This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 792037

Multi-sites EGS Demonstration

MOBILE Organic Rankine Cycle (ORC) units for electricity production– project results and lessons learned

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Overview

An important part of the **MEET project** is to demonstrate the production of electricity from geothermal sources at low temperatures and low flows. To do this, it was necessary to develop a new ORC machine. Three ORC machines have been manufactured and installed on five demonstration sites with various geological settings: sedimentary, volcanic and granite.

To achieve the objectives, the following tasks were carried out:

- Coupon testing of various material candidates
  - Stainless steels, nickel alloys, titanium, carbon steel and even plastic
  - In the demonstration sites
- Adaptation of standard ORC Machine for geothermal market
- Test on site in three first demonstration sites
- Adaptation of ORC Machine for the second demonstration sites
- Test on site in the second demonstration sites

During this talk we will present the various in-situ tests performed and some of their results. A summary of lessons learned during the project will also be provided.

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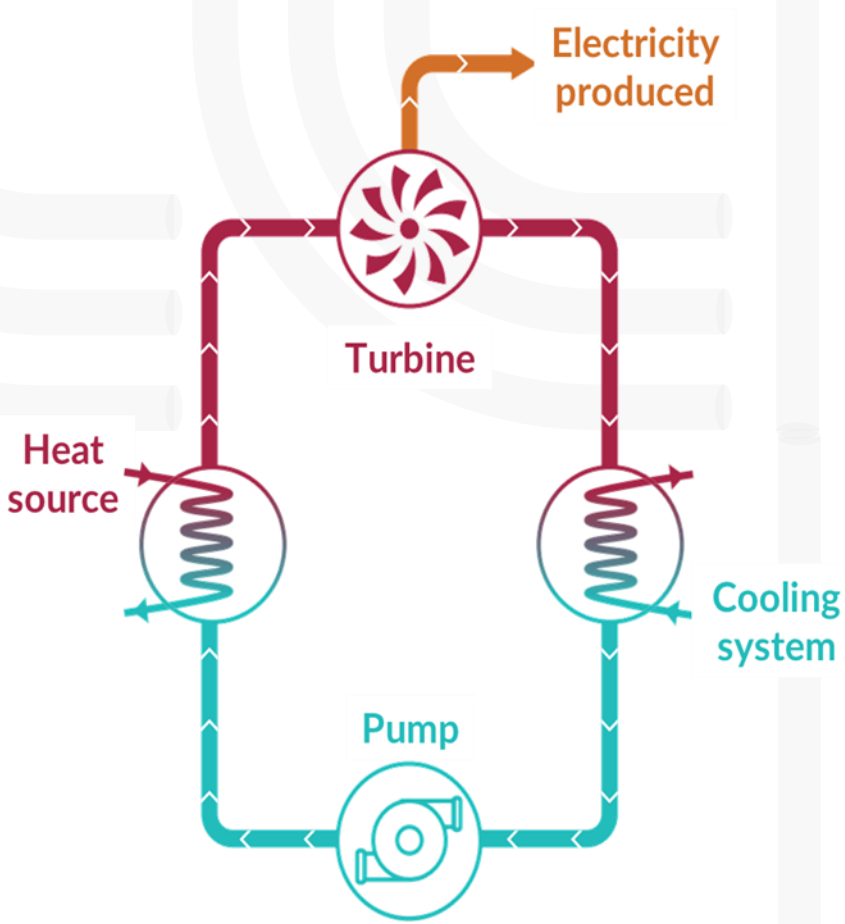
What is an ORC and how it works?



Organic Rankine Cycle (ORC) uses an organic, high molecular mass fluid with a liquid-vapor phase change occurring at a lower temperature than the water-steam phase change. The fluid allows Rankine cycle heat recovery from lower temperature sources. The low-temperature heat is converted into useful work, that can itself be converted into electricity.

The main benefits of ORC technology

- Optimized yields over a wide temperature range,
- Reduced operating costs,
- Reliable and compact turnkey solution with minimum maintenance costs.

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Heat Exchanger material

The first step of our work was to select the most cost effective material for the heat exchanger. ICETEC performed an in-situ corrosion test of coupons on various locations, using different materials. With the results of these tests ICETEC advises ENOGIA to use the 254 SMO (see the presentation on corrosion and scaling for more information)

Materials:

- Stainless and duplex steels: 254SMO
- Titanium: Ti gr. 2

Sites:

- Grásteinn and Krauma - Volcanic sites in Iceland
- Cazaux and Chaunoy - Sedimentary sites in France
- Soultz-sous-Forêts - Granitic site in France)

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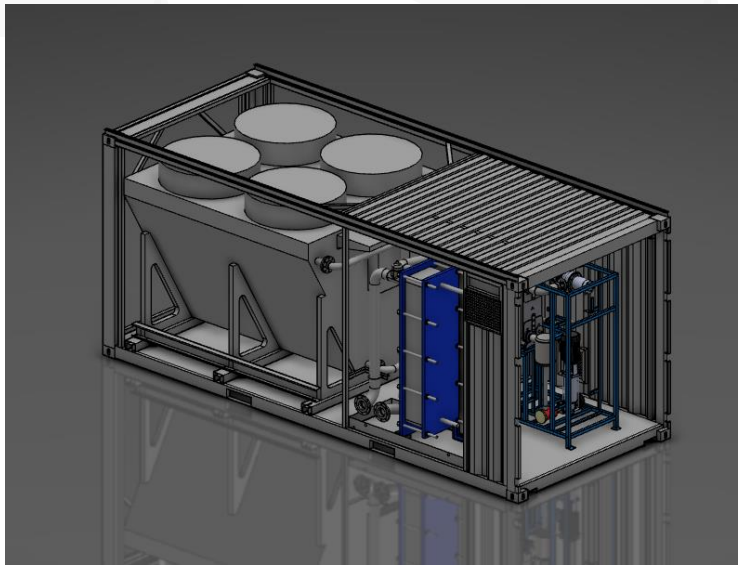
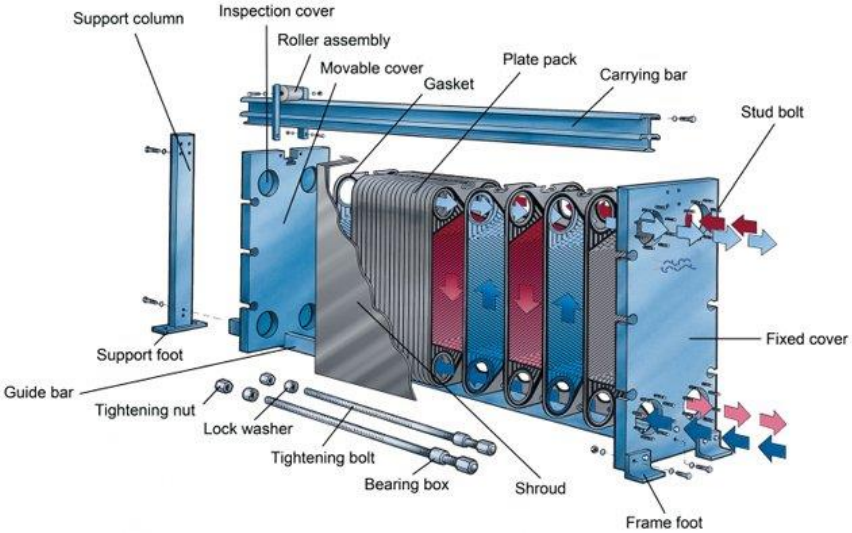
Adaptation of the existing ENOGIA ORC machine

The main objective of the work is to adapt the existing ENOGIA's ORC to the specificity of geothermal application, especially through the sourcing and testing of adapted, cost-effective, heat exchangers technology in order to make the ORC compatible with geothermal water chemistry variability originating from various geological conditions

- Select the heat exchanger technology: Performance, compacity, easy maintenance.
- Select the heat exchanger material to fit with corrosion issue in various geological context.
- Adapt the existing ORC machine 20 kWe and 40 kWe



20 kW ORC Machine adapted to the geothermal application



Heat exchanger technology: Gasketed Plate Heat Exchanger (Alfa Laval)

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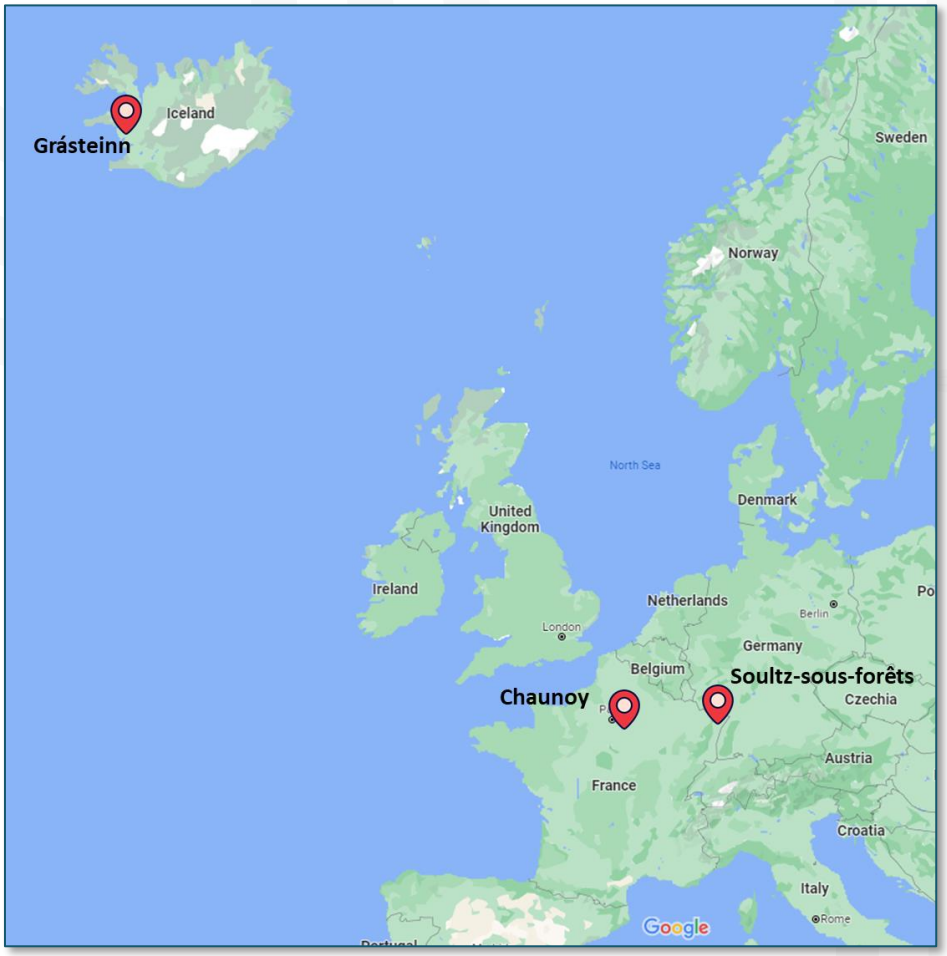
First demonstration site

The initial ORC tests were performed at Chaunoy, Grásteinn and Soultz-sous-Forêts.



Name		Chaunoy	Grásteinn	Soultz-sous-Forêts
Geological Context	-	Sedimentary	Volcanic	Granitic
Temperature	°C	90	115	65
Pressure	Bar	11	10	25
Flow	m^3/h	20.16	25.2	108
Fluid	-	Mixture of water (98%), oil and gas	Water, total dissolved solids (20 g/l)	Water, total dissolved solids (100 g/l)

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First demonstration sites - Chaunoy

Name: CNY40
Location: Chaunoy oil field, Paris (France)
Owner: Vermilion Energy
Operator: Vermilion Energy
Test duration: 13/06/2020-13/10/2020
Key figures: Petroleum well on production since 1984, it is producing 500 m^3/d of water and some oil. The brine temperature is 93°C.

20 kW ORC Machine installed in Chaunoy CNY40

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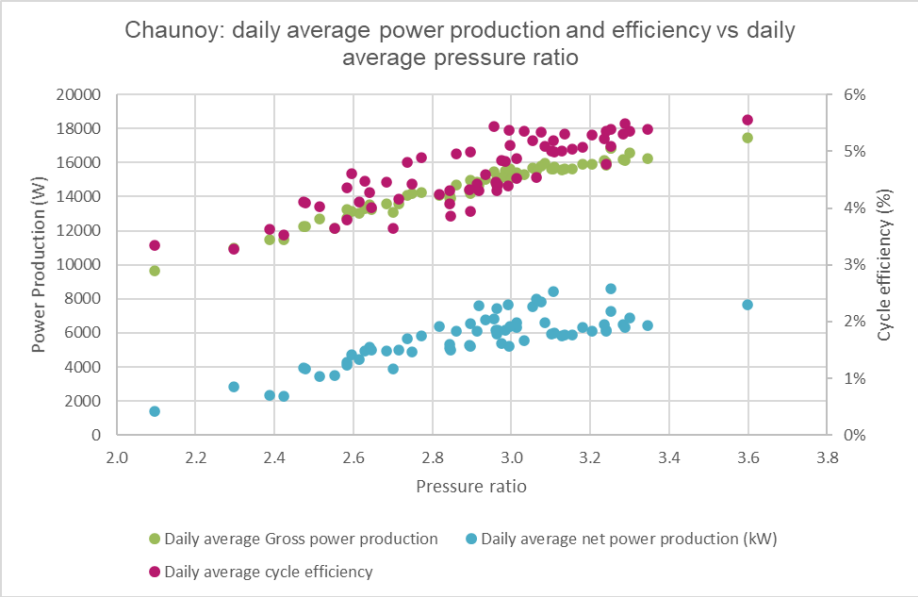
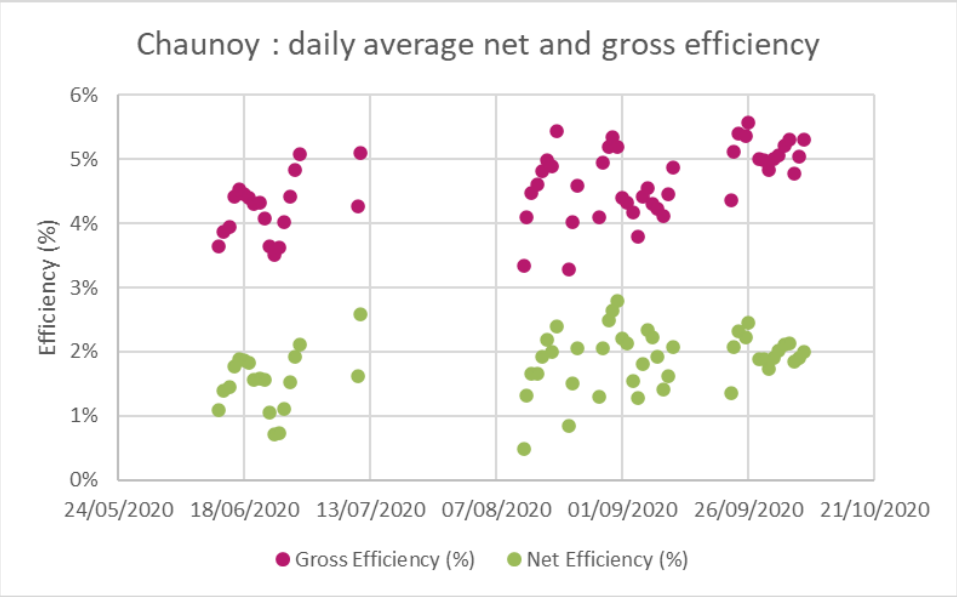
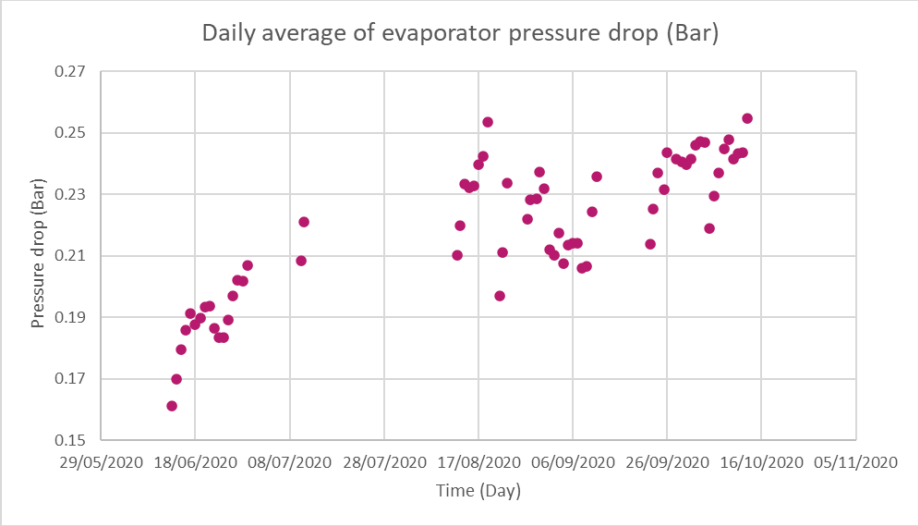
First demonstration sites - Chaunoy







Chaunoy performance

- **Gross efficiency**: 4.6%
- **Net efficiency:** 1.6%
- **Pressure drop evolution**: 0.09 Bar in 120 days

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First demonstration sites - Grásteinn

Name: Grásteinn
Location: Ölfus, Iceland
Owner: Kjartan Björnsson
Operator: Kjartan Björnsson
Test duration: 18/10/2020-01/12/2020
Key figures: Private well commisionned in 1995. The well is producing 115°C and 7.5 l/s. The hot water is used for greenhousing and building heating,

40 kW ORC Machine installed in Grásteinn

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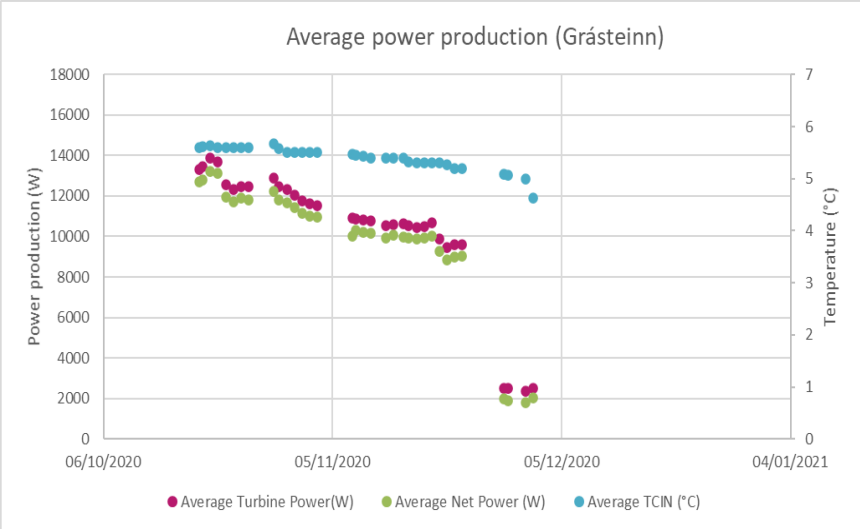
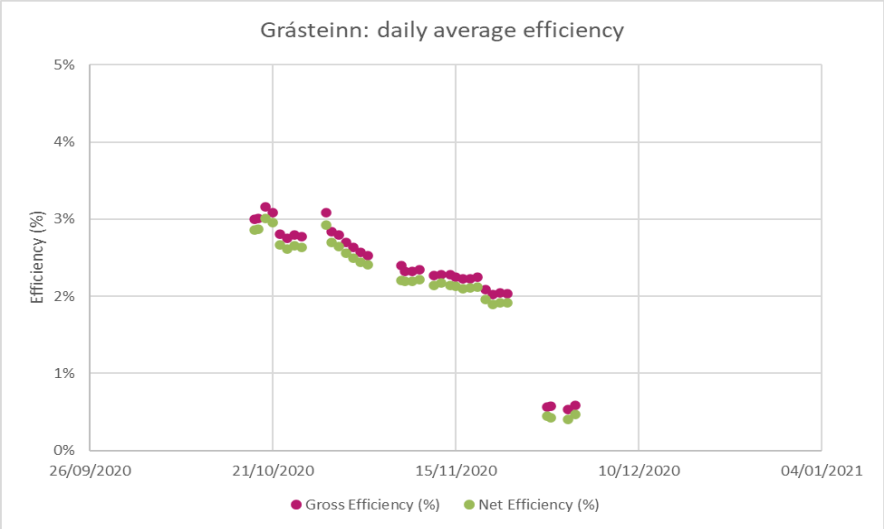
First demonstration sites- Grásteinn





	Unit	On site
Geothermal well composition	Water	
THIN (Temperature inlet Evaporator)	(°C)	99.25
Geothermal fluid flow (estimated)	(m^3/h)	4.81
TCIN (Temperature inlet condenser)	(°C)	5.6
Cold water flow (estimated)	(m^3/h)	17.03

Grásteinn performance

Gross efficiency: 2.3%

Net efficiency: 2.2%

Pressure drop evolution: No pressure drop

- From the start, a failure of the pump was noted. Really low flow in the brine.
- The tests were carried out during the winter period. The thermal needs of the end user were such that there was no more for the ORC machine.

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First demonstration sites – Soultz-sous-Forêts

Name: Soultz power plant
Location: Soultz-sous-Forêts, France
Owner: GEIE Exploitation Minière de la Chaleur
Operator: ES-Géothermie (ESG)
Test duration: 13/03/2021-13/06/2021
Key figures: 3 wells drilled from 1995 to 2004 @ 3900 then 5000 m deep. There is an ORC already instaled with an electrical capacity of 1.7 mWe. The production temperature of the well is 150 °C.

40 kW ORC Machine installed in Soultz Power plan

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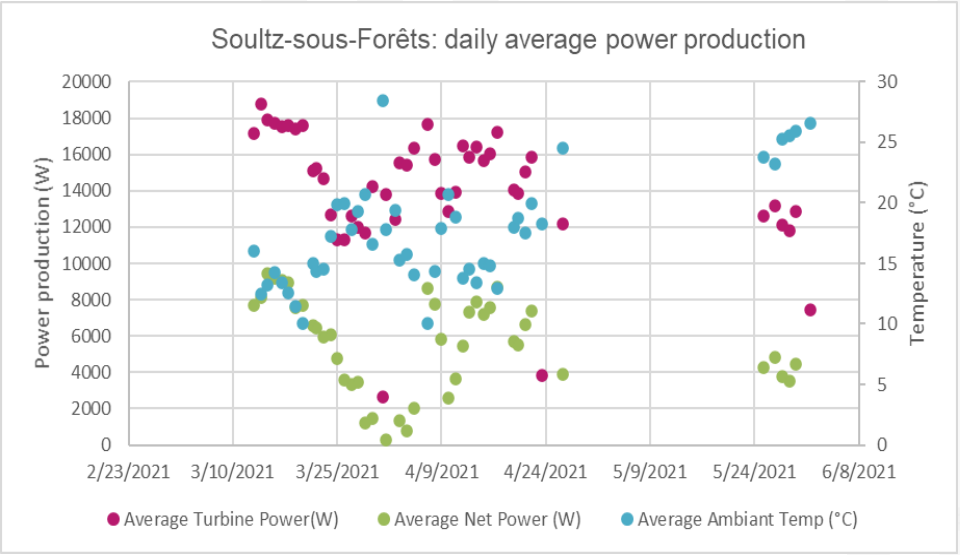
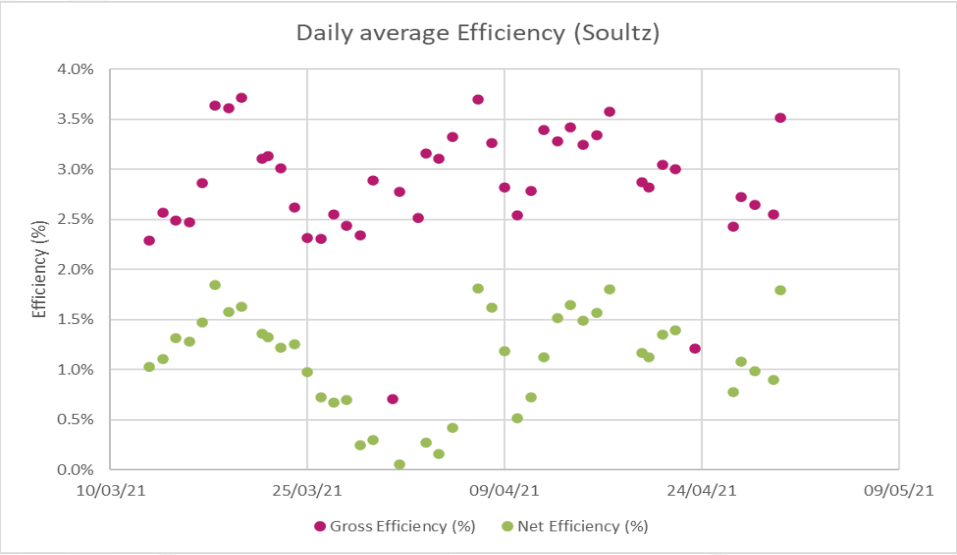
First demonstration sites- Soultz





	Unit	On site
Geothermal well composition	Water	
THIN (Temperature inlet Evaporator)	(°C)	70
Geothermal fluid flow (estimated)	(m^3/h)	108
TCIN (Temperature inlet condenser)	(°C)	5.6
Cold water flow (estimated)	(m^3/h)	35

Grásteinn performance

Gross efficiency: 3.2%

Net efficiency: 2.1%

Pressure drop evolution: No pressure drop

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Learnings from the first demonstration sites

- To integrate an ORC machine, one can not only consider the conditions (pressure, temperature) and the geological context (composition of the water, pH…), but also other parameters inherent to the well (natural radioactivity, presence of H_2S, CO_2).
- We are able to produce electricity at a very low rate, although the ORC turbines were designed for much more (seen on Grásteinn)
- We are able to produce electricity at low temperature (60-70°C), but with very low performance and higher risks of fouling formation (seen on Soultz)
- With the design of these machines, it is important to carry out soft starts. We have seen the importance of having valves regulated by the ORC to optimize the start-up phases. (seen on Grásteinn)
- For systems with dry cooler, the impact of ambient temperature is significant. It is necessary to have properly sized the dry cooler but also to optimize its regulation to obtain a better net electrical production.

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Second demonstration site

The second ORC tests were performed at Cazaux, Krauma and Balıkesir*.

		Cazaux	Krauma	Balıkesir*
Geological context	-	Sedimentary	Volcanic	Granitic
Temperature	°C	111	97	103
Pressure	Bar	30	10	4
Flow	m^3/h	35.5	32.4	54
Cold loop type		Dry cooler	External water cold water source	Dry cooler
Geothermal fluid	-	Mixed oil, water, gas	Water	Mixed oil, water, gas

*Balıkesir site is not yet equipped with an ORC

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Second demonstration sites - Cazaux

Name: CAX47
Location: Cazaux Oil file CAX47 (France)
Owner: Vermilion Energy
Operator: Vermilion Energy
Test duration: 13/01/2022-ongoing
Key figures: Petroleum well on production. The Cazaux Purbeckian field was discovered in 1961 and is located 3200 m deep. The fluid extracted from CAX85 shows a temperature of 111°C at the surface and flows at 852 m^3/d.

20 kW ORC Machine installed in Chaunoy CAX47

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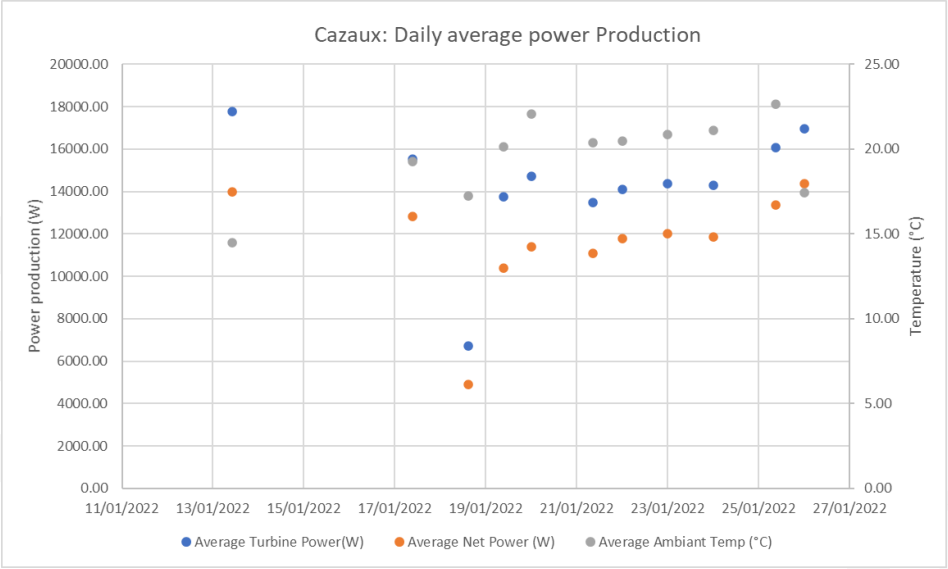
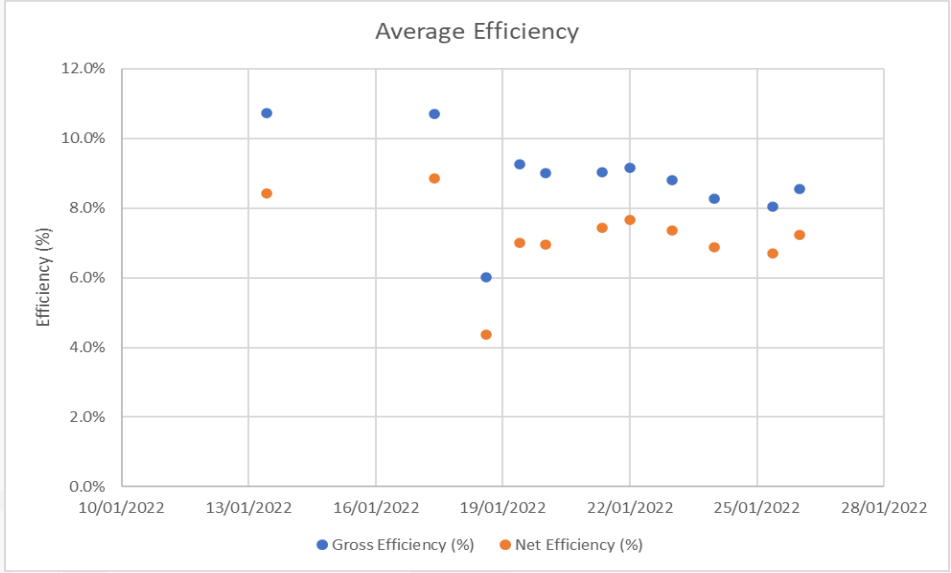
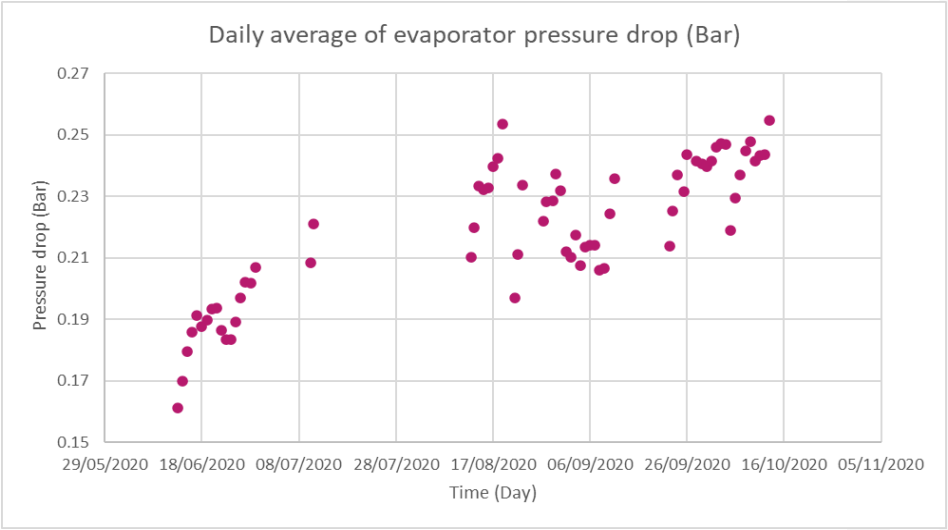
Second demonstration sites - Cazaux







Chaunoy performance
Gross efficiency: 8.9%
Net efficiency: 7.2%
Pressure drop evolution: 0.34 Bar in 12 days

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Second demonstration sites - Krauma

Name: Krauma geothermal baths
Location: Deidartunguhver, Iceland
Owner: Krauma ehf.
Operator: Krauma ehf.
Test duration: 25/10/2021-ongoing
Key figures: Number of wells: 2, in addition to natural hot spring flow. The Deildartunguhver hot spring has been used since Iceland was settled. Production temperature, flow rate: 100°C, 180 l/s

40 kW ORC Machine installed in Krauma

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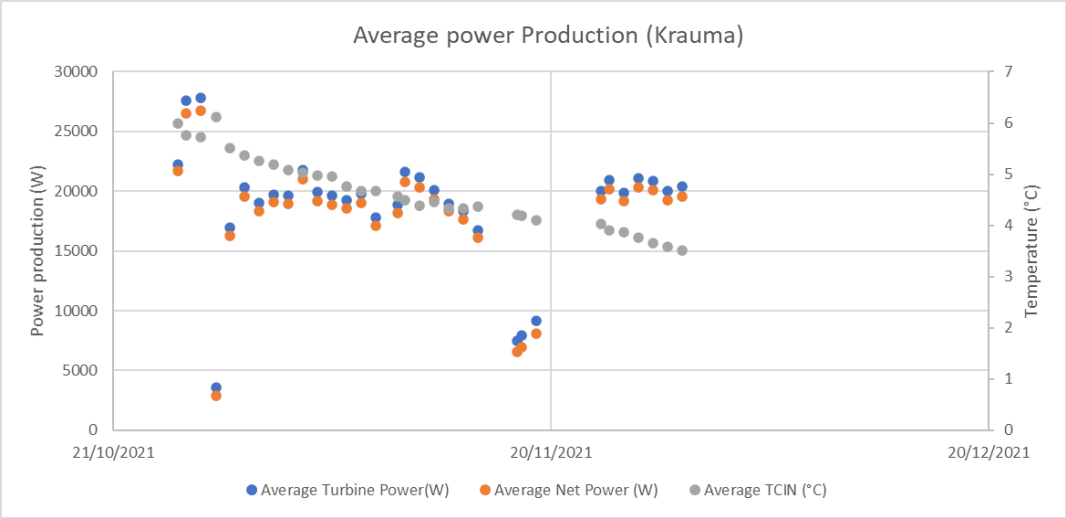
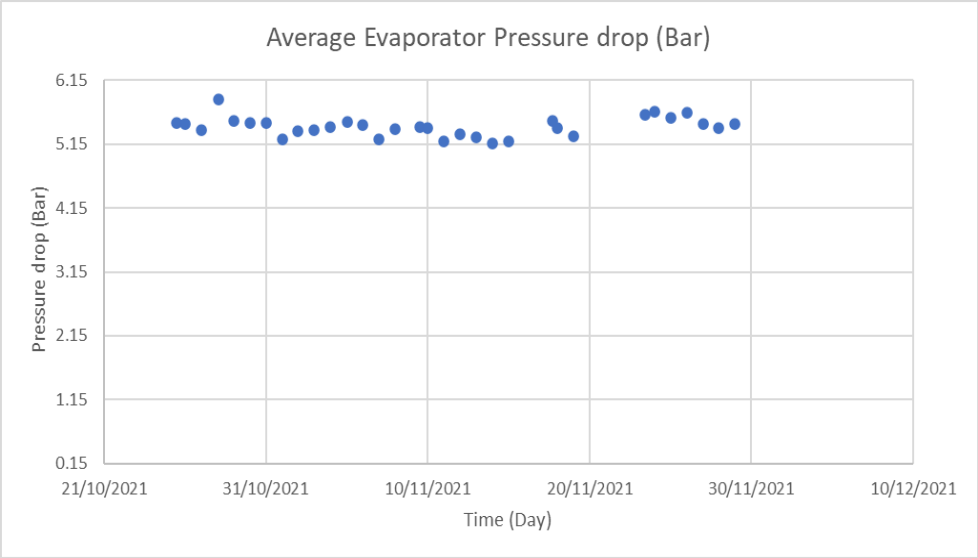
Second demonstration sites - Krauma



Chaunoy performance
Gross efficiency: 5.2%
Net efficiency: 5%
Pressure drop : 0.5 Bar



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Learnings from the second demonstration sites

- The quantity of fluid in the machine must be revised according to the temperature of the cold loop. (seen in Krauma)
- Sites like Krauma are the best opportunity to have a ROI* < 5 years.
- Take into account the constraints of the site to intervene effectively.
- Adapt machine safety rules to those of the end user.

* ROI: Return On Investment

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Thank you for your attention

For more information see MEET website: https://www.meet-h2020.com/

enogia

DATASHEET

ORC ENO-GEO-20LT

" Generate power from your geothermal source "

Founded in 2009, ENOGIA is a turbine based ORC manufacturer specialised in waste heat recovery with systems producing from 10 kWe to 180 kWe.

THE PRODUCT

The ENO-GEO-20LT module is an ORC manufactured by ENOGIA, able to recover until 320 kWth with a nominal power output of 20 kWe even after low grade heat source at 70°C.

- High speed patented micro-turbines
- Hydraulic connections with standard flanges
- Remote control and access 24/7
- Assembling and performance testing in ENOGIA workshop
- Plug-and-play system on a single skid

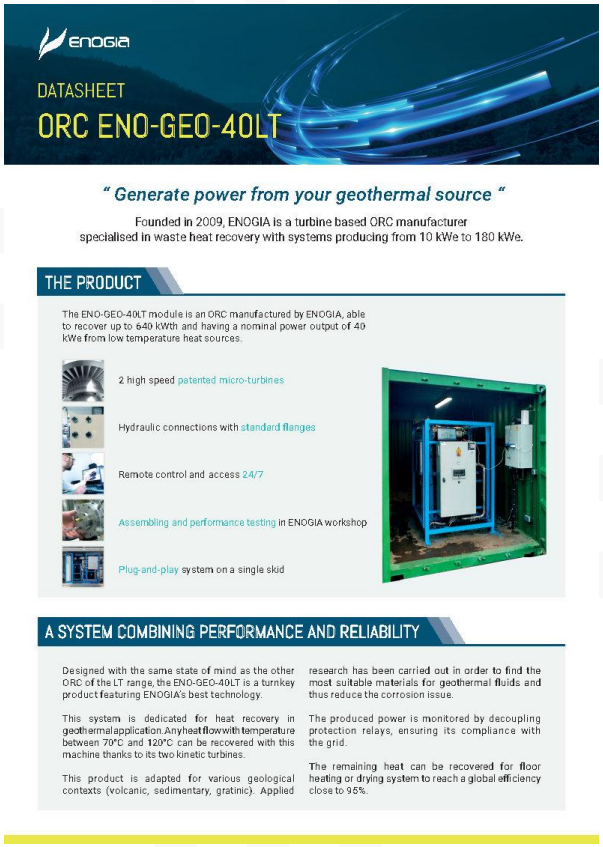
A SYSTEM COMBINING PERFORMANCE AND RELIABILITY

Designed with the same state of mind as the 10kWe ORC manufactured by ENOGIA, the ENO-GEO-20LT is a turnkey solution involving few hydraulic and electrical modifications to be integrated thanks to its play and play features.

This system is dedicated for heat recovery in geothermal application. Any heat flow with temperature between 70°C and 120°C can be recovered with this machine thanks to its two kinetic turbines.

This product is adapted for various geological contexts (volcanic, sedimentary, granitic). Applied research has been carried out in order to find the most suitable materials for geothermal fluids and thus reduce the corrosion issue.

It is also possible to connect the cold loop of the ORC to a drying system, a floor heating system or greenhouses to reach global efficiency close to 95%.



enogia

DATASHEET

ORC ENO-GEO-40LT

" Generate power from your geothermal source "

Founded in 2009, ENOGIA is a turbine based ORC manufacturer specialised in waste heat recovery with systems producing from 10 kWe to 180 kWe.

THE PRODUCT

The ENO-GEO-40LT module is an ORC manufactured by ENOGIA, able to recover up to 640 kWth and having a nominal power output of 40 kWe from low temperature heat sources.

- 2 high speed patented micro-turbines
- Hydraulic connections with standard flanges
- Remote control and access 24/7
- Assembling and performance testing in ENOGIA workshop
- Plug-and-play system on a single skid

A SYSTEM COMBINING PERFORMANCE AND RELIABILITY

Designed with the same state of mind as the other ORC of the LT range, the ENO-GEO-40LT is a turnkey product featuring ENOGIA's best technology.

This system is dedicated for heat recovery in geothermal application. Any heat flow with temperature between 70°C and 120°C can be recovered with this machine thanks to its two kinetic turbines.

This product is adapted for various geological contexts (volcanic, sedimentary, gratinic). Applied research has been carried out in order to find the most suitable materials for geothermal fluids and thus reduce the corrosion issue.

The produced power is monitored by decoupling protection relays, ensuring its compliance with the grid.

The remaining heat can be recovered for floor heating or drying system to reach a global efficiency close to 95%.

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