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# International cooperation for decarbonizing energy intensive industries – The case for a Green Materials Club

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## Abstract

Basic materials are traded globally and responsible for roughly 22 % of global carbon emissions. It is technically possible for the energy intensive industries (EIIs) that produce these materials to reach zero emission, but at a cost. So far, the fear of carbon leakage has been a barrier for implementing ambitious domestic climate policies that targets theses globally traded commodities. The introduction of border carbon adjustments (BCAs) for levelling the global playing field has been suggested to ameliorate these concerns. However, another way is to focus more on innovation, adopting green industrial policies and to cooperate internationally for developing technologies for net zero EIIs. In this chapter we explore the opportunities for enhanced cooperation for enabling deep decarbonization for EIIs and how that links to BCAs. We argue for establishing a green materials club focusing on long-term technology development and discusses limitation and opportunities for this approach. A green materials club could ease the conflicts between trade and ambitious climate policy and complement BCAs.

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## 1. Introduction

The Paris Agreement from 2015 states that the world should limit the increase of the global mean temperature to "*well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C*" (UNFCCC 2015). According to the IPCC (2018), this means that global greenhouse gas emissions (GHGs) need to be reduced to zero between 2050 and 2070 and thereafter become negative (IPCC 2018).

Reducing GHGs down to zero is especially challenging for the energy intensive industries (EIIs) that produces basic materials such as steel, cement, aluminum, petrochemicals and fertilizers. These basic materials account for approximately 22% of global greenhouse gas (GHG) emissions (Bataille 2019). Technically, it is possible to reduce emissions from these industries to zero but this requires major innovation and investments efforts over a sustained period of time (Bataille et al 2018). A challenge for policy-making is the national responsibility for implementing climate policy enshrined in the Paris Agreement as opposed to the global nature of the markets that these industries operates on. Steel, aluminum, petrochemicals, fertilizer and to a certain extent also cement are all traded on a price competitive global market. Being both carbon and trade intensive, differentiated carbon prices in various part of the world can lead to relocation of industries to countries with less stringent climate policy, so called carbon leakage (Antoci et al 2021)**.** The concern for carbon leakage has been a major barrier even in climate ambitious countries for implementing long-term and effective climate policies targeting EIIs (Åhman et al 2017). As an effect, the global GHG emissions from EIIs have seen a steady increase the past 20 years despite global climate targets (Crippa et al. 2019).

One of the main propositions to solve the conflict between global trade and differentiated national climate ambitions has been to propose the introduction of border carbon adjustments (BCAs). An adjustments or tax at the border has the potential to equalize the carbon costs for traded carbon-intensive commodities. The discussions on whether a BCA is compliant with the principles of the World Trade Organisations (WTO) has been going on for a while and most legal analysts agree that, if designed right, a BCA could very well survive a challenge in the WTO (Cosbey et al. 2019, Mehling et al. 2019, Dröege and Panezi 2021). However, the WTO is not the only international treaty that we need to consider here. In parallel, the United Nations Framework Convention on Climate Change (UNFCCC), upon which the Paris Agreement builds on, introduces a number of principles in Article 3 that are relevant here. Article 3.1 states that all parties have a "*common but differentiated responsibility according to their respective capabilities*" (CBDR). In practice, this means that industrialized countries (mostly OECD countries) should take a greater responsibility and mitigate GHGs faster compared to developing countries. Directly related to trade, Article 3.5 in the UNFCCC further states that "*measures taken to combat climate change, including unilateral ones, should not constitute a means of arbitrary or unjustifiable discrimination or a disguised restriction on international trade*" (UNFCCC 1992). From an UNFCCC perspective, BCAs are thus not forbidden but neither endorsed (Bodansky et al. 2017). The discussion of what constitutes acceptable trade adjustments should thus be agreed upon both in the WTO and within the UNFCCC where it has not been resolved yet and continues[2].

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[2] The UNFCCC is especially concerned about negative impacts for developing countries and at COP17 in Durban, India tried to introduce a text that would expressively forbid trade measures, but this was not accepted (Bodansky et al. 2017).

Associated with BCAs is the idea of establishing "climate clubs" to motivate the adoption of more ambitious climate policies by trading partners. The idea of a climate club is that a group of likeminded climate ambitious countries join together and impose a BCA on trade for non-members (Nordhaus 2015, Victor 2011, Evans and Sesmero et al 2021). The benefit of joining the club by implementing ambitious national climate legislation would be to *avoid* a BCA, free trade thus being the "club good". This would, according to the proponents, create a momentum where more countries join and adopt binding ambitious climate targets as the benefits of joining the club (free trade) outweigh the cost of domestic climate policy. Most ideas around climate clubs centers on imposing trade restrictions as the main leverage point for motivating countries to join. However, as shown by Sabel and Victor (2017), Hovie et al. (2016), Green (2017), and Prakash and Potoski (2007), the idea of Climate Clubs could also include more nuanced and positive ideas on what could constitute a club good such as sharing intellectual properties rights, free access for renewable energy or simply a good reputation.

In this chapter, we explore the potential for developing a "green materials club" with an aim to support the adoption of green industrial policies for deep decarbonizing of EIIs as a part of the global climate policy framework. Throughout this chapter, we use the EU to exemplify the challenges that come with high climate ambitions and decarbonizing trade exposed sectors. The EU is a frontrunner in climate policy and has also since the start of UNFCCC been actively supporting international cooperation in climate mitigation technologies.

In section 2 we review EU climate policy and trade and discuss which commodities are affected by more ambitious climate targets. In section 3, we review how EIIs have been dealt with in the UNFCCC negotiation process so far and in section 4 we describe both the technical and institutional barriers for deep decarbonization. The elements of a green industrial policy targeting EIIs and deep decarbonization is presented in section 5. With this framework for a green industrial policy we analyze the opportunities for developing a green materials club as part of a "cooperative sectoral approach" within the Paris Agreement in section 6. Section 7 summarizes and concludes.

## 2. EU climate policy and trade of energy intensive commodities

The EU has been a strong supporter of ambitious climate policy and has reduced its emissions by 21% below year 1990 levels in 2018 (EC 2021a). The risk of carbon leakage has been on the agenda all along and the EU has introduced several measures to protect vulnerable industries. Measures include free allocation of emission allowances within the EU ETS, exemptions from paying levies for renewable electricity expansion, partial exemption from energy taxes, and financial support for increasing energy efficiency (Åhman and Nilsson 2015). This have worked so far as no strong evidence for carbon leakage from EU industries has been found (Venmans et al 2020, Antoci et al 2021). The downside of this strategy of sheltering industries from the direct and indirect carbon costs caused by climate policy is that we have only seen marginal emission reductions in industry and that the strategy has reduced the incentives for industry to invest in long-term deep decarbonization options (Åhman and Nilsson 2015).

The EU has recently agreed upon a climate law that includes a strict 55% emission reduction target by 2030 and a long-term strategy for achieving carbon neutrality by 2050 (EC 2021b). As the EU is now aiming for carbon neutrality within the next three decades, a new policy strategy is required that will induce industry to make the necessary investments for deep decarbonization while at the same time protect them from carbon leakage. In December 2019, the "European Green Deal" (EC 2019) was agreed upon including several initiatives to support innovation and development for decarbonizing energy intensive industry such as e.g. developing lead markets for green materials and support for large-scale demonstration facilities (EC 2021b). In order to protect against carbon leakage, the Green Deal also proposes a "Carbon Border Adjustment Mechanism" (CBAM) (EC 2019). The aim of the CBAM proposal is to mitigate the risk of carbon leakage but also to motivate trading partners to adopt more stringent climate polices (EC 2020a). The actual design of the CBAM is being negotiated and is expected to be presented in June 2021. Below we exemplify the conflict between trade and climate ambitions by analyzing the trade of carbon intensive commodities to and from the EU28 in 2018.

## 2.1 Trade, embodied carbon and carbon costs in the EU

The risk of carbon leakage is not equal for all traded commodities and depends on the carbon intensity of the traded commodities, the volumes traded and which trading partners. The EU CBAM will only apply to selected sectors that are deemed to be at high risk of carbon leakage (EC 2020a). In this section we analyze the trade volumes, the flows of embodied carbon and the potential effects of a carbon price adjustment at the border for the most likely carbon-intensive candidates such as steel, cement, chemicals and aluminum in order to get a better understanding of which sectors that matters.

In Figure 1, the traded volumes and the embodied carbon for the selected commodities exported from or imported into the EU-28 is given and in Figure 2, we show the share that an assumed carbon price of 50 Euros/ton$CO_2$ would have compared to the traded export value. These two figures gives us a hint on how much the trade of these materials and their embodied carbon matter for EU climate targets and how exposed these materials are to increasing carbon prices.

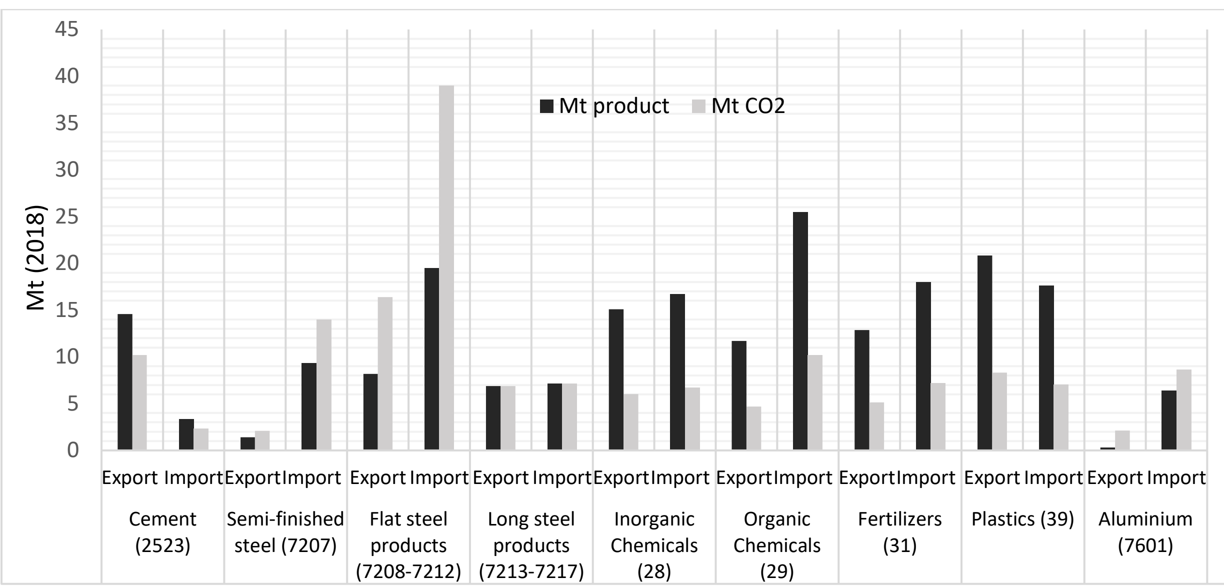


**Figure 1 Import to and export from EU28 in Million tons (Mt) by 2018 and respective associated $CO_2$ emissions by selected product categories (Combined Nomenclature) Sources: EC 2020b. Assumptions on embodied carbon in Annex 1.**

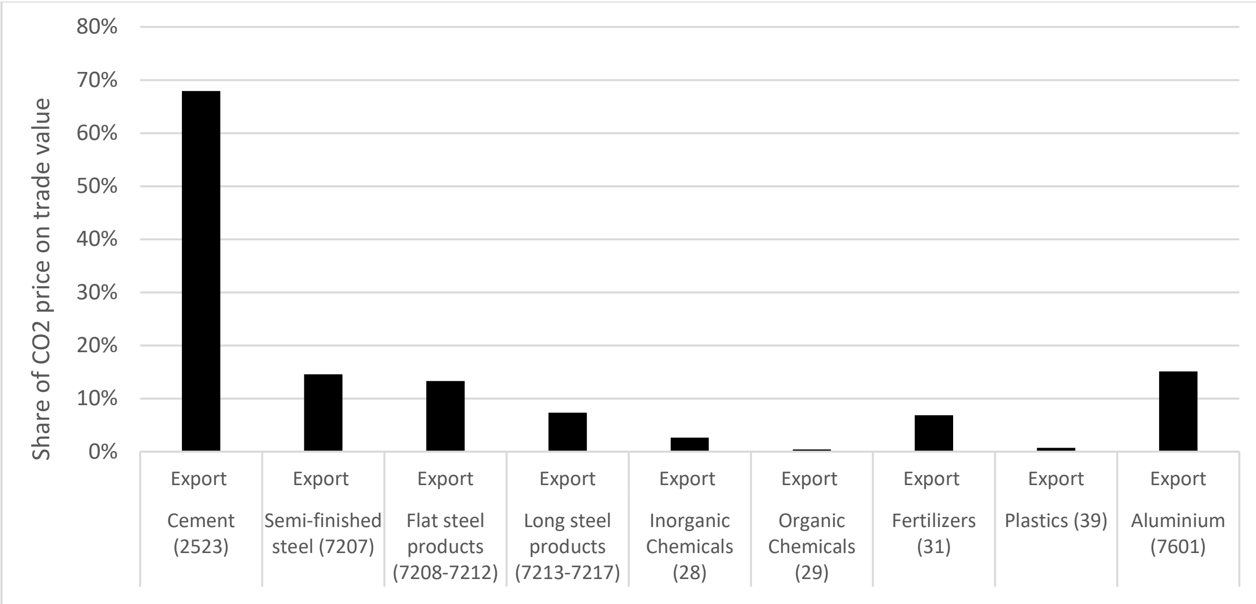


**Figure 2. Impact of a $CO_2$ price of 50 Euros per ton of emitted $CO_2$ on selected products (CN classification) on trade value by 2018.Source: EC 2020b. Exported value and assumption on embodied carbon in Annex 1**

Cement is only traded to a limited degree due to high transport costs compared to the relatively low sales value. The limited imports of cement come mainly from neighboring countries such as Turkey, Ukraine and Belarus (Cembureau 2020). The export of cement is substantially larger compared to the imports (see Figure 1) with exports mainly to USA, Ghana and Cameroon (Cembureau 2020). As can be seen in Figure 2, cement would be highly affected by a carbon price and a major effect would come from the cement industries ability to export.

Steel, in various grades, imports 60 Mt of embodied carbon from mostly Russia, Turkey and China (EC 2020b) and exports 25 Mt of embodied carbon. The carbon balance for steel is especially uneven for semi-finished steel. This is an example of carbon leakage, as the carbon-intensive step (the reduction of iron ore) is done in regions with less strict climate policy, such as Russia, and then the intermediate product (e.g. sponge iron/direct reduced iron (DRI)) is imported to the EU for continued steel making. Steel is relatively exposed to increasing carbon costs, which for a carbon price of 50 Euros would range between 8 and 15% of total value (Figure 2).

Aluminum has a high sales value and is easily transported and is thus is extensively traded. Nearly all aluminum consumed in the EU is imported from countries with access to low-cost electricity (frequently hydropower), as this is the main input to aluminum production. The import of aluminum is in these cases beneficial from a climate point of view as the EU imports the majority of its aluminum from regions with lower $CO_2$ intensities of the electricity such as Norway and Iceland (EC 2020b).

Chemicals has a relatively even import/export balance of embodied carbon (Figure 1) and is, with the exception of fertilizers, less affected by carbon pricing (Figure 2). This can be explained by the high value of chemical products and the comparatively lower emissions associated with the production. Note here that the emission associated with the feedstock in itself that will be emitted when the waste is eventually combusted is not included in the embodied carbon. Chemicals are a special case when it comes to trade and the risk of carbon leakage. The carbon price matters but access to feedstock (from refineries or low-cost natural gas) is more crucial.

If we summaries all the imported and the exported embodied carbon in trade in Figure 1, we find that the EU28 imports more embodied carbon than it exports, 102 Mt $CO_2$ versus 61 Mt $CO_2$ respectively. Compared to the total EU emissions of 4,294 Mt$CO_2$eq in 2018, the net import of embodied carbon (41 Mt $CO_2$) from these selected commodities is relatively marginal (less than 1% of the total $CO_2$ emissions). Taking into account all imports of consumer goods from outside of the union, the EU estimates that a total of ~500 Mt$CO_2$eq/year is avoided (Eurostat 2021). The amount of embodied carbon in consumer goods is thus substantially higher. However, consumer goods have much lower carbon intensity (carbon value/sale value). They are thus not that sensitive to increasing carbon costs and not at risk of carbon leakage.

### 2.2 Future imports and exports of low-carbon commodities to the EU

In the longer-term, it is not always obvious or advisable that energy-intensive commodities are produced at the current volume in the EU. Older industrial regions with large energy-intensive clusters have historically been developed around strategic resources such as coal as in the case of Ruhr area in Germany, or hydroelectricity as in the case of aluminum production in Iceland and Norway. Access to renewable electricity is a key future resource for the deep decarbonization of EIIs. In a long-term perspective moving production to countries with higher potentials for biomass or renewable electricity could be beneficial for climate mitigation and national comparative advantages for EIIs could change dramatically. Countries and regions with favorable conditions for developing low-cost renewable electricity are, for example, Australia, Saudi Arabia, Northern Africa, and Chile (Bogdanov et al. 2019; IRENA 2019). The need for free trade of green commodities to enable a global decarbonisation of EIIs needs also to be considered the discussion on EU industrial policy, trade and climate change.

New intermediate energy-intensive commodities based on access to renewable electricity are emerging today such as green iron (DRI), green ammonia, and green hydrogen. Currently, several oil producing states in the middle east are today exploring the opportunities to expand exports of green hydrogen/ammonia as a strategy to move away from an increasingly unreliable oil market (Fattouh and Sen 2021). Ammonia and hydrogen based on renewable electricity produced in countries with large renewable potential can be used as a future feedstock for fertilizers and chemicals and compete with fossil alternatives in scenarios with low electricity prices (Gidey et al. 2017; Armijo and Philibert 2019). Another example would be to trade DRI (direct reduced iron) from countries with good renewable resources to countries with downstream steel processing (e.g. rolling and finishing). Dielen et al. (2020) make the case for a shift from exporting iron ore to exporting DRI in Australia based on a large domestic potential for renewable electricity. A challenge in the future will be to facilitate trade in commodities from geographies that are beneficial for the climate (e.g. reducing iron in renewables rich regions of the world) and then to separate trade in green commodities from “brown” commodities. Free trade for green goods would benefit climate but as can be seen from the lack of progress with the Green Goods Trade Agreement (Melo and Sollder 2021) and from the current trade conflicts on renewable energy (Monti 2021) this is not yet the case.

## 3. The UNFCCC negotiations related to the EIIs and carbon leakage

### 3.1 Burden sharing and sectoral approaches in the Kyoto architecture

For the first commitment period, the Kyoto-protocol (2008-2012), the differentiation in Article 3 meant that non-industrialized countries had no reduction commitments whereas industrialized countries had. This “burden sharing principle” led to a heated discussion on the risk of loss of competitiveness and carbon leakage for the energy-intensive industries, i.e. that increasing costs of carbon emissions would lead to a shift in production away from industrialized to developing or transitional countries, see e.g. (Dröge et al 2009, Renaud 2008).

In the discussions for the commitment period after the Kyoto-protocol (>2012), several initiatives were put forward in the negotiations on how to deal with these industries. These initiatives had in common that they targeted specific sectors instead of the whole economy, so called "sectoral approaches". In Table 1 below an overview of these sectoral approaches tried in the negotiations is given. The approaches are grouped according to whether they were primarily linked to *carbon trading*, *technology development*, or *policies and programs* and how the issue of differentiated responsibility was dealt with in the proposals.

**Table 1. Summary of proposals and initiatives with a sectoral focus pre-COP 15. Adapted from Åhman et al. 2017**

| Sectoral Approaches linked to : | Proposals | Differentiated responsibility (Article 3.1 CBDR) | Status |
|---|---|---|---|
| **Carbon Trading** | EU-sectoral crediting | Efforts required by developing countries (15-30% below BAU) | Failed |
| | New Market Mechanisms (NMMs) | Undefined – varying and voluntary | Survived partly via the NDC concept |
| | Sectoral-CDM | All resp. on industrial countries (Kyoto style) | Failed at the time but discussed again. |
| **Technology development** | Japanese sectoral approach ("carve out" model) | No differentiation at all | Failed |
| | Asia Pacific Partnership (APP) | No differentiation as no targets (only info sharing) | Abandoned, but never part of UNFCCC process |
| **Policies and programs** | SD-PAMs (Sustainable Development –Policies and Measures) | All responsibility on industrialized countries (Kyoto-style) | Not accepted by Annex-1 but resembles NAMAs and NDCs |
| | National Appropriate Mitigation Actions (NAMAs) | Undefined-varying and voluntary | A part of NDC concept |

For more details on the various approaches, see Åhman et al. (2017), Meckling and Chung (2011) or Schmidt et al. (2008).

Some industrialized countries (EU, Japan and the US) suggested several sectoral approaches that meant that developing countries should shoulder some, or even equal, mitigation responsibility compared to industrialized countries for decarbonizing the targeted sector. The EU based their suggestions mostly on linking sectoral approaches to carbon trading with some differentiation between Annex 1 and non-Annex 1 countries whereas both Japan and the US favored sectoral approaches linked to technology development and with no differentiation such as the Japanese "carve out model" and Asia Pacific Partnership (APP). Developing countries (non-Annex 1) put forward suggestions (mostly via South Africa) that focused on broader development issues and increasing opportunities for identifying and attracting international climate financing (SD-PAMs, then later NAMAs).

All proposals had their own interpretation of how respective *differentiated responsibilities* should be viewed in the post-2012 agreement. The Japanese technology oriented "carve out" model or the EU's ideas of a sectoral crediting mechanism with "no-lose targets" for non-Annex 1 were never accepted by the relevant parties as the sensitive issue of what is a fair distribution of responsibilities and costs was not resolved. In the negotiations up to Copenhagen 2009, non-Annex 1 countries at the time could not accept any share of the mitigation responsibility as was suggested both by the EU, Japan and the USA and all sectoral approaches for "levelling the playing field" were rejected in the post-Kyoto negotiations

(Åhman et al. 2017). Approaches linked to policies and programs have survived in various forms in the Paris Agreement as the voluntary effort sharing principle resembles the bottom-up approach in the Paris Agreement.

### 3.2 The Paris Agreement and need for greater global cooperation

When the Paris Agreement was signed in December 2015, this marked a shift in global climate governance. The top-down architecture[3] in the Kyoto-protocol was abandoned. The Paris Agreement instead rests upon a bottom–up and voluntary architecture. This means that the Paris Agreement sets the overarching target (1.5 to 2°C) but leaves it to each country to set their own nationally determined targets with the overarching idea that they should respect the principles of the convention. With no legally binding targets, the architecture of the Paris Agreement depends on deeper cooperation among parties for being effective (Keohane and Victor 2016). An idea for the Paris Agreement to strive for is to coordinate bottom–up initiatives with a strategic aim and build upon "*a series of small wins that is guided by a unifying big dream*" (Urpelainen 2013). Complementing the international climate regime with a technology-oriented agreement could strengthen this cooperation and deliver immediate "small wins" to participating countries, see e.g. Lessman and Edenhofer (2011). For the EIIs, the risk of carbon leakage is however still very present in the Paris Agreement as the nationally determined climate targets still should reflect "differentiated responsibilities". However, the Paris Agreement opens up more flexibility in interpreting the CBDR principle. The discussions on global cooperation for advancing mitigation is taking place within the scope of Article 6 in the Paris Agreement and includes much of the negotiations on carbon trading and earlier ideas on cooperation based on a wider sectoral basis. The details of how to operationalize article 6 is currently still being negotiated.

## 4. Pathways to deep decarbonization of EIIs

The Paris Agreement has meant a shift in focus for the EIIs and put the spotlight on the challenges of reducing GHG emissions to essentially zero within the next 30 to 40 years. Several approaches need to be pursued simultaneously including increasing recycling, circularity and material and energy efficiency along the whole value chain, but zero emission cannot be attained without technology innovation to reduce the emissions from the energy and emission-intensive production process itself. A limited number of technological options for producing basic materials with zero carbon footprint are currently explored. The changes necessary for deep decarbonization of EIIs are not about replacing specific technical components but requires technological changes to the very core production processes and will thus be systemic, i.e. will require changes to all surrounding systems that support this technology such as infrastructures, regulations and market regimes. All of these options need public support, especially to support RD&D efforts to demonstrate functionality and to reveal the true production cost in the coming 5 to 10 years (Bataille et al. 2017; Napp et al. 2016).

The technical options available for a deep decarbonization in industry can be structured as:

(i) *Electrification:* Avoiding fossil energy/feedstock by shifting the production process to the use of renewable electricity, either directly or via e.g. hydrogen

(ii) *Biomass:* Replacing fossil energy/feedstock with the various types of biomass derived energy carriers or feedstock

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[3] Top-down architecture: $CO_2$-targets and timetables set centrally by the COP for all parties; Bottom-up architecture: parties defines their own $CO_2$-targets and timetables based on their "respective capabilities"

(iii) *CCS/CCU:* Maintaining the fossil-based production process but reducing emissions by adopting carbon capture and storage/utilization technologies

Electrification is currently the option with most optimism around. This optimism has been driven by the rapid decline of renewable electricity costs the past 10 years (IRENA 2019). The view that the techno-economical potential for expanding renewable electricity production is less limited compared to expanding biomass use or adoption of CCS at large scale (Lechtenböhmer et al. 2016). CCS has still some rationale for e.g. cement production or in regions with poor renewables potential but has suffered from poor acceptability in the countries where actual investments have been realized. This has resulted in wavering political support, economic uncertainties and stalling investments (Åhman et al 2018). Biomass will be needed as part of the solution for almost all industrial sectors but the amount of available biomass for industry will be limited if sustainability is to be taken seriously. How much global bioenergy can be produced under sustainable conditions is still being debated (Wang et al. 2019).

Examples of systemic shifts in the energy-intensive industry are the replacement of blast furnaces with a new system around hydrogen direct reduction for steel (Vogl et al. 2018), shifting from fossil feedstock to "electric feedstock" (green hydrogen and $CO_2$) for chemicals (Palm et al. 2015), or rebuilding cement kilns for capturing $CO_2$ from flue gases (Rootzen and Johnsson 2016). Biomass as an energy source can be used for many applications in industry with varying needs for further processing and can also substitute fossil feedstock for the chemical industry (Cherubini and Strömman 2011). Another systemic change required is the building of infrastructure for supporting the supply of new energy carriers at scale such as electricity, hydrogen or biogenic $CO_2$ and the abandonment or repurposing of old infrastructures (harbors for coal, and oil storages).

Decarbonizing basic materials will increase their production costs. A carbon price might be the most straightforward way towards decarbonized production routes. The carbon cost needed are relatively high and varying. Steel and cement could be made carbon neutral and competitive at a carbon price of 50 to 80 Euros/ton $CO_2$ (Vogl et al. 2018, Rootzen and Johnsson 2016) whereas petrochemicals would require substantially higher carbon prices in order to motivate a complete shift from fossil to renewable feedstock (electricity or biomass) of around 200 to 300 Euros/ton $CO_2$ (Palm et al. 2016).

# 5. A green industrial policy for unlocking fossil dependency

## 5.1 Breaking the carbon lock-in of EIIs

The current state of EIIs can all be described as cases of strong carbon lock-ins that has developed over a century or more and would thus require more than just available technologies to shift production processes. The state of carbon lock-in is based on technical and economic realities but also a co-evolution with institutional regimes (Seto et al. 2016, Unruh 2000). For EIIs, fossil fuels are not just used for energy purposes but also as feedstock for petrochemicals and further GHG emissions also come from the process itself (so-called process emissions). The technical and economic dependencies come from long investment cycles where e.g. a blast furnace, cracker or a cement kiln normally operates continuously for 18 to 23 years before temporarily closed for major renovations (Wesseling et al. 2017). These assets have no strictly defined technical lifetimes and can be refurbished several times, but typically will be replaced in response to increasing demands on size and efficiency (Lempert et al. 2002). The institutional dimension of carbon lock-in comes from the long co-evolution of regulating authorities and industrial practices. Janipour et al (2020) gives a detailed example of this from the chemical sector and Wesseling and Van der Vooren (2017) from the cement sector.

Breaking carbon lock-in is challenging but recent developments in renewable electricity generation shows that it is possible. Meckling et al. (2015) argue that a pragmatic policy mix that rewards the few at the start for building up momentum has worked better as a strategy for breaking carbon lock-in compared to punishing the many via a strong carbon price. This is what has been evidenced for electricity generation, where several sequential policies including a generous support for renewable niche markets (feed-in tariffs, quotas etc.) created the momentum needed to eventually break away from the incumbent large thermal power plants as the dominating option (Meckling et al. 2015). His argument is based on the theoretical underpinnings of Levin et al. (2012) that calls for policy packages that are "sticky" meaning that the policy is directly attractive, easy to accepts but difficult to reverse once adopted, that "entrench" the support over time as the actors involved benefits from increasing returns from the actions induced by the policies, and eventually that the policies can "expand" and attract more actors to support the policies. Together, these attributes of a policy package build momentum and create a *positive path dependency* for low-carbon options that could challenge the incumbent carbon lock-in.

## 5.2 Elements of a green industrial policy

Industrial policy is generally defined as the combination of instruments and measures that directly or indirectly affect industrial development in a certain direction (Rodrik 2014). Based on this, a framework for an industrial policy with the *specific aim of decarbonizing the EIIs* is outlined in Nilsson et al. (2021). It builds on six pillars: (i) directionality, (ii) knowledge creation and technological development, (iii) creating and (re)shaping markets, (iv) building capacity for governance, (v) international coherence and (vi) managing the socio-economic effects of phasing out carbon-intensive infrastructures. This framework provides the basic preconditions for an industrial decarbonization but leaves room for adapting to various national political contexts and to the specific industries involved. A pathway towards a decarbonized industry is a long-term endeavor that requires a sequencing of different policy measures over time (Pierson 2000; Meckling et al. 2017). The six pillars are of varying importance in the different stages of a transition.

After establishing directionality via long-term climate targets and supporting climate-relevant R&D, pillars (i) and (ii), industry has started to move in the right direction with a number of R&D projects, pilot plants and up-coming demonstration projects targeting zero emission in the pipeline. Most of these projects can today be found in the EU, but other regions are preparing to follow (Bataillle 2019**,** ETC 2018). The crucial aspect of reshaping or creating niche markets, pillar (iii), for green materials is still missing in policy mixes around the world. Green public procurement, labelling, or/and specific support schemes resembling the support schemes deployed for renewable electricity could create niche markets for "green" materials (Vogl et al. 2020) as is currently discussed within the EU (EC 2019). Pillar v (international coherence) addresses the issues discussed in this paper as trade policy always is a central part of any industrial policy and pillar (vi) is currently discussed under the label of "just transition" in the EU (EC 2019) and abroad. A just transition for EII differs from the power sector in that it is mainly concerned with industrial restructuring rather than phase-outs and plant closures.

# 6. The case for a Green Materials Club

The current discussions on trade measures and global climate policy is to a large extent motivated by carbon leakage concerns for the EIIs. However, these concerns do not directly address the main challenge that is to induce the investments needed for enabling a deep decarbonisation of EIIs at a global scale. These efforts would be aided by the adoption of a green industrial policy at a national level. Below we outline how international sectoral cooperation, framed as a *Green Materials Club,* could encourage countries to adopt green industrial policies targeting EIIs.

## 6.1 The logic of a green materials club

The idea of a green materials club is to create a coalition of like-minded countries willing to adopt an ambitious green industrial policy to decarbonize EIIs. We base our assessment on the functions of a green materials club on the framework put forward by Levin et al. (2012), who argues for policies that stick immediately, entrench support and expand their reach over time. In an international climate club context stickiness refers to the ability of a policy intervention to attract and lock in the support of the first members to a club by providing an immediate benefit and avoiding short-term costs. Entrenchment refers to a logic in the design of a club that produces increasing member support over time and the start of a low-carbon lock-in. Finally, expansion means that it must be in the club members' interests to expand the club further, and in the interest of non-members to join the club.

A club would need to start with a small number of parties that already have the ambition to decarbonize EIIs and that want to become green industrial leaders. There are already initiatives that point to the direction that such interest exists, see LeadIT (UN 2019), Mission Innovation and the Energy Transition Commission (ETC 2018) that have several country and business members committed to net-zero emissions in 2050 and beyond.

*Stickiness* for these already ambitious countries can be achieved by presenting roadmaps and visions to showcase ambition and opportunities. These can be developed jointly by policy makers and industry. A vision of how to technically decarbonize EIIs gives the needed directionality for industry and a shared basic understanding of the level and forms of public support needed reduces the policy risk. To join the club and to develop and publicly communicate these visions can be considered a "no-lose" option for ambitious countries and a start of a wider discussion of how to formulate the content of a future green industrial policy. Reversal will still be possible but unlikely and difficult as the first members will want to appear as leaders and hold their governments accountable for the promised pathway.

*Entrenchment* is achieved when the visions are followed by real investments in R&D for key technologies, for collaborative pilot and demonstration projects, and stakeholder capacity building (GHG measurement, reporting, planning etc.). These types of actions will require substantial up-front investments but will make successive steps cheaper and thus lead to entrenchment. Capacity building is an important part as club members can enjoy "climate finance readiness" status for multi- or bilateral climate support. Financing broad sectoral climate plans instead of focusing on singular projects would be more effective (Steckel et al. 2017) and will also help to build domestic climate mitigation capacity, see e.g. Climate Focus (2019). Entrenchment will also be achieved when the planning and future investments of infrastructures (power grids, pipelines) are aligned to support a low-carbon pathway.

For *expansion*, a club needs to be increasingly attractive for more countries/industries to join. The "carrot" in most suggested climate clubs so far has been the opportunity to avoid BCAs by becoming a club member. However, in our case we see the biggest carrot as (i) access to financing (e.g. via multilateral banks or bilateral funds) to key infrastructures in line with industrial decarbonization and (ii) access to policy-created green niche markets. Creating (or re-shaping) niche markets to favor "green" materials is a key component in a green industrial policy for reducing risks for industrial leaders and to learning for reducing costs further. Niche markets for green materials do not yet exist but are being discussed in the EU by methods of green public procurement, contract for differences, quotas, or a materials tax (Vogl et al. 2020; EC 2019). Green niche markets are an example that can enable both entrenchment and expansion. As more members take part in supply and demand of green materials, the benefit for members grows and the disadvantages of staying outside the club increases. Although the inclusion of new members increases the competition for club producers, also the size of the green markets increases. By expanding the reach of the club, countries should be able to put the comparative advantage earned through early membership to use.

The dynamics anticipated means that a green materials club would need to adopt a strategic sequential framework, i.e. that the club and its policy initiatives will evolve over time both in strength and in form. A sequential framework would allow the club to strengthen their ambitions following the logic of the Paris Agreement. As an example, access to green niche markets could only be available once these are implemented and functioning. Another example would be how to address future BCAs in this context. Agreement on BCAs or other trade measures could be a part of a green materials club but is not intended to be the prime motivator for joining in the first phase. However, as momentum builds and the need for deep decarbonizing of the EIIs is more widely seen as both possible and inevitable, BCAs could be used as a last leverage point. BCAs might also ease the separation of “brown” versus “green” energy-intensive intermediates in global trade that are likely to increase in volume, such as ammonia or hydrogen.

## 6.2 Membership qualifications

There are at least two minimum requirements that are needed for a membership in order for a green materials club to become effective. The first requirement is a commitment to the long-term target of developing EIIs with a zero-carbon footprint compatible with the Paris Agreement. This ambition will need to reflect that zero emission in EIIs will not be achieved over night but needs time to prepare, develop and demonstrate before being implemented. Plans and roadmaps will also need to take into account  that there will be a variety of options for each material as well as large difference between different materials.

The second requirement is a commitment to jointly work on openness and accountability rules for data and carbon footprints from the targeted sectors. This can be a sensitive issue but is important for international credibility. Access to data will also have the effect to empower stakeholders, such as NGOs and academia, to influence the direction of policy (Dai 2010). For the same reason, transparency of visions/roadmaps are also important for increasing credibility.

Club membership is foremost directed toward nations/parties to the convention as they have the competence to implement the wide scope of interventions needed in a green industrial policy. However, a green materials club should also welcome industries and multilateral institutions as members. Both are needed and can play different parts as enablers for financing, technology expertise to the negotiations, and technology transfer.

## 6.3 Risks and factors determining success

The long-term success of a green materials club rests upon technical development and investments in infrastructures reducing the costs of low-carbon options such that it will become increasingly attractive to join the club over time. An underlying assumption to this is the emergence of a globally growing awareness and demand for green basic materials that will strengthen this positive trend. These factors will, if successful, create increasing returns towards net-zero basic materials that eventually can break the existing fossil-based carbon lock-in.

There is always a risk of prematurely “picking winners” when governments adopt a technology policy that supports a development path that is not ambitious enough and will instead lead to a premature or entrench an existing carbon lock-in. A government cannot really be “neutral” when it comes to EIIs as current institutional frameworks are adapted to support existing industries. An effective green industrial policy must adopt a strategic view on near-term actions that will give directionality and enable future developments aligned with the Paris Agreement. A transparent vision/roadmap that outlines the pathways possible to reach net-zero emission within the stated timeframe will disqualify some technical options that will lead to a premature carbon lock-in. A difficult choice here will thus be on how to define what a “green development pathways” looks like and make it ambitious enough (Vogl and Åhman 2019).

A green materials club will still need to overcome the always present issues of fairness in global climate negotiations. A club must have an understanding of fair trade that includes each member’s right to industrial development and right to implement industrial policies. A just transition is not only a north/south issue but is also a sensitive political issue within industrial countries that needs to be addressed which the inclusion of a “just transition mechanism” as the EU Green Deal reveals. Agreeing on a “common but differentiated" green industrial policy will involve several sensitive issues such as trade, domestic direct or indirect subsidies, and privileging national champions in public procurement, for instance. Several developing countries confer advantages to their industries as part of an industrialization strategy but e.g. in India, industry rather supports other objectives such as agriculture. With regards to the debate of avoiding relocation and carbon leakage, a club needs to consider that there will be several cases of relocation of EIIs to regions with better access to renewable electricity that will have a climate benefit.

## 7. Conclusions

The global policy response for mitigating GHGs in EIIs have so far been weak. EIIs are stuck in a “carbon leakage trap”: One the one hand, ambitious national climate policies are needed to spur action; on the other hand, fears of losing competitiveness in global markets scare away these very policies. The dominant suggestion for how to exit the trap has been to implement border carbon adjustments. However, the main challenge for reaching the Paris Agreement is not carbon leakage itself but the constraint on adopting ambitious climate policies that the perception of carbon leakage poses to national policy makers.

The architecture of the Paris Agreement emphasizes deeper global cooperation for being effective. For the EIIs to be compliant with the ambitions set out in the Paris Agreement, the current fossil lock-in of the EIIs needs to be broken and a new pathway towards future net-zero for EIIs must be established. This will require a green industrial policy with the specific aim of decarbonizing EIIs. Such a green industrial policy will include a comprehensive set of sequentially adopted policies.

In this context, we propose a Green Material Clubs especially designed for deep decarbonization of the EIIs as a part of a voluntary cooperative sectoral approach in global climate policy. The idea of a green materials club is to create a coalition of member countries that will implement green industrial policies. The activities of a green materials club would be to start at a relatively low level of ambition with developing and adopting long-term deep decarbonization visions or roadmaps for EIIs. After that, the support of these pathways for deep decarbonization of EIIs would be entrenched with dedicated support for R&DD and infrastructure planning. In order to be effective towards the Paris target, a green materials club would need to expand beyond the first enthusiastic members. The carrot for joining the club and thus adopting a green industrial policy would be to get access to future niche markets for green basic materials. We conclude that a green materials club has the potential to create a *positive path-dependency* towards deep decarbonization of EIIs. This could be a viable way to ease the current short-term conflicts and mitigate the need for a carbon tariff. However, a green materials club would still be a part of a wider discussion around what are considered fair trade practices under the convention and how this relates to national interest and industrial policy for the decarbonization of basic materials production.

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**Annex 1**

| product | Trade | Mt product | Mio EUR value | EUR value/t product | t CO2/t product | Mt CO2 |
|---|---|---|---|---|---|---|
| Cement (2523) | Export | 14,56 | 750 | 52 | 0,70 | 10 |
| | Import | 3,34 | 228 | 68 | 0,70 | 2 |
| Semi-finished steel (7207) | Export | 1,40 | 724 | 516 | 1,50 | 2 |
| | Import | 9,30 | 4370 | 470 | 1,50 | 14 |
| Flat steel products (7208-7212) | Export | 8,19 | 6152 | 751 | 2,00 | 16 |
| | Import | 19,48 | 12072 | 620 | 2,00 | 39 |
| Long steel products (7213-7217) | Export | 6,89 | 4681 | 679 | 1,00 | 7 |
| | Import | 7,13 | 4188 | 587 | 1,00 | 7 |
| Inorganic Chemicals (28) | Export | 15,10 | 11409 | 755 | 0,40 | 6 |
| | Import | 16,72 | 13034 | 780 | 0,40 | 7 |
| Organic Chemicals (29) | Export | 11,71 | 55365 | 4729 | 0,40 | 5 |
| | Import | 25,44 | 57065 | 2243 | 0,40 | 10 |
| Fertilizers (31) | Export | 12,88 | 3772 | 293 | 0,40 | 5 |
| | Import | 17,98 | 4365 | 243 | 0,40 | 7 |
| Plastics (39) | Export | 20,83 | 57320 | 2751 | 0,40 | 8 |
| | Import | 17,63 | 44062 | 2500 | 0,40 | 7 |
| Aluminium (7601) | Export | 0,31 | 703 | 2247 | 6,80 | 2 |
| | Import | 6,36 | 12649 | 1988 | 1,36 | 9 |