MCEDD

DEEPWATER DEVELOPMENT

28 - 30 March 2023 | Millennium Gloucester Hotel | London, UK

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Subsea Organic Rankine Cycle (ORC) for subsea satellite power supply

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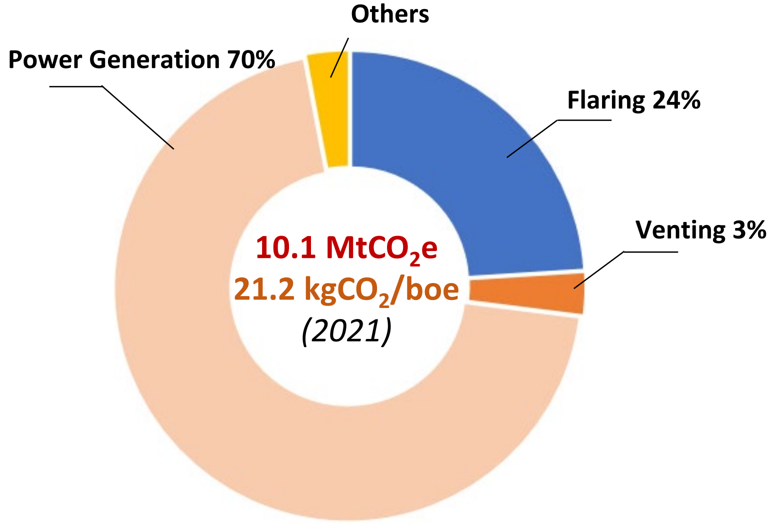
Agenda

- Subsea tie-back: Power Generation & GHG reduction stake
- R&D to screen innovative local power solutions
- Subsea ORC design & performances
- Benchmark
- Concluding Remarks

Subsea tie-back : Power Generation & GHG reduction stake

The GHG Stakes (scope 1 and 2)

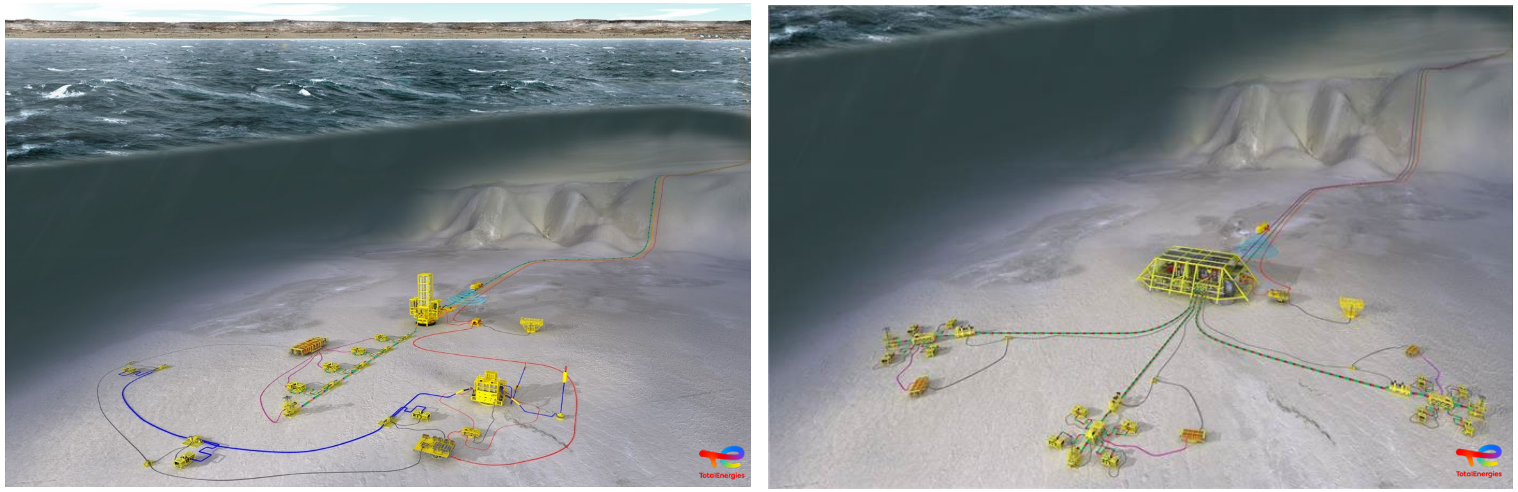


UK Upstream Offshore Oil&Gas emissions[1]

~50 % of new fields development are subsea tie-back in North Sea[2]

New development to target a Zero Carbon Emission approach

Long subsea tie-back Oil & Gas vision



All electric power demand from 100 KWe (Well control/command) to Tens of MWe (Subsea Processing)

Conventional approach: power supply through umbilical or subsea power cables from offshore facilities or from shore

Alternative : Supply a "Local" & Green Power?

1 Emissions Monitoring Report 2022, North Sea Transition Authority
2 Offshore technology, 2018

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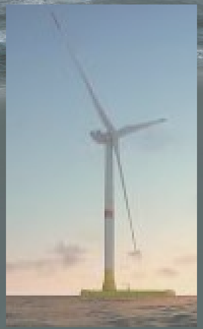
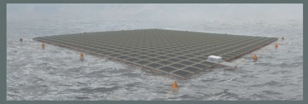
R&D to screen innovative local power solutions

Subsea ORC: a new equipment of the subsea factory?



Offshore Wind[1]



Floating solar[2]

Ocean energies[1]

Advantages:

- Local hot source (Production fluid) & Cold source (Sea water)
- Reduce power losses / Exploit thermal losses
- Mitigate issues of weight & congestion, additional power on topsides

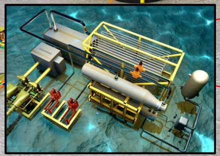
Upsides:

- Subsea architecture simplification *(Umbilical, Pipeline)*
- Export the “green” excess power

Points of attention:

- Limited to sufficiently “High” Temperature Field (>100°C)
- To be combined with a dedicated hydrate & Wax strategy (fluid compatibility, cold flow transport…)

Subsea ORC to produce power from the “excess” well head temperature



Subsea ORC

***Case study** : 40 kbopd, 50 km*

Sensitivity	100 kWe	500 KWe	> 1MWe
Power application	Local	Local	Local *or* Power Export
Power demand	WH command	WH command + SCSI*	WH command + subsea processing

**SCSI: Subsea Chemical Storage & Injection*

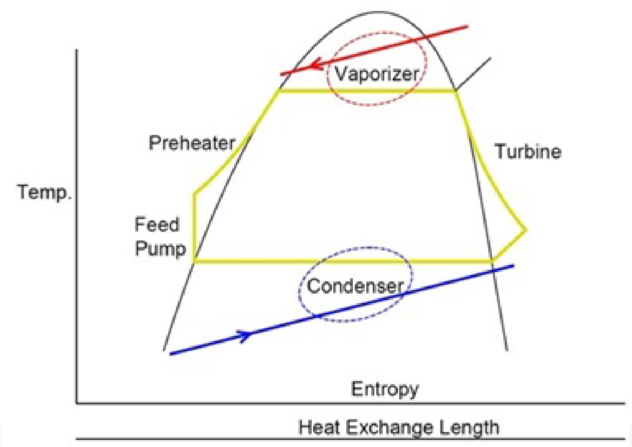
1 Illustration, TotalEnergies
2 Illustration, Moss Maritime (Saipem)

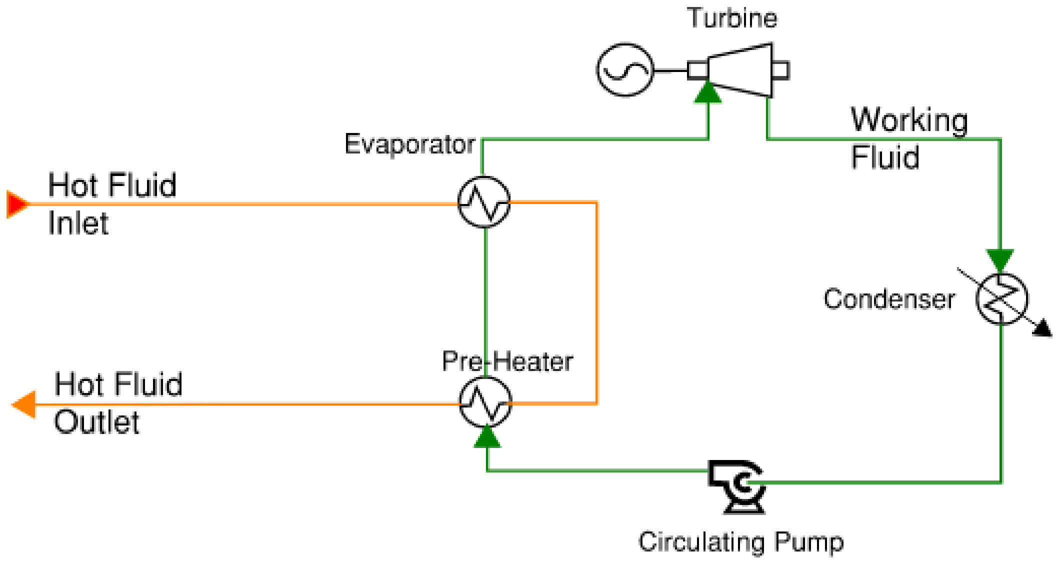
3D © Techniques-Effects 2015

Subsea ORC principle

- Objective of the study:
  - Develop a subsea ORC (organic Rankine cycle) module connected to a production manifold
  - Convert the well heat potential to electrical power

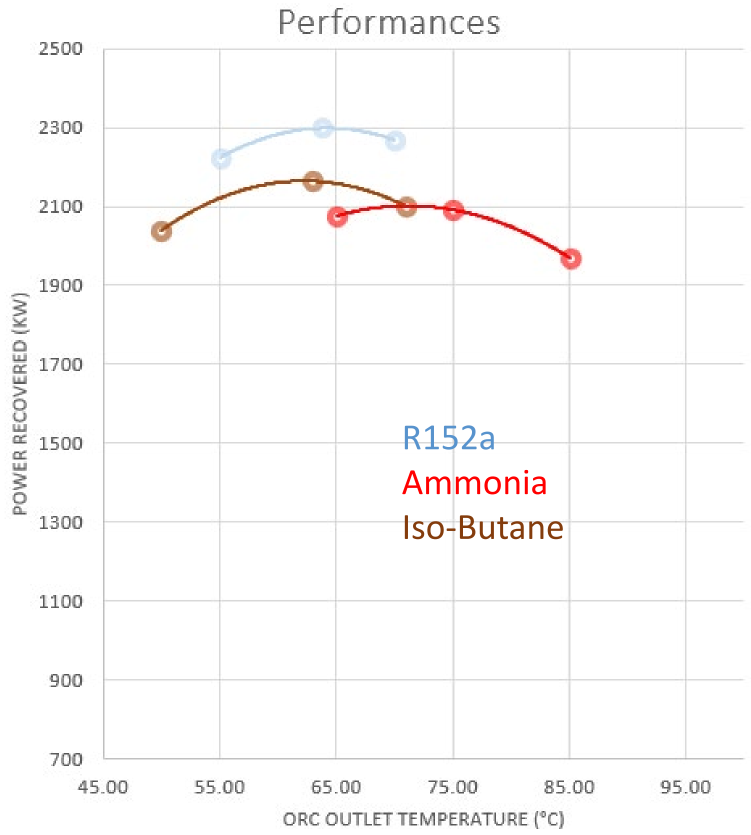
- Typical onshore application :
  - Range from 100 kWe to 10 MWe
  - Efficiency between 10%-20%





ORC submarinization

- How to submarinize this onshore system ?
  - Designed for a high range of water depth
  - Designed considering maintenance plan
- Process simulation:
  - Min t° to avoid hydrate formation at well fluid outlet
  - Sea water temperature to fix the condenser condition
  - Evaporation performed up to intermediate fluid vapor saturation
- Selection of working fluid:
  - Environmental consideration (GWP > 150)
  - Phase envelope compatible with hot source temperature
  - Fluid screening study to maximize performances



Selected working fluid : *i-butane*

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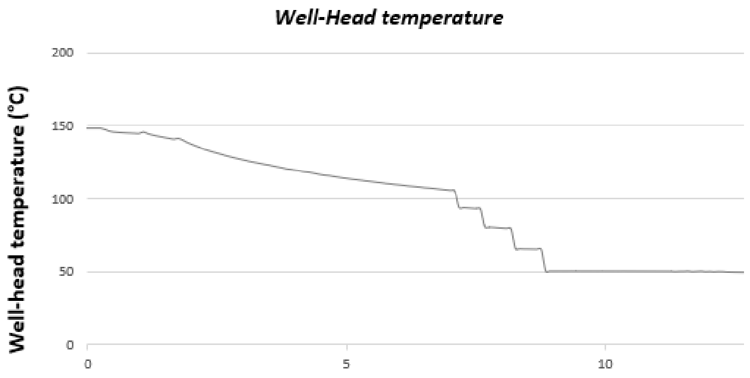
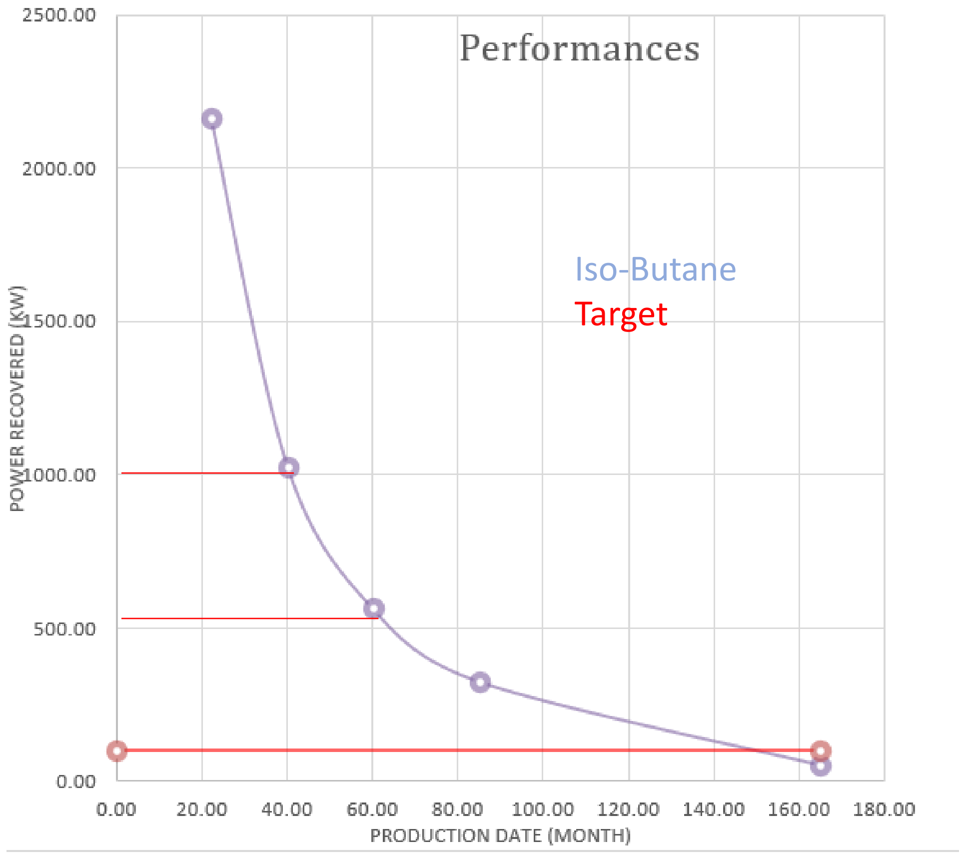
Subsea ORC Performances



Two modules** of 1 **MW** each in parallel, **2x50%** sized for production profiles at **year 2 (peak flow rate)



Rapid decline of the **power production** with the **production profile**

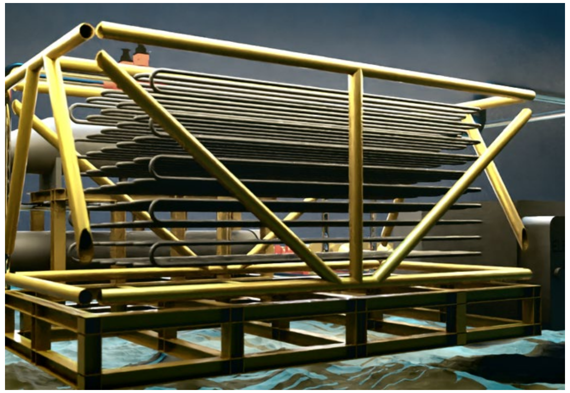
Allow a **continuous power supply** of the **WH Control & Command** + **export** of the power excess

Subsea ORC design

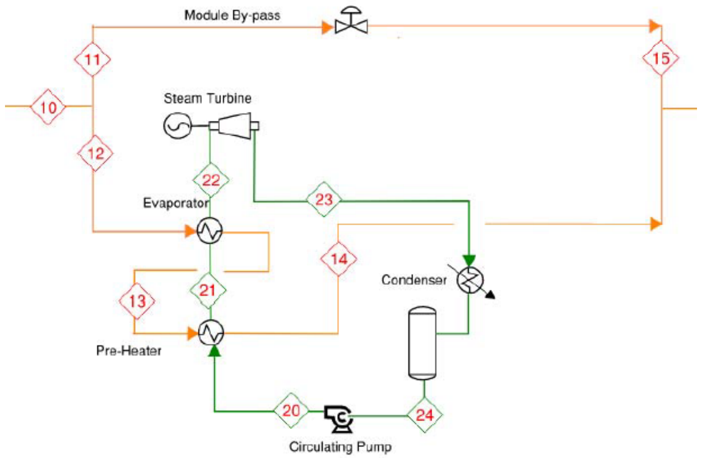
Design scenario :

- Sizing of equipment **limited to the need**: produce **a constant power** (100 KWe, 500 KWe) as long as possible
- **Drivers:** optimize **size & weight**

Pre-heater/evaporator



Passive condenser



pump

Turbine/alternator/ cable

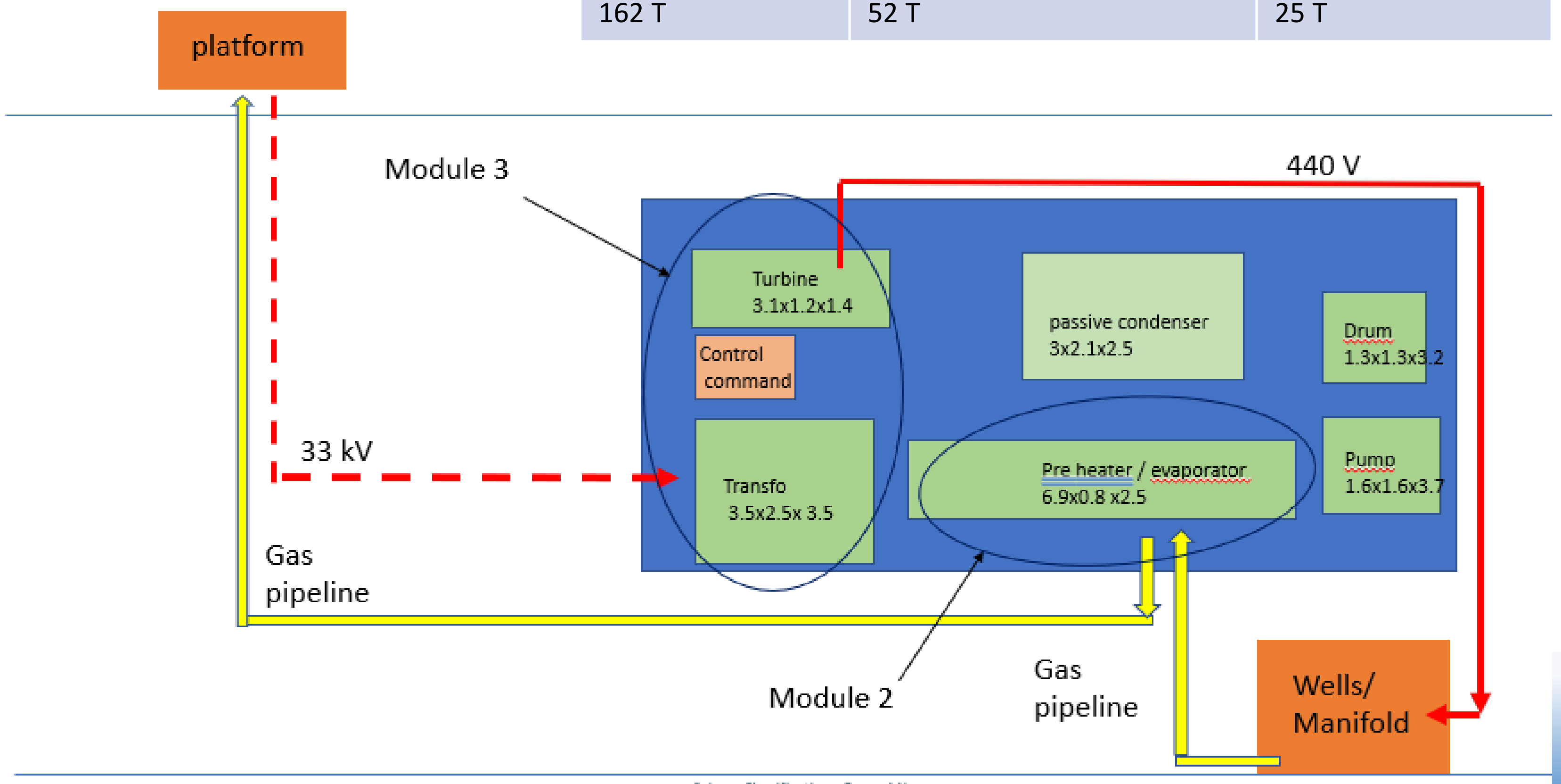
scenario	100 kWe	500 KWe
Power application	Well head control command	Well head control command + light subsea processing
Module weight (tons)	135	235

Subsea architecture & modularization

- 100 kW : 1 single module 135 T (10x10x4)
- 500 kW : 3 sub-modules
- 1 MW : 4 sub-modules

Main module	Module 2 (exchanger module)	Module 3 (electrical module)
Pre installation	Post installation	Post installation
15x10x4 m	6.9x0.8x2.5 m	7.5x2.5x3.5 m
162 T	52 T	25 T

Installation with MSV for module until 500 kW



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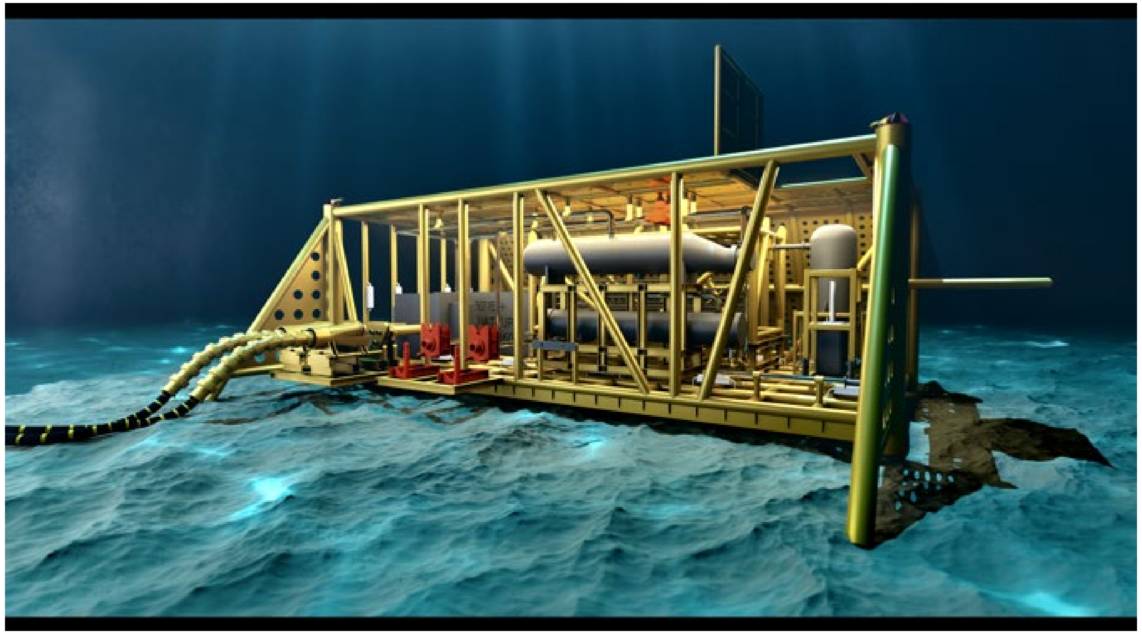
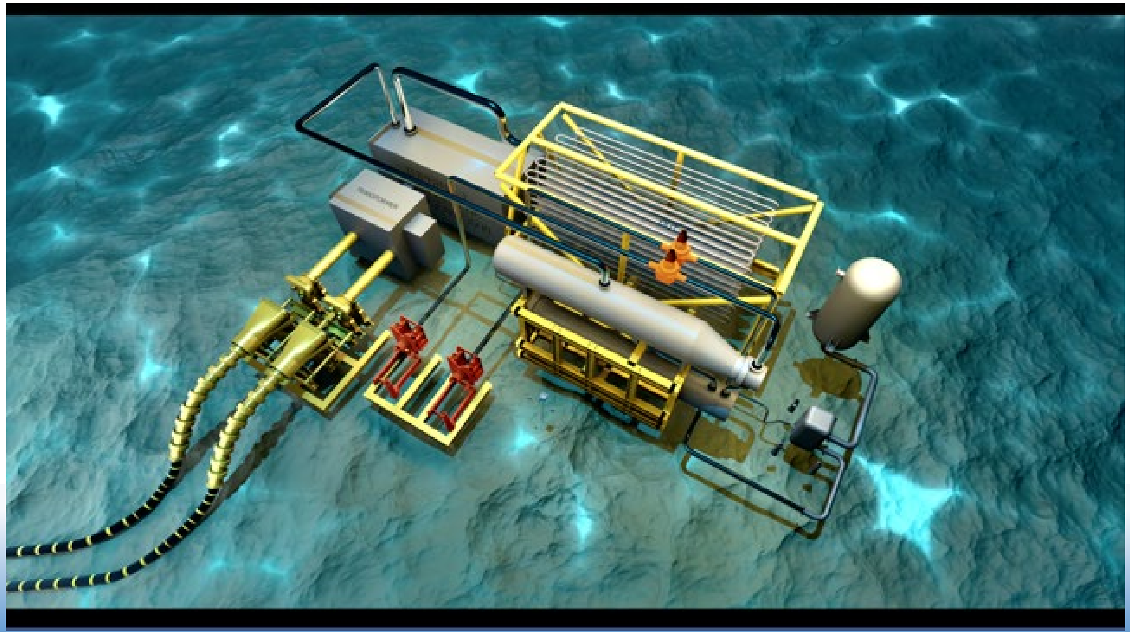
Subsea architecture & modularization



3D model
General arrangement & basic design of the structure



Benchmark

- **Comparison for a typical subsea tie-back application, North Sea:**

	Subsea ORC	Offshore floating wind	Ocean wave energy
Power range capacity (MWe)	2 MWe max (0.6 MWe average)	8 MWe / turbine	From few to several MWe systems
Applicability	(North Sea) High Temperature reservoir (> 120°C)	Depends on wind resources capacity on area	Depends on wave resources capacity on area
Intermittency	Continuous ☺	Intermittent / seasonal effect ☹	Intermittent / Seasonal effect ☹
Technology Maturity	Low ☹	medium 😐	medium 😐
Estimated LCOE ($/MWh)	> 1 000* ☹	100 to 300[1] 😐	200 to 600[2] 😐
GHG saving technical cost ($/t$CO_2$eq)	> 1 000		

** Expected to improve with maturity evolution*

A non-intermittent solution, but subsea ORC penalized by its low maturity & dependance to the field production profile. Additional R&D work required.

1 - Offshore Renewable Energy (Catapult Research Center UK), Jan 2021
2- Ocean Energy Technologies, IRENA 2020

Concluding Remarks

- **R&D** to identify **new solutions to decarbonize** the **Oil&Gas offshore industry**
- **Subsea ORC**, a new **subsea processing** item for a **local & green electricity** at satellite location
- **Use of environment energy** (production fluid/sea water) to **reduce GHG emissions**. May enable to **simplify the subsea architectures** (umbilical size)
- A solution to **power continuously** well head **control/command** and **light subsea processing**
- **Low maturity,** necessity to **onboard vendors** to mature the solution & need of breakthrough **R&D on ORC** to **broaden the application case** *(lower temperature & improve efficiency)*

We need to work together (Contractors & Operators) to achieve the Net Zero Emission

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