New gases: energy transition for the gas industry

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The context of the energy transition in France

- **A debate focused in France, so far, on the electrical issue and on nuclear** in particular (respectively 1/4 and 1/6th of energy consumption) culminating in the decision of the President of the Republic to relaunch the nuclear power program to compensate for the aging of the fleet (6 EPR2 + 8?)
- **A weakening of energy systems** linked to the drop in electrical capacities, for instance those that can be controlled in France and in neighboring countries (between 70 and 110 GW by 2035 depending on the sources)
- **Extremely proactive energy saving** programs whose level of ambition may call into question the closure of the provisional balance sheets
- **With a view to carbon neutrality in 2050**, a strong acceleration of decarbonization objectives through the "fit for 55" program: approximately -47% in France in 2030 compared to 1990, knowing that half was achieved in 30 years the other must be within 9 years

The conditions for the success of a competitive and safe transition

- **Express a clear and unequivocal political will** to no longer oppose energies but to make the best use of their complementarities and the use of existing means with the objective of controlling costs
- **Accelerate energy efficiency programs**
- **Betting on technologies of the future**, a factor in strengthening the sovereignty of our country and creating local added value
  - EPR2 and SMR
  - Floating offshore wind turbines
  - **New technologies to produce renewable and carbon-free gases**
  - Tandem solar panels (perovskite/silicone)
  - High temperature electrolysers
- **Accelerate the development of new gases** (renewable and carbon-free)
  - Electric: solar, wind
  - **Gas: biomethane, methane from waste treatment, methane from CO_2 capture, renewable and low-carbon hydrogen**

The potential of new gases: an asset for France

- A potential for renewable and carbon-free gases far greater than current consumption, which will ensure:
  - The resilience of energy systems
  - The reindustrialization of the country and in particular of the rural areas
  - Strengthening the country's energy independence and sovereignty
  - The development of a circular economy at the heart of the territories and the creation of non-relocatable jobs
  - Support for the development of sustainable agriculture
  - The development of high-performance solutions for waste treatment

New gases allow a gas transition for the benefit of the community

- Renewable and carbon-free gases are vectors of reindustrialization and strengthening of our sovereignty
  - 75% of the added value created by anaerobic digestion benefits the French economy, as do the wind (40%) and solar (44%) sectors
  - The sector generates jobs that cannot be relocated to the territories; in addition to the 60,000 direct and indirect jobs that will be generated by 2050 by the renewable and carbon-free gas production sector, approximately 200,000 local jobs will be sustained
  - The production of renewable and carbon-free gases strengthens the energy independence of the territories and has a positive impact on the French trade balance: by 2030, a reduction of around 4 billion euros in gas imports is envisaged with our script

New gases: energy for our territories

- New gas technologies ready today
- The potential for renewable and carbon-free gases: an asset for France
- Gas infrastructure, an essential element of the competitiveness of the energy transition
- The deployment of a competitive renewable and low-carbon hydrogen economy
- Optimization of flexibility needs through gas solutions for buildings
- Strengthening industrial competitiveness from renewable and low-carbon gases
- The role of gases in the decarbonization of heavy transport and maritime mobility
- Gas flexibility at the service of the resilience and cost optimization of the electricity system

The methane gas industry has five technological and innovation building blocks

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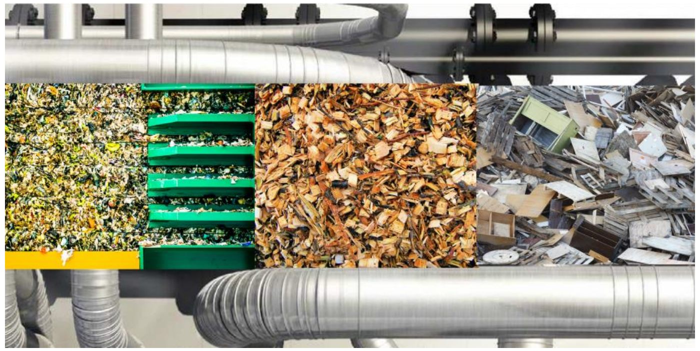
Anaerobic digestion: methane by fermentation



Pyrogasification: methane by thermal treatment of carbonaceous waste

Hydrothermal gasification: methane by aqueous treatment at high temperature

Methanation: methane from CO_2 and hydrogen

The use of fossil gas coupled with carbon capture and storage

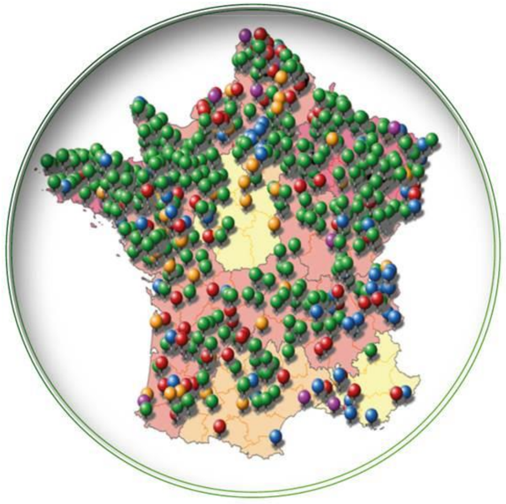
These technologies are being developed in France in all territories

Hydrothermal gasification

2 pilot projects:

- CEA Liten Grenoble: Capacity of 10 kg/h
- Saint-Nazaire: 1st pilot project of 1 t/h (1 MWth) being set up (injection 2024)

Méthanisation



Source : Sinoe, ADEME

365

Production sites of injected biomethane

1000

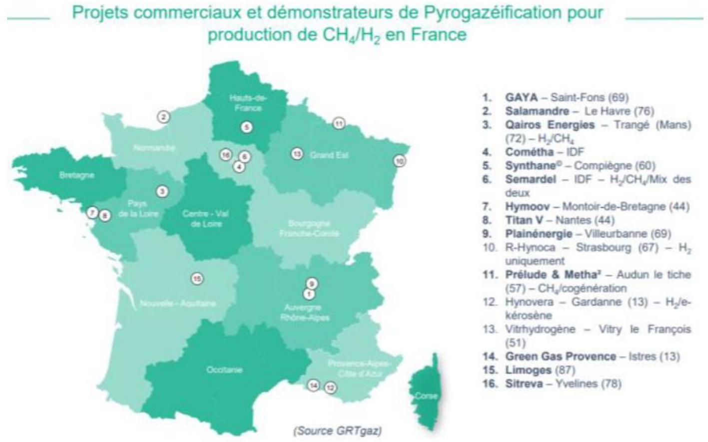
Cogeneration sites (renewable electricity)

80 %

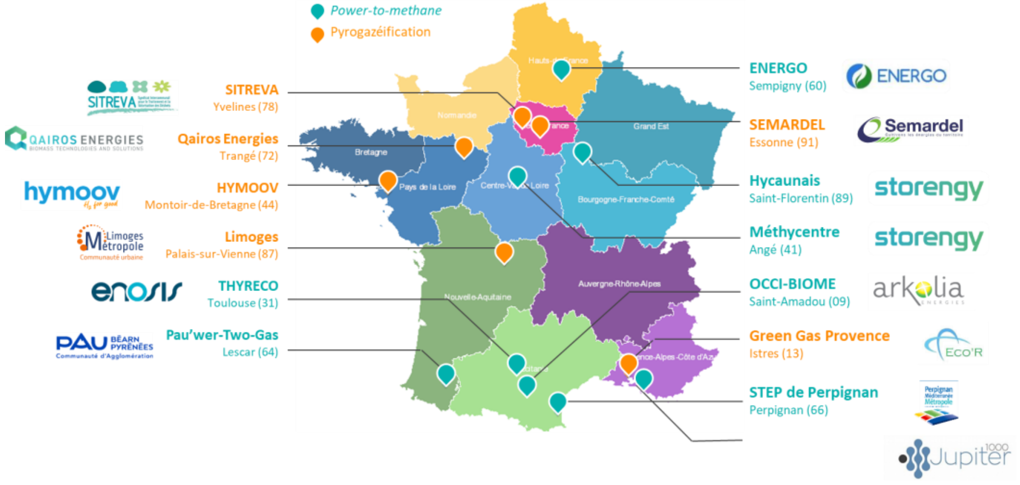
Sites own by farmers

Methanisation sites
- *Farm*
- *Centralised*
- *Industrial*
- *Industrial waste treatment*
- *Domestic waste*
- *other*

Pyrogazification



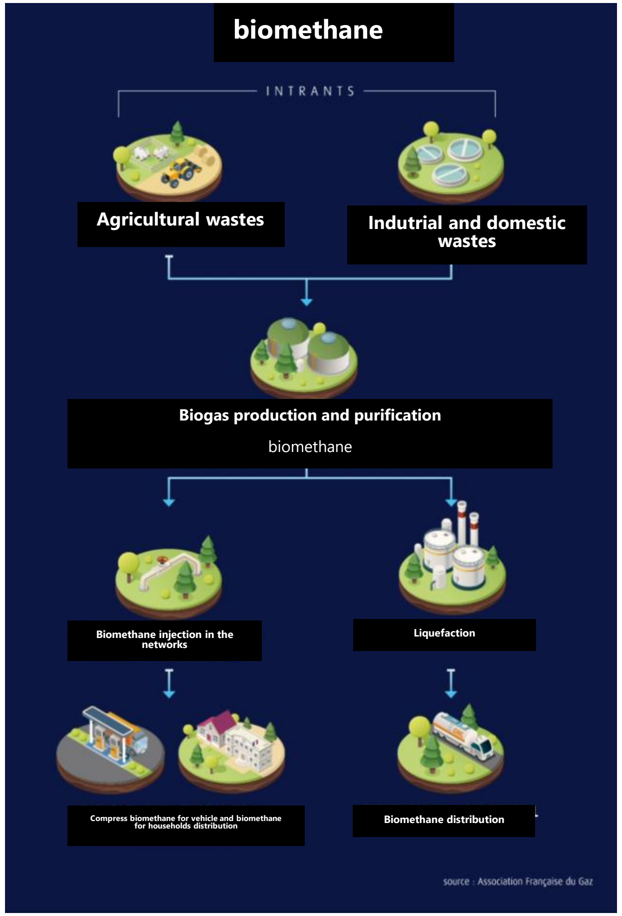
Methanation



The potential and the levers of anaerobic digestion

- **A potential estimated at 190 TWh**

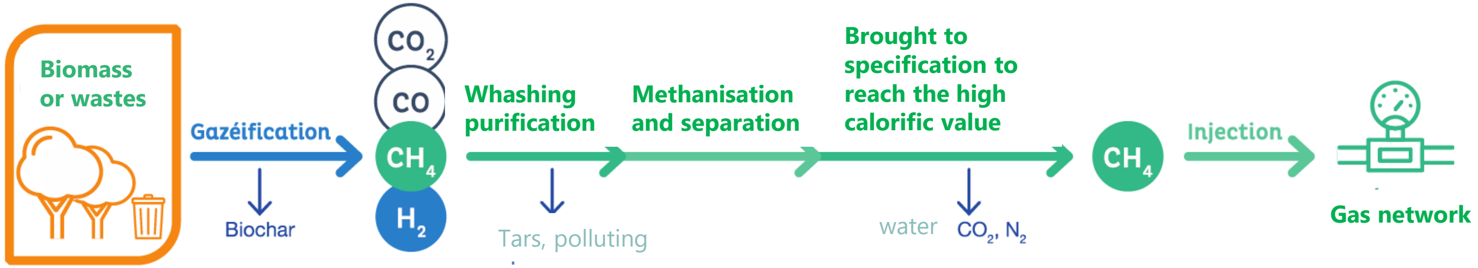
- Today, 1,200 installations listed in the capacity register for production estimated at 26 TWh
- The implementation of biogas production certificates will lead to an increase in the number of these small installations
- Hypothesis of reinforced use of intermediate crops for energy purposes (CIVE)
- In 2050 we can estimate
  - Between 5000 and 5500 installations
  - For a production of around 135 TWh



The levers to be implemented

- Continue production support to achieve the expected scale effects
- Launch the call for tender system for larger installations and publish the biogas production certificate system
- Have a stable regulatory framework
- Enable the development of a demand policy
- Promote the use of CIVEs

The pyrogasification process



- Based on pyrolysis and gasification processes by heating relatively dry carbonaceous material at high temperature (400 to 1,500°C) in the absence or lack of oxygen. This material is then transformed into methane

- Pyrogasification recovers dry inputs, namely a wide variety of resources that are difficult to recover: wood residues, non-hazardous demolition wood (doors, windows, old furniture, industrial panels, etc.) and solid recovered fuels

The potential and levers of pyrogasification

The mobilizable potential is significant

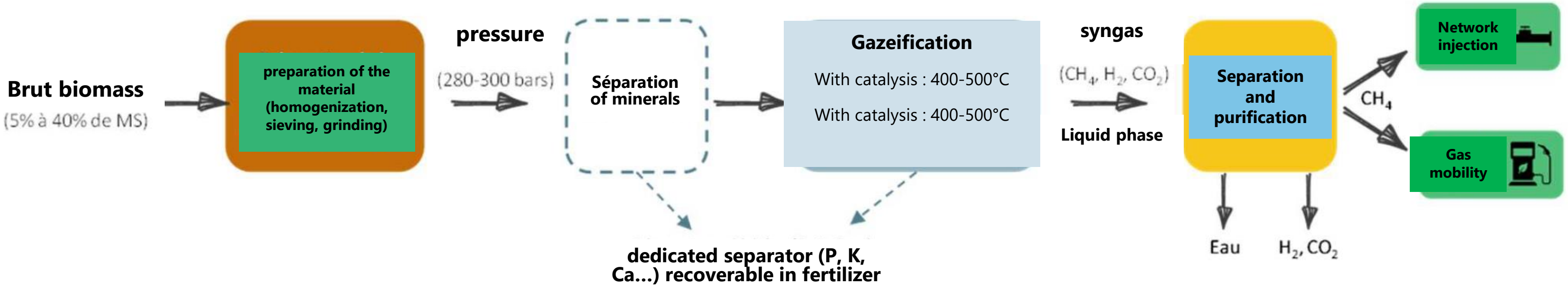
- Energy deposit from the forest of 120 TWhLCV/PE* which takes into account compliance with the hierarchy of uses and recovery of the residual share after lumber and industrial wood after allocation to priority uses
- With regard to non-forest resources, the potential is distributed as follows:
  - Solid recovered fuels: 90 TWhLCV/EP
  - Wood outside the forest: 35 TWhLCV/EP
  - Wood-waste: 8 TWhLCV/EP
  - Lignocellulosic cultures: 50 TWhLCV/EP
- As a precaution, lignocellulosic crops that raise questions in terms of land use change are not retained.
- The overall mobilisable potential respecting the hierarchy of biomass uses and waste recovery amounts to approximately 255 TWhLCV/EP or 180 TWhHCV/EF
- For 2050 we retain a realistic production of 90 TWh including 60% CSR, 20% wood waste and 20% biomass
- Use limited to non-recyclable waste, competing uses of waste are priced into account

The levers to be implemented

- Recognize the role of these technologies for the recovery of certain waste and residues with no outlet (CSR, wood B)
- Quickly deploy calls for projects to set up experimental contracts for the production of gas using innovative technologies
- Launch calls for projects to support methane production units from the pyrogasification of non-renewable waste
- Extend the CPB system to pyrogasification facilities
- Optimize the supply and logistics of inputs

*Lower calorific value in primary energy

The hydrothermal gazification process



- Hydrothermal gasification is a thermochemical conversion process at high pressure (210 to 350 bar) and high temperature (360 to 700°C)
- It offers a wet waste treatment solution which has the advantage of achieving carbon conversion rates of around 90%, complementary to those of methanation (40 to 70%)
- In Europe, several players are already developing or operating pilot projects or technology demonstrators
- In the Netherlands, a very first industrial installation of 20 MWth is in the process of being commissioned. The sector is the first in this country with an objective in 2030 of 12 TWh
- France has two pilot projects, the sector is able to accelerate

The potential and levers of hydrothermal gasification

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The potential between 58 TWh and 138 TWh

- Agricultural methanisation digestates that cannot be composted, spread or in excess or from WWTP sludge and digestates (40%)
- Sludge from cleaning and dredging (ports, rivers and canals) whose discharge into the sea will be prohibited in 2025 (9%)
- Animal by-products (carcasses) and plants (vinasses) not recovered in methanization (2%)
- Black liquors from the paper industry burnt because there is no outlet, of which 60% recovered (9%)
- Other inputs: industrial sludge, industrial waste (sugar beet pulp co-produced from biodiesel and bioethanol, landfill leachate) in search of alternatives (40%)

- A production of 50 TWh in 2050 is realistic

The levers to be implemented

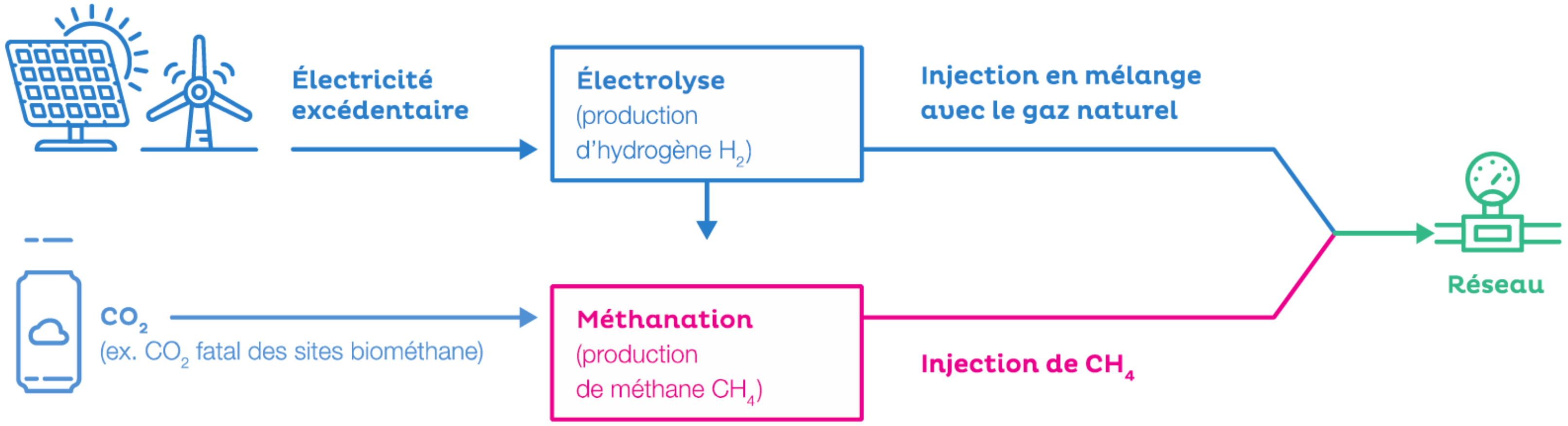
- Launch experimental contracts to bring out the sector
- Extend existing support schemes for biomethane (CPB type)

It should be noted that the increase in the constraints of recovery of sludge and liquid waste will be favorable to the deployment of this technology

	Typologie de déchets	Tonnage brut annuel (kt)	Hypothèse de mobilisation	Production théorique annuelle de méthane renouvelable (TWh_{PCS})
Effluents d'élevage	Lisiers d'élevage (bovin, porcin, volailles)	48 000	20%	4,7
	Fumier d'élevage (bovin, porcin, volailles)	119 000	20%	29,3
Boues de STEP	Boues non digérées de stations urbaines d'épuration	19 000	40%	3,1
	Digestats de méthanisation en **2018** (incl. boues digérées de STEP)	12 000	20%	1,5
Digestats de méthanisation	Digestats de méthanisation à horizon **2030** (incl. boues digérées de STEP)	120 000	30%	22,1
	Digestats de méthanisation à horizon **2050** (incl. boues digérées de STEP)	400 000	40%	98,4

Tableau 2 Potentiel de production de méthane renouvelable par gazéification hydrothermale

The methanation process



- Methanation allows the production of synthetic methane by combining CO2 and green hydrogen
- A sector with multiple advantages:
  - Electricity-gas coupling and recovery of surplus renewable energy production
  - Decarbonization of gas uses
  - Recovery of biogenic CO2 (methanization, combustion of organic matter) or industrial

The potential and methanation levers

A trajectory of 60 TWh is realistic

- This trajectory is identified by evaluating the possible optimizations of CO_2 recovery according to two sources:
- CO_2 from agricultural methanation: recovery of biogenic CO_2 from agricultural methanation with electrolyzers, systematic implementation of such recovery on all methanation facilities from 2028, on the basis of operation at 4000 hours

  => 50 TWh
- Industrial CO_2 (food industries in particular)

  => 10 TWh

- The potential is estimated at 120 TWh

The levers to be implemented

- Define a regulatory framework (definition) for methane produced by methanation as a renewable gas and a development trajectory in the PPE
- Set up an aid system (OPEX) for the first projects to produce methane produced by methanation

A specific support mechanism for the production of renewable H_2 will be decisive

A trajectory with significant renewable gas volumes is realistic

	Potential	Realistic production trajectory		
		2030	2040	2050
Methanisation	190 TWh	49 TWh	100 TWh	135 TWh
Pyrogazeification	180 TWh	6 TWh	30 TWh	90 TWh
Hydrothermal Gazeification	100 TWh	2 TWh	25 TWh	50 TWh
Methanation	120 TWh	3 TWh	30 TWh	60 TWh
Total	**>> 335 TWh**	**60 TWh**	**185 TWh**	**335 TWh**

- In addition to these figures, there are various options that allow for flexibility Carbon capture and storage solutions
- A bio-propane potential exists: estimated at 4 TWh in 2030 and 10 TWh in 2050
- France could also be a hub for e-methane in transit or imported if the economic conditions are favorable: volumes estimated to be significant from 2040 to 2050, of which more than 70% transit
- Finally, renewable and low-carbon hydrogen will be present

The potential for new gases is an asset for France

- The renewable and carbon-free methane potential is higher than current consumption, and much higher than future consumption, which will decrease
- They allow an ambitious production trajectory in line with carbon neutrality objectives with a target of 335 TWh in 2050
- The new gas sector is ahead of its 2023 objectives, an acceleration to reach 60 TWh in 2030 is ambitious but possible
- To achieve the European "fit for 55" objectives, all sectors must be mobilized, accelerating the new gas trajectory will make it possible to achieve this objective
- One of the challenges lies in research and development
- By 2050, gas will be totally decarbonized

What are the levers?

- An acceleration of production in the various sectors is necessary to reach 60 TWh in 2030
- The development of a policy promoting consumer access to new gases and promoting their efforts in favor of renewable and low-carbon energies, through the creation of a regulatory and tax incentive framework, is necessary

These potentials are the subject of numerous studies, the results of which are consistent

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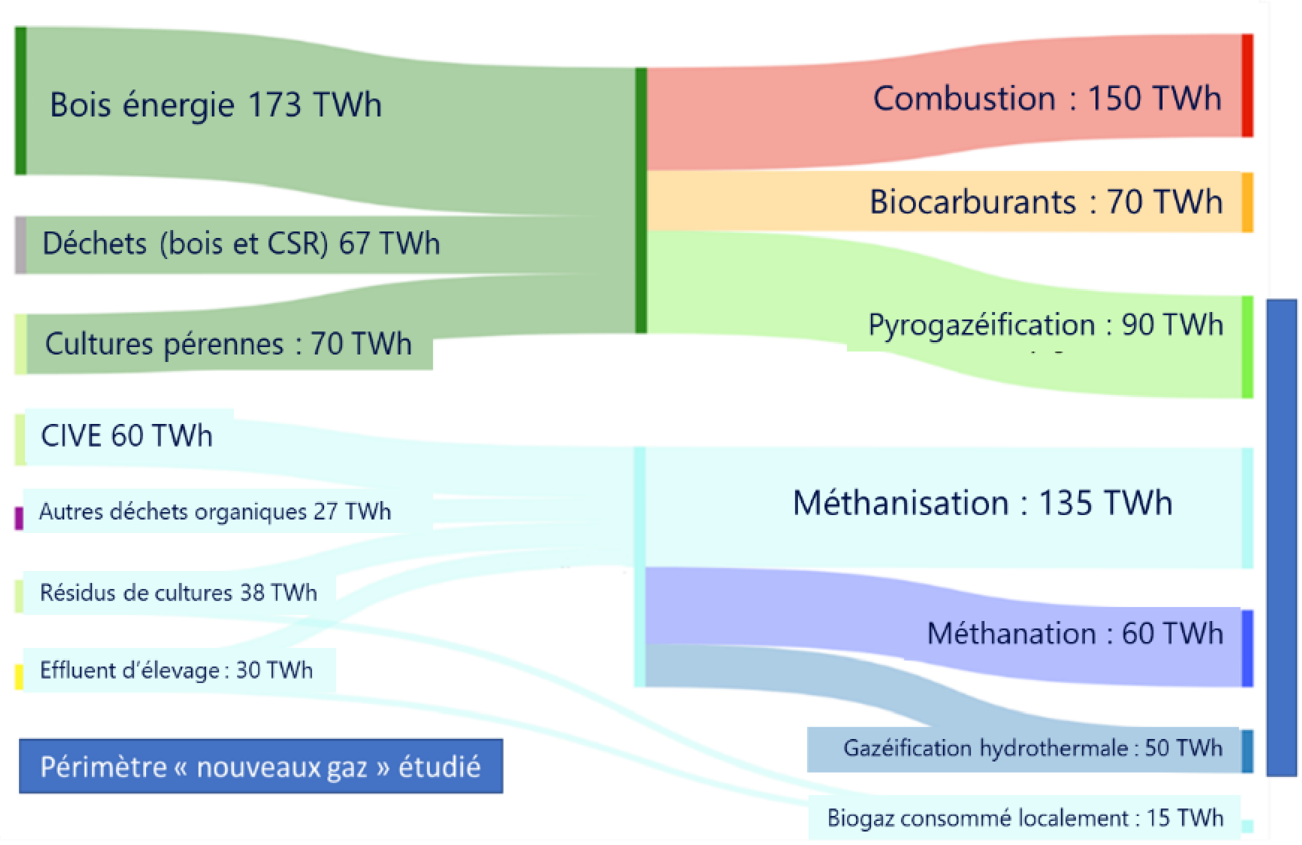
TWh	Potential 2050				Production 2030
	Methanisation	Pyrogazification	Hydrothermal gazification	Methanation	Methanisation
SNBC / PPE (2020)	130 à 140	24 à 85		6	22 (2028)
ENGIE (2021)	158	49 à 94		179	45
ADEME / Solagro (2018)	140	180		140	
CRE (2019)	39 à 42				39 à 42
ADEME (2021)	104 à 141	0 à 180		0 à 40	42 à 51
France Stratégie (2021)	109 à 138				
négaWatt (2021)	139	51		20	
Fraunhofer Institut					41 (4 pyro)
Trinomics (2020)	125	60			
EC JRC (2015)	125	65			
Imperial College	300	221			301
Prospective Gaz Territoires	130	50	37	9 (local)	30-49
GRDF- GRTgaz	142	189	58	50 (local)	42-49
ENEA			58 à 138		

An association of uses rather than conflicts of use

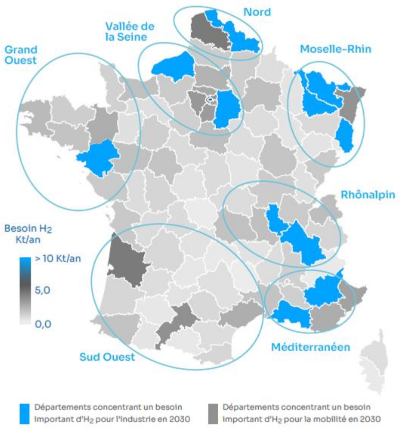
- An overview shows that the potential identified is part of a complementarity of the different uses



The deployment of a competitive renewable and low-carbon hydrogen economy

- Hydrogen will play an important role in the transition of industry (refining, chemicals, steel) or energy (long-term storage), it should remain marginal for domestic uses
- **It could represent ≈ 100 TWh by 2050**
- A bouquet of technologies is necessary to meet the demand for carbon-free hydrogen: renewable or network electrolysis, gas and CCS coupling, biomass pyrogasification

- The role of infrastructure (transport, storage) is key for the development of hydrogen: economic optimization, security of supply, multiplication of outlets
- The development will take place in 3 phases: emergence, connection, integration
- Converting existing gas infrastructure to hydrogen is the most economical option (about 10 times more than laying a new pipeline)



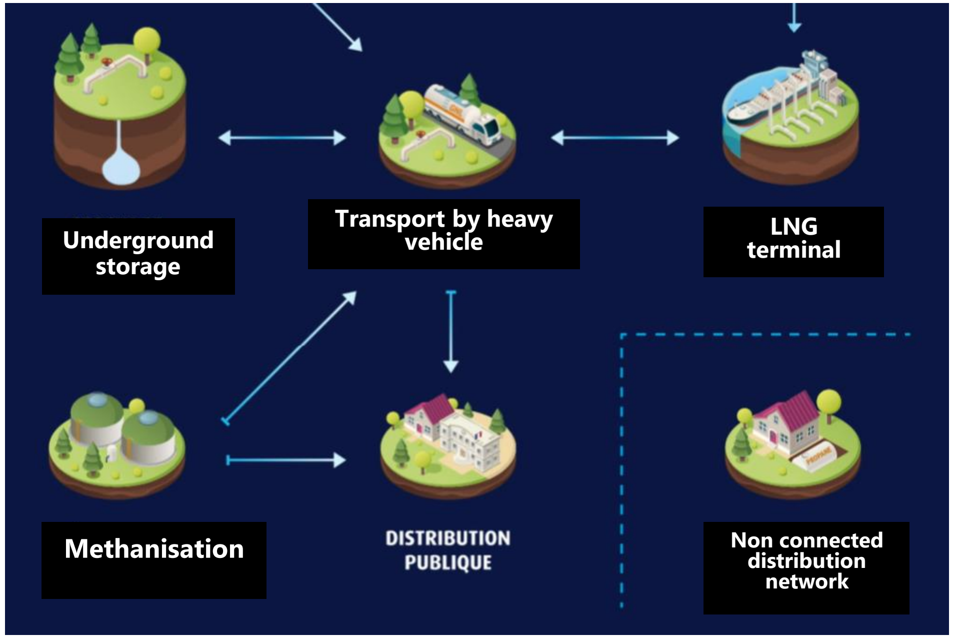
Source: Guidehouse

A large-scale and integrated system, based on national and interconnected hydrogen infrastructures, in this analysis reduces the cost of delivered hydrogen by around 30% in 2040.

Gas infrastructure, an essential element of the competitiveness of the energy transition

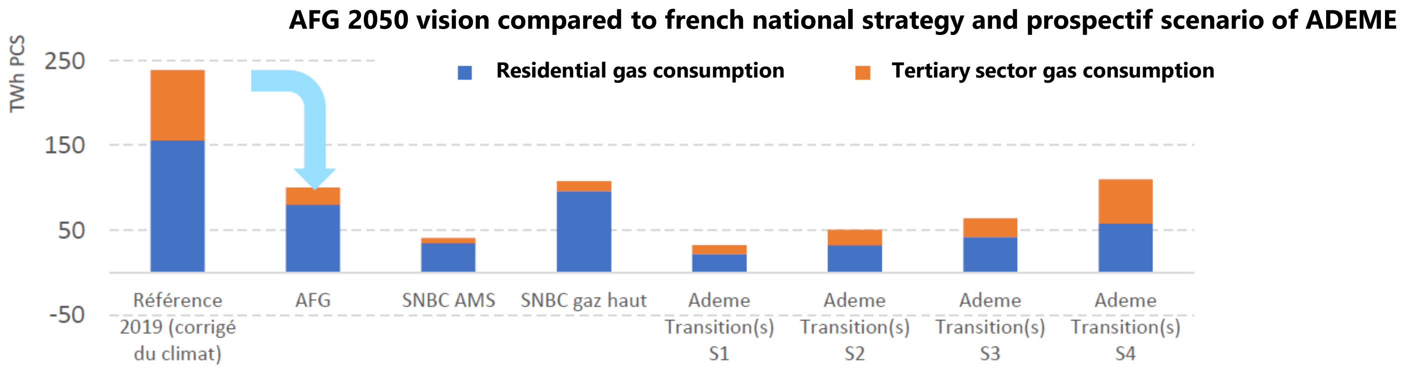
Gas infrastructure:

- Bring flexibility and resilience to the energy system as a whole
- Can accommodate an entire volume of renewable and carbon-free gases without significant investment
- Can be converted to hydrogen and accelerate its penetration
- Are key to optimizing the operation of the energy system of tomorrow
- Gas infrastructures ensure energy security and enable significant system efficiency: it is 10 times cheaper to transport gas than to transport electricity



Optimization of flexibility needs through gas solutions for buildings

- It involves accelerating energy efficiency, the energy performance of buildings and sobriety
- In collective housing individually heated by gas, the generalization of the THPE boiler in association with efficient insulation of the building must be targeted. This allows an immediate 25% reduction in emissions
- A 2050 scenario of 100 TWh of gas, 80% of which in residential, compared to 190 TWh in 2019, of which 150 TWh in residential



- The potential for exploitable renewable or low-carbon gas is compatible with a significant proportion of heating needs in buildings.
- Territorial anchoring and proximity between production sites, networks and consumption sites are both assets and a condition for the development of renewable and low-carbon gases
- Hybrid heat pumps are a system flexibility solution that should be promoted
  - 3 to 4 million "hybrid" dwellings without major technical and economic difficulties
  - 100,000 to 150,000 pieces of equipment hybridized per year from 2030 => a sector, skills and jobs challenge

Strengthening industrial competitiveness from carbon-free gases

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Gas solutions will make it possible to meet industrial demand (≈100 TWh in 2050) taking into account the challenges of decarbonization

- Gas represents 40% of the industrial energy mix (140 TWh), including 125 TWh of methane and 15 TWh of hydrogen
- Industries are attached to the gas vector for non-substitutable uses: high-temperature heat, methane as a raw material
- An interest in renewable gases reinforced by the increase in energy and carbon prices and investments in electrification hampered by current price levels

Decarbonizing industry will go through

- **The new methane gas**
  - The potential is widely available and exceeds the demand
  - Directly compatible with current equipment, it does not require significant investment
- **Renewable and low-carbon hydrogen**
  - as a substitute for hydrogen carbon, in new sectors such as the steel industry
  - synergies are possible with existing gas connections
  - 60% of manufacturers identify hydrogen as a lever for decarbonization
- **CO_2 capture and storage solutions**
  - Technologically mature solution to treat residual CO_2 emissions
  - Proposed trajectory: 5 Mt/year in 2030 and 40 Mt/year in 20502050

In heavy land transport, the dynamic initiated will continue

- NGV/bioNGV is today, and until at least 2030, the most credible alternative to diesel for heavy transport
- The PPE objective is between 140 and 360 public NGV refueling points by the end of 2023 and between 330 and 840 public NGV points by the end of 2028. The lower limit of the PPE objective for 2028 will be exceeded

- The fleet of vehicles running on CNG of 3.5t and more could reach:
  - 71,000 vehicles in 2030
  - 6,000 BOMs, 18,000 tractors, 29,000 carriers, 11,000 buses and 7,000 coaches

- The sector assesses the energy needs of vehicles over 3.5t at around 20 TWh in 2030 and 25 to 30 in 2033

- Low emission zones and air quality constraints will play an accelerating role for a transition of gas mobility solutions
- Hydrogen could penetrate certain heavy vehicles but CNG will remain in the majority

Maritime transport has a favorable context where gases will play a role

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- Regulatory context is demanding for shipowners: the IMO and the EU (Fuel-EU maritime, ETS extension), define strong emission reduction trajectories by 2050
- France is well positioned with four major terminals on the three metropolitan seaboards to supply ships around the world and transport this energy of the future in the interconnected networks of the European continent
- Consumption projections for 2030 are between 4.5 and 15 TWh per year
- The main thing is not in the consumption of ships but much more in the attractiveness of French ports and facilities
- The alternative ammonia, methanol or electrification solutions are not suitable or still available at a cost comparable to that of LNG
- In 2050, among the solutions, LNG will be the main one without necessarily being the only one
- The question arises of France's ability to accept any type of gaseous carburation in its ports
- The challenge is therefore also that of decarbonizing LNG with solutions such as synthetic methane or liquefied biomethane

Gas flexibility at the service of the resilience and cost optimization of the electricity system

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Report

- The combined cycle gas turbine (CCGT) fleet represents approximately 6.5 GW installed, to which must be added approximately 5 GW of cogeneration and 0.5 GW of combustion turbine
- Flexibility needs are on the rise
- In France, the 2050 outlook for the electricity system envisages an increased need of 25 to 70 GW
- In Germany, the need for additional CCGT is estimated at 54 GW (DENA – scenario K100)
- In the UK, 50 GW of CCGT is needed according to the National Grid (Leading the way)
- The shares of associated CO_2 emissions will decrease as the gas mix decarbonizes

Needs

- Ensure that the economic and regulatory framework allows the maintenance of existing capacities and the development of new capacities if necessary (capacity-energy balance)
- Ensure sufficient sizing of gas and/or hydrogen infrastructures to meet peak needs
- Consider relaxing the provisions of the current PPE which prohibits the development of new CCGTs (including those compatible with new methane or hydrogen gases)
- Consider supporting cogeneration solutions to limit the decline in system flexibility

Renewable and carbon-free gases combine, at the heart

- of the territories,
- circular economy,
- sustainable agriculture,
- waste treatment,
- creation of local jobs.

They will make the energy transition a lever

- of reindustrialization
- strengthening France's sovereignty

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Thank you for your attention