#Industry

I4CE INSTITUTE FOR CLIMATE ECONOMICS
Une initiative de la Caisse des Dépôts et de l'Agence Française de Développement

Investments to decarbonise heavy industry in France: what, how much and when?

A study on steel, cement, ammonia and high-value chemicals

Paris,
May 2023

Authors: Solène **Metayer** | Erwann **Kerrand** | Hadrien **Hainaut** | Louise **Kessler**

Supported by
RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité
ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

ACKNOWLEDGMENTS

This report was prepared with the support of ADEME and the European Climate Foundation.

Supported by

The authors would like to thank all the people who contributed to this report, through their interviews or reviews and in particular: **Cyrielle Borde**, **Antoine Deswaziere**, **Michelle Houngbe**, **Elliot Mari**, **Quentin Minier**, **Sylvain Sourisseau** (ADEME); **Gabriel Jacqmin**, **Philipp Niessen** (ECF); **Eric Bergé**, **Maxime Efoui-Hess** (The Shift Project); **Laure Helard**, **Nicolas Mouchnino** (SFIC); **Murielle Gagnebin**, **Oliver Sartor**, **Wido Witecka** (AgoraEnergiewende); **José Noldin** (GravitHY); **Damien Demailly**, **Vivian Depoues**, **Maxime Ledez**, **Thomas Pellerin-Carlin**, **Lucile Rogissart**, **Charlotte Vailles** (I4CE).

The information and opinions expressed in this report are the sole responsibility of the authors.

EXECUTIVE SUMMARY

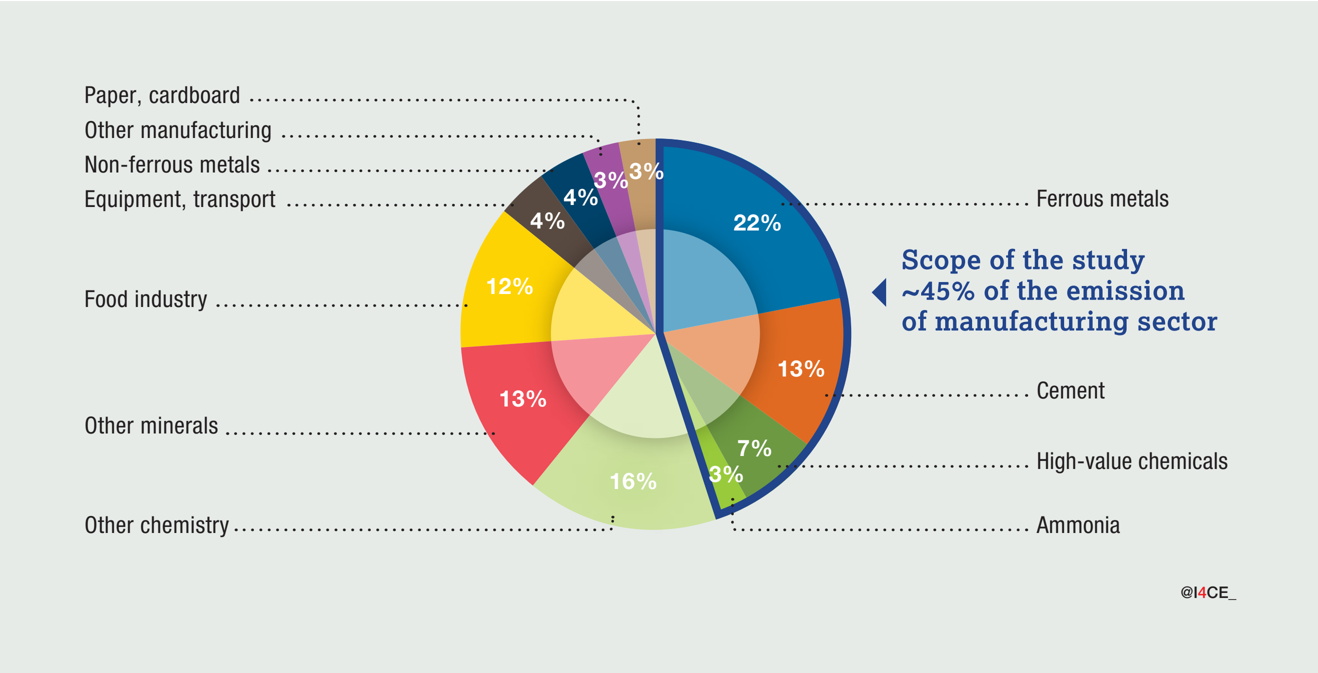
Industry: relocation and decarbonisation at the heart of the debate

The recent succession of crises (health, energy, geopolitical) and increased international competition have prompted France to look for ways to strengthen its industrial and energy sovereignty. It faces this challenge in addition to the challenge of decarbonising its industry. In this context, France and Europe are developing industrial policies with two objectives – relocation and decarbonisation – and with new tools such as the France 2030 plan and the Net Zero Industry Act at the European level. These policies target both 'historical' industries, such as steel and cement, and new clean technologies, from solar panels to batteries.

Industry is a high-emitting sector, accounting for 20% of total territorial greenhouse gas emissions. According to the National Low-Carbon Strategy (*Stratégie Nationale Bas-Carbone*, SNBC), in order to reach carbon neutrality by 2050, these emissions will need to be reduced by 81%. A considerable proportion of industrial emissions are concentrated in the 'heavy industry' sectors, covering chemicals, metallurgy, and minerals and construction materials. (**Figure A**). Located upstream on the production chain, heavy industry is characterised by a small number of production sites and emissions linked to both the energy used and the production processes themselves. This industry will have to undergo a major transformation, through changes in production linked to changes in other economic activities (*e.g.*, fewer new buildings by 2050, which will require less cement), or through the deployment of new technologies to reduce emissions. The current SNBC sets a decarbonisation course for the industry but provides very little detail on the technologies and public policies that will be required.

In this study, we estimate the investment needs of four heavy-industry sectors: steel, cement, high-value chemicals, and ammonia, which together represent about half of industrial emissions in France. This is key information: knowing the amount and pace of deployment of investments is essential towards identifying financing needs and calibrating the need for public support to industry. The few existing estimates are not very comparable, both in terms of the methods used and the scenarios selected.

FIGURE A. DISTRIBUTION OF GREENHOUSE GAS EMISSIONS IN INDUSTRY IN FRANCE (2019)



Source: Authors' calculations based on data from the report Secten edition 2022 from Citepa and the Sectoral Transition Plans memos from ADEME.

A method for estimating investment needs under various decarbonisation scenarios

To shed light on the investments required to decarbonise the heavy-industry sector, we have developed a method to estimate investment needs, on site, for the four industrial sectors selected. We applied the method to four contrasting scenarios for achieving carbon neutrality, developed by ADEME within the Transition(s) 2050 project.

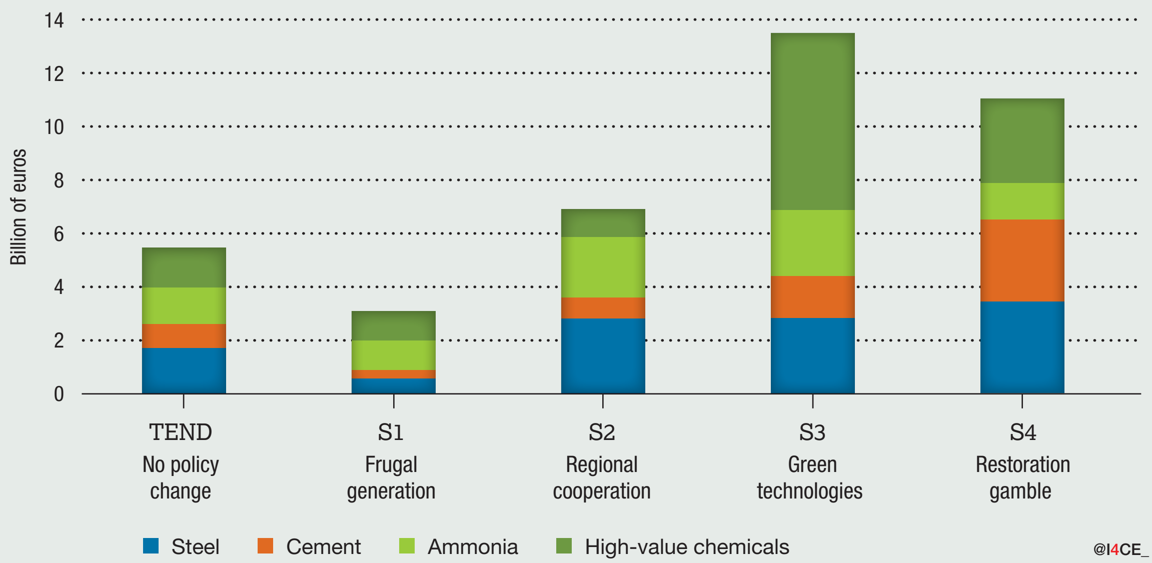
The estimates of investment needs correspond to the cumulative investments required to transform the existing industrial base by 2050, and cover both the maintenance and decarbonisation of existing equipment and the deployment of new technologies on production sites. We do not cover equipment operating costs. Our estimates also exclude measures related to adaptation to climate change, a topic that is still poorly documented for the industry sector.

By estimating the investment needs on the production sites themselves, we are ignoring for now the investments needed elsewhere to decarbonise the industry: infrastructure for low-carbon energy production and transport, hydrogen transport and CO_2 transport and storage.

From €3 to €14 billion of investments: which industry for tomorrow?

The investment needs to decarbonise steel, cement, high-value chemicals, and ammonia production range from €3 billion in ADEME's S1 'Frugal generation' scenario to €14 billion in its S3 'Green technologies' scenario.

FIGURE B: CUMULATIVE INVESTMENT NEEDS TO 2050 IN FOUR INDUSTRIES



Note: The trend scenario (TEND) only takes into account the policies adopted before 2021 and the main economic trends. It does not reach the objective of carbon neutrality in 2050.

The first striking result is the size of the gap between the investment needs of the different scenarios. This difference essentially reflects two interdependent characteristics of the decarbonisation scenarios: the level of industrial production and the production technologies used. The scenarios that anticipate the highest demand for industrial products (cement, steel, plastics, etc.) require major investment to replace existing processes with new ones that emit less. Conversely, scenarios that rely on other economic activities becoming less dependent on materials (*e.g.*, less new construction in the building sector, or more recycling and reuse) can retain existing technologies, which require less new investment.

Depending on the decarbonisation scenario in question, the investment needs at production sites therefore vary greatly. Consequently, it is necessary to clarify the decarbonisation strategy in order to adapt the tools for supporting the transition and to give private investors more visibility. We will come back to this.

Investments to be made quickly

In addition to the difference in investment needs between the scenarios, what is noteworthy is the apparent weakness of the estimated amounts: €14 billion for the most investment-intensive scenario by 2050. It is important to bear in mind that these estimates relate to less than half of industrial greenhouse gas emissions, and sectors whose production is concentrated in a small number of sites. Decarbonising the entire industry will therefore require much more investment. Moreover, these investment needs are limited to production sites, and do not include the investment required in the infrastucture on which they depend (*e.g.*, for transporting hydrogen, and transporting and storing CO_2).

Above all, although the objective is carbon neutrality by 2050, investment will have to be made in the next few years. The 2030 decarbonisation targets and the end of free allowances in the European Union Emissions Trading System (EU ETS) are an incentive to invest quickly to decarbonise industry.

We have built investment deployment trajectories that reflect these incentives and also incorporate several sectoral and technological constraints, such as equipment renewal cycles and the deployment time of certain technologies. Depending on the scenario, between 55% and 80% of investment is deployed before 2035.

Better planning for industry transition

In order to rapidly deploy industry decarbonisation investments, the State must develop effective plans for carrying out the necessary tranformations. There are many possible scenarios. This uncertainty is logical; after all we cannot know precisely the shape of tomorrow's economy and technologies. But this level of uncertainty poses a problem. It poses a problem for private players: will the industries studied need to invest €3 billion or €14 billion? It poses a problem for the State and, more generally, for public players: what aid and what budget should be allocated to the decarbonisation of industry? The State and industrialists will have to clarify the strategy for decarbonising the industry, including the development of the necessary infrastructure, and ensure that it is consistent with the decarbonisation of the other sectors.

It is interesting to note that the new industrial policy packages introduced by the government (the France 2030 plan, a consultation process with the owners of the 50 highest-emitting sites) as well as several projects announced by industrialists, seem to give rise to a 'Green technologies' scenario, relying on a quasi-maintenance of current heavy-industry production levels and the use of new low-carbon technologies. This emerging scenario will require considerable investment in the production sites, but also in infrastructure outside of industrial sites (for low-carbon electricity, hydrogen transport, and CO_2 transport and storage). The State will have to play an active role in coordinating private stakeholders, possibly sharing part of the risk, and clarifying the infrastructure financing model.

TABLE OF CONTENTS

1. REDUCING GREENHOUSE GAS EMISSIONS FROM HEAVY INDUSTRY: AN INVESTMENT ISSUE

Achieving carbon neutrality requires faster reductions in industrial greenhouse gas emissions

The rate of reduction of industrial emissions must increase from 1% to 4% per year by 2030

In France, the industrial sector is reducing its greenhouse gas (GHG) emissions at a rate that is insufficient to meet climate targets. From 2015 to 2021, emissions fell from 84 to 78 million tonnes of CO_2 equivalent, an annual decrease of 1.1%. To reach the objective of the current National Low-Carbon Strategy (*Stratégie Nationale Bas-Carbone*, SNBC), industrial emissions must decrease by 4% per year from 2021 to 2030. This target could soon be raised with the transposition of the European Green Deal. In fact, the European target could imply a 45% reduction in industrial emissions between 2015 and 2030, *i.e.*, a rate of 5% per year from 2021 to 2030.

Achieving carbon neutrality by 2050 requires a radical transformation

In addition to the question of the pace of decarbonisation, the French objective of carbon neutrality by 2050 requires a radical transformation of industry as a whole and, in particular, the heavy-industry sector.[1] The emergence of this need to radically reform industry in France can be seen by comparing the two editions of the SNBC. In the 2015 edition, energy efficiency gains were the main lever mentioned for both the short and medium term (2030). By 2020, the revised National Strategy, which incorporates the objectives of the Paris Agreement, is calling for 'a radical transformation of the industry, as incremental changes will not suffice'.[2] The new strategy recognises that marginal improvements to existing, emitting industrial processes will not be enough: they must be replaced by new, much lower-emitting processes and disruptive technologies. The document also stresses the need to anticipate the deployment of these solutions, taking into account their implementation timeframe.

Heavy industry faces the challenge of radical transformation in particular because it produces materials that are used in the rest of the production chain, using emission-intensive processes. Three sectors account for nearly three-quarters of manufacturing industry emissions in France: i) non-metallic minerals and construction materials – in particular cement production, ii) chemicals, iii) ferrous metals. Unlike the rest of industry, these sectors have relatively few production sites, which means that decarbonisation efforts can be concentrated.[3] For example, recent announcements of investments in two steel production sites in France should make it possible to reduce industrial GHG emissions in France by 9% by 2030.[4]

1 Nilsson *et al.* « An Industrial Policy Framework for Transforming Energy and Emissions Intensive Industries towards Zero Emissions ». Climate Policy 21, n°8 (14 September 2021).

2 In addition to energy efficiency measures, it mentions the use of breakthrough technologies and decarbonised resources, the use of technologies for the capture, storage or reuse of GHGs emitted by industrial processes to compensate for residual emissions, and the intensification of downstream recycling, reuse and energy recovery.

3 Four production sites for ammonia, six steam crackers for high-value chemicals, three blast furnace sites for primary steel production, some 20 electric steel mills recycling scrap metal and nearly 30 production sites for cement.

4 ArcelorMittal. « 1,7 milliard d'investissements pour accélérer la décarbonation d'ArcelorMittal en France ». 3 February 2022.

There is no consensus today on the investment needs to radically transform the industry

A recent surge in prospective work on the decarbonisation of industry

The adoption of ambitious national decarbonisation targets was followed, around 2020, by a number of publications proposing decarbonisation scenarios for industry. Several of these scenarios, like the SNBC, cover all economic activities, including industry.[5] The transformations proposed for industry are consistent with the expected changes in other sectors: how much electricity production? what competition with other sectors on the use of resources? what changes in demand for industrial products? These studies do not always offer a granular approach to industry[6] but are supplemented by publications on specific industrial sectors.[7] The latter, often carried out in consultation with representatives from industry, provide a more precise description of the technological levers to be used for each sector.

These two types of publication complement each other and propose increasingly detailed scenarios. They highlight two key parameters for a radical transformation of industry: the level of industrial production and the type of technologies to be deployed. While some scenarios assume that existing industrial capacities will be maintained, or even that green reindustrialisation will take place, others assume that the level of production will be lowered in order to reduce GHG emissions from industry. For many sectors, there are several technologies, sometimes complementary, sometimes competing, that can be used to decarbonise processes. The use of these different levers varies from one scenario to another, depending on the trade-offs between their maturity, their cost and their implications for the rest of the economy.

Investment needs: a key component for implementing an industrial policy

Estimating investment needs provides useful information for industrial policy to be implemented. With clear estimates of the amount and timings of investments, the authorities can put in place support systems that are proportionate to the anticipated investments. This information, which is complementary to information on production costs and profitability, enables the most appropriate tools to be introduced (subsidies, carbon prices, development of demand via public procurement, changes in taxation or other forms of regulation, etc.). A timetable with clear milestones can be used to monitor the progress of the transition and adjust the support measures if necessary.

Investments associated with industry decarbonisation scenarios are still poorly documented

Only a few studies (ADEME, Institut Rousseau, Rexecode) propose an estimate of the investments required to decarbonise industry, and these follow different approaches based on several structural parameters. Depending on the studies, the sectoral scope and the levers taken into account differ, and the investment level may vary depending on whether it corresponds to the total investment needs or to additional investments compared to a trend scenario.

In light of the poor comparability of these studies, as well as the fact that the literature has not yet been completed for all industrial sectors, it is not yet possible to infer the amount of investment required to decarbonise the industry. A first review of the existing studies is presented below.

ADEME, 2022 (cement), 2023 (aluminium), and other upcoming releases: Sectoral Transition Plans (see **Box 1**)

- **Scope:** in its Sectoral Transition Plans (STPs), ADEME proposes estimates of investment needs for the most energy-intensive industrial sectors (cement, aluminium, etc.), with a detailed set of levers used in different scenarios.
- **Estimate:** ADEME proposes an estimate of the costs of all the equipment deployed by 2050. For example, for cement, €240 million for a 'market shock' scenario and €8 billion for a 'technological bet' scenario.
- **Deployment of investments over time:** ADEME's STPs present the most detailed approach to the investment deployment schedule. They propose a yearly timetable, which takes into account the current industrial baseline, the deployment time and the level of maturity of the envisaged technologies. The comparison of the two scenarios presented in the cement STP illustrates the importance of the maturity of the technologies for the schedule. The 'market shock' scenario, which relies on existing technologies, foresees the deployment of all investments before 2035, while the 'technological bet' scenario presents a phased deployment with far more significant investment needs.

Rexecode, 2022 *'Les enjeux économiques de la décarbonation de la France - Une évaluation des investissements nécessaires'*

- **Scope:** the Rexecode study proposes an estimate of investment needs for the manufacturing industry as a whole and considers five decarbonisation levers[8] deployed by 2050 to meet the SNBC emissions trajectory.

5 For example, ADEME's 'Transition(s) 2050'; RTE's 'Futurs énergétiques 2050', whose central scenario assumes an increase in national industrial production; the Negawatt 2022 scenario; the Shift Project's 'Plan de transformation de l'économie française'.

6 For example, the SNBC does not provide much detail on the decarbonisation objectives of the various sectors of industry, and even less on the levers to be deployed to achieve them.

7 Decarbonisation roadmaps produced by the National Industry Council, ADEME's STPs, specific publications of the Shift Project, and of the European Commission on steel.

8 Low-carbon hydrogen substitution for current uses of hydrogen produced from fossil fuels; new uses of hydrogen; carbon capture and usage; electrification of low-temperature heat production; biogas in place of natural gas.

- **Estimate:** the Rexecode study proposes an estimate of the investment surplus compared to a trend investment scenario. According to this method, the amount of additional investment in the manufacturing industry increases progressively, from €1.8 billion per year in 2023 to €7.9 billion per year in 2050. Over the entire 2023-2050 period, this figure is equivalent to an investment surplus of around €130 billion.
- **Deployment of investments over time:** the study proposes annual deployment of investments based on a quantity of emissions to be reduced that primarily reflects the SNBC's emissions reduction trajectory.[9]

Institut Rousseau, 2022, '2% for 2°C: How to achieve and finance France's carbon neutrality by 2050'

- **Scope:** The Institut Rousseau proposes an estimate of investment needs for the whole industry, with a focus on energy-intensive industries (EIIs)[10], and considers a diverse set of decarbonisation measures.[11]
- **Estimate:** The estimate covers all the costs of the equipment deployed. The decarbonisation of the manufacturing industry would require a cumulative investment of €48 billion by 2050.[12] The Institut Rousseau estimates that €26 billion of this will be additional investment.[13]
- **Deployment of investments over time:** The Institut Rousseau distinguishes two investment periods for the transformation of production processes, before and after 2030. Most of the investment needs[14] are expected in the second period.

Our work complements this literature on investment needs by transparently documenting how they vary depending on the transformation scenario chosen. We propose a simplified approach to document the different scenarios from ADEME's prospective study Transition(s) 2050. Our approach considers the evolution of production levels and the production routes[15] to be deployed and documents their deployment schedule up to 2050. This work aims to better identify investment needs for the transformation of industry in order to facilitate their deployment.

BOX 1. ADEME'S SECTORAL TRANSITION PLANS: A PROJECT TAKING INTO ACCOUNT THE SPECIFICITIES OF EACH INDUSTRIAL SECTOR

The Sectoral Transition Plan (STP) develops tools to support forward-looking dialogue in nine industrial sectors, in consultation with sector players (industrialists and federations). Carried out over a period of 12 to 18 months, an STP builds decarbonisation scenarios aimed at achieving France's energy and climate objectives by 2050, which represents a reduction of 81% of greenhouse gas emissions from industry compared to 2015.

Unlike the vast majority of national, European or international literature which essentially approaches industrial transition from a technological point of view, the ADEME project adopts a 360° perspective in order to consider the aspects of markets, costs, financing and jobs. Integrated into a European LIFE programme entitled 'Finance ClimAct'[16], these transition plans are based on an analysis across decarbonisation technologies and how they affect demand. They propose a timetable of investments up to 2050, as well as an estimate of the evolution of production costs linked to technological deployment and to the likely development of energy and CO_2 prices. The effects on employment and the possible changes in skills required to adapt to the transition of the sector are also discussed in the context of the STPs, as is the subject of territorial anchoring and the degree of dependence of a territory on the industrial sector studied. Ultimately, this work should allow the formulation of proposals for 'public-private' actions to accelerate the transition of these key sectors.[17]

The cement[18] and aluminium[19] STPs have already been published. The ammonia and steel STPs will be finalised by the summer of 2023, while the STPs for the other five sectors (sugar, paper and cardboard, glass, olefins and chlorine) will be completed by the end of 2023.

---

9 With the ad hoc hypothesis: immediately deployable investments with an immediate effect on emissions abatement.
10 The proposed estimates for the rest of the industry are based on the extrapolation of the results for the EIIs, considering that the investments for the rest of the industry are proportional to their share in total industrial emissions.
11 The transformation of production processes (including energy efficiency); the recycling and thermal recovery of waste; the decarbonisation of energy sources used by industry, in particular by substituting 'green' gases for the 'grey' fossil gas and hydrogen currently used; the reduction of production through an effort to reduce consumption, and to reuse products and make them more sustainable.
12 For EIIs, investments are estimated at €32 billion, including €18 billion in additional investments.
13 Compared to a projection of current investments, including, for the 2022-2030 period, the investments set out in the France 2030 plan.
14 Investments related to the transformation of production processes for EIIs are estimated at €26.6 billion (€4.1 billion before 2030, and €22.5 billion after).
15 A production route characterises the set of technological processes used to produce a material. A given material can be produced via several different production routes.
16 More information available on the dedicated website: https://finance-climact.fr/
17 All documents related to the STP project are available at: https://agirpourlatransition.ademe.fr/entreprises/demarche-decarbonation-industrie/actualites/plans-transition-sectoriels-decarboner-lindustrie
18 https://librairie.ademe.fr/changement-climatique-et-energie/5041-plan-de-transition-sectoriel-de-l-industrie-cimentiere-en-france-9791029718212.html
19 https://librairie.ademe.fr/changement-climatique-et-energie/6167-plan-de-transition-sectoriel-de-l-industrie-aluminium-en-france-rapport-de-synthese-9791029720840.html

2. ESTIMATING INVESTMENT NEEDS: A TRANSPARENT METHOD TO ILLUSTRATE THE CHALLENGES OF THE INDUSTRY'S RADICAL TRANSFORMATION

What industry in 2050?

Transition(s) 2050: four scenarios that illustrate the options for transforming the industry

In this study, we estimate the investment needs to implement ADEME's 'Transition(s) 2050' scenarios, published in 2021, which explore four contrasting paths to achieve carbon neutrality in 2050. This work, carried out for all economic activities, is presented by ADEME[20] as 'archetypal strategies' for 'collectively reflecting on possible alternatives, on what seems more realistic, more desirable'. ADEME does not claim to cover 'all possible scenarios'. While the choice of path to take to transform the industry remains an open question (see **part 1**), these contrasting scenarios have the advantage in that they illustrate a range of options.

For industry, the Transition(s) 2050 scenarios are based on four main decarbonisation levers: process changes, the use of low-carbon energy (such as low-carbon electricity and hydrogen, and biomass), the use of CO_2 capture technologies, or a decrease in production volumes (linked to changes in consumption). Each scenario has its own combination of levers. The first three levers characterise the production routes, while the last one defines the production level in 2050.

Two scenarios, S1 'Frugal generation' and S2 'Regional cooperation', are presented as favouring quality over production volumes, with products that are 'more expensive but lasting, eco-designed, repairable, reusable and recyclable'.[21] In these scenarios, the volume of industrial production falls by 35% for S1 and 20% for S2 by 2050 compared to 2015, due to lower consumption choices of citizens, companies and communities. In both scenarios, the context of production decline is accompanied by limited changes in the production routes.

The other two scenarios assume a level of production close to the current one: production falls by 14% in the S3 'Green technologies' scenario and is stable in the S4 'Restoration gamble' scenario. In this context of maintaining the level of production, these scenarios rely on major transformations of the production routes.

These scenarios contrast with a trend scenario (TEND), which takes into account only policies adopted before 2021 and major economic trends, and which does not achieve the objective of carbon neutrality by 2050. The precise variations of these scenarios within the industrial sectors studied are detailed in **Part 3**.

Scenarios that reflect the industry's strong integration with other activities

The Transition(s) 2050 scenarios integrate the industry's dependencies on the upstream and downstream sectors of the production chain. They thus determine future production based on the material needs of the main consumer sectors (*e.g.*, transport, construction, packaging, etc.), modulating the share of imported or exported materials. They also take into account the upstream needs for raw materials, energy and infrastructure. These scenarios enable the radical transformation of the industry to be seen within the context of global decarbonisation of all economic activities in France.

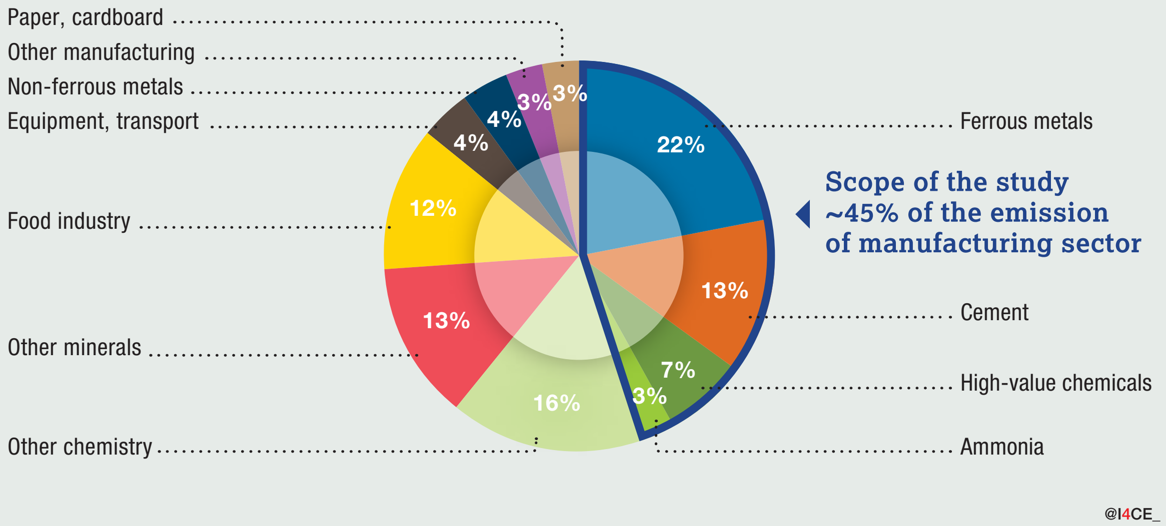
20 ADEME. « Transition(s) 2050. Choisir maintenant. Agir pour le climat ». ADEME, November 2021.
21 *op.cit.*

Scope: investments linked to high-emitting processes in four heavy-industry sectors

Four sectors with high emissions

In this study, we propose an estimate of the investment needs to decarbonise four of the highest-emitting sectors of heavy industry: the production of steel, cement, high-value chemicals, and ammonia. This scope represents about 45% of industrial emissions in mainland France. These are also industrial sectors for which the literature is sufficiently mature, in terms of both the precision of the decarbonisation scenarios and the costs of the production routes. The rest of the industrial GHG emissions in France are distributed over a few other high-emitting industries, but mainly over a variety of other 'diffuse industries' (cf. **Figure 1**).

FIGURE 1. DISTRIBUTION OF GREENHOUSE GAS EMISSIONS IN INDUSTRY IN FRANCE (2019)



Note: The ferrous metals category encompasses several activities in the steel industry (processing, alloying, etc.), and is broader than the primary steel production studied here.

Source: Authors' calculations based on data from the report Secten edition 2022 from Citepa and the Sectoral Transition Plans memos from ADEME.

Documenting the investments made by industrialists

The figures presented in this study cover investments in production equipment at industrial sites. This includes the installation of equipment related to new activities at the production sites, such as the use of hydrogen as a reducing agent for steel production and as a raw material for ammonia, or the production of methanol for high-value chemicals. For this reason, investments related to hydrogen production by electrolysis have been included in the calculation of investment needs, even where the prospective scenarios foresee that hydrogen production sites are geographically distant and connected by a distribution network.

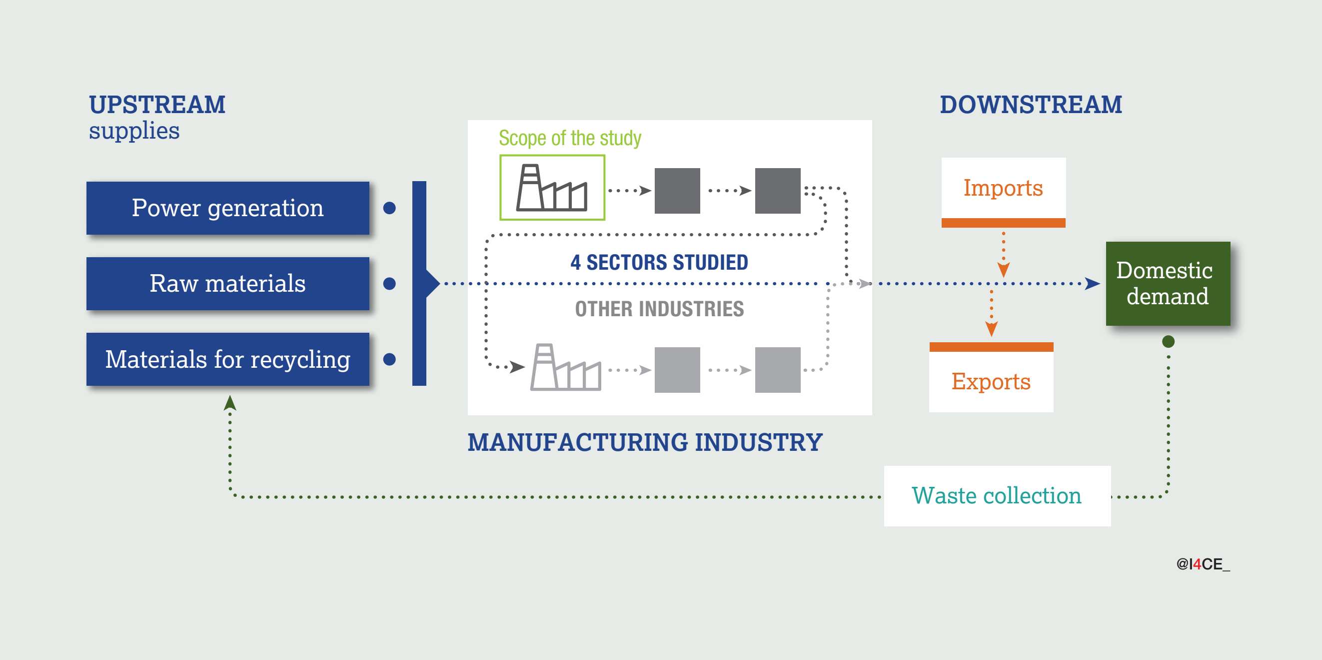
The figures presented here exclude:

- equipment related to utilities, such as building heating and lighting.
- downstream investments of the sectors covered by the study, such as steel rolling. The associated equipment, which is more difficult to identify and quantify, seems less critical in terms of emissions and investments, but would require further work to understand its full impact.
- a series of investments that today are not carried out by heavy industry: upstream investments that come under the energy sector, infrastructure investments (transport and storage of CO_2 after capture, transport of hydrogen) and some downstream investments such as those linked to the development of recycling, reuse and repair channels. These actions are often critical for the decarbonisation of heavy industry, and the issues related to their deployment are further documented in **Part 4**.

BOX 2. INDUSTRY'S ADAPTATION TO CLIMATE CHANGE

The estimates do not include investment needs related to adaptation to climate change. This subject has not yet been fully explored for industry, but several types of risk can already be identified. On the one hand, risks related to geographical location, in particular the port or river locations of the main heavy-industry sites (risks of flooding, submersion, drought); on the other hand, risks related to the value chain due to the many upstream and downstream links between industry and other sectors. In complementary work to Transition(s) 2050,[22] ADEME indicates that climate change does not call into question the main levers of the transition for scenarios S1, S2 and S3 (with the use of hydrogen remaining a point of caution). Scenario S4 is subject to greater risks concerning both the industrial and economic organisation and the decarbonisation technologies.[23]

FIGURE 2. SURVEYED AREA



22 ADEME. « Transition(s) 2050. Feuilleton Adaptation au changement climatique », March 2022.
23 This scenario is based on highly globalised trade, which amplifies the risks in the industry's value chain, whether they affect production in exporting countries, the transport of raw materials or have cascading effects. Several risks concern technological levers such as CO_2 capture and storage (CCS) (flooding of coastal installations and land movements on transport and storage infrastructures) or bionaphtha steam cracking (availability of biomass).

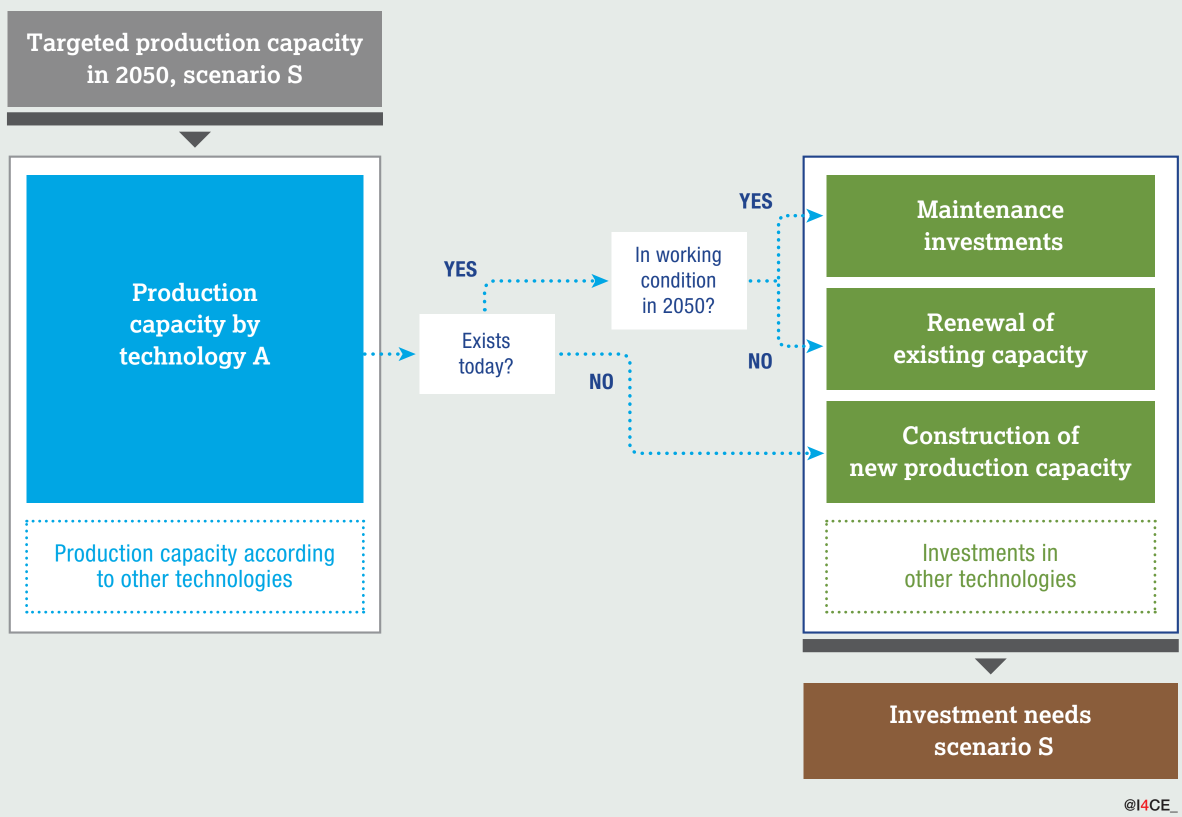
Modelling of investment needs based on decarbonisation scenarios

What?
Identifying the investments needed to make the existing industrial base compatible with the 2050 target

The estimation of investment needs we propose is based on two key characteristics of the scenarios: the level of production and the production routes employed. To estimate the investment needs associated with each scenario, we compare the current industrial base with the envisaged future production base: does it correspond to the production capacities described in each scenario, both in terms of production levels and production routes? If so, will these production capacities still be operational in 2050? If not, what new capacities should be deployed?

Consequently, our estimate reflects a diversity of operations that need to be carried out on the current production sites so that they correspond in 2050 to the proposed scenarios (maintenance, renewal, development of new technologies, see **Figure 4**). However, since we do not know the lifespan of new production technologies, we do not include investments for their maintenance or renewal in our figures. Our calculation reports the investment needs to achieve the transition and possibly underestimates certain investments in equipment that would need to be replaced prior to 2050.[24]

FIGURE 3. IDENTIFICATION OF INVESTMENT NEEDS FOR EACH SCENARIO



Note: The construction of new production capacity here covers several distinct actions and includes additions or adaptations to existing equipment (capture device or adaptation to a new input such as biomass).

24 This is especially relevant for electrolysers, whose lifespan would be around ten years. **See footnote 34** for an estimate of the associated investments.

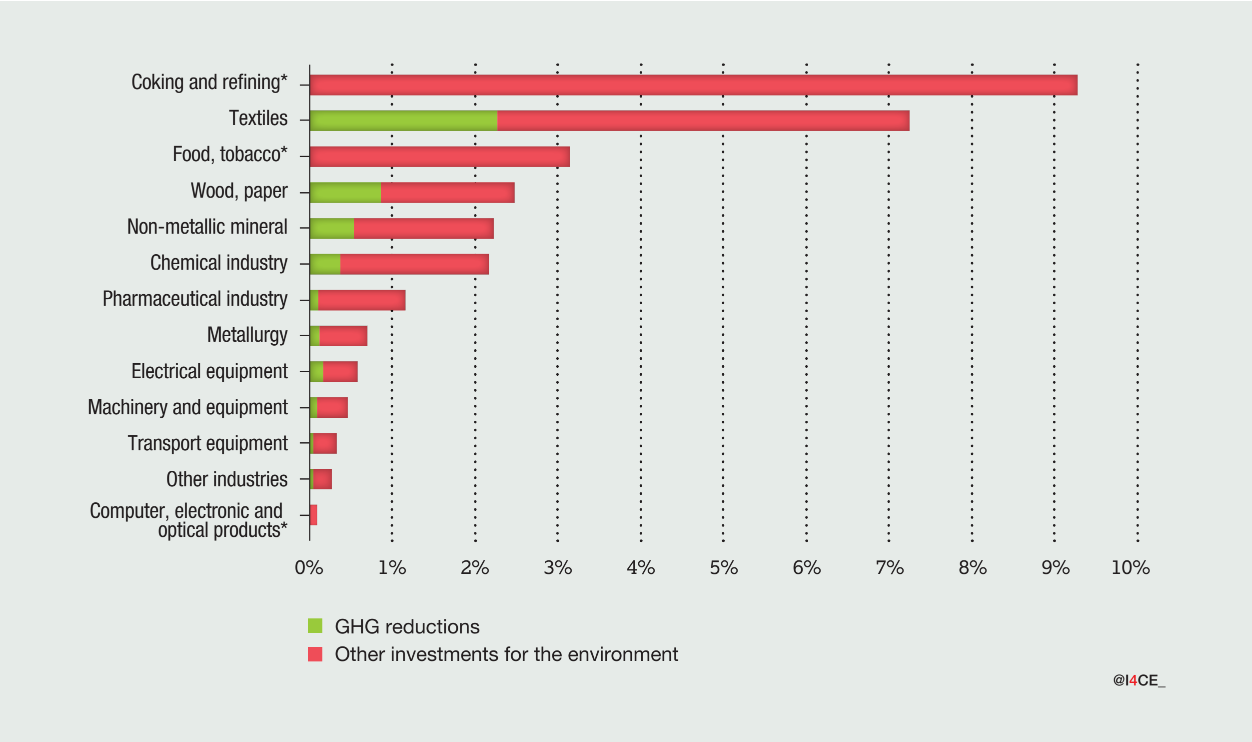
BOX 3. AVAILABLE STATISTICS SHED ONLY A PARTIAL LIGHT ON DECARBONISATION INVESTMENTS MADE BY INDUSTRY

INSEE, the French National Institute of Statistics and Economic Studies, maintains several databases that document investments in industry. These data show the main investment trends but several methodological limitations make them unsuitable for quantifying all the investments to decarbonise industry in France.

There are two main sources of data:

- a quarterly survey of investment in the manufacturing and extractive industries,[25] conducted among industrialists, provides information on the economic reasons for the investments they make. It reports, in particular, an increase in the share of investments whose main purpose is to achieve energy savings: 9% of all industrial investments today compared to 3% in 1990. However, these data have several limitations: they are based on company declarations and are only available for the entire industrial sector. In addition, the reasons for investment are given in a predefined list that makes it difficult to identify decarbonisation investments;[26]
- the Antipol survey[27] aggregates environmental spending reported by industrialists, distinguishing between several activities within the industry. In particular, it reports investments made for the 'limitation of greenhouse gas emissions'. The data from this survey suggest that this expenditure represents a very small share of total industrial investment (**Figure 4**). These data are likely to underestimate climate-related investments actually deployed. Firstly, they are based on the declarations of companies, which may omit certain investments. Secondly, their scope is limited (the survey does not yet cover investments related to energy efficiency[28]). Finally, for a part of the investments, they don't report the actual investment cost but only the additional cost relative to a comparable asset that is less efficient from an environmental point of view.[29] These limitations illustrate the difficulties in identifying and quantifying existing investments to decarbonise the industry.[30]

FIGURE 4. SHARE OF ENVIRONMENTAL INVESTMENT IN TOTAL INVESTMENT BY MANUFACTURING INDUSTRY (%)



** Data on investments to limit GHG emissions not available.*

Source: Authors' calculations based on INSEE data: Antipol survey and national accounts.

25 Link to the survey: https://www.insee.fr/fr/metadonnees/source/serie/s1207

26 The reasons presented in the survey are: renewal, modernisation, rationalisation, automation, new techniques, energy savings, expansion of production capacity, introduction of new products, other (safety, environment, working conditions...).

27 Link to the survey: https://www.insee.fr/fr/metadonnees/source/serie/s1232

28 This category was added from the 2021 survey, the results of which are not yet available.

29 This survey distinguishes between investments that are entirely dedicated to environmental protection, have a preventive or curative role, 'so-called specific investments', and 'integrated investments', to replace production equipment with equipment with better environmental performance. This last type of investment is not valued at its nominal cost, but only at the value of the additional cost relative to a comparable asset that is less efficient from an environmental point of view.

30 This data can be supplemented using information from other organisations that track decarbonisation investment announcements around the world such as: Agora Energiewende, 'Global Steel Transformation Tracker'; or Leadership Group for Industry Transition, 'Industry Transition Tracker.'

How much?
Using existing cost estimates to calculate investment needs

The amount of investment required is calculated from cost data available in the literature. The cost data are expressed in euros per tonne produced (€/tonne), *i.e.*, the monetary value of a piece of equipment in relation to its annual production capacity. These costs can vary depending on several factors. The costs of some decarbonisation equipment vary according to the size of the sites as a result of economies of scale.[31] Equipment costs for some production routes are lower at a pre-existing site (brownfield) compared to the same route built at a new site (greenfield). Finally, for most technologies,[32] in the absence of robust information, our estimates are based on the default assumption that costs do not vary over time. Maintenance costs are also documented by gathering publicly available information on historical investments and scaled to the existing capacities.

When?
Assessing the incentives for and constraints on investment deployment

The two previous steps allow us to estimate the investment needs up to 2050 but do not provide information on their distribution over time. To clarify, we develop investment schedules.

Several factors influence the timing of the investment needs by 2050.

- **Economic factors:**
  - the reduction of free allowances under the EU ETS, until their complete phase-out in 2034, provides an economic incentive for some industries to make decarbonisation investments before this deadline.[33]
  - the international competition in developing green industry (see **part 4**) encourages investments to decarbonise the industry.
- **Equipment factors:**
  - some industrial production equipment has a limited lifespan. Equipment renewal or renovation cycles are defined by these lifespans. When a piece of emitting equipment reaches the end of its lifespan, there is the opportunity it can be replaced with a new low-carbon production equipment.
  - the level of maturity of some technologies does not allow their implementation on an industrial scale in the short term. In addition, some technologies have a long deployment time between their adoption and their implementation. These technical constraints influence the realisation of the associated investments.

Our schedules also take into account intermediate deployment targets by 2030 for some of the technologies included in the Transition(s) 2050 scenarios.

The investment scenarios developed attempt to strike a balance between the influences of these different factors for each industrial sector and each production route considered. The data and assumptions used for the calculations were discussed with experts and industry representatives. These schedules are not comparable to the data available today on industrial investments, notably because they are built on a smaller scope than the sectors from which the statistics are aggregated.

31 The data used to estimate investment requirements reflect, depending on the sector and the sources available, either an average observed at different sites or costs close to those corresponding to the size of French plants.
32 Electrolysers for hydrogen production are an exception, with costs expected to halve by 2050.
33 « Le PE adopte cinq textes clés pour atteindre l'objectif climatique de 2030 », Actualité, European Parliament, 18 April 2023.

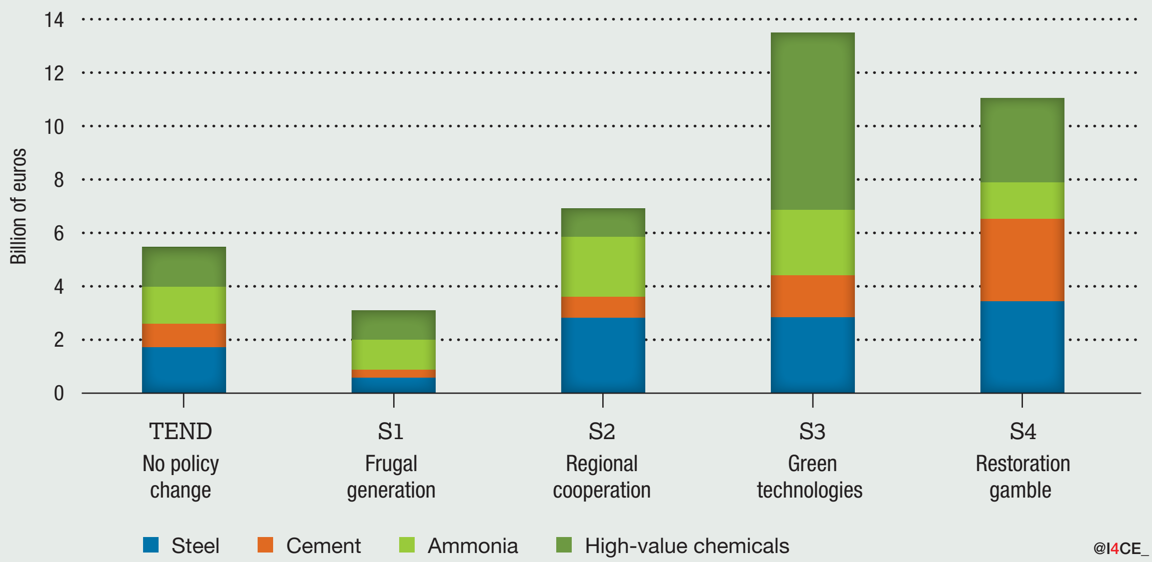
3. STEEL, CEMENT, HIGH-VALUE CHEMICALS, AND AMMONIA: INVESTMENT NEEDS DEPEND ON THE TRANSITION SCENARIO

€3-€14 billion of investment needed by 2050, depending on the transition scenario

Investment needs vary by a factor of 1 to 4 between the scenarios

The investment needs to decarbonise steel, cement, high-value chemicals, and ammonia production range from €3 billion for the S1 'Frugal generation' scenario to €14 billion for the S3 'Green technologies' scenario, by 2050 (**Figure 5**).

FIGURE 5. CUMULATIVE INVESTMENT NEEDS TO 2050



Note: The trend scenario (TEND) only takes into account policies adopted before 2021 and major economic trends. It does not reach the objective of carbon neutrality in 2050.

This gap between investment needs from one scenario to another results from different decarbonisation strategies. The production routes employed, and the level of production targeted in 2050, are the two main characteristics that influence the investment needs associated with each scenario.

Scenario S1 assumes a sharp decline in production, maintaining current emitting processes. The emissions reduction is based on a reduction in production volume. The investment needs associated with this scenario are low, as they consist mainly of investments to maintain existing production equipment and, to a lesser extent, investments in technological levers for decarbonisation.

Scenarios S3 and S4 aim at maintaining or moderately reducing the current production level, but with a radical transformation of the processes towards low-carbon production modes. The emissions reduction is mainly based on the decarbonisation of production. The investment needs associated with these scenarios are higher. Scenario S4 relies primarily on significant investments in carbon capture technologies, whilst scenario S3 relies mainly on low-carbon hydrogen production.

Scenario S2 represents an intermediate situation. It is based on both a decrease in production – although more moderate than in scenario S1 – and on a transformation of some production processes.

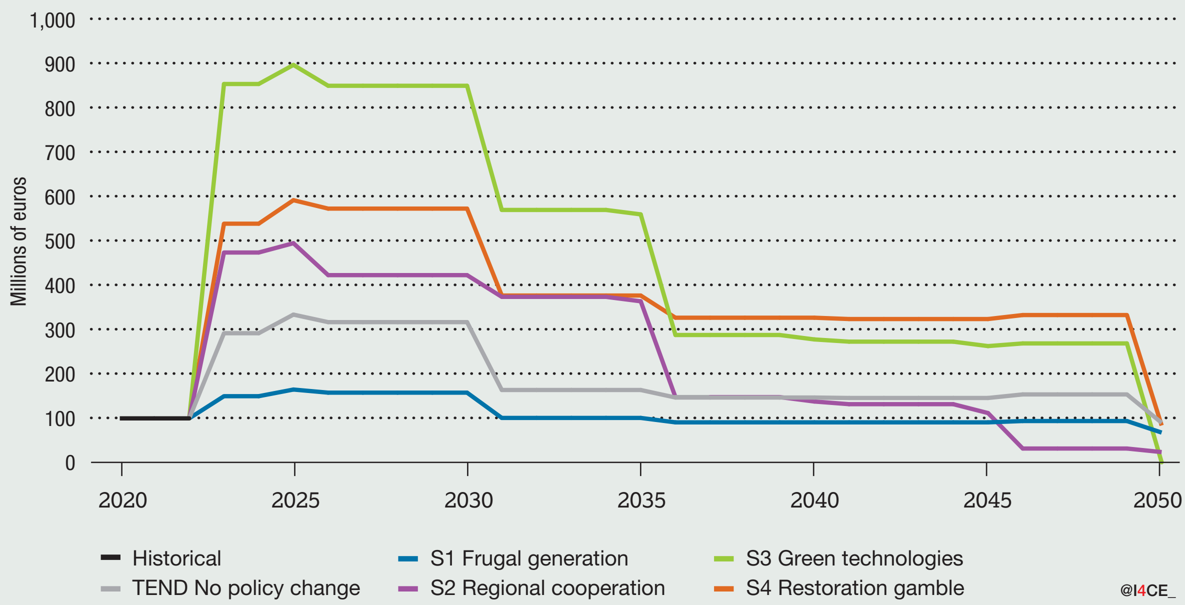
The estimated investment needs are limited to the scope of the study. Only four sectors are covered, and the investments relate only to the changes at the production sites, and not all the production lines and infrastructure on which these sites depend. Therefore, the decarbonisation of these four industrial sectors also requires other types of investment, depending on the scenario. For example, the scenarios that rely on CO_2 capture technologies require the development of CO_2 transport and storage infrastructures. Similarly, scenarios using hydrogen produced by water electrolysis require investments in low-carbon electricity production, and in hydrogen networks when the hydrogen is not produced on site. Finally, the decarbonisation levers that lead to an increase in low-carbon electricity consumption require investments in the reinforcement of electricity grids. All these investments are outside the scope of our estimation.

A peak in investment over the next decade

To build the investment schedule for the decarbonisation of steel, cement, ammonia and high-value chemicals production, we take into account the various factors that influence the distribution of investments over time (see **Part 2**).

The general shape of the investment schedule does not vary across the scenarios. Investments are highly concentrated before 2035, then decrease and level off from 2035 to 2050, and finally fall away until a next cycle of investment is required (**Figure 6**).

FIGURE 6. INVESTMENT SCHEDULE FOR THE FOUR INDUSTRIAL SECTORS STUDIED



This shape is partly due to the combination of equipment renewal cycles, which offer opportunities to transform production routes over the next fifteen years, and the end of free emission allowances in 2034, which provides an incentive to make investments by then. Both factors play an important role in the decarbonisation of steel in particular.

The deployment of investments also depends on the level of maturity of the technologies considered. On the one hand, renewal cycles and the end of free emission allowances encourage the rapid deployment of already mature technologies. On the other hand, investments in technologies still at an early stage of development (such as CCS) are more spread out over the end of the period, despite the incentives to invest early. The late development of these technologies on an industrial scale explains part of the investment needs between 2035 and 2050. The remaining needs correspond to investments required to maintain existing equipment.

This study presents the investment needs up to 2050 that are required to implement ADEME's decarbonisation scenarios. After 2050, some production equipment will potentially need to be renewed – both existing equipment today and new low-carbon production equipment – which will result in a new cycle of reinvestment.[34]

34 Some new low-carbon production equipment, particularly that deployed before 2030 or 2040, will potentially have to be renewed even before 2050, depending on its lifespan. This is particularly the case for electrolysers, whose operating life is currently estimated at around ten years. These investment needs are not included in the above estimates or in the envisaged schedule. For electrolysers, the additional investment would be between €0.2 and €1 billion according to different hypotheses of cost reduction and operating time of electrolysers by 2050 - these sums are cumulative for the three sectors that consider the use of low-carbon hydrogen (steel, ammonia, high-value chemicals) and represent additional investment needs for the two scenarios that use low-carbon hydrogen (S2 and S3).

Decarbonisation of steel production

Steel: four possible routes for a slightly lower production

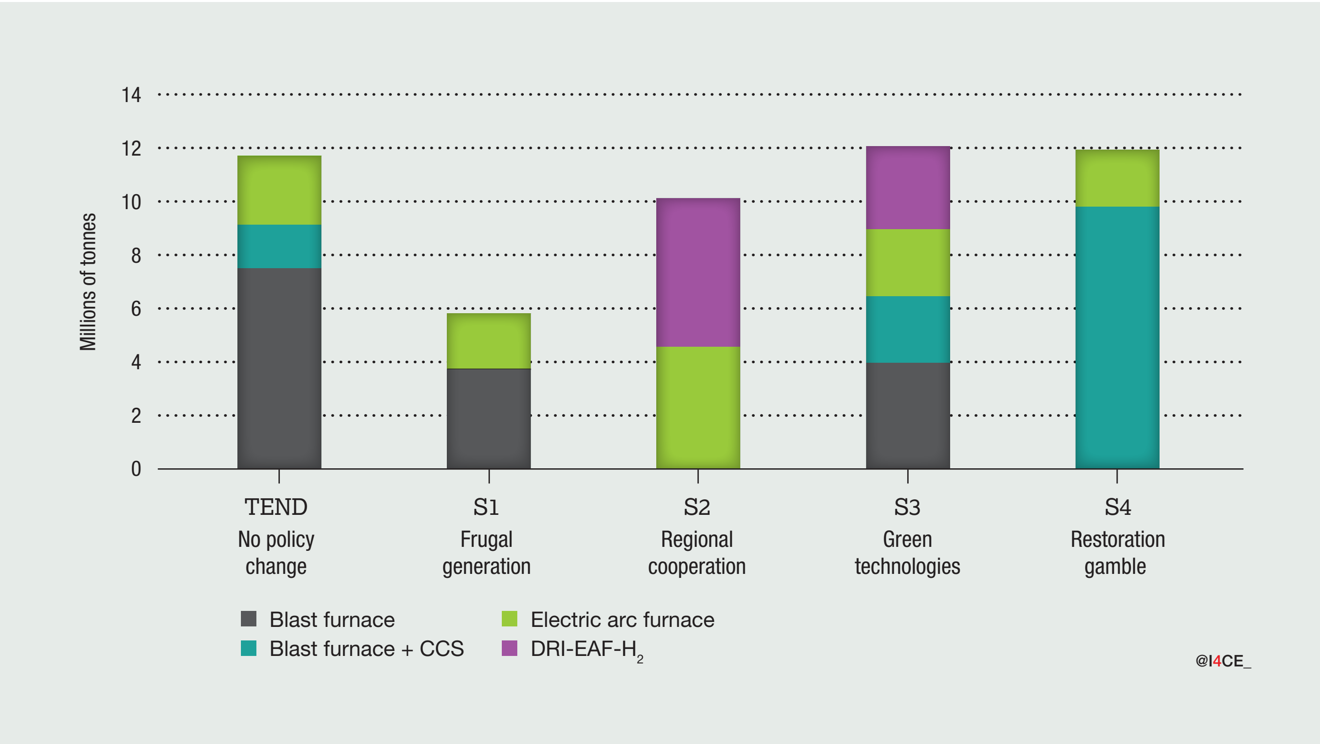
The Transition(s) 2050 scenarios are based on four steel production routes, including two new decarbonised routes:

- **Blast furnace:** iron ore is reduced in blast furnace in the presence of coke (the current primary process).
- **Blast furnace and CCS:** the current blast furnace process with the addition of a CO_2 capture unit, for its transport and offshore storage.
- **Electric Arc Furnace (EAF):** scrap metal is recovered and melted in electric arc furnaces (the current secondary route).
- **Direct reduction and electric arc furnace (DRI-EAF-H_2[35]):** in this new production process, iron ore is reduced with low-carbon hydrogen and then smelted in an electric arc furnace (the iron ore can also be reduced initially with natural gas, but the use of low-carbon hydrogen significantly reduces the process emissions).

All the scenarios are based, in different proportions, on the secondary sector of electric arc furnaces – in particular scenario S2 which is a scenario of 'Regional cooperation' resolutely focused on the incorporation of raw materials from recycling and the structuring of the reuse and recycling sectors. The new DRI-EAF-H_2 route is developed in scenarios S2 and S3, while the CCS technology is used in scenarios TEND and S3 and is very strongly developed in S4. Neither of the two new decarbonised routes is developed in scenario S1, which relies solely on a reduction of the level of production and the incorporation of scrap metal (recycling) to reduce emissions.

All scenarios foresee a decrease in the level of production, in line with the decrease in the rate of new construction in the building sector, but this trend is more pronounced for S1: 5.8 Mt in 2050, compared to the current production of about 15.0 Mt per year. In scenarios S2, S3 and S4, steel production decreases more moderately: it reaches 10.1 Mt in S2, and 12.0 Mt in S3 and S4 (**Figure 7**).

FIGURE 7. STEEL PRODUCTION LEVELS AND ROUTES IN 2050 IN THE TRANSITION(S) 2050 SCENARIOS



35 For Direct Reduced Iron - Electric Arc Furnace.

Steel: investment needs estimated at between €0.6 and €3.4 billion

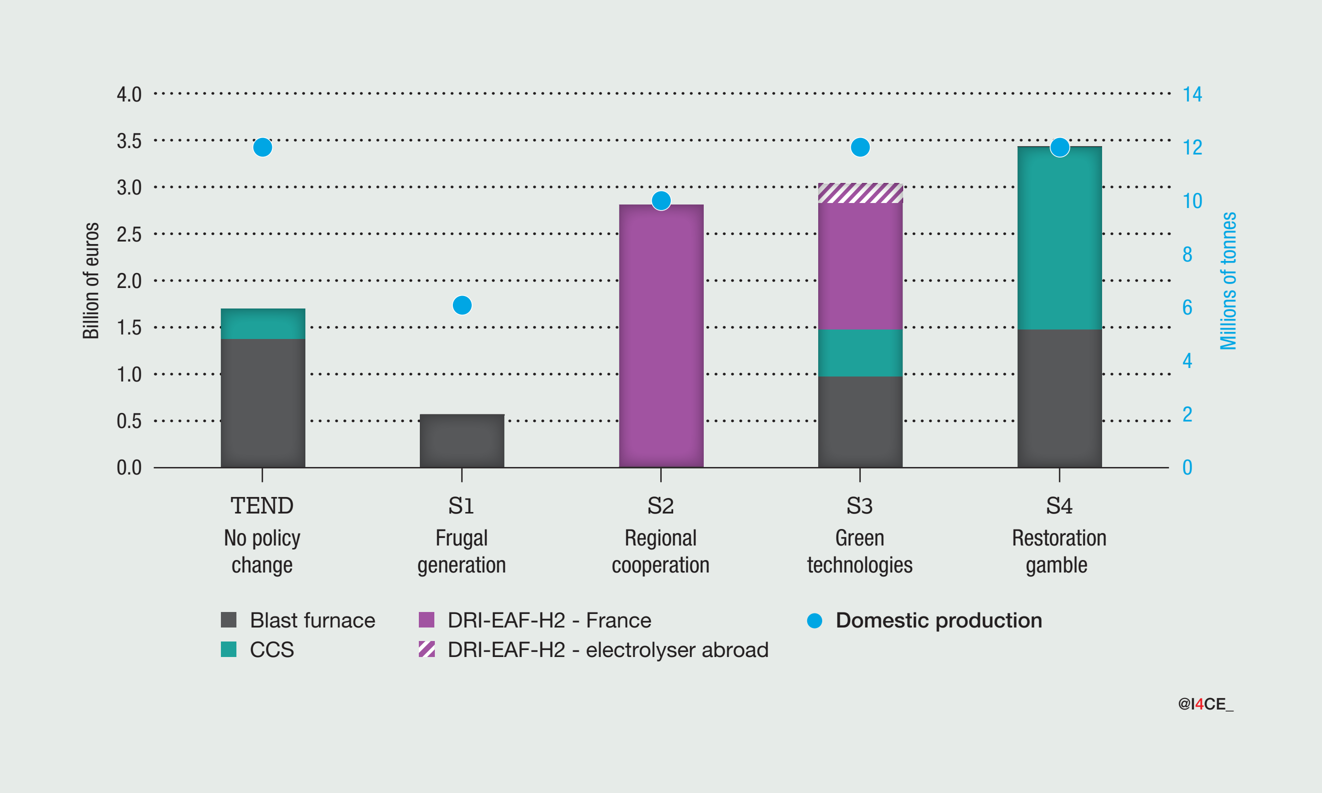
Decarbonising steel production by 2050 requires investments in:

- the renewal of part of the blast furnace production capacity;
- the deployment of equipment related to new production routes (CO_2 capture units and equipment for the DRI-EAF-H_2 route, including electrolysers for on-site hydrogen production).

In the absence of available data on maintenance or renewal needs for electric arc furnaces, we do not identify any investment needs for this equipment – except for the construction of new EAFs for the DRI-EAF-H_2 sector.

The investment needs to decarbonise steel production vary significantly between the ADEME scenarios: €0.6 billion in S1 to €3.4 billion in S4 (**Figure 8**). This difference reflects not only the differences in production capacity by 2050, but also the differences in costs between the production routes deployed. Scenario S2 requires investments only in the deployment of the DRI-EAF-H_2 route of €2.8 billion. In scenario S3, part of the hydrogen used by the DRI-EAF-H_2 route is imported, which lowers the investment needs for producing hydrogen in France to €2.8 billion, compared to €3.0 billion if all the hydrogen was produced in France.

FIGURE 8. STEEL INVESTMENT NEEDS AND PRODUCTION LEVELS TO 2050



The investment needs using the DRI-EAF-H_2 production route include the installation of electrolysis capacities. However, in S3, hydrogen is mainly transported *via* networks to industrial sites instead of being produced directly by the sectors themselves. For simplicity, we do not differentiate the investments in electrolysis capacities in France according to whether they are located at industrial sites or not.

These investment needs do not include those for the supply of low-carbon electricity for hydrogen production, the reinforcement of electricity grids, hydrogen networks and the transport and storage of CO_2.

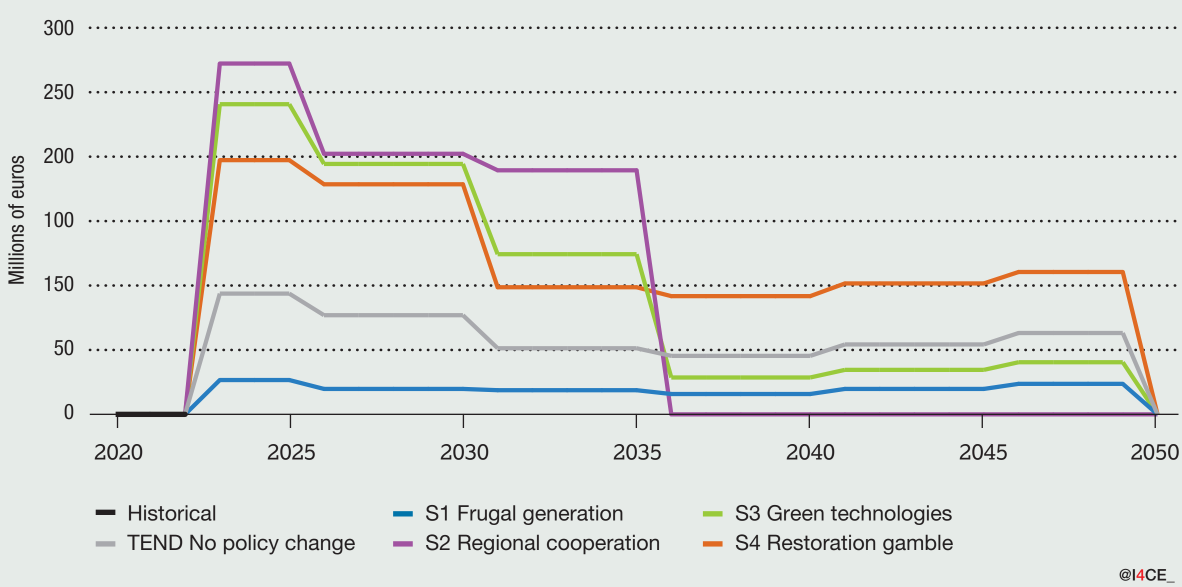
Steel: investment needs are concentrated between now and 2035

The distribution over time of the investments to decarbonise steel production is influenced by two main timing constraints. On the one hand, blast furnaces have a lifespan of between 15 and 20 years, after which the equipment must be renovated. These overhauls define regular renewal cycles for blast furnaces. As the last renewals took place between 2006 and 2015, all blast furnaces must be renovated between 2021 and 2035 at the latest,[36] then between 2035 and 2050 for the blast furnace capacities maintained. These equipment renewal periods offer opportunities to make decarbonisation investments, whether it be the addition of CO_2 capture units, or the conversion of sites to the DRI-EAF-H_2 production route. On the other hand, the investment schedule takes into account the incentives arising from the end in 2034 of free emission allowances under the EU ETS.

We construct the investment schedule[37] in steel production decarbonisation from the two previous constraints. **Figure 9** shows the following:

- blast furnaces maintained in the scenarios are renewed once by 2035 and again by 2050;
- DRI-EAF-H_2 production capacities are deployed during the first blast furnace renewal, *i.e.*, by 2035;
- CO_2 capture units are developed in part before 2030, and then between 2030 and 2050, based on the CO_2 capture targets in the Transition(s) 2050 scenarios.

FIGURE 9. INVESTMENT SCHEDULE IN STEEL PRODUCTION



36 Agora Energiewende. « Global Steel Transformation Tracker ». https://www.agora-energiewende.de/en/service/global-steel-transformation-tracker/

37 In addition to these investment schedules, associated with the scenarios of the Transition(s) 2050 project, ADEME will publish by summer 2023 an STP focused on the decarbonisation of French steel production, with detailed timings.

Decarbonisation of cement production

Cement: decarbonisation scenarios that differ mainly in their production levels

Two-thirds of cement production GHG emissions correspond to process emissions (from clinker production), and one-third from combustion emissions (from energy consumption). The decarbonisation of the cement industry in the Transition(s) 2050 scenarios relies on both the deployment of decarbonisation levers and a decrease in production.

There are two main levers to lower process emissions: reducing the clinker content in cement or capturing the CO_2 emissions. Carbon capture is considered in all scenarios except S1. However, in S4 only this solution is deployed on a large scale (for about half of the production).

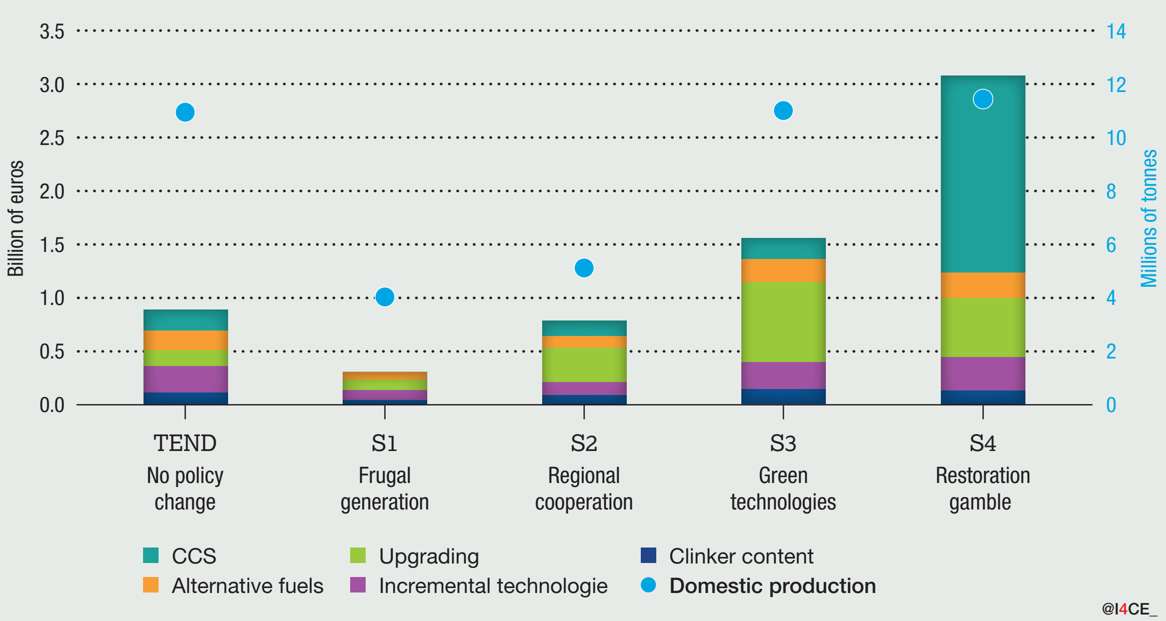
In addition, all scenarios use three levers to reduce combustion emissions: the use of less carbon-intensive fuels such as solid recovered fuels; the *upgrading* of plants to dry process with precalciner close to the best performance level (*upgrading*, which is a prerequisite for the integration of alternative fuels); and the implementation of incremental technologies (other one-off improvements in energy efficiency and emission reductions).

The use of each of these decarbonisation levers varies according to the scenarios, in line with the production levels. Cement production in 2050 decreases in all scenarios, from 30% to 70%, mainly due to the decrease in the rate of new construction in the building sector. S1 and S2 foresee the lowest production levels, respectively 4.3 Mt and 5.4 Mt, compared to the current production of 16.5 Mt. These two scenarios rely on a reduction of CO_2 emissions through a decrease in the volume of production and rely to a lesser extent on the various decarbonisation levers. In comparison, the decline in cement production is more moderate in S3 and S4, at 11.0 Mt and 11.5 Mt respectively: these scenarios rely to a greater extent on decarbonisation technologies to reduce CO_2 emissions.

Cement: investment needs estimated at between €0.3 and €3.1 billion

The investment needs to decarbonise cement production vary mainly according to the level of production capacity in 2050 and the levers used in the different scenarios (**Figure 10**). S1, which foresees the largest decrease in cement production, requires limited investment needs, around €300 million by 2050. S2 and S3 require investment of €780 million and €1.6 billion respectively, driven in particular by *upgrading* actions, prior to the integration of alternative fuels. S4 has much higher investment needs than the other scenarios, around €3.1 billion, largely driven by investment in CO_2 capture units.

FIGURE 10. CEMENT INVESTMENT NEEDS AND PRODUCTION LEVELS TO 2050



These investment needs do not include investments in CO_2 transport and storage.

Cement: an investment chronicle reaching a peak over the next five years

The maturity of the technologies, combined with the end in 2034 of free emission allowances under the EU ETS, is the main factor underpinning the investment deployment schedule in cement decarbonisation (**Figure 11**). Mature technologies today are deployed over the next decade, in line with the technology deployment schedule in the cement industry's STP (see **Box 2**):

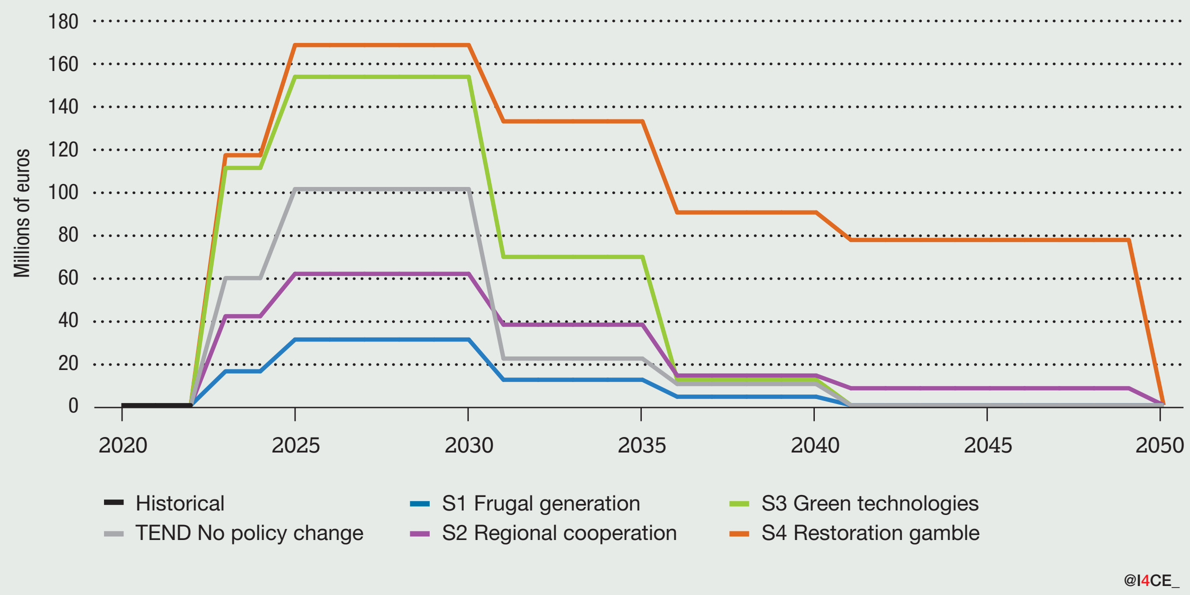
- the reduction of the clinker content is mainly implemented before 2030;
- incremental technologies are deployed between 2025 and 2030;
- the *upgrading* of cement plants is completed by 2035.

The deployment of these technologies explains why part of the investment needs are concentrated between now and 2035.

Between 2035 and 2050, investments correspond mainly to the development of less-mature levers:

- alternative fuels are integrated by 2040;
- CO_2 capture units are developed in part before 2030 and then between 2030 and 2050, depending on the CO_2 capture targets in the Transition(s) 2050 scenarios.

FIGURE 11. INVESTMENT SCHEDULE IN CEMENT PRODUCTION



BOX 4. THE SECTORAL TRANSITION PLAN FOR THE CEMENT INDUSTRY IN FRANCE

ADEME published a Sectoral Transition Plan (STP) for the cement industry in France in 2021. The STP presents three scenarios of the sector's future by 2050. There is a reference scenario (which does not achieve carbon neutrality) and two decarbonisation scenarios: the 'market shock' scenario and the 'technological bet' scenario. The STP presents the investment needs for the implementation of the three scenarios:

- €4.4 billion in the reference scenario,
- €204 million in the 'market shock' scenario,
- €7.7 billion in the 'technological bet' scenario.

Although the STP exercise and the one presented here follow similar methods, it is not possible to directly compare the two estimates as the modelled production levels are very different, and the higher the production levels, the greater the decarbonisation investment needs on a national scale.

Production levels reach 14 Mt in 2050 in the STP reference scenario, compared to 4.3 Mt to 11.5 Mt between S1 and S4. In the Transition(s) 2050 scenarios, the decrease in cement production (generated by a strong development of renovation and a limitation of the new housing construction market) generates reconversions of cement sites which strongly lower the investment needs.

The 'market shock' scenario is relatively close to S1. S1 includes some additional levers such as the use of incremental technologies and upgrading, but with a lower level of production. The investment needs of the two scenarios ('market shock' and S1) are of the same order of magnitude.

The 'technological bet' scenario proposes a production level much higher than all the Transition(s) 2050 scenarios, including S4. It also foresees other more innovative levers that are not included in our estimate for the cement industry, such as mineralisation, which concerns the downstream part of the production chain, the electrification of precalciners or a more intense use of some costly levers such as CCS.

Decarbonisation of high-value chemicals production

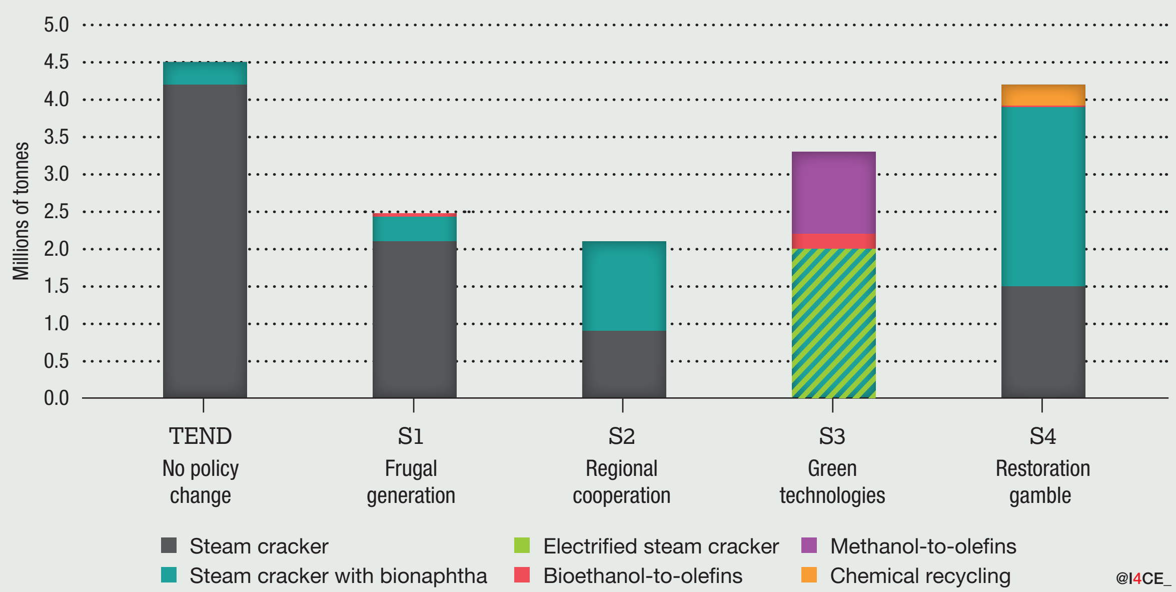
High-value chemicals: contrasting decarbonisation scenarios involving either new production routes or a sharp decline in production

High-value chemicals (HVC) are chemical compounds produced by steam cracking from compounds derived from oil refining, such as naphtha. Ethylene is the main product of steam crackers and today represents about 40% of the HVCs produced in France. 65% of the products from steam cracking are then used to manufacture plastics.

The Transition(s) 2050 scenarios propose two main strategies to decarbonise the production of HVC (**Figure 12**). S1 and S2 are characterised by a sharp decline in the level of HVC production, to 2.5 Mt and 2.1 Mt respectively, compared to more than 5.4 Mt today, resulting from the implementation of the regulation putting an end to single-use plastic packaging.[38] This decrease is accompanied by a strong development of mechanical recycling of plastics (activity downstream of the production of HVC and outside the scope studied here). These two scenarios do not foresee any change in the HVC production processes, except for the integration of some bionaphtha as an input to steam crackers and, marginally, of the bioethanol-to-olefins route in S1. Steam crackers need to be converted above a certain threshold of bionaphtha incorporation, to be better adapted to the new input mix.

Scenarios S3 and S4 forecast a smaller decrease in HVC production, to 3.3 and 4.3 Mt respectively, and rely on the development of new low-carbon production routes. S3 relies in particular on the development of the methanol-to-olefins route[39] and on the electrification of steam crackers, while S4 includes the development of chemical recycling of plastics. Except for S3, the scenarios all retain a share of steam cracking from oil products, which entails maintaining upstream oil refining activities (outside the scope of our study).

FIGURE 12. HIGH-VALUE CHEMICALS PRODUCTION LEVELS AND ROUTES IN 2050 IN THE TRANSITION(S) 2050 SCENARIOS

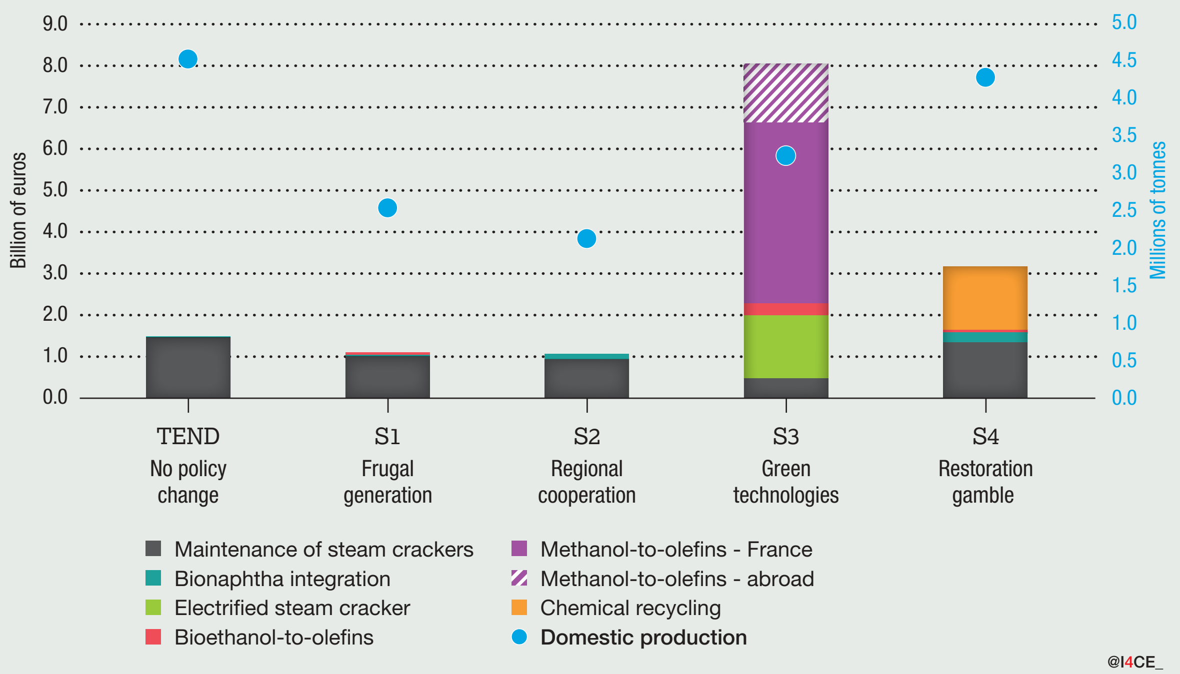


38 The effect of this regulatory provision on the production level of steam crackers can nevertheless be offset by new outlets for HVCs.
39 The methanol-to-olefins production route is a chemical process that converts methanol into HVCs. When the methanol used is produced from CO_2 and low-carbon hydrogen, the production of HVCs by the methanol-to-olefins route is low-emission.

High-value chemicals: investment needs estimated at between €1.1 and €6.7 billion

The significant difference in investment needs between the scenarios is mainly due to the development of new expensive production routes, particularly in S3, where the investment needs in France amount to €6.7 billion (**Figure 13**). The development of the methanol-to-olefins route requires, in addition to investments in HVC production capacities, investment in the production of low-carbon methanol from CO_2 and low-carbon hydrogen. This involves installing electrolysers (some of which are installed abroad with a hydrogen network developed outside of France and the hydrogen produced there imported to France). The investment needs of S4, of €3.1 billion, are notably driven by the development of chemical recycling of plastics, whose cost is high in relation to production capacity. The investment needs of S1 and S2 are equivalent, at €1.1 billion, and are largely related to the maintenance of existing steam crackers and their conversion for the integration of bionaphtha as an input. These two scenarios also imply additional investment in the mechanical recycling of plastics, not included in the scope of this study.

FIGURE 13. HIGH-VALUE CHEMICALS INVESTMENT NEEDS AND PRODUCTION LEVELS TO 2050



The investment needs in the methanol-to-olefins production route include the installation of electrolysis capacities to produce low-carbon methanol. However, in S3, hydrogen is mainly transported *via* networks to industrial sites instead of being produced directly by the sectors themselves. For simplicity, we do not differentiate the investments in electrolysis capacities in France according to whether they are located at industrial sites or not.

The investment needs do not include those in the supply of low-carbon electricity for hydrogen production, the reinforcement of electricity grids, hydrogen networks and the transport and storage of CO_2. Nor do they include investment needs in oil refining or mechanical recycling, which are outside our scope.

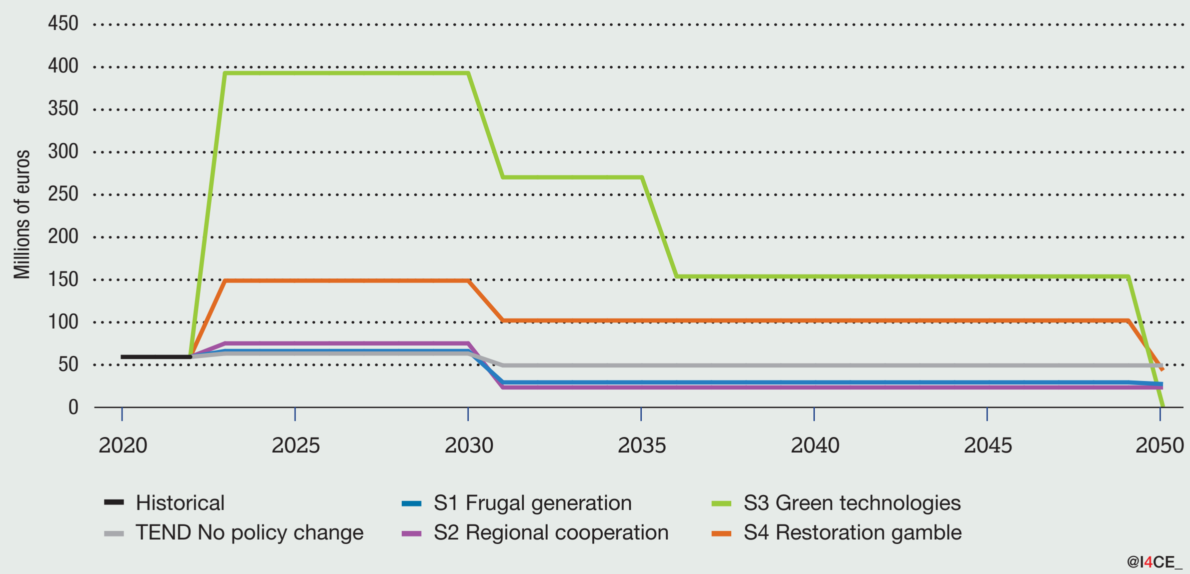
High-value chemicals: investments are concentrated over the next ten years

HVC production sites are inspected and upgraded every seven years. During these regulatory shutdowns, capacity maintenance investments are made, which constitute the major part of the investment needs in S1 and S2. In addition, these periods offer opportunities to make investments in the decarbonisation of steam crackers and the development of new production routes. As the next shutdowns are scheduled to take place between 2023 and 2029,[40] part of the decarbonisation investment is concentrated in this period. As some production routes are not yet mature today, their development and the corresponding investments are spread over the entire 2023-2050 period.

Our investment schedule for HVCs takes into account the regulatory shutdowns and technologies maturity (**Figure 14**):

- bionaphtha integration and steam cracker electrification are implemented by 2030 and 2035 respectively, around the next regulatory shutdowns;
- the bioethanol-to-olefin production route and chemical recycling of plastics are developed between 2023 and 2050;
- the methanol-to-olefins production route is developed between 2023 and 2050, taking into account the development of low-carbon methanol production, which depends on electrolysis capacities and new infrastructures allowing hydrogen imports. In S3, about three-quarters of the methanol production capacity is developed after 2030. Some of the electrolysis capacities are installed in France before 2030, while after 2030 most of the additional low-carbon hydrogen needs are imported. This is reflected in the S3 schedule by a decrease in investments from 2030 although the pace of methanol-to-olefin capacities accelerates.

FIGURE 14. INVESTMENT SCHEDULE IN HIGH-VALUE CHEMICALS PRODUCTION



40 All steam crackers had their most recent shutdown between 2016 and 2022.

Decarbonisation of ammonia production

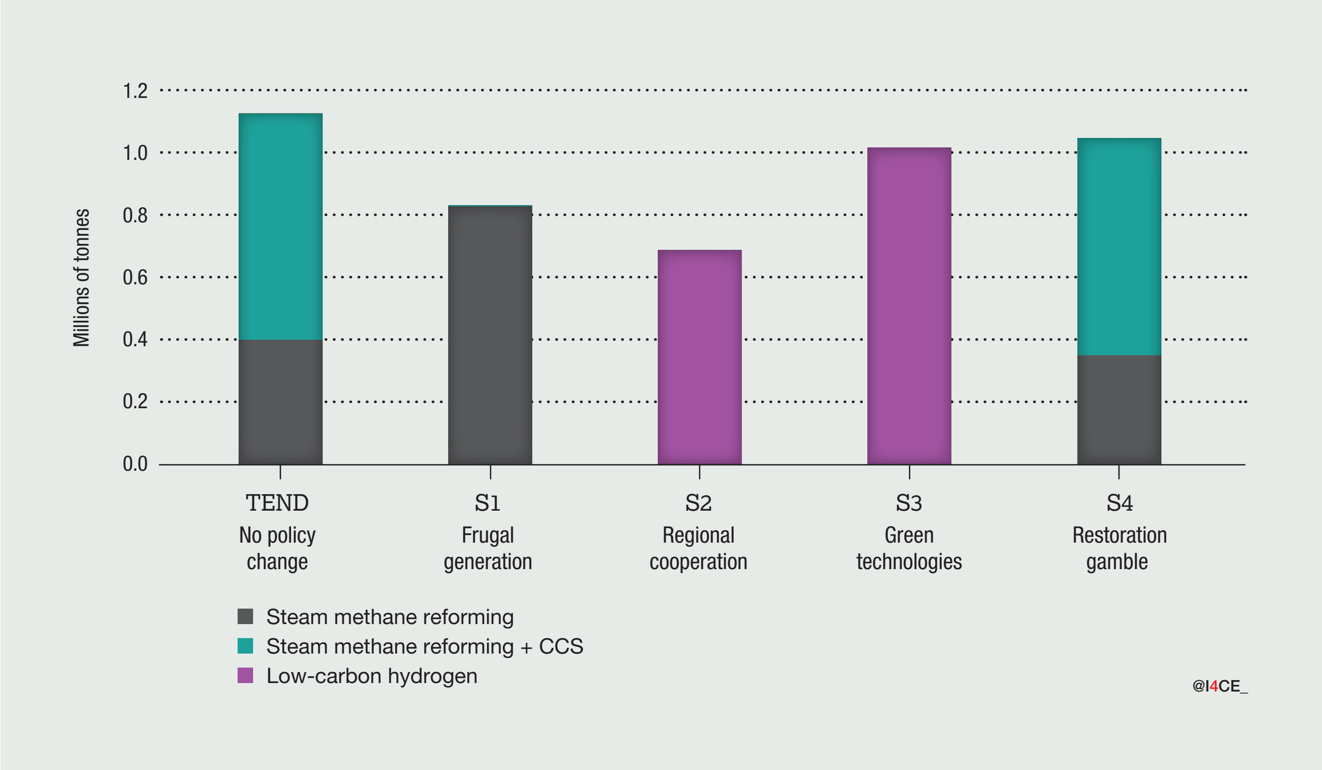
Ammonia: Three possible production routes for relatively stable production levels

Ammonia production levels in 2050 in the ADEME scenarios range from 0.7 Mt in S2, to 1.1 Mt in the TEND and S4 scenarios. This upper limit is at a level equivalent to current production, between 0.9 and 1.1 Mt per year over the 2015-2020 period.

Three production routes, two of which are decarbonised, have been considered for ammonia production (**Figure 15**):

- the current ammonia production route by steam methane reforming;
- the current route with the addition of CO_2 capture units for storage;
- a new ammonia production route using low-carbon hydrogen produced by water electrolysis.

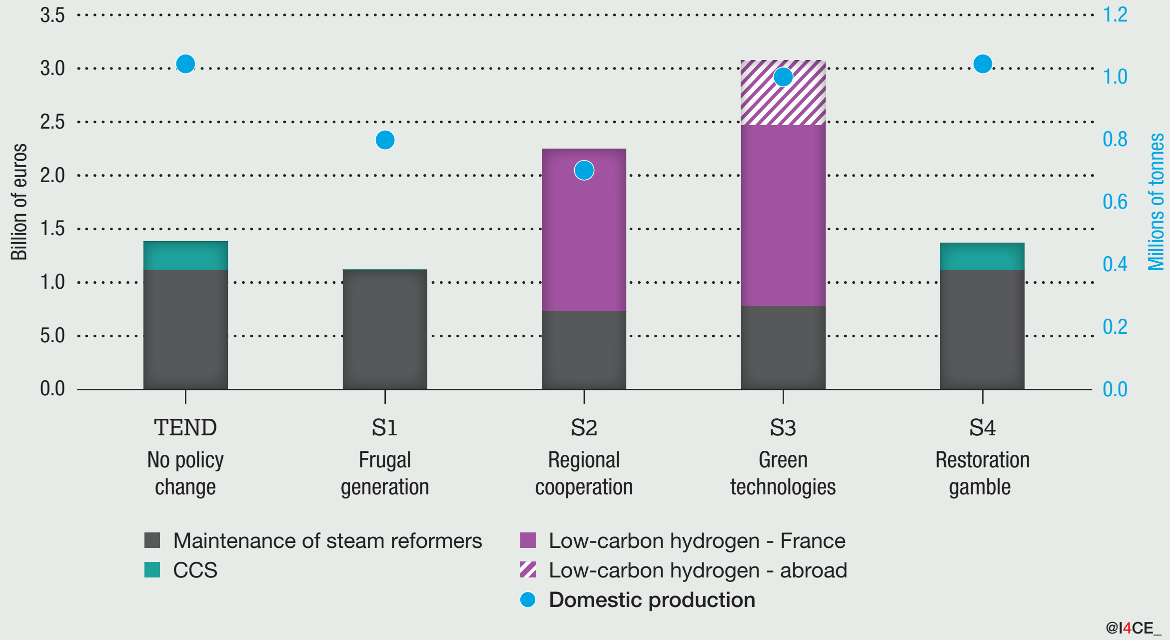
FIGURE 15. AMMONIA PRODUCTION LEVELS AND ROUTES IN 2050 IN THE TRANSITION(S) 2050 SCENARIOS



Ammonia: investment needs estimated at between €1.1 and €2.5 billion

Investment needs in ammonia production are divided between maintaining existing steam reformers and deploying new production equipment, including steam reformer emissions-capture units and electrolysis capacity for low-carbon hydrogen production[41] (**Figure 16**). In addition, above a certain level of hydrogen use in ammonia production, investments are required to convert production sites to this new production route. These investments are expensive and explain the high investment needs of S2 and S3, up to €2.3 billion and €3.1 billion respectively. However, S3 foresees the import of part of the hydrogen used, which lowers the investment needs strictly related to the domestic production capacities to €2.5 billion. The investment needs of the two other scenarios are relatively close: €1.1 billion in S1 and €1.4 billion in S4. This difference essentially reflects the addition of CO_2 capture units in scenario S4. This decarbonisation option appears less costly at first sight, but in this scenario part of the ammonia production is not eligible for CCS, and therefore not covered, which implies more residual emissions than the electrolysis route.

FIGURE 16. AMMONIA INVESTMENT NEEDS AND PRODUCTION LEVELS TO 2050



The investment needs in the low-carbon hydrogen ammonia production route include the installation of electrolysis capacities. However, in S3, hydrogen is mainly transported *via* networks to industrial sites instead of being produced directly by the sectors themselves. For simplicity, we do not differentiate the investments in electrolysis capacities in France according to whether they are located at industrial sites or not.

The investment needs do not include those in the supply of low-carbon electricity for hydrogen production, the reinforcement of electricity grids, hydrogen networks and the transport and storage of CO_2.

41 The investment needs take into account the assumption that the cost of electrolysers will halve by 2030 (International Energy Agency, 'Ammonia Technology Roadmap', 2021).

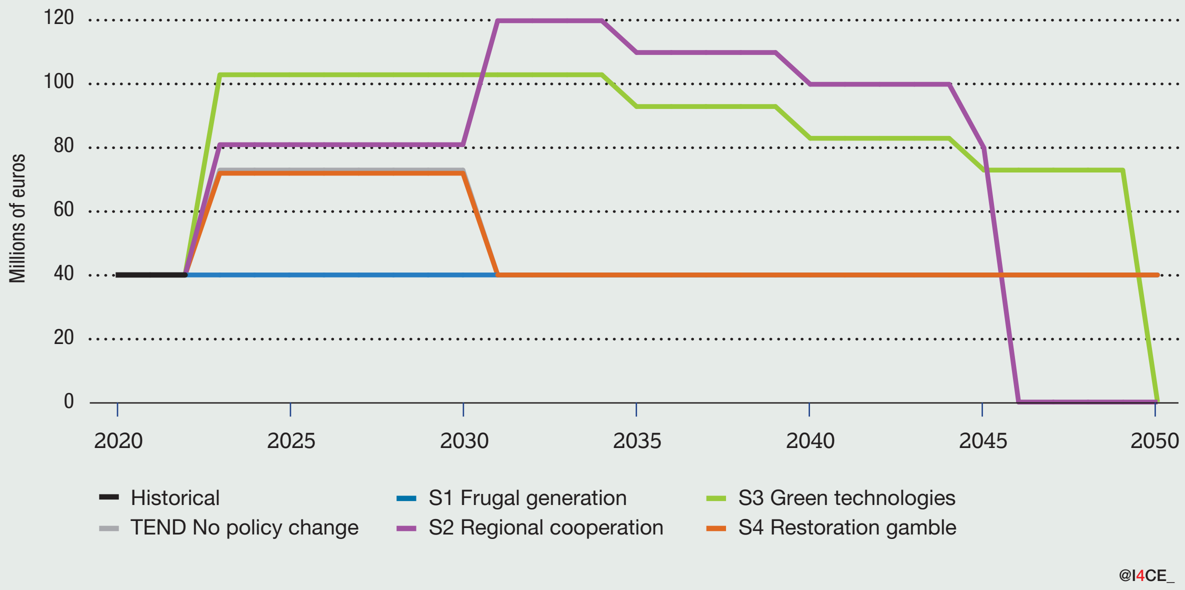
Ammonia: two investment phases, before and after 2030

Steam reformers can have a long lifespan, around 100 years, provided that regular investments are made to maintain the capacity. This is reflected in the ammonia decarbonisation investment schedule by a permanent base level of investment for the scenarios based on the steam methane reforming production route in 2050 (TEND, S1 and S4). In S2 and S3, investments to maintain steam reformers are retained until each site is converted to produce ammonia using only low-carbon hydrogen.

Decarbonised production routes are deployed in part before 2030 and then between 2030 and 2050[42] (**Figure 17**) :

- investments in the conversion of production sites for the full integration of low-carbon hydrogen (S2 and S3) are made from 2030. One site is converted every five years, until 2045 in S2 and until 2050 in S3;
- investments in water electrolysis capacities (S2 and S3) are distributed between 2023 and 2030 and then between 2030 and respectively 2045 and 2050 for S2 and S3, dates after which all steam reformers have been converted;
- CO_2 capture units (the TEND and S4 scenarios) are developed around 2030.

FIGURE 17. INVESTMENT SCHEDULE IN AMMONIA PRODUCTION



42 In addition to these investment schedule, associated with the scenarios of the Transition(s) 2050 project, ADEME will publish by summer 2023 an STP focused on the decarbonisation of the French ammonia production, with detailed timings.

4. FROM THE IDENTIFICATION OF INVESTMENT NEEDS TO THEIR IMPLEMENTATION

Comparison of industrial announcements with the estimated investment needs: what transformation is underway?

Industrialists have announced several projects to decarbonise steel production by using disruptive technologies while maintaining production levels

French steel production is provided by three blast furnace plants and some twenty electric arc furnaces that recycle scrap metal. The decarbonisation of steel production began with the announcement[43] by the ArcelorMittal group in February 2022 that it would deploy, with the support of the State,[44] new facilities in Dunkirk and Fos-sur-Mer to replace three blast furnaces. At Dunkirk, a direct reduction unit (DRI) to transform iron ore with hydrogen, with a production capacity of 2.5 Mt per year, will be coupled with an innovative electric furnace technology and completed by an additional EAF. At Fos-sur-Mer, the company plans to install an EAF with a production capacity of 2 Mt per year.[45] Furthermore, the ArcelorMittal group is studying a second investment phase, with the development of CCS in addition to the technologies implemented during the first phase.

These announcements of high investment deployed before 2030 and of the coexistence of several disruptive technologies, including CCS, are consistent with the schedule of investment needs that we estimate for ADEME's S3 scenario.[46] They imply the deployment of additional investment outside the production sites for the supply of electricity and the reinforcement of electricity networks to connect the electrolysers, as well as for CCS infrastructure development.

Cement companies are considering multiple decarbonisation levers to transform their activity

The cement industry is different from the other industries studied here in that it has a relatively high number of cement plants. There were 27 in mainland France in 2015.[47] Recent announcements by cement groups in France indicate the use of several levers to reduce their GHG emissions:

- the cessation of clinker production at certain sites;[48]
- the deployment of facilities to reduce energy-related emissions (with the installation of new dry process furnaces and the use of biomass and waste as alternative fuels);[49]
- the development of other binders as substitutes for clinker such as calcined clays;[50]
- the initiation of CO_2 capture projects.[51]

These various projects outline the start of a transformation relying on several decarbonisation levers. This transformation will depend on the industrial choices made by cement groups, which are highly dependent on market evolution perspectives. To accomplish this transformation, it may be useful to specify both the prospects for the evolution of demand (linked in particular to regulatory developments relating to new construction and land artificialisation) as well as those regarding the potential deployment of CCS.

43 ArcelorMittal, *op.cit*. These investments aim at reducing ArcelorMittal's CO_2 emissions in France by nearly 40%, which is equivalent to 7.8 Mt of CO_2 per year.
44 Matignon. « Dossier de presse France 2030. Décarbonation de l'industrie », 4 February 2022.
45 As part of the French Recovery plan (the France Relance plan), the government is also supporting a project to inject natural gas into the site to replace coal and coke, which will save 0.133 Mt of CO_2 , or 2% of the site's emissions. French government. « Dossier de presse : 47 nouveaux lauréats pour les appels à projets décarbonation », 14 March 2023.
46 The overall cost of these investments of €1.7 billion for a production capacity of 4.5 tonnes is also comparable to the cost data we have identified.
47 ADEME. « Plan de transition sectoriel de l'industrie cimentière en France. Premiers résultats technico-économiques. Rapport final », December 2021.
48 Two Lafarge plants were converted in 2016 and 2017. In November 2020 Calcia announced the end of clinker production at two sites: the Gargenville plant in the Yvelines converted into a grinding station and the Cruas plant in the Ardèche region which becomes a terminal automating the distribution of white cement.
49 Most of these actions have been supported by the France Relance plan: biomass installations for two Lafarge cement plants and one Eqiom cement plant, processes allowing the use of solid recovered fuels for a Vicat cement plant and a Calcia cement plant.
50 Supported within the framework of the France Relance plan for two Holcim sites and one Vicat site.
51 This is particularly true of the Lumbres production site (Eqiom), which is supported by the European Innovation Fund and could contribute to the development of a new CCS ecosystem near Dunkirk for transport and storage in the North Sea. This is also the case for the Martres-Tolosane site (Lafarge), which is expected to host an R&D platform to test new, more efficient CO_2 capture technologies. In addition, the Vicat cement plant in Montalieu-Vercieu should be equipped with CO_2 capture devices to produce carbon-free methanol by 2027, as part of a partnership with a hydrogen subsidiary of EDF.

Breakthrough technologies are being studied for the production of high-value chemicals, with no precise timetable

In France, six steam crackers are used to produce high-value chemicals. We are not aware of any projects concerning the decarbonisation of these production sites. Some communications from the groups that operate these sites indicate prospective work on solutions similar to those presented in the ADEME scenarios, such as electrified steam crackers. However, these documents do not detail a timetable or location for the deployment of these solutions which are still at the early stage of development.

On the other hand, several investments have recently been announced to develop chemical recycling units that could provide inputs to some steam crackers, including the launch of two sites with production capacities of several thousand tonnes:

- €250 million investment for the opening of a Loop/Suez plant scheduled in 2024, with a production capacity of 70,000 tonnes per year of recycled plastic.
- €850 million investment, with state aid, in an Eastman plant scheduled in 2025, which will recycle 16,000 tonnes of plastic waste per year.

At this stage, industrialists have only publicly announced the deployment of chemical recycling solutions,[52] a technology that is only marginally included in ADEME's S4.

Ammonia producers are launching research projects to deploy new technologies using low-carbon hydrogen and CCS

In France, ammonia production is spread over four production sites. Two decarbonisation projects are under study: one on the use of low-carbon hydrogen and the other on the capture and sequestration of CO_2.

Concerning the production of low-carbon hydrogen, a memorandum of understanding was signed at the end of 2021 between the chemical company Borealis and Hynamics, a subsidiary of the EDF Group specialising in low-carbon hydrogen. Their aim is to study the development of a low-carbon ammonia production project on the Borealis production site in Alsace, curently producing a combined total of 1 Mt per year (nitrogen fertilisers, ammonia and nitric acid). The objective is to produce 24,000 tonnes of low-carbon ammonia per year by 2025-2026, thus avoiding 33,000 tonnes of CO_2 each year.[53]

The option of CO_2 capture is being considered for production sites in the Normandy industrial zone (including two ammonia sites in Grand-Quevilly and Le Havre) as part of a memorandum of understanding[54] to work on developing a CCS infrastructure. The signatory companies of this agreement will work together to assess the technical and economic feasibility of implementing CCS infrastructure from their industrial activities to the final storage in the North Sea.

Therefore, projects are under assessment at most of the ammonia production sites in France.[55] Industrialists seem to consider using CCS more than in the scenarios studied. This option seems to be preferred to the more expensive low-carbon hydrogen. The timing of these announcements also suggests a later deployment than that envisaged in our investment schedules. As these projects are at the assessment stage, there is still some uncertainty about their actual deployment.

The announcements made by the industrialists in these four sectors show that they are initiating a radical transformation of their production. The solutions envisaged seem to focus on maintaining production levels, as well as on the use of both mature solutions and disruptive technologies. Most of the documented projects are in the launch phase, with some still subject to uncertainties as to whether the solutions envisaged will be implemented, and thus whether emissions will be reduced. These announcements do not make it possible to identify an overall strategy within these sectors or for the industry as a whole, which would ensure the coherence of decarbonisation actions and the achievement of climate objectives.

52 Although several low-carbon methanol production sites are planned in France, for the time being, their production is intended to be used as fuel for maritime or air transport.
53 «Borealis et Hynamics travaillent sur un projet de production d'ammoniac bas-carbone». Borealisgroup, November 2021.
54 «Air Liquide, Borealis, Esso, TotalEnergies et Yara coopèrent en vue de contribuer à la décarbonation du bassin industriel normand». Borealisgroup, July 2021.
55 We are not aware of any plans to decarbonise production at the Borealis Grandpuits site, which underwent maintenance in 2021.

The State has recently introduced promising policy packages to support the transformation of heavy industry

France 2030: transforming heavy industry by deploying disruptive technologies

Announced at the end of 2021, this new investment plan focuses its support to industry on the heavy-industry sector. Of the €5 billion allocated to decarbonising industry, €4 billion will be devoted to the deployment of 'deep decarbonisation solutions for high-emission industrial sites, particularly in the steel, heavy chemicals, cement and aluminium sectors'.[56] Public support for these sites could be increased by an additional €5 billion over the next 18 months, following the French President's announcement in November 2022. This additional support will be granted if the total of the commitments made by the industrialists results in a reduction of their emissions of 10 $MtCO_2$.

The estimates we present in this study do not allow us to analyse this policy package from a financial point of view: the scope of our review is more limited than the industries eligible for France 2030 and we do not document the financing constraints of industrialists. This new package, which differs from its predecessors by its specific targeting of heavy industry (see **Box 5**), sends a signal about the industrial transformation policy pursued by the State. It accompanies and confirms the direction that is emerging in the investment plans of industrialists to transform their activity: maintaining production capacities by deploying new technological levers.

BOX 5. A RECENT TARGETING OF NATIONAL SUPPORT TOWARDS DISRUPTIVE INVESTMENTS IN HEAVY INDUSTRY

Public policies supporting the decarbonisation of industry are deployed at both European and national levels

At the European level, industrial policy is based on the EU ETS (Emissions Trading System), which encourages decarbonisation through the price of carbon, and on support for innovation through the Innovation Fund (€38 billion)[57] for the period 2020-2030. In France, industry benefits from both research support schemes and investment support.

- Tools that support industrial R&D included the research tax credit, the *Programmes d'investissements d'avenir* (PIA) (€610 million planned to accelerate the decarbonisation of industry following the integration of PIA4 into France 2030)[58] and funding from the French National Research Agency.[59]
- Tools such as the Fonds Chaleur (Heat Fund)[60] and the energy savings certificates (CEE),[61] support the deployment of mature decarbonisation solutions, but do not target the wholesale transformation of production processes that are specific to the decarbonisation of heavy industry.

Finally, the National Strategy for the Development of Low-carbon Hydrogen (SNH), announced in September 2020, also includes a decarbonisation component for industry.[62] However, for the time being, it focuses on the decarbonisation of hydrogen for existing industrial uses. This strategy is expected to be strengthened as part of its update by summer 2023 to include new industrial uses.

56 The industry component also includes €1 billion for the deployment of more mature solutions in the French industry, including low-carbon heat and energy efficiency, without targeting any specific industry or territory. The France 2030 plan also includes €2.3 billion for low-carbon hydrogen and the development of cutting-edge renewable energy technologies, €1 billion to develop small-scale nuclear reactors in France and €3.8 billion for the transportation of the future: electric vehicles and low-carbon aircraft.

57 The Innovation Fund supports demonstration activities of innovative low-carbon technologies in industry, and disruptive innovations, including CCS. It will be financed in particular by the ETS auction system and the remaining funds of the NER300 programme.

58 French government. « Stratégie d'accélération "Décarbonation de l'industrie" ». Direction Générale des Entreprises, 4 February 2022. There have already been several calls for projects to support industry. For example, the 'Low Carbon Industrial Zone' (ZIBAC) call for projects will provide €13.6 million in aid to carry out engineering and feasibility studies for the decarbonisation of the Dunkirk industrial zone.

59 To illustrate this, a 2019 Senate report identifies support of several tens of millions of euros per year for the steel industry. Valérie Létard. «Les enjeux de la filière sidérurgique dans la France du XXIe siècle : opportunité de croissance et de développement». French Senate, July 2019.

60 During the 2009-2020 period, the Fonds Chaleur was endowed with €2.6 billion to support more than 6,000 projects representing €9.4 billion of work and a total heat production of 35.5 TWh per year (i.e., more than 3 million toe per year). This fund is managed by ADEME, which allocates appropriate investment grants (subsidies, reimbursable grants, etc.) to enable projects to be economically balanced and to offer a competitive price for heat to users.

61 Over the 2018-2021 period, according to data from the Ministry of Ecological Transition, €4.8 billion in grants were issued under this framework for industry.

62 It provides for public support of €9 billion between now and 2030 and aims to develop a French electrolysis industry in order to promote economies of scale and lower production costs (with a target of 6.5 GW of electrolysers installed by 2030).

The support system for the deployment of industrial investments introduced as part of the French recovery plan for 2020-22 was welcomed by the heavy-industry sector, which was quick to take up the subsidies on offer

Through the industry decarbonisation component of the French recovery plan (the France Relance plan), the State has proposed a budget of €1.2 billion via three calls for projects. At the last count in March 2023, 47 projects had been supported, for a total of 3.6 $MtCO_2$ avoided per year.[63]

In particular, the DecarbINd call for projects[64] supports the electrification and in-depth transformation of industrial processes if they result in lower emissions. An initial assessment of this industry decarbonisation component[65] shows that heavy industries such as cement and chemical-refining have been the main beneficiaries.[66] However, it is difficult at this stage to isolate the triggering effect[67] of the France Relance plan for accelerating investments in these sectors, which are also identified as less likely to decarbonise.[68] In fact, several triggering effects came together when the France Relance plan was launched: a sharp rise in the price of carbon on the SEQE market,[69] reinforced by the geopolitical crisis in Ukraine.

The consultations per sector organised by the State aim to facilitate the deployment of the necessary investments throughout the production chain

As part of the France 2030 investment plan, the French government has developed a new consultation approach with the industrialists of the 50 highest-emitting sites, which complements the decarbonisation roadmaps,[70] developed by the National Council for Industry at sectoral level. This '50 sites' approach extends the time horizon to 2050, as opposed to 2030 in the roadmaps. It also aims to specify the investments to make at the site and regional levels[71] while ensuring the coherence of the deployment of some technological levers at the industrial zone level (hydrogen, CCS). This consultation among the 50 sites is expected to lead to the signing of ecological transition contracts by mid 2023, listing the investments planned and the aid needed to implement decarbonisation projects.[72] This is a promising approach for supporting a radical transformation of the sites. It proposes to combine financial support for investments and consultations with the various players involved in their deployment. However, to our knowledge, it does not include a component aimed at securing solutions for carrying out and financing the deployment of CO_2 and hydrogen transport infrastructures. Moreover, the deployment of these infrastructures must be part of a broader reflection at the European level.

63 French government. « Dossier de presse : 47 nouveaux lauréats pour les appels à projets décarbonation », 14 March 2023.

64 Which has so far provided financial support of €444 million of a total planned investment of €2.1 billion and a reduction in GHG emissions of 1.8 $MtCO_2$ per year.

65 « Comité d'évaluation du plan France Relance - Deuxième rapport, Chapitre 3. Les mesures de décarbonation de l'industrie ». France Stratégie & IGF, 20 December 2022.

66 The cement production sector received the most aid: 33.3% of the total aid distributed under the two calls for projects excluding heat. The chemical and refining sector also received a significant share of total aid (16.1%).

67 The first analyses do not allow us to conclude on the causal impact of the schemes on investments in decarbonisation and emissions reduction. The evaluations conducted by the team of researchers at the Institut des Politiques Publiques will continue in 2023.

68 Faquet, Romain. « Which Industrial Firms Make Decarbonization Investments? » Directorate General of the Treasury, August 2021.

69 Among the other factors that explain the over-representation of these sectors among the applicant companies, the France Relance plan Evaluation Committee details: with the predominant weight on the criterion of efficiency for the aid allocation *i.e.*, the amount of subsidy relative to the carbon emissions reduction which favours the companies with the highest emissions, or the fact that the investment projects of these sectors, potentially riskier, would benefit more from public support to ensure sufficient profitability.

70 Provided for in Article 301 of the 'Climate and Resilience' law, which established the obligation for all emitting sectors and industries to draw up decarbonisation roadmaps.

71 In particular, Dunkirk (59) and Fos-sur-Mer (13) are mentioned with projects to develop 'green hubs', providing decarbonised technologies to a whole range of industrial activities from energy production to carbon recycling, integrating the connections of all these technologies.

72 These contracts are also intended to feed into the development of strategies carried out with the Ministry of Energy Transition: updating the National Hydrogen Strategy, developing a National Biomass Strategy, planning electricity connections in industrial decarbonisation zones, drafting a National Strategy for Carbon Capture, Use and Storage.

A political agenda to further accelerate the transformation of the industry

Linking the 'ecological planning' process and the update of the National Low-Carbon Strategy for a radical industrial transformation

The National Low-Carbon Strategy is expected to be updated following the adoption of the Energy-Climate Programming Law (LPEC) expected in the summer of 2023. This update will set a new decarbonisation pathway for industry, taking into account the strengthening of emission reduction targets by 2030 under the European Green Deal. This update could be the opportunity to integrate into the SNBC the investments and actions planned by the industry and the State in the framework of France 2030.

Through multi-sectoral modelling, the SNBC update ensures that an energy and climate balance is achieved by 2050. Several recent initiatives are already helping to ensure consistency between the different actions that need to be taken within an industrial territory. Transformation strategies on the scale of an industrial zone with the '50 sites' approach are complemented by the Low-Carbon Industrial Zones approach (ZIBAC, public support for engineering and feasibility studies on decarbonisation at the scale of an industrial zone). Nevertheless, the technological levers envisaged for the four industrial sectors studied in this report imply the use of numerous resources and infrastructures: CO_2 storage capacities and potential associated transport infrastructure, the supply of low-carbon electricity in sufficient amounts to produce hydrogen and the reinforcement of electricity grids. The update of the SNBC will make it possible to identify whether the directions taken by the industrial sector are consistent with the decarbonisation strategies envisaged for other sectors of activity and at the national level.

This modelling work could be linked to a trade-off process when the modelling reveals incompatible sectoral strategies or planned actions (insufficient resources, incompatibility of emission reduction trajectories, etc.). The General Secretariat for Ecological Planning seems to be a relevant institution to lead this process. It is the guarantor of the coherence of the overall strategy and, placed under the Prime Minister, it is the appropriate institution for organising discussions and making the necessary decisions.

The strengthening of international competition for the development of a green industry requires an acceleration of the transformation of the French industry

International competition may have previously been regarded as a factor that slowed the decarbonisation of industry, but several recent changes have made it a factor that accelerates it. On the one hand, at the European level, the agreement for a carbon border adjustment mechanism and the gradual end of free emission allowances aim to both limit the risks of carbon leakage and to accelerate the decarbonisation of European production. On the other hand, international competition, in particular from the United States, has led to the presentation by the European Commission in January 2023 of a Green Deal Industrial Plan which aims to 'enhance the competitiveness of Europe's net-zero industry and support the fast transition to climate neutrality'.[73] This initiative aims to provide an initial response to the U.S. Inflation Reduction Act, which proposes at least $369 billion in federal public investment support.[74] Several other countries are developing investment plans to support the decarbonisation of their industry: China adopted a five-year plan in March 2022, India has set up production incentive programme and Japan has launched a 'Green Transformation' programme.

73 European Commission. « Pacte vert : un plan industriel pour la compétitivité de l'industrie européenne neutre en carbone. », Communiqué, 12 April 2023.
74 Congressional Budget Office estimate, but support could be higher as most of the planned schemes are uncapped. See in particular, Pellerin-Carlin, Thomas. "Think house, not brick: building an EU Cleantech Investment Plan to match the US Inflation Reduction Act", I4CE, February 2023.

CONCLUSION

Estimating the investment needs to decarbonise heavy industry is necessary to implement an industrial policy. The few existing estimates currently provide incomplete information. Therefore, we propose a transparent method to estimate the investment needs at production sites of four industrial sectors, and for different decarbonisation scenarios. Our results highlight the great variability of investment needs around two parameters: (1) the evolution of economic activities and demand for industry products, and (2) the new technologies deployed to ensure low-emission production. These results underline the importance of precisely defining an integrated multi-sectoral strategy to decarbonise heavy industry.

In addition to national GHG emission reduction targets, the international context and carbon price constraints in Europe are driving the acceleration of industry decarbonisation. We show with our investment schedules, which take into account technological and sectoral constraints, that most of the investment needs are concentrated in the next decade.

Industrialists are gradually moving in this direction, supported by the government, which is stepping up its efforts particularly in heavy industry, through the France 2030 investment plan. These initiatives outline the initial trends towards decarbonising industry: supporting the maintenance of domestic production capacity by deploying new technological levers. We identify several levers for action to enable the transformation of the industry. Firstly, make the industrial decarbonisation strategy more explicit and visible, and ensure that it is part of an overall coherence at the national level. Secondly, clarify the model for financing the infrastructure needed to deploy the technologies envisaged (low-carbon electricity, hydrogen transport and CCS). Finally, all of this should be achieved through State-led planning involving the main industries concerned and reconciling industrial and climate policies into one coherent, integrated policy.

LIST OF FIGURES AND BOXES

I4CE is a non-profit research organisation that provides independent policy analysis on climate change mitigation and adaptation. We promote climate policies that are effective, efficient and socially fair. Our 40 experts engage with national and local governments, the European Union, international financial institutions, civil society organisations and the media. Our work covers three key transitions – energy, agriculture, forests – and addresses six economic challenges: investment, public financing, development finance, financial regulation, carbon pricing and carbon certification.

I4CE
INSTITUTE FOR CLIMATE ECONOMICS
Une initiative de la Caisse des Dépôts et de l'Agence Française de Développement

Notes

INSTITUTE FOR CLIMATE ECONOMICS
30 rue de Fleurus - 75006 Paris

www.i4ce.org
Contact: contact@i4ce.org

Follow us