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Club Pyrogazéification

Présentation des technologies de méthanation : grands principes et caractéristiques techniques, quelques exemples d'acteurs et développement

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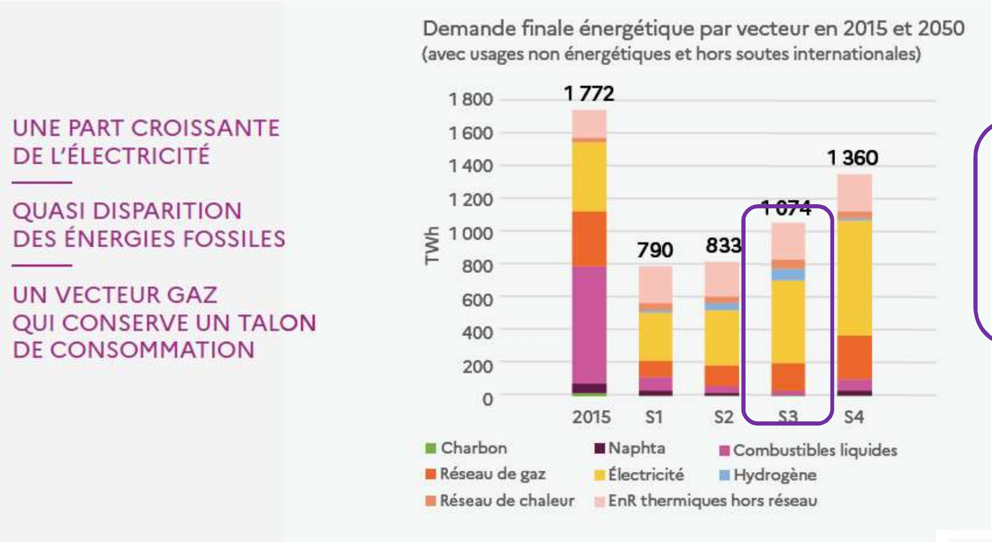
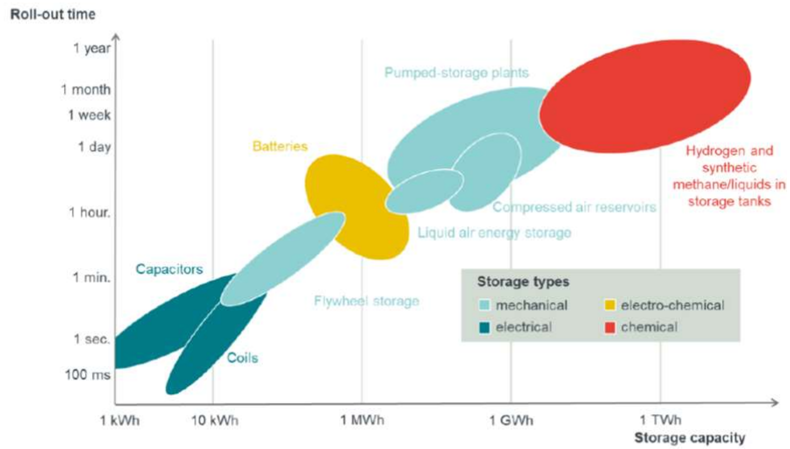
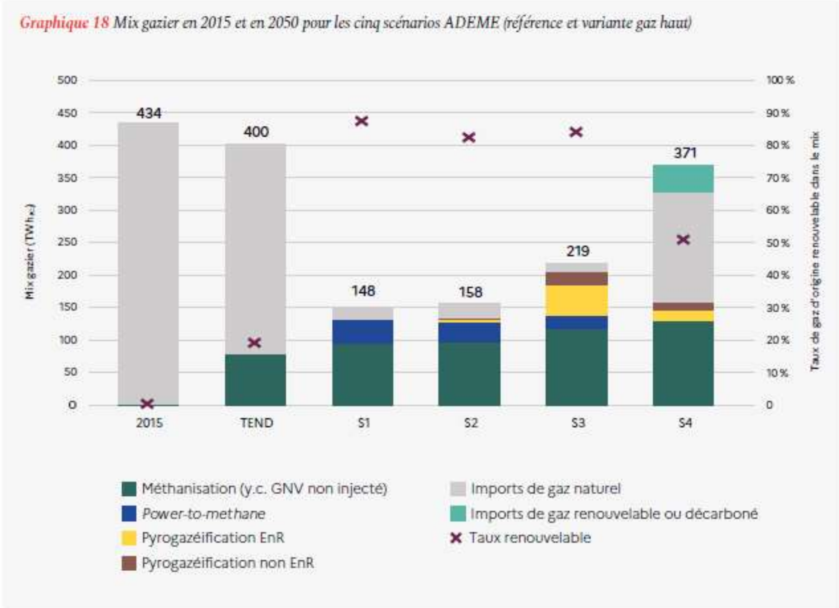


En 2050 – Scénario 3 :
Le mix de la consommation d'énergie finale est composé de 517 TWh d'électricité, 290 TWh de chaleur, 161 TWh de gaz et 36 TWh de combustibles liquides.

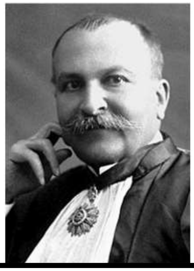
sources: INTERNATIONAL ASPECTS OF A POWER-TO-X ROADMAP A report prepared for the World Energy Council Germany





METHANE SYNTHESIS

Sabatier reaction : **equilibrated**, **highly exothermic**, and **catalyzed by metals** :



$$CO_2 + 4\,H_2 = CH_4 + 2\,H_2O \qquad \Delta_r H^0 = -165\ kJ/mol\ [R1]$$

Direct path

$$CO_2 + H_2 = CO + H_2O \qquad \Delta_r H^0 = +\,41\ kJ/mol\ [R2]$$

$$CO + 3\,H_2 = CH_4 + H_2O \qquad \Delta_r H^0 = -\,206\ kJ/mol\ [R3]$$

Indirect path

- 1902: CO and CO_2 methanation processes discovered by Sabatier et Senderens
- 1970s: CO methanation applied for the production of SNG using syngas from coal gasification.

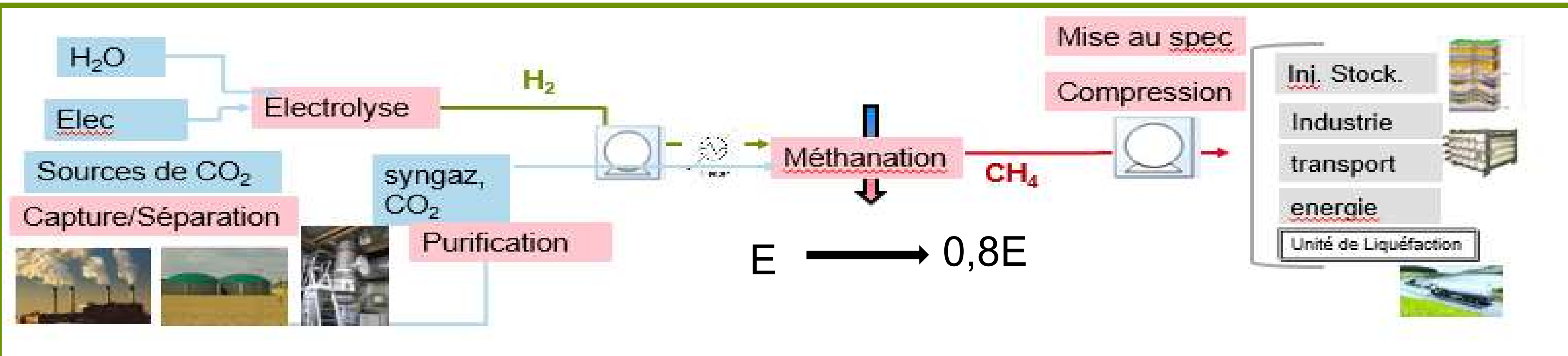
→ several methanation concepts developed. (Kopyscinski, Schildhauer, et Biollaz 2010

- 1980s: CO_2 methanation processes focused on the use of coke oven gas or blast furnace gas

→ Due to high efforts for the gases cleaning, few concepts reached a commercial scale.

- Beginning 21st century: CO_2 methanation processes gained new attention at research institutions and in industry

Over the last 50 years, several methanation concepts have been developed.



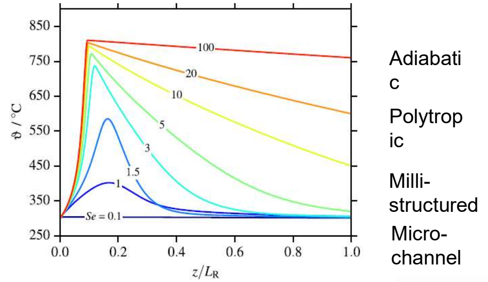
CATALYTIC METHANE SYNTHESIS : a trade-off between

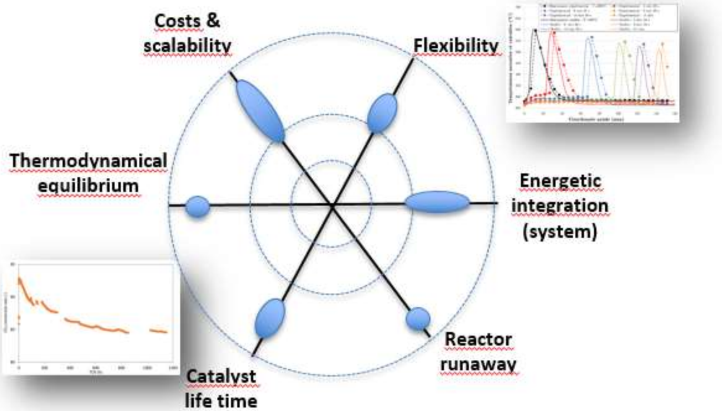
Ni/Al_2O_3

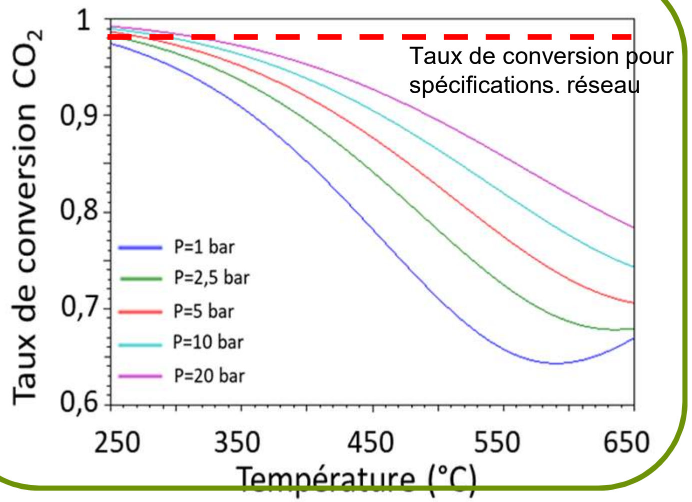
CO and CO_2 methanation : **finely dispersed nickel on an oxide support with a large specific surface area (alumina)**

Deactivation issues (leading to unwanted shut-down of the PtG unit and an increase of the maintenance costs)

- **Poisoning : (chemisorption of poisons on reactive sites (H2S, SO2))**
- **Thermal degradation (Sintering)**
- **Fouling (Carbone deposition)**







Catalyst desactivation

Interest to control T,P as much as possible

Chemical management

Exothermic reaction

Thermal management

Thermodynamical equilibrium

Reaction kinetics

$$k = k°. e^{-Ea/RT}$$

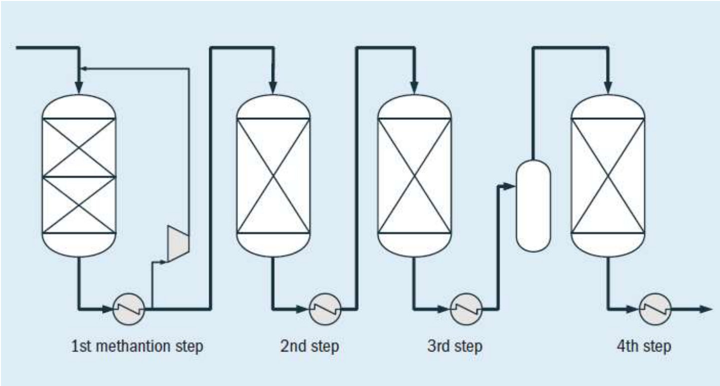
Kinetics enhanced at high temperature

METHANE SYNTHESIS & REACTORS

The catalytic methanation reactors are either state of the art technologies adapted from large scale stationary Coal-To-SNG systems, or new concepts designed to reach the specific requirements for smaller scale, more compact units and unsteady operation due to fluctuating availability of renewable hydrogen.

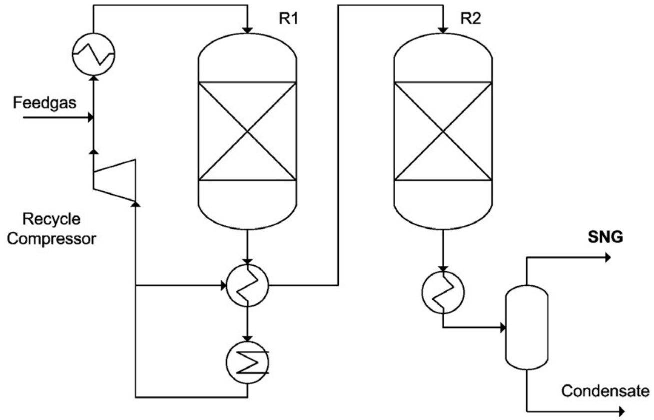
The main difference between the methanation technologies is the temperature profile inside the reactor.

Réacteurs adiabatiques en série



TREMP (Haldor Topsøe) :

- ✓ Topsoe's Recycle Energy-efficient Methanation Process
- ✓ Gestion temperature dans le premier réacteur par recyclage des gaz (≈ 70%)
- ✓ Température dans les réacteurs : 700°C (1er réacteur) → 250°C (dernier réacteur)
- ✓ Valorisation chaleur en électricité
- ✓ Durée de vie du catalyseur ≈ 3 ans



Procédé Lurgi

- ✓ Gestion température dans le premier réacteur par recyclage des gaz (> 85%)
- ✓ Température plus faible dans le premier réacteur
- ✓ Valorisation chaleur en électricté

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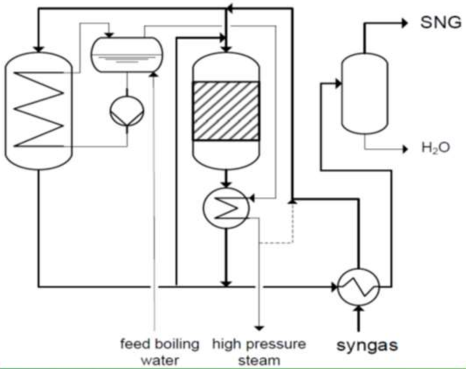
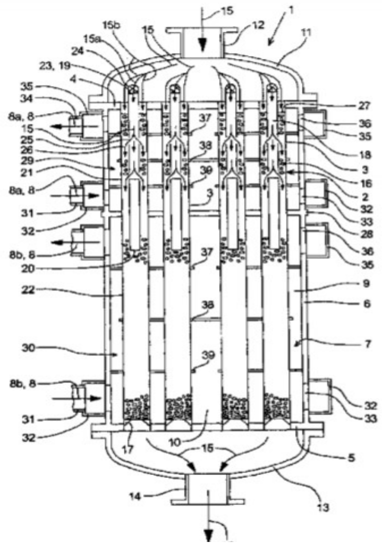
Réacteurs tube-calandre



Cooled fixed bed reactors (Linde process)

- ✓ Simple manufacturing (up to 10000 tubes)
- ✓ Lit de catalyseur refroidi par circulation d'un fluide thermique pour contrôler la temperature
- ✓ → need reactants dilution/staged injection
- ✓ Better thermal management when decreasing the tube diameter

réacteur DWE (MAN)



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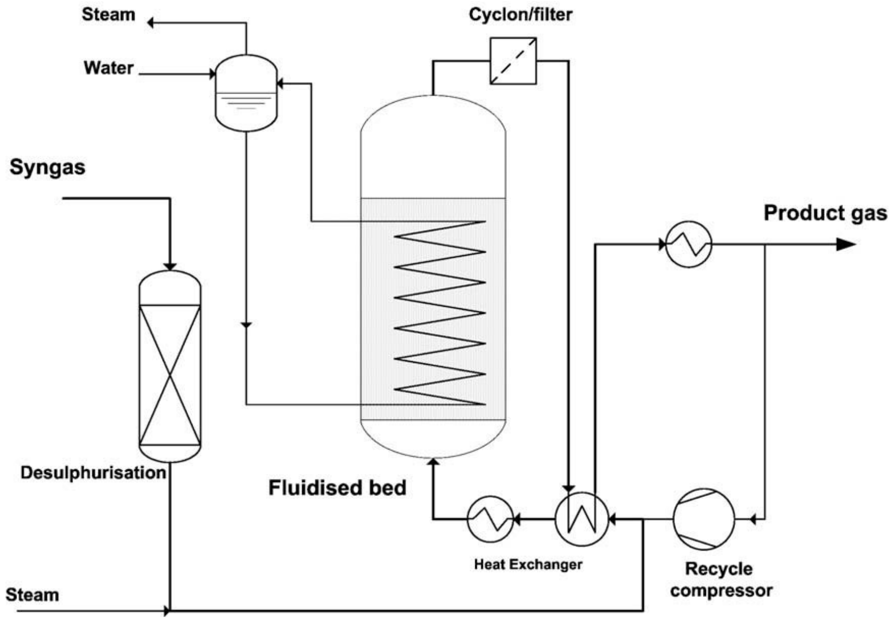
Réacteurs lits fluidisés

- ✓ Procédé Comflux : Thyssengas et Univ. Karlsruhe
- ✓ Température isotherme dans le lit
- ✓ Gamme de débit pour le contrôle de la fluidisation
- ✓ very good heat exchange at the walls.
- ✓ catalyst may suffer from attrition
- ✓ not well adapted to load variations

- ✓ Technologies dans des démonstrateurs (Gussing et GAYA)



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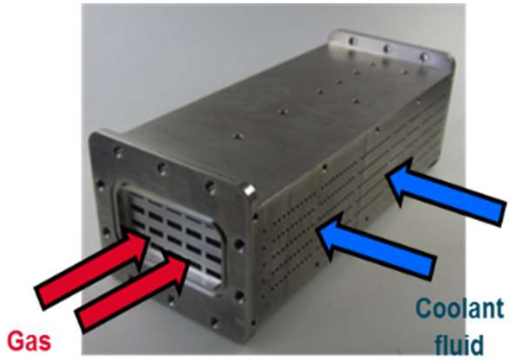
Réacteurs structurés

Micro-structured reactors

- ✓ Intensification of heat and mass transfer
- ✓ High catalyst density and easy loading
- ✓ Intensification cross flow cooling
- ✓ Complexity for large scale appli



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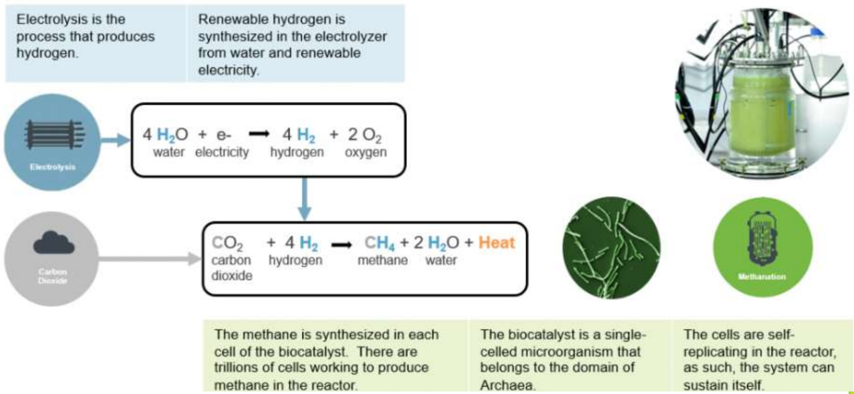
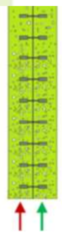
Réacteurs biologiques (bactéries)

https://www.electrochaea.com/technology/

- ✓ Production de méthane à basse température
- ✓ CAPEX potentiellement plus faible
- ✓ Tolère mieux les impuretés
- ✓ Conversion de H_2 et CO_2 par des bactéries en milieu aqueux vers 60°C (refroidissement car réaction exothermique)
- ✓ Solubilité du CO_2 et l'H_2 limitée en phase aqueuse
- ✓ Energie d'agitation nécessaire pour assurer un transfert de masse suffisant (Pas d'information validée sur l'énergie d'agitation par Nm^3 CH_4 produit)
- ✓ VVH ≈ 10-50 h-1 : faible compacité

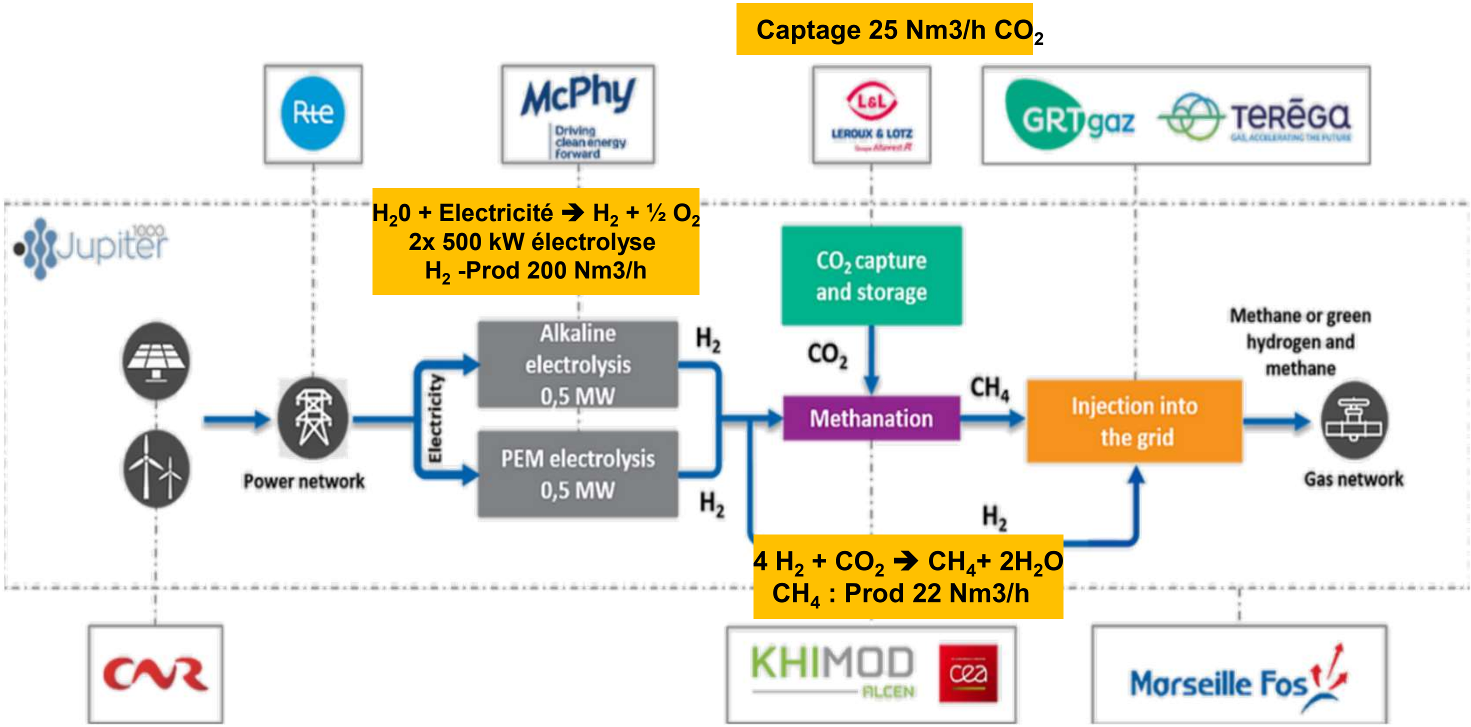




METHANE SYNTHESIS & POWER TO METHANE PROJECTS

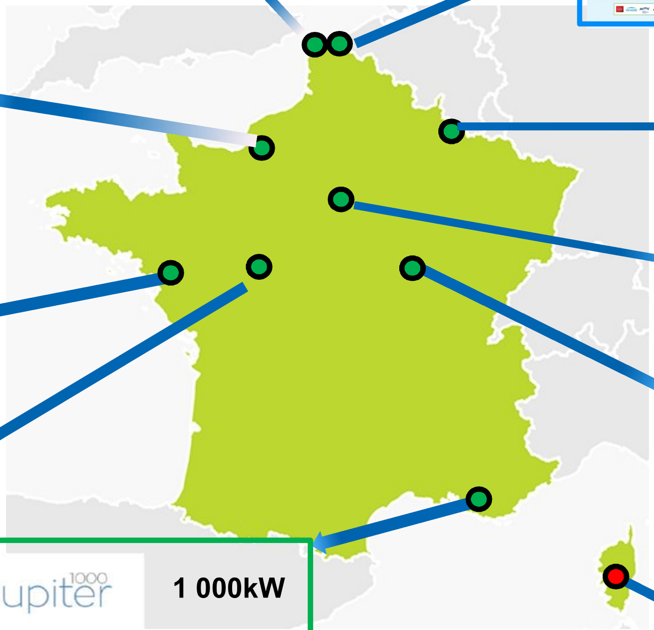
Project	Country	Power Mwe	year	Methanation type / concept	Constructor	H2	CO_2
e-Gas-AUDI	DE	6	2013	One tubular Catalytic Molten salted cooling	MAN	Alkaline electrolysis	Biogas Amine absorp
CO_2_SNG	PL	0.12	2018	Millistructured reactors (2 stages)	Atmostat	Alkaline electrolysis	Flue
Biocat	DK	1	2016	biologic	Electrochea	Alkaline electrolysis	Biogas
SUNFIRE-HELMET	DE	15kW	2017	Two catalytic fixed bed	KIT design	SOEC	
STORE&GO Falkenhagen	DE	1	2016-2020	2 catalytic reactors: Honeycomb and tubular	Thyssenkrupp	Alcalin	From bioethanol
STORE&GO Solothurn	CH	0.7	2016-2020	Biologic	Electrochea	PEM	From waste water
STORE&GO Troia	It	0.2	2016-2020	Millistructured catalytic reactor (recycling)	KHIMOD	PEM	DAC
JUPITER 1000	Fr	1	En cours	Millistructured catalytic reactor	KHIMOD	Alkalin and PEM	Flue
Great Plains Synfuels Plant	USA	1500		Lurgi methanation	Air liquid (lurgi)		
GOBIGAS	Sweden	20		TREMP	Haldor Topsoe		
				Vesta	Clariant and Foster wheeler		
Fuxing and Xinwen projects	China	4billion m3/y		HICOM	JM		
				Linde isothermal reactor	Linde		

METHANE SYNTHESIS & JUPITER 1000



- # Projets de démonstration de Power to Gas en France

● Projets en cours
● Projets finis ou en stand-by



H2V Normandy 2x100 MWe
Ely➔ usage indus

H2V 59 2x100 MWe
Ely➔ inj res

Ely➔ inj res

GRHYD 50kW
Renouvelons nos énergies

Metha2 ~50kW (?)
Ely+Méthanisation + P2G ➔ Mob GNV

Methamod 20kW
P2G

ATMOSTAT

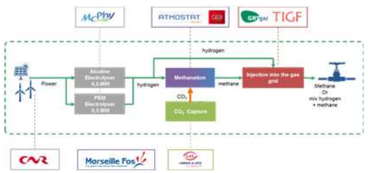
Hycaunais 1 Mwe
Ely➔ P2G B➔ Inj res

MINERVE 12kWe
MINERVE : Un démonstrateur *power-to-gas* pour expérimenter l'avenir
Ely+P2G➔ mob GNV

METHYCENTRE 250kW

Ely+Méthanisation + P2G➔ inj res

Jupiter 1000 1 000kW



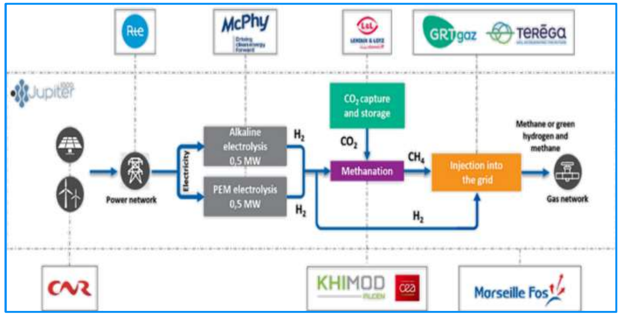
Ely+P2G➔ inj res

MYRTE 200kW
cea, capenergies, HELION, VILLE D'AJACCIO, Collectivité de Corse
Ely➔ stock ➔PAC

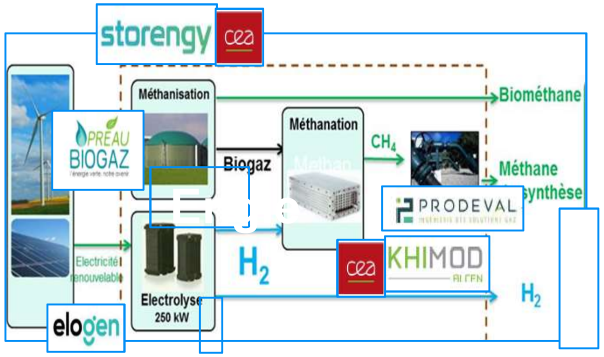
atee Club Power to Gas

CONCLUSIONS

Méthanation – méthaneurs



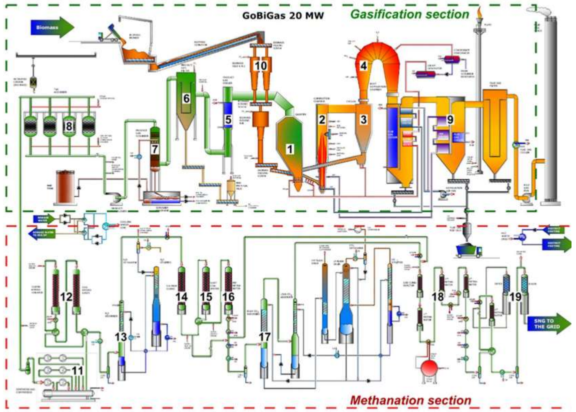
- **Système de conversion (Matures, ... Améliorables...)**



- **Plusieurs marchés : réseaux / stockage / mobilité ?**

- **Intégrant plusieurs filières potentielles**

- **Power 2 Gas ⇔ Jupiter 1000**
- **Power&Biomass 2 Gas**
  - **Méthanisation/Méthanation ⇔ Méthycentre**
  - **Pyrogazéification/Méthanation ⇔ GoBiGas**



Coûts de production dépendant des hypothèses mais couramment « autour de 100-150 Euros / MWh » avant 2021.

...ACV...