KHIMOD

ALCEN

A Green Tech Company

Fight CO_2

CONFIDENTIAL

V7B-05/07/19

CO_2: PROBLEM & SOLUTIONS

- Reducing global CO_2 emissions is an **absolute** necessity in the nearest future as the situation is **worse** than officially acknowledged

  In consequence

- CO_2 must be fought in every possible ways

CO_2: PROBLEM & SOLUTIONS

- CO_2 emissions must be dealt with
  - CO_2 transformation (CCU)* in valuable molecules → Direct impact
  - Better chemical processes emitting less CO_2 → Indirect impact

…and these are the paths KHIMOD decides to take

* CCS is not a sustainable solution

KHIMOD: FIGHT CO_2

- Combining different kinds of gas with a specific catalyst in a specifically designed Heat Exchanger / Reactor (HER) allows KHIMOD to produce
  - Green molecules from CO_2
  - Chemical molecules with a reduced CO_2 impact

KHIMOD CONCEPT – DIRECT IMPACT

H_2

- Electrolyser

CO_2

- Methanisation plant
- Glass plant
- Cement plant
- Steel plant
- Gasification plant

C_nH_{2n+2}

- Methane

Field proven

- Kerosene

Laboratory proven

- Other hydrocarbons molecules

In our road map

KHIMOD: A COMPREHENSIVE OFFER

From a mature generic technology we dedicate a specific HER for each application

- **CH_4** → METHAMOD
- **Kerosene** → KEROSMOD
- **…** → …

KHIMOD PROFILE

- KHIMOD is a **French green tech** company
  - Based in Paris area
  - Spin-off of an established industrial and innovative group present in challenging markets (Defense, Aeronautics, Energy)
  - Experienced in international projects

KHIMOD TECHNOLOGY

- KHIMOD technology consists of the development of innovative Heat Exchanger / Reactor for reactions
  - Exothermic or endothermic
  - Highly sensitive to temperature control
  - Primarily heterogeneous in its usage of catalysts
  - With maximum efficiency obtained even with small volume
  - With unlimited scalability

KHIMOD TECHNOLOGY

- The KHIMOD HER(s) have been designed in order to be integrated in on demand systems without size limitation of the production. From 1.5 Nm^3/h of gas production to infinite by steps of 2.5 Nm^3/h
- The KHIMOD reactors allow to reach the best efficiency from the use of a single reactor
- The KHIMOD reactors allow quick On&Off
- Khimod reactor allows continuous and adjustable production avoiding potentially hazardous batch process

KHIMOD TECHNOLOGY

- KHIMOD technology consists of the development of innovative Heat Exchanger / Reactor
- HER are designed using HIP (Hot Isostatic Press) processes mastered by KHIMOD thanks to 20 years of expertise which allows:
  - Optimized geometry of reactors
    - 225 reaction canals of section 7.5 mm x 4 mm
  - Compactness
    - Dimensions (length x width x height) 350 x 300 x 300 mm
  - Fine tuning of temperature management
    - 1024 cooling canals of section 2 mm x 2 mm

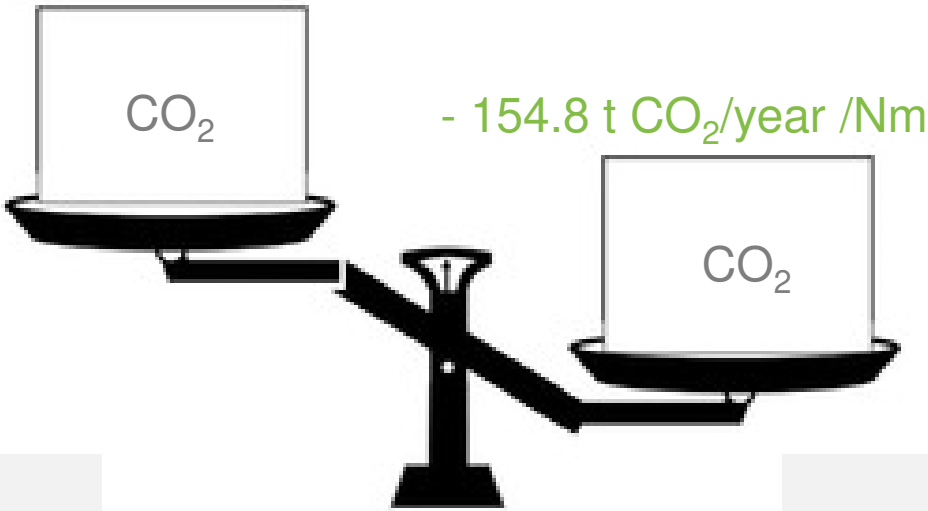
KHIMOD TECHNOLOGY

- Efficiency:
  - CO_2 conversion rate : more than 95%
  - Energy efficiency of the system: 92% with heat valorization
- Small quantity of catalysts
  - 0.53 kg catalyst for 1 Nm^3/h production
- Easily refilled catalysts
- Long lifecycle and availability:
  - 20 years for the reactor (2 years for catalyzer), operating full time excluding the refill period
- Cost effective production
- Recyclability of metals:
  - More than 90% recyclable

KHIMOD: BENEFITS FOR THE ENVIRONMENT

LIFE CYCLE ANALYSIS* (LCA) OF METHAMOD

+ 0.7 t CO_2/year /Nm^3/h



- 154.8 t CO_2/year /Nm^3/h

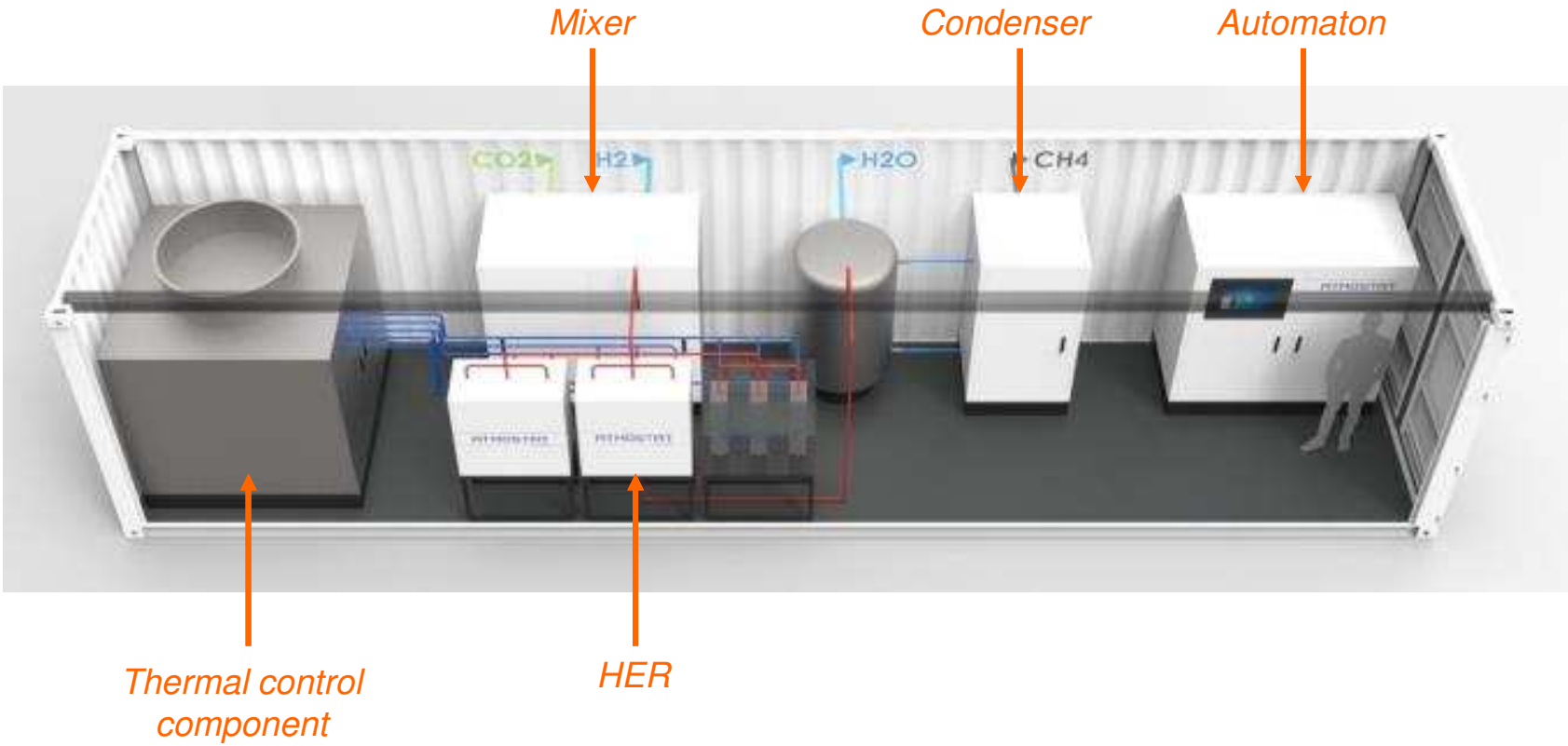
Produced CO_2 to manufacture, use and recycle METHAMOD reactor

Avoided CO_2 thanks to METHAMOD

* Operating life of the installation 20 years

A MODULAR ARCHITECTURE OF SYSTEMS

- A compact unit in a mobile container



KHIMO: ADDED VALUE FOR CHEMISTRY

- KHIMOD's disruptive technology for chemical reactions:
  - A solution for continuous process intensification
    - High capability to control temperature in exothermic or endothermic reactions allows a maximum efficiency as soon as small volume
  - A solution for massive parallelization of production units
    - HER have been designed in order to be integrated in on demand systems without size limitation of the production

KHIMOD: ADDED VALUE FOR CHEMISTRY

- KHIMOD's disruptive technology for chemical reactions:
  - A solution for high safety in chemical process
    - Can be used for hazardous chemistry under safe conditions, due to the very low internal HER volumes (a few milliliters' compared to several m^3 for a batch) and to acute temperature control.
  - A solution to valorize industrial waste (CO_2) or to reduce it
    - Transform CO_2 into a valuable resource

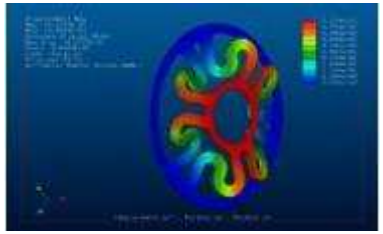
KHIMOD MANUFACTURING POLICY

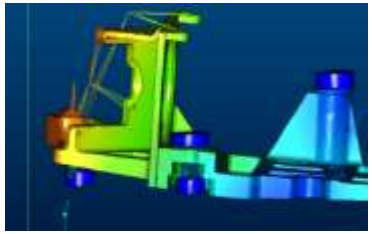
- KHIMOD relies presently on Alcen group's capacities
  - MACHINING MEANS
    - Turnery
    - Milling
    - Wire and sinker EDM

  - ASSEMBLY & CLEANING MEANS
    - TIG, electon beam and Laser (YAG) welding
    - Clean room (class 100)

KHIMOD MANUFACTURING POLICY

- KHIMOD relies presently on Alcen group's capacities
  - CAD & SIMULATIONS
    - Pro/Engineer, Catia
    - Ansys, Nastran, Fluent





- KHIMOD will build its own industrial base as soon as the market volume will be significant

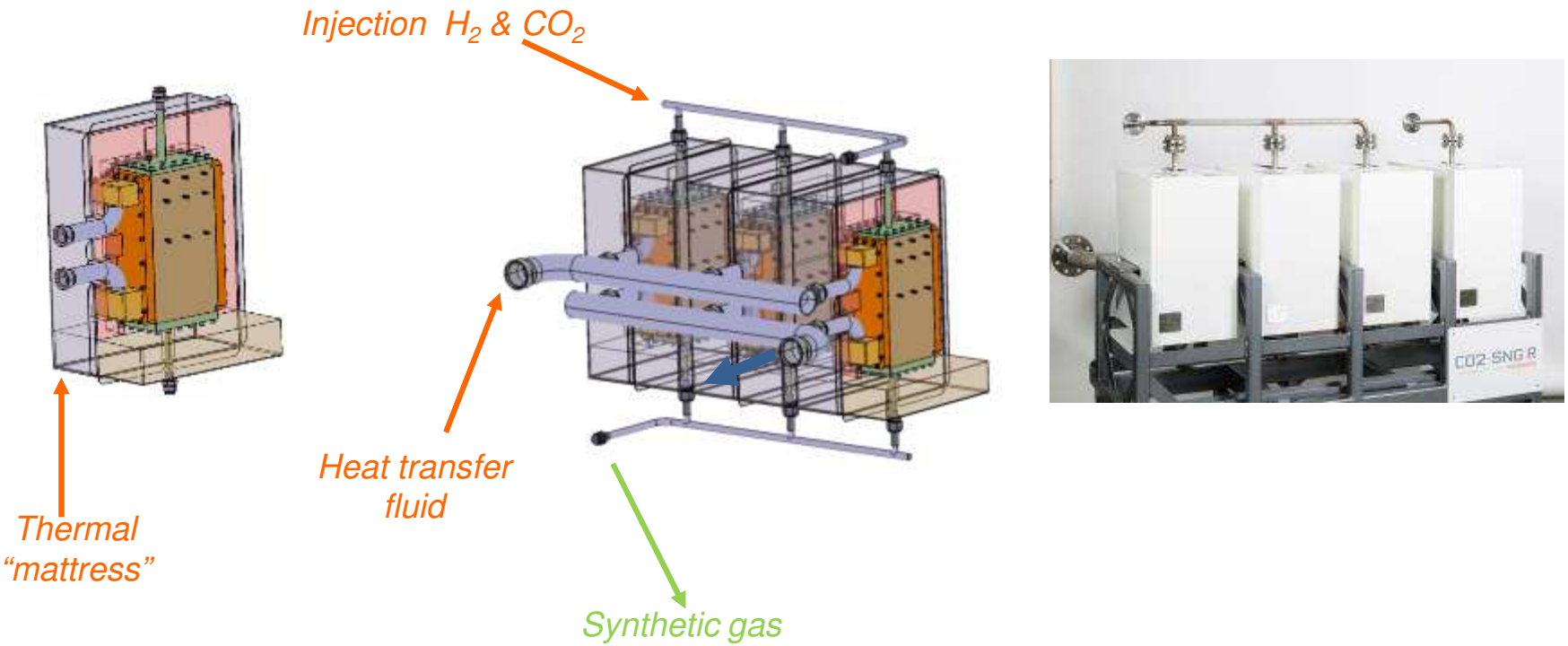
KHIMOD PARENT COMPANY

ALCEN

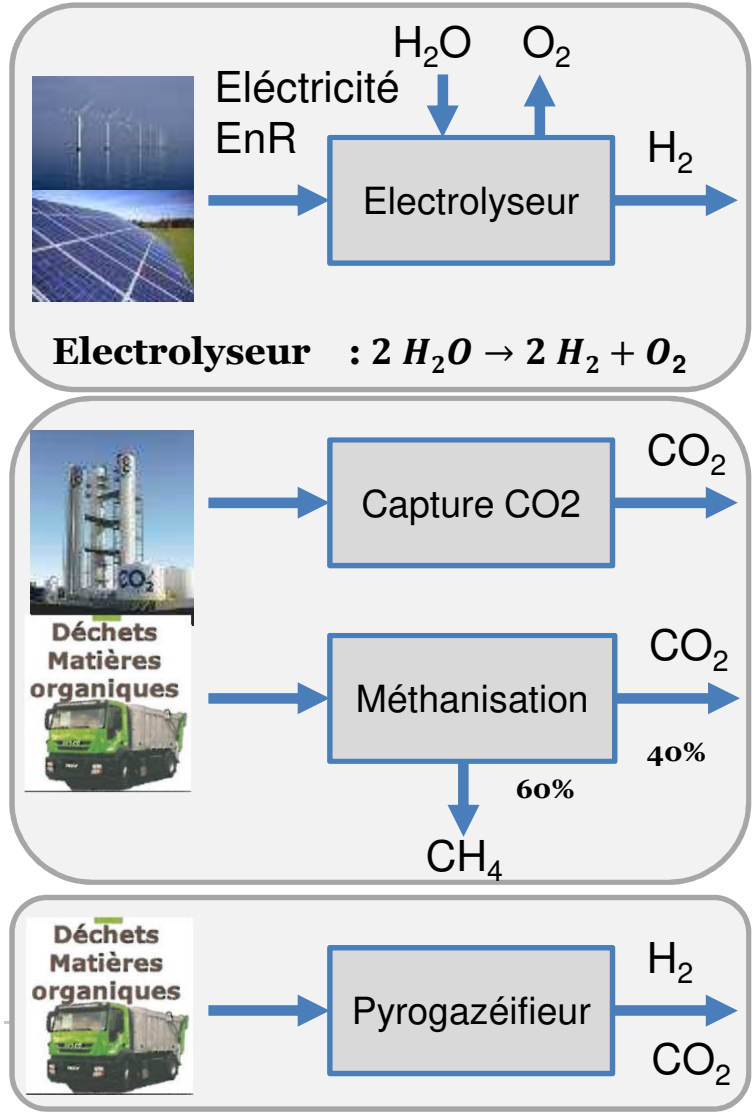
- Family private company
- Turnover ≃ 250 M€
- 1800 employees
- 5 strategic domains
  - Defense
  - Energy
  - Medical
  - Aeronautics
  - Large scientific instruments

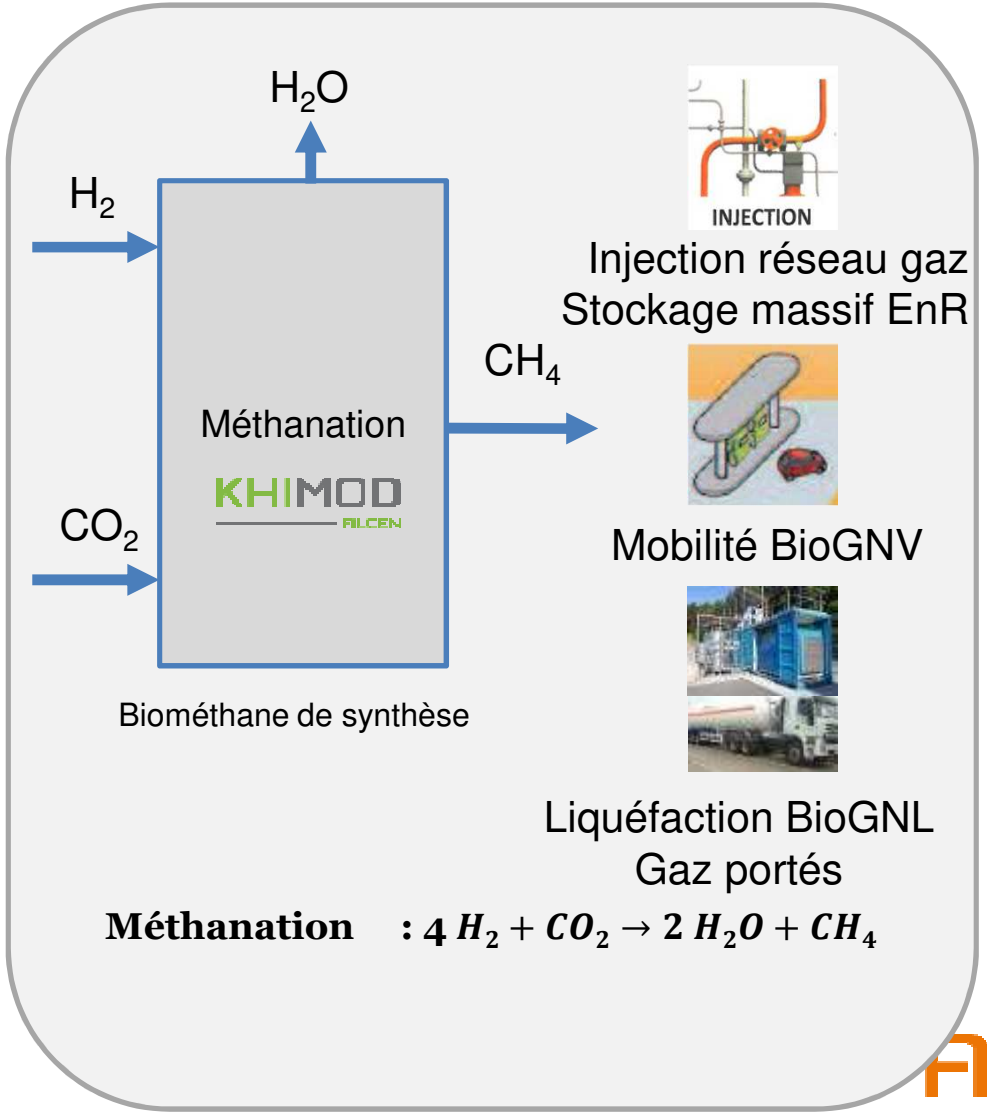
A MODULAR ARCHITECTURE OF SYSTEMS

- A standard HER configurable in stages, islands and modules



Methanation, a solution to produce synthetic biomethane : « Power to Gas » and « Waste to Gas »



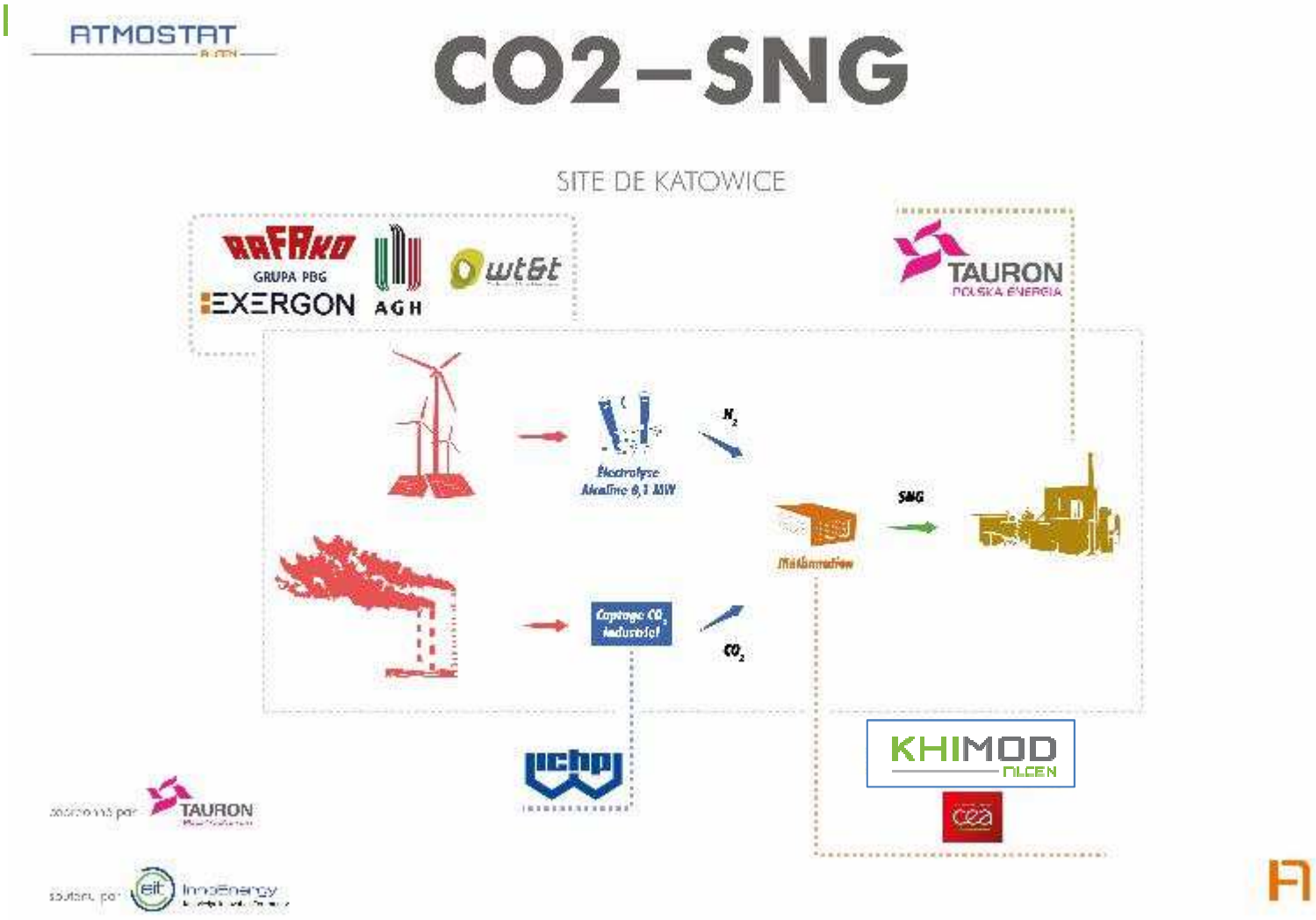


USE CASE N°1 : POLISH OPERATION

- CO_2 from coal-fired power plant
  - Power to Gas **CO_2-SNG** project in Katowice installed in one of TAURON power plants in March 2018
  - The goal of the project is to recover CO_2 emitted by coal-fired power plant by transforming it into green synthetic methane
  - The project seeks to experiment the recycling of CO_2 as an alternative mobility application

Field Proven

USE CASE N°1: POLISH OPERATION



CASE N°1: POLISH OPERATION

- According to Tauron (Tauron Polska Energia S.A., the incumbent energy company in Poland) and an independent Polish laboratory, Institute for Chemical Processing of Coal, the results obtained during the first test campaign coming from coal-fired power plant (CO_2-SNG project in Poland) demonstrate the exceptional performance of METHAMOD reactors

TAURON

INSTYTUT CHEMICZNEJ PRZERÓBKI WĘGLA

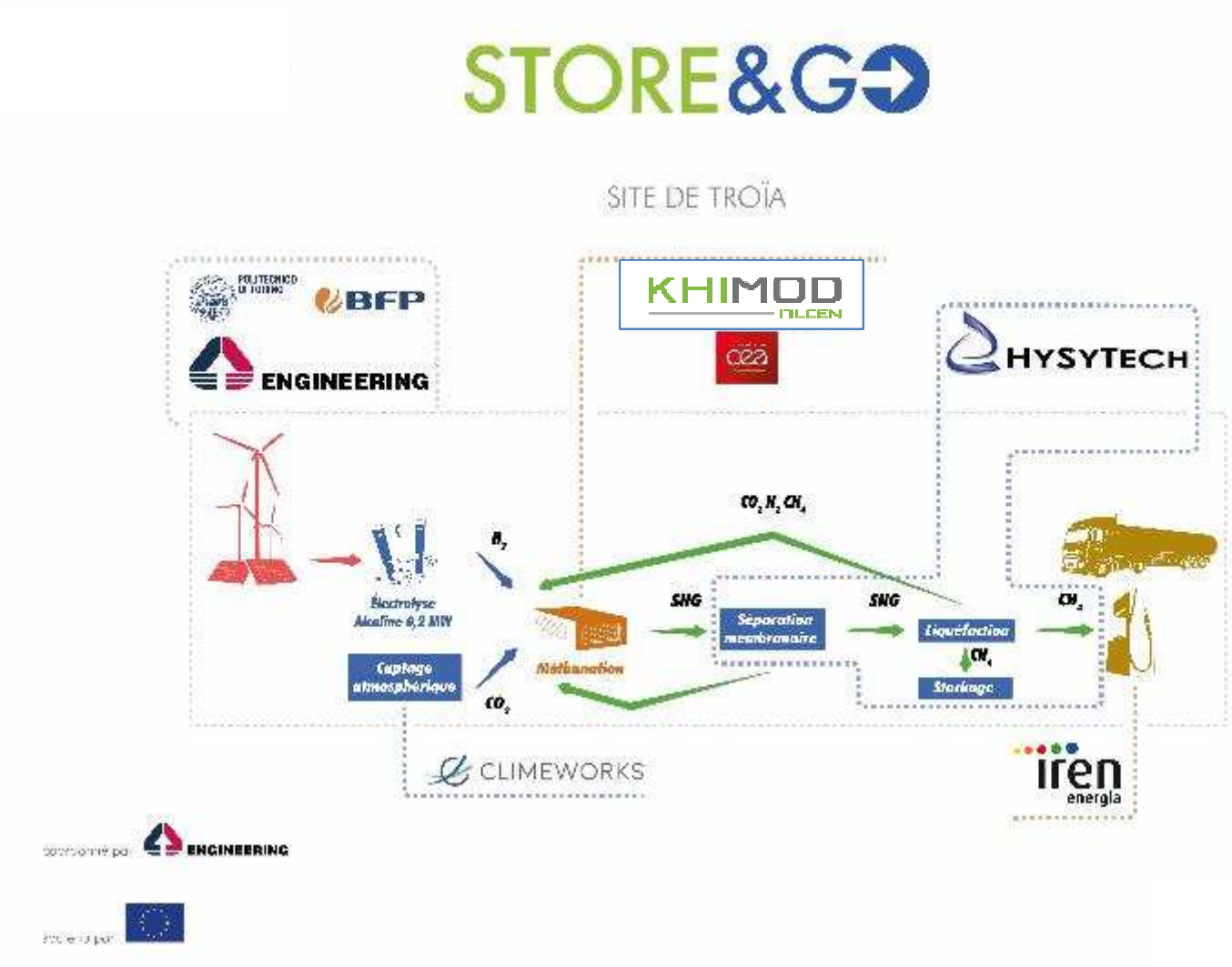
Obtained conversion rate from CO_2 to CH_4 is greater than 98.5 %

CASE N°2: ITALIAN OPERATION

- CO_2 from atmosphere
  - As part of the European **STORE&GO** project, KHIMOD is developing the methanation unit installed at the Troïa site in September 2018
  - The objective of the project is to produce LNG for mobility applications. Electricity comes from locally installed photovoltaic panels or wind turbines and CO_2 is captured in the atmosphere

Field Proven

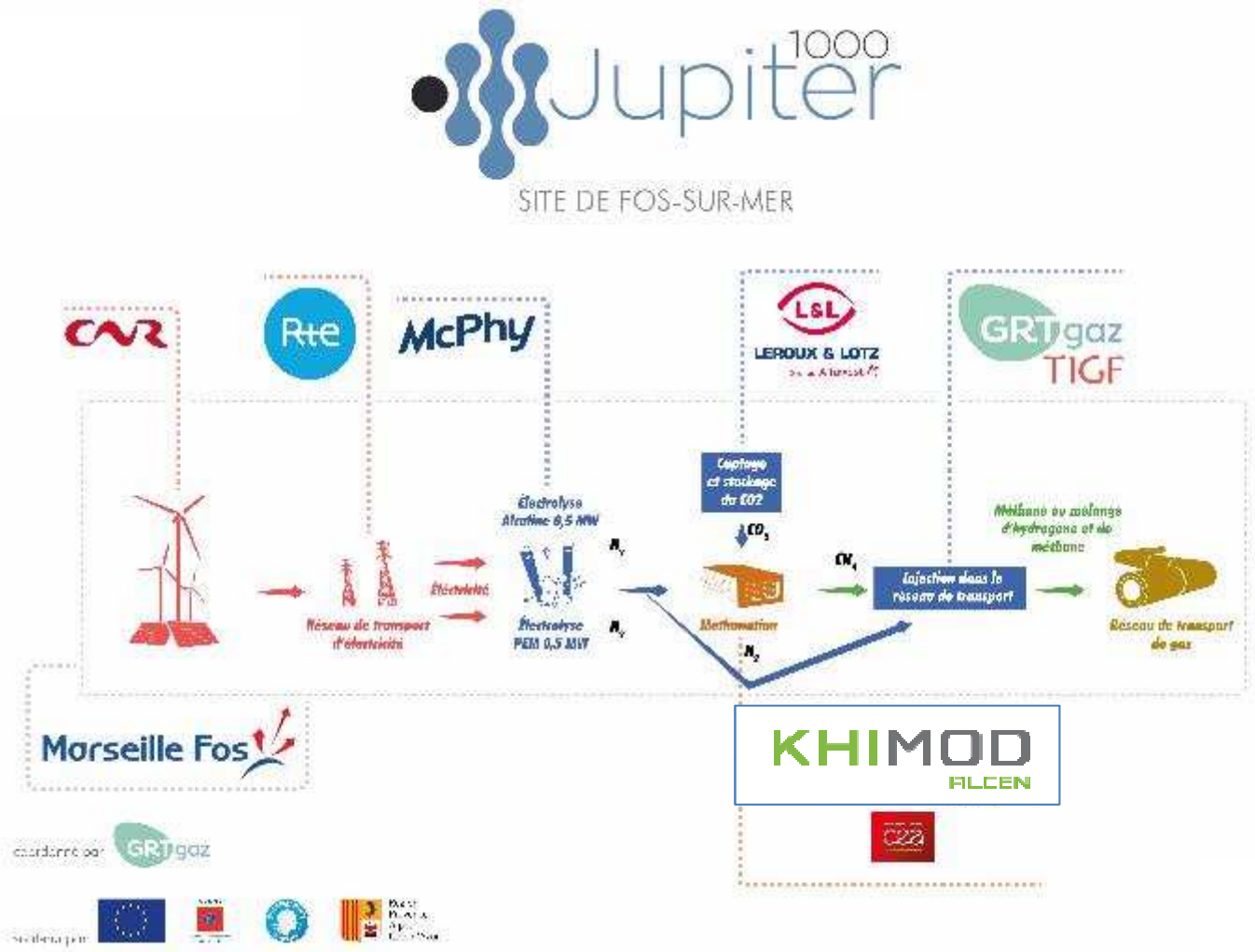
USE CASE N°2: ITALIAN OPERATION



CASE N°3: FRENCH PROJECT

- A METHAMOD system developed by KHIMOD equips the **JUPITER 1000** installation, a collaborative project coordinated by GRTgaz
  - Located in the harbor of Fos-sur-Mer, near an industrial CO_2 source
  - Windmill electrical source of 1 MW capacity that activates two electrolysers
  - The objective of this project is to inject the methane produced in the gas grid

USE CASE N°3: FRENCH PROJECT

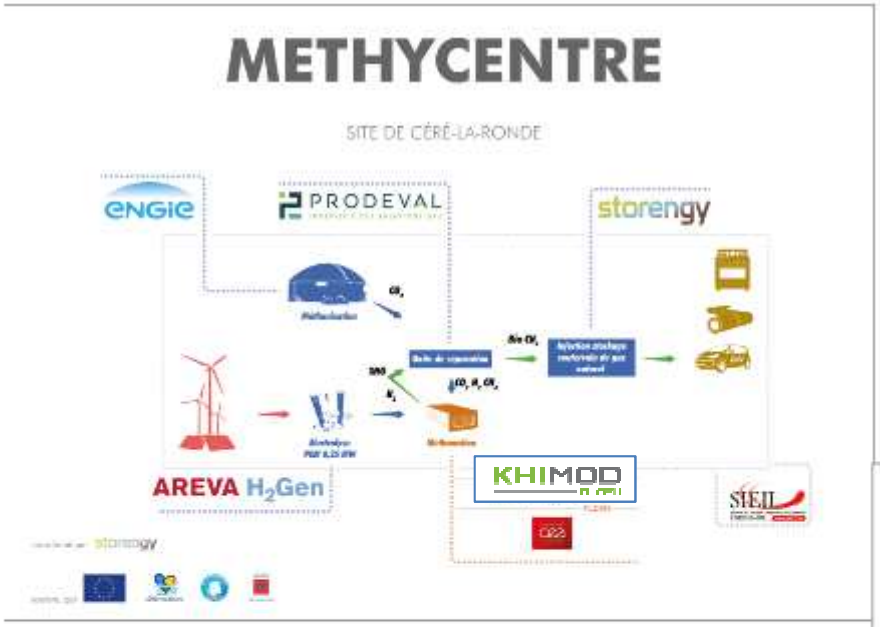


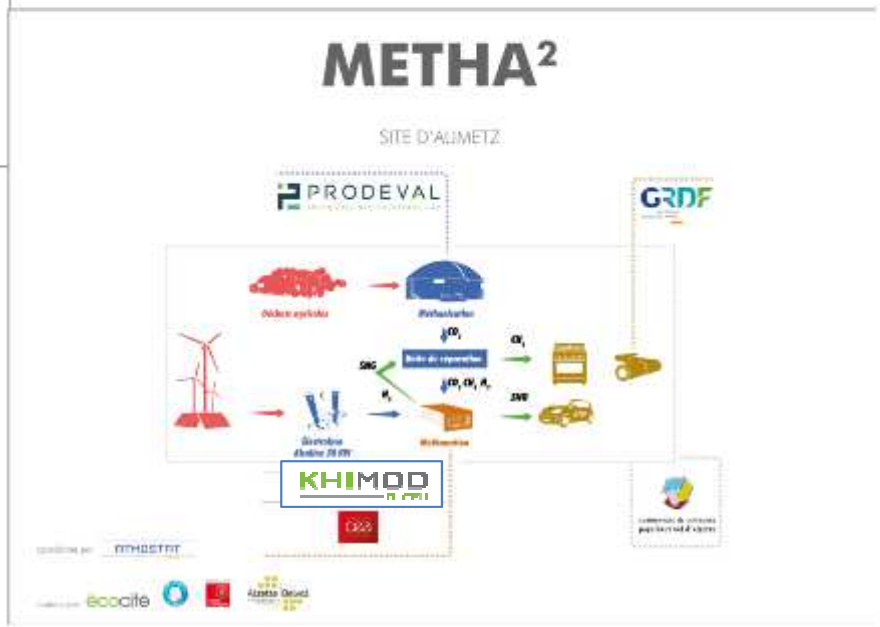
USE CASE N°3: FRENCH PROJECT

USE CASE N°4 - 5: FRENCH PROJECTS

- CO_2 from methanisation unit in Ceré-la-Ronde & Aumetz
  - METHA^2 & METHYCENTRE address the combination of methanisation with METHAMOD system
  - This combination makes it possible to recover the CO_2 emitted by methanisation as an input to CH_4 production
  - In the case of Methycentre the methane produced will be used to supply a fleet of waste collection trucks

USE CASE N°4 - 5: FRENCH PROJECTS





transform CO_2 into a **green asset**

Fight CO_2

USE CASE N°6: EUROPEAN PROJECT

- Heat-to-Fuel is a Horizon 2020 EU-funded project carried out by 14 partners from across Europe that aims to deliver the next generation of biofuel production technologies

- For KHIMOD the Heat-to-Fuel project will allow the strengthening of expertise in usage the HER for the Fischer-Tropsh chemical reaction
- **The HER produced its first kerosene in March 2019**