Geothermal contributions to offshore energy systems: North Sea.

John Zuta – EOR/SCAL
Walter Wheeler – Subsurface / Sustainable Energy Labs

“The geothermal energy industry has never quite realized its true potential despite the seemingly magical promise of nonstop, 24/7 renewable energy sitting just below the surface of the Earth.”

Molina et al. 2021.
Geothermal Production from Existing Oil and Gas Wells: A Sustainable Repurposing Model. SPE-207801-MS.

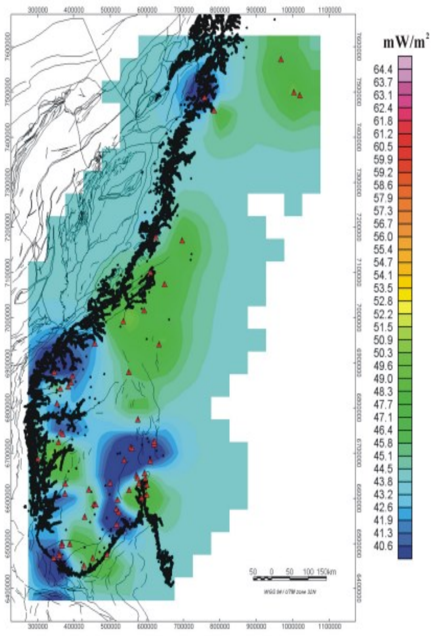
Geothermal potential on NCS

Mainland Norway

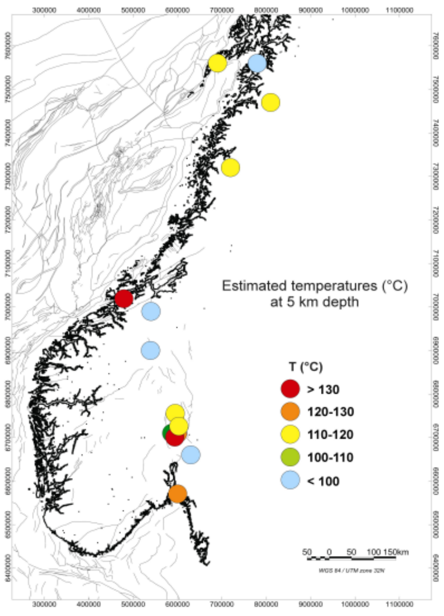
- 18 °C/km mainland average.
- Several deep wells indicate >26°C/km (red dots)

North Sea/NCS

- 34.6 °C/km North Sea average geothermal gradient
- 45°C/km locally in e.g. Central Graben, central Utsira High.
- 59 °C/km Gro discovery



Maystrenko Heat flow map on the NCS



Temperature Distributions NCS

Field	Well	Water depth	Geothermal gradient avg.,°C/km	Reservoir		200°C Isotherm		Notes
				approx. T °C	depth (m rsf)	depth (m rsf)	Dist. below reservoir (m)	production; structure
Balder	25/11-4 S	127	52.9	94	1773	3782	2009	Oil/Gas; fpso
Grane	25/11-21A	129	46.8	83	1775	4275	2500	Oil; platform
Fram H-Nord	35/11-15	360	46.5	121	2601	4298	1697	Oil/Gas; subsea
Johan Sverdrup	16/2-10	115	46.1	84	1820	4337	2517	Oil; platform, electrif.
Tambar	1/3-4	72	45.1	186	4128	4430	302	Oil; wellhead platf.
Edvard Grieg	16/1-15	111	44.7	95	2125	4476	2351	Oil; platform
Rev	15/12-17	87	44.3	123	2770	4512	1742	Gas/cond; subsea
Dvalin	6507/7-15	399	39.9	164	4100	5012	912	Gas; subsea
Gyda	2/1-8	66	38.6	154	4000	5183	1183	Oil; decommissioned.
Morvin	6506/11-8	380	38.6	167	4320	5186	866	Gas/Oil; subsea
Kristin	6406/2-3	372	38.5	163	4230	5198	968	Gas/Cond; semi-sub
Embla	2/7-27	71	37.7	151	4000	5307	1307	Oil/Gas; wellhead platf.
Valemon	34/11-5	190	37.8	152	4010	5292	1282	Gas/Cond; platf.
Kvitebjorn	34/11-3	208	37.5	142	3790	5337	1547	Gas/Cond; p latf.
Martin Linge	29/6-1	125	34.9	149	4275	5723	1448	Gas/Cond; Platf+FSO

Source: NPD fact pages

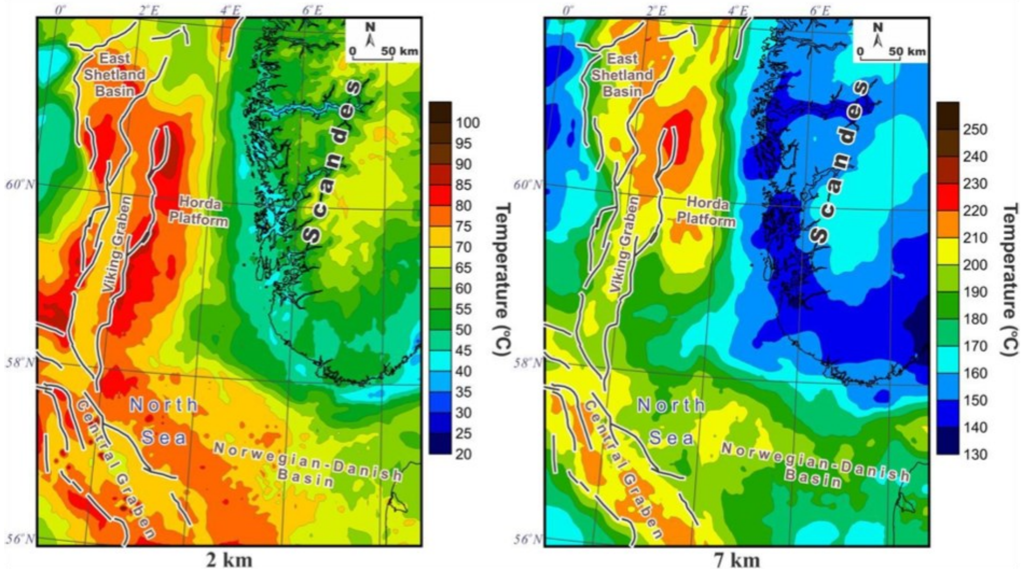


Figure 5: Modelled temperatures within the upper part of the study area. Temperature maps for depths of 2 km and 7 km which are extracted from the 3D thermal model.

Geothermal potential on NCS

NORCE

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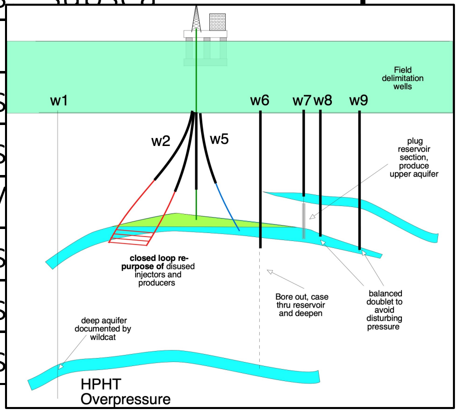
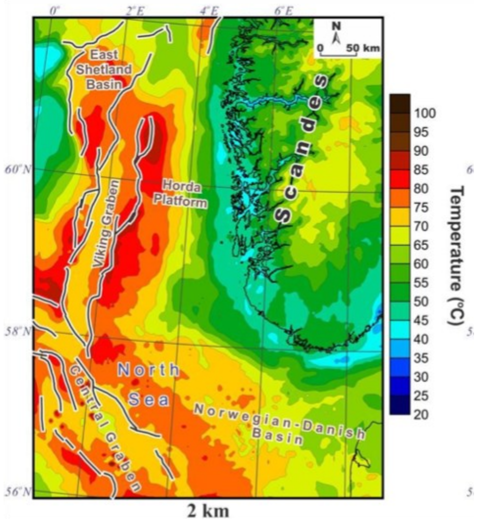


Geothermal potential on NCS

Maystrenko



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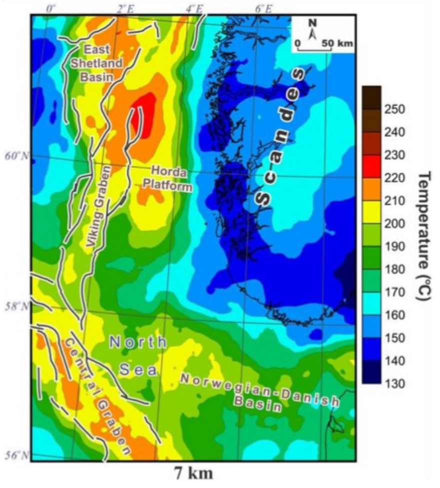
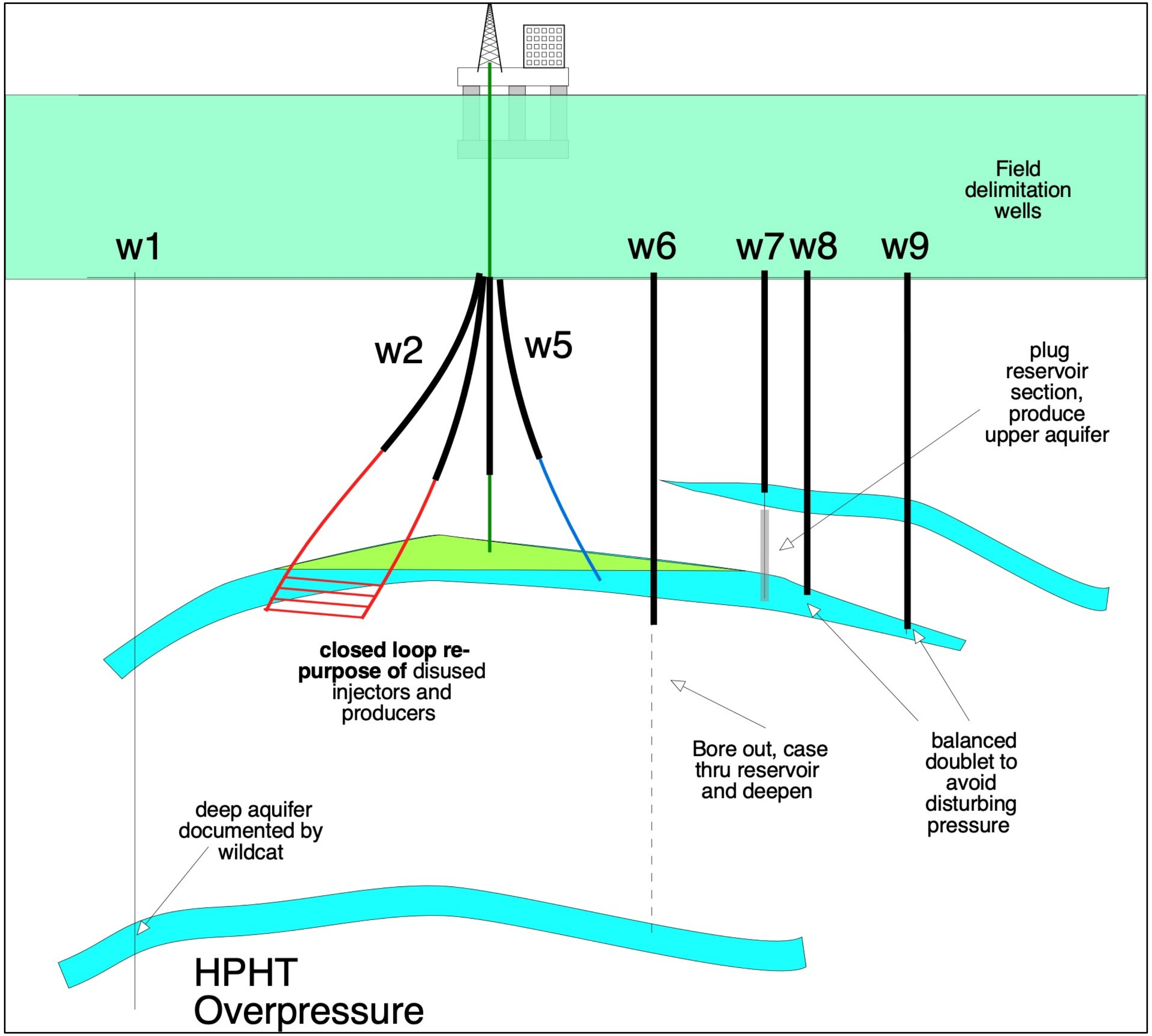


study area. Temperature maps for depths of 2 km and 7 km



Source: NPD fact pages

Moving forward: R&D Proposals

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APPLY NOW

Knowledge-building Project for Industry

PUBLISHED 08 MAR 2022 | LAST UPDATED 11 JAN 2023

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Application type: Collaborative and Knowledge-building Project

Application deadline: 15 February 2023, 13:00 CET

Relevant thematic areas for this call: Energy, transport and low emissions, Petroleum

Target groups: Research organisations

Funding scale: minimum NOK 4 000 000

Amount of funding presumed available for this call for proposals: up to NOK 270 000 000

Project duration: 24-48 months

Contact for the call: KSP contact | ksp@forskningsradet.no

Create application | Download all files

https://www.forskningsradet.no/en/call-for-proposals/2023/knowledge-building-project-industry/

NFR: Energy, transport and low emissions

ENVIRONMENT-FRIENDLY ENERGY

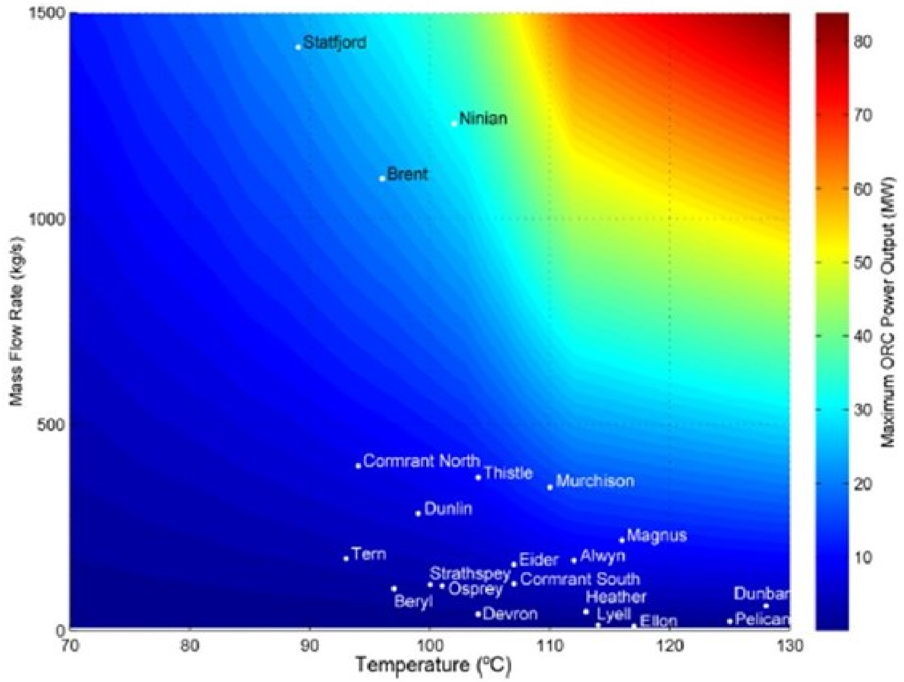
- Up to NOK 160 million for research on environmentally friendly energy
  - Demonstrate **support of long-term and sustainable development of the energy system,**
  - **contribute to the transition to a zero-emission society, and**
  - **promote a competitive Norwegian industry**.
  - The project must concern at least one of the following eight areas:
    - ✓ energy transitions and impacts on society, the climate and environment
    - ✓ new renewable electricity based on solar energy, wind power, hydropower, bioenergy or other thermal energy
    - ✓ energy efficiency and decarbonisation of industrial processes
    - ❑ hydrogen and other hydrogen-based energy carriers, as well as biofuels
    - ❑ batteries and electrification of transport
  - NFR funds up to four times the confirmed industry cash contributions, max 14 M NOK.

Important dates

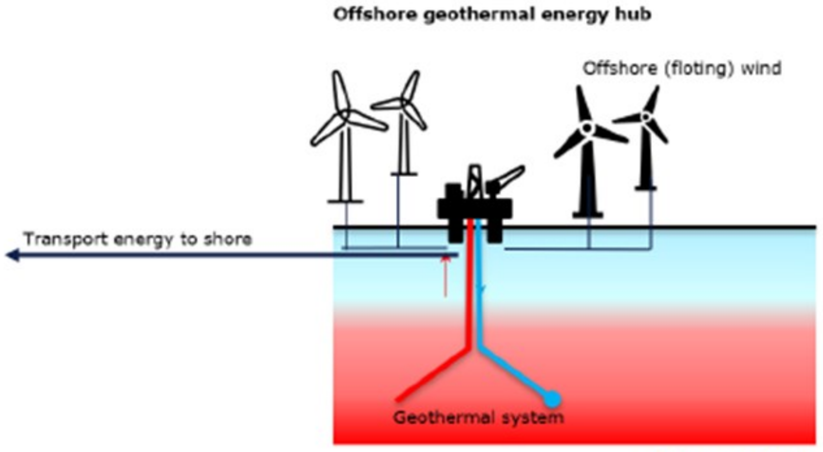
15 FEB 2023	01 JUL 2023	01 DEC 2023	30 NOV 2027
Application submission deadline	Earliest permitted project start	Latest permitted project start	Latest permitted project completion

Scope/deliverables

- Demonstrate the potential for offshore geothermal as part of the energy mix
  - Map geological potential - evaluation of data from oil, gas, and water wells to map “hot” spots for possible geothermal projects.
  - Use digital solutions to assess geothermal resource potential and accelerate prospectivity analysis and, ultimately, the delivery and performance of geothermal installations
  - Conceptual offshore plant designs and integration into existing grid systems
  - Business cases:
    - Address the economics (CAPEX/OPEX/LCOE)
    - Map synergies with CCS, blue- and green H_2, and sustainable marine mineral mining)
  - Addressing Scope 3 synergies
  - Policy framework – social and environmental issues
    - Oil and gas wells/geothermal wells
    - Governments, regulators and stakeholders



Potential power output of ORCs for some selected fields on UKCS. Source: Auld et.al (2014):



Source: DNV

Work packages

Work packages	Title
WP 1	Exploration & characterization of geothermal resources
WP 2	Upstream technologies for heat mining options
WP 3	Downstream technologies for heat mining options
WP 4	Costs, ROI, Business cases
WP 5	Social, environmental and regulatory challenges
WP 6	Education and dissemination
WP7	Project Management

Geothermal in the media

From long-list to short-list

Long-list of decarbonisation measures

- Electrification: Power from shore (coordinated approach)
- Electrification: Power from shore (individual approach)
- Electrification: Local supply from offshore wind
- Gas-fired power plant with CCS
- Compact topside CCS
- Hydrogen and hydrogen-derived fuels for power production
- Energy efficiency through reservoir management: Water management
- Energy efficiency through reservoir management: Artificial intelligence
- Energy efficiency through reservoir management: CO_2-EOR
- Optimized gas turbines: Waste heat recovery
- Optimized gas turbines: Utilisation
- Geothermal energy to reduce electrical power demand offshore

Short-listed measures to be prioritised

- **Electrification: Power from shore (coordinated approach)**
- **Electrification: Power from shore (individual approach)**
- **Electrification: Local supply from offshore wind**
- **Gas-fired power plant with CCS**
- **Energy efficiency through reservoir management: Water management**

Non-prioritised measures comparison (2/2)

High | Medium | Low

Decarbonisation measure for Scope 1 emissions	Application scope	Screening criria						Additional comments
		Maturity High: TRL 6-7 Medium: TRL 4-6 Low: TRL <4	Scale-up timeline High: Before 2030 Medium: 2030 – 2035 Low: After 2035	Main development and implementation obstacles High: Limited obstacles Medium: Obstacles that are solvable in the short term Low: Substantial obstacles not solvable in the short term	Industry opportunities High: Clear and important opportunities Medium: Possibly important opportunities, but less clear Low: Little opportunities	Realistic GHG emission reduction potential (total NCS) High: >55% Medium: 30-55% Low: <30%	Synergies with Scope 3 High: Clear scope 3 synergies Medium: Limited scope 3 synergies Low: No scope 3 synergies	
Geothermal energy		Mature technology onshore, less mature offshore.	Project realization in 3-5 years onshore. Demonstration projects can form a basis for plant design for scale up.	Explore and map geological potential, offshore geothermal plant design to de defined and tested.	Potential for being leading within offshore geothermal, potential for connecting to shore	Geothermal power can be self sustaining to achieve high emission reductions, but application potential uncertain	No synergies	

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DNV

High costs and limited potential to reduce GHG through electrification offshore

Description/application scope and maturity

Geothermal energy can be used to generate electricity for self consumption by platforms or for third parties reducing the GHG up to 100% for that specific power production. Geothermal power is a proven technology deployed onshore with over 15 GWe in operation worldwide. There might be a potential for offshore geothermal power plants on the NCS, especially if re-using existing or abandoned oil and gas wells and platforms. However offshore geothermal power plants is not operational at this moment and needs to be explored in the coming years to understand its full potential.

Short description

A conventional geothermal system consists of two wells (production and injection well). Heat from the deep subsurface is extracted by circulating the geothermal brine in a closed loop system.

Geothermal heat can be applied for electricity production using (see figure):

1. Flash steam (>~180°C).
2. Dry steam plants.
3. Binary (~90-180°C) (ORC)

Note: In stead of a two well system, single borehole heat exchangers are available. A mono well then acts as production and injection well. First estimates on thermal output are several 100's kWth, which is considerably lower than the geothermal doublet system (of several 10's MWth).

Application scope and scaling potential

Application scope

1. Production of electricity (for self consumption or third party use).
2. Production of thermal energy for self consumption of processes at the platform.
3. Re-use abandoned well from dry oil/gas wells for geothermal energy
4. Potential coproduction of geothermal-energy from oil or gas recovery processes.

Scaling potential and timeline

Short term (2022-2030): Onshore geothermal plants have an expected timeline from idea to operations of 3-5 years (optimistic). Offshore systems will likely be more complex. No offshore geothermal plants installed as of yet. Expected developments:

- Concept Development Process for first demonstration projects
- Step B+C will be shortened by using existing geological knowledge from OG production (decrease drilling risk)

Long term (2030-2050): Proven concept and working towards more standardized solutions for geothermal plants using platforms.

Maturity
Technology Readiness Level (TRL)

Short term (2022 – 2030):
Well technology : TRL 7 (onshore)
Conversion technologies (onshore):

- ORC/Rakine: TRL 7
- Flash: TRL 7
- Over 15.000 MWe realised worldwide

Offshore geothermal: TRL 2 to 4

Long term (2030 – 2050):

- TRL 7 concepts for offshore geothermal plants

Accelerating developments

- Cope with decarbonisation requirements
- Research projects off shore geothermal energy: North Tech Energy (NTE), Transmark Renewable; SINTEF and Iceland Geosurvey (ISOR).
- Reusing wells for geothermal energy postpones well abandoned and increase well lifetimes.
- Significant lower drilling cost compared with onshore geothermal energy.

Illustration of geothermal electricity production concepts

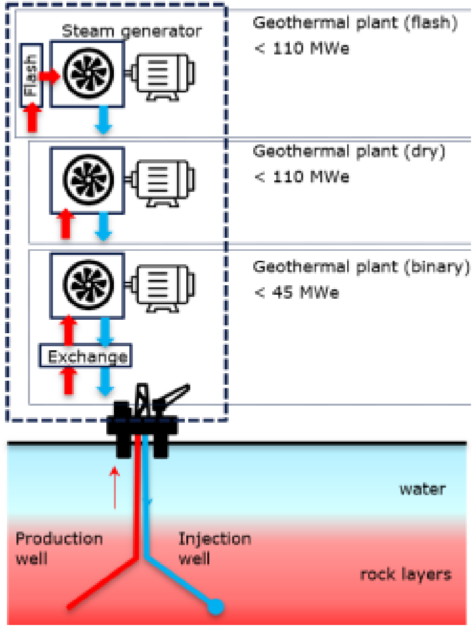


Illustration: DNV

GHG reduction potential/main challenges and opportunities

GHG reduction potential

Target emission sources
Replacing gas turbines at platforms for power production and heat demand by geothermal power plants. Although geothermal plants use some electricity for operation (e.g. ESP-pumps, cooling tower), this can be self-supplied.

Technical reduction potential
By replacing gas turbines with geothermal electricity and heat, the theoretical GHG emission reduction potential can be up to 100%. The potential per geothermal power plant is typically:

- Geothermal binary technology provides 2-3 MWe [2]
- Geothermal a flash or dry steam technology provides 17 tot 23 MWe [2].

Note: The potential is based on worldwide existing geothermal plants, and has no direct relation with specific local Norwegian geothermal potential. However the ranges show a first indication of typical power plant sizes. In case of "increasing operational platform efficiency' gas turbines on the platform can be replaced by geothermal electricity. For this a reference case of 75 MWe per platform could be used (3x25 MWe gas turbine per platform [1])

Realistic reduction potential
The realistic reduction potential is case specific and has not been studied in detail for this report. The main requirements for deployment of offshore geothermal energy are:

- Geological conditions and subsurface temperatures/flowrates available.
- Platform should be suitable for the construction of geothermal plant (conversion technology)
- A platform in use or close to shore for power distribution if abandoned.

Main challenges and opportunities

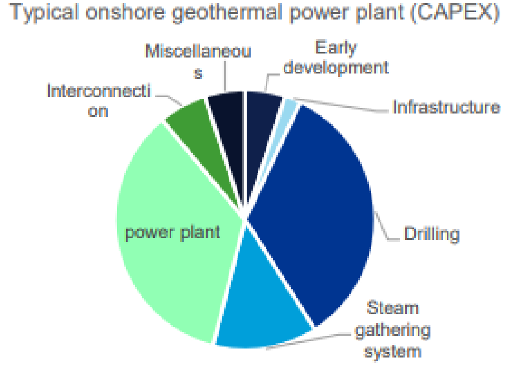
Development and implementation obstacles

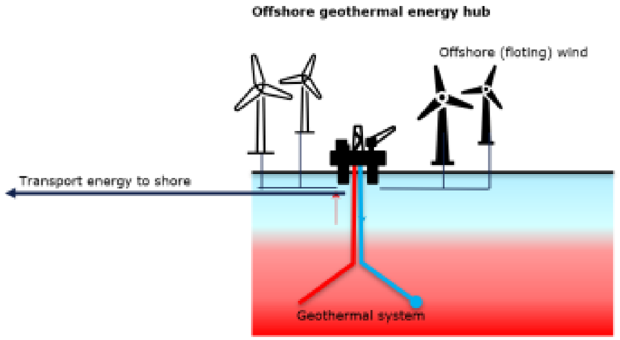
- Availability of thermal aquifer systems nearby the offshore platform with good conditions for geothermal energy (high temperature, high mass flowrates). Analysis show ~10% of reservoirs on the NCS are above 120 degrees, and even less above 180 degrees, although there are some hot-spots. Further assessment of geothermal potential is needed.
- Possibility to repurpose O&G wells might be limited (e.g. casings, insulation, well heads, tubing)
- Harsh offshore environment.
- Return on investment of geothermal plant compared to platform lifecycle (remaining lifetime of platform should be at least 20 years or more in order to justify investment, or find ways to re-use the power plant for other purposes).
- Subsea electricity cables needed in case of transport to shore.
- Permits and licensing (exploration + exploitation, environmental, grid access).
- Installation of technical room(s) at platform.
- High drilling cost compared to onshore geothermal plants (see CAPEX distribution figure)

Industry opportunities and synergies

- Extend lifetime of wells and installations by utilising platforms after O&G production has ended and repurpose oil/gas wells for geothermal heat/electricity.
- Create a offshore geothermal power hub, e.g. for hydrogen production, deep-sea mining, grid connection to shore, floating wind turbines connected to the hub, local offshore geothermal electricity.

Typical distribution of onshore geothermal power plant CAPEX (top) and potential offshore geothermal energy hub (bottom)





Source: DNV

[1] Overview gas turbines Norway: https://no.wikipedia.org/wiki/Liste_over_gasskraftverk_i_Norge
[2] Calculation by DNV based on source: Efficiency of geothermal power plants: A worldwide review

https://www.nrk.no/norge/xl/kraften-fra-havbunnen-1.15854345

NORCE

Geotermal varme fra norske oljebrønner

- Det finnes tusenvis av potensielle brønner for framtidig kraftproduksjon i Norge.
- Flere av dem er i ferd med å gå tomme for olje og gass.
- Kostnadene for å avvikle de om lag 500 innretningene på norsk sokkel er usikre, men foreløpige anslag ligger på ca. 160 milliarder kroner. Staten dekker i dag ca. 80 prosent av kostnadene.
- Typisk dybde på norske oljereservoarer er mellom 1200 og 5000 meter.
- Temperaturen nede i brønnene på norsk sokkel ligger mellom 70 og 170 grader.
- Noen brønner går også mer enn 10 kilometer horisontalt.
- Det finnes i dag varmevekslere som lager strøm av varmen fra spillvannet fra industrien. Kanskje kan samme teknologi brukes offshore?
- Ny teknologi gjør det i dag mulig å utnytte gamle oljebrønner på land til geotermi. Dette er ikke testet offshore.
- EU støtter prosjektet MEET, som er en sammenslutning av energiprodusenter som ønsker å demonstrere potensialet til geotermisk kraftproduksjon i Europa.
- Programmet støtter forskning på å hente geotermal kraft fra tørrlagte oljebrønner på land.
- Et polsk-norsk forskningssamarbeid forsøker å kombinere karbonfangst og -lagring med geotermi. Her vil de utnytte varmen i CO_2 som pumpes ned i havbunnen til å lage strøm.
- Men ennå er det ingen i Norge som forsker på å lage strøm av det varme vannet i oljebrønnene.

Discussion

- Way forward:
  - mature project proposal with partners
  - In-kind contribution