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From 0,5 kW till 5 MW

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rising from nature

Gravity pump based ORC cycle

OTEC pilot plant and beyond

by ir. H.M.D. (Harold) Lever
In coöperation with

Europese Unie

Europees Fonds voor Regionale Ontwikkeling

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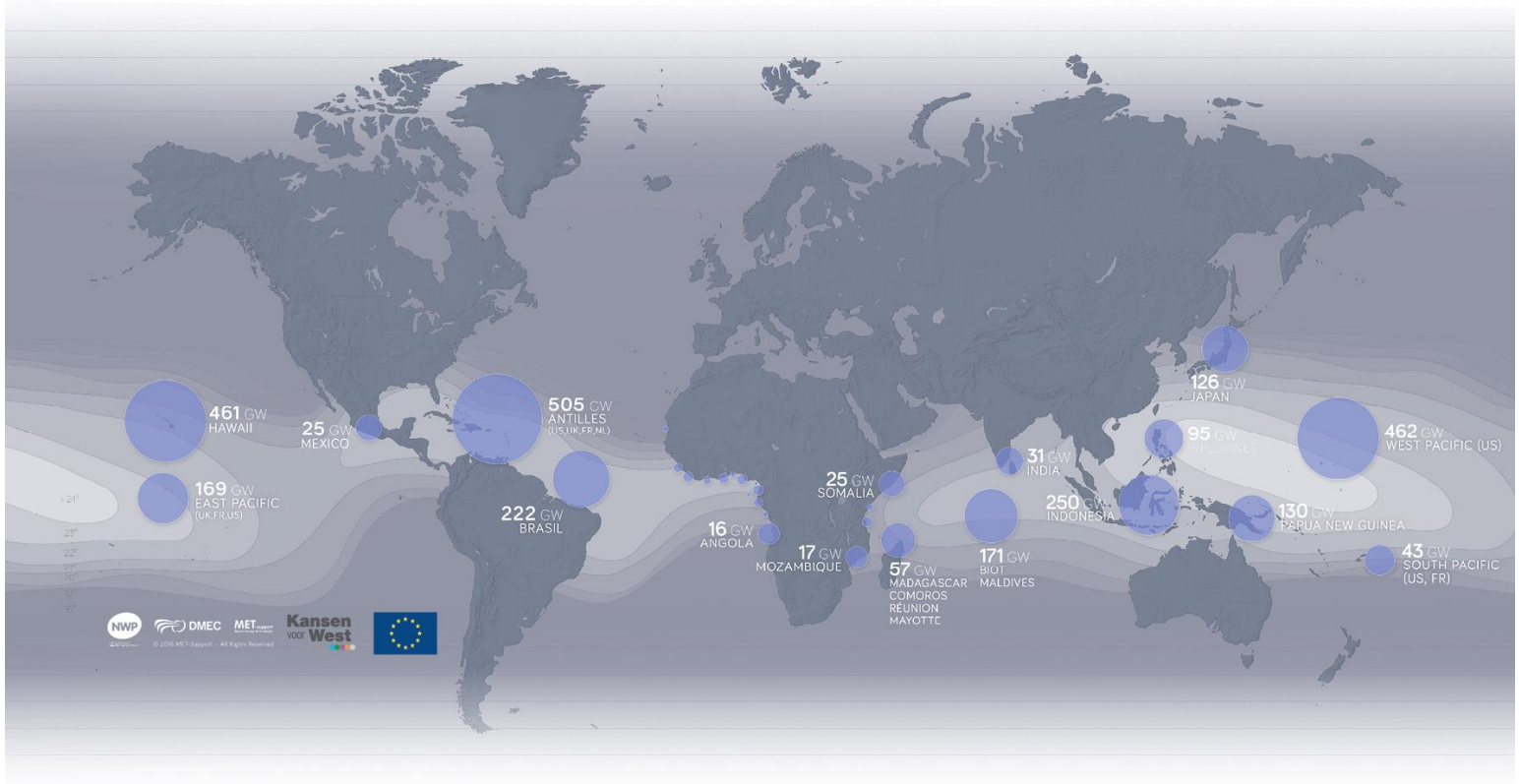
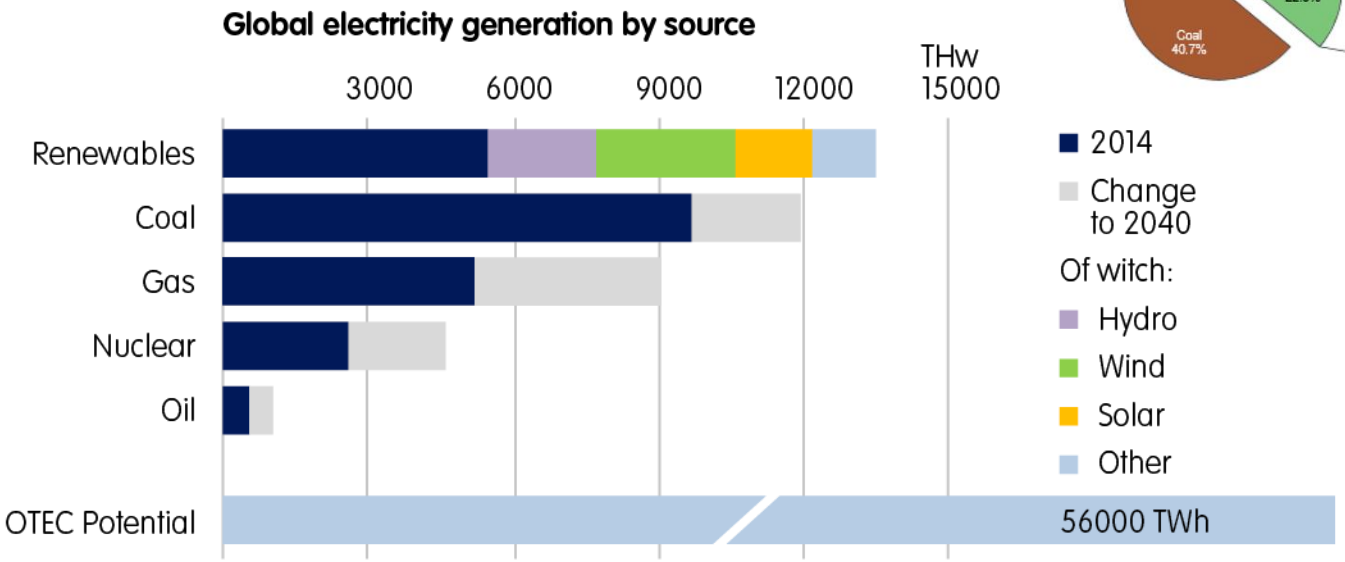
OTEC worldwide potential (7TW)

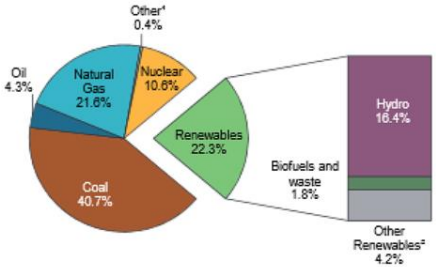


Available for 8000 hrs/yr mean potential capacity is 56.000 TWh

Source: NWP, Partners for West

IEA forecast for power 2014-2040 vs. OTEC potential





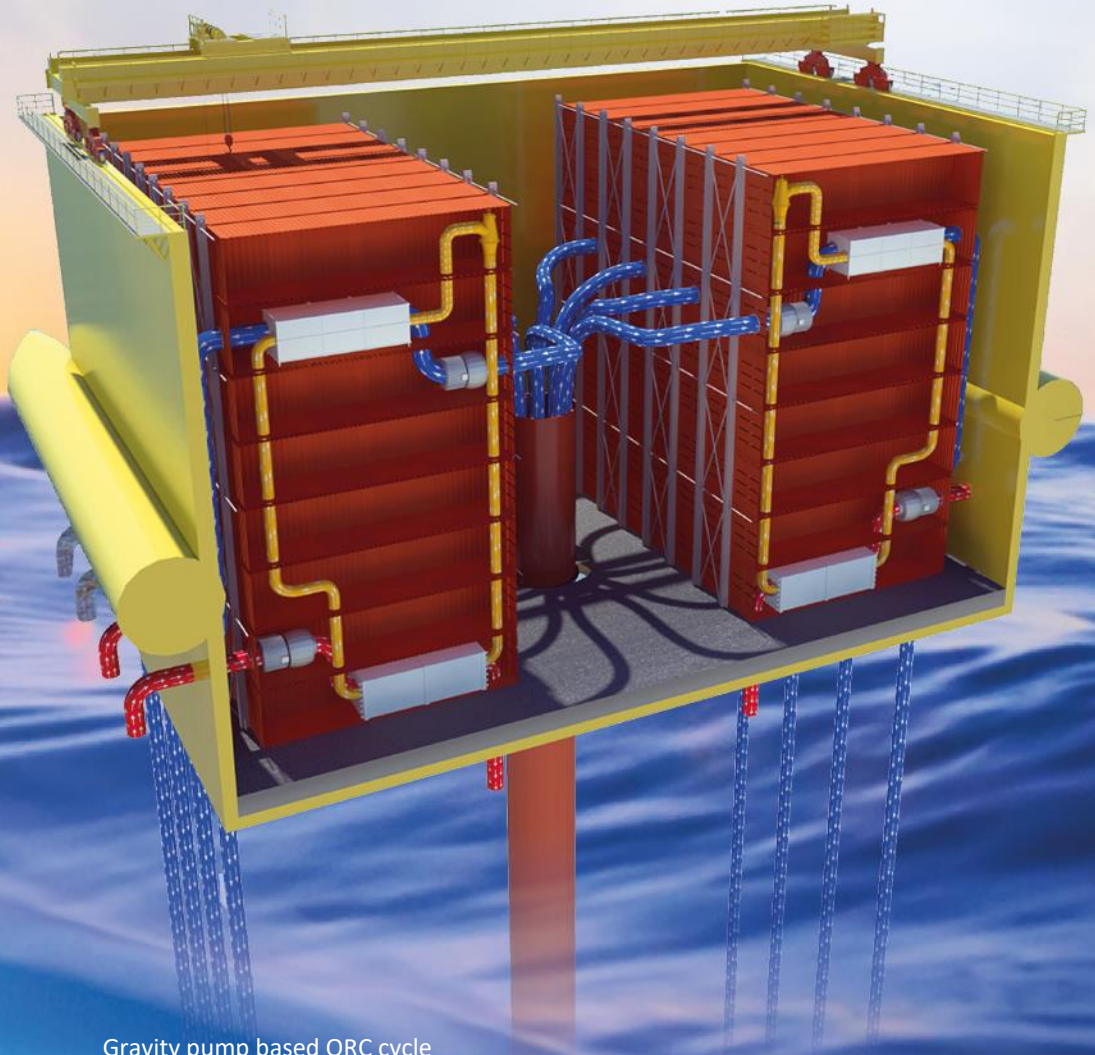
Other renewables includes geothermal, wind, solar, tide. In 2015, 1,033 GWh of electricity were generated from tide, wave and ocean motion

Driven by continued policy support, renewables account for half of additional global generation, overtaking coals around 2030 to become the largest power source

On shore energy and cooling from OTEC

Enogia and ArteqPower work together with Bardot

Off shore base load for off shore platforms and coastal areas



Gravity pump based ORC cycle

Opportunities Off Shore

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Opportunities Near Shore

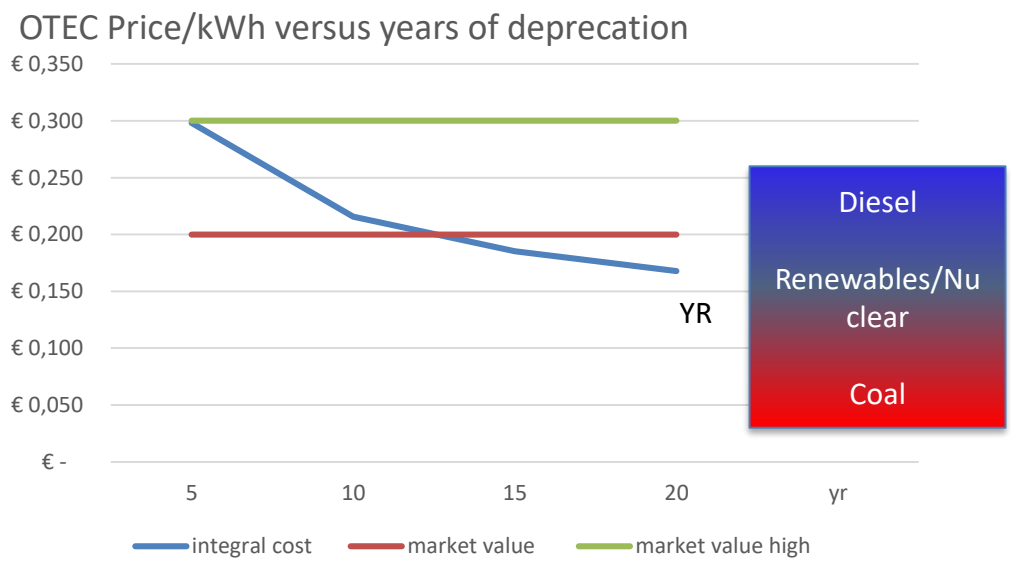
Energy for coastal cities: where deep water is close to big populations

Gravity pump based ORC cycle

Business case 5MW Off Shore OTEC

Output	5000 kW
Investment factor	€ 10.000/kW
Investment	€ 50 Mio
Equity/loan	25 %
Equity	€ 12.5 Mio
Loan	€ 37.5 Mio
Remaining value	30 %
Required return on equity	15 %
interest on loan	4 %
OPEX/CAPEX	4,0 %
OPEX	€ 2.0 Mio
Power generated	
Capacity factor	91 %
Productive Hours/yr	8000 hr/yr
Yearly production	40000 MWh
Value at € 0,25/kWh	€ 10 Mio
Linear payback CAPEX	5 – 6 yr

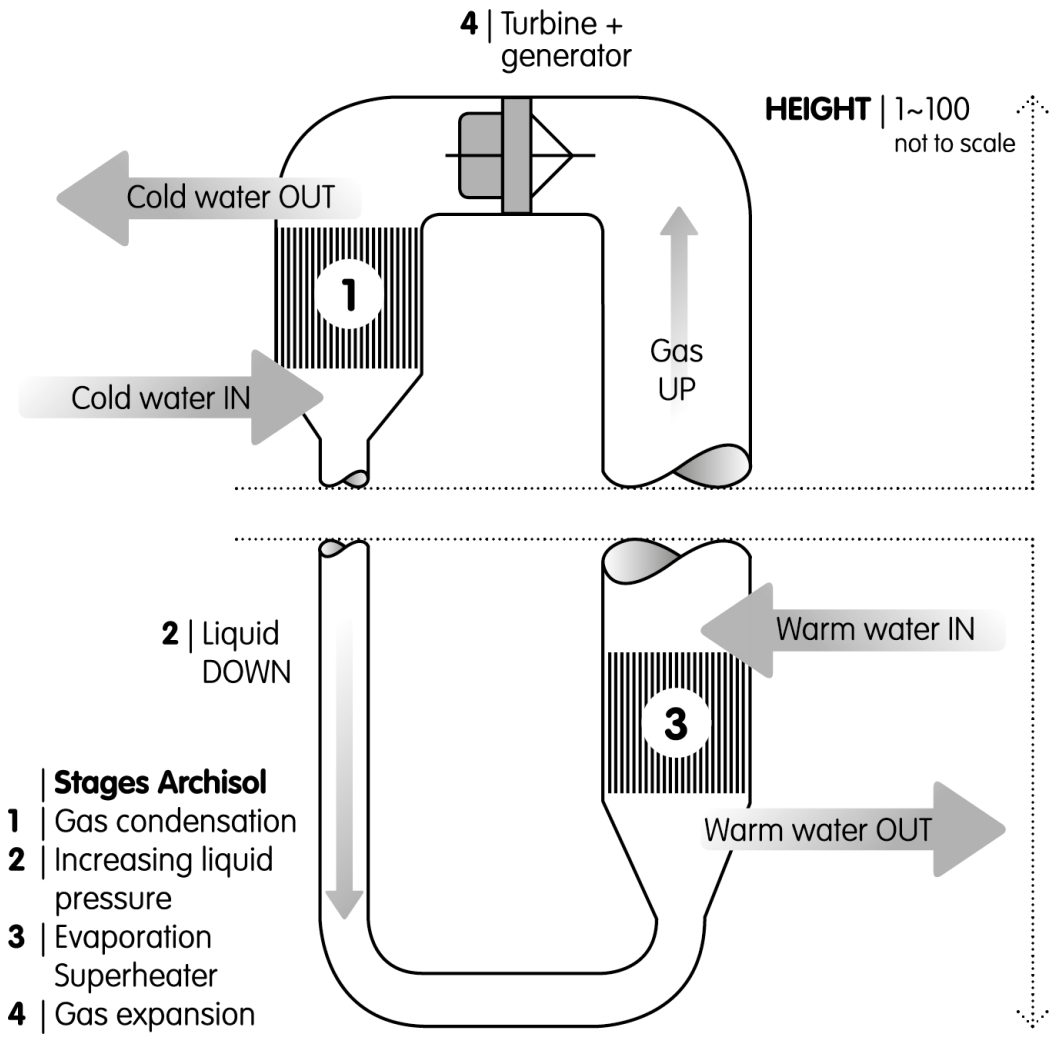
Market prices vary with source



Gravity pump based ORC cycle

Technology

Gravity pump based ORC cycle



For a typical OTEC application with 20°C temperature difference, the height would be 15 to 20 meter, using standard refrigerants

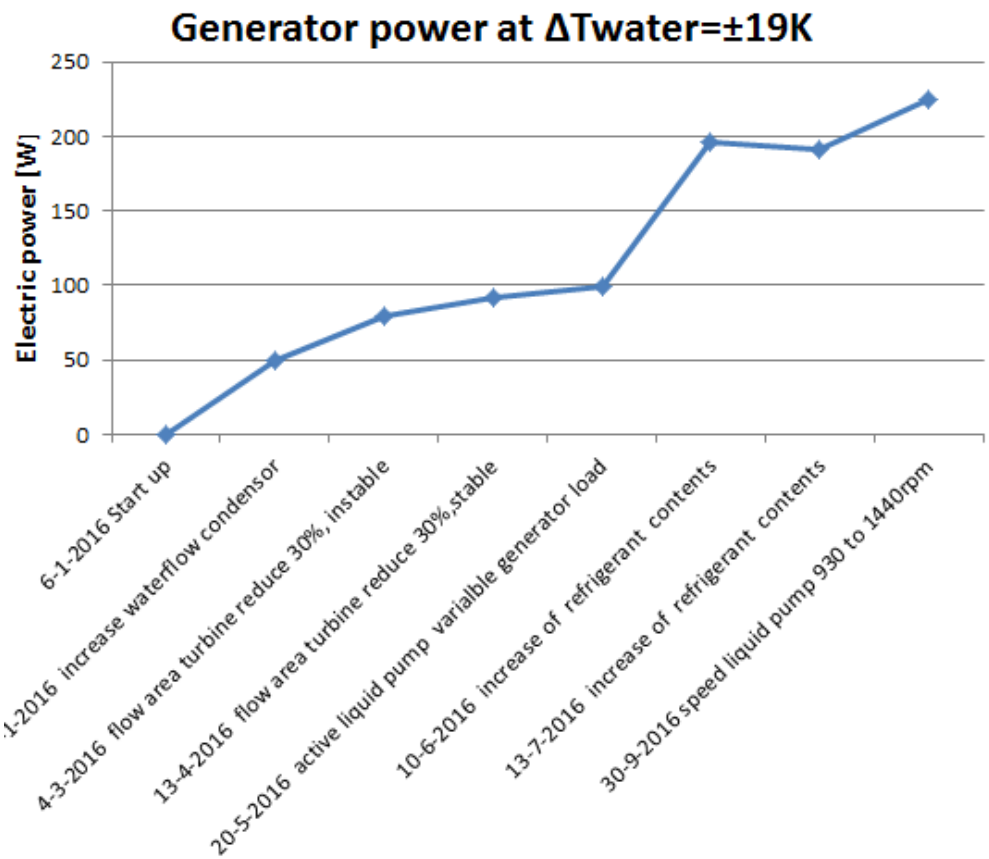
Gravity pump based ORC cycle

OTEC testing 35kWTH prototype

using the Archimedes principle

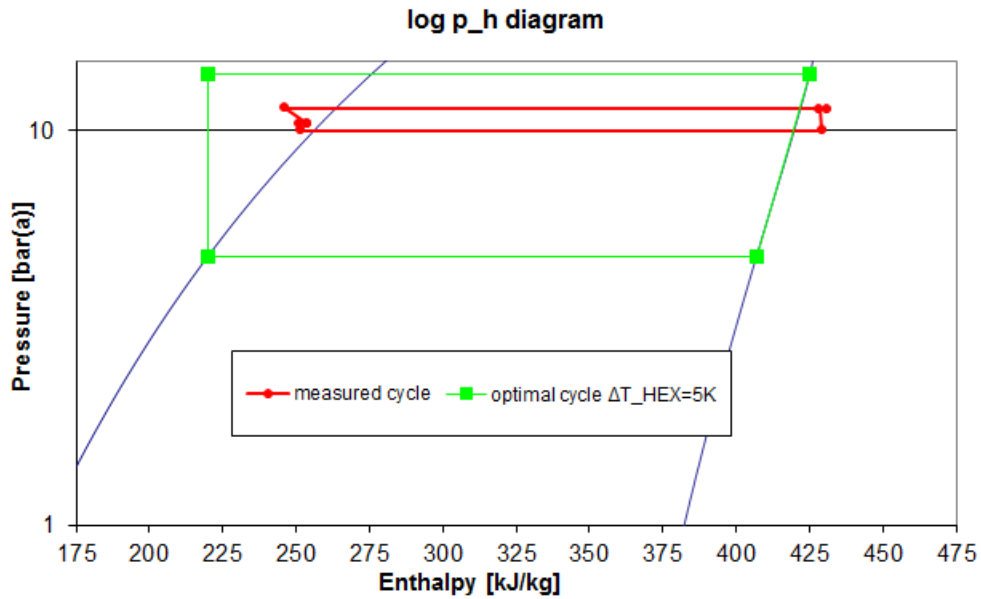
| Test results
Power development & cycles
Temperature difference

Results Power development in time



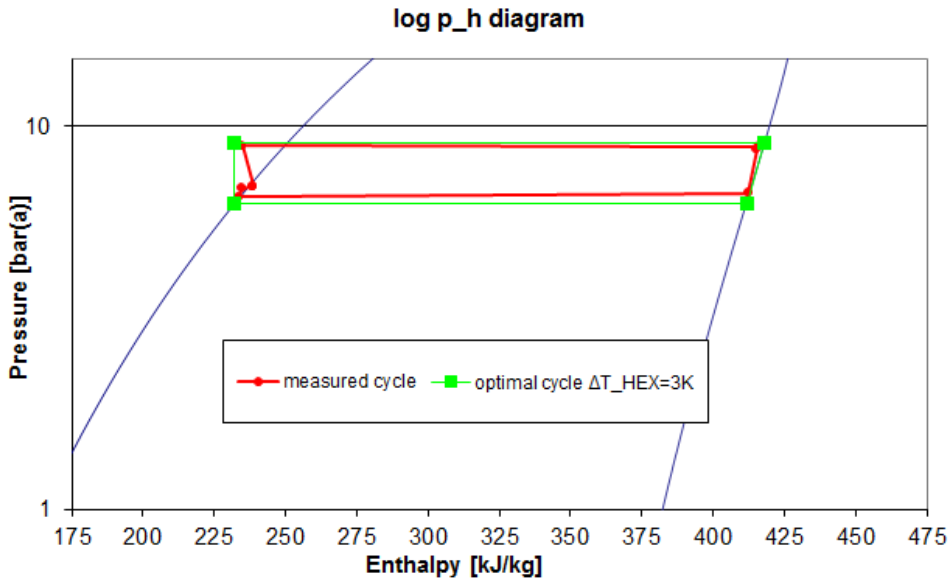
Results Design & measured cycles

Start up: high water temperatures, no power



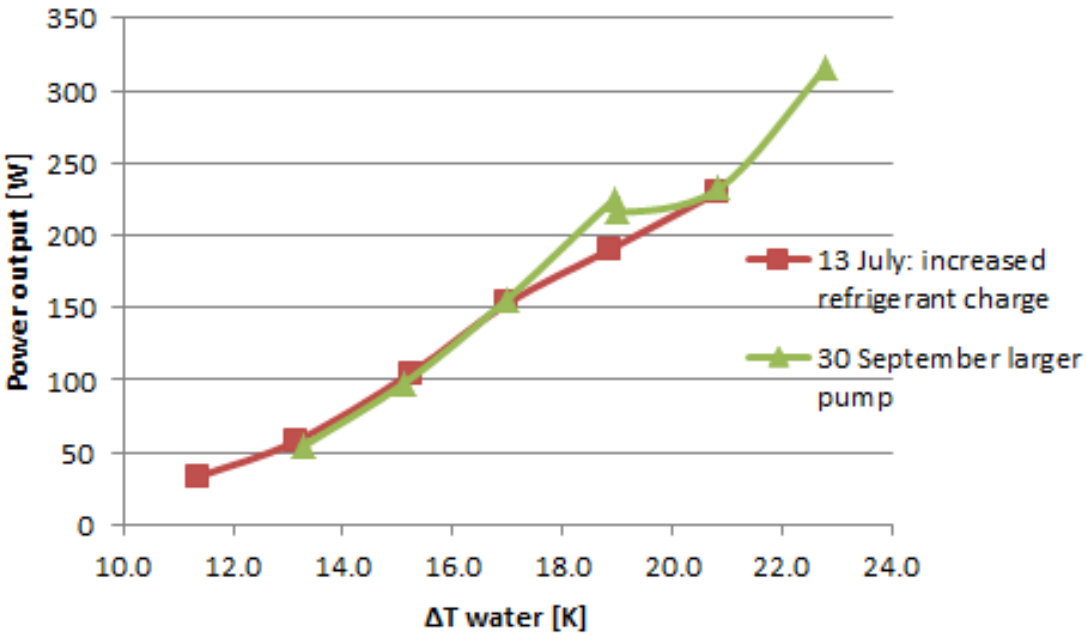
Results Design & measured cycles

- Turbine -30%
- 30-9-2016: realistic OTEC water temperatures, approaching design cycle



Results

Importance of optimal use of temperature difference

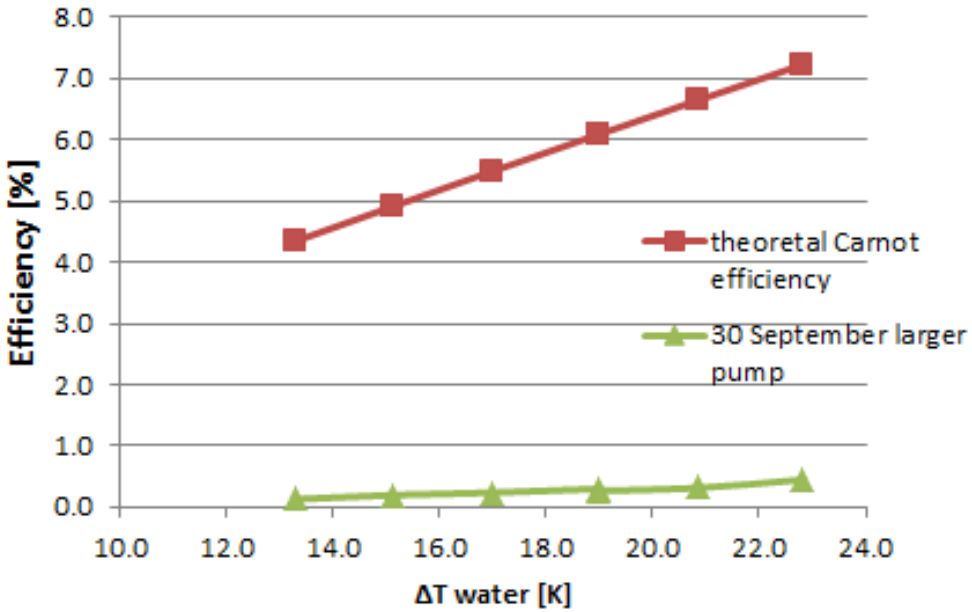


Tools to optimize output:

1. Use evaporator with limited or no superheat
2. Use gravitation to prevent turbine from wet running

Results

Evaluating efficiency



There is a huge gap between measured and max theoretical efficiency.

Main causes:

1. Scale of the prototype is 1:1000
2. Turbine is much to large for actual cycle

Good efficiency is required to reduce investment and incease netto output

Conclusion

- Prototype of 35 kW^{TH} (= scale 1:1000), using standard industrial components, is successfully designed, build and tested

- The very simple thermodynamically cycle works well and can be controlled easily

- Cycle can run well without pump support, but to run without pump support at OTEC water temperatures a higher installation is required

- Larger scale of full scale cycle is needed to improve the efficiency

Goals for near Future:
- build larger scale prototype without pump support to proof efficiency
- proof that open seawater heat exchangers work well over a long time period
- proof reliability of turbine design at minimum superheat.

ENOGIA
The Small Turbine ORC Company

orteq power

Enogia designs and produces Organic Rankine Cycle turbines based on proprietary technology

- an innovative company since 2009
- head office and facilities in Marseille, France
- 25 employees including 18 highly skilled engineers
- 1.5 M€ turnover in 2016
- 35 References in 11 countries
- Strategic partnership with the famous research group

IFP Energies nouvelles

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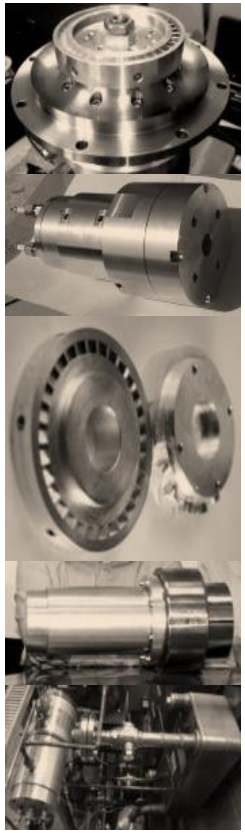
ENOGIA's turbine-expander technology



Proprietary hermetic **high speed turboexpander** technology

Why the **kinetic turbogenerator** ?

| **Proven concept** on larger ORC units
| **No friction**, no wear

Hermetic turbogenerator with PMG generator inside

| No **fluid leaking**
| **Reduced** maintenance

Extremely **Compact** units

Made in France with EU only components, in house assembly

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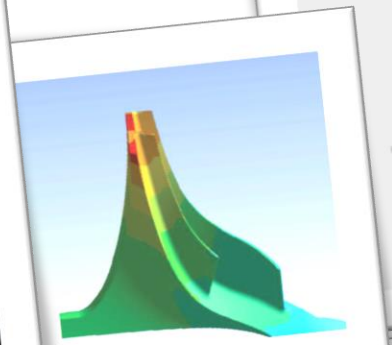
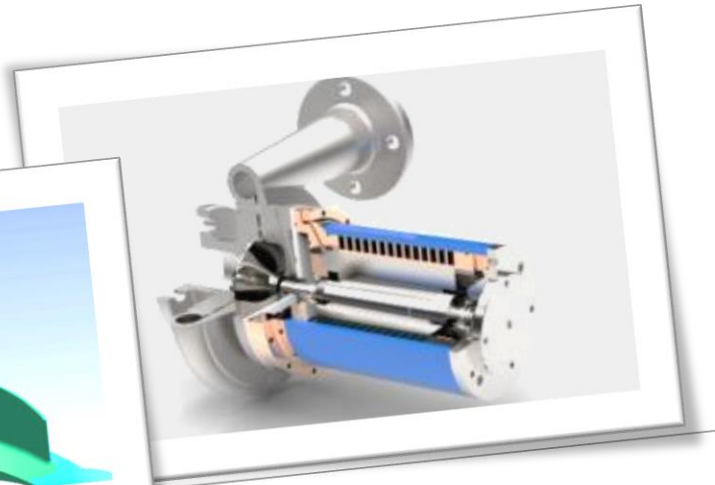
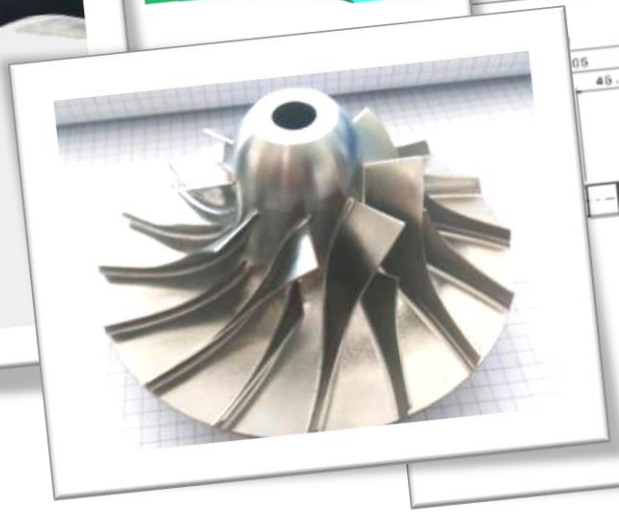
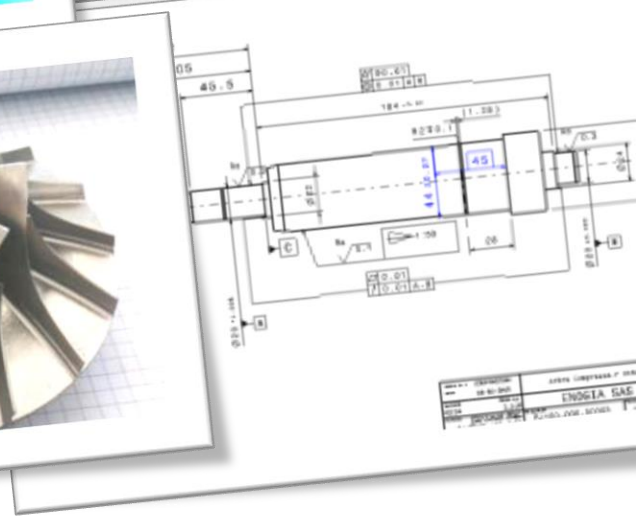
From CFD to prototype









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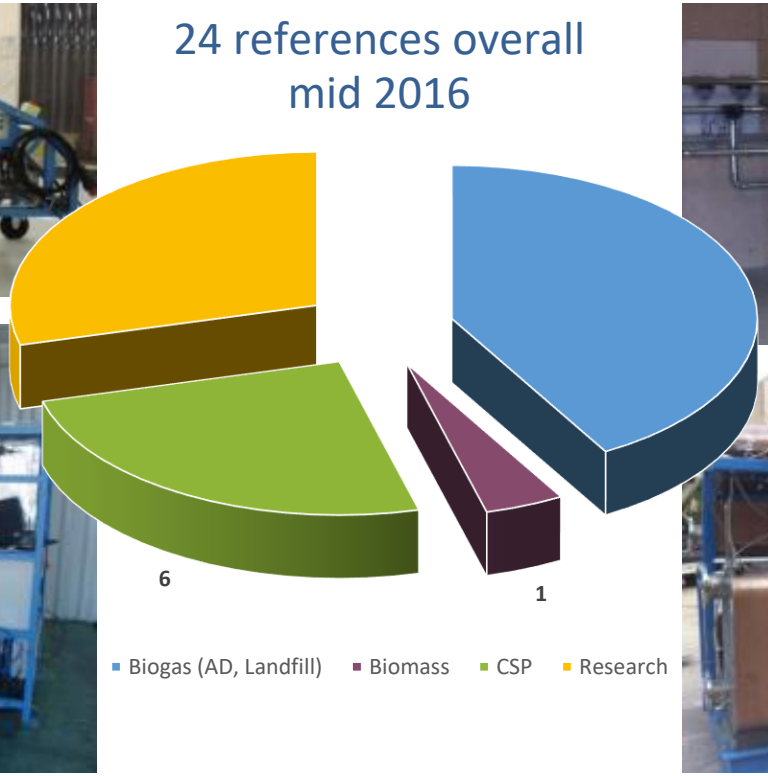
Some references of ORC systems



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About working fluids for OTEC

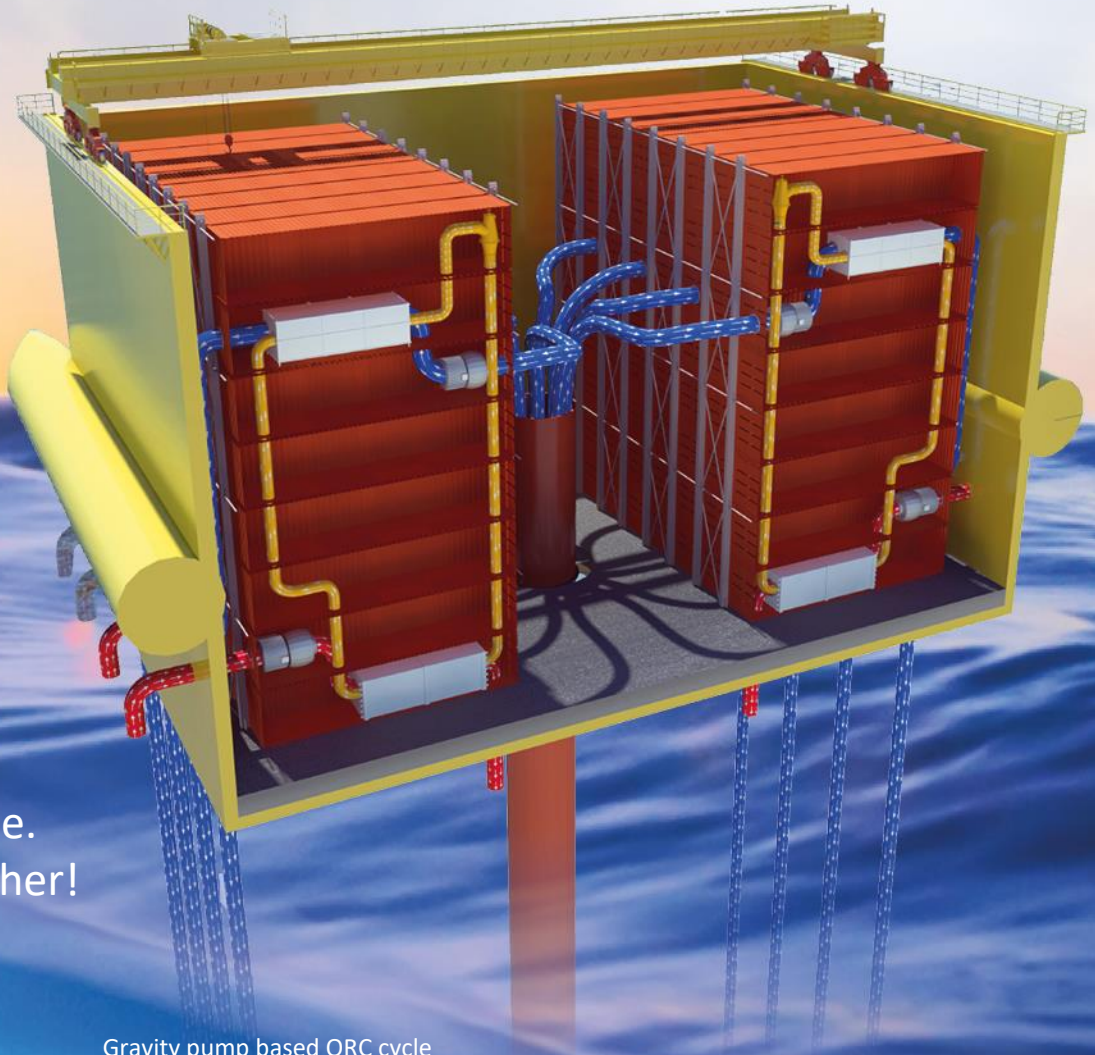
- Arteq and ENOGIA used R134a for the first prototype

- R134a is an effective refrigerant but will be banished

- Other alternatives exists and are undergoing investigation:
- NH3
- R1234yf
- Other refrigerants
- …

Into the future

Next step: Coalition for Off Shore OTEC



If you want to go fast, go alone.
If you want to go far, go together!

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