RÉPUBLIQUE FRANÇAISE
Liberté
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ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

Sectoral Transition Plans

CHEMICALS

ETHYLENE & CO - CHLORINE - AMMONIA

Avec la contribution du programme LIFE de l'Union Européenne

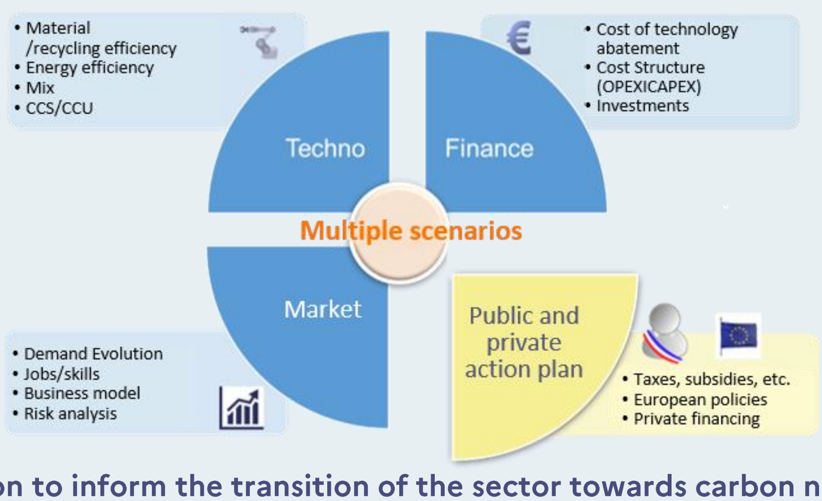
Finance ClimAct

What is a Sectoral Transition Plan?

The "Sectoral Transition Plans", led by ADEME, constitute one of the actions of the LIFE Finance ClimAct project.

Objective:
Promote investment in the transition of the French energy-intensive industry to aim for its decarbonisation by 2050, taking into account the specificities of each sector

The Sector Transition Plan (STP) is a work in progress drawing up tools to support forward-looking dialogue in 9 industrial sectors, in cooperation with sector players (manufacturers and federations). Carried out over a period of 12 to 18 months, an STP builds decarbonisation scenarios aimed at achieving France's energy-climate objectives by 2050 (-81% of emissions compared to 2015 for industry), quantifies the impacts on production costs, assesses climate investment needs and analyses job changes. Finally, the Sectoral Transition Plan offers public and private actions that allow to create the socio-economic conditions necessary for the decarbonisation of the sector.



360° vision to inform the transition of the sector towards carbon neutrality.

This document is the first deliverable of the STP Chemistry. Its objective is to present the key issues of the sector's decarbonisation to a wide audience in order to initiate dialog pertaining to the action plan. It was carried according to a bibliographic research and to the first discussions with industry key players. These results and proposals will be further developed during the next stages of the project.

Key Figures - CHEMICAL INDUSTRY

Many chemical sites ...

- France is the **2nd producer in Europe** after Germany and the 7th in the world
- 6,000 Sites and 3,000 companies (94% of which are SMEs) provide ~**170,000 direct jobs** (6% of industry) *(Source: France Chemistry 2019)*

An innovative sector

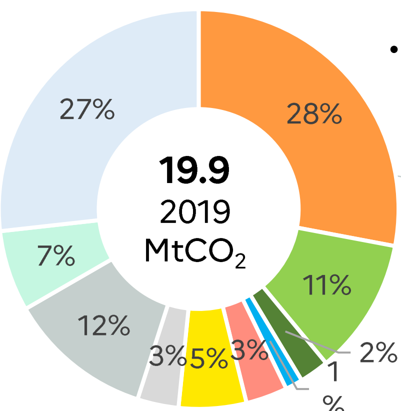
In 2019:

- **€74 billion** in turnover and an added value of €20 billion
- **€3.8 billion** in mature investments and **€1.8 billion** in R&D investments

(Source: France Chemistry 2019)

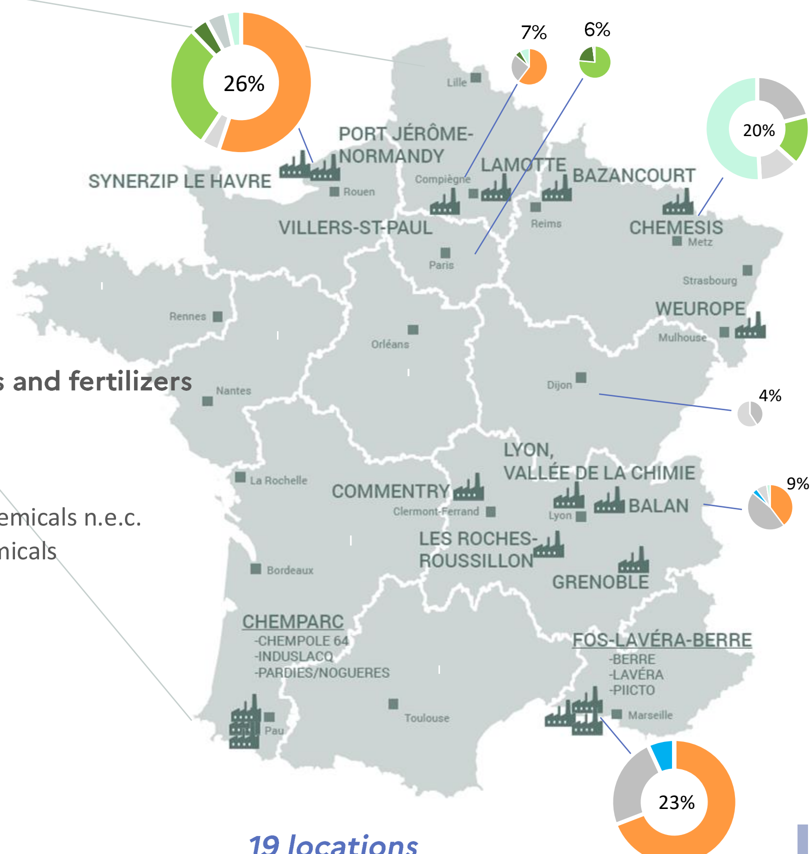
... but concentrated and localized emissions

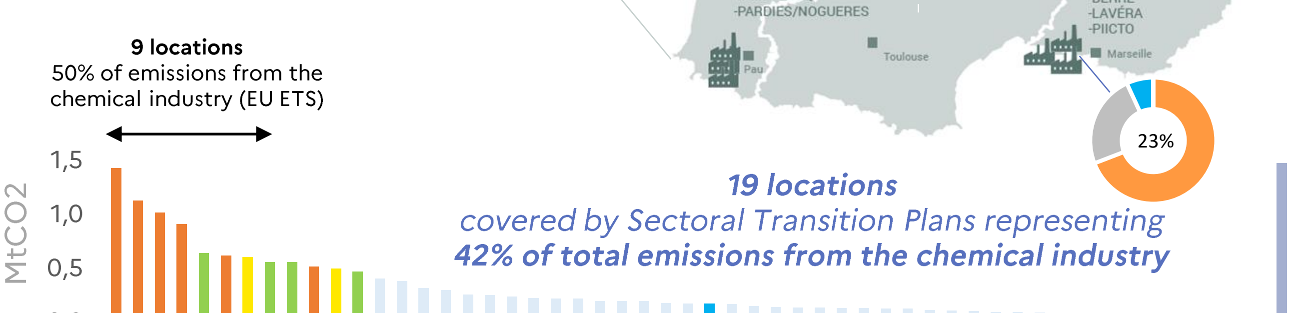
- Chemistry accounts for **26% of industry emissions,** 5% of French GHG emissions *(CITEPA Secten),* 34% of industry thermal energy and 20% of electric energy. *(CEREN)*
- **18 chemical platforms in France** bringing together 140 players around shared services and energy and material synergies.



Source: Citepa, April 2020

- **Site producing ethylene&Co**
- **Site producing ammonia**
- **Manufacture of nitrogen products and fertilizers**
- **Sites producing chlorine**
- Site producing hydrogen
- Site producing (bi)carbonate
- Manufacture of other basic inorganic chemicals n.e.c.
- Manufacture of other basic organic chemicals
- Other Chemistry
- Non-SEQE



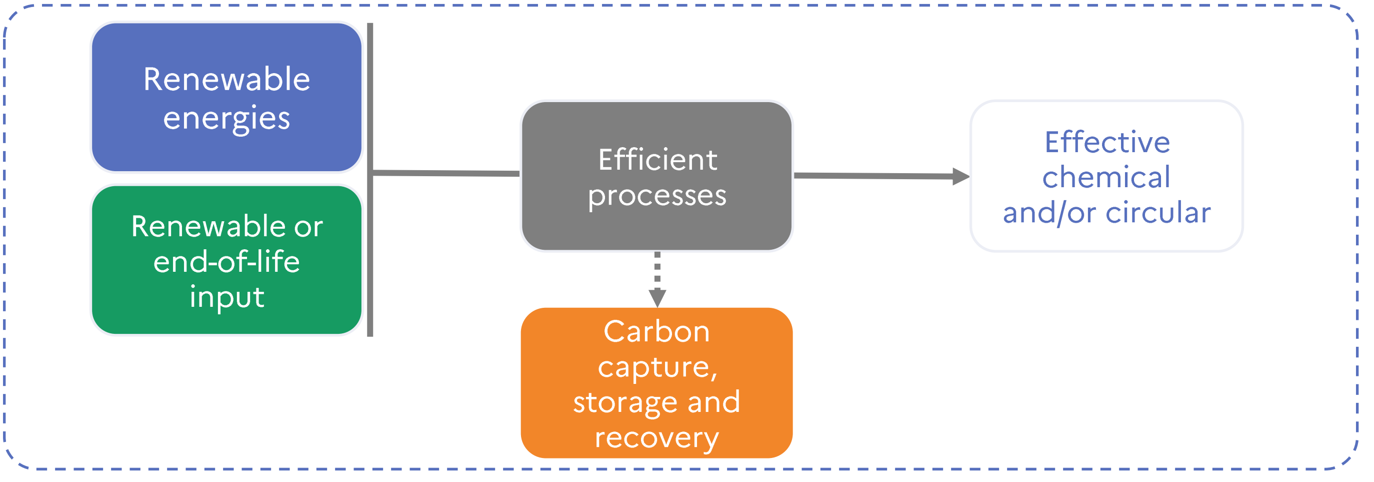


19 locations
covered by Sectoral Transition Plans representing
42% of total emissions from the chemical industry

CHEMICAL INDUSTRY

Decarbonisation issues

75 % of emissions from the chemical industry are subject to the EU ETS, which will make the carbon price a decisive factor in the transition. The decarbonisation must take into account the specificities of each sub-sector, however, different levers can be activated upstream and downstream of the synthesis processes, which requires a global vision of the chemical industry



Main lines of thinking

Renewable energies

- Renewable biomass heat and solid recovery fuel
- Electrification of furnaces and heating systems (resistors, heat pump, plasma, radiant energies, etc.)
- New electrified processes: electrochemistry, membrane separation, photochemistry, etc.

Renewable material inputs

- Use of low-carbon hydrogen
- Incorporation of recycled raw materials (recycled plastics) or biosourced materials (e.g. conversion of glycerol to acrylic acid, production of biosourced isobutene, etc.)

Efficient processes

- Intensification of production processes (e.g. reactive distillation, reactive grinding, membrane reactors, flow chemistry)
- Development of more efficient catalysts
- Fatal heat recovery
- Other investments in energy efficiency to achieve the Best Available Techniques

Carbon capture, storage and recovery

- Carbon capture, of fossil or biogenic origin
- Carbon storage (geological, soil and forest)
- Recovery of CO_2 captured for chemical production (production of ethanol, methanol, salicylic acid, succinic acid, dimethylether...)

Effective chemical and/or circular

- Innovation to create high performance, durable, reusable, compostable, recyclable materials.

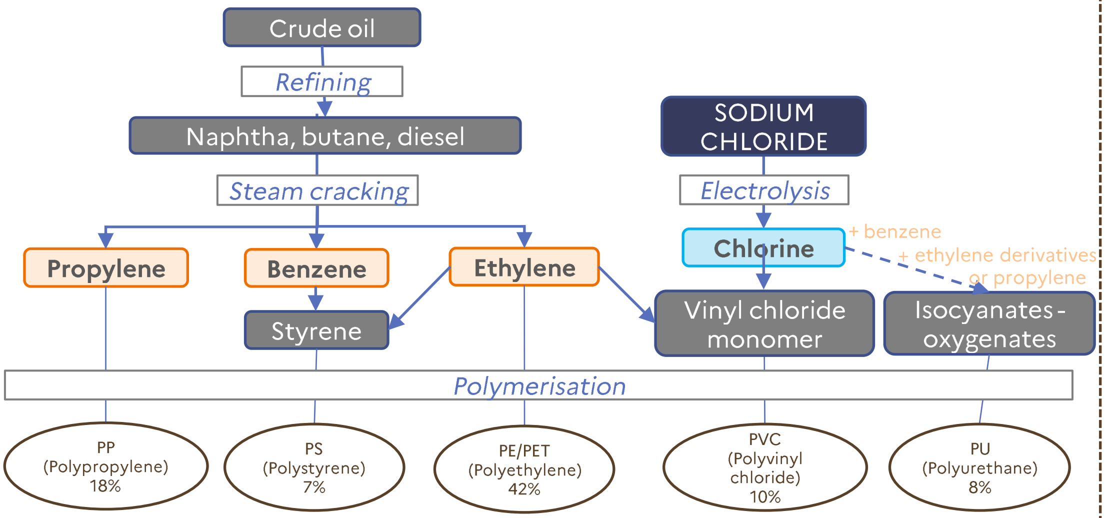
Plastics
Focus

500 resin and plastic producers
4,000 plasturists (of which 56% very small company)
130,000 employees

Turnover: €30 Bn
Commercial balance: -4 Billion €
for 8 billion € of exports

(Source: BNR 2008-2017; Waste recycling in metropolitan France, 2020)

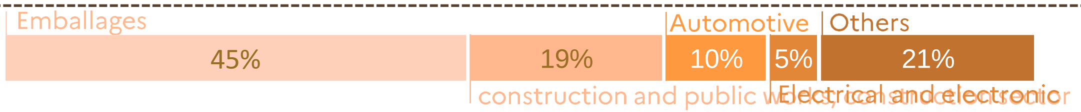
Production



Distribution of demand in France
(BNR 2017)

	PP	PS	PE/PET	PVC	PU
Emission factor *(Plastics Europe Eco-profiles, cradle-to-gate system)*	*1.6 tCO2/t*	*2.3 tCO2/t*	*1,9/2,2 tCO2/t*	*2.0 tCO2/t*	*3.5 tCO2/t*

Use

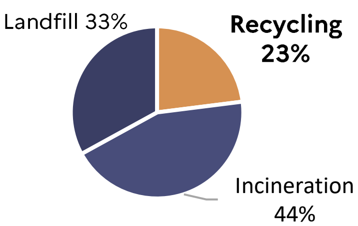


Lightweight, multifunctional material contributes to energy efficiency and reduces food waste.

(Source: BNR 2017)

End-of-life

Plastic waste treatment in 2018 in France



The **end of life** of plastics accounts for **60% of their emissions when incinerated.**

≈2,5 tCO2e and ≈10 MWh avoided per ton of RRM produced

(Source: BNR 2017)

- **3.4 Mt** of plastic waste produced in 2016: **50 kg** per person.
- Only **1/5** are collected for recycling, and the RRM production vs. VRM production is 10%.
- **Low recovery** between plastic regeneration sites and virgin resin producers (1 site for 6 producers).
- France is a **net exporter** of plastic waste (exports: 45 % of the collection; imports: 10%).

Example of regulations promoting the circular economy
(Anti-waste law for a circular economy, TECV and FREC law 2018)

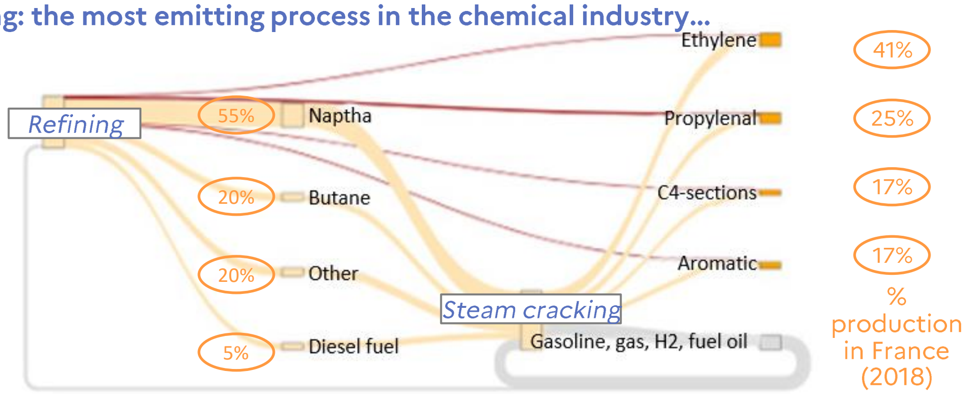
- Progressive prohibition of certain single-use plastic products
- Sorting 5 required streams and extending sort guidelines
- 100% recycled plastics by 2025
- Ecodesign: single material products, durability index, spare parts
- Minimum incorporation rate of recycled material for single-use beverage bottles only
- Public order promoting re-use and recycling
- Creation of new lines of responsibility Extended Producer responsibility

Ethylene etc.

Production and markets

5.6 MtCO2/an	**6** steam crackers in France producing **5.4 Mt** of alkenes and aromatics in 2018	**5** actors: • Total • INEOS • Exxonmobil • Lyondellbasell • ENI	**~65%** products **steam cracking** used to make plastics

The steam cracking: the most emitting process in the chemical industry...



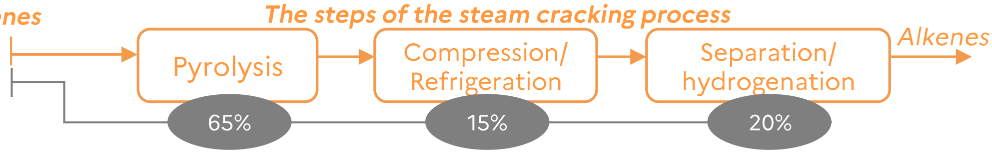
Steam cracking is a petrochemical process that produces alkenes by breaking oil sections such as naphtha, butane or ethane. Depending on the inputs, the distribution of outgoing products varies: the ethane steam cracking produces mainly ethylene while the distribution is more diversified for a naphtha basis. The fossil resource: **75% of the cost of production** of alkenes.

Steam cracking is carried out by vaporizing fuel at 800 °C, requiring the combustion of **25% of the fossil resource:** this represents **almost all GHG emissions.**

Energy requirements by tAlkenes

Feedstock	13-15 MWh
Combustion	3-5 MWh
Electricity	0.05 MWh

The steps of the steam cracking process



... only slightly affected by CO2 prices

Steam cracking at the heart of the plastics lifecycle

Emissions (tCO2e/tProducts) *Scope 1+2, EU values with electric mix FR Steam cracking of naphtha*	Extraction	Refinery	Steam cracking	Polymerisation	Incineration
	0.37	0.13	**0.85**	0.6-2.0	3.1

0.702 tCO2/t
Benchmark EU ETS & EU Taxonomy

Integrated factories to support a cyclical market and an international price war

France is the 3rd largest producer of plastics in Europe and is almost self-sufficient in the production of olefins: **98 %** of ethylene consumption is produced in the territory. However, it **imports 30% of its consumption of plastics**. After a sharp decline between 2005 and 2009, French consumption of virgin and aromatic resins increased again, reaching 5.3 Mt in 2018.

International competition is exacerbated by **unequal access to fossil fuels** and **recent US investments in ethane steam cracking** from shale gas ($100 billion in investments announced in 2014 for 148 projects). The cost of producing alkenes in Europe from naphtha is **2.5 times higher** than in the United States from ethane. In 2019, INEOS announced the construction of a 1.25 Mt ethane steam cracker in Antwerp for €3.4 billion.

European naphtha steam crackers remain competitive thanks to their product **diversity and an integrated plastics production chain on chemical platforms.**

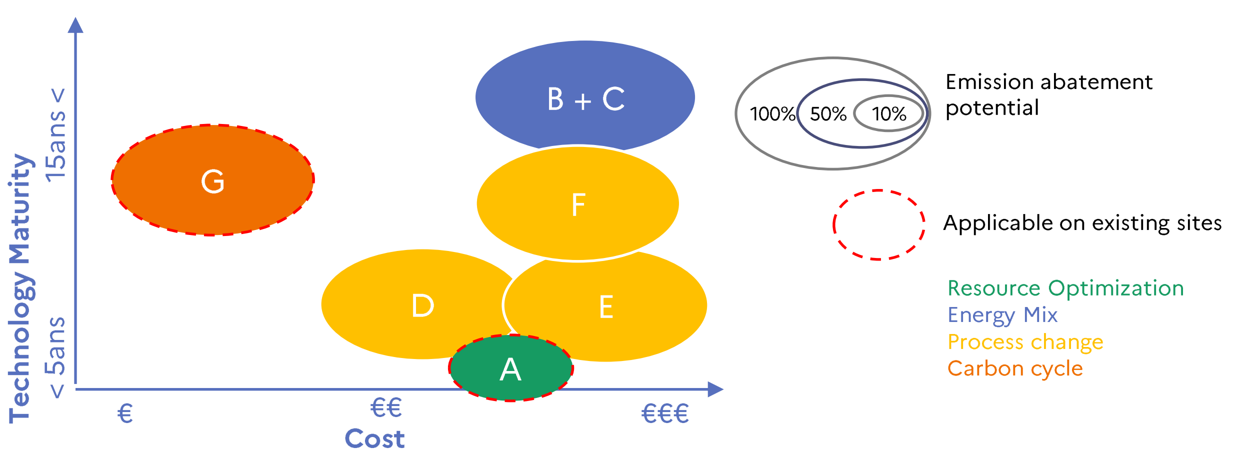
Main sources: IEA, the Future of Petrochemicals; Data Lab, MTES, September 2019; PlasticsEurope JRC Negawatt

Ethylene etc.
Decarbonisation levers

Ecodesign and recycling: preferred routes for more durable plastics.

Major electrification decarbonisation projects or process changes can **decarbonise primary production of ethylene & others to 100%**. Alternative modes of production are at various stages of development but will require major investments. Thus, unlike some sectors, **carbon capture will be economically competitive with other decarbonisation drivers**.

		Detail/barriers identified
A	Steam cackers with the Best Available Techniques	*Energy optimization to reach 12 GJ or 3.3 MWh per tAlkenes*
B	Biosourced fuel	*Establishment of a biodiesel/bio-naphtha pipeline*
C	Electrification of the steam craker	*BASF, Borealis, BP, LyondellBasell, SABIC and Total partners in the "Cracker of the Future" consortium for an electric steam-cracker.*
D	Methanol to Olefin synthesis of alkenes and aromatics from decarbonised CO2 and H2	*Cost of production 2-3 times higher (DECHEMA, 2019) 3.9 tCO_2 and 0.5tH_2/ton alkenes*
E	Bioethylene by dehydration of bioethanol	*Production cost ~4 times higher (DECHEMA, 2019)*
F	Chemical or biological recycling	*Depolymerization of used plastics (solvolysis, pyrolysis or gasification) mechanical recycling in the first place*
G	Carbon capture on steam and incinerator: the CO2 from the steam cracking is concentrated, allowing efficient capture	*High CAPEX and OPEX. Plants near geological storage sites may consider CCS, others chemical use (CCU).*



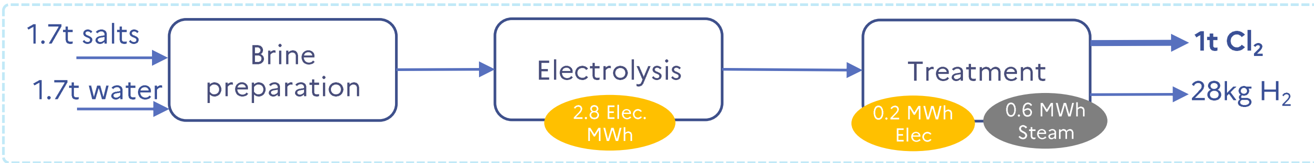
Examples of actions to create a favorable investment environment

Best practices	Regulation	Financial Support
Transparency on packaging carbon footprint	Regulatory guidance and transparency on product ecodesign	Long-term deployment financial support schemes (CAPEX, Carbon Contracts for Difference, electricity price visibility)
Commitments by plastics manufacturers to reintegrate recycled raw material	Mechanisms for limiting carbon leakage and leakage of collected plastic waste	Financial support for R&D and innovation, in particular on recycling topics
	Economic support mechanism for the incorporation of recycled raw materials	

Chlorine

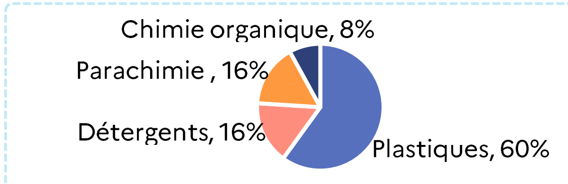
Production, Markets and decarbonisation Levers

0.5 MtCO2/an	**9** production sites in France **1.4 Mt** capacity used **~80%** in 2019	**3** actors cover **75%** capacity	**Polyvinyl chloride (PVC): ~55%** of overall consumption



- > **85%** the capacity installed in the most efficient production process (membrane water electrolysis process).
- An intensive electro process: **~3 MWhe/tCl_2**. Energy accounts for **more than 50% of costs.**
- In France**, steam and electricity** each account for **~50% of direct and indirect emissions** (vs. 17/83% at European level).
- EU Taxonomy Reference: **2.45 MWh/tCl_2** and a low carbon electrical mix (< 100 kg CO_2/MWh)

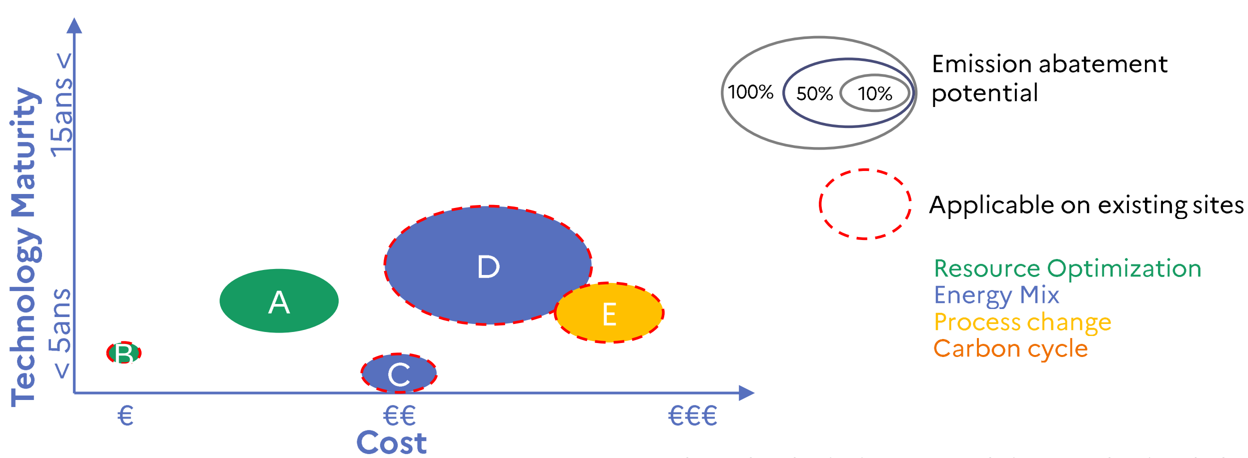
- Chlorine is a dangerous product and is not easily transported. French production covers domestic demand.
- Various uses as input or solvent.



Main sources: Eurochlor, Negawatt, CEREN, France Chemie

The decarbonisation levers of chlorine production mainly concern **energy savings** and **decarbonised heat** use.

		Detail/Identified Barriers
A	**Chlorine recycling**	Ex: PVC material recycling or incineration
B	**Upgrading ofco-produced hydrogen**	According to Dechema 2018, 9 % of the H2 produced does not seem to be upgraded in Europe
C	**100% decarbonised electricity**	Independent of industry
D	**100 % decarbonised steam** (from biomass, biogas or H2)	OPEX, biosourced resource availability
E	**Retrofit of membrane technology:** oxygen depolarized cathode	Oxygen depolarized cathode technology provides **30% energy savings but requires** better oxygen quality and no longer produces H2



Ammonia

Production and markets

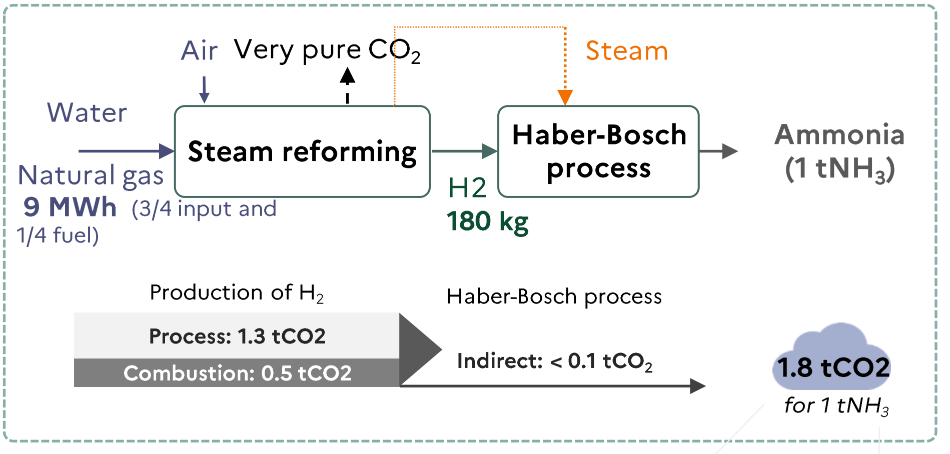
2.2 MtCO2/an	**4** production sites in France **1.5 Mt** capacity used at~**80%** in 2018	**2 producers**: Borealis (73%) Yara France (17%)	**~80% used for fertiliser manufacturing** **5,500 jobs** Nitrogen products and fertilizers

Optimized process and emissions focused on hydrogen production

Industrial production of ammonia (NH_3) is done by the Haber-Bosch process by combining dinitrogen and dihydrogen at a temperature of 450 °C depending on the reaction:

$N_2 + 3 H_2 \Rightarrow 2 NH_3$

For 1 ton of ammonia, 820 kg of nitrogen and 180 kg of dihydrogen are required. Nitrogen comes from the air.



In France, H_2 is mainly produced by vaporeforming methane: between 700 and 1100 ° C, water vapor reacts with methane by giving carbon monoxide and hydrogen. Natural gas accounted for **80 % of** NH_3 production **costs** in 2016 in the European Union at an average natural gas price of 4 c€/kWh. The optimization limits of the Haber-Bosch process would be reached.

+11 % of cost of production
Without free allowances and €25/tCO_2

A stable but diversified and increasingly important fertiliser demand ...

France produces 34% of its nitrogen fertiliser needs, 24% comes from the rest of Europe and the remainder is imported (Egypt, Russia, USA, Algeria, Trinidad and Tobago).

France produces mainly *ammonitrate,* which consumption has been decreasing for 20 years in favor of imported products: *urea*, and *nitrogen solution* mixing urea and ammonium nitrate.

Urea, manufactured from ammonia and CO_2 collected after reforming, has a **lower carbon footprint** than ammonitrate but its potential for ammonia emissions during application is higher. The "Air Pollutant Reduction Plan" (Prepa) includes strong restrictions on urea use by 2020.

... and a shift in agricultural practices towards more agroecology and less fertiliser

In 2019, fertilizers represent **10% of total production costs for an average French cereal farm**.

ADEME's 2035-2050 energy-climate scenario (ADEME, 2017) includes modelling of change in the agricultural system that includes change in demand (in particular changes in the diet), but also a change in agricultural practices towards agroecology. The result is a 40% decrease in mineral nitrogen fertiliser consumption in 2035 and 50% in 2050 (based on 2010 consumption).

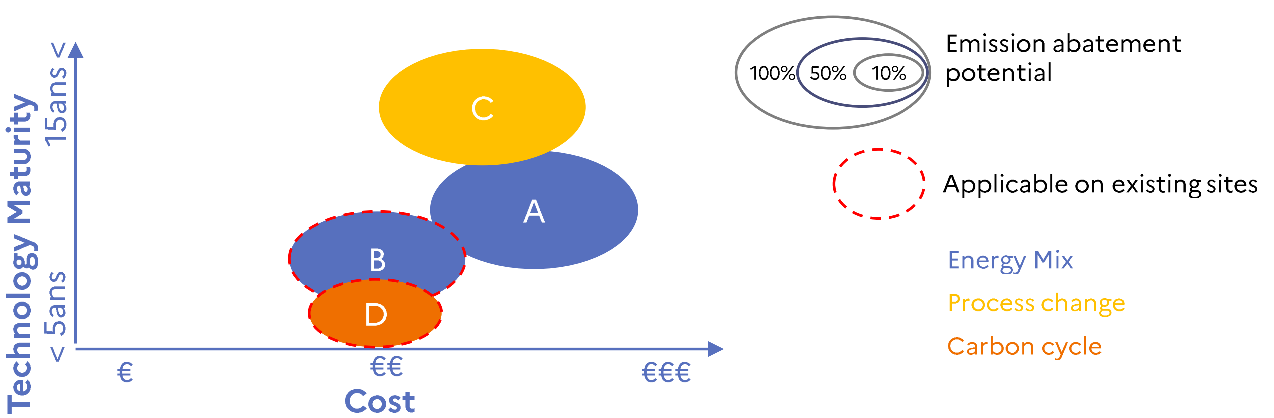
Main sources: UNIFA, Agoraenergiewende, CEREN, INSEE

Ammonia

Decarbonisation levers

The decarbonisation of the ammonia sector will mainly be through the **decarbonisation of hydrogen production. The use of biogas combined with CCS/CCU and process electrification** are preferred routes.

		Details/Barriers identified
A	Generate hydrogen by electrolysis of water	*CAPEX, sizing, connection:* ***2.2 GW*** *electrolyzer capacity* ***to be installed*** *to produce the 200 kt H_2 required for current production*
B	Use of **biogas as a fuel and material** in the vaporeforming process	*Resource Availability: 600 kt biomethane or 1000 kt biogas* ***-> 40 % of the PPE target in 2028***
C	**Direct synthesis of ammonia** from water and air without intermediate hydrogen production	*R&D. Process blocks can be small and located close to power generation and needs*
D	**Carbon capture**: the CO2 from vaporeforming is concentrated, which allows an efficient capture	*CAPEX, Plants near geological storage sites may consider CCS, others chemical use (CCU), already deployed*



Examples of actions to create a favorable investment environment

Best practices	Regulation	Financial Support
Common transparency devices on the carbon footprint and the fertiliser production process.	Mechanism to limit carbon leakage and unbalanced competition between European and border countries	Financial support schemes for the deployment of electrolyzers or biogas production (CCFD, visibility on electricity prices)

Ref ADEME 011516