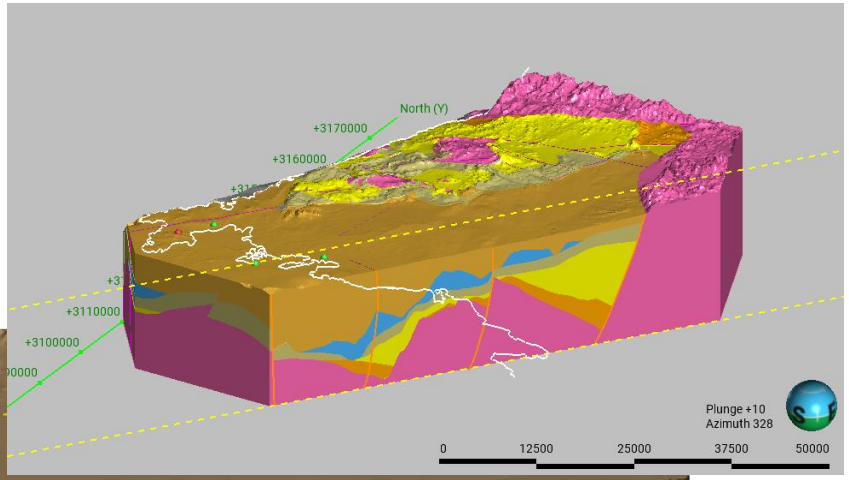
Unit Capacity (MWe)	13	24	12	24	24	20	22	22	22	22	25	50	25	24	24	7.9	9.5	17	34	36	102	18	176	25	26	25	6.5	3.8	3.5	Total = 757

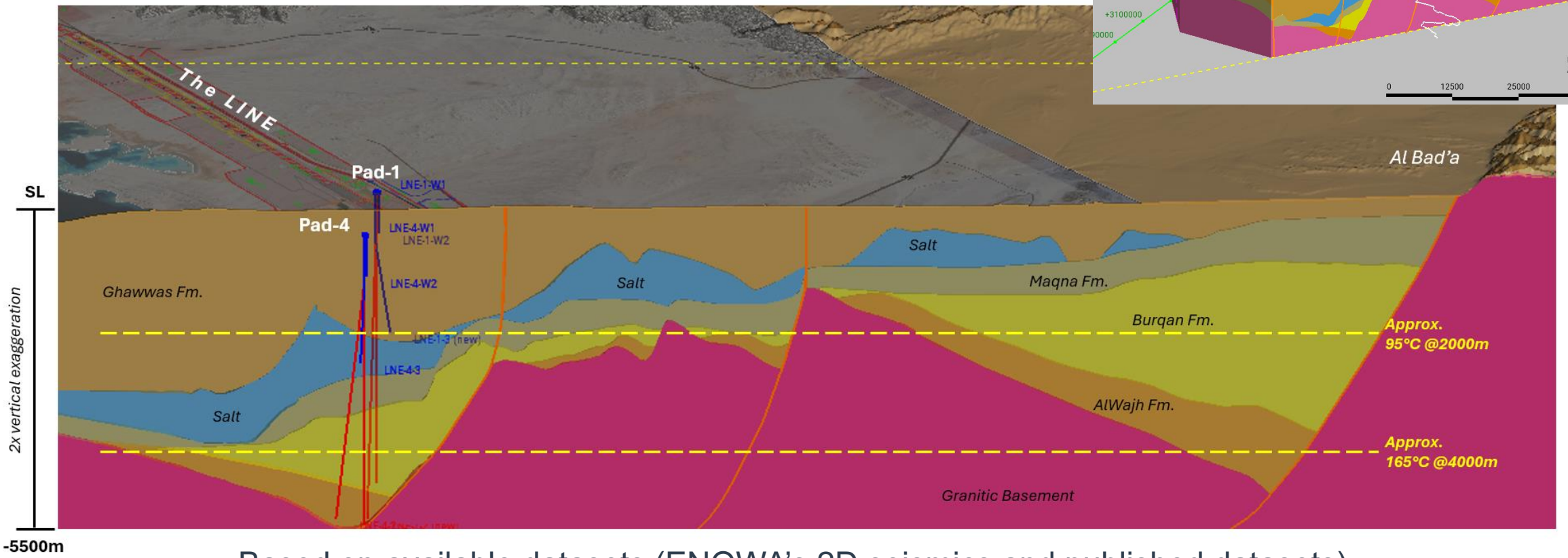
- Turkey developed ~30 Binary Cycle projects from 5-177 MWe in this region with LCOEs ranging from 60-90 $/MWh.
- This was done in ~10 years.
- THE LINE could look like this, and even better.

ENOWA. NEOM

CHARACTERIZATION OF SUBSURFACE GEOLOGY:

Essential for geothermal exploration, resource assessment, development, production and monitoring



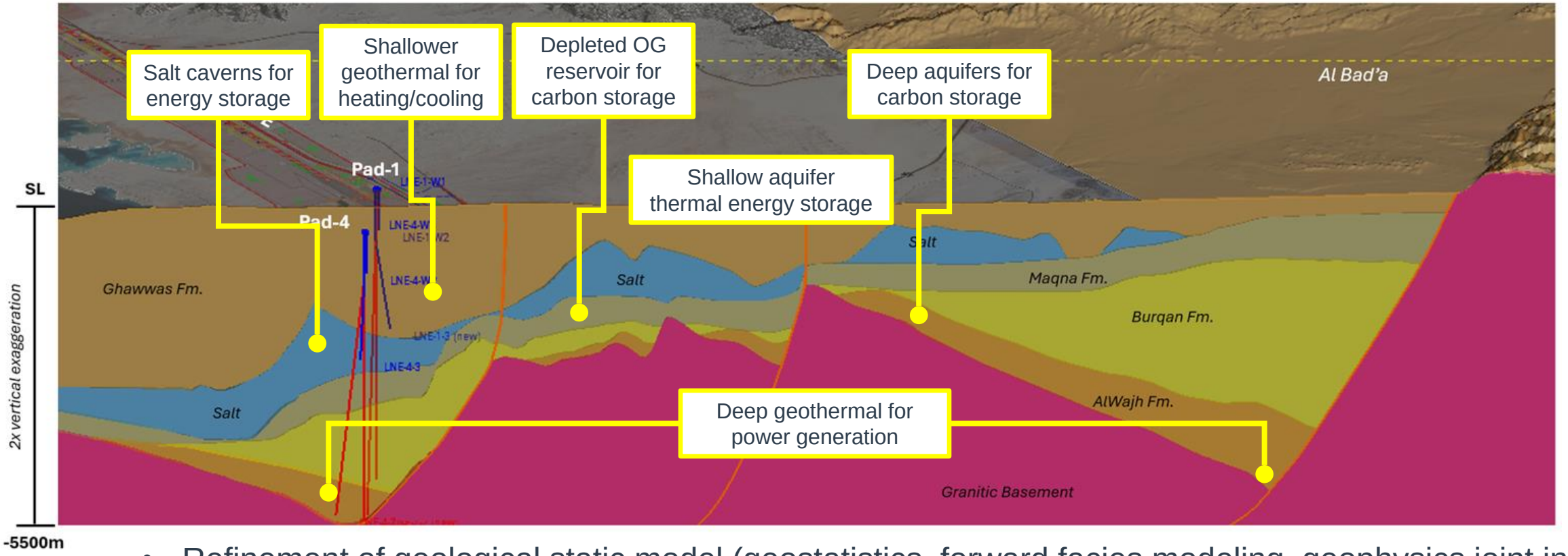


- Based on available datasets (ENOWA's 2D seismics and published datasets)
- Eventually, validated and updated by well data
- Continued with reservoir property modelling and numerical simulation for resource management

ENOWA. NEOM

BEYOND GEOTHERMAL: **SUBSURFACE 'SPATIAL PLANNING' AND MONITORING**

Utilization of various geologic formations for geothermal, carbon storage, underground energy storage, waste disposal, hydrogen production, in a safe and sustainable manner



- Refinement of geological static model (geostatistics, forward facies modeling, geophysics joint inversion modeling, tomography, geomechanics)
- Monitoring during operation and production (MEQ, gravity-leveling, well data, chemistry, hydrology, etc.)
- Numerical simulation for resource management (forecasting and monitoring)
- Digital twin for Earth's model

ENOWA. NEOM

CURRENT STATUS OF THE LINE PILOT:

THE LINE'S AMBITION IS TO LEVERAGE GEOTHERMAL AND PROVIDE POWER TO LABOR AND LOGISTICS CAMPS.

Development to Date

- ☑ Assessment of legacy data
- ☑ Literature review
- ☑ Reconnaissance survey
- ☑ Preliminary resource estimation
- ☑ Additional FTE hired
- ☑ 2D seismic survey
- ☑ Geological model developed
- ☑ Site assessment
- ☑ Drilling strategy
- ☑ Procurement of engineering support
- ☑ First two locations of well pads
- ☑ LUP Memo from THE LINE

On going

- ☑ PQQ of drilling services
- ☑ Awarding of drilling materials
- ☑ Awarding of ESIA and ENVID
- ☑ Eng. for access and well pads
- ❑ Procurement of Civil Contractor
- ❑ Awarding of water well drilling

Next Steps

- ❑ Procurement of materials
- ❑ Awarding of MAGNA exploration
- ❑ RFP of drilling services
- ❑ RFP for access and well pads
- ❑ Drilling of water wells.
- ❑ Power plant concept selection
- ❑ EPC RFP preparation

ENOWA. NEOM


ENOWA.
NEOM

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Geothermal Potential, Challenges and Efforts in the Kingdom Of Saudi-Arabia

Marije van Koolwijk, VP Geosciences & Engineering

IADC 8 November 2024

TAQA Geothermal

VISION – To become the *Enabler of Clean, Reliable and Sustainable Geothermal Energy*

1 GW to the Energy mix

Emissions **reduction** projects to meet
(NDC, SGI and and NET Zero Ambitions)

Energy efficiency and diversification

Contributing to Kingdom GDP

Partnership with Academic Institutions and New Technology players

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TAQA Geothermal

Leading the way in Renewables, through Geothermal Energy Exploration

- Joint venture with Reykjavik Geothermal established March 2023
- Continue journey that started in Turkey in 2021 with Geothermal Center of Excellence

Stake holder engagement

- MoE, SGS, MEWA, ARAMCO, NEOM, KACARE, KAUST and regional efforts with ADNOC, MASDAR, TABREED

Scope

- Resource assessments and pilot projects
- Exploration & Development programs
- development of geothermal resources

Technology

- Monitor emerging technologies to increase resource viability
- Pioneer Geothermal adoption via technology in KSA and region

Why Geothermal?

- Baseload renewable power
- ***Least Cost*** economics
- Strong potential in KSA
- SGI alignment
- Part of renewable strategy to add 1 GWe to grid

Why RG?

- Industry leader
- Experience in region (KSA and UAE)
- Aligned objectives
- Global project experience

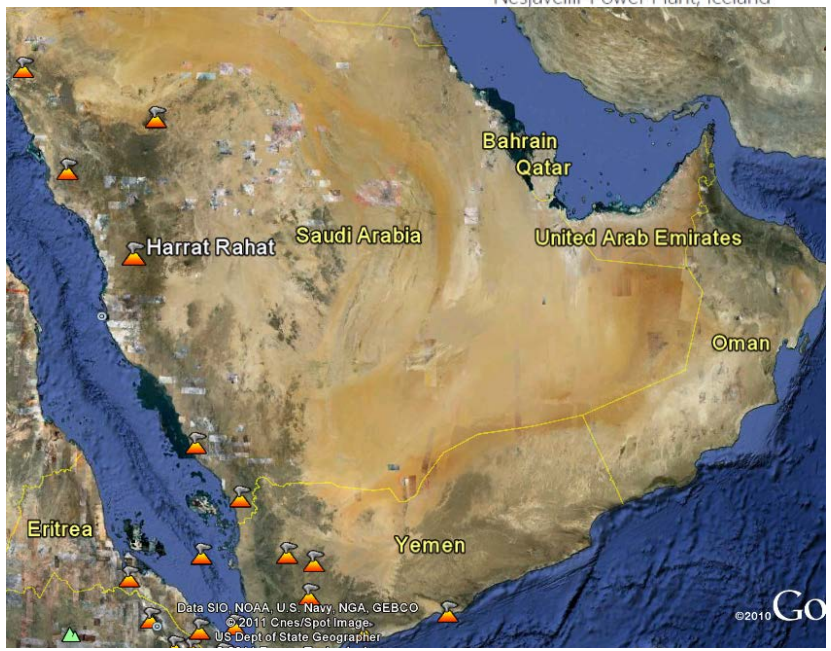
by **2030**

120 Gwa – KSA Yearly electricity consumption

60 GWa – Target Renewables

1 GWa Target Geothermal

Nesjavellir Power Plant, Iceland



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Reykjavik geothermal beach
Iceland

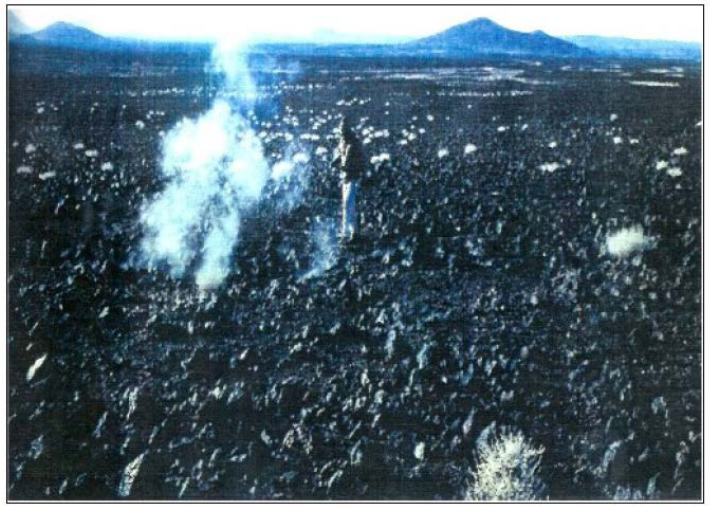
Ain Al-Harrah – Al Lith
Saudi Arabia

Rotorua Hot Springs
New Zealand

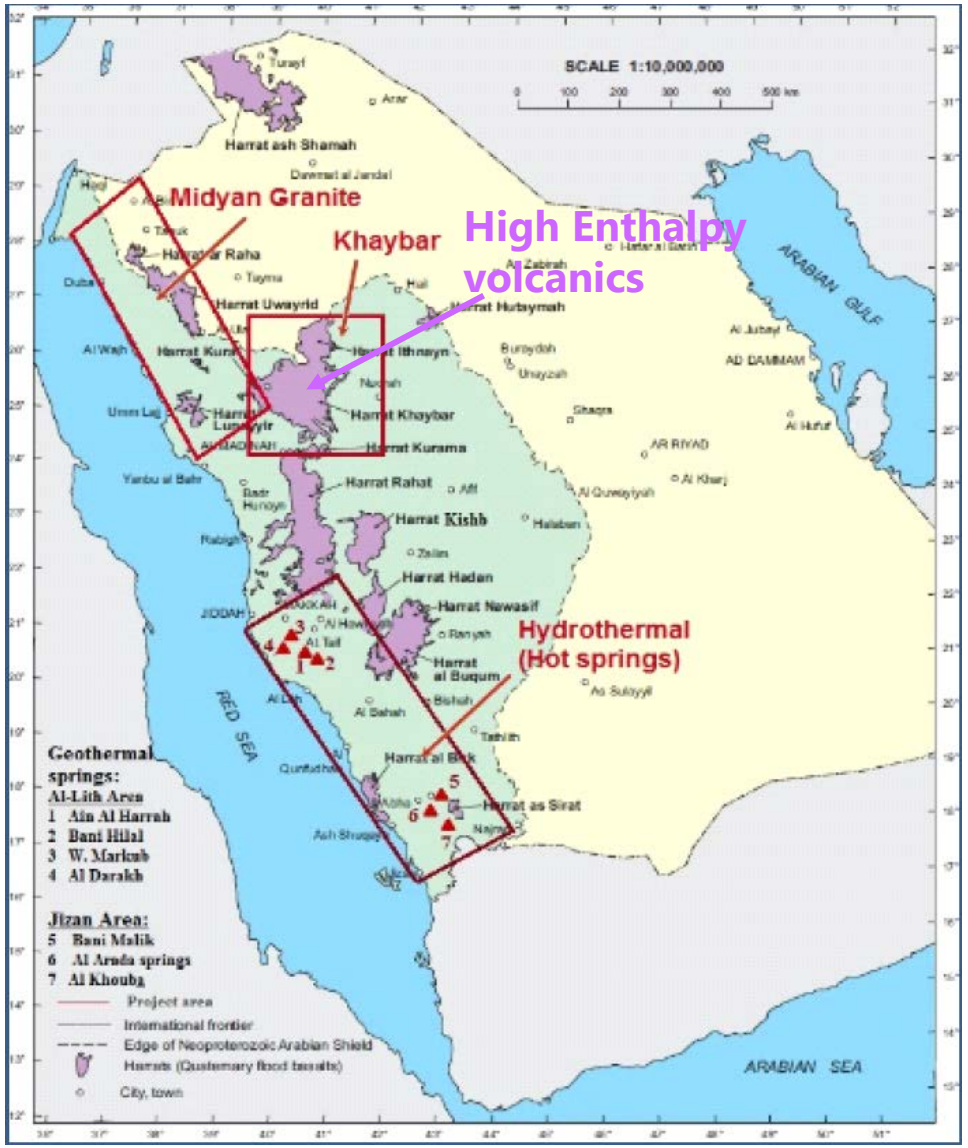
Jabal Bayda & Jabal Abyad Lava Dome – Harrat Khaybar volcanic field - Last confirmed eruption 650 AD (+/- 50 yrs)
Saudi Arabia

Geological Areas of Interest

- Western and south western coast of Saudi Arabia – known as Arabian Shield – Jizan and Al-Lith
- Harrats covering approx. 80,000 km2 basaltic high enthalpy rocks
- Midyan and Haal granites are good examples located in the north and north-western part of KSA.
  - Very good candidate for Enhanced Geothermal System (EGS) to support economical development



Steam Fumaroles escaping from geothermal rocks at Harrat Khaybar



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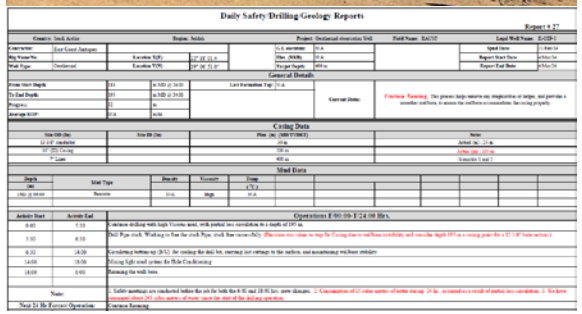
Project Updates – KAUST Observatory Well

"KAUST ambition to become first GREEN/renewable campus in Saudi Arabia"

- Well successfully drilled to TD depth of 400 m without incident in spring 2024
- Planning of deep wells for extended exploration of geothermal resources


Daily Safety/Drilling/Geology Reports

Well Name: K-GEP-#1
Rig Name: EastCoast-1

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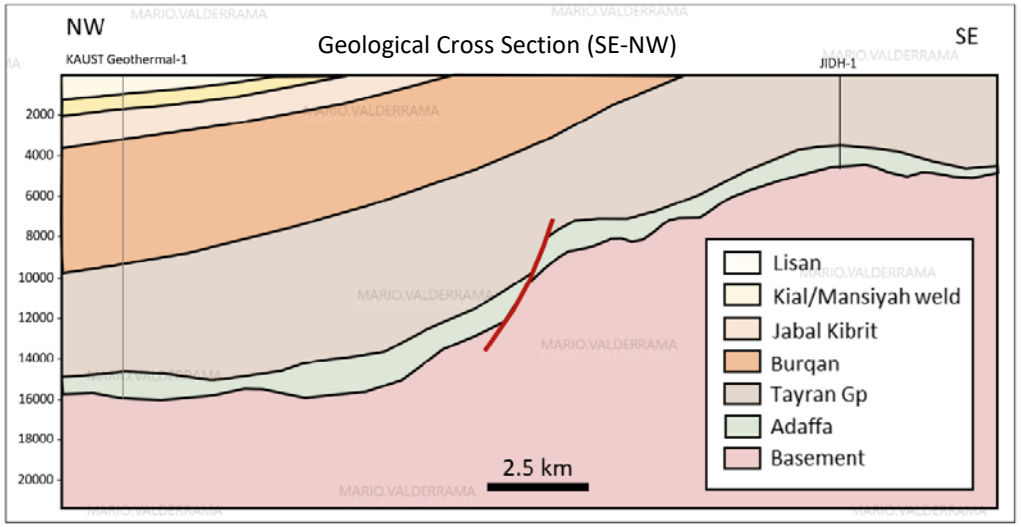
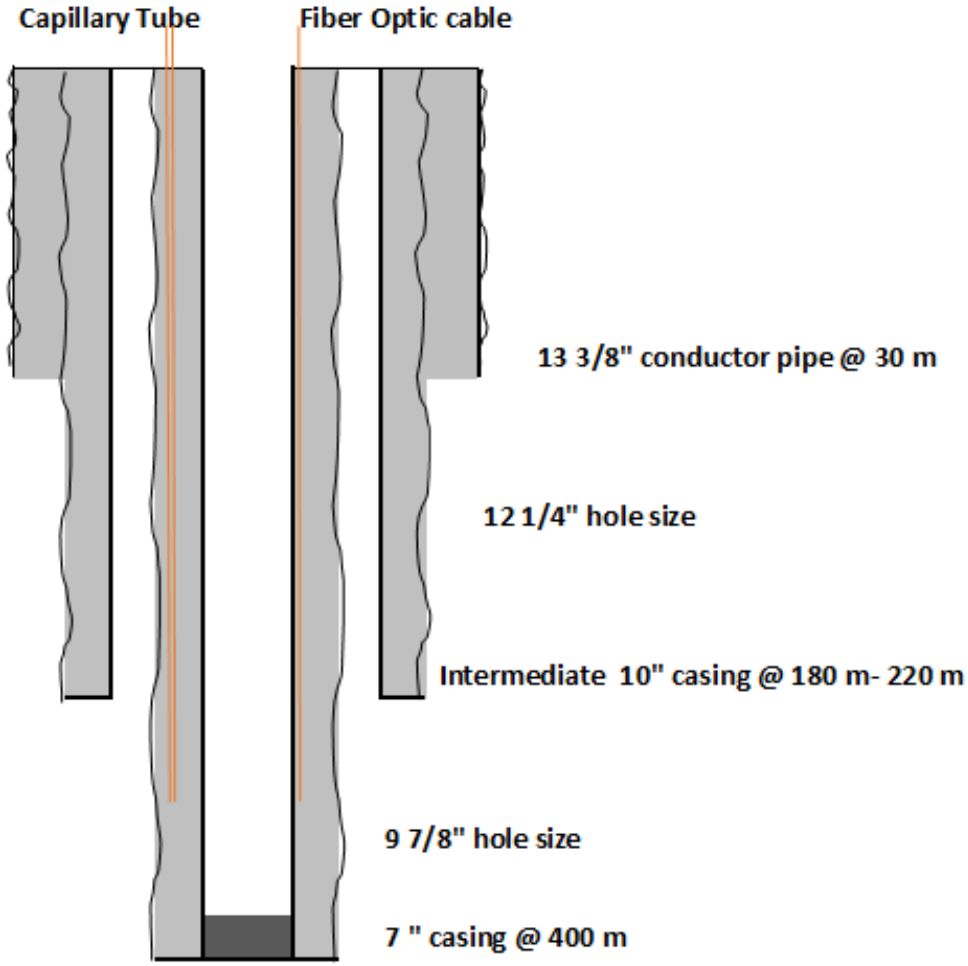
A 400m Deep Geothermal Research Well

- Drilled for evaluation of low enthalpy wet geothermal system: 2200 m - 100 deg c, 4400 m, 176 deg C
- Required 30 k bbl/day flow rate of water.
- Experimenting with different well evaluation technologies:
- Testing of Fiber Optics installations and data acquisition and processing hardware and technologies.
- Continuous downhole seismic monitoring & calibrating surface seismic data.
- Formation water samples collected to test the lithium potential for enhancing project economics.



Surface Acoustic Sensor Set-up



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KSA Geothermal Outlook

Geothermal energy development requires massive efforts, joined industry efforts to accelerate

- The next ~2 - 3 years KSA Geothermal development will be in exploration, assessment, drilling, and testing phase
- Power generation and large-scale projects will start to be understood after initial assessment, drilling and testing of wells
- Key projects to be piloted with tremendous potential:
  - District Cooling
  - Desalination
  - Data Centers

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Drilling Developments

Drilling efficiency key to lower cost and accelerate geothermal activities as crucial component in project economics

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KSA Opportunities

Geothermal energy development will assist in district cooling and desalination power and freeing fossil fuel-based systems

KSA Facts:

- Global warming hotspot: T increased with more than 3 °C in the last 40 years.
- Third-largest consumer of cooling electricity in the world (after US and China)
- AC accounts for more than 50% of total annual electricity consumption in buildings and for around 70% at peak cooling demand.
- Highest usage of AC in the world, with 101 TWh used by households and 70 TWh by businesses in 2018.

KSA Electricity

- Consumption 331 bn kWh
- Production 362 bn kWh from 99.9% from fossil fuels
- Installed capacity of solar currently at ~500-700 MW

Renewables

- Solar: targets of ~20 GW by 2023, 40 GW by 2030
- Wind: target of ~7 GW by 2023, 16 GW by 2030

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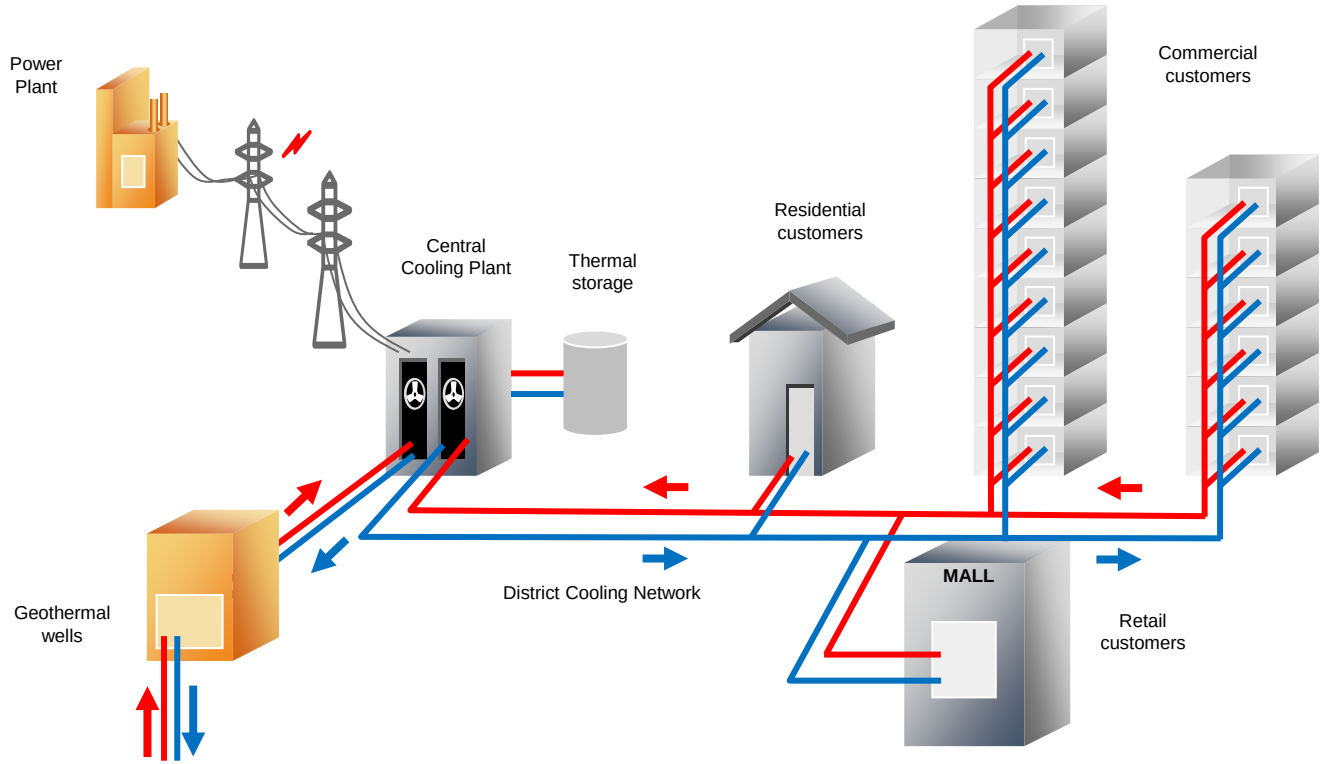
District Cooling

District Cooling System (DCS) in the Middle East using geothermal energy

- District cooling consumes majority of electricity needs in KSA
- Case for scaled up district cooling using shallow well geothermal with geothermal based heat exchange pumps



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Abu Dhabi: Madsar Geothermal Project

- Masdar UAE project
- First geothermal project in the UAE
- Drilling of two ~2600 m wells started 2010
- IPM done by Reykjavik Geothermal
- Services partly provided by AMPS
- 2023 stimulation performed by TAQA Well Solutions
- Temperature exceeding 90°C and flow rates of approximately 100 liters per second (l/s)
- Absorption cooling system used to feed Tabreed's district cooling network at Masdar City, accounting for 10% of its cooling needs

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Global Experience and Growth Opportunities

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TURKEY

- **Geothermal in TURKEY**
- **300 wells milestone reached by TAQA drilling services**

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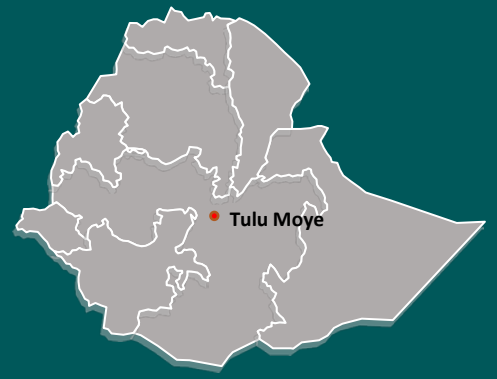
Iceland: Hellisheidi Geothermal Power Plant

- **One of the largest geothermal plants in the world:**
  - **303 MWe of electric power capacity**
  - **400 MWth of hot water capacity (200 MW currently utilized)**
- **Developed under the then Reykjavik Energy CEO and current RG Board Chairman Guðmundur Thoroddsson**
- **RG team members were responsible for decision making, contracting, geoscience, financing and operations**
- **Located in Hengill, an active volcanic ridge in Southwest Iceland**

Ethiopia: Tulu Moye Geothermal Project

- **150 MWe**
- **Extensive geological studies indicate the presence of some of the world's larger high-temperature geothermal resources (third party estimates put the size of each resource at up to 1,500-2,000 MW)**
- **Drilling in Tulu Moye, first steam encountered**



RG Case Studies
Tulu Moye Geothermal Project in Ethiopia

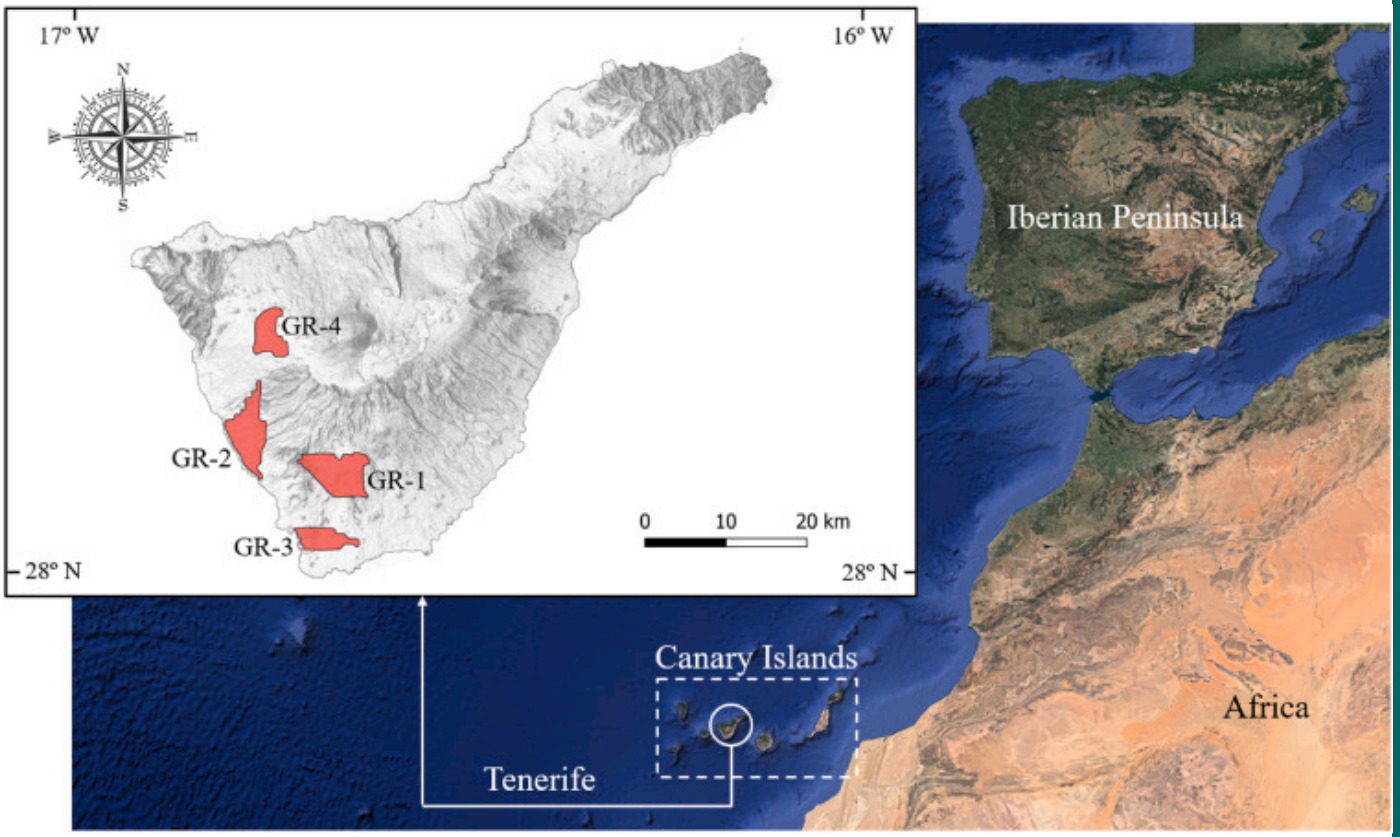
RG
Reykjavík Geothermal

Geothermal Development Opportunities RG

ICELAND

- Olfus project a 10 MW_e, 50 MWth
  - Resourche assessments in final stages
  - Planning in process
  - ESIA done
  - Permitting and PPA in final stage
- Bolalda project a 100 MW_e, 500MWth
  - Resource assessments in final stages
  - Planning in process
  - ESIA done
  - Permitting and PPA in final stages
  - PPA in final stages
  - Execution staggered with Olfus

Geothermal Development Opportunities



SPAIN

- Tenerife- 3 project areas under exploration, 100-300 MW_e planned
  - Surface exploration in final stages
  - Drilling tendering ongoing with expected start Q2 2025
  - EISA and Permitting in final stages
  - EU grants in place (42 million Euro)
  - PPA under negotiation
- Las Palmas 20-30 MW_e planned
  - License area granted
  - EU grants in place (14 million Euro)
  - Surface exploration to start soon

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Conclusions and Recommendations

- The different Geothermal Energy Resources in KSA need to be further investigated and evaluated with a focus on acceleration.
  - Low to medium enthalpy geothermal energy can be directly deployed in KSA to replace electricity for heating, cooling, and desalination.
  - EGS can be a solution for developing vast high heat flow radiogenic granites geothermal resources in KSA and enhance economics.
  - Potential to reduce local fossil fuel consumption with up to 1,000,000 bbl of oil per day.
  - Significant GHG emissions reduction assist in achieving KSA NDC targets.
- Drilling challenges related to materials, efficient drilling still require industry and academic joint efforts to improve economics, efficiency and longevity.

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Acknowledgements

- TAQA Geothermal and RG for allowing the use of TAQA Geothermal data
- KAUST for allowing the use of KAUST research well design and objectives

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OMV

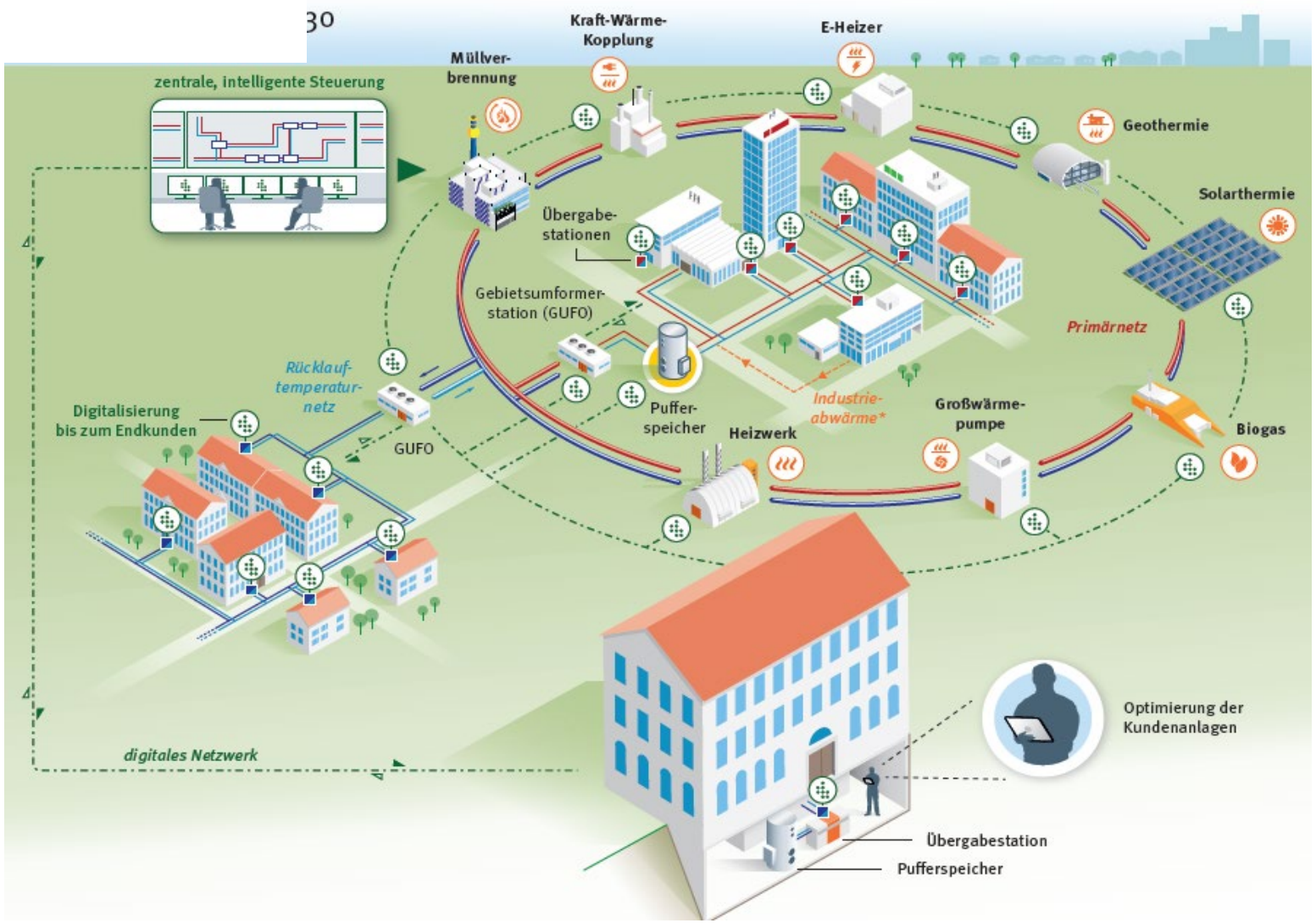
Deep Geothermal Energy for Decarbonizing the City of Vienna

IADC Meeting Dubai 2024

Alexander Heger

Decarbonizing heating grids

What do we want to achieve? – Example Vienna



Current heat distribution network

- Heat distribution network covers ca. 36% of the entire heat market in Vienna
- Stake of renewables: 18%
- Customers: ca. 400.000
- Network length > 1.200 km

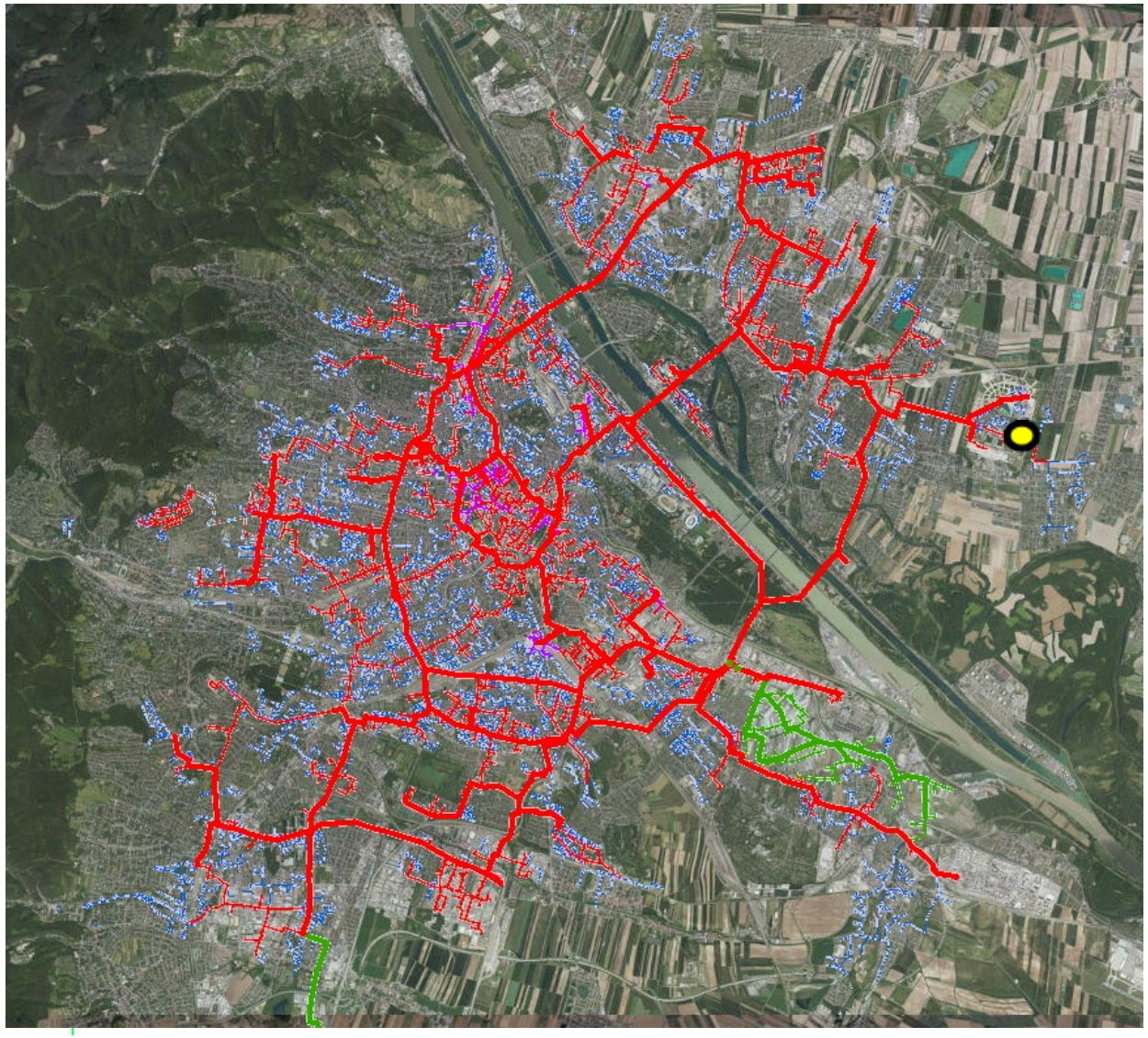
3 pillars of decarbonizing the heat distribution network

- Diversification of production portfolio
  - Deep geothermal energy
  - Usage of waste heat
  - Saisonal heat storages
- Digitization of heating grid
- Sustainable optimization of the customers

Climate neutral heating grid 2040

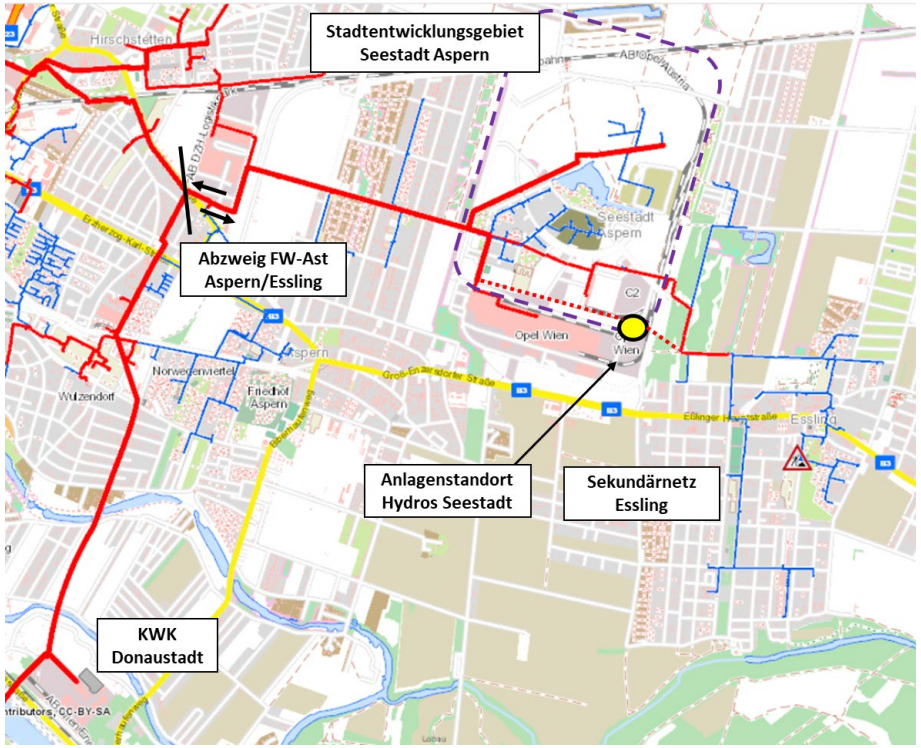
- 2040, 56% of heating demand to be covered by heat distribution network
- 55% in the portfolio of the heat distribution network will come from deep geothermal energy and industrial heating pumps

Hydros Seestadt
City of Vienna disctrict heating network



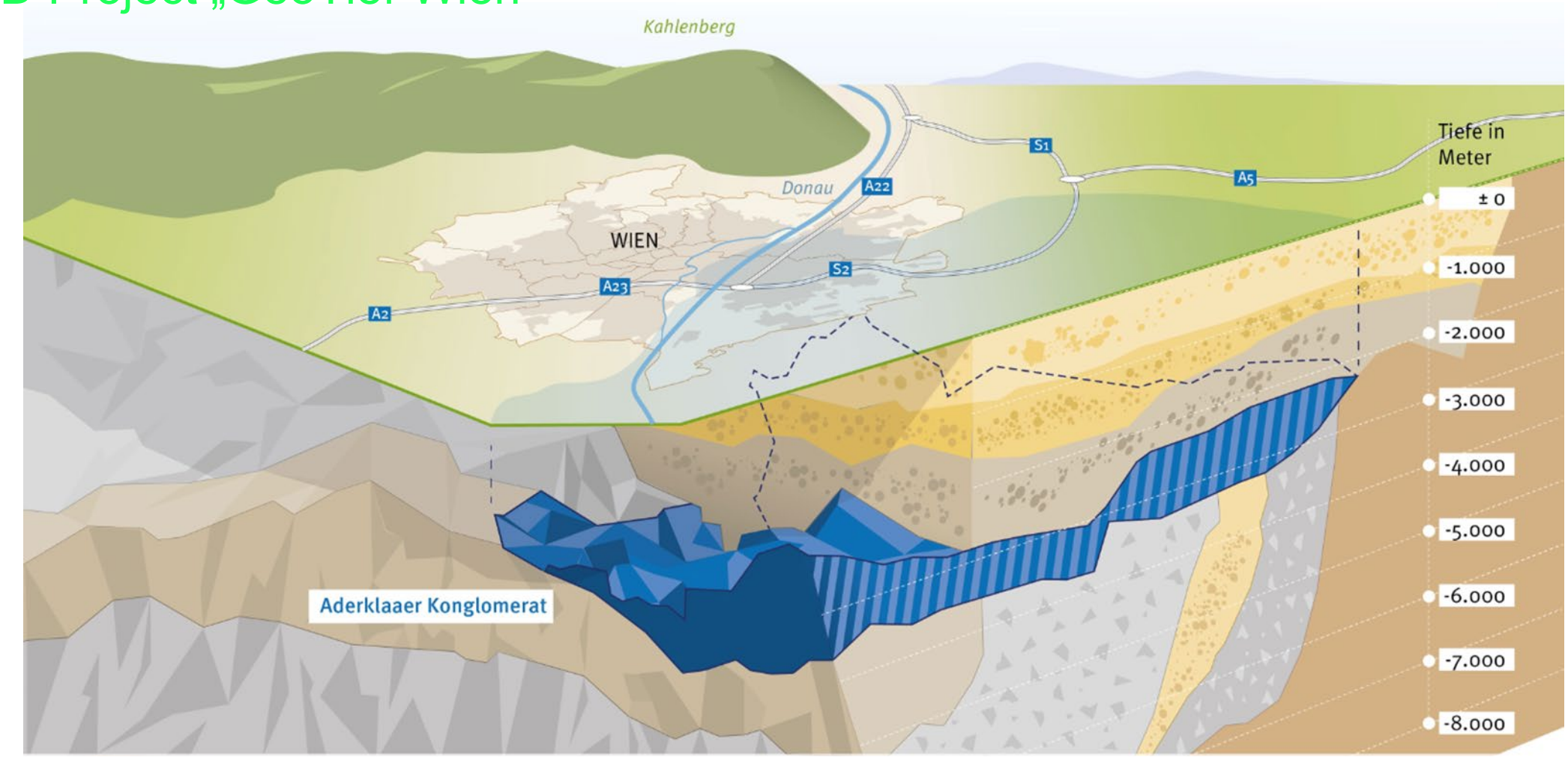
Overview map of the **district heating network in Vienna** (red = primary network; blue = secondary network) with the location of the **future geothermal energy plant " Hydros Seestadt"**

Aspern/Essling district heating network area



„Treasure beneath Vienna‘s feet“

R&D Project „GeoTief Wien“



Production Test: Essling TH-1

R&D Project „GeoTief Wien“

Production test
Proof of hot water in Vienna‘s subsurface

Knowledge gain
Test results de-risk planning of pilot plant Hydros Seestadt

deeep Tiefengeothermie GmbH

Joint Venture OMV / Wien Energie

WIEN ENERGIE

Wien Energie operates numerous **heat generation plants** and one of the **largest district heating networks** in Europe.

By 2040, Wien Energie aims to make its **district heating production** completely **climate-neutral**. Geothermal energy plays a decisive role.

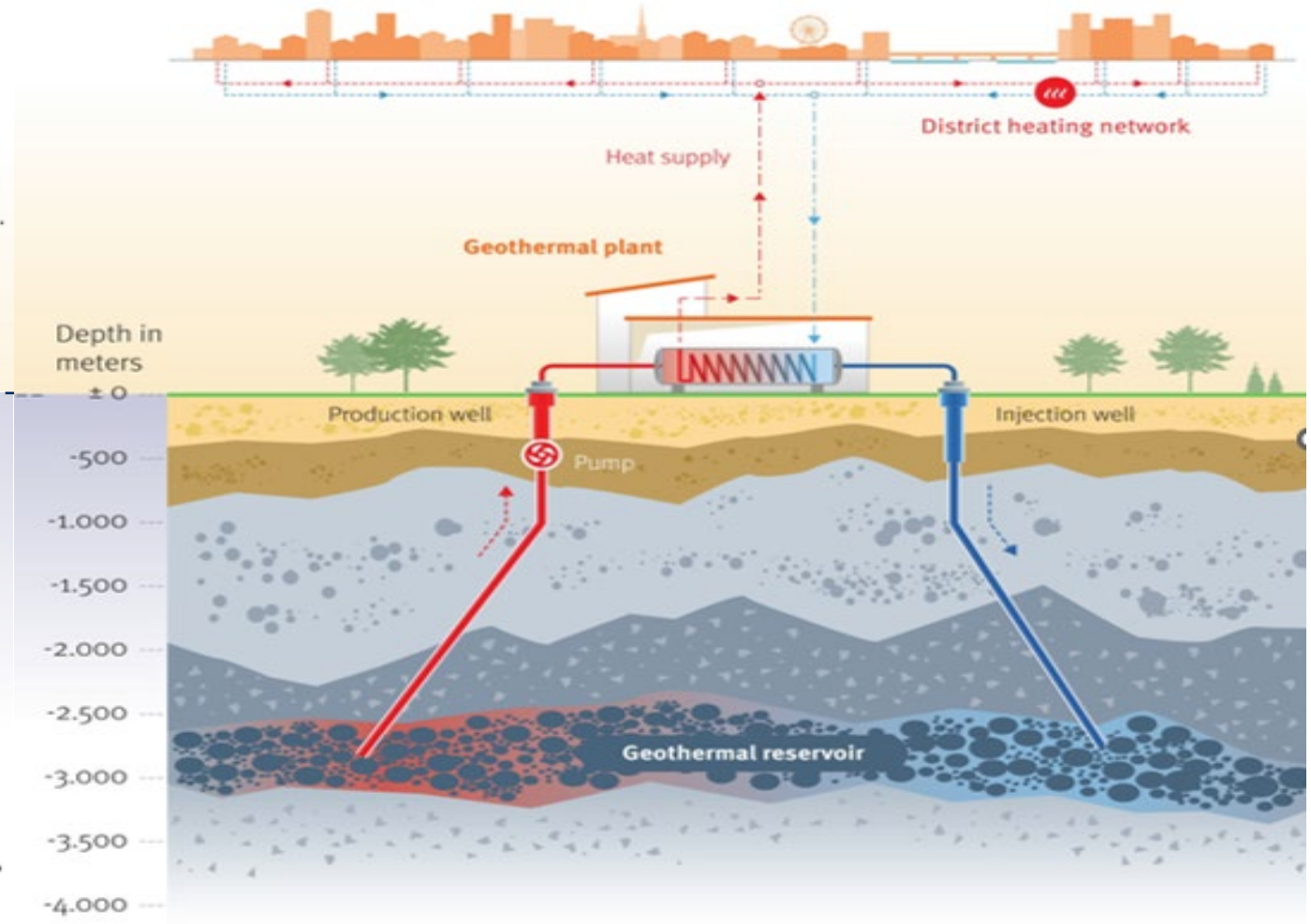
Wien Energie is responsible for the **planning and construction** of the surface facilities, including **construction and operation** of heat exchangers, heat pumps and the transfer of the heat to the district heating network.

OMV

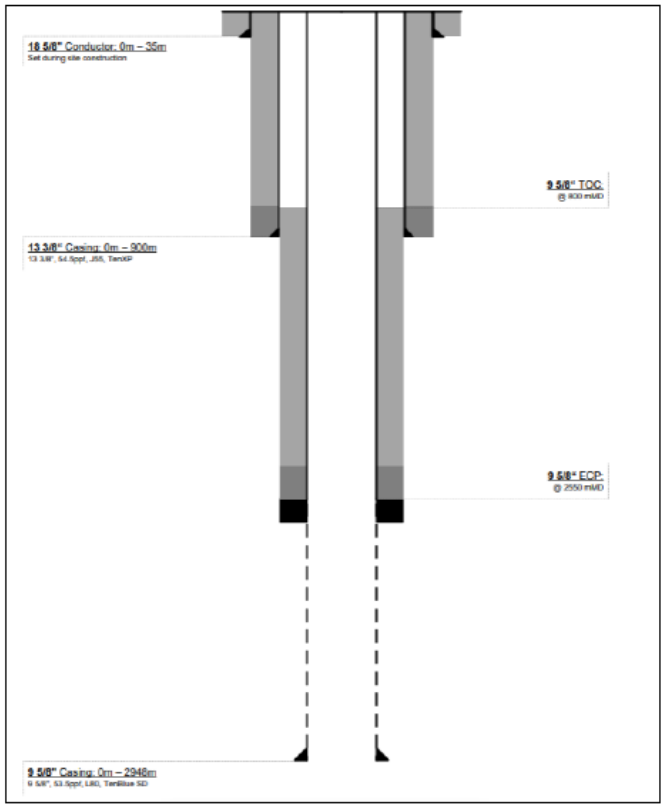
As a globally active company, OMV has decades of experience in the fields of **geology and geophysics** as well as **drilling and production technology**.

The use of deep geothermal energy is one of OMV's strategic goals to provide **low-CO_2 forms of energy** in the future.

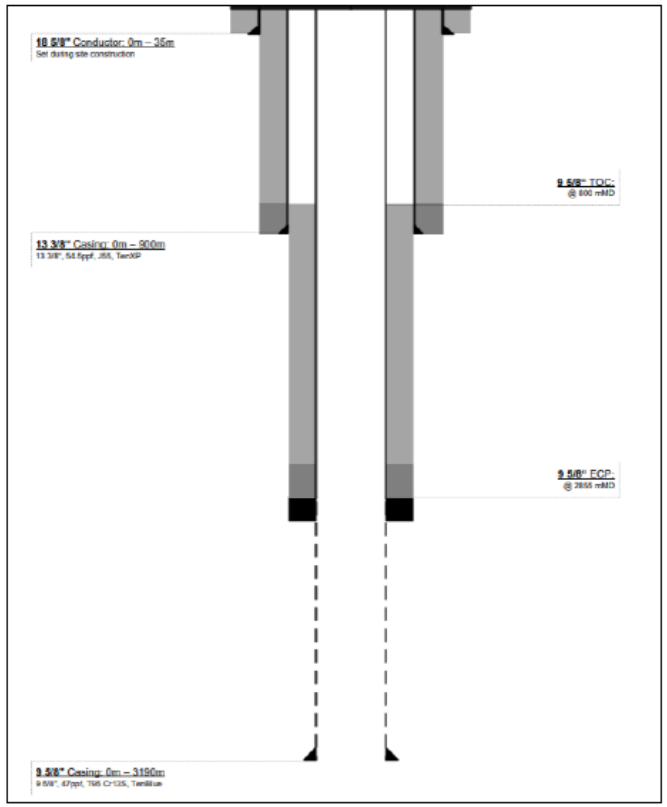
In the joint venture, OMV is responsible for all **subsurface activities**, i.e. the **planning and drilling** of geothermal wells and the **production** of hot water.



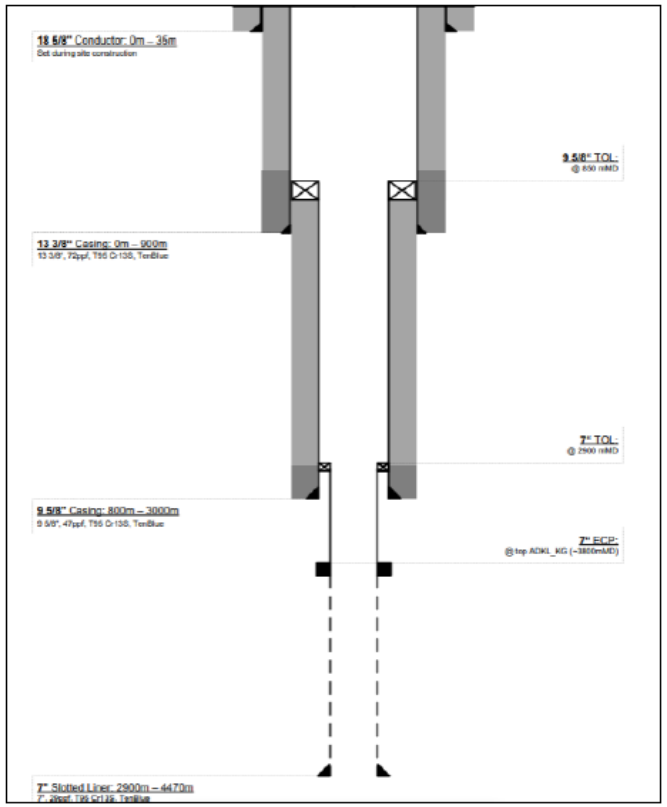
Well Construction



Pilot well / Backup Injector
Vertical well (max. 10° deviation)
Carbon steel
Fiber Optics on casing
9 5/8“ slotted liner in reservoir



Injector well
40° deviation
Mainly Cr13S
9 5/8“ slotted liner in reservoir



Production well
50° deviation
Mainly Cr13S
7“ slotted liner in reservoir
ESP on 9 5/8“ production string in 13 3/8 Casing

Project Hydros Seestadt

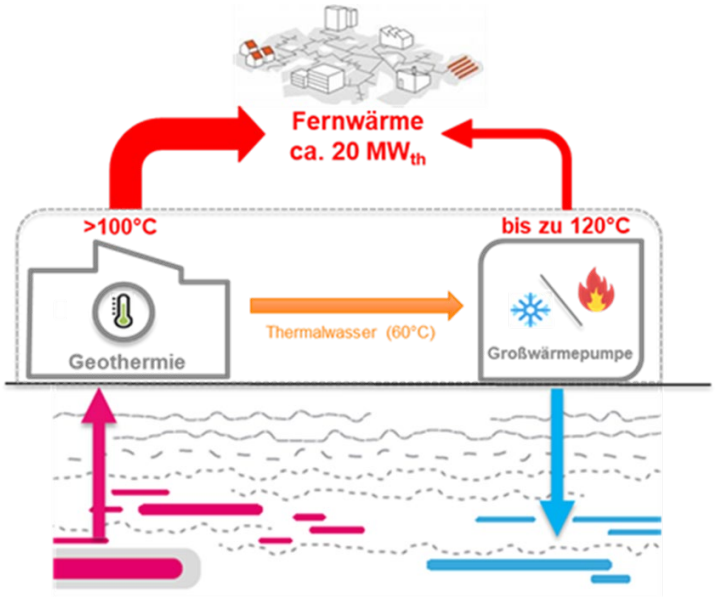
Overview

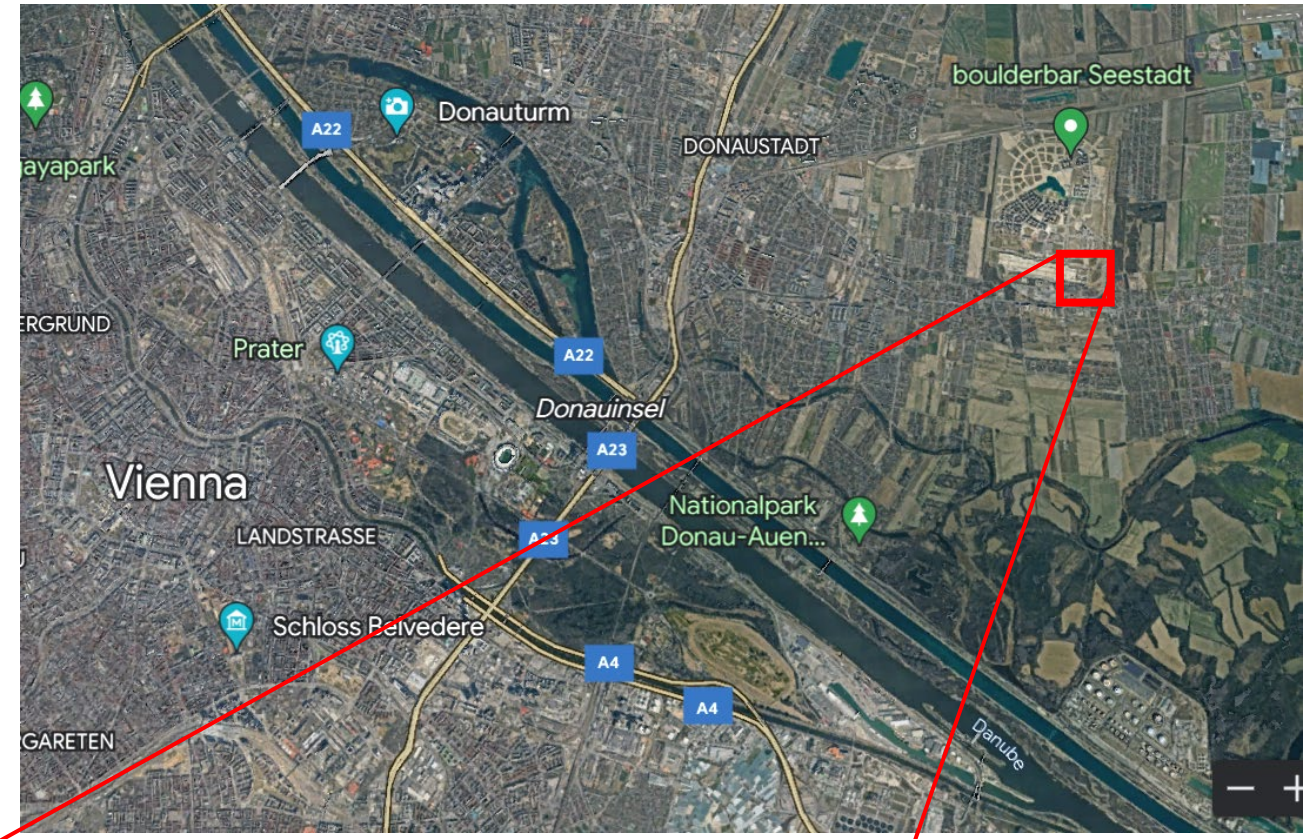
20 MW_{th}

Geothermal plant combined with industrial heat pumps

From 2027

Supplying 20.000 Viennese households with green energy from the subsurface

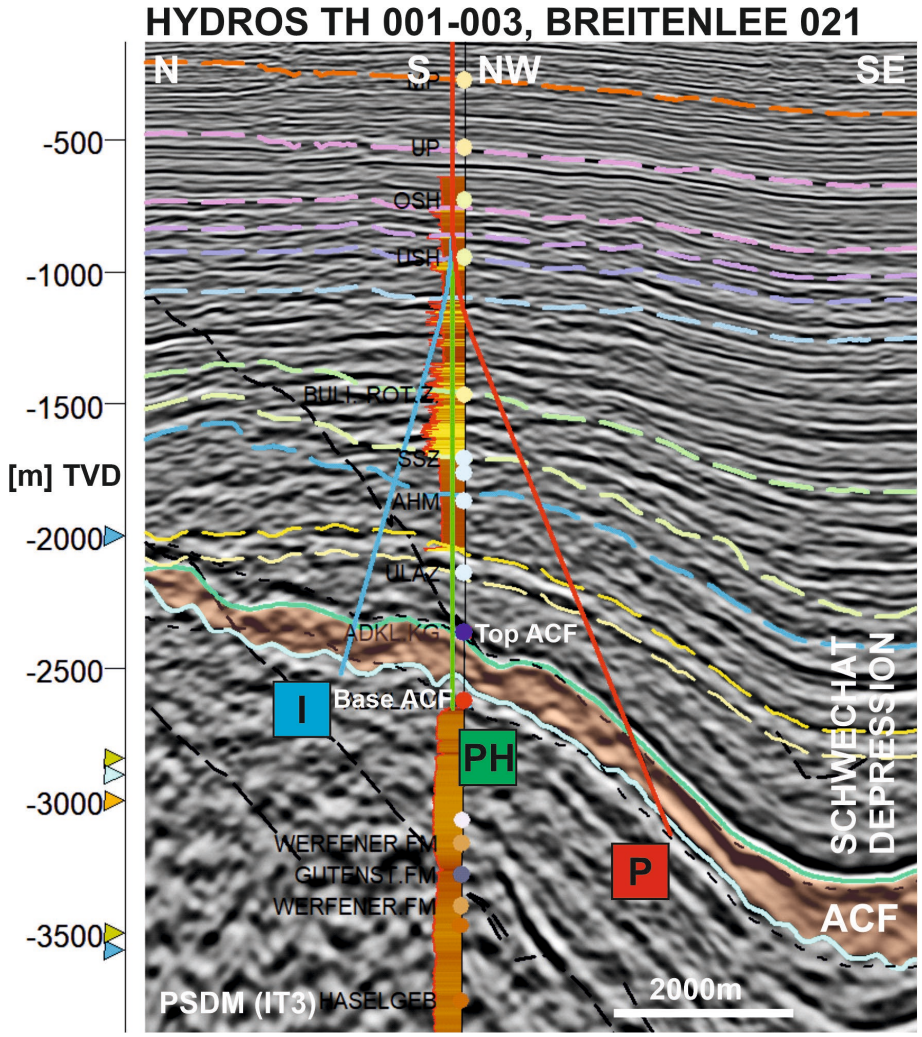




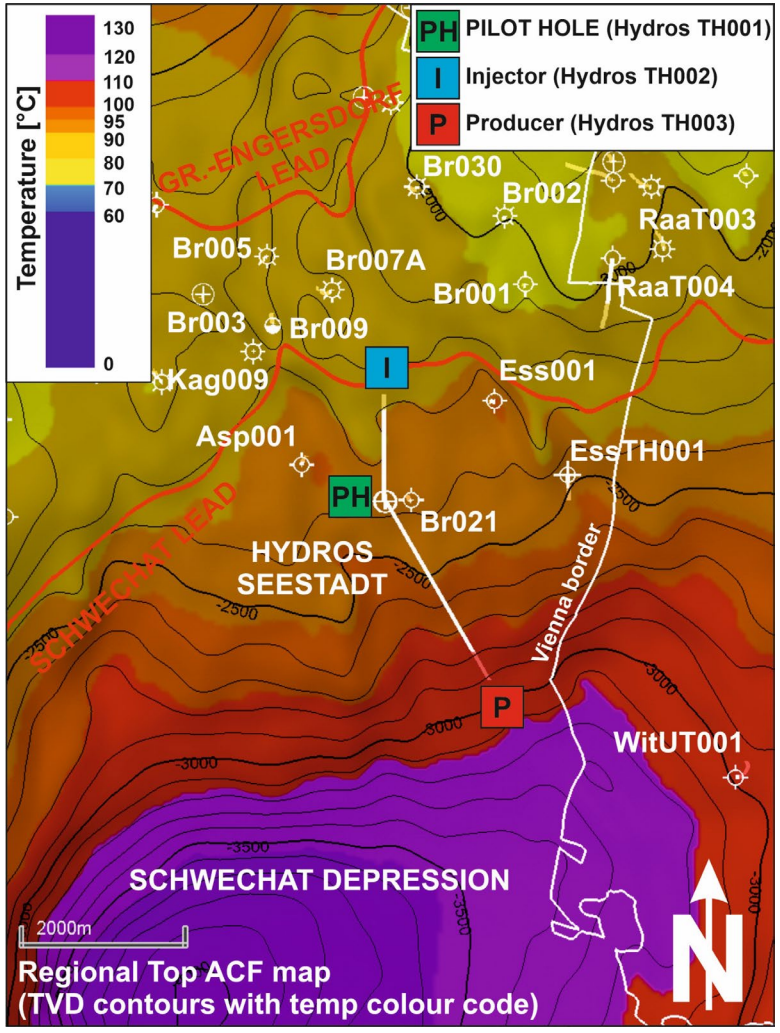
Hydros Seestadt location

Project Hydros Seestadt

Reservoir & Drilling information



Seismic cross section



Structural map of the ACF with temperature overlay

- **Reservoir:**
  - ACF in the Schwechat depression
  - Conglomerates of L. Badenian in a braided river system
  - Depth: ca. 3000m with thickness of >350m
  - Temp. of ca. 100°C und anticipated production rate of around 80l/s
- **Pilot well (PH):**
  - Possible backup as injector well
  - Monitoring: Induced seismicity, tracers
  - Generating additional data (cores, logs)
- **Injection well (I):**
  - Located in the shallower part of the reservoir
  - Big distance to the producer to avoid an early thermo hydraulic break through
- **Production well (P):**
  - Achieve highest possible temperature and long exposure to the reservoir
  - Penetrating the reservoir southeast of the well site in the deeper part of the Schwechat depression

Thank you