Demonstration of the DMX™ process description of the Octavius SP3 project

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+ other colleagues !
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OCTAVIUS
OPTIMISATION OF CO_2 CAPTURE TECHNOLOGY ALLOWING VERIFICATION AND IMPLEMENTATION AT UTILITY SCALE

IEA-GHG 2nd Post-Combustion Capture Conference

17th -20th September 2013, Bergen, Norway

Outlook

- Octavius project
- DMX™ process
- SP3 : Demonstration of the DMX™ process
- Conclusions & future work

OCTAVIUS in Brief

- **O**ptimisation of $\underline{C}O_2$ Capture **T**echnology **A**llowing **V**erification and **I**mplementation at **U**tility **S**cale

  FP7 Project (Call DG Energy 2011)

- Start-up: 01/03/2012
- Duration : 60 Months
- Coordinator IFPEN (Paul BROUTIN)
- Total Budget: 13.56 M€
- EU Funding: 7.96 M€


Kick-off Meeting on 13-14 March 2012 in Solaize

17 Partners + 1 Sponsor

No	Name	Short name	Country	Project entry month[10]	Project exit month
1	IFP Energies nouvelles	IFPEN	France	1	60
2	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO	TNO	Netherlands	1	60
3	STIFTELSEN SINTEF	SINTEF	Norway	1	60
4	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	NTNU	Norway	1	60
5	INSTITUT NATIONAL DE L ENVIRONNEMENT ET DES RISQUES INERIS	INERIS	France	1	60
6	DANMARKS TEKNISKE UNIVERSITET	DTU	Denmark	1	60
7	TECHNISCHE UNIVERSITAET HAMBURG-HARBURG	TUHH	Germany	1	60
8	E.ON NEW BUILD & TECHNOLOGY LIMITED	E.ON	United Kingdom	1	60
9	EnBW Kraftwerke AG	EnBW.KWG	Germany	1	60
10	DOOSAN POWER SYSTEMS LIMITED	DOOSAN	United Kingdom	1	60
11	Enel Ingegneria e Innovazione SpA	ENEL	Italy	1	60
12	ESKOM HOLDINGS LTD	ESKOM	South Africa	1	60
13	BELGISCH LABORATORIUM VAN DE ELEKTRICITEITSINDUSTRIE	Laborelec/GDF SUEZ	Belgium	1	60
14	ELECTRICITE DE FRANCE S.A.	EDF	France	1	60
15	PROSERNAT SA	PROSERNAT	France	1	60
16	ECOMETRIX AFRICA LTD	EcoMetrix	South Africa	1	60
17	A.V. TOPCHIEV INSTITUTE OF PETROCHEMICAL SYNTHESIS - RUSSIAN ACADEMY OF SCIENCES	TIPS	Russian Federation	1	60

Sub-Project SP3 Sponsor: TOTAL (F)

OCTAVIUS Organisation

- 2 main technical Sub-Projects
  - SP2 dedicated to demonstration of operability and flexibility aspects of first generation processes to be used for first full scale demo plant (ROAD and Porto Tolle Projects)
  - SP3 dedicated to the demonstration of the DMX™ process
  - 2 independent Subprojects
- a R&D Sub-Project
  - SP1 will support SP2 & SP3 and will also include cross-cutting issues such as benchmarking activities

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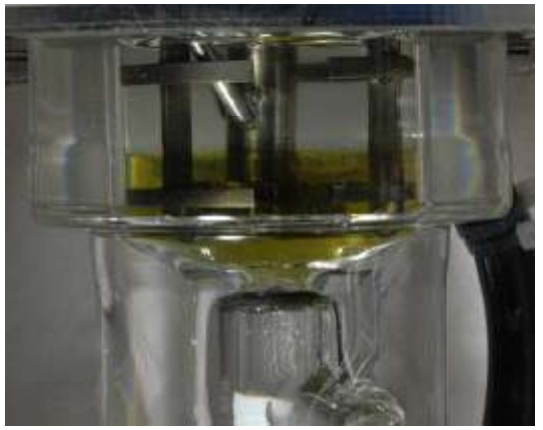
Post-combustion capture @ IFP Energies nouvelles

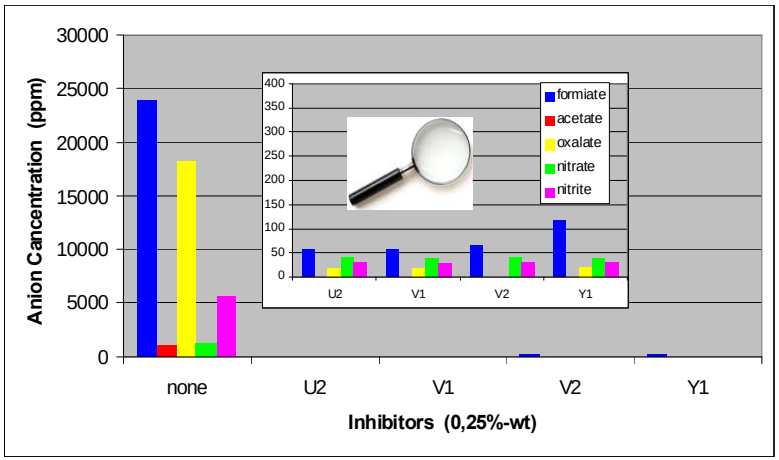
- Development of new PCC processes
  - G1 : industrial pilot tests => commercialization
  - HiCapt+™ : 40 wt.% MEA + additives
  - G2 : R&D developments => industrial pilot tests
  - DMX™
  - G3 : laboratory studies – proof of concept
  - new chemistry solvents, sorbents, hydrates...
- Development of new technologies
  - gas/liquid contacting devices ...



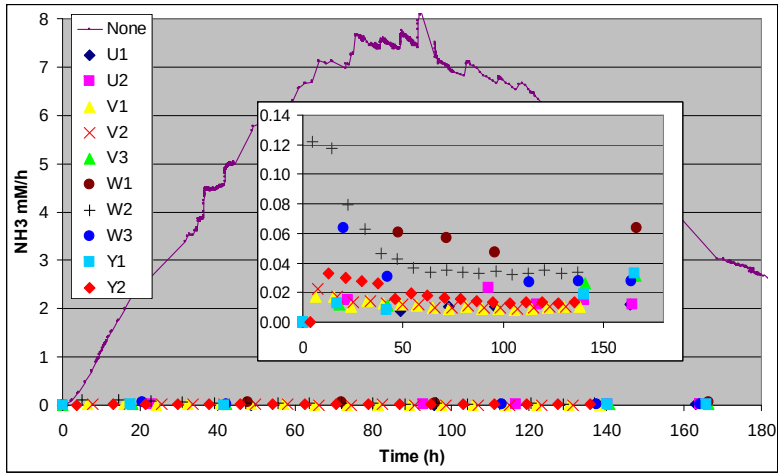
HiCapt+ process

MEA 40 wt % after 1000 h mini-pilot test (with and without inhibitor)

- Degradation tests
  - very good performances of the oxidative inhibitor
- Corrosion tests
  - Identification of materials with no corrosion in presence of the oxidative inhibitor (e.g. Duplex steel)
  - Price difference is very small (higher cost but less material since better mechanical properties) + availability of material is industrial



MEA 40% at 80 C under air + CO_2 during 12 days

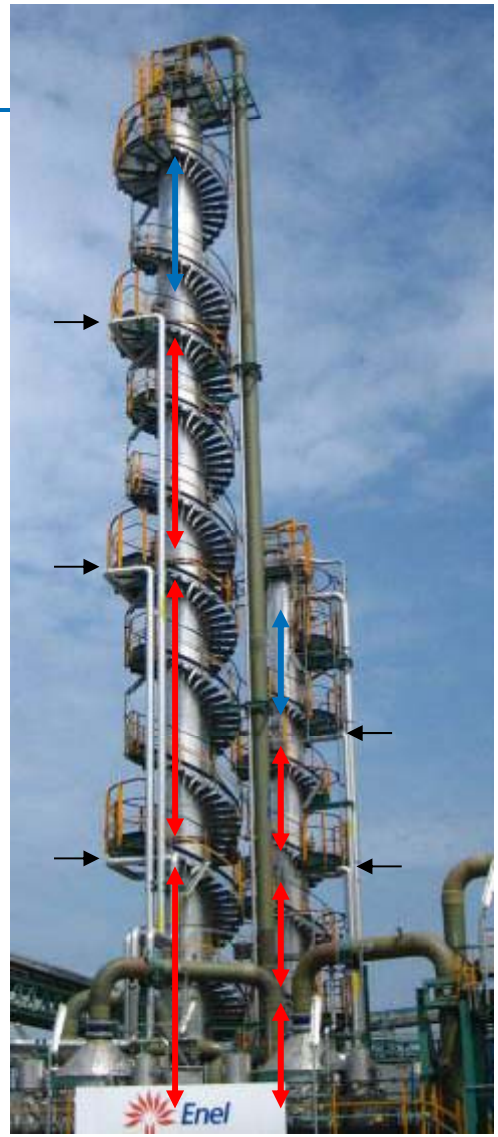


MEA 30% at 80 C under air + CO_2 during 7 days

Pilot plant presentation
Main Characteristics

CCS unit – Main equipments

- Absorber
  - Φi = 1.5 m / H_{LT} = 45 m
  - 3 stages solvent inlet
- Stripper
  - Φi = 1.3 m / H_{LT} = 31 m
  - Reboiler : Kettle type ~ 1 to 3 MWth
- Solvent / Solvent cross heat exchanger
  - Plates type



HiCapt+ main conclusions

Long run industrial pilot test main results (Enel – Brindisi)

- Test duration : 380 h
- CO_2 prod. : 2 327 kg/h
- Efficiency : 89,7 %
- Loadings : $\alpha_L = 0,23 \Rightarrow \alpha_R = 0,48$
- Energy : ~ 3,02 GJ/t_{CO2}
- in good agreement with process simulations

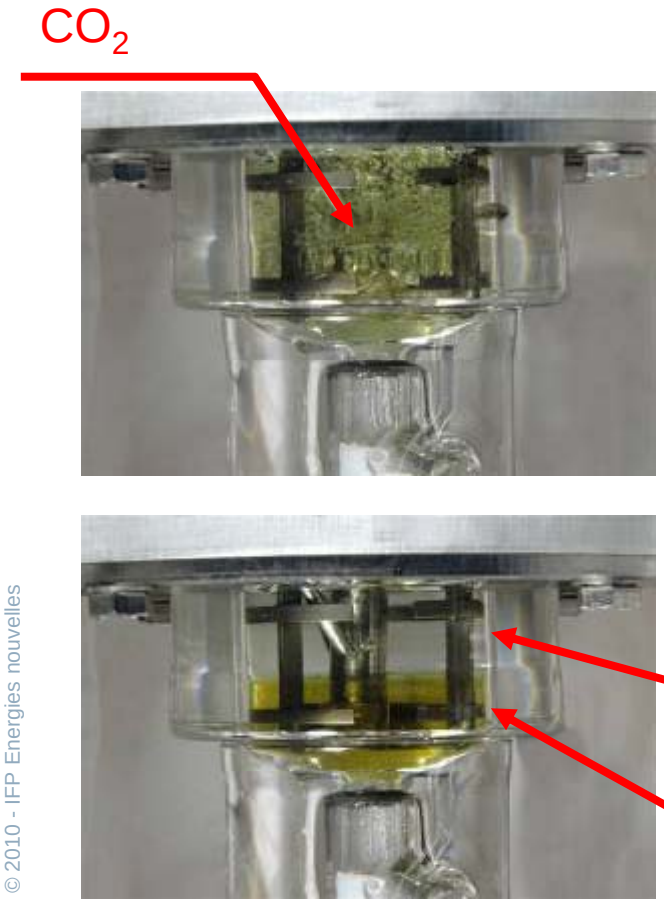
Lab and mini-pilot test main results (IFPEN)

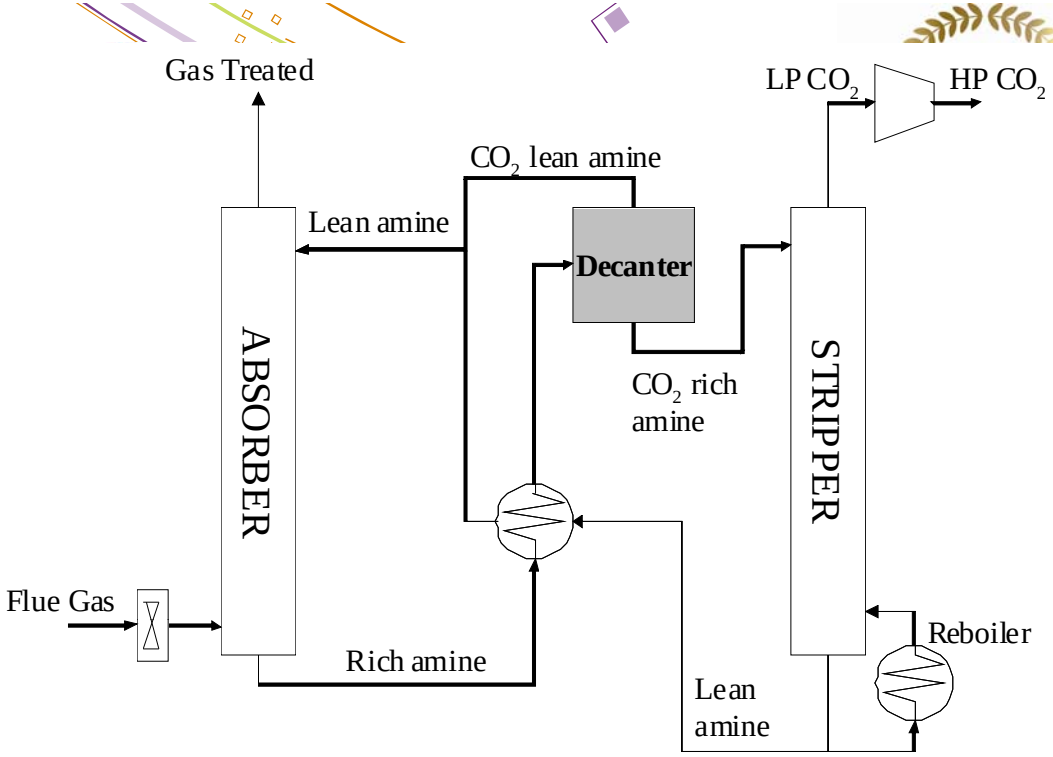
- use of additives
- no or little degradation
- much lower emissions
- no corrosion with Duplex (even in hot regions)

ready for commercialization

PROSERNAT
HEURTEY PETROCHEM • IFP Group Technologies

DMX™





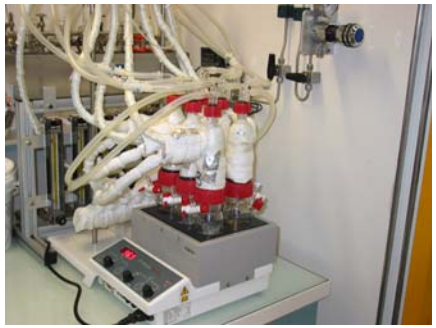
DMX-1™ : a low stripping, low heat of reaction, high capacity demixing solvent

+ lower degradation (and further lower emissions => interest in HP stripper) // no corrosion

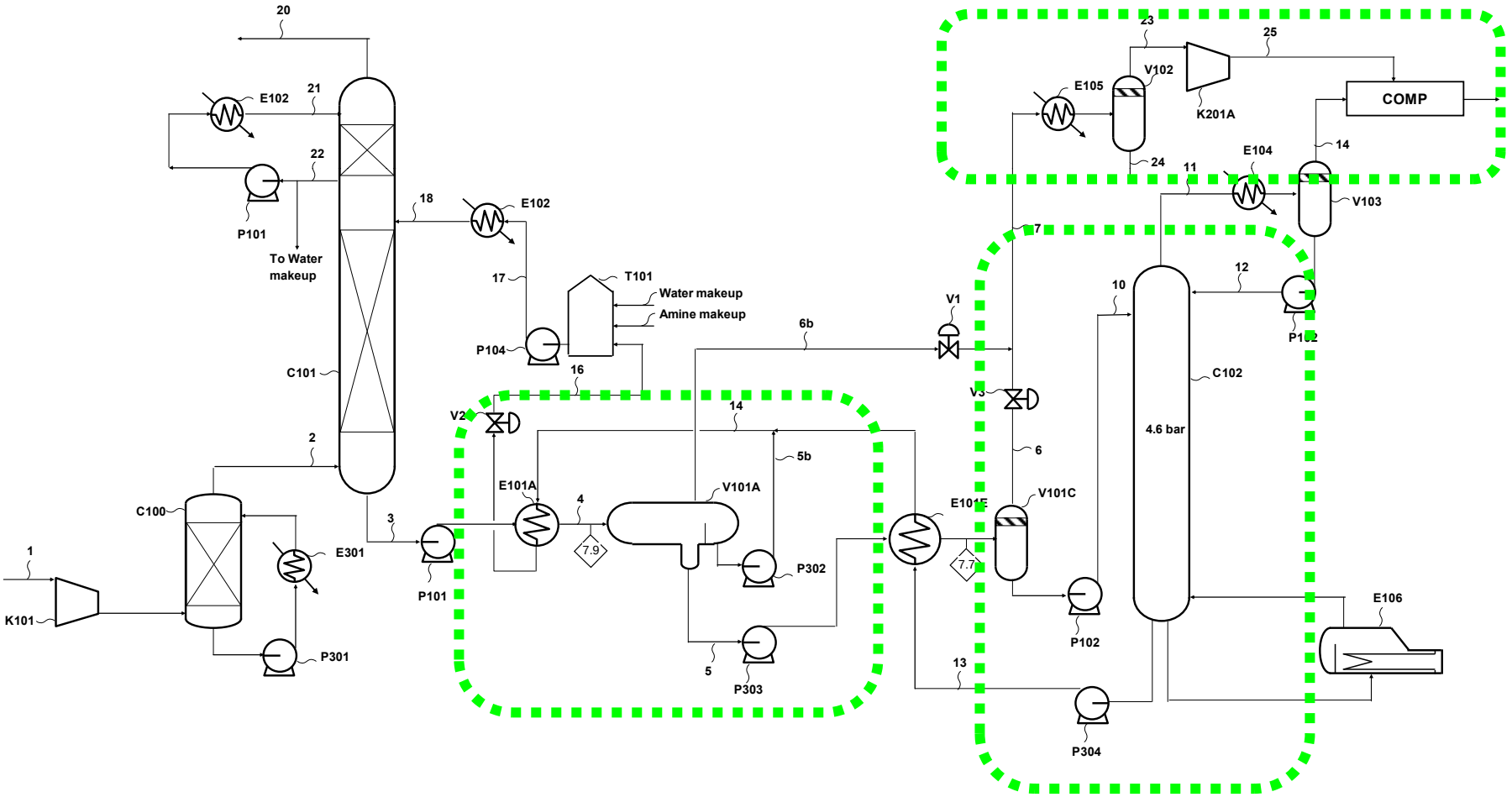
2.5 – 2.1 GJ/ton CO_2
-20-30 % in CO_2 total cost

Scientific & Technical information

- VLLE data + adapted thermodynamic model
- Degradation / Emissions / Corrosion
- Operational issues
- Kinetics & Mass transfer performances
- Laboratory and mini-pilot tests
- Process simulations / cost evaluations

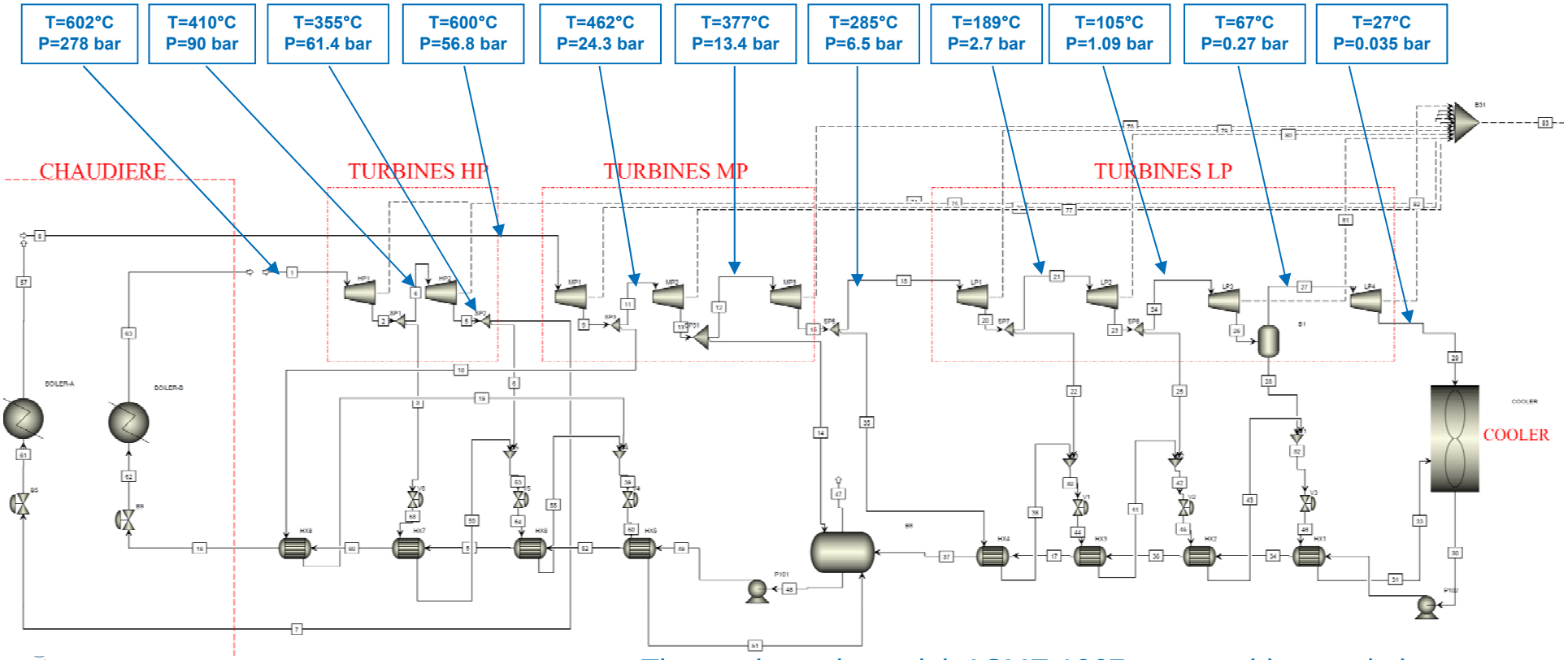


DMX-1 Process – Full Scale Unit PFD



Steam Cycle Simulation: IFPEN model

- Temperature and pressure levels available



Thermodynamic model: ASME 1967 steam table correlations
Heat Exchanger pinch: 5 °C, pressure drop neglected

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Methodology

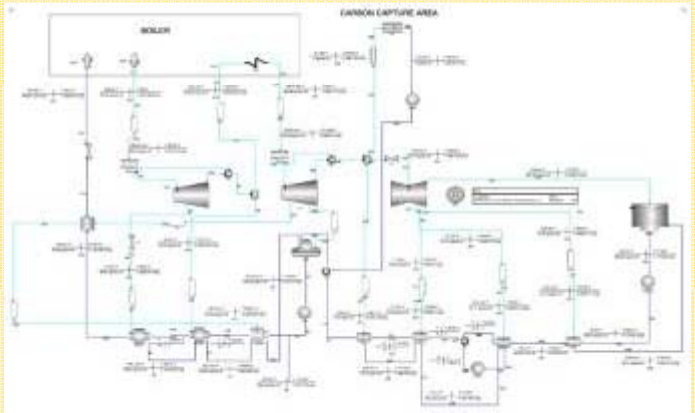
From lab to Pilot demonstration

Lab

Process testing
Analytical methodologies development

Process modeling

- Process Design

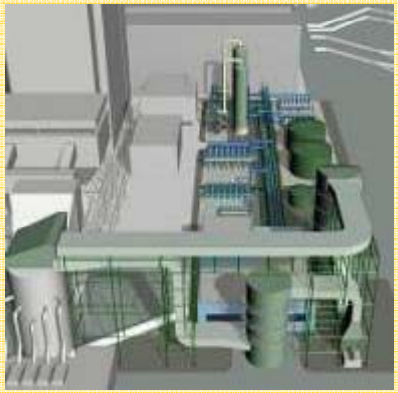


Pilot

Flue gases : 10.000 Nm^3/h
CO_2 : 2500 kg/h

- Performance testing
- Validation of design
- Emissions measurement and waste characterization
- Development and testing modeling tools

Full scale - feasibility study

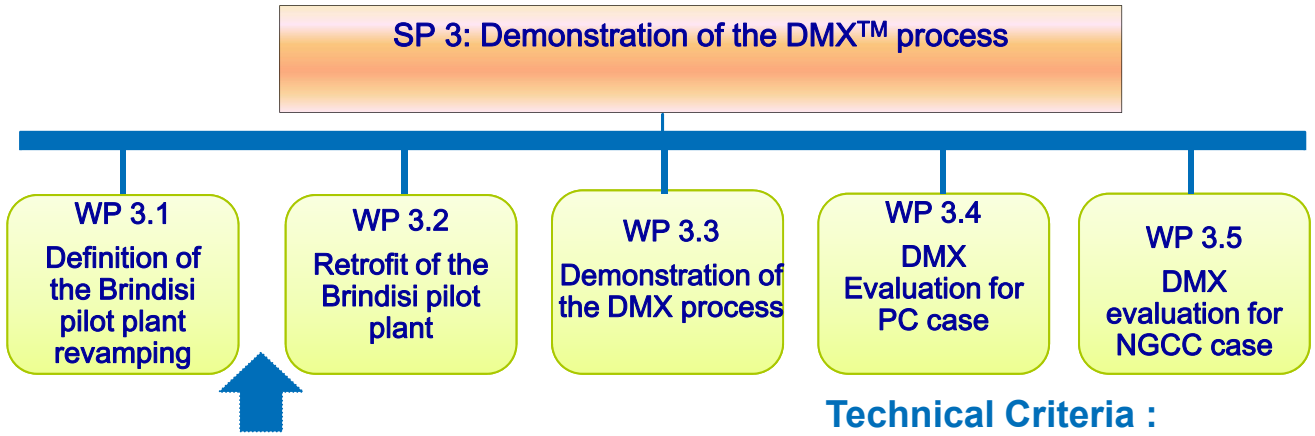


- Criteria for technology scale-up
- Full scale application Capex and Opex evaluation (cost of CO2 avoided)
- Basic engineering

SP3 Structure & Objectives

SP3 Objectives

- The main objective of SP3 is to demonstrate the DMX ™ process on pilot scale and study its application to coal power station and NGCC units with industrial pilot test on the Enel's coal fired power plant of Brindisi.



Go / No Go decision
11th Dec. 2013

Technical Criteria :
- **energy consumption**
- **solvent degradation and emission**
- **main component design criteria**
- **HSE**
- **Capex and Opex of full scale application**

Financial Criteria : cost of retrofit (budget !)

SP3 Work Packages Description – WP3.1

WP 3.1: Definition of the Brindisi pilot plant revamping

Participants: IFPEN, Enel, Laborelec/GDF SUEZ, Prosernat

Objectives

- **Define modifications** to be carried out on Enel Brindisi CO_2 capture pilot plant to test DMX
- Design and Estimate the **cost** of the pilot revamping

Task

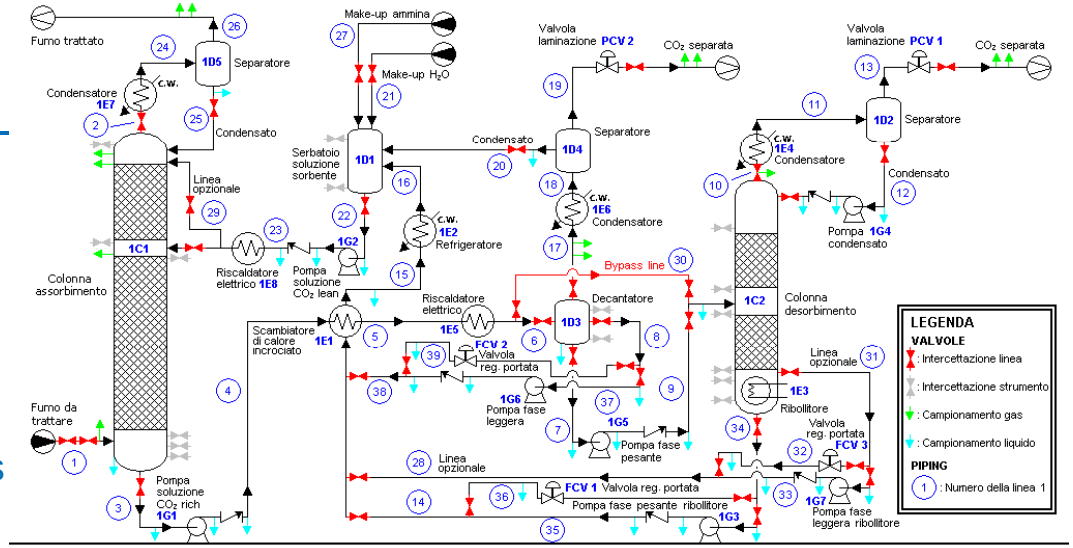
- **3.1.1** Experimentation of DMX on Enel minipilot at Brindisi lab facilities and at IFPEN research centre
- **3.1.2** Experimentation at IFPEN on decantation rate on a representative cold mock-up
- **3.1.3** Preliminary process study– full scale case
- **3.1.4** FEED for Enel CO_2 capture pilot plant revamping
- **3.1.5** Cost estimation of revamping

Minipilot activities - Enel mini-pilot

Brindisi pilot:

Sensitivity test: to optimize the mini-pilot plant operating conditions

Long run test: focused on the study of solvent's degradation / emissions in the optimized conditions.



Flue gas condition

CO2(%mol,dry)	14.12
O2(%mol,dry)	5.13
SO2 (mg/Nm^3)	25
NO2(mg/Nm^3)	10
NO(mg/Nm^3)	130

Brindisi pilot:

Emissions measurements: participation of Laborelec via FTIR measurements (with calibration at IFPEN)

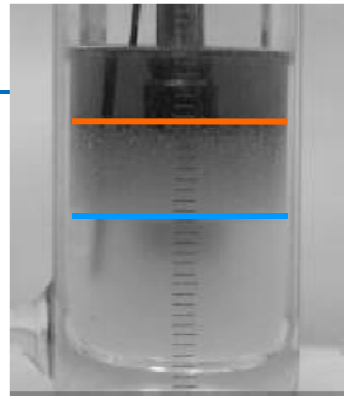
Lab & Minipilot activities – IFPEN

Target :

- ✓Demixing test to decanter design
- ✓Capture efficiency (lean and reach loadings)
- ✓Solvent degradation
- ✓Emission
- ✓Corrosion

Bottle-tests decantation
Ultaturrax – 11,000 rpm

	dmax (mm)
fresh case	3.9
degraded	2.5



IFPEN Lab test

- ✓ VLE data + adapted thermodynamic model
- ✓ Degradation / Corrosion and other operational issues
- ✓ Kinetics & Mass transfer performances
- ✓ L/L decantation – effect of degradation

Semi-open batch reactor degradation tests
T = 80°C, Patm
PO2 = 200mbar PCO2 = 4.6mbar
Vsolvent = 130 ml
1 week

	% amine loss[a]	[formiate] ppm[b]
DMX-1	6%	100
MEA	58%	19000
Ratio	0.10	0.005

a : GC analysis
b : IC analysis

Lab & Minipilot activities – IFPEN

Target :

- ✓Demixing test to decanter design
- ✓Capture efficiency (lean and reach loadings)
- ✓Solvent degradation
- ✓Emission
- ✓Corrosion

IFPEN mini-pilot

- ➢Mechanical/validation tests : T1 2013
- ➢Operation on a 24/7 basis
- ➢Long run tests on MEA (reference case) : 1000 hrs
- ➢ Long run tests on DMX : in progress
- ➢Operation on representative synthetic gas (SOx/NOx)

Full scale application and costing

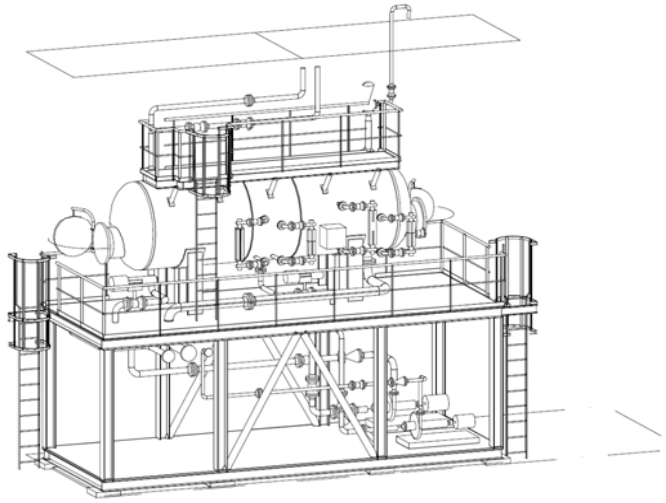
Preliminary process study for application on a 660 MWe power plant, comparison between two cases:

- **MEA 30% (benchmarking)**
- **DMX**

- Assessment of the energy consumption :
  - Process scheme definition (steam turbine and capture process):
    - Definition of the steam turbine scheme and optimization for the two cases
    - Simulation and evaluation of the impact on the thermal cycle for each capture process
  - CAPEX and OPEX estimation:
    - Definition of the method
    - Cost estimation with accuracy ± 30%
  - Final comparison based on :
    - LCOE
    - Cost of CO2 avoided

FEED study for Enel's pilot revamping

- Pre-FEED in 2012 with strong interaction between ENEL / IFPEN / PROSERNAT teams
- FEED : ENEL engineering + PROSERNAT with support of IFPEN
- Kick-Off Meeting in Milan (28th May 2013)
  - basis of design
  - Heat and Mass Bances
  - PFD – PID
  - piping classes
  - list of chemicals
  - Process Data Sheets of main/retrofitted equipments
  - Instrument list + controls
  - Plot plan
  - Operating manual
  - Cost estimation
- HAZOP meeting (30th Sept. 2nd Oct. 2013)
- Final documents for November



VISTA ISOMETRICA

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Conclusions & perspectives

- Conclusions
  - HiCapt+ : a G1 process (MEA 40wt.% + proprietary oxidation inhibitor + material recommendation) => PROSERNAT
  - DMX-1™ : a promising G2 process under development for reducing energy penalty
  - long duration mini-pilot tests + FEED study for Enel's pilot retrofit under progress
- Future steps
  - Octavius EU project - Go/NoGo milestone Dec. 2013 (technical – financial criteria – budget !)
  - tests of DMX-1 on Enel's Brindisi industrial pilot for further evaluation on full scale cases – tests in 2015-2016
  - process ready for commercialization T1 2017

Thank you !

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