# THE CLIMATE FRIENDLY TRANSITION OF EUROPE'S ENERGY INTENSIVE INDUSTRIES

**Carbon Market Watch Policy Brief**
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# Executive summary

The EU has a long-term climate objective of achieving economy-wide emission reductions of 80-95% by 2050 to avoid dangerous climate change. It is often argued that such deep emission reductions are technically impossible or that they would harm the economy and create unemployment.

In the spring of 2016, Carbon Market Watch therefore asked the Institute for European Studies to look at the feasibility of such emission cuts by 2050 in three of the most important manufacturing sectors in Europe: chemicals, steel and cement. The main findings of the report "The Final Frontier – Decarbonising Europe's energy intensive industries" are summarised in this briefing.

The study illustrates that deep emission reductions, up to -80% or more, are possible in each of the industries considered. This transition will also enable opportunities that can enhance the competitiveness of European industry. However, tapping into this emission reduction potential will not be easy, as most of the low-hanging fruit has already been picked.

Most energy intensive industries face major challenges regardless of the EU's climate commitments. These include capacity surpluses, as well as increased competition with other regions that have competitive advantages through better access to raw materials or larger sized domestic markets. These challenges can, on the other hand, also become an opportunity to focus on the climate friendly solutions that come with co-benefits, which would increase the economic performance of these industries and reduce the reliance on imports.

The economically attractive low-carbon transition will require the combination of three pillars: the process, product, and business-model transformations. The decarbonisation options for the chemicals, steel, and cement sectors are described in more detail in this briefing and in the study.

What is clear is that the necessary transformation of energy intensive industries will not take place in the absence of smart and committed public policies. Governments assistance will be vital to bolster industry innovation through modernisation & rationalisation, the reduction of capital costs on low-carbon projects, market creation for new low-carbon products through public procurement and the avoidance of regulatory misalignment.

One of the more challenging elements of the industrial low-carbon transformation will be how to bring promising low-carbon process technologies to the commercialisation stage. These new process technologies will need to be market-ready by 2030 to allow for deployment across the EU by 2050. They will be capital intensive, but also, due to their pioneering nature, risk intense. The proposed Innovation Fund under the EU's Emissions Trading System (ETS) for the post-2020 period can become an important tool to enable a timely commercialisation of these process technologies.

This briefing ends with five ideas to strengthen the design of the EU ETS Innovation Fund.

[1]This briefing has been produced using the information of the report by the Institute for European Studies (2016), 'The Final Frontier - Decarbonising Europe's energy intensive industries' available here

# Chemical Sector

Since 1990, the chemical sector's greenhouse gas emissions have decreased by almost 60% - from over 300 million tonnes $CO_2$-eq in 1990 to less than 150 million tonnes in 2013. Most of this mitigation is due to reductions in process emissions (such as $N_2O$), but further reductions are still possible.

These reductions are impressive, as the chemical sector managed, at the same time, to significantly increase its value added to the economy through growth in sales value of almost 80% in the 1994-2014 period. The EU internal market is of major importance to the chemical sector, as nearly two-thirds of the chemicals produced in the EU are supplied to other industrial sectors inside the EU.

In the coming decades, there will be a reduced availability of petrochemical feedstocks, in particular naphtha, an issue that will force the European chemical sector to pursue biomass-based replacements for its fossil-fuel based feedstocks. This is predominantly due to the accelerated growth of affordable electric vehicles which will lead to an almost unavoidable disruption in global oil production and a contraction in oil refining in the EU and beyond.

# Achieving deep emission reductions in the chemical sector

The chemical sector, with current emissions close to -60% compared to 1990, comes already close towards meeting the EU's 2050 objectives. However, most of the low hanging fruit seems to be picked. The below sections demonstrate how further deep emission cuts are possible in the petrochemical and fertiliser sectors.

# Decarbonisation of the petrochemical sector

Steam cracking is the most important process to produce basic chemicals, through the cracking of long-chain hydrocarbons into short-chain hydrocarbons. The EU chemical sector and the refineries are strongly integrated and also the feedstock of petrochemical production (in particular naphtha) comes from oil refineries through the refining process.

Two main options for achieving deep mitigation in the production of petrochemicals are described below:

1. **Bio-based chemicals**: The replacement of fossil fuel-based feedstock with biomass-based alternatives.
2. **Circular economy**: The reduction of production volumes of some important petrochemical products through enhanced recycling.

**Changing petroleum based inputs to bio-waste feedstock can eliminate most direct emissions in the petrochemical sector.** Most petrochemicals and equivalent products can be constructed from a bio-based feedstock. However, there can be intense competition for biomass waste from other sectors, such as electricity and biofuels production. Since the chemical sector will be able to generate much higher levels of value added to the economy from biomass waste compared to these other sectors, it should be given priority.

**The transition to a circular economy by fully embracing recycling options in the production of plastics can result in further savings**. Emissions can be reduced through higher levels of resource efficiency and through the circular economy. Increased recycling of plastics could save up to 8 Mt of $CO_2$-eq emissions per year by 2020 and up to 13 Mt by 2025. By 2025, employment could increase considerably by 80,000 direct jobs and 120,000 indirect jobs. Finally, enhanced recycling will address the issue of resource leakage. In 2010, 13 million tonnes of plastic waste were separately collected in the EU but nearly a quarter of that volume was exported overseas.

### Policies that can help support the decarbonisation of the petrochemical sector:

- Introduce product standards (e.g. eco-design) that require an increased use of bio-based chemicals over time to help create demand.
- Replace the current target of renewable energy in transport (through biofuels) by targets to increase the use of biomass waste in the chemical sector.
- Set ambitious recycling goals that will assist in cost-effectively reducing the emissions from virgin plastic production in the short term.
- Support the development of EU-wide biomass-waste supply chains from agriculture and forestry sectors to the chemical sector.

# Decarbonisation of the ammonia and fertiliser sector

Ammonia is one of the most important basic chemicals and its most common use is in the production of fertilisers. Making ammonia consists of two major stages: the manufacturing of hydrogen and the synthesis of ammonia. The latter process, through which nitrogen gas and hydrogen gas are reacted together to create ammonia, is called the Haber-Bosch process. The whole process requires the usage of a feedstock; in Europe, mainly natural gas is used.

Process emissions from the production of ammonia stood at almost 27 million tonnes of $CO_2$-eq in 2013, representing around 20% of all greenhouse gas emissions from the chemical sector. Emissions related to ammonia production were 16% lower in 2013 compared to 1990. Further deep emission reductions will have to come from technological and business model innovations, such as:

1. **The electrochemical production of ammonia** without the use of fossil fuels.
2. **The use of bio-based waste** in the production of fertilisers.
3. **The reduction of fertiliser use** itself, while keeping the same crop yields.

**New electrochemical technologies can radically alter the production process of ammonia and related emissions**. New types of electrolysers - splitting water into hydrogen gas and oxygen - in combination with cheap low-carbon power generation can make this process attractive, especially if natural gas or carbon prices would significantly rise in the future. These new processes can support the transition to high levels of renewable energy in the EU, through the application of demand response and energy storage in conjunction with advanced electricity-based ammonia production.

**Fertilisers can be produced from bio-based waste through nutrient recovery from waste streams**. This would enable the substitution of at least 10% of nitrogen and phosphorus with recycled components in commercial fertilisers.

The most important mitigation option is to **reduce the use of fertilisers itself**, while keeping the same crop yields. This would also result in other environmental benefits such as a reduction in the eutrophication of waters. **Direct nitrogen fixation** allows plants to obtain nitrogen directly from the atmosphere. The first trials of this technology resulted in savings of around 50% of ammonia-based fertiliser against increased crop yields.

The fertiliser sector could also be reshaped into one that not only provides fertilisers to the agricultural sector, but one that aims to provide a wide range of services to the agriculture sector towards achieving higher crop yields. New agro-technologies such as **technological optimisation of fertiliser use** (through targeted micro dosing) will significantly reduce the need for ammonia in fertiliser production while leading to higher productivity.

## Policies that can help support the decarbonisation of the fertiliser sector:

- Ensure a higher carbon price in the EU ETS to incentivise the uptake of electrochemical technologies that uses renewable power generation.
- Set strict limits on the use of nitrogen fertilisers to reduce the nitrogen pollution from agriculture.
- Promote the use of bio-based waste by mandating a certain percentage of the marketed fertilisers to use recovered nitrogen and phosphorus.

# Steel sector

In 2013, the total EU emissions from steelmaking were 166 Mt $CO_2$-eq. The EU steel industry saw a total emissions decrease of 39% between 1990 and 2013. Recent decarbonisation efforts have contributed to the mitigation, but the economic recession and closure of EU steel plants also played a significant role in the decrease of overall emissions.

The steel industry is currently struggling to cope with low steel prices due to overcapacity and strong international competition, particularly from China. The Chinese overcapacity is estimated to be almost twice the total EU yearly production, while the European steel production (including Turkey) accounted for 14% of the world's overcapacity of steel in 2013. This makes Europe the second largest contributor to produced overcapacity after China (50%).

Primary production of crude steel is normally performed through the blast furnace – basic oxygen furnace (BF-BOF) route. In the EU, the BF-BOF route produces 1,888 tonnes $CO_2$ per tonne of steel produced. Secondary production is conducted in an electric arc furnace (EAF), where steel scrap is melted into new products. As steel is 100% recyclable, the main resources needed are steel scrap and energy. Scrap-EAF steel production mills have lower environmental impact and investment costs. In the EU, the EAF route produces 0,455 tonnes $CO_2$ per tonne of steel produced.

BF-BOF production currently accounts for around 61% of EU crude steel production, and EAF for the remaining 39%. The scrap-EAF route emits around $1/4^{th}$ as much $CO_2$ as the BF-BOF route.

# Achieving deep emission reductions in the steel sector

The emission reductions in the EU steel industry are already almost 40% below 1990 levels, and hence halfway towards -80% by 2050. Three approaches that can enable further deep emission cuts in the steel sector by 2050 include:

1. Low-carbon technologies in the **production process**.
2. **Production innovations** by moving into high-value-low-volume products.
3. A **business-model transition** that uses recycled scrap for secondary steelmaking.

Substantial emission reductions in the steel sector can be achieved through breakthrough technologies in the **production process**. The most important initiative in the EU over the past decade has been the ULCOS programme – an initiative aiming to reduce $CO_2$ emissions from steelmaking with at least 50% per tonne steel produced.

**The most advanced process innovation in the EU is HIsarna**. The HIsarna route can use the raw materials directly in the process, without requiring refinement of the coal and iron ore. The process needs significantly less coal usage and can reduce $CO_2$ emissions by 20% compared to current blast furnace technologies. CCS can relatively easily be applied at a later stage, resulting in reductions of around 80%. The HIsarna process has been successfully tested at the first pilot plant at Tata Steels's plant in Ijmuiden (the Netherlands). The goal is to build a first full size demonstration plant and have it operational between 2020 and 2025.

**In April 2016, three Swedish actors launched an initiative for further development of advanced Direct Reduced Iron (DRI)**. The project uses hydrogen instead of natural gas as the reactant for the DRI. The technology is expected to be deployed in Sweden around the year 2030. The cost of hydrogen production is one of the major challenges of the project, and the initiative therefore aims to produce hydrogen through electrolysis, which requires extensive amounts of electricity. This could be provided by electricity that is currently being exported out of Sweden.

**Product innovations** could help reducing emissions and at the same time provide a great business opportunity to the EU steel industry. **The steel industry could increase profits by moving into high-value-low-volume products**. High strength steel enables decreased steel volume and weight in the final product, which could both increase the product value for the customer and at the same time help decrease the overall environmental footprint. Nano-technologies can create stronger steel so that less volume of the material is needed in the final product. This is especially relevant for the automotive industry that is facing the possibility of a major transformation, with the rapid development of heavier electric vehicles. Saving weight through lighter and stronger steel could extend the range of electric vehicles.

Finally, **a paradigm shift**, from blast furnace steel to increased electric arc furnace production from scrap, would significantly help reduce emissions. The availability of renewable energy can be expected to grow during the upcoming decades, lowering the indirect emissions from electric arc steel production further. At the same time, EAF steel production can be integrated with high levels of variable renewable energy due to the smaller size of an EAF mill that would make it easier to balance steel and power production.

**The EU is the world's biggest scrap exporter, and instead of importing iron ore and coke for primary steelmaking, the exported scrap could be used for secondary steelmaking instead**. The scrap-EAF route would make the EU steel producers less dependent on imports, substantially decrease emissions and could be key to bringing the EU steel industry into the circular economy. By increased downstream integration, the steel industry could change its business model towards leasing steel products instead of selling them. Hence, the steel industry would also remain in control of scrap recycling, and would no longer solely be selling steel, but instead offer a valuable service to society.

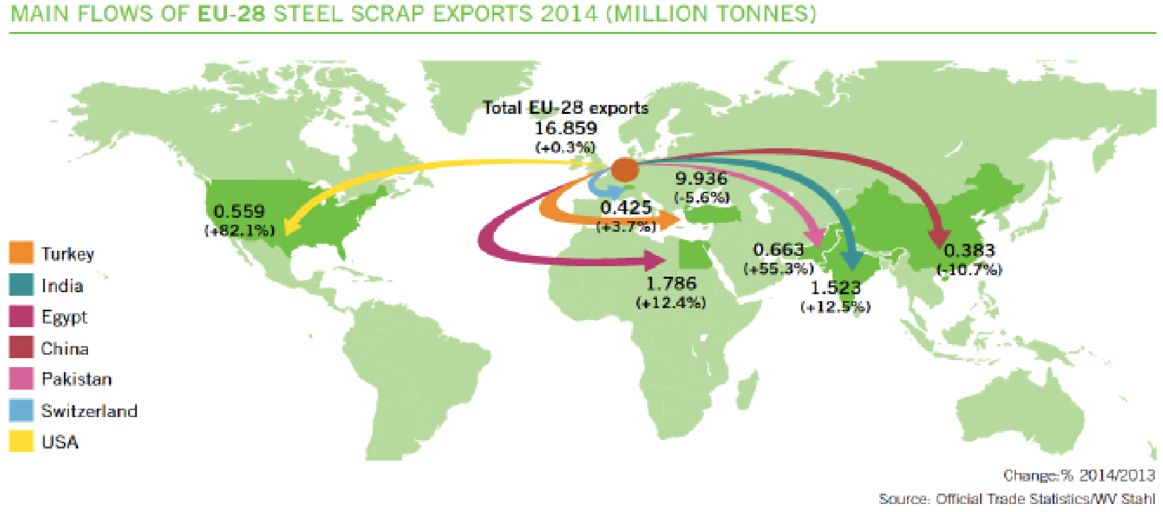


**Figure 2.8. EU steel scrap exports in 2014.**
**Source: Bureau of International Recycling (2015).**

## Policies that can help support the decarbonisation of the steel sector:

- Make more support available for low-carbon process technologies, for example through a larger EU ETS Innovation Fund.
- Support advanced research development for more cost-efficient sorting and recycling of scrap.
- Increase availability of funding schemes for improvements of the industry's value chain management.
- Encourage the steel industry to switch towards increased scrap-EAF production. EAF steel production currently has higher total regulation costs than BOF steel production, including from the EU ETS. Steel manufacturers who seek to transition from blast furnace production to electro-steel production could be aided to use renewable power, while the protection of blast furnace steel production through free allocation could be lowered.

# Cement sector

The EU cement industry's greenhouse gas emissions decreased by almost 40% between 1990 and 2013 from 164 million tonnes $CO_2$-eq in 1990 to almost 103 million tonnes in 2013. The reductions occurred mainly due to lower production levels.

More than half of the cement industry's $CO_2$ emissions are process emissions from the clinker production process, where limestone is heated to produce lime. Reducing the ratio of clinker in the cement produced is, therefore, an important measure for reducing greenhouse gas emissions.

The main process routes for cement manufacturing are the dry, semi-dry, semi-wet and wet kiln processes. The latter two are significantly less energy efficient. Yet, around 10% of cement in the EU is still produced using semi-wet and wet kilns.

At the moment, cement production outside the EU often has a better energy performance than the EU plants. Indian cement production, in particular, is 20% more energy efficient than the European. This is partly explained by the fact that most of the cement production investments in new capacities in emerging economies are likely modern.

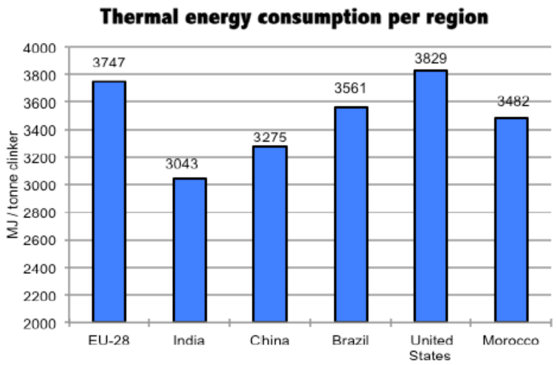


**Figure 3.4. Thermal energy consumption per region for grey clinker production. [MJ/t clinker.] Source: World Business Council for Sustainable Development (2015).**

# Achieving deep emission reductions in the cement sector

The EU cement industry still has ample opportunities to reduce its emissions. Achieving deep emission reductions in the cement sector will require a portfolio of different approaches:

1. **The phase out of older production technologies**.
2. **Process innovation** such as the use of Calcium looping carbon capture and storage.
3. **Clinker substitution.**
4. **Downstream demand reduction** by reducing the amount of concrete or cement needed.

**The older production technologies will have to be phased out**. Closing older and inefficient production sites, especially as the market has a production surplus, and modernising other plants will make the sector more resilient against "carbon leakage".

**The use of the calcium looping Carbon Capture and Storage (CCS) technology has the potential to capture more than 80% of the cement production emissions**. It would use solid CaO (lime)-based sorbents to remove $CO_2$ from flue gases, producing a concentrated stream of $CO_2$ suitable for storage. When integrating the process into cement production, the use of the spent sorbent (lime) can result in nearly 50% reductions in the energy required for cement production. Due to its close affinity with clinker production itself, it is one of the few (if not only) CCS options with the potential to be economically viable even at a low carbon price. The Calcium looping carbon capture is currently being tested at a cement plant in Taiwan with a $CO_2$ capture cost of around US$40 per tonne.

**There is still significant potential for clinker substitution in the future, which is an important option to reduce process $CO_2$ emissions in cement production**. Currently, the most common clinker substitutes include granulated blast furnace slag, fly ash material from coal power production, and even limestone itself. In the future, enhanced landfill mining (ELFM) in the EU can produce an interesting clinker substitute. Full implementation of ELFM in the EU could reduce emissions by 3 to 11 Mt of $CO_2$ per year. Another, very promising, example is replacing clinker using three relatively abundant alternative resources (Belite, Ye'elimite and Ferrite). The $CO_2$ emissions in the production process are expected to be up to 30% lower compared to traditional clinker.

**Innovations that reduce the amount of concrete needed or the amount of cement needed to bind concrete will have a direct impact on the total emissions of the cement sector**. The multiple benefits of advanced material science, such as nano-technology, make it an area that can be prioritized with the goal to further reduce $CO_2$ emissions through optimalisation of the use of cement in concrete and mortars. To further reduce the consumption of cement, the design stage for infrastructure and buildings will have to further prioritise material and resource efficiency.

## Policies that can help support the decarbonisation of the cement sector:

- Close old cement units and reduce the capital costs for capital-intensive modernisation investments through government backed loan guarantees.
- Create markets by using the power of public procurement. For example, new large-scale infrastructure projects in the EU could make the use of low-carbon cement obligatory.
- Timely develop product standards that allow the safe application of new cement types to allow market uptake as early as possible.
- Invest research & development in downstream innovation leading to lower consumption of (higher quality) concrete.
- Support the development of advanced training and tools for architects and civil engineers, with the aim of minimising the use of inputs such as concrete, while giving buildings the same (or improved) levels of strength and resilience.
- Support the development of supply chains for alternative inputs into the production process.

# Designing the EU ETS Innovation Fund

As part of the ongoing legislative process the revise the EU ETS rules for the post-2020 period, the European Commission proposed to set aside 400 million emission allowances in an Innovation Fund. The auctioning of these allowances could make up to €10 billion[2] available for innovative demonstration projects in the energy and industry sectors. Five ideas to further strengthen the design of this Innovation Fund:

1. **Increase the amount of money available for industrial innovation by enlarging the Innovation Fund** (e.g. by setting aside more emission allowances than the currently proposed 400 million for innovation).
2. **Introduce technical criteria for access to the fund**. These can include performance based criteria to assess different technologies, such as at least 20-25% GHG mitigation compared to current best-available-technologies for industrial installations, or a significant reduction in the Levelised Cost of Electricity (LCOE) for energy technologies. Furthermore, to increase the likelihood of the breakthrough technology becoming widely adopted, it is relevant to include “co-benefit” criteria, such as increased productivity or other cost savings.
3. **Develop and use a financing toolbox regarding the disbursement of the fund**, due to the diverse nature of sizes, types and risk-profiles of likely projects. This toolbox could consists of loans and grants. Grants, including equity participation, should be used with projects that carry a high project risk. Loans, including loan guarantees, can be more appropriate in case companies have difficulty with balance sheet financing or to reduce the cost of raising (additional) capital.
4. **Introduce a lean management structure** (using highly skilled and experienced management) **and streamlined administrative procedures** as regards the governance of the Innovation Fund. This limits the administrative burden for participating companies and allows for fast-track decisions during the selection and implementation phase of the projects.
5. **Help ensure adequate and timely co-financing by Member States**, by considering a State Aid waiver or fast track procedure, under certain conditions, for example. Member States should also be able to use a broad range of tools to provide co-financing, such as the use of public procurement to advance market access.

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[2] Assuming a carbon price of €25/tCO2



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