mcT Petrolchimico

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Contenuti Tecnico Scientifici

ENERGY RECOVERY AND EMISSION REDUCTION: SAIPEM CASE STUDIES IN INDUSTRIAL PLANT

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San Donato Milanese, 25 November 2015

INTRODUCTION

Approach that reduces the electric energy requirement and CO_2 emission of process units with optimized, innovative solutions:
Organic Rankine Cycles (ORC), Mini Hydro and Solar applied in industrial context

OBJECTIVE: Improved efficiency process units, energy requirement and CO_2 emission reduction

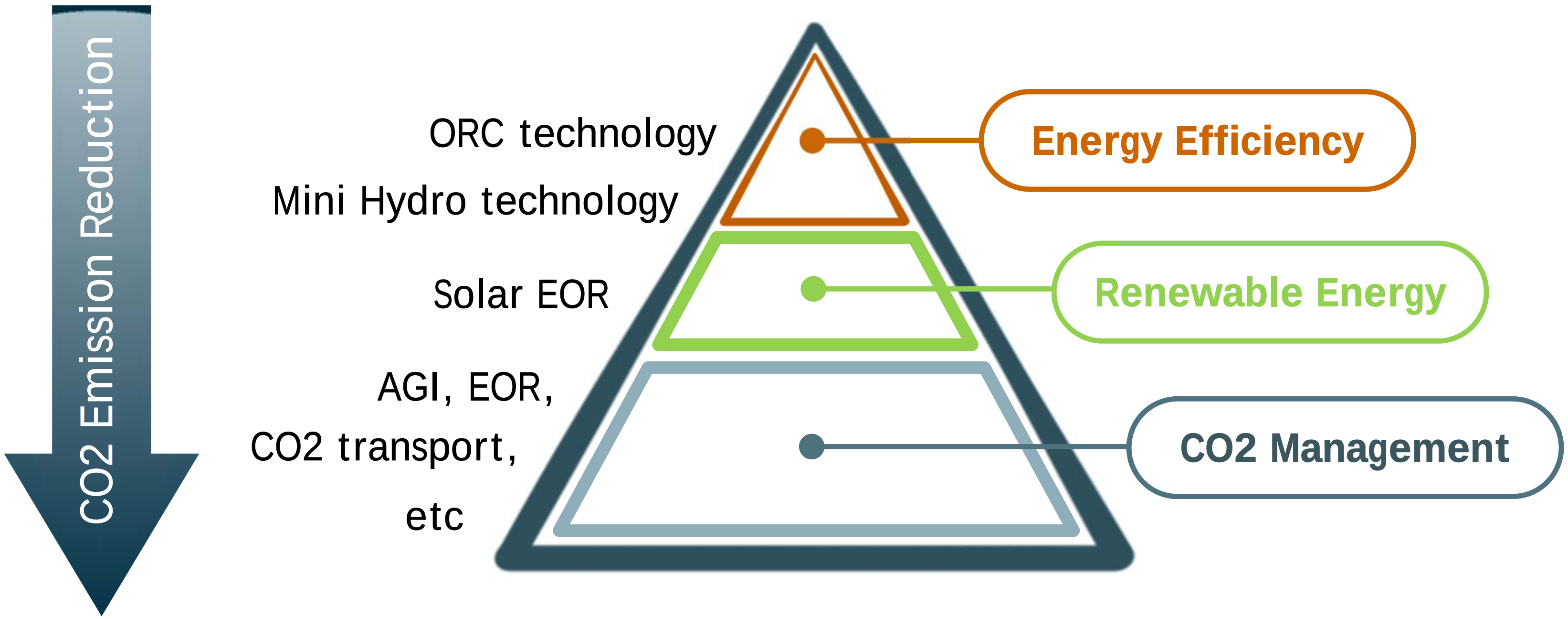
SUMMARY:

- **ORC technology: Ammonia Urea plant, NGL plant & Refinery**
- **Mini Hydro technology: Ammonia Urea & NGL plant**
- **Solar EOR: Heavy Oil Exploitation plant**
- **CO_2 Management**
- **Conclusions**

Introduction

The CO2 path Illustration

CO_2 emission reduction grows up according to the selected technology.



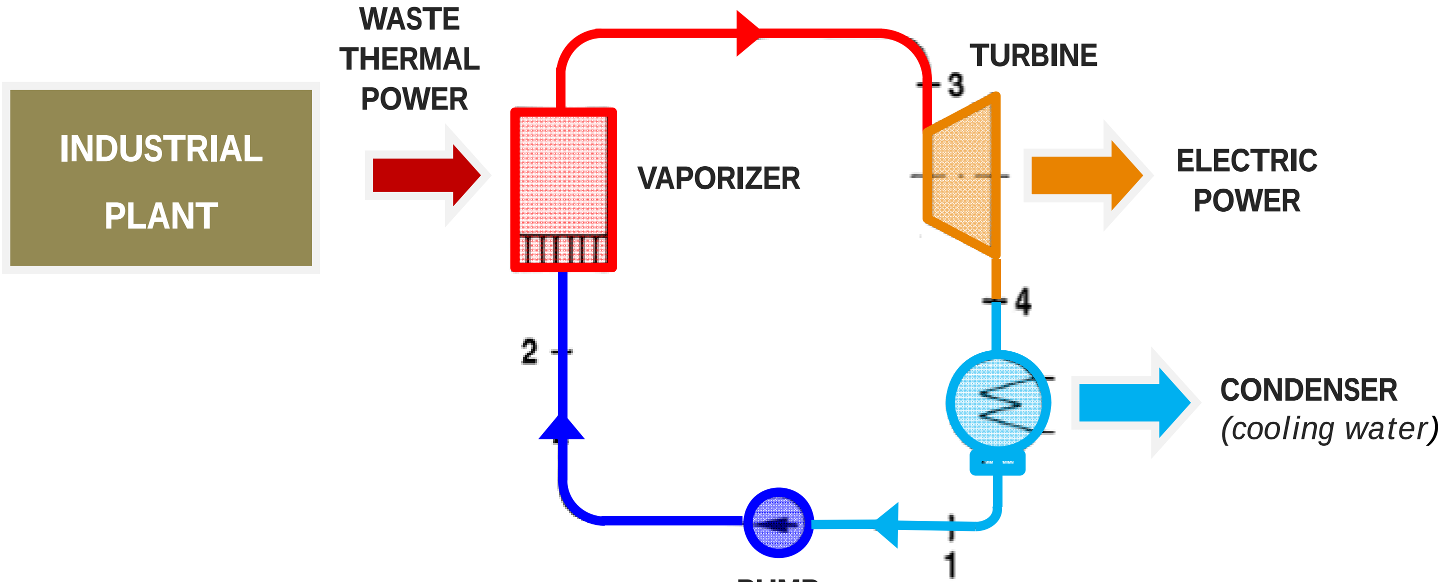
ORC technology

Heat Recovery in Oil&Gas application

ORC technology

Cycle description

ORC are Rankine thermodynamic cycles where a suitable organic fluid is used instead of water.



PHASES DESCRIPTION:

- **1-2** **Liquid phase compression** *(pump)*
- **2-3** **Vaporization** (*heat recovery vapor generator*)
- **3-4** **Organic steam expansion** (*turbine*)
- **4-1** **Condensation** (*condenser*)

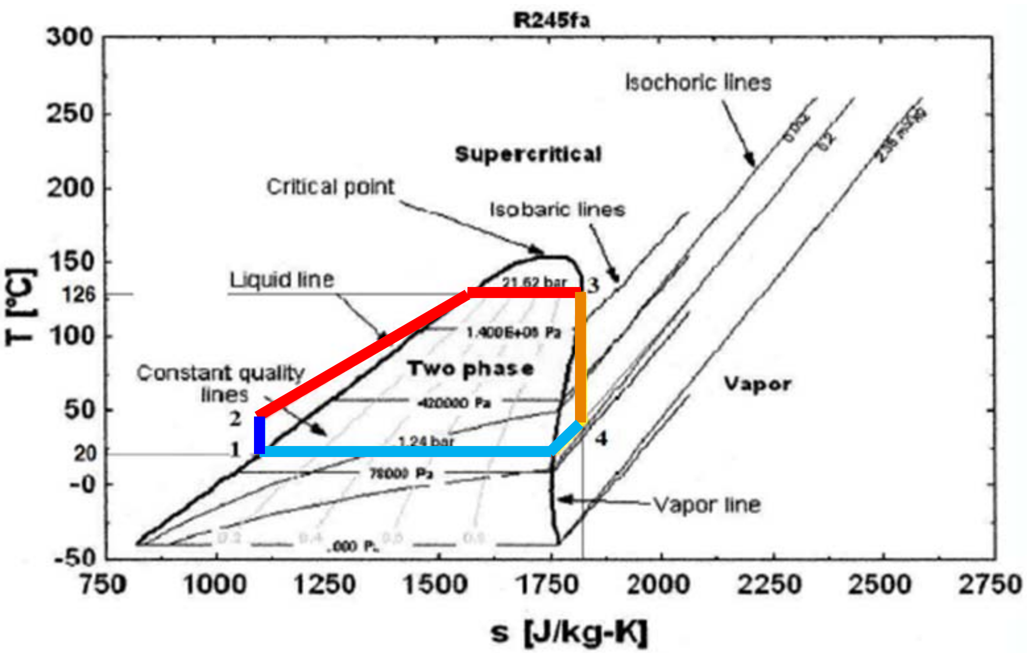
ORC technology

Organic fluid characteristics

The choice of the working fluid must be done considering both thermodynamic and economical aspects, essential for the performance of the ORC system.

MAIN CHARACTERISTICS:

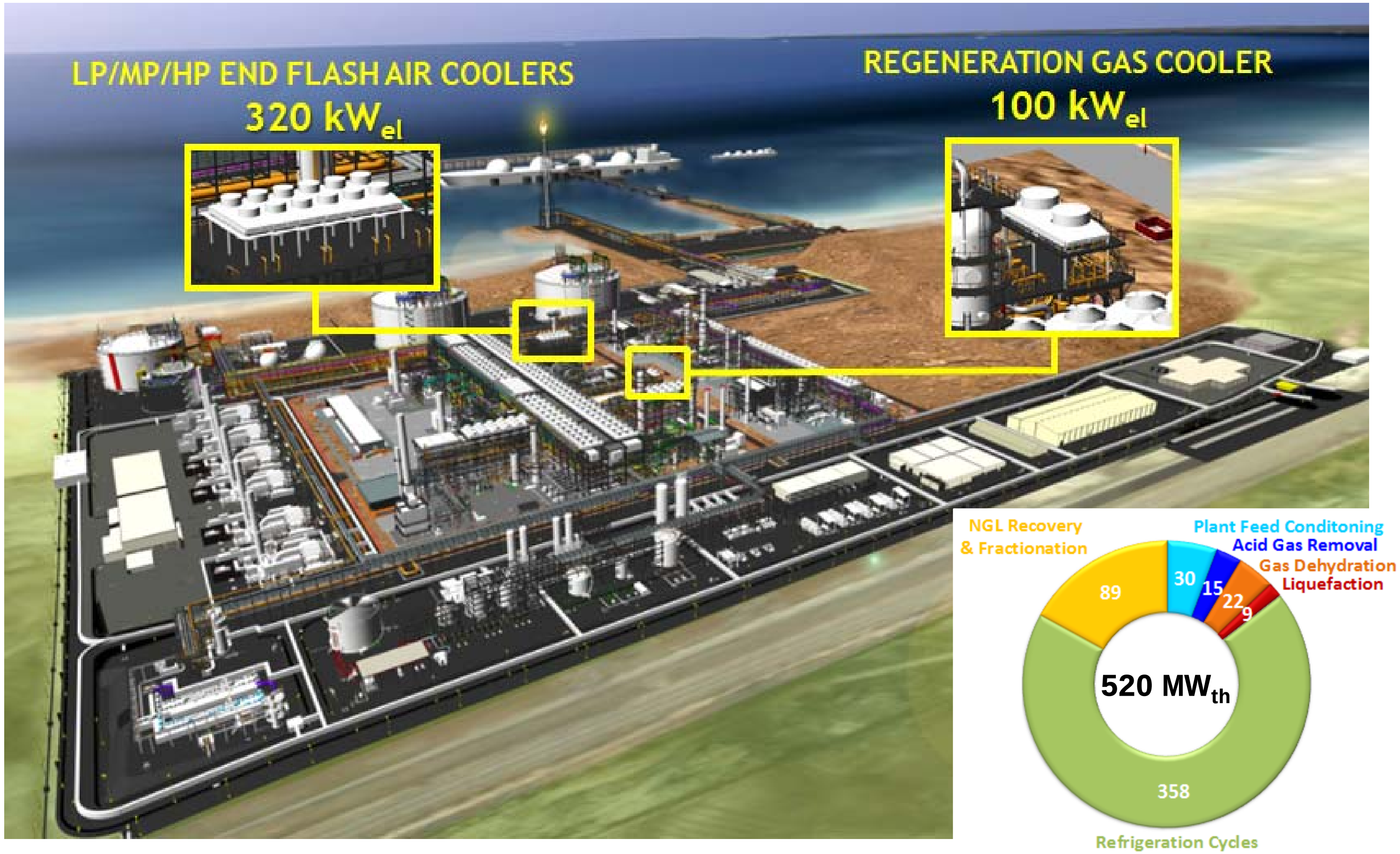
- Maximization of cycle efficiency
- Low vaporization heat
- High density
- Few or unique turbine stage
- Low peripheral speed of blades
- Direct coupling to generator



ORC technology

Case study 1: thermal power recovery in NGL plant

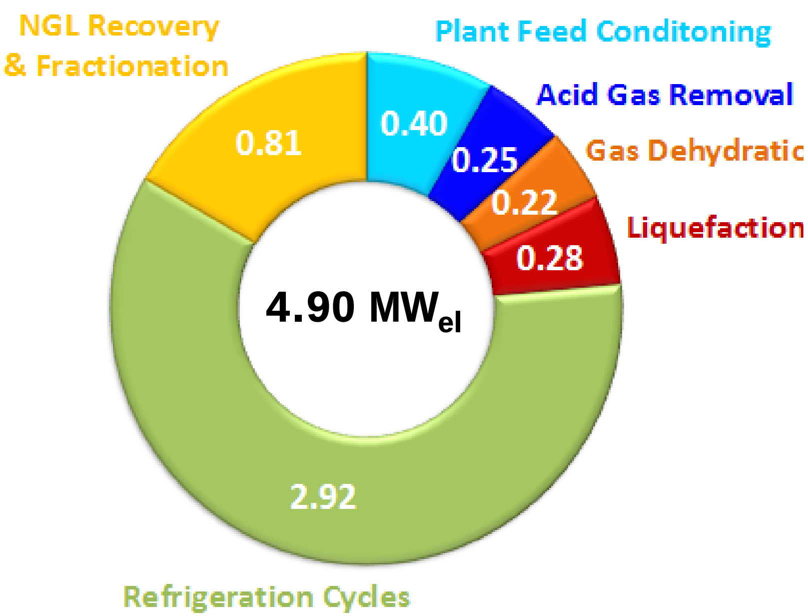
In NGL plant a large amount of thermal power is dissipated on air coolers (520 MW_{th}).



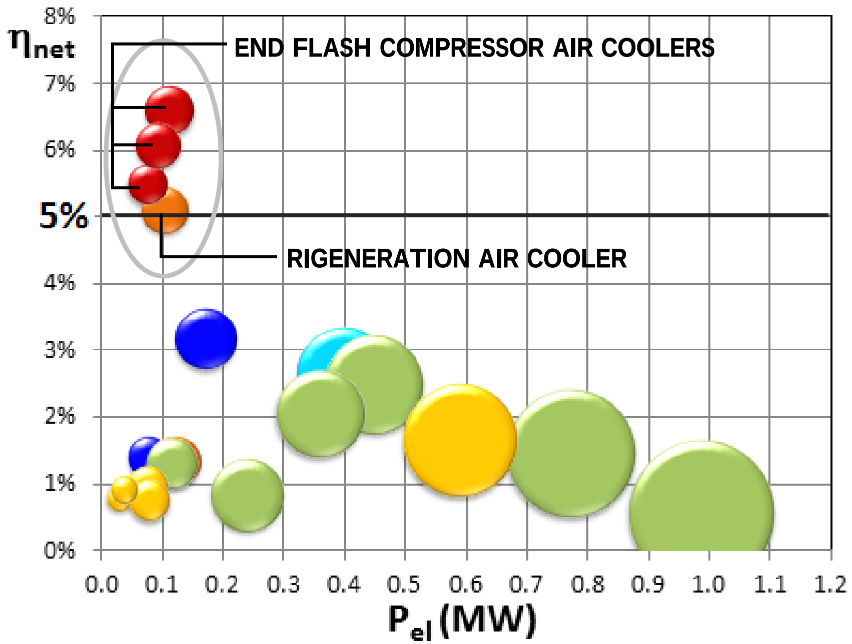
ORC technology

Case study 1: NGL plant, efficiency vs expected electric power

The most of air coolers work in correspondence of low temperature, reducing the potential energy recovery by an ORC system.



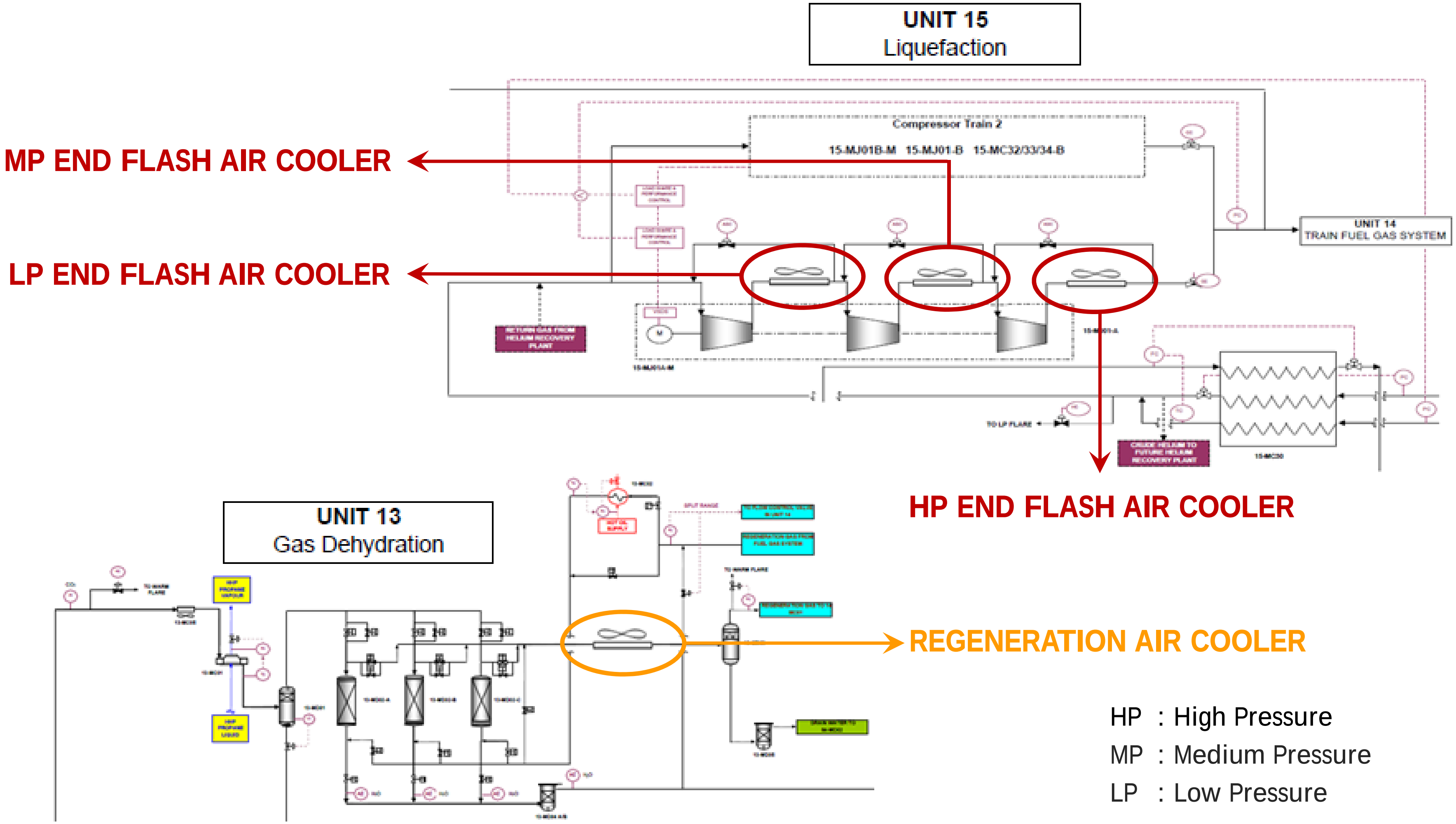
Expected electric power



Net efficiency vs expected electric power

ORC technology

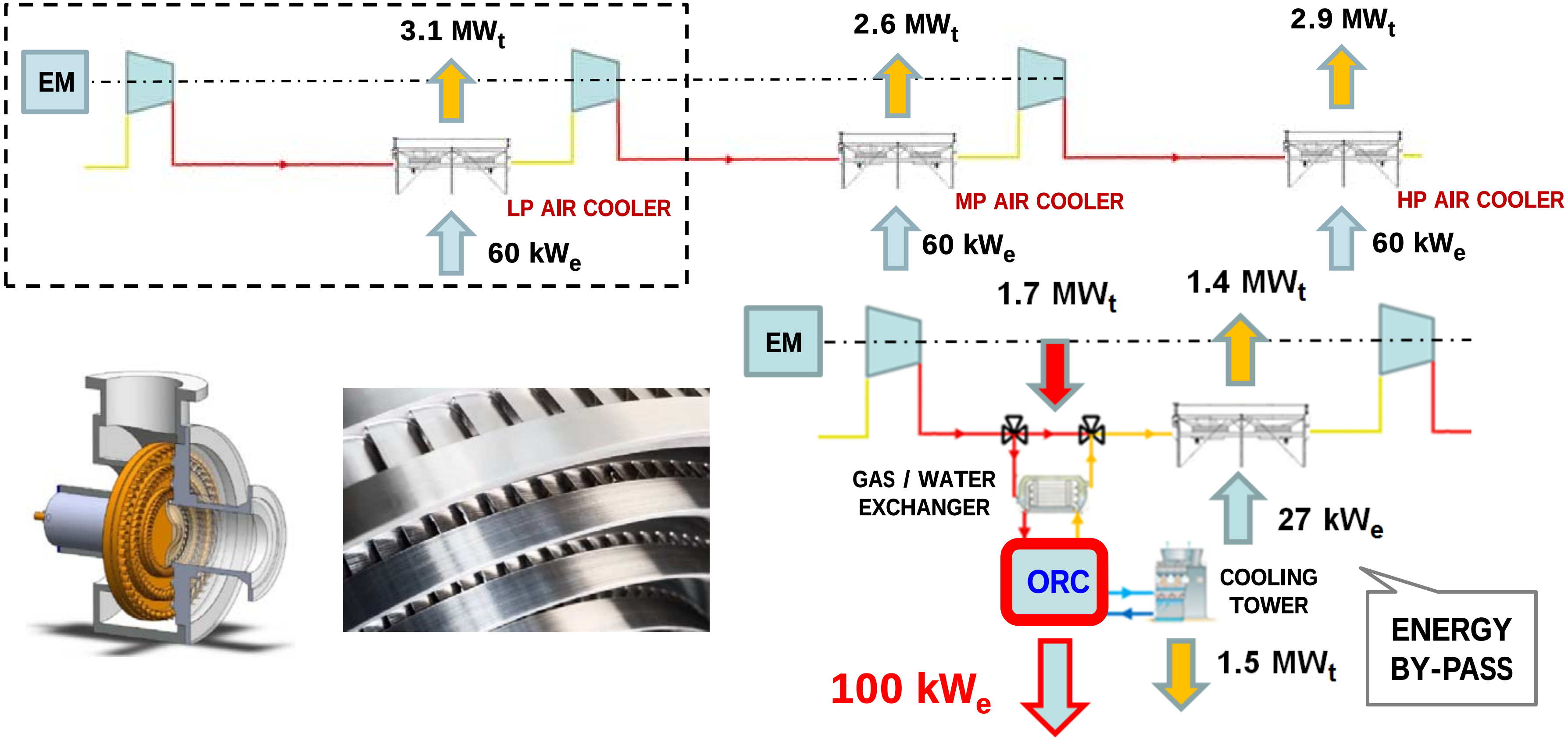
Case study 1: NGL plant, selected air cooler PFD's



HP : High Pressure
MP : Medium Pressure
LP : Low Pressure

ORC technology

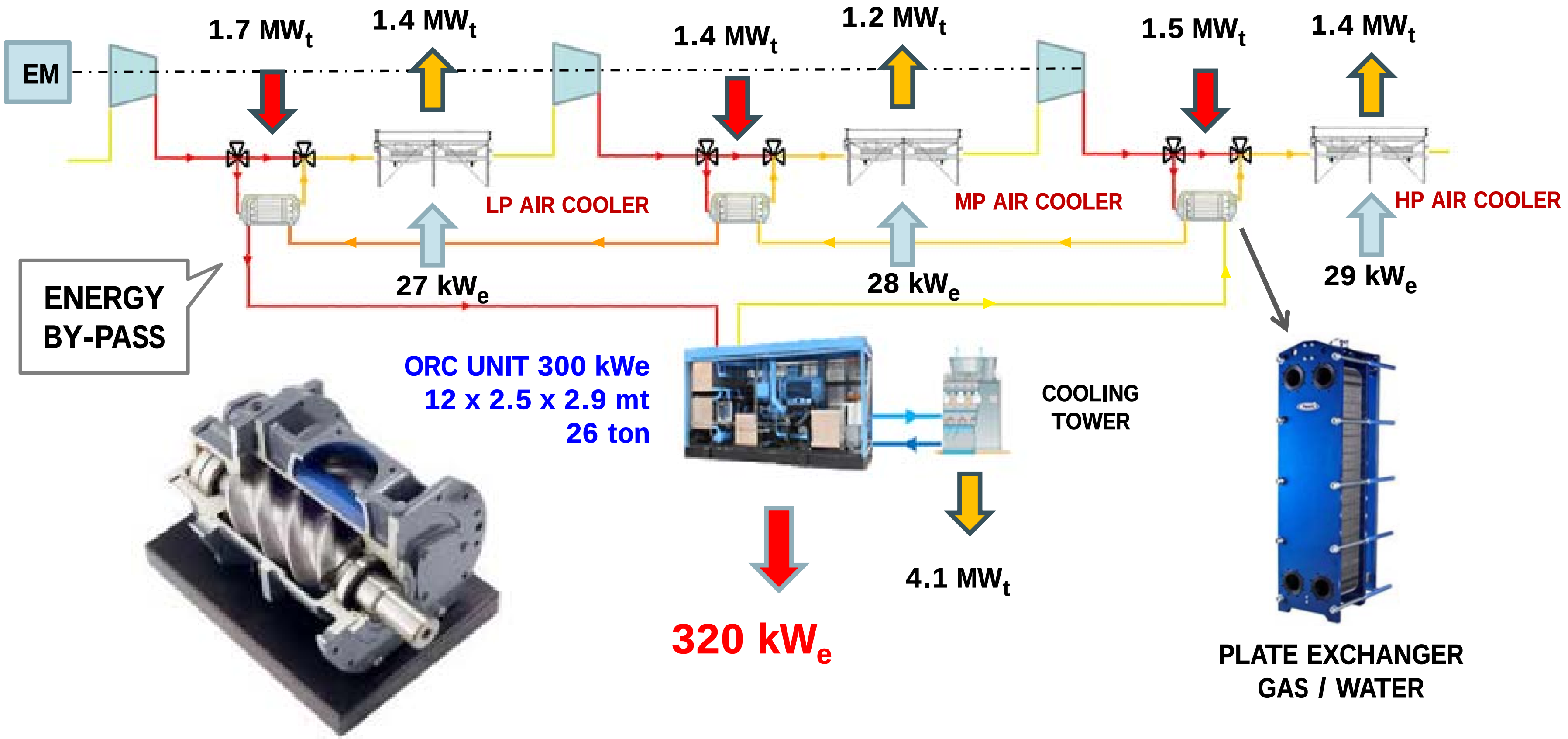
Case study 1: NGL plant, LP air cooler



RADIAL TURBINE ORC TECHNOLOGY: 130 ÷ 350 °C, 100 kWe ÷ 14 MWe

ORC technology

Case study 1: NGL plant, LP/MP/HP air coolers



SCREW EXPANDER ORC TECHNOLOGY: 90 ÷ 300 °C, 70 kWe ÷ 600 kWe

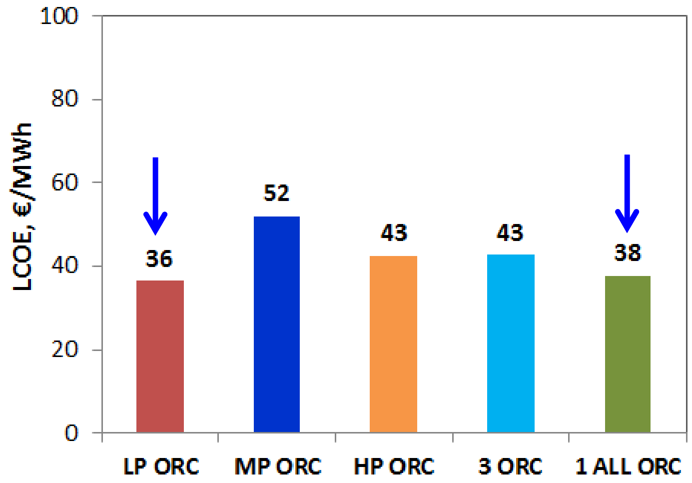
ORC technology

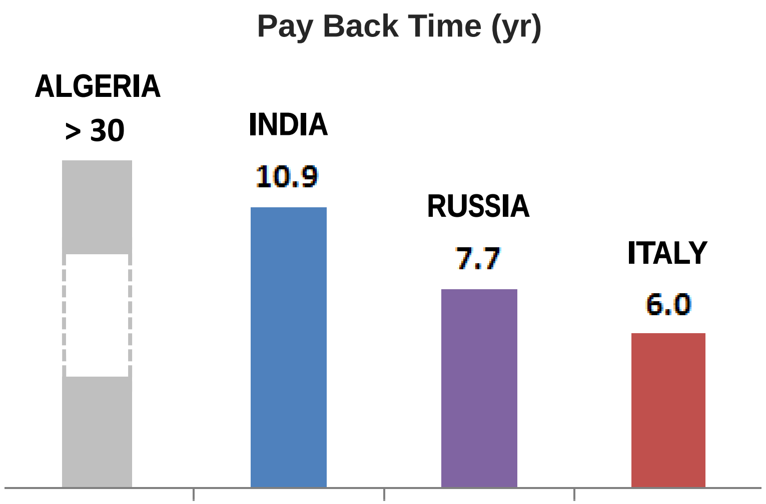
Case study 1: NGL plant, energy & economic assessment

- Net Electric Power : **320 kW$_e$**
- Yearly Electricity Production : **2.72 GWh$_e$/yr** (8300 hours/yr)
- Reduction in CO_2 Emission : **1540 ton/yr**

CAPEX (± 20%) : **1,440,000 €** (4500 €/kW)

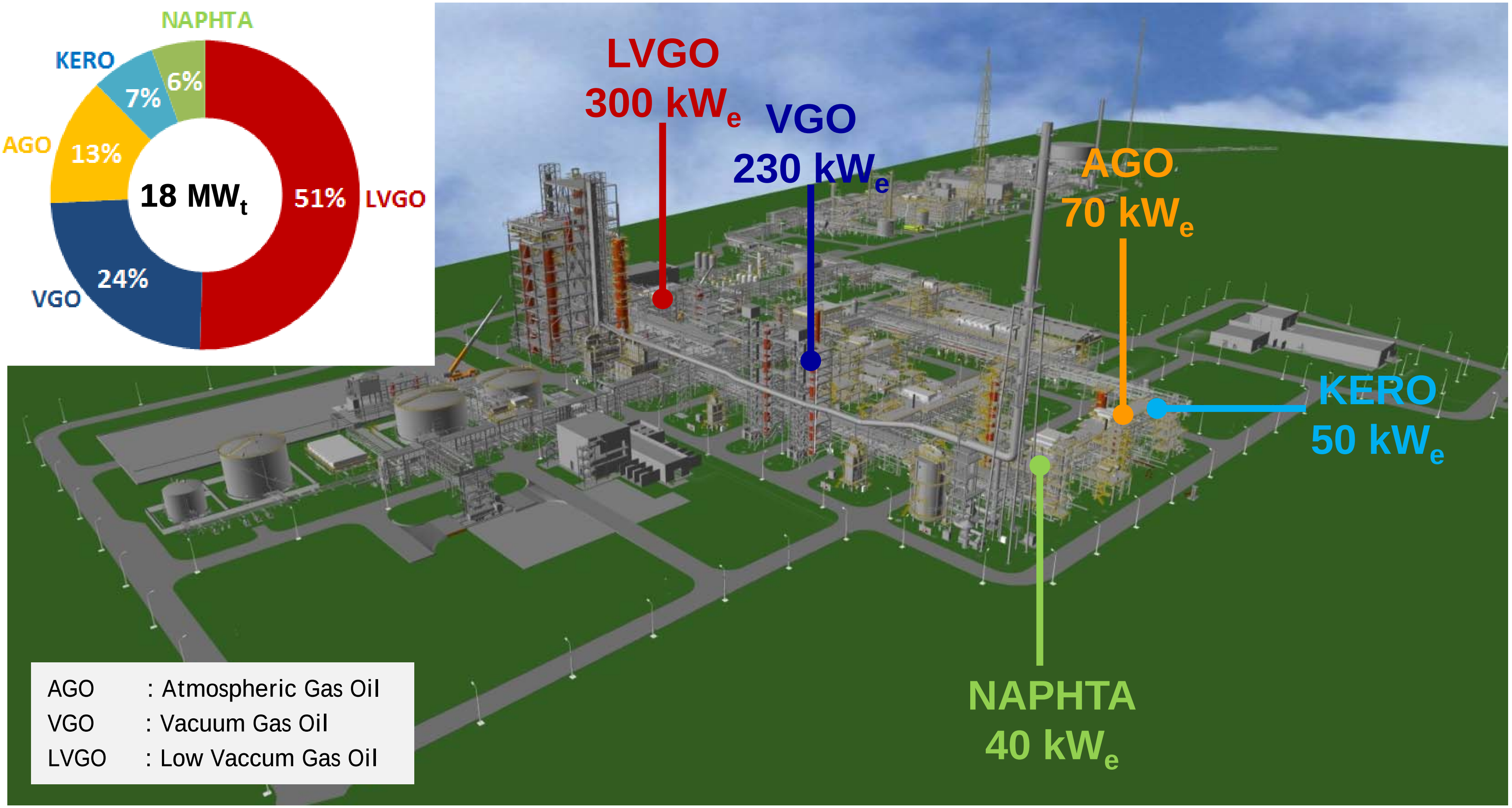
OPEX (± 20%) : **5 €/MWh**





ORC technology

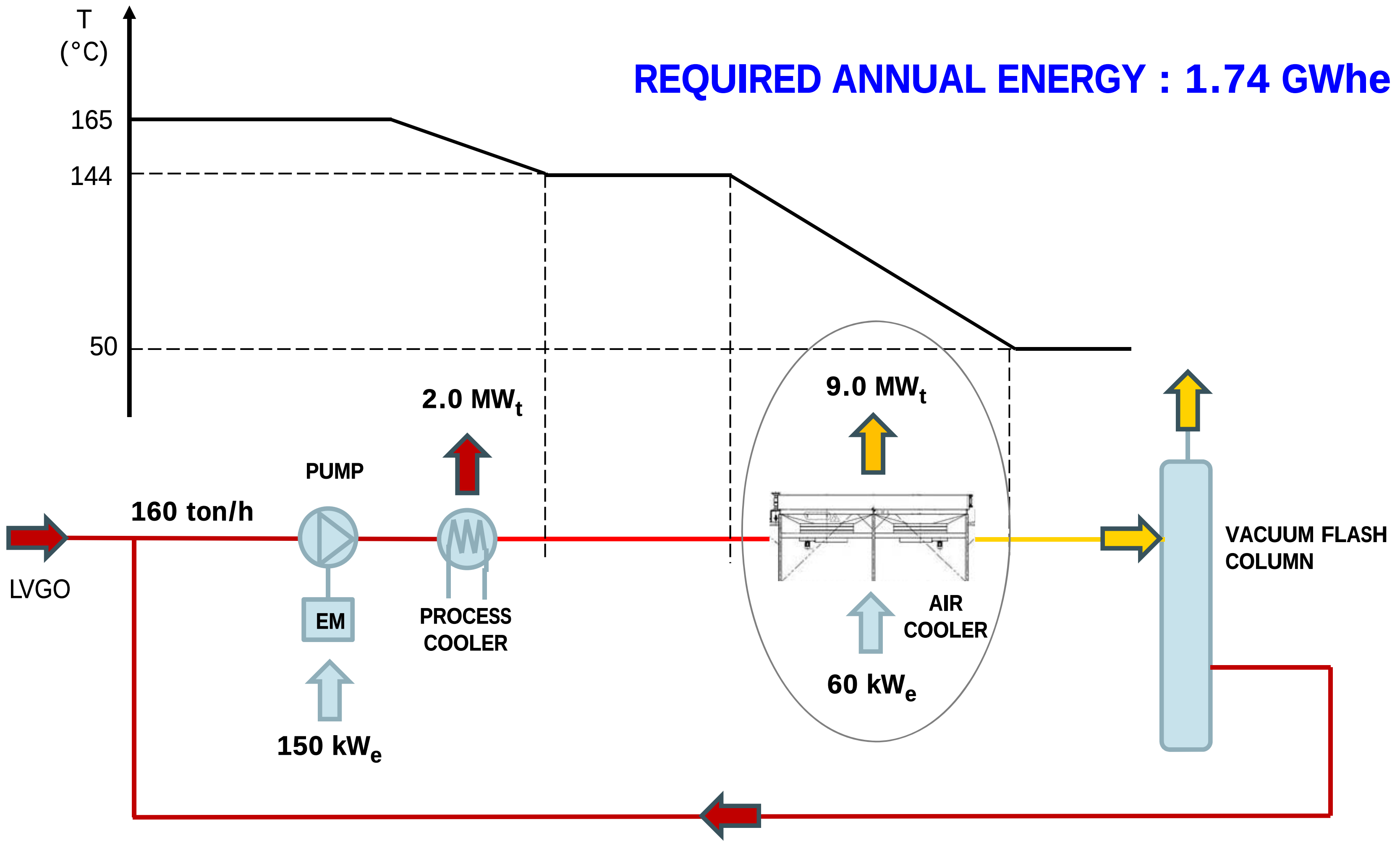
Case study 2: thermal power recovery in Refinery plant



ORC technology

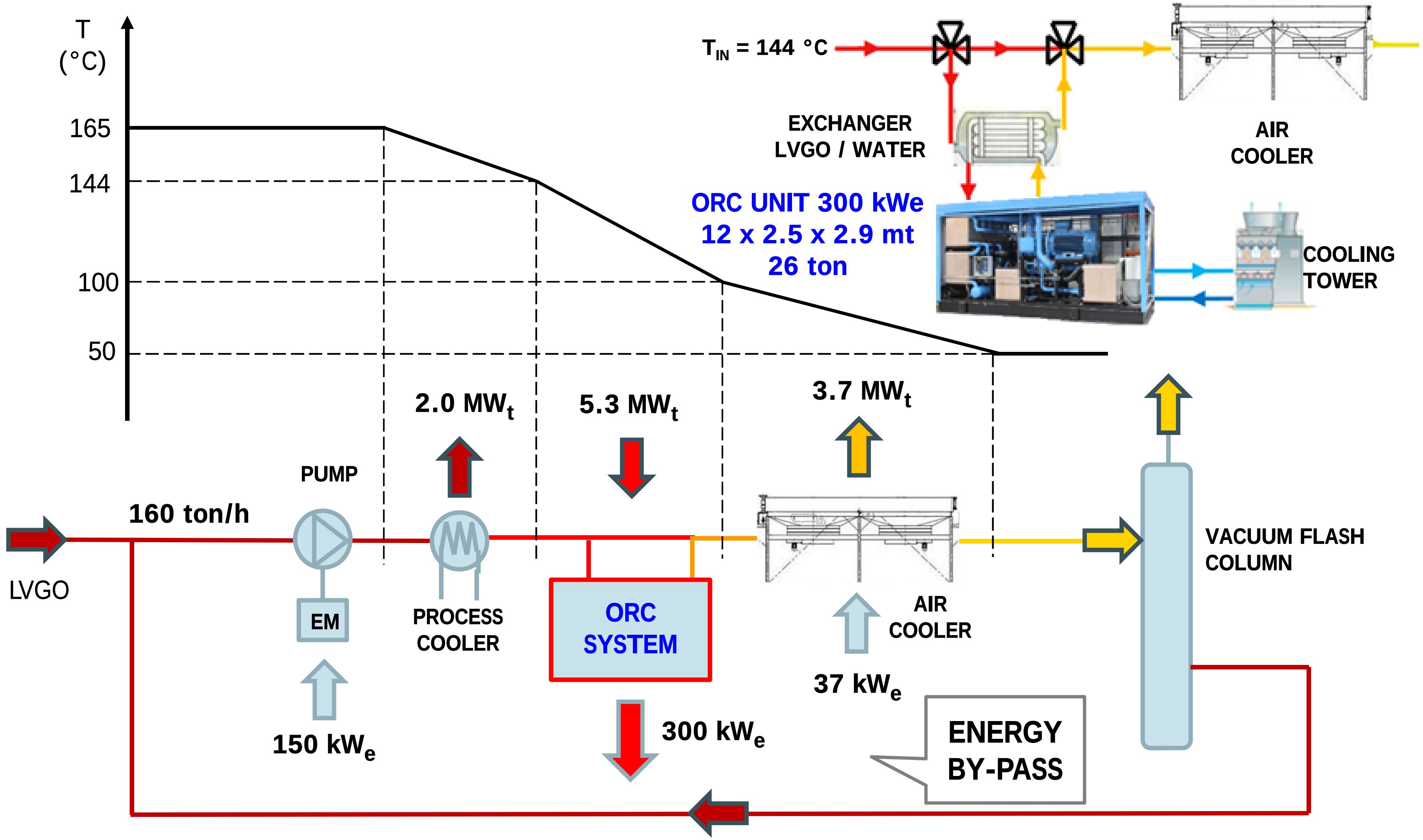
Case study 2: Refinery Products, Low Vaccum Gas Oil circuit

REQUIRED ANNUAL ENERGY : 1.74 GWhe



ORC technology

Case study 2: Refinery Products, Low Vaccum Gas Oil circuit



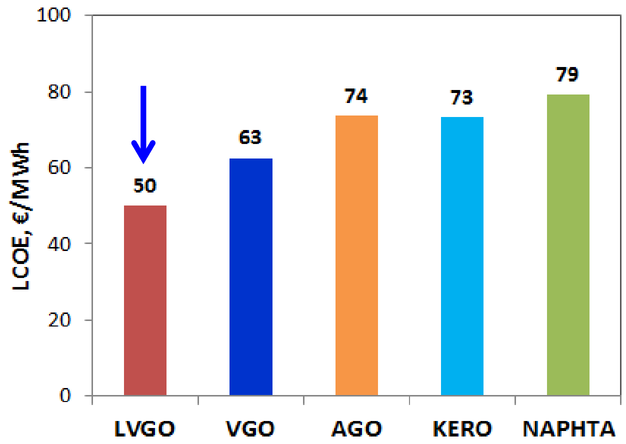
ORC technology

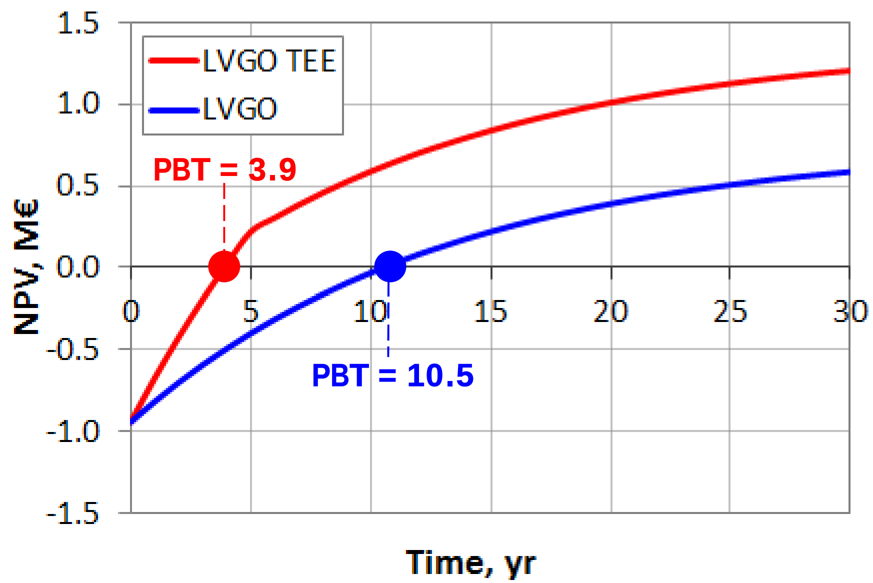
Case study 2: Refinery Products, energy & economic assessment

- Net Electric Power : **300 kW_e**
- Yearly Electricity Production : **2.49 GWh_e/yr** (8300 hours/yr)
- Reduction in CO_2 Emission : **980 ton/yr**
- TOE : **460 ton/yr** Utilization factor **t = 3.36**

CAPEX : **930,000 €** (3100 €/kW)

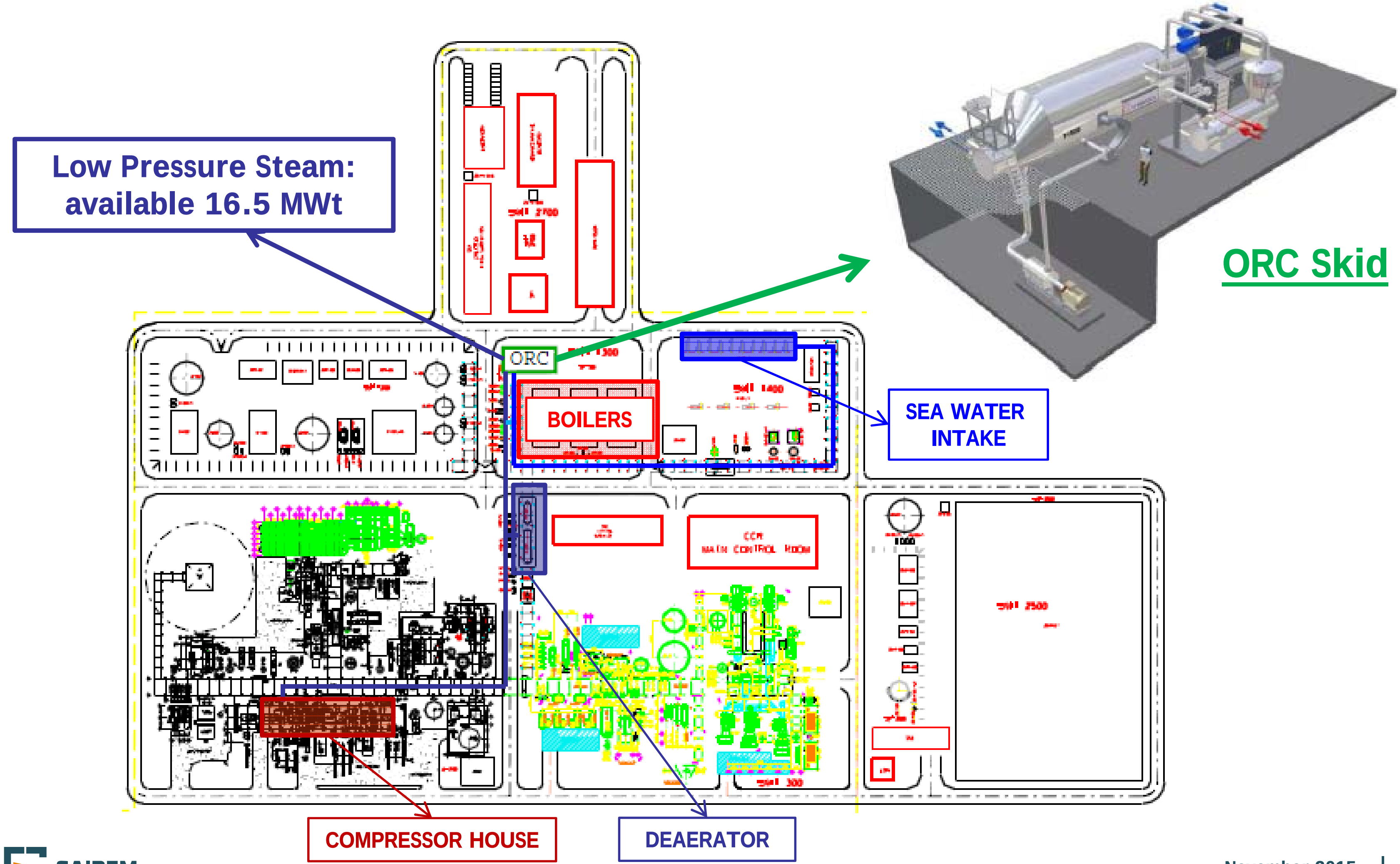
OPEX : 5 €/MWh





ORC technology

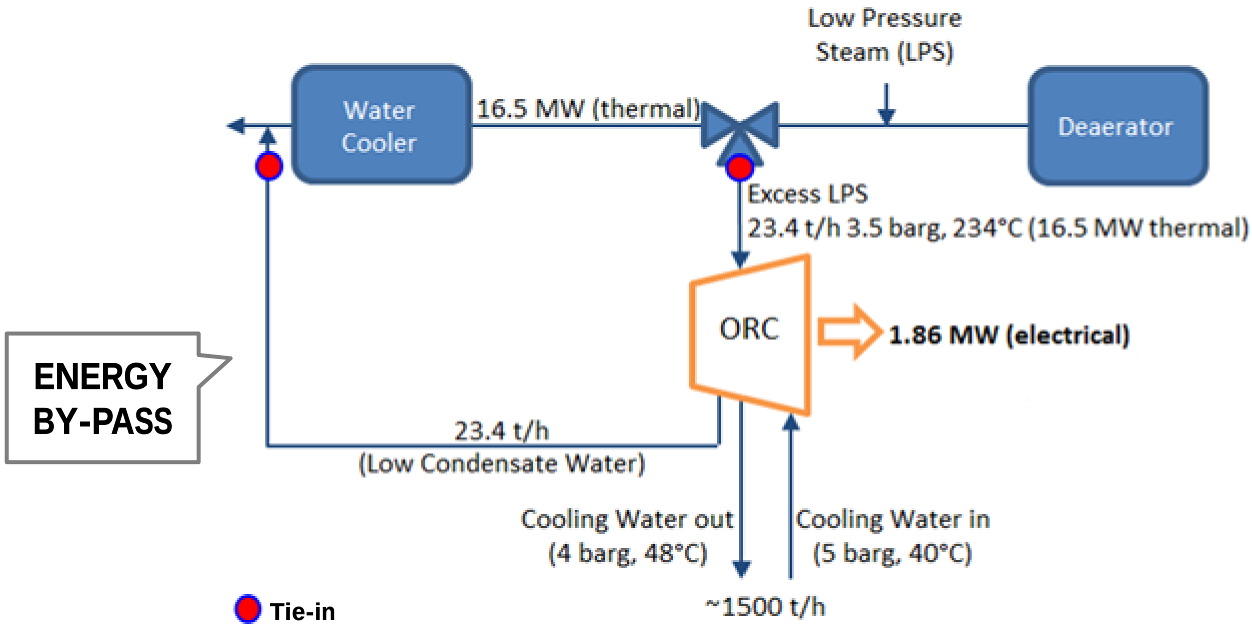
Case study 3: thermal power recovery in Ammonia Urea plant



ORC technology

Case study 3: thermal power dissipated in Ammonia Urea plant

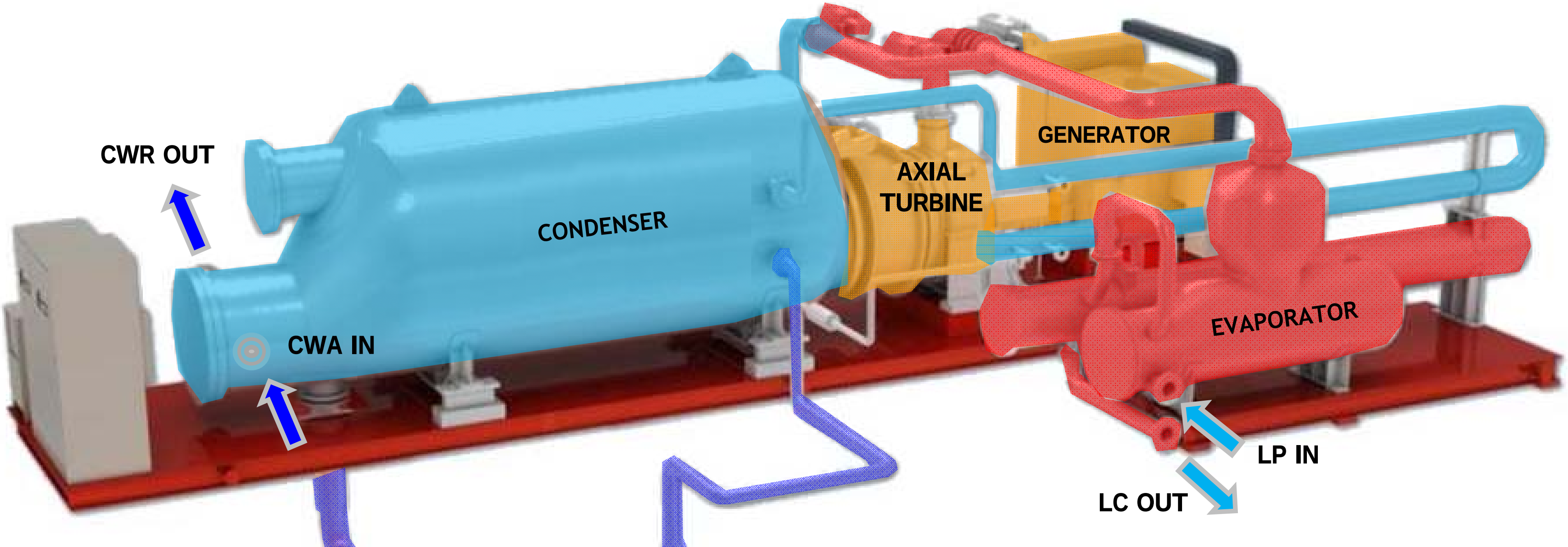
The excess LP steam in the Urea plant has the aim to increase the plant reliability, sometimes it is re-injected in a steam turbine or is condensed on an water cooler: in this case 16.5 MWt of thermal power are continuously wasted.

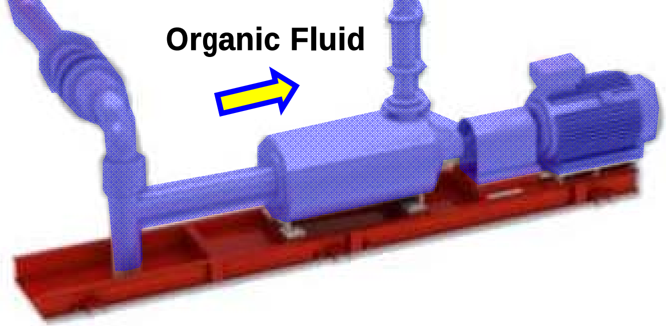


Supplying the LP steam to an ORC thermal energy can be recovered and **1.86 MW_e** of net electric power will be generated.

ORC technology

Case study 3: Ammonia Urea plant, turbo-generator 3D view

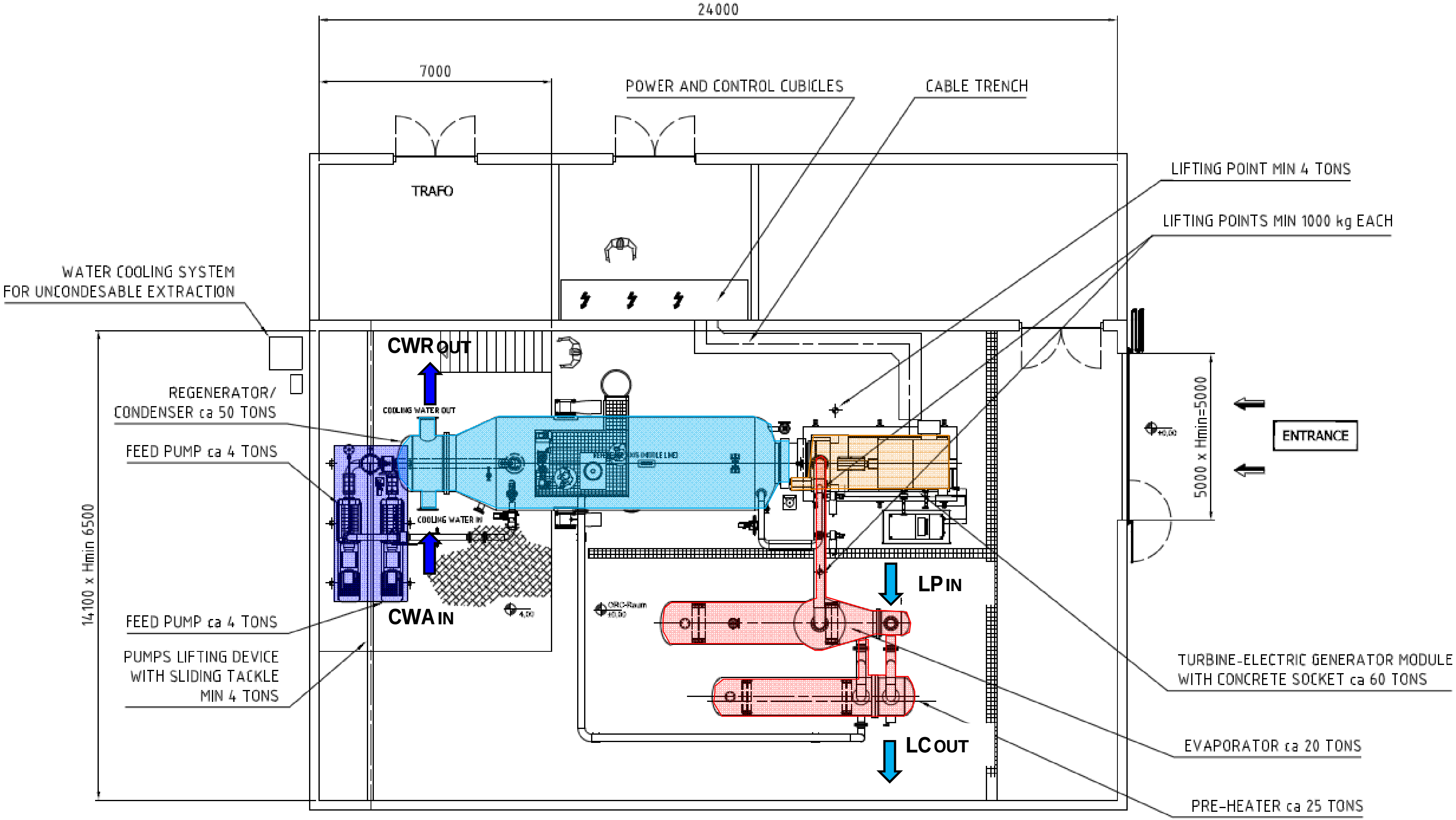




AXIAL TURBINE ORC TECHNOLOGY: 150 ÷ 350 °C, 0.5 MWe ÷ 10 MWe

ORC technology

Case study 3: Ammonia Urea plant, turbo-generator layout



430 m², 150 ton

ORC technology

Case study 3: Ammonia Urea plant, energy assessment

Thermodynamic Efficiency is influenced by the LP Steam condensing pressure (**p_V**) and by the temperature (**T_{CW}**) of the cooling water available in the site:

p_v [barg]	T_{CW} [°C]	Net Electric Power [MWe]	Net Yearly Electric Energy [GWe/yr]	CO2 Emission Reduction [ton/yr]
3.5	40	1.86	15.41	**6100**
5.0	40	2.00	17.44	**6900**
3.5	25	2.12	17.62	**6980**
5.0	25	2.38	19.74	**7800**

- the higher the value of **p_V** the better the thermodynamic efficiency

- the lower the value **T_{CW}** the better the thermodynamic efficiency

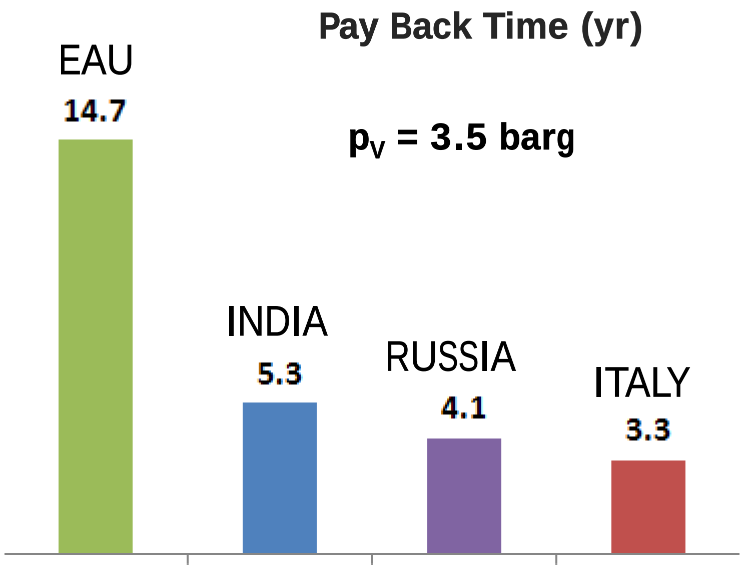
In the table the net electric power considers the power consumption need of cooling water pump.

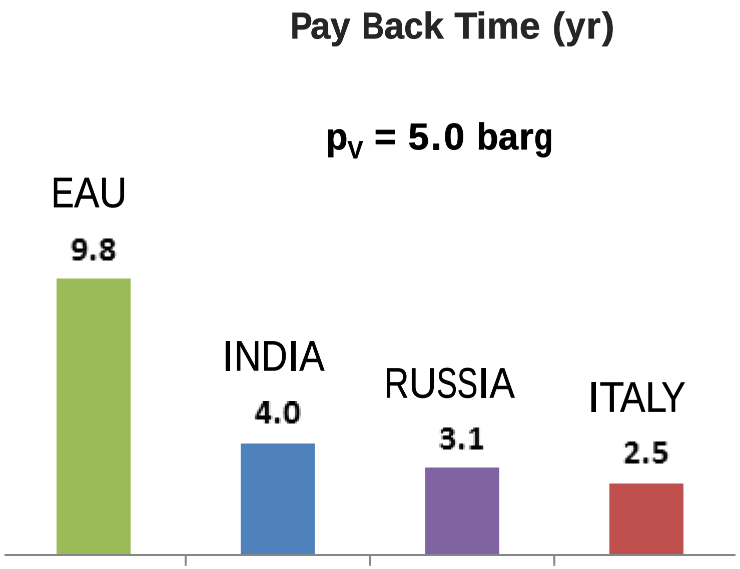
ORC technology

Case study 3: Ammonia Urea plant, economic results

CAPEX (± 20%) : **5,300,000 €** (2200 €/kW)

OPEX (± 20%) : **5 €/MWh**



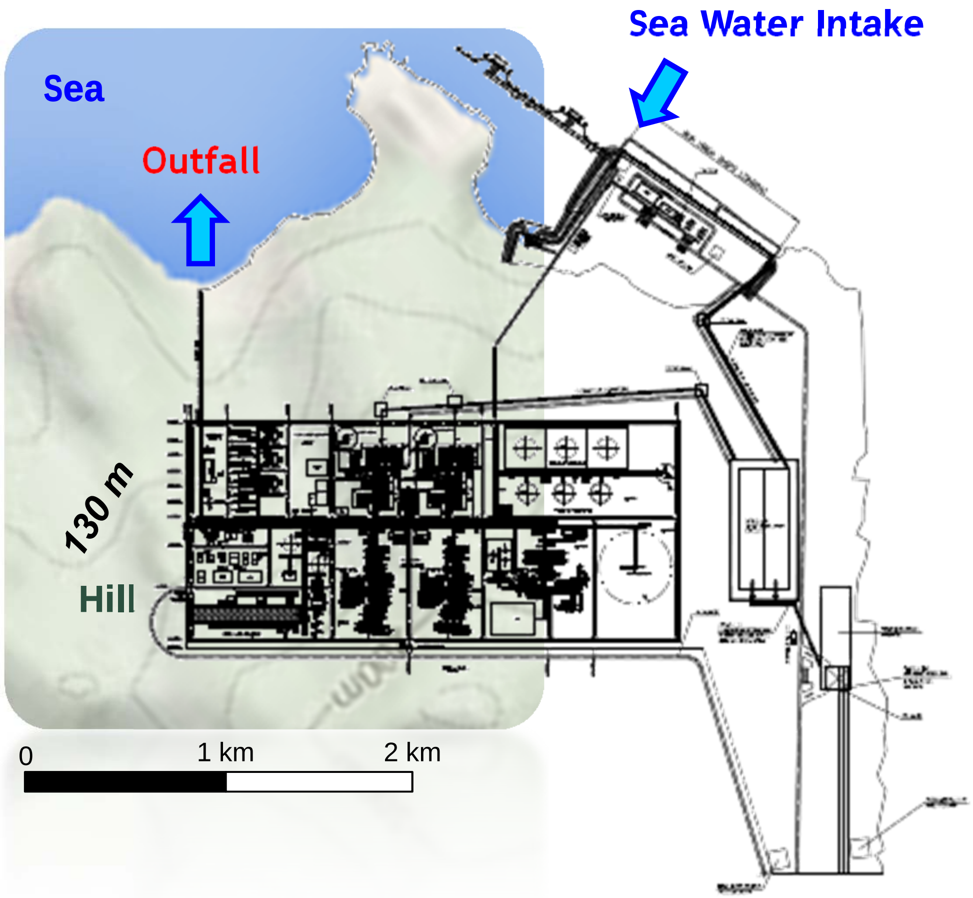


Mini Hydro technology

Renewable technology in Oil&Gas Application

Mini Hydro technology

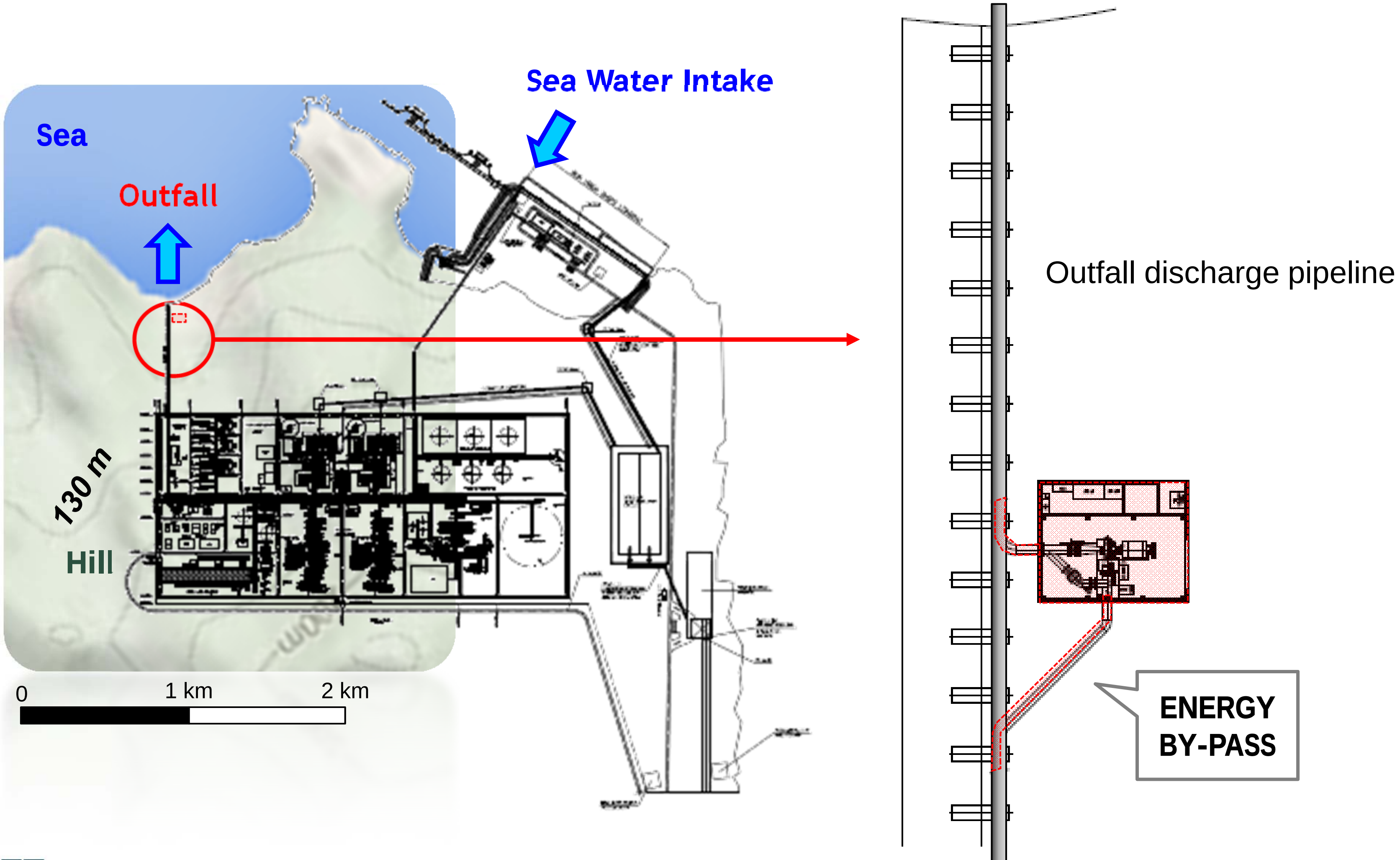
Case study 4: outfall pipeline in Ammonia Urea plant



Head	: **130 m**
Flow	: **1.65 m³/s**
Available Power	: **2.16 MW**

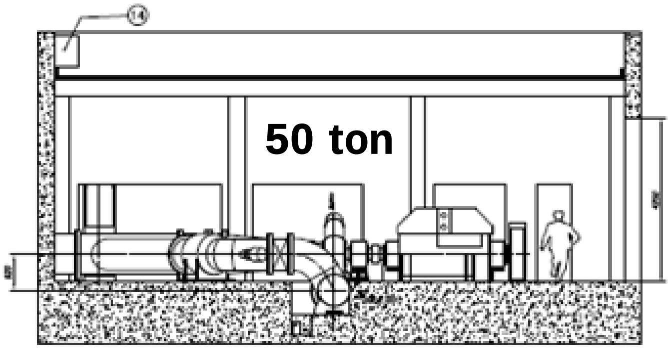
Mini Hydro technology

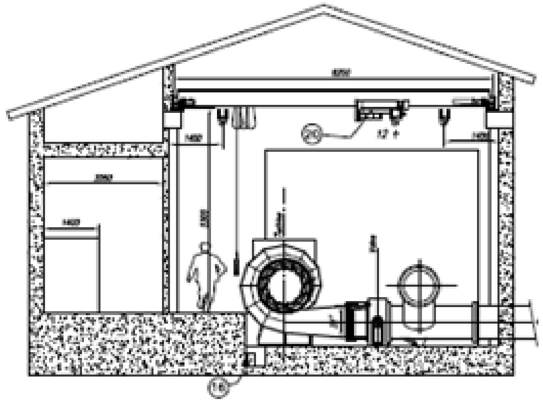
Case study 4: Ammonia Urea Plant, energy by-pass

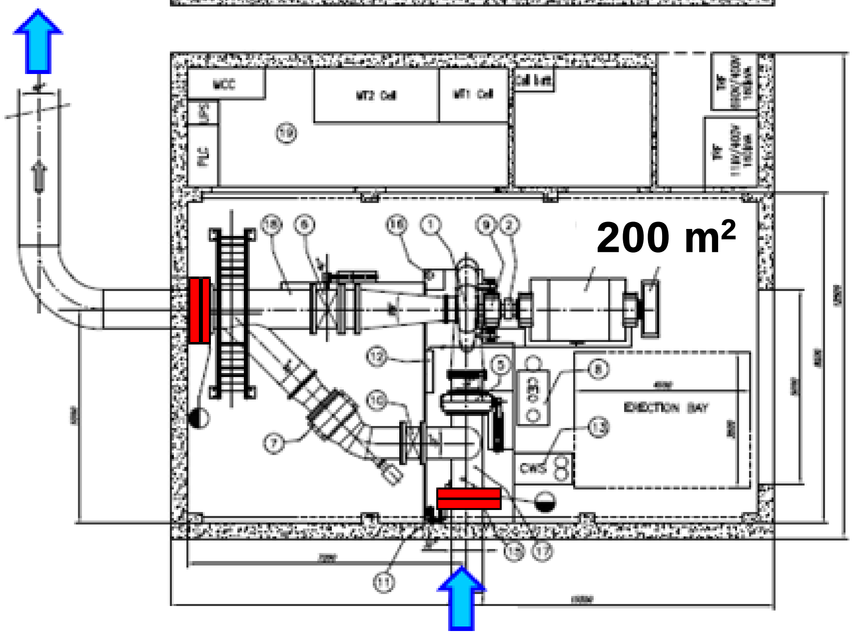


Mini Hydro technology

Case study 4: Ammonia Urea Plant, turbine hall







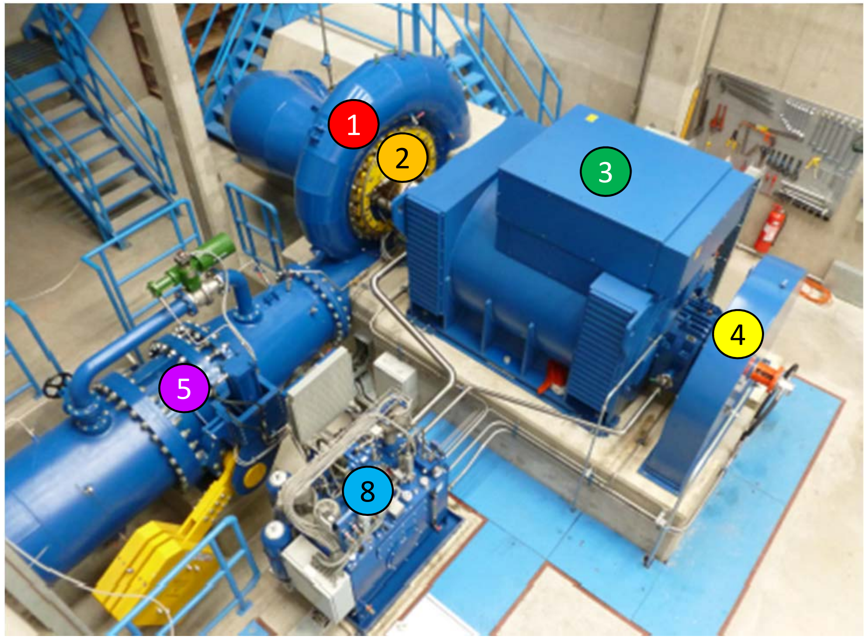
FRANCIS TURBINE: 1000 rpm

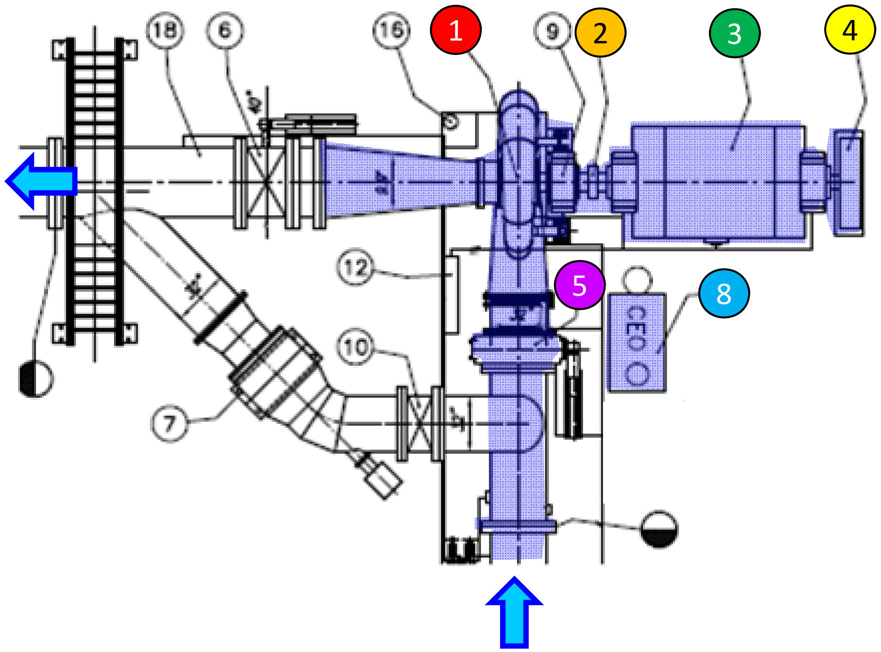
SAIPEM

Mini Hydro technology

Case study 4: Ammonia Urea Plant, turbine hall

1 TURBINE
2 Coupling
3 GENERATOR
4 Fly-wheel
5 Guard Valve
8 Hydraulic Console





Mini Hydro technology

Case study 4: Ammonia Urea plant, energy & economic assessment

- Net Electric Power : **1.70 MW_e**
- Yearly Electricity Power : **14.11 GWh_e/yr** (8300 h/yr)
- Reduction in fuel consumption : **2000 ton/yr** (NG LHV= 50 MJ/kg)
- Reduction in CO_2 Emission : **5500 ton/yr**

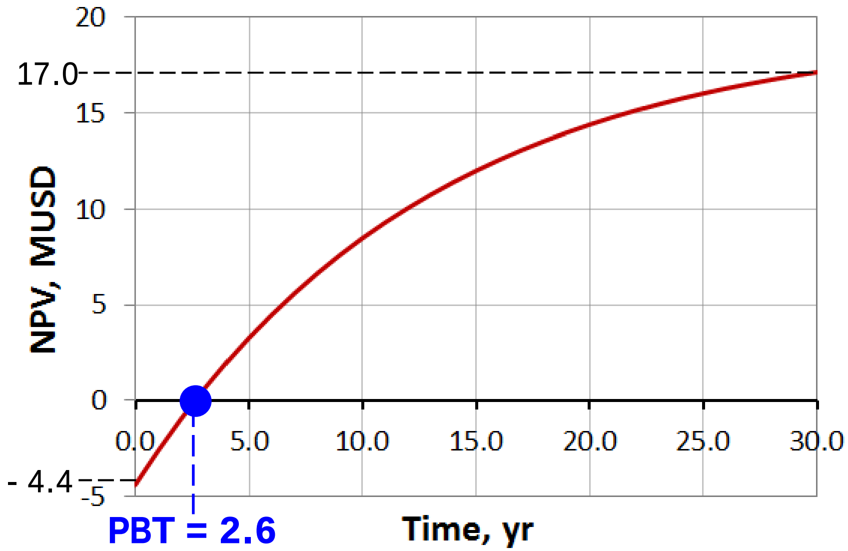
CAPEX (± 20%) 4.400.000 USD

PERIODO (yr)	OPEX (± 20%) (USD/yr)
0 ÷ 5	7,500
5 ÷ 15	17,500
15 ÷ 30	35,000

PBT : 2.6 anni

NPV : 17.0 MUSD

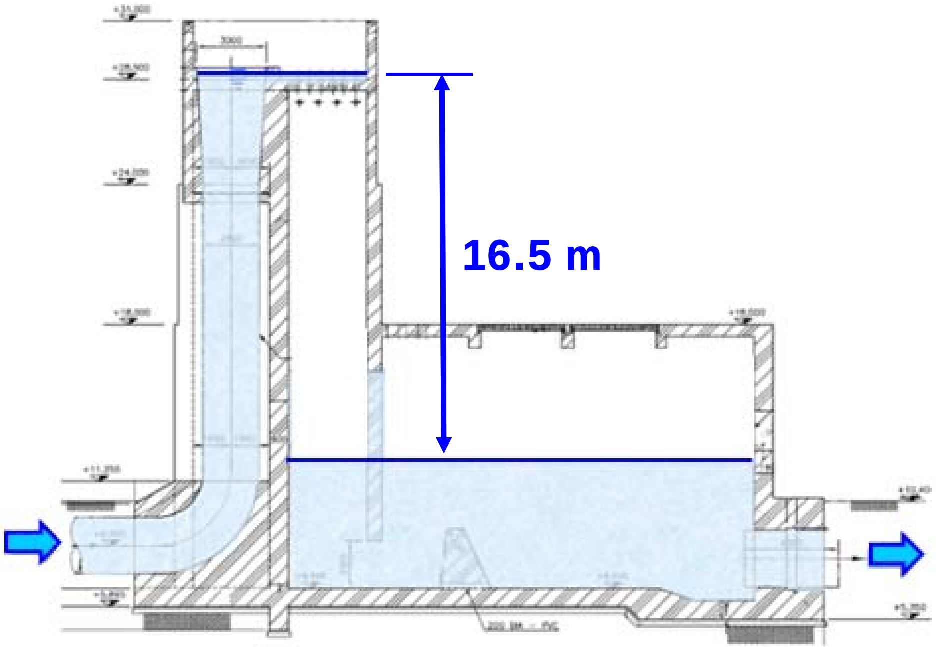
IRR : 42%

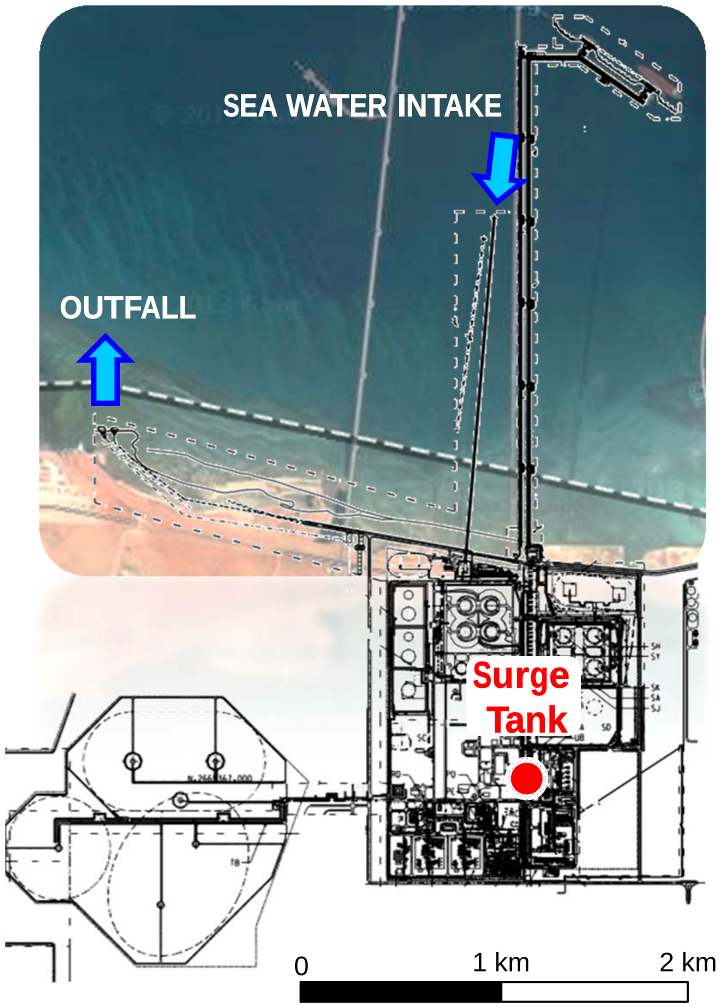


Cost of Electricity: 140 USD/MWh

Mini Hydro technology

Case study 5: surge tank in NGL plant

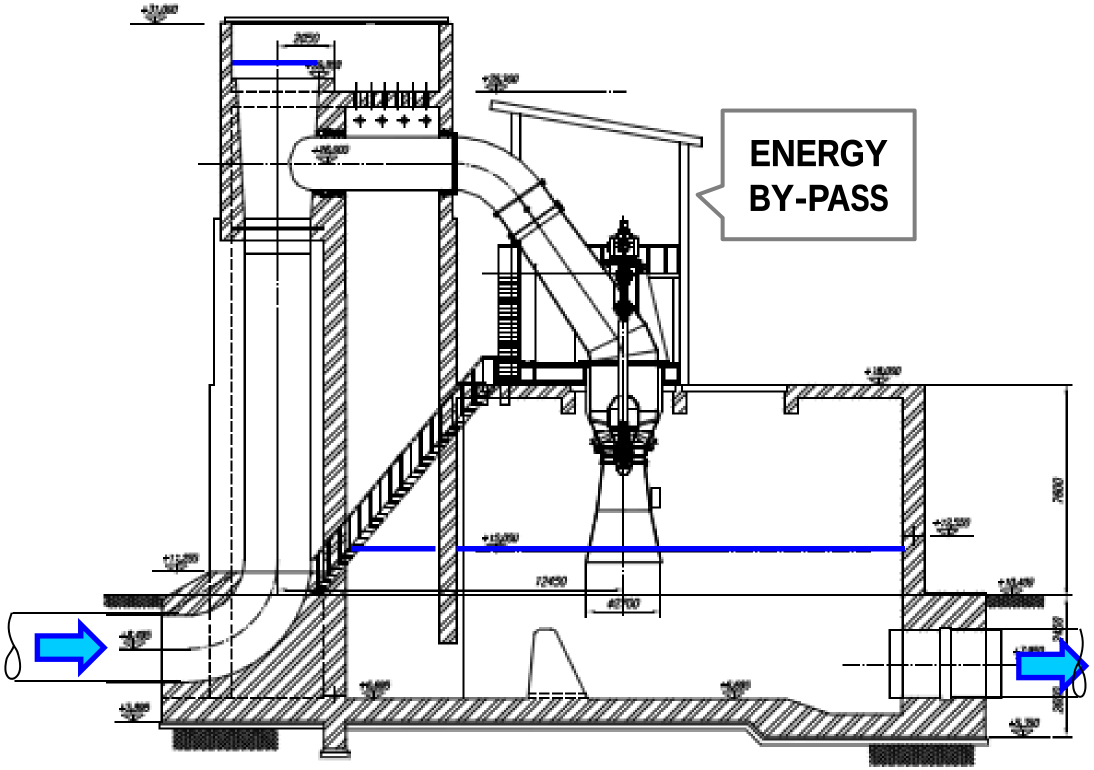




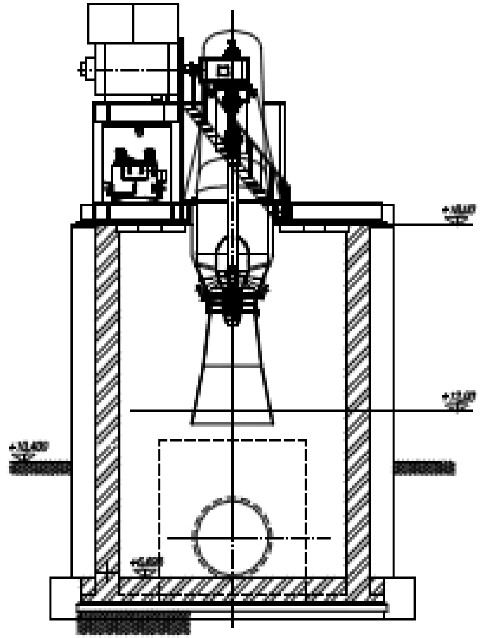
Head	: **16.5 m**
Flow	: **8.70 m³/s**
Available Power	: **1.43 MW**

Mini Hydro technology

Case study 5: NGL plant, integrated layout



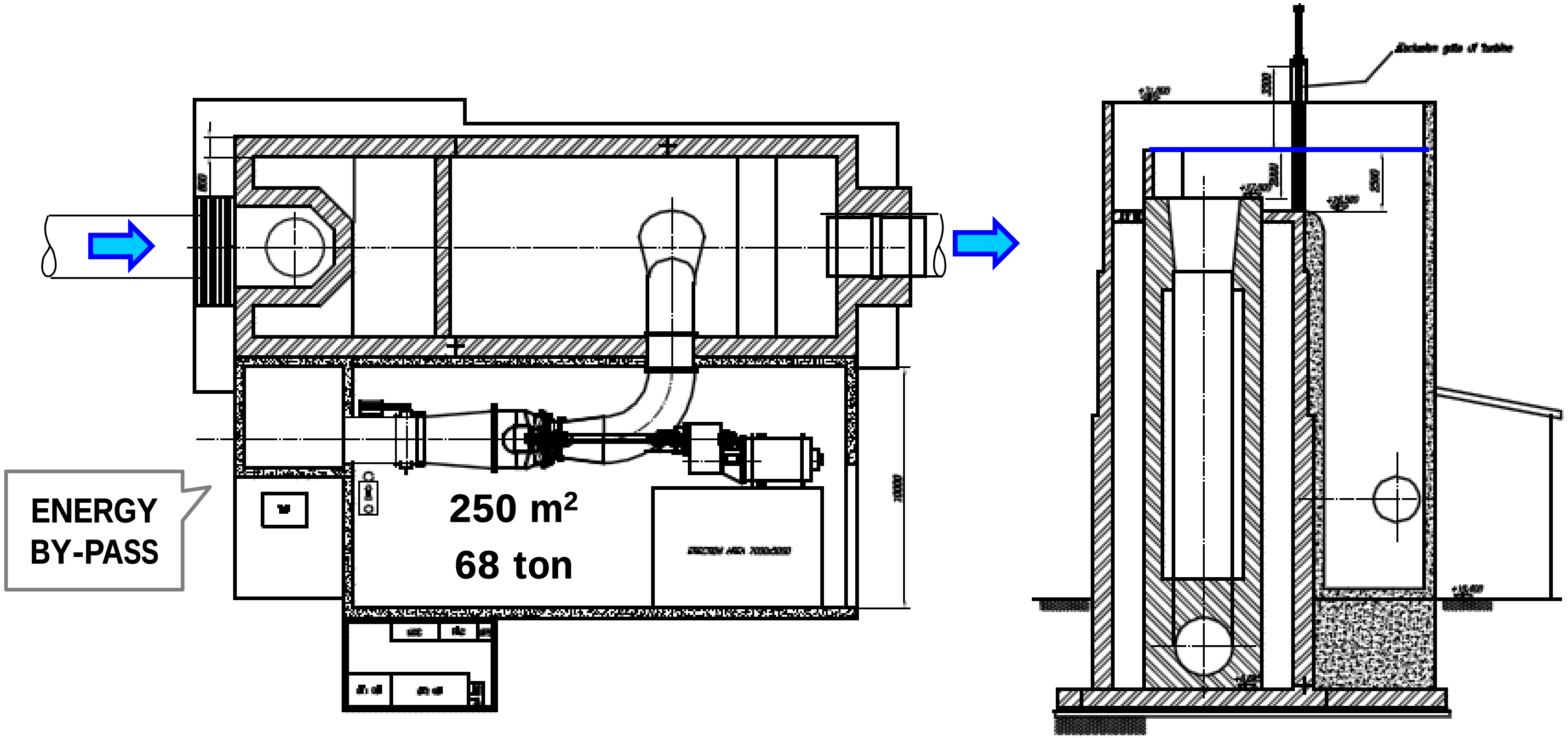
57 ton



KAPLAN TURBINE 330 rpm, Generator 1000 rpm

Mini Hydro technology

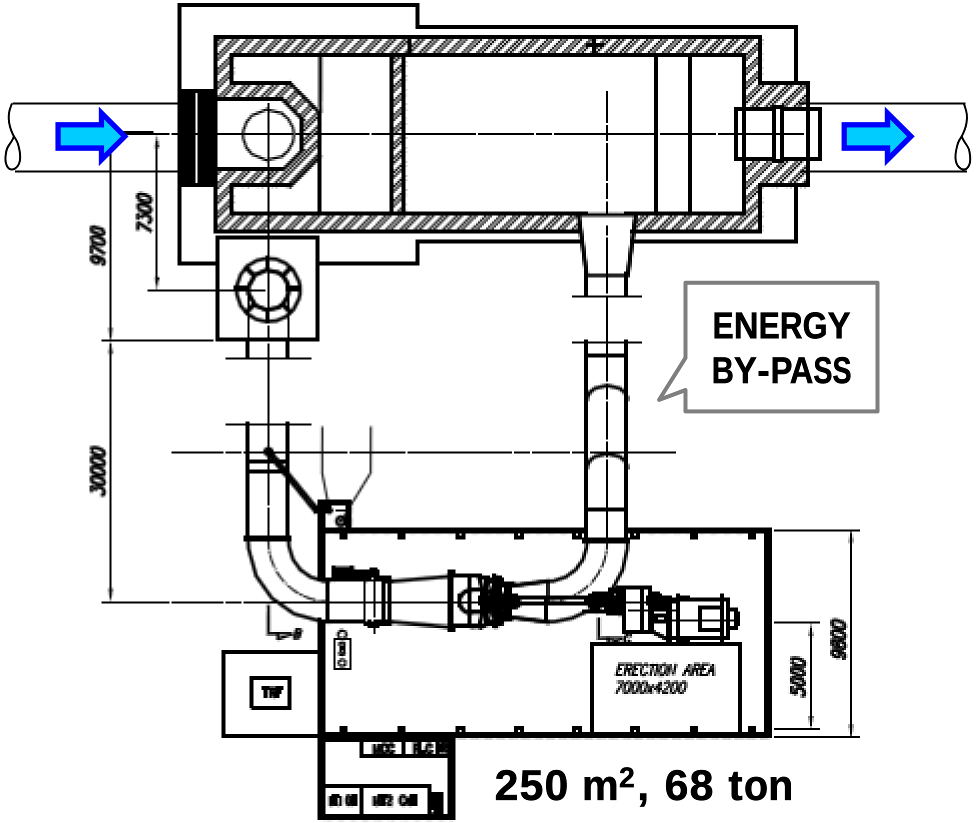
Case study 5: NGL plant, connected layout



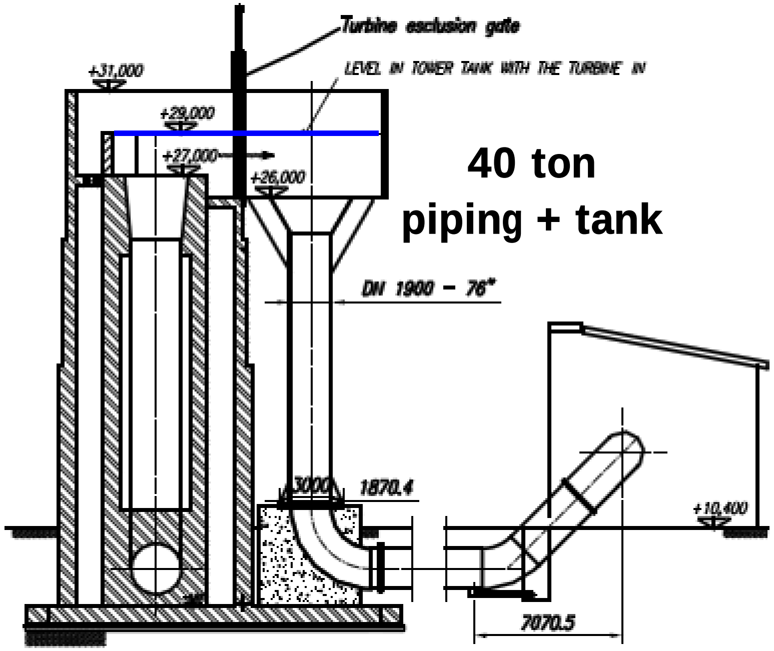
KAPLAN TURBINE 330 rpm, Generator 1000 rpm

Mini Hydro technology

Case study 5: NGL plant, disconnected layout



250 m², 68 ton



40 ton
piping + tank

KAPLAN TURBINE 330 rpm, Generator 1000 rpm

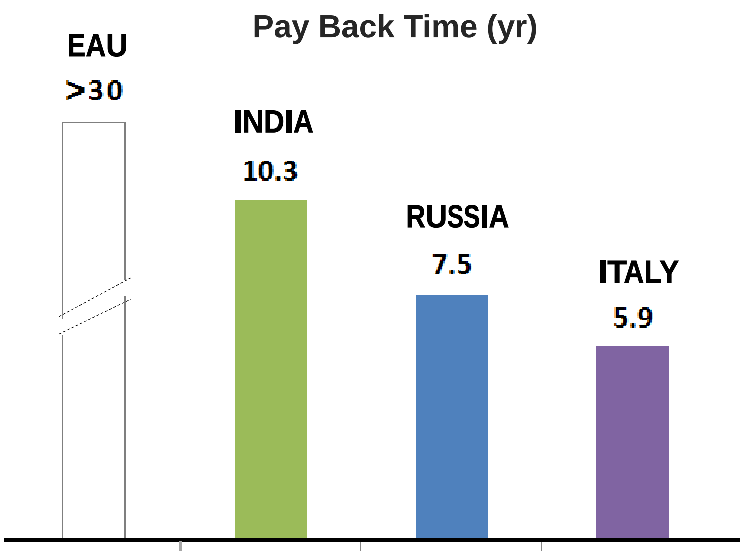
Mini Hydro technology

Case study 5: NGL plant, energy & economic assessment

- Net Electric Power : **1.20 MW_e**
- Yearly Electricity Power : **9.96 GWh_e/yr** (8300 h/yr)
- Reduction in fuel consumption : **1450 ton/yr** (NG LHV= 50 MJ/kg)
- Reduction in CO_2 Emission : **4000 ton/yr**

CAPEX (± 20%) 5.000.000 €

PERIODO (yr)	OPEX (± 20%) (€/yr)
0 ÷ 5	7,500
5 ÷ 15	11,000
15 ÷ 30	30,000



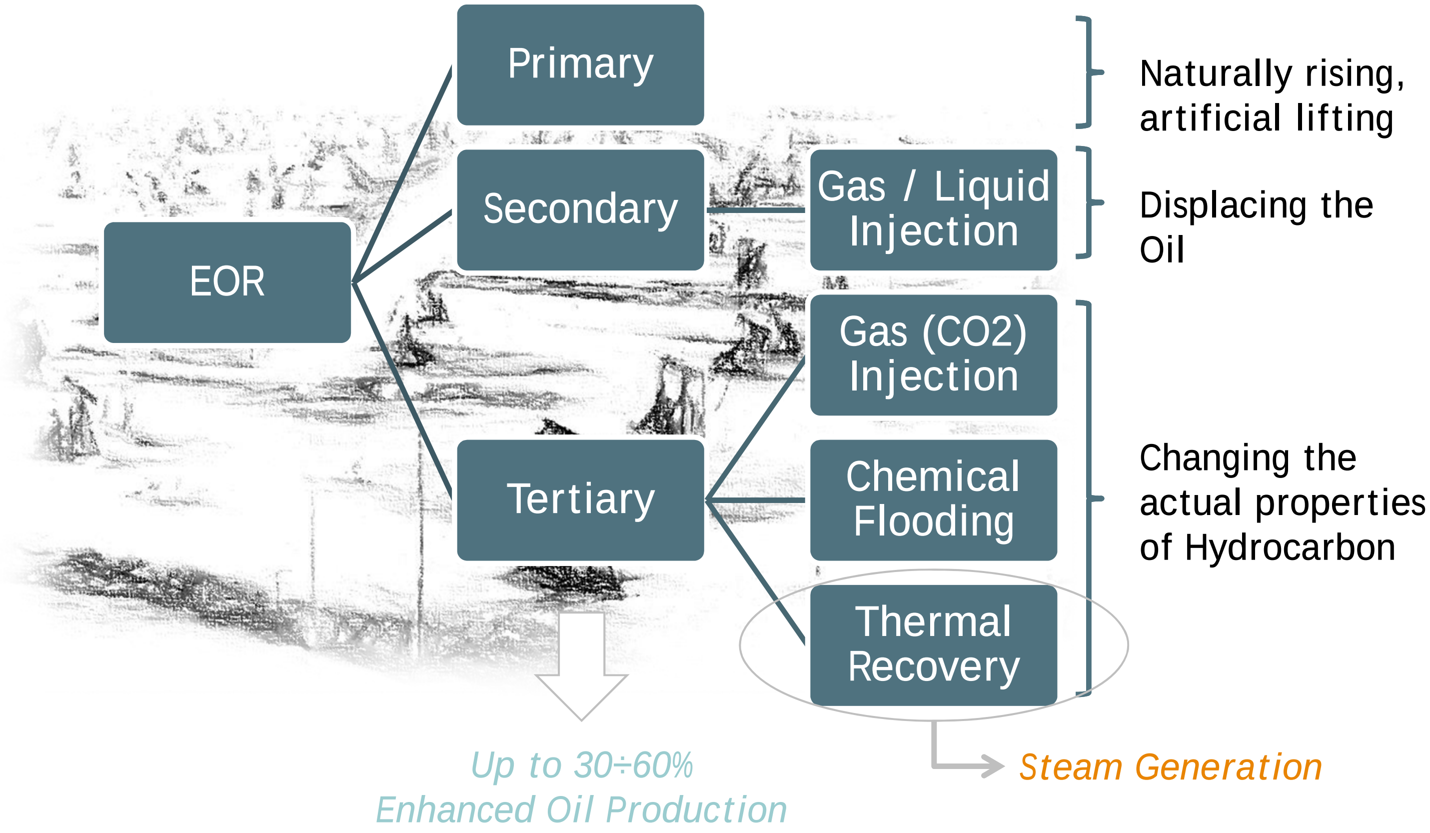
Solar EOR

Renewable Energy in Oil&Gas Application

EOR

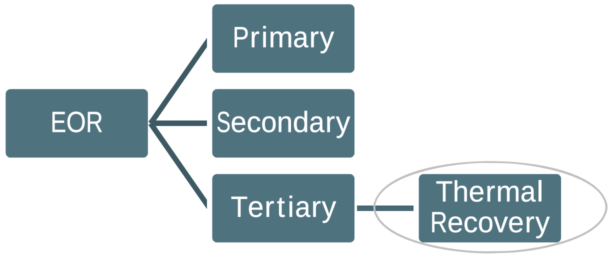
EOR techniques

- Enhanced Oil Recovery (EOR) are techniques for increasing the amount of crude oil that can be extracted from an oil field.

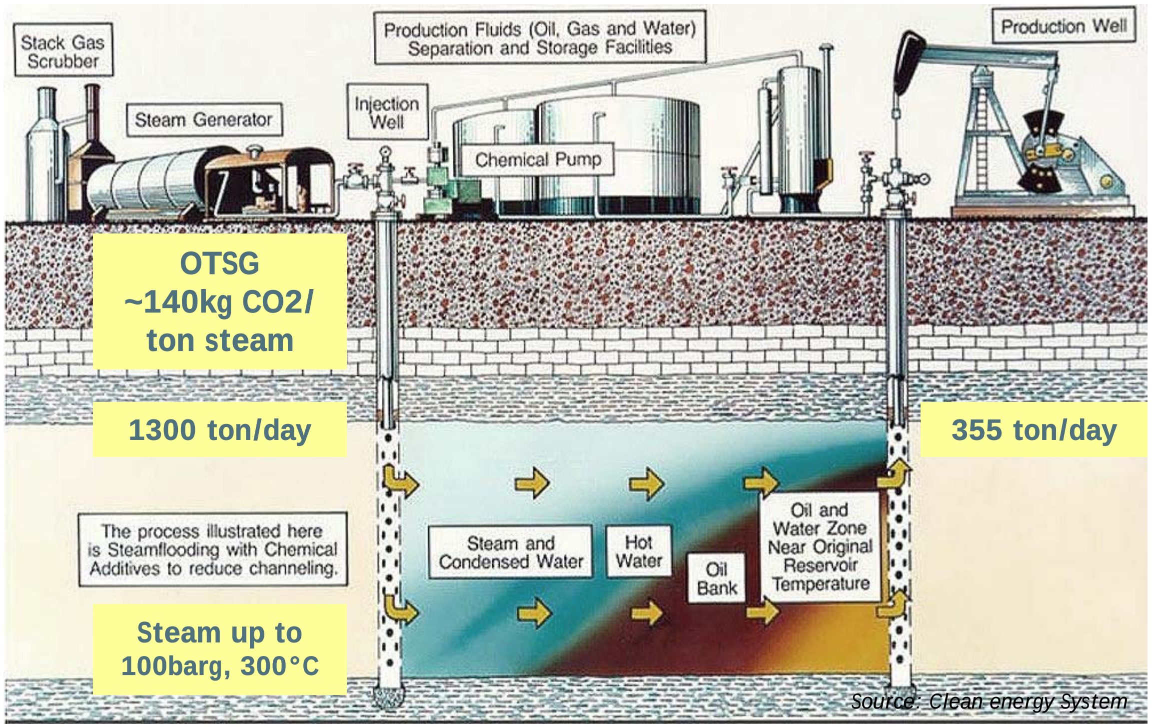


EOR

Conventional solution



Thermal recovery is accomplished by use of hot water or steam (burning a part of the crude oil / gas in place). Variations of these methods improve production of crudes by heating them, thereby improving their mobility and ease recovery by fluid injection.



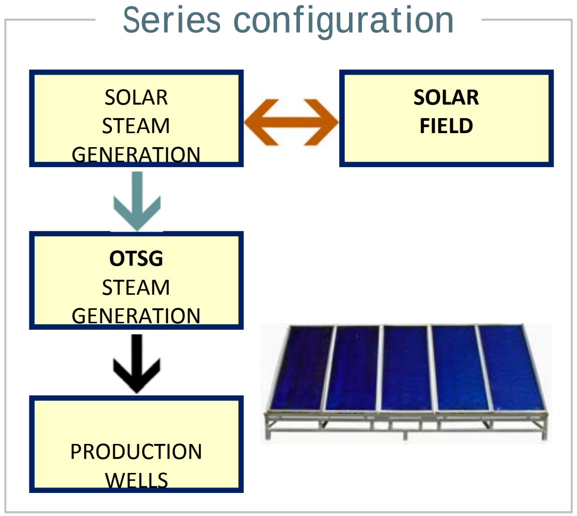
EOR and *Solar EOR*

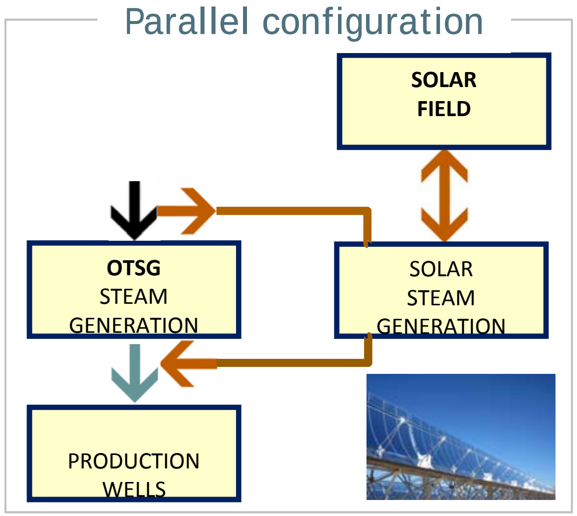
Innovative solutions in Heavy Oil exploitation plant

Solar Energy technology applied to Oil&Gas industry, with particular reference to heavy oil reservoir exploitation.

Solar power technology can be adopted for producing steam that, once injected inside the reservoir, led to an increase of oil-in-place production.

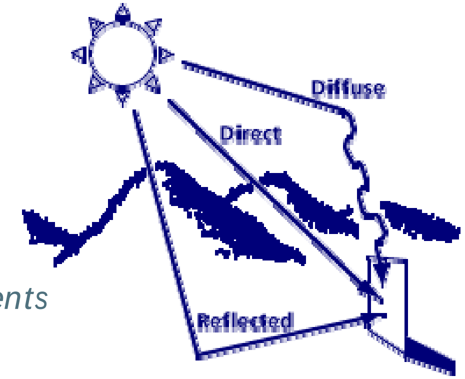
When the steam generation is made using energy from solar source, the application is commonly defined as "Solar EOR".





Solar EOR

Low and High temperature for Process Heat



Next improvements

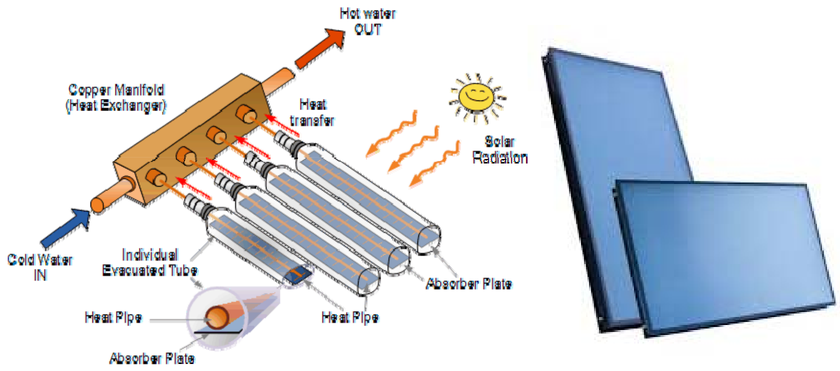
- Low Temperature Process Heat
  - Op. Temp <200°C
  - no or low concentration
  - Global energy

→ *Vacuum technology*

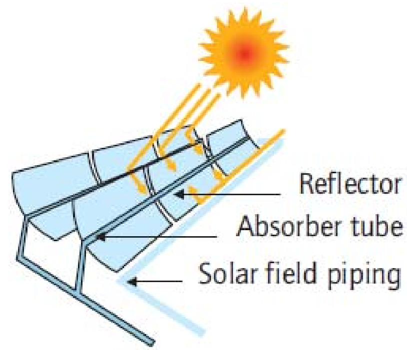
- High Temperature Process Heat
  - Op. Temp >200°C
  - concentration up to 100 times
  - DNI

→ *Cover and receiver technologies*

Solar Thermal Panel (series config.)



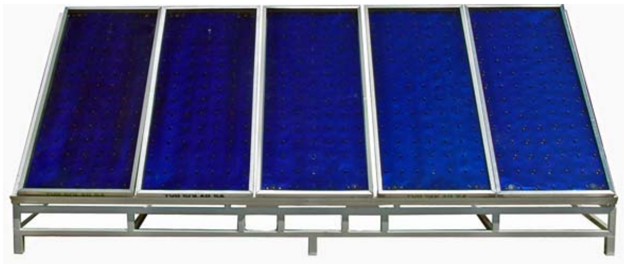
CSP (parallel config.)



Solar EOR

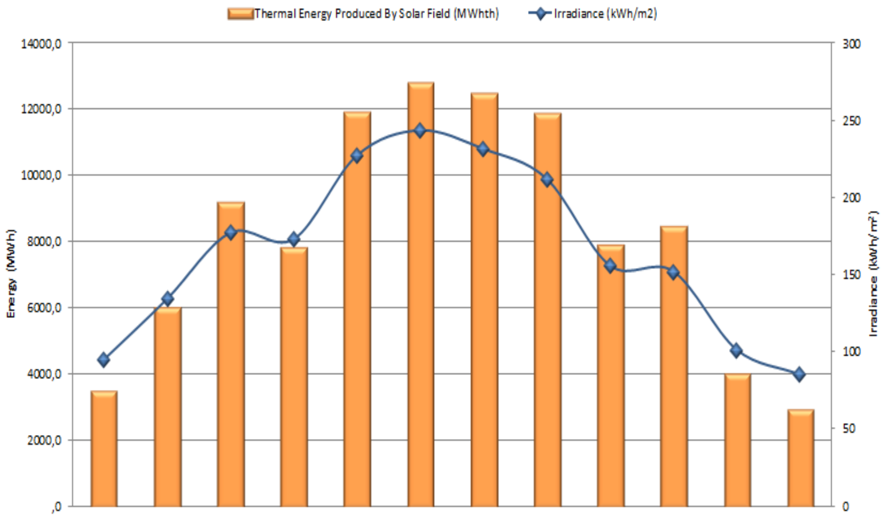
Case study 6: Thermal Vacuum Panel in HO Exploitation plant

Design Data
16 MWt for ~12 hours – 1300 ton of steam per day
Water @ 100 barg, 78 to 200°C



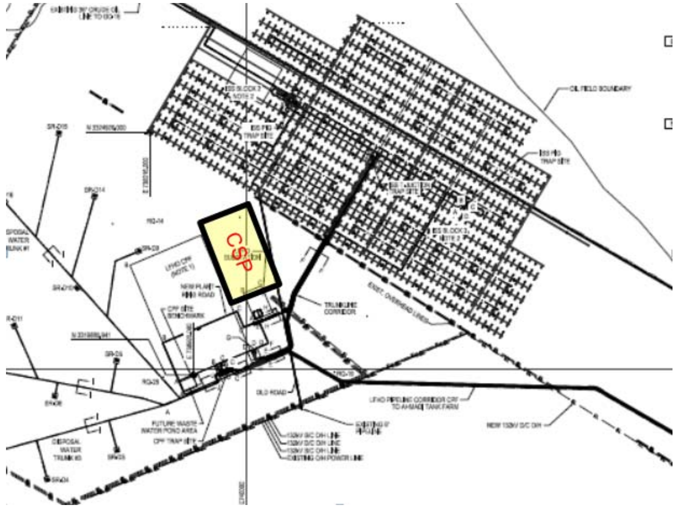
Main results

- Hybridization of Solar field with conventional OTSG (in series)
- OTSG partial load in the range 50 to 100%
- Smoothing tank for transitions only (reservoir is the main storage)
- Produced Energy: 64 GWht/year
- Footprint 65 ha
- Lifetime>20 years
- Avoided CO_2 > 20000 ton/year
- Gas saving ~4 Mton/year
- CAPEX: ~50 Mln$
- PBT 8 years



Solar EOR

Case study 7: CSP in HO Exploitation plant



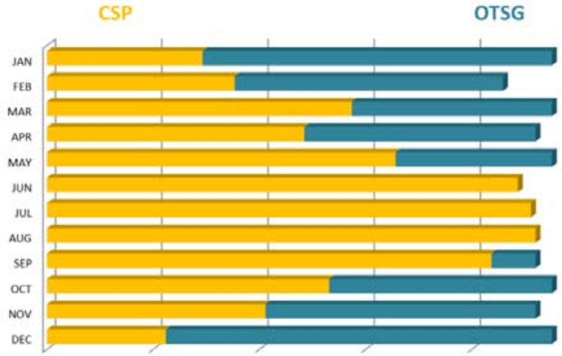
Design Data

32MWt for 12 hours – 1300 ton of steam per day

Steam @ 100 barg, 78 to 312°C, steam concentration 80-100%

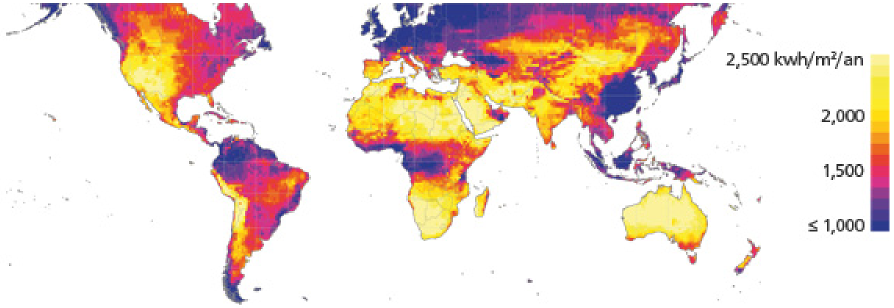
Main results

- Hybridization of CSP with conventional OTSG (in parallel)
- OTSG partial load in the range 44% to 76%
- Smoothing tank for transitions only (reservoir is the main storage)
- Produced Energy: 128 GWht/year
- Footprint 130 ha
- Lifetime>25 years
- Avoided CO_2 > 40000 ton/year
- Gas saving ~8 Mton/year
- CAPEX: ~100 Mln$
- PBT 8-10 years



Solar EOR

Suggestions and Considerations



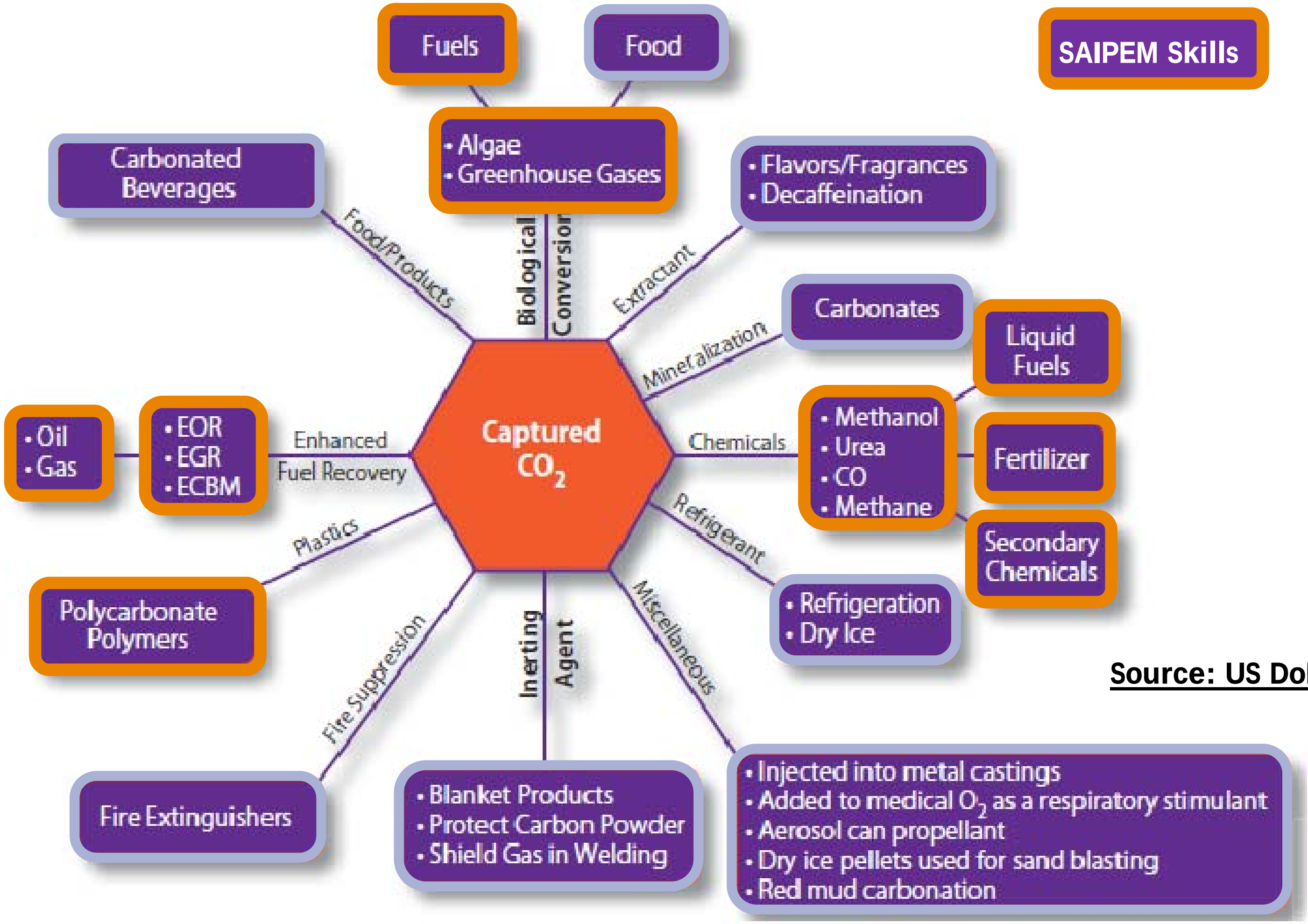
- The economics of the development equation must make sense. Therefore, each field must be heavily evaluated to determine which type of EOR will work best on the reservoir.
- Optimized solution in case of *Solar EOR.* Hybrid combination strongly suggested.
- Energy recovery and avoided CO_2 emissions up to 70%
- Different approach for existing and new production plant
- Strong dependency from location and environmental conditions
- Predictive Analysis System (control and instrumentation) to manage meteorological unplanned variations

CO2 Management

Saipem Expertise

CO2 management

Reuse technology



Source: US DoE (2013)

CO2 management

Considerations

- CO2 reuse technologies can manage only few percent when large quantity of CO2 are involved. Exploiting large quantities of CO2 is not envisioned as a realistic solution for the time being
- most of the emerging re-use technologies are in the research and development phase, years far from commercial deployment
- when large quantity of CO2 has to be treated the main technologies presently available to reduce emissions are **Acid Gas Injection (AGI)** and possibly **Enhanced Oil Recovery (EOR)** application if EOR fields are available at reasonable distance
- Saipem has developed several optimization projects/studies for EOR, AGI and transport technologies

CO_2 management

Saipem CCS expertise

- SAIPEM has a considerable experience in the entire **CO_2 capture, transportation and storage chain** having provided engineering services for O&G companies
- SAIPEM has been also involved in the joint ENEL-ENI (2009-2013) CCS technical programme
- Environmental impact studies

Capture:

- Post-combustion (CO_2 washing)
- Pre-combustion (Steam reforming/gasification)
- Oxy-firing (Oxygen combustion)

Storage:

- Geo-mechanical modeling and monitoring
- Well and reservoir modeling, including rocks and cement alteration
- Environmental and wellbore integrity monitoring

Transport:

- Pipelines design & construction
- Pipelines for CO_2 transport in supercritical phase

CO2 management

Saipem Projects/Initiatives

- **Saipem references on conventional CO2 removal/capture units**
- **Advanced CO2 management: Armatella EOR pilot plant, proposal for EPC**
- **Advanced CO2 management: AGI – Ras Laffan Complex – Qatar, FEED**
- **Advanced CO2 management: AGI - CO2 emissions reduction, study**
- **Advanced CO2 management: supercritical pipeline transport, study**
- **Advanced CO2 management: pilot supercritical pipeline transport, FEED**

CONCLUSIONS

- Saipem has the capability for a focused CO2 management fitted to the entire process from innovation, design, manufacturing and erection
- Adoption of renewable energy in O&G applications
- Optimized solutions for innovative application with commercially proven technology
- No change of industrial process: ENERGY BY-PASS
- Mitigation of environmental impact with consistent reduction of CO2 emissions
- Sustainability as strategic commitment for Saipem

Thank You for Your Attention

Website : www.saipem.com