Study on the inclusion of the chemical sector in CBAM

Eindrapport

Trinomics

Contract details

Onderzoek inclusie chemische sector in CBAM

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Trinomics B.V.
Westersingel 34
3014 GS Rotterdam
The Netherlands

Authors

Long Lam
Tatiana Cuervo Blanco
Nora Cheikh

Contact person

Long Lam
E: long.lam@trinomics.eu

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Table of abbreviations

Abbreviation	Full name
ABS	Acrylonitrile-butadiene-styrene
ATR	Autothermal reforming
BDO	Butanediol
CBAM	Carbon Border Adjustment Mechanism
CL	Carbon leakage
CN	Combined Nomenclature
EB	Ethylbenzene
EC	European Commission
EG	Ethylene glycol
EO	Ethylene oxide
EP	European Parliament
EPS	Expansible polystyrene
ETBE	Ethyl tert-butyl ether
ETS	Emissions Trading System
EU	European Union
GHG	Greenhouse gases
GVA	Gross value added
HS	Harmonised system
HVC	High value chemicals
LOHC	Liquid organic hydrogen carrier
LPG	Liquified petroleum gas
Mt	Million tons
MTBE	Methyl tert-butyl ether
NACE	Statistical Classification of Economic Activities in the European Community (*FR: Nomenclature statistique des Activités économiques dans la Communauté Européenne*)
NL	Netherlands
PBL	Netherlands Environment Assessment Agency (*NL: Planbureau voor de Leefomgeving*)
PBT	Polybutylene terephthalate
PE	Polyethylene
PET	Polyethylene terephthalate
PIA	Isophthalic acid
PO	Propylene oxide
PVC	Polyvinylchloride
SAN	Styrene-acrylonitrile
SBI	Standaard bedrijfsindeling
SBR	Styrene butadiene rubber
SMR	Steam methane reforming
THF	Tetrahydrofuran
TPA	Terephthalic acid
VNCI	Association of the Dutch Chemical Industry (NL: *Koninklijke Vereniging van de Nederlandse Chemische Industrie*)

Executive Summary

The aim of this study is to investigate the key issues to consider when including chemicals and plastics under the European Carbon Border Adjustment Mechanism (CBAM), focussing on the Netherlands. This study provides insights on the impact of a CBAM on the carbon leakage risks of the most important chemical value chains in the Netherlands. It also identifies the risks and challenges of implementing CBAM on the products in these value chains. These analyses aim to determine the considerations most relevant to the Netherlands on the scope of CBAM to mitigate carbon leakage and circumvention risks while keeping implementation feasible.

The Dutch chemical sector and CBAM

It is estimated that at least 9 megatons of carbon dioxide ($MtCO_2$) of embedded emissions in chemical and plastic products are imported into the Netherlands from outside the EU every year. This should be treated as a lower estimate as the intensities are based on EU industry and it does not include upstream emissions. For comparison, the Dutch chemical sector emitted roughly 19 $MtCO_2$ in 2021, about 10% of the CO_2 emissions of the Netherlands.

The Netherlands heavily produces and imports organic chemicals and polymers, making them the most relevant chemical value chains for CBAM, with hydrogen also of interest due to their proposed inclusion by the European Parliament (EP).[1] Together, basic organic chemicals and polymers make up about 6 $MtCO_2$ of embedded emissions imported into the Netherlands from outside the European Union (EU). Further, basic organic chemicals and polymers are also the most heavily produced chemical products in the Netherlands.

The inclusion of products within CBAM can have both a positive and negative impact on the carbon leakage risks of those products compared to the status quo. CBAM can reduce carbon leakage risks for products that are imported from outside the EU. At the same, free ETS allowances are phased out at an accelerated pace for products covered under CBAM. Carbon leakage risks would therefore increase for Dutch products exported to outside the EU. Additionally, if CBAM covers the feedstock of a product, the risk of carbon leakage increases due to the potential pass through of costs associated with the production emissions of the feedstock (indirect carbon leakage risk from upstream emissions). CBAM can also reduce the risk of circumvention if it covers the derivative of a product.

Summary of findings for the analysed chemical value chains in the Netherlands

The considerations for including a chemical or plastic product in the scope of CBAM depends on the resulting direct and indirect carbon leakage risks, the feasibility of determining a product's embedded emissions and circumvention risks. Table 0-1 summarises the findings for the products analysed in this study. The table shows that inclusion in CBAM does not mitigate the risk of carbon leakage for every product. For some of the analysed products, a significant share of the production in the Netherlands is exported to outside the EU. In addition, many analysed midstream and downstream products observe a significant risk of indirect carbon leakage if their chemical precursors are also covered under CBAM, even if the products themselves are covered under CBAM. At the same time, almost every analysed product has issues regarding the determination of embedded emissions and circumvention risk that need to be considered.

[1] The proposal of the European Parliament also calls for the additional inclusion of ammonia, which is already included in the European Commission's proposal as ammonia is classified under the product group Fertilisers.

Table 0-1 Overview of carbon leakage risk after CBAM inclusion, challenges for determining embedded emissions and circumvention risks for the analysed products for the Netherlands

Value chain	Product	Significant carbon leakage risk after CBAM inclusion		Determining of embedded emissions		Circumvention risks within the value chain
		Direct[2]	Indirect[3]	ETS product benchmark available	Main emission attribution issues[4]	
Steam cracking	Ethylene & propylene	No	No	Included in product mix 'HVC'	Production	• High for ethylene via the import of polyethylene (PE), EG and other PE-finished products • Limited for propylene but might increase via the import of PO and tetrahydrofuran
	Butadiene	Yes	No			• *Circumvention risks were not analysed for butadiene derivatives*
	Aromatics[5]	Yes	No	Only for product mix 'aromatics'	Production	• *Circumvention risks were not analysed for aromatics' derivatives*
Ethylene oxide	Ethylene oxide (EO) & Ethylene glycol (EG)	Yes	Yes	Only for product mix 'EO/EG'	Production	• High via the import of EG if EO is covered under CBAM and EG is not. • High via the import of bottle-grade PET and other finished products
	PET and derivatives	No	Yes	No	Upstream and production	
Ethylbenzene	Ethylbenzene (EB)	No	No	Only for production route EB/styrene	Upstream	• High via the import of styrene and its derivative products if only EB is covered under CBAM. • High via the import of SAN if acrylonitrile is covered under CBAM
	Styrene	No	Yes			
	Propylene oxide (PO)	No	No	No	Upstream	
	SAN	No	No			
	ABS & latex rubber	Yes	Yes			
	Plastics of styrene	No	Yes		Upstream and production	
ETBE/MTBE	Methanol	Yes	Yes	No	Production	• High via the import of MTBE in case a CBAM covers HVC chemicals affecting the production costs of isobutene/ isobutylene
	Isobutylene	Yes	Yes	No	Upstream	
	Isobutane	No	Yes			
	ETBE	No	Yes			
	MTBE	Yes	Yes			
	Hydrogen (H_2)	No	No	Yes, but may not include all emissions relevant to H_2 imports	Production	• High via the import of H_2 carriers such as methanol and products further downstream • Limited via the import of LOHC • None via import of NH_3 as there is EU level consensus for it to be included under CBAM
	Ammonia (NH_3)	No	No	Yes, but only for NH_3 production with integrated H_2 production	None	• High via the import of acrylonitrile, caprolactam, and nylon (polyamide-6) derived products. • Limited via the import of melamine

Key takeaways on carbon leakage risks

The impact of CBAM on the risk of carbon leakage of chemical and plastic products has different implications across the chemical and plastic value chains:[6]

- **Including upstream chemicals under CBAM shows mainly a positive picture on reducing direct carbon leakage risk for Dutch producers.** For the analysed upstream chemicals (i.e. ethylene, propylene and ammonia), CBAM inclusion would have a largely positive impact on reducing direct carbon leakage risks. However, for upstream chemicals such as aromatics, which export heavily to non-EU markets, the risk of carbon leakage in non-EU markets remains, and could even increase due to the accelerated phase out of free allowances.
- **Including midstream organic chemicals (including polymers) and downstream plastics under CBAM shows a mixed picture on carbon leakage risks relating to relatively high non-EU export shares and indirect carbon leakage risks.** Some midstream chemicals show relatively high indirect carbon leakage risks when their upstream chemical precursors are covered under CBAM.

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[2] This refers to the presence of significant risks of direct carbon leakage after inclusion of the product under CBAM due to relatively high non-EU export intensity.
[3] This refers to the presence of significant risks of indirect carbon leakage after inclusion of the product under CBAM due to the cost pass through of carbon costs from upstream chemical precursors in combination with a relatively high non-EU export intensity, assuming that the upstream chemical precursors are also covered under CBAM.
[4] Main emission attribution issues can be due to a) upstream (i.e., attributing the upstream emissions to the embedded emissions of the product is complex) or b) production (i.e., different process conditions affect the embedded emissions related to the production and/or multiple products are produced from the same production process, making attribution of emissions complex). Table 0-1 differentiates the *main* attribution issues, but it is noted that in most cases both types of issues are present to varying extents.
[5] Benzene, toluene, xylenes.
[6] Note that in this study, the carbon leakage risk of products has been analysed for individual products and interdependencies between products, e.g. the yield patterns of steam cracking products, are not taken into account.

Covering midstream chemicals and downstream plastics under CBAM would mitigate indirect carbon leakage risks for products sold on the EU market, but the risk would remain for products exported to outside the EU.

- **Including hydrogen in CBAM practically has no impact on its carbon leakage risks in the short-term but it could mitigate future carbon leakage risks.** The Netherlands currently has very little non-EU trade of hydrogen, but as demand for hydrogen is expected to grow, CBAM could limit the imports of emissions-intensive hydrogen from outside of the EU. However, the resulting price increase of hydrogen due to passed on CBAM/ETS costs could introduce indirect carbon leakage risks on downstream products of hydrogen.
- **Maintaining free allowances could mitigate direct carbon leakage risks related to non-EU exports but not indirect leakage risks.** The EP proposed to maintain free allowances for non-EU exports, although such a measure may risk non-compliance with World Trade Organisation rules on non-discrimination and/or export subsidies. Furthermore, the current system of free allowances would be unable to mitigate indirect carbon leakage risks as upstream emissions are not compensated.

Key takeaways on determining embedded emissions

There are various practical challenges with regards to determining the embedded emissions of imported chemical and plastic products from outside the EU:

- **Determining the embedded emissions of imported products could be based on ETS product benchmark methodologies, but some cannot be directly used due to challenges with emission attribution.** In addition, the ETS product benchmark data could be used to determine default values if importers are unable to report embedded emissions. However, for some products, the product benchmark is only available for the resulting product mix (such as high-value chemicals[7] and aromatics) or include the production processes of precursors of the chemical product (ethylene oxide – ethylene glycol process, and ethylbenzene/styrene). Commonly accepted methods would need to be developed to attribute emissions to specific products.
- **For products without a product benchmark, the challenge for determining embedded emissions is even greater as clear methodologies are yet to be established.** These methodologies need to define which processes need to be included for determining the embedded emissions of each imported product.
- **Emission attribution rules also need to be established for upstream emissions from precursors that are also covered under CBAM.** This requires the importer to report the quantity of a precursor that has been used to produce one kg of the imported chemical (conversion factors), and what the actual emissions were associated with the production of that precursor. This becomes increasingly difficult to trace as more precursors are involved, especially if this relates to precursors several production steps upstream in the chemical value chain.

Key takeaways on circumvention risks

Determining the scope of CBAM also has implications on non-EU importer's ability to circumvent CBAM:

- **Circumvention risks vary for each of the value chains, with multiple determinants for high circumvention risks.** The transportability of products, availability of established import partners from outside the EU to the Netherlands, and usable transport infrastructure, are all factors that may reinforce or prevent circumvention risks. For most of the value chains analysed, circumvention risks are intensified downstream (e.g., after polymerisation processes) as the nearly finished products are easier to transport and already show a high non-EU trade intensity.

[7] Including ethylene, propylene and butadiene

- **There are also circumvention risks through the import of non-CBAM chemicals that can be converted back to the original precursor that are covered under CBAM to make other products.** Such circumvention risks were gauged as possible during the interviews conducted for this study. Whether this will actually occur depends on the presence of or investment required for necessary infrastructure for conversion.
- **Specifically for hydrogen, the carbon leakage risks mainly lie with the circumvention risks via non-EU imports of hydrogen carriers such as methanol and liquid organic hydrogen carriers (LOHCs).** Methanol is already the top imported chemical from outside the EU by the Netherlands and the Netherlands has the infrastructure to handle LOHCs. Since there is a consensus on the EU level to cover ammonia under CBAM, there would be no circumvention risks using ammonia.
- **Circumvention risks can be reduced by covering products down the value chain.** However, determining the embedded emissions of these downstream products is much more complex.

CBAM scope considerations

Based on the commonalities between the analysed products, upstream basic chemicals (steam cracking products and hydrogen) can be considered the most relevant group of chemicals for inclusion in CBAM and would likely see an overall reduction of direct carbon leakage risks. Upstream organic chemicals are part of the most heavily non-EU imported and domestically produced products in the Netherlands. However, this comes with high circumvention risks and increases indirect carbon leakage risks for downstream products. However, some basic organic chemicals with more exposure to non-EU exports than imports could see their carbon leakage risk increase.

Expanding the scope to midstream organic chemicals (including polymers) would reduce some circumvention risks but introduce new ones related to their downstream products. It also increases the complexity in determining embedded emissions. Further, it shows a mixed picture of a reduction of carbon leakage risks due to the relatively high non-EU export share of some of these midstream products.

Expanding the scope even further downstream to plastic products would further limit circumvention risk and indirect carbon leakage risks. This corresponds to the scope extension as proposed by the EP. Extending the scope further downstream does add more challenges to the practical feasibility with regards to determining embedded emissions.

Instead of including an entire group of organic chemicals, polymers or plastics, an alternative is to include specific chemical value chains where the positive impact of CBAM to reduce carbon leakage risks is optimised. This could be a certain value chain from upstream chemical emissions to the downstream finished plastic product, where products throughout the value chain have a relatively high non-EU import and low non-EU export. Further analysis is required to identify value chains that meet these criteria, which will be a particular challenge since steam cracking products are an integral part of many chemical value chains. Selecting an appropriate value chain without introducing significant circumvention risk will therefore be difficult. Lessons could also be learned from the CBAM inclusion of fertilisers, for which there is consensus at the EU level, as the fertiliser value chain covers various chemicals.

More chemical value chains could be added in the future, especially since the carbon leakage risks in the status quo are already increasing, meaning that the relative negative impact of CBAM inclusion on increasing carbon leakage risk for non-EU exports reduces over time. Free allowances under the EU ETS continue to decrease under the status quo and ETS prices are expected to rise. This means that even without CBAM inclusion, the carbon leakage risks are already increasing, not only for non-EU exports but also for non-EU imports. An accelerated phase out of free allowances due to CBAM inclusion would therefore have a relatively more limited impact on the carbon leakage risk of non-EU exports in the future than it would have now.

Table 0-2 provides an overview of the potential scope for CBAM and a summary of the pros and cons relative to each other as identified in this study.

Table 0-2 Overview of potential CBAM scopes for considerations and their relative pros and cons compared to each other

Potential CBAM scope	Pros	Cons
Upstream organic basic chemicals + hydrogen	• Mainly positive CL impact of CBAM due to relatively high non-EU imports compared to non-EU exports • Limited complexity to determine embedded emissions	• Some negative CL impact for specific products with high non-EU exports • Indirect CL risks downstream • High circumvention risks
All organic basic chemicals and polymers + hydrogen	• Positive CL impact with high non-EU imports	• Indirect CL risks downstream • Negative CL impact with high non-EU exports • Complex to determine embedded emissions • High circumvention risks
All organic basic chemicals, polymers and plastics + hydrogen (EP proposal)	• Limited circumvention risks • More limited indirect CL risks	• Negative CL impact for high non-EU exports • Highly complex to determine embedded emissions
Specific chemical value chains	• Can be optimised for positive CL impacts of CBAM • Can be optimised to limited indirect CL risks downstream • Limited circumvention risks	• Challenge to select the appropriate value chains for CBAM inclusion • Complex to determine embedded emissions

CL = carbon leakage

Samenvatting

Het doel van deze studie is het identificeren van de belangrijkste overwegingen bij het opnemen van chemie en kunststof onder het Europese *Carbon Border Adjustment Mechanism* (CBAM), met een focus op Nederland. Deze studie geeft een overzicht van de mogelijke impact van CBAM op het koolstoflekkagerisico van de belangrijkste chemische waardeketens in Nederland. Ook zijn de risico's en uitdagingen bij de invoering van CBAM op producten in deze waardeketens geïdentificeerd. Deze analyses dienen de meest relevante overwegingen voor Nederland vast te stellen rondom de uitbreiding van de reikwijdte van CBAM naar chemie en kunststof. Hierbij ligt de focus op koolstoflekkagerisico's, risico's van ontwijking van CBAM en de praktische uitvoerbaarheid.

De Nederlandse chemiesector en CBAM

Naar schatting wordt jaarlijks ten minste 9 megaton kooldioxide ($MtCO_2$) aan *embedded* emissies in chemische en kunststofproducten van buiten de EU in Nederland ingevoerd. Dit is een onderschatting, aangezien de gebruikte intensiteiten voor de schatting gebaseerd zijn op de Europese industrie en de *upstream*-emissies niet zijn meegerekend. Ter vergelijking: de Nederlandse chemische sector stootte in 2021 ruwweg 19 $MtCO_2$ uit, ongeveer 10% van de CO_2-emissies van Nederland.

Nederland produceert en importeert veel organische chemicaliën en polymeren, waardoor dit de meest relevante chemische waardeketens voor CBAM zijn, waarbij waterstof ook relevant zijn vanwege het voorstel van het Europees Parlement (EP).[8] Samen zijn organische basischemicaliën en polymeren goed voor ongeveer 6 $MtCO_2$ van de ingebedde emissies die van buiten de Europese Unie (EU) in Nederland worden ingevoerd. Bovendien zijn organische basischemicaliën en polymeren ook de meest geproduceerde chemische producten in Nederland.

De inclusie van producten in CBAM kan zowel een positief als een negatief effect hebben op het weglekrisico van die producten in vergelijking met de status quo. CBAM kan het weglekrisico voor producten die van buiten de EU worden ingevoerd verminderen. Tegelijkertijd zullen gratis ETS-rechten versneld afgebouwd worden voor producten die onder CBAM vallen. Koolstoflekrisico's zouden daarom toenemen voor Nederlandse producten die naar buiten de EU worden uitgevoerd. Als de grondstof van een product ook onder CBAM valt, neemt bovendien het risico van koolstoflekkage toe. Dit als gevolg van de mogelijke afwenteling van kosten gerelateerd aan de productie-emissies van de grondstof (indirect koolstoflekrisico via upstream-emissies). Verder kunnen ontwijkingsrisico's worden verminderen als CBAM ook derivaten van een product dekt.

Samenvatting van bevindingen voor de geanalyseerde chemische waardeketens in Nederland

De overwegingen om een chemisch of kunststofproduct onder CBAM op te nemen, hangen af van de resulterende directe en indirecte risico's op koolstoflekkage, de haalbaarheid van de bepaling van de ingebedde emissies van een product en de risico's op ontwijking. Tabel 0-1 vat de bevindingen samen voor de producten die in deze studie zijn geanalyseerd. Hieruit is op te maken dat inclusie in CBAM niet voor elk geanalyseerd product het risico op koolstoflekkage mitigeert. Van sommige producten die in Nederland worden geproduceerd wordt namelijk een aanzienlijk deel naar buiten de EU uitgevoerd. Veel producten in het midden of aan het einde van de chemische waardeketen hebben bovendien een significant risico op indirecte koolstoflekkage als hun chemische precursoren ook onder CBAM vallen, zelfs ze ook door CBAM zijn gedekt. Tegelijkertijd zijn er complicaties rondom het

[8] Het EP stelt ook voor om ammoniak onder CBAM mee te nemen, wat al onderdeel is van het CBAM-voorstel van de Europese Commissie aangezien ammoniak onder de productgroep Meststoffen valt.

bepalen van de embedded emissies en ontwijkingsrisico's bij zowel elk geanalyseerd product waar rekening mee gehouden moet worden.

Tabel 0-1 Overzicht van het risico van koolstoflekkage na CBAM-opname, uitdagingen voor het bepalen van embedded emissies en ontwijkingsrisico's voor de geanalyseerde producten voor Nederland

Waardeketen	Product	Significant risico op koolstoflekkage na CBAM-inclusie		Bepaling van embedded emissies		Ontwijkingsrisico's binnen de waardeketen
		Direct[9]	Indirect[10]	ETS-product-benchmark beschikbaar	Belangrijkste emissie-attributie-kwesties[11]	
Stoomkraken	Ethyleen en propyleen	Nee	Nee	Onderdeel van de productmix "HVC"	Productie	• Hoog voor ethyleen via de invoer van polyethyleen (PE), EG en andere PE-eindproducten • Beperkt voor propyleen maar zou kunnen toenemen door de invoer van PO en tetrahydrofuraan
	Butadieen	Ja	Nee			• *Ontwijkingsrisico's zijn niet geanalyseerd voor butadieenderivaten*
	Aromaten[12]	Ja	Nee	Alleen voor productmix "aromaten"	Productie	• *Ontwijkingsrisico's zijn niet geanalyseerd voor aromatenderivaten*
Ethyleen oxide	Ethyleenoxide (EO) & Ethyleenglycol (EG)	Ja	Ja	Alleen voor productmix "EO/EG"	Productie	• Hoog via de invoer van EG als EO onder de CBAM valt en EG niet • Hoog via de invoer van PET voor flessen en andere afgewerkte producten
	PET en derivaten	Nee	Ja	Nee	Upstream en productie	
Ethylbenzeen	Ethylbenzeen (EB)	Nee	Nee	Alleen voor productieroute EB/styreen	Upstream	• Hoog via de invoer van styreen en daarvan afgeleide producten indien alleen EB onder de CBAM valt • Hoog via de invoer van SAN als acrylnitril onder CBAM valt
	Styreen	Nee	Ja			
	Propyleenoxide (PO)	Nee	Nee	Nee	Upstream	
	SAN	Nee	Nee			
	ABS & latex rubber	Ja	Ja			
	Kunststoffen van styreen	Nee	Ja		Upstream en productie	
ETBE/ MTBE	Methanol	Ja	Ja	Nee	Productie	• Hoog via de invoer van MTBE indien een CBAM betrekking heeft op HVC-chemicaliën die de productiekosten van isobuteen/isobutyleen beïnvloeden
	Isobutyleen	Ja	Ja	Nee	Upstream	
	Isobutaan	Nee	Ja			
	ETBE	Nee	Ja			
	MTBE	Ja	Ja			
	Waterstof (H_2)	Nee	Nee	Ja, maar omvat mogelijk niet alle emissies die relevant zijn voor de invoer van H_2	Productie	• Hoog via de invoer van H_2 dragers zoals methanol en producten verder downstream • Beperkt via de invoer van LOHC's • Geen via invoer van NH_3 omdat er een consensus is op EU-niveau om NH_3 in CBAM op te nemen
	Ammoniak (NH_3)	Nee	Nee	Ja, maar alleen voor NH_3 productie met geïntegreerde H_2 productie	Geen	• Hoog via de invoer van acrylonitril, caprolactam en van nylon (polyamide-6) afgeleide producten • Beperkt via de invoer van melamine

Belangrijkste bevindingen rondom koolstoflekkagerisico's

Het effect van CBAM op het koolstoflekkagerisico van chemische en kunststofproducten heeft verschillende implicaties in de chemische en kunststofwaardeketens:

- **De inclusie van *upstream*-chemicaliën in CBAM levert vooral een positief beeld op met betrekking tot de vermindering van het directe weglekrisico voor Nederlandse producenten.**

[9] Dit verwijst naar de aanwezigheid van significante risico's op directe koolstoflekkage na inclusie in CBAM als gevolg van de relatief hoge exportintensiteit van een product naar buiten de EU.
[10] Dit verwijst naar de aanwezigheid van significante risico's op indirecte koolstoflekkage na inclusie in CBAM, veroorzaakt door de afwenteling van koolstofkosten van upstream chemische precursoren in combinatie met een relatief hoge exportintensiteit van een product naar buiten de EU. Hierbij is aangenomen dat de upstream chemische precursoren ook onder CBAM vallen.
[11] De belangrijkste problemen bij de attributie van emissies kunnen het gevolg zijn van complexiteiten met emissies van a) upstream (d.w.z. de toerekening van de upstream-emissies aan de embedded emissies van het product is complex) of b) productie (d.w.z. verschillende procesomstandigheden beïnvloeden de embedded emissies gerelateerd het productieprocess en/of er worden meerdere producten geproduceerd in hetzelfde productieproces, waardoor de attributie van emissies complex is). Table 0-1 geeft een overzicht van de *belangrijkste* kwesties rondom de attributie van emissies, maar in de meeste gevallen zijn beide soorten complexiteiten in verschillende mate aanwezig.
[12] Benzeen, tolueen, xylenen.

Voor de geanalyseerde *upstream*-chemicaliën (d.w.z. ethyleen, propyleen en ammoniak) zou de opname van CBAM een grotendeels positief effect hebben op de vermindering van het directe weglekrisico. Voor *upstream*-chemicaliën zoals aromaten, die in hoge mate naar niet-EU-markten exporteren, blijft het risico van koolstoflekkage op niet-EU-markten echter bestaan of neemt zelfs toe door de versnelde uitfasering van gratis emissierechten.

- **Wanneer *midstream* organische chemicaliën (inclusief polymeren) en *downstream* kunststoffen onder CBAM vallen, levert dat een gemengd beeld op voor weglekrisico's door hun relatief groot aandeel van niet-EU-uitvoer en indirecte weglekrisico's.** Sommige *midstream*-chemicaliën vertonen relatief hoge indirecte weglekrisico's wanneer hun *upstream* chemische precursoren onder CBAM vallen. Wanneer *midstream*-chemicaliën en *downstream*-kunststoffen onder CBAM vallen, worden de indirecte weglekrisico's voor producten die op de EU-markt worden verkocht, beperkt. Het risico blijft echter bestaan voor producten die naar buiten de EU worden uitgevoerd.
- **De opname van waterstof in CBAM heeft praktisch geen effect op de weglekrisico's op korte termijn, maar zou toekomstige weglekrisico's kunnen verminderen.** Nederland handelt momenteel slechts zeer beperkte in waterstof met landen buiten de EU. Naar verwachting zal de vraag naar waterstof echter groeien, waardoor CBAM de invoer van emissie-intensieve waterstof van buiten de EU zou kunnen beperken. De prijsstijgingen van waterstof als gevolg van doorberekende CBAM/ETS-kosten zouden echter tot indirecte koolstoflekkagerisico's voor downstreamproducten van waterstof kunnen leiden.
- **Het behouden van gratis emissierechten kan de directe risico's van koolstoflekkage met betrekking tot niet-EU-uitvoer verminderen, maar niet indirecte koolstoflekkagerisico's.** Onderdeel van het EP-voorstel van CBAM is het behouden van gratis emissierechten voor export naar buiten de EU. Een dergelijke maatregel zou echter mogelijk in strijd kunnen zijn met de regels van de Wereldhandelsorganisatie rondom non-discriminatie en/of exportsubsidies. Bovendien zouden de risico's van indirecte koolstoflekkage met een dergelijke maatregel niet worden beperkt, aangezien de upstream-emissies niet onder het huidige systeem van gratis emissierechten worden gecompenseerd.

Belangrijkste bevindingen rondom het bepalen van *embedded* emissies

Er zijn verschillende praktische uitdagingen wat betreft de bepaling van de embedded emissies van ingevoerde chemische en kunststofproducten van buiten de EU:

- **De bepaling van de embedded emissies van ingevoerde producten zou kunnen worden gebaseerd op de methodes van ETS-productbenchmarks, maar sommige daarvan kunnen niet rechtstreeks worden gebruikt vanwege complicaties met de attributie van emissies.** Ook zou de ETS-benchmark data gebruikt kunnen worden om standaardwaarden te bepalen indien importeurs de embedded emissies niet kunnen bepalen. Voor sommige producten is de productbenchmark echter alleen beschikbaar voor een productmix (zoals *high value chemicals*[13] en aromaten) of omvat het ook de productieprocessen van precursoren van het chemische product (ethyleenoxide – ethyleenglycolproces, en ethylbenzeen/styreen). Hiervoor zouden algemeen geaccepteerde methoden ontwikkeld moeten worden om emissies aan specifieke producten toe te schrijven.
- **Voor producten zonder productbenchmark is de uitdaging om de embedded emissies te bepalen nog groter, aangezien er nog geen duidelijke methodes zijn vastgesteld.** Deze methodes moeten bepalen welke processen meegenomen moeten worden bij het bepalen van de embedded emissies van elk ingevoerd product.

[13] Waaronder ethyleen, propyleen en butadieen

- **Ook voor upstream-emissies van precursoren die eveneens onder CBAM vallen, moeten regels rondom emissie-attributie worden vastgesteld.** Dit betekent dat de importeur moet rapporteren hoeveel van een precursor is gebruikt om één kg van de ingevoerde chemische stof te produceren (conversiefactoren), en wat de werkelijke emissies waren voor de productie van die precursor. Dit wordt steeds moeilijker te traceren naarmate er meer precursoren bij betrokken zijn, met name precursoren van verschillende productiestappen hoger in de chemische waardeketen.

Belangrijkste bevindingen rondom de ontwijkingsrisico's

Het vaststellen van de reikwijdte van CBAM heeft ook gevolgen voor het mogelijkheden van importeurs van niet-EU producten om de CBAM te omzeilen:

- **Het ontwijkingsrisico varieert voor elk van de waardeketens, waarbij er meerdere factoren bepalend zijn voor een hoog ontwijkingsrisico.** De vervoerbaarheid van producten, de aanwezigheid van gevestigde partners om producten van buiten de EU naar Nederland te importeren, en de beschikbaarheid van een transportinfrastructuur zijn allemaal factoren die ontwijkingsrisico's kunnen versterken of beperken. Voor de meeste geanalyseerde waardeketens worden de ontwijkingsrisico's downstream (bv. Na de polymerisatieprocessen) groter, aangezien de semi-afgewerkte producten makkelijker te vervoeren zijn en al een hoge niet-EU-handelsintensiteit hebben.
- **Ook zijn ontwijkingsrisico's aanwezig rondom chemicaliën die niet onder CBAM vallen maar wel omgezet kunnen worden in een precursor die wel onder CBAM valt om andere producten te maken.** Dergelijke ontwijkingsrisico's werden tijdens de interviews met bedrijven die voor deze studie zijn gehouden als mogelijk ingeschat. Of dit in werkelijkheid zal plaatsvinden hangt af van de aanwezigheid van of benodigde investeringen voor de benodigde infrastructuur voor een dergelijke omzetting van chemicaliën.
- **Specifiek voor waterstof liggen de koolstoflekrisico's vooral bij de ontwijkingsrisico's via niet-EU-invoer van waterstofdragers zoals methanol en *liquid organic hydrogen carriers* (LOHC's).** Methanol is al het meeste ingevoerde chemieproduct van buiten de EU door Nederland en Nederland beschikt over de infrastructuur om LOHC's te verwerken. Aangezien er op EU-niveau al een consensus is om ammoniak onder CBAM op te nemen, zouden er geen ontwijkingsrisico's moeten zijn met betrekking tot ammoniak als waterstofdrager.
- **De ontwijkingsrisico's kunnen worden beperkt door producten verderop in de waardeketen in CBAM op te nemen.** Het bepalen van de embedded emissies van deze downstreamproducten brengt echter de benodigde complexiteit met zich mee.

Overwegingen met betrekking tot de reikwijdte van CBAM

Op basis van de overeenkomsten tussen de geanalyseerde producten is wel te zien dat upstream basischemicaliën (stoomkraakproducten en waterstof) de meest relevante groep van chemische stoffen is om in CBAM op te nemen, en hun risico's van directe koolstoflekkage in het algemeen daarmee waarschijnlijk zullen afnemen. Upstream organische chemicaliën maken deel uit van de meest ingevoerde en in Nederland geproduceerde producten die niet uit de EU afkomstig zijn. Dit gaat echter gepaard met hoge ontwijkingsrisico's en verhoogt het indirecte weglekrisico voor downstreamproducten. Daarnaast kan het koolstoflekkagerisico voor sommige basischemicaliën met een relatief hoge exportintensiteit naar buiten de EU na inclusie in CBAM toenemen.

De uitbreiding van de CBAM-reikwijdte naar midstream organische chemieproducten (inclusief polymeren) zou een deel van de ontwijkingsrisico's kunnen verminderen, maar tegelijkertijd nieuwe ontwijkingsrisico's introduceren bij hun downstreamproducten. Een uitbreiding naar midstream producten verhoogt ook de complexiteit voor het bepalen van de embedded emissies.

Daarnaast is het beeld rondom de vermindering van de risico's op koolstoflekkage gemengd door het relatief hoog aandeel van niet-EU-uitvoer van sommige van deze midstream producten.

Door de reikwijdte nog verder downstream uit te breiden naar kunststofproducten zouden het ontwijkingsrisico en indirecte koolstoflekkage verder worden beperkt. Dit komt overeen met de uitbreiding van de CBAM-reikwijdte die door het EP is voorgesteld. Door de reikwijdte verder downstream uit te breiden, wordt de praktische haalbaarheid met betrekking tot de bepaling van embedded emissies wel moeilijker.

In plaats van een hele groep organische chemicaliën, polymeren of kunststoffen op te nemen, zouden specifieke chemische waardeketens als alternatief opgenomen kunnen worden waar het positieve effect van CBAM ter vermindering van koolstoflekkagerisico's is geoptimaliseerd. Dit kan een bepaalde waardeketen zijn, van upstream chemische emissies tot het downstream eindproduct van kunststof, waarbij producten in de gehele waardeketen relatief veel niet-EU-invoer en weinig niet-EU-uitvoer hebben. Verdere analyse is nodig om te bepalen welke waardeketens aan deze criteria voldoen. Dit zal een mogelijk een uitdaging worden, aangezien stoomkraakproducten deel uitmaken van vele chemische waardeketens. Het kiezen van een waardeketen waarbij ontwijkingsrisico's beperkt zijn wordt daardoor bemoeilijkt. Er kan ook lering worden getrokken uit de inclusie van meststoffen in de CBAM, waarover op EU-niveau consensus bestaat, aangezien de waardeketen van meststoffen verschillende chemische producten omvat.

In de toekomst zouden vervolgens meer chemische waardeketens kunnen worden toegevoegd, aangezien koolstoflekkagerisico's in de status-quo al toenemen, wat betekent dat de relatief negatieve effect van CBAM-inclusie op niet-EU-uitvoer over de tijd heen afneemt. De gratis ETS-rechten blijven in de status-quo namelijk dalen en de ETS-prijzen zullen naar verwachting stijgen. Een versnelde uitfasering van de gratis rechten als gevolg van CBAM-inclusie heeft in de toekomst daarom een beperkter effect op het weglekrisico van niet-EU-uitvoer dan nu het geval is.

Tabel 0-2 geeft een overzicht van het potentiële reikwijdtes voor CBAM en een samenvatting van de relatieve voor- en nadelen van elk van deze potentiële reikwijdtes t.o.v. elkaar.

Tabel 0-2 Overzicht van potentiële CBAM-reikwijdtes voor overwegingen en hun relatieve voor- en nadelen t.o.v. elkaar

Potentiële reikwijdte CBAM	Voordelen	Nadelen
Upstream organische basischemicaliën + waterstof	• Hoofdzakelijk positieve CL-impact van CBAM door de relatief hoge niet-EU-invoer t.o.v. niet-EU-uitvoer • Beperkte complexiteit om embedded emissies te bepalen	• Enige negatieve CL-impact voor specifieke producten met een hoge niet-EU-uitvoer • Indirecte CL-risico's downstream • Hoge ontwijkingsrisico's
Alle organische basischemicaliën en polymeren + waterstof	• Positief CL-effect voor hoge niet-EU-invoer	• Indirecte CL-risico's downstream • Negatief CL-effect voor hoge niet-EU-uitvoer • Complex om ingebedde emissies te bepalen • Hoge ontwijkingsrisico's
Alle organische basischemicaliën, polymeren en kunststoffen + waterstof (EP-voorstel)	• Beperkte risico's op ontwijking • Beperktere indirecte CL-risico's	• Negatief CL-effect voor hoge niet-EU-uitvoer • Zeer complex om ingebedde emissies te bepalen
Specifieke chemische waardeketens	• Kan worden geoptimaliseerd voor positieve CL-effecten van CBAM • Kan worden geoptimaliseerd om de indirecte CL-risico's downstream te beperken • Beperkte ontwijkingsrisico's	• Uitdaging om de geschikte waardeketens voor CBAM-inclusie te selecteren • Complex om embedded emissies te bepalen

CL = koolstoflekkage

1 Introduction

1.1 Context

The expansion of the European Carbon Border Adjustment Mechanism (CBAM) to include chemical products is currently being explored. On 14 July 2021, the European Commission (EC) proposed a European CBAM as part of the Fit-for-55 policy package. This CBAM proposal would impose a carbon price on products imported from outside the European Union (EU) where they do not face an equivalent carbon price as in the EU, incentivising non-EU producers to reduce their emissions. At the same time, this creates a level playing field on carbon costs within the EU. In the Commission's proposal, products from five sectors would be initially covered under CBAM: iron and steel, cement, fertilisers, aluminium, and electricity. The European Council adopted its general approach on CBAM on 15 March 2022, which included the same CBAM coverage as the Commission's proposal. On 22 June 2022, the European Parliament adopted amendments to the Commission's proposal to also include organic chemicals, hydrogen, ammonia and plastics under CBAM. The exact scope of CBAM will be determined in the trilogue negotiations between the Commission, the European Parliament and the European Council.

The Dutch parliament has called for a study on the effects of the inclusion of the chemical sector under CBAM. On 12 April 2022, a motion from Thijssen and Kröger was adopted in the Dutch parliament that requests the government to investigate the consequences of the inclusion of the chemical sector under CBAM.[14] The Netherlands has a large chemical sector of which several parts of the value chain are considered to be at significant risk of carbon leakage. A previous Trinomics study concluded that the Netherlands imports about €14 billion per year of chemical products, with 37% of the imports coming from outside the EU.[15] These imports are used to produce a variety of products in the Netherlands in the chemical sector as well as further downstream in other sectors.

It is unclear what the impact of the inclusion of chemical products under CBAM will be for the Netherlands. The direct impact of the inclusion of chemical products under CBAM is that Dutch companies importing these products will face additional costs associated with the emissions for producing these products. This could negatively affect the competitive position of companies in the Netherlands and therefore increase the risk of carbon leakage. At the same, the intra-EU competitive position of Dutch companies producing the same products as the imported ones would improve compared to the status quo where free allowances under the EU Emissions Trading System (ETS) are decreasing and the ETS price increasing. For these companies, CBAM would therefore help lower their risk of carbon leakage. Which parts of the Dutch value chains would be most affected by including chemicals under CBAM will depend on which chemical products would fall under CBAM and the dependencies of the value chains on these products. Box 1-1 provides an overview of the definitions of carbon leakage used in this study.

[14] Thijssen, J. & Kröger, S. (2022). Motie van de leden Thijssen en Kröger over onderzoeken van de gevolgen van inclusie van de chemische sector in CBAM.
[15] Trinomics (2021). Onderzoek nationale effecten CBAM.

Box 1-1 Definition of carbon leakage risks used in this study

Carbon leakage refers to when an emissions reduction policy inadvertently causes an increase in emissions in other jurisdictions that do not have equivalent emissions reduction policies. If production and investment would shift to countries with more lenient climate policies, it could increase in emissions in those countries, and thus is considered carbon leakage. In the context of this study, we make a distinction between the following risks of carbon leakage:

- **Direct carbon leakage risk** of a product refers to the risk of production and/or investment of a product (and associated emissions related to the manufacturing of the product) shifting to other jurisdictions due to a product being included in the scope of CBAM. On the one hand, inclusion in CBAM would reduce this risk for products sold in the EU. On the other hand, the accelerated phase out of free ETS free allowances associated with the inclusion of CBAM would increase this risk for products sold outside the EU (see Section 2).
- **Indirect carbon leakage risk** of a product refers to the risk of production and/or investment and associated emissions of a product shifting due to CBAM indirectly affecting the competitiveness of a product. Specifically, this refers the changes in the cost of input materials (feedstock) of a product due these input materials being included in CBAM, affecting the production costs for the product.
- **Circumvention risk** refers to the risk of importing a derivative of a product from outside the EU to avoid the cost increases due to the inclusion of the product under CBAM, i.e. circumventing CBAM. If import of the derivative leads to a displacement of emissions from within the EU to a country outside the EU, this would be a form of carbon leakage.

Insights on the impacts of a CBAM on the most important chemical value chains in the Netherlands can help inform the issues to consider in the expansion of the EU CBAM to chemical products. The inclusion of chemical products under CBAM can have a wide range of impacts throughout the value chain depending on the scope of the chemical products covered. Practical issues, such as the feasibility to determine emissions associated with the production of products, also plays an important role. An overview of the most relevant Dutch chemical value chains that could be affected by CBAM could help in identify the risks and challenges associated with the expansion of CBAM to chemical products. This could inform the considerations on the scope of CBAM to mitigate carbon leakage and circumvention risks while keeping implementation feasible. At the same time, it could also help inform the Dutch negotiation position on the inclusion of chemicals under CBAM.

1.2 Objectives and research questions

The main purpose of this study is to provide an overview of the key issues to consider for the inclusion of the chemical sector in CBAM for the Netherlands. This requires an overview of the most important Dutch chemical value chains and the associated challenges and risks the inclusion of chemicals under CBAM would bring to these value chains. These include risks on carbon leakage and challenges with implementation. We focus on the European Parliament proposed chemical sector products: organic chemicals, hydrogen, ammonia and plastics, but do not directly limit the study to these products. The identification of key issues is tackled through the following research questions:

1. Which Dutch chemical value chains are most relevant related to the inclusion of chemicals under CBAM?

2. Which downstream products may be potentially at risk of (indirect) carbon leakage?
3. What is the quantitative carbon leakage indicators of the different chemical products and most relevant downstream products?
4. What are the potential scopes for the inclusion of chemicals in CBAM, particularly in terms of leakage risks and practical feasibility?
5. What are the risks and challenges regarding the inclusion of chemicals in CBAM, particularly on implementation and feasibility to determine the emissions of products that do not have product benchmarks under the EU ETS?

These research questions have been tackled using Dutch and EU public statistics and literature, complemented with some insights from companies in the Dutch chemical sector. Public statistics and literature have been used to identify the most relevant products for the Dutch chemical sector and map out the most important aspects of their value chain. These have been further refined based on inputs from companies in the Dutch chemical sector. For the most relevant value chains where information is available, the impact of CBAM on the indicators for carbon leakage risks have been quantified based on data from CBS, Eurostat and PBL (MIDDEN). Other risks of the inclusion of chemicals in CBAM have been identified using literature and complemented with insights from the Dutch chemical sector association VNCI and some of its members.

1.3 Scope

The study focusses on the key risks and challenges associated with the expansion of the Commission's CBAM proposal to chemical and plastic products relevant for the Netherlands. The chemical value chain is complex and consists of multiple segments. It is therefore not feasible in the context of this study to conduct a comprehensive analysis on the impact of the inclusion of all chemical products in CBAM. The scope of the study is therefore limited to the following:

- **NACE sector 20 *Chemicals and chemical products* and NACE sector 22.2 *Plastic products*:** for determining the non-EU chemical and plastic imports most affected by CBAM, the study focus on chemical products that fall under the NACE sector 20 *Manufacture of chemicals and chemical products* and 22.2 *Manufacture of plastic products*. This corresponds to the adopted motion in the Dutch Parliament to investigate the consequences of including the chemical sector under CBAM, but also takes into account the scope proposed by the European Parliament. However, this does not fully correspond to other product classifications such as the Combined Nomenclature (CN) used for trade that the European Parliament used to specify the additional proposed products to be included. The proposed scope expansion of the European Parliament covers CN codes 29 *Organic chemicals* under Section VI *Products of the chemical or allied industries* and 39 *Plastics and articles therefore*. The key difference is that certain basic pharmaceutical products under CN code 29 are not included, which are classified under NACE 21.1 *Manufacture of basic pharmaceutical products*. The omission of these products from this study to focus on the most relevant chemical value chains in the Netherlands is discussed in Section 2.2.
- **Top chemical products affected by inclusion in CBAM relevant to the Netherlands:** Due to the expansive nature of the chemical value chain, this study focuses on the chemical products that could potentially be most affected by their inclusion in CBAM. These are the top 20 chemical products that the Netherlands is importing from outside of the EU and the top 20 chemical products produced in the Netherlands.
- **Products not included in the Commission's proposal:** the focus of this study lies on chemical products that are currently not included in the Commission's proposal on CBAM. This means

that this study does not look at the fertiliser value chain, i.e. products that fall under the NACE code 20.15 *Manufacture of fertilisers and nitrogen compounds*. Non-EU imports of these products are limited for the Netherlands in terms of value, constituting only 2% of chemical products that the Netherlands imports from outside the EU (see Section 3.1.1). The only exception is ammonia, which is considered further in this study. Ammonia is used to make various other products in addition to fertilisers and could become a common energy carrier in the future.

1.4 Structure of this report

The rest of this report is structured as follows:

- Section 2 introduces the potential impacts that CBAM could have on the carbon leakage risks of products, followed by a high-level discussion on the relevance of including chemicals and plastics in CBAM and an overview associated challenges;
- Section 3 aims to identify and map the most relevant chemical value chains to the Netherlands, with a high-level analysis of the potential risks of carbon leakage in the context of CBAM;
- Section 4 dives into the carbon leakage risk and challenges on the inclusion in CBAM for several chemical value chains based on their relevance to the Netherlands and data availability; and
- Section 5 summarises the key findings and provides a set of considerations on scope of chemical and plastic products to be covered under CBAM.

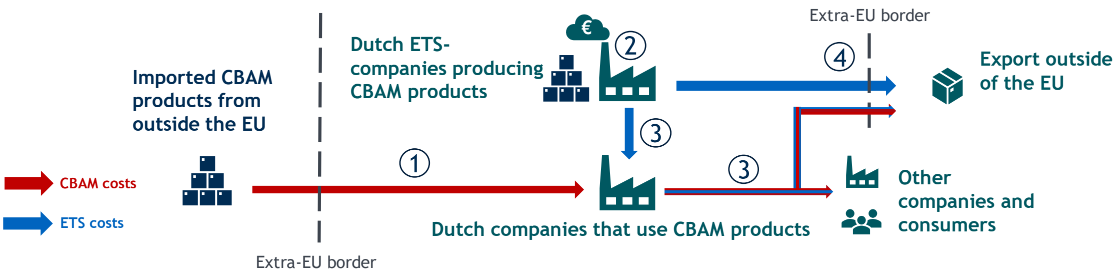
2 CBAM and its relevance for chemical value chains

2.1 Potential impacts of CBAM on carbon leakage risks

CBAM can affect the costs of products and competitiveness in different ways. In the proposed CBAM, products that are imported from outside the EU and covered under CBAM face a carbon costs equivalent to the ETS costs that EU producers face. At the same time, free allowances that EU producers receive for products covered under CBAM are phased out at a faster rate than if they would not be covered under CBAM.[16] Figure 2-1 shows a schematic overview of the different ways CBAM can change the costs of a product and with that their competitiveness, which can be summarised in four effects:

1. **Higher costs on non-EU imports for downstream producers**, which use these imports as input material. This leads to carbon leakage risk of downstream products if these products are not covered by CBAM, as the higher costs lowers their competitiveness in comparison to non-EU competitors. This could in turn lead to circumvention risks where downstream products that are not covered by CBAM start to be imported and replace domestic production;
2. **A level playing field on carbon costs for EU producers in the EU market**, because competition from non-EU imports face higher costs, making it easier for EU producers to pass on the carbon costs in the same products sold within the EU market. This lowers the risk of carbon leakage of these products;
3. **Higher costs on products produced in the EU for downstream producers**, which could occur because of EU producers being able to pass on carbon costs easier, in turn increasing the costs of input materials for these downstream producers. This leads to carbon leakage risk of downstream products if these products are not covered by CBAM; and
4. **Higher costs on products produced in the EU for export outside of the EU**, if the measure is linked with an accelerated phase out of free allowances for products that fall under CBAM. EU producers would not be able to pass on the carbon costs in markets outside of the EU where competitors do not face equivalent carbon costs, negatively affecting their competitive position.

Figure 2-1 Schematic overview of the different cost impacts of CBAM



Source: Trinomics

These cost impacts of CBAM should be reflected against the current method of carbon leakage protection with free allowances, which are already set to decrease over time. Currently, EU producers receive free allowances under the EU ETS to mitigate carbon leakage risks, because (most of) their competitors outside EU do not face similar costs. The amount of free allowances EU producers receive is determined based on benchmarks, which are based on the top 10% best performing

[16] The European Commission proposed a complete phase out by 2035 whereas the Parliament proposal is by 2032.

installations in the EU. These benchmarks are set to decrease over time, which also translates in a reduction in free allowances. At the same time, the overall emission cap in the EU ETS is set to decrease, which will likely lead to higher carbon prices that incentivises cleaner production. Consequently, higher ETS prices with the gradual decrease in free allowances means that the carbon cost differential between the EU and non-EU producers become larger over time. Therefore, the carbon leakage risks are already increasing in the status quo.[17]

The inclusion of products within CBAM can therefore have both positive and negative impact on the carbon leakage risks of those products compared to the status quo. Overall, the impact of CBAM can be summarised as follows:

- CBAM **reduces carbon leakage risks** related to products that are heavily imported from outside the EU and sold in the EU, because these imports would become more expensive due to the carbon costs imposed by CBAM;
- CBAM **increases carbon leakage risks** for products that are domestically produced and heavily exported to outside of the EU due to the accelerated phaseout of free ETS allowances. This risk decreases over time compared to the status quo as free allowances are also being reduced for products not covered under CBAM, albeit at a slower rate;
- If CBAM covers the feedstock of a product, the **risk of indirect carbon leakage increases** due to the potential pass through of costs associated with the production emissions of the feedstock (upstream emissions); and
- If CBAM covers the derivative of a product, the **risk of circumvention decreases** where the derivative would be imported from outside the EU instead of being made in the Netherlands to circumvent the carbon costs on the product.

The impact of including certain products in CBAM on their carbon leakage risks therefore has different implications across the value chain of a product. The direct/indirect impact of CBAM depends on the position of a product within the value chain as well as how extensively the product and its derivatives are imported from outside the EU and produced in the Netherlands.

Direct carbon leakage risks related to non-EU exports can be mitigated by maintaining free allowances for non-EU exports, but not for indirect carbon leakage risks. The European Parliament has proposed that free allowances could be maintained for non-EU exports,[18] although whether this will be implemented in the actual CBAM design is uncertain. Such a measure could be considered as treating a part of the products manufactured in the EU differently from non-EU imported products in terms of carbon costs, even though the products are sold in different markets. This could risk non-compliance with World Trade Organisation (WTO) rules on non-discrimination. Direct linking free allowances to non-EU exports may also risk non-compliance with the WTO rules on the Agreement on Subsidies and Countervailing Measures. Furthermore, such measure would only be able to mitigate direct carbon leakage risks as the benchmarks for determining free allowances are based on production emissions only. If a product has significant upstream emissions and the upstream producers are able to pass down

[17] Since free allowances only cover direct emissions, producers of some electricity-intensive products can also receive financial compensation to mitigate carbon leakage risks related to carbon costs passed down in their electricity bill. Similar to free allowances, the maximum financial compensation companies can receive is based on benchmarks that are set to decrease over time. Furthermore, the financial compensation is directly linked to the ETS price. Whether companies receive financial compensation for these carbon costs is up to the discretion of the EU Member States and this varies among Member States. Should CO_2 emissions associated with electricity consumption be covered under CBAM, this carbon cost compensation may also see an accelerated phase out. However, it is yet unclear whether carbon cost compensation will continue in the Netherlands beyond the costs related to electricity consumption in 2021. It is therefore uncertain whether an accelerated phase out of the maximum financial compensation will affect eligible producers in the Netherlands compared to the status quo and thus not further discussed in this report.
[18] European Commission (2021). COM/2021/564 final

their carbon costs (whether it be CBAM or ETS), the downstream producers could see their cost rise. The current system of free allowances would not be able to compensate these upstream costs and therefore unable to mitigate indirect carbon leakage risks.

2.2 CBAM inclusion of chemicals and plastics

The Netherlands imports a significant amount of chemicals and plastics from outside the EU, which currently have a cost advantage in the EU market compared to domestic products due to no or lower carbon costs. In 2019, the Netherlands imported about €39 billion of chemicals and related products from outside the EU, about 15% of the EU's non-EU import of chemicals.[19] This number also includes main downstream products of chemicals such as plastics and pharmaceuticals. In the same year, value of sold production of chemicals, pharmaceuticals and plastics was €52 billion.[20] The high non-EU import relative to the domestic production could be an indicator that there is already competition in the EU market between producers in the Netherlands and outside the EU.[21] This also means that a significant amount of embedded emissions are already imported via chemicals into the Netherlands. CBAM could therefore mitigate future carbon leakage risks to restrain the growth of non-EU imports at the expense of domestic production due to the rising ETS costs. Where in the chemical value chain CBAM could potentially have a positive impact on reducing carbon leakage risks, is explored further in the next two sections of the report.

CBAM could therefore mitigate significant carbon leakage risks for chemicals and plastics, but it comes with a lot of challenges as the chemical value chain is long and complex. Broadly speaking, the chemical value chain can be divided into basic chemicals, specialty chemicals and consumer chemicals.[22] Basic chemicals cover petrochemicals (organic chemicals), polymers and inorganic chemicals, where the most greenhouse gas (GHG) emission-intensive processes take place. Determining the emissions associated with the production of these chemicals come with significant challenges. Some chemicals are produced with other chemicals in one process, raising the issue of how to attribute emissions. In addition, chemical products can undergo multiple product steps, making it difficult to trace the emissions associated with the production of these chemicals. Furthermore, many intermediate products in the chemical value chain are traded internationally at a varying degree, which could lead to circumvention risks if only a part of the value chain is covered. These issues on embedded emissions and circumvention risks are further explored in Section 4 for a few selected chemical value chains.

At the same time, the Netherlands also exports a lot of chemicals and plastics to outside the EU, for which inclusion in CBAM could increase carbon leakage risks due to the accelerated phase out of free allowances. In 2019, the Netherlands exported about €41 billion of chemicals and related products, which include plastics and pharmaceuticals, to countries outside the EU.[23] This is a substantial share of the sold production of €52 billion.[24] This indicates that some of the producers of chemicals and plastics have a lot of export to markets where they cannot pass on their carbon costs. An

[19] Eurostat (2022). Non-EU import of products under SITC code 5 *Chemicals and related products, n.e.s*.
[20] Sum of the value of sold production of NACE codes 20, 21 and 22 based on CBS (2021). Verkopen; industriële producten naar productgroep (ProdCom). Note that the values for non-EU imports and sold production are not fully comparable due to differences in product classifications in public statistics.
[21] It should be noted that this includes non-EU import in the Netherlands to re-export to other EU countries and therefore does not necessarily compete with domestic production. However, there is no publicly available data to estimate this.
[22] Cefic (2022). 2022 Facts and figures of the European chemical industry.
[23] Eurostat (2022). Non-EU import of products under SITC code 5 *Chemicals and related products, n.e.s*.
[24] Similar as to imports, a part of the non-EU export also includes re-exports of products manufactured elsewhere in the EU. However, there is no publicly available data to estimate this share.

accelerated phase out of free allowances would therefore increase the carbon leakage risks of the highly exported products. Where in the chemical value chain CBAM could potentially increase carbon leakage risks related to non-EU exports, is explored further in the next two sections of the report.

The European Parliament proposal for the addition of organic chemicals, plastics and hydrogen to CBAM[25] could therefore have varying effects on the carbon leakage risks. The European Parliament proposed to include the combined nomenclature (CN) codes *29 Organic Chemicals, 39 Plastics and articles thereof*, and *2804 10 000 Hydrogen*.[26] This would cover a broad range of products from basic organic chemicals to polymers and finished plastic products. Whether this will have a positive, negative or no impact on the carbon leakage risks of products produced in the Netherlands will be different for each product. As indicated above, this will depend on whether a product is mainly imported from outside the EU or exported to non-EU countries, as well as the significance of their upstream emissions.

The European Parliament proposal also includes basic pharmaceutical ingredients as organic chemicals, which are not analysed further in this study. This study uses the NACE/PRODCOM code classification as the basis for our analysis. NACE/PRODCOM is the statistical classification for products manufactured in the EU and most of the available data for the analysis is categorised accordingly. CN codes are mainly used for trade statistics, which does not fully match with the categorisation of products under NACE/PRODCOM. As a result, almost all products under NACE code *21.1 basic pharmaceutical ingredients* are also included in the product scope as they fall under CN code *29 Organic Chemicals*.[27] In the Netherlands, the production of basic pharmaceutical ingredients is, however, much smaller compared to other organic chemicals.[28] The magnitude of carbon leakage risk is therefore much lower. Furthermore, the downstream products of basic pharmaceutical ingredients are pharmaceutical preparations, which have a relatively high value added.[29] They would therefore be less prone to indirect carbon leakage risks from upstream emission costs. This study therefore does not analyse the basic pharmaceutical ingredients further.

This study focusses on NACE *20 Manufacture of chemicals and chemical products* and NACE *22.2 Manufacture of plastic products*, which includes hydrogen as it falls under chemicals. Specifically, hydrogen falls under NACE *20.11 Manufacture of industrial gases*. In Section 3, the chemical sector is analysed as a whole instead of only focussing on chemical products proposed by the European Parliament. This analysis aims to confirm if the proposed scope extension by the European Parliament matches the most relevant chemicals and its derivatives for the Netherlands.

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[25] The proposal of the European Parliament also calls for the additional inclusion of ammonia, which is already included in the European Commission's proposal as ammonia is classified under the product group Fertilisers.
[26] European Parliament (2022). Texts adopted - Carbon border adjustment mechanism.
[27] Only NACE *21.10.60 Glands and other organs; extracts thereof and other human or animal substances n.e.c.* is not included.
[28] In 2019, the sold production of products under NACE *20.14 Other basic organic chemicals* was €15 billion whereas that of NACE *21.1 Basic pharmaceutical ingredients* was €0.6 billion. Source: CBS (2021). Verkopen; industriële producten naar productgroep (ProdCom).
[29] For comparison, in the Netherlands, the gross value added of the downstream sector NACE *21.2 pharmaceutical preparations* is 35-40% of the production value, whereas for the main downstream sector of other basic organic chemicals NACE 20.16 *Plastics in primary form* is 15-25%.

3 Overview of non-EU imports and production of chemical and plastic products in the Netherlands

The expansion of CBAM to include the chemical sector affects importers of chemicals from outside the EU and Dutch manufacturers of these products, as well as downstream products indirectly. This section provides an overview of which chemical products are most imported from outside the EU by the Netherlands and where CBAM could affect the carbon leakage risk. This gives an indication on where largest impact of CBAM inclusion may lie in terms of monetary value and emissions. This is followed by an overview of the top produced chemicals in the Netherlands whose sectors are currently considered at risk of carbon leakage. The list of top non-EU imported and Dutch produced chemicals serves as a basis to determine the Dutch chemical value chains and downstream products that could be most affected.

The non-EU[30] imported and produced chemical and plastic products in the Netherlands are mapped out to provide insights on the most relevant products for the Netherlands when covered under CBAM. This analysis is based on public data available from Eurostat COMEXT[31] and CBS Statline.[32] It considers all chemical products at PRODCOM 8-digit level under the NACE sector 20 and plastic products under the NACE sector 22.2. There is particular focus on products under the basic chemicals sector (NACE 20.1) as that is where most of the carbon leakage risks lie. Trade and production values are reported as an average of 2018-2021, as statistics at product level are not always available or consistently updated annually. All values are expressed in 2021 million euros.

Although statistics on non-EU imports and Dutch production of products across the chemical value chain provide an indication of what products could be most affected by CBAM, ultimately, these values alone cannot determine the risk of carbon leakage. The analysis of risk of carbon leakage is provided in further detail in Section 4, which investigates the carbon leakage indicators of productions across a selection of chemical value chains.

3.1 Non-EU imports of chemical and plastic products in the Netherlands

3.1.1 *Non-EU imports of chemical products to the Netherlands*

Non-EU imports of chemicals mainly consists of basic chemicals (NACE 20.1), with organic chemicals being the largest product group of imported chemicals. Table 3-1 highlights the relatively high importance of non-EU imported basic chemicals in the Dutch industry, considering that basic chemicals make up over 61% of all non-EU imports of chemical products. Of the basic chemicals, most of the imports are *other organic basic chemicals* (NACE 20.14) (40%). Annex I.1 provides the overview of the top 20 imported non-EU chemical products to the Netherlands, which mainly consists of basic organic chemicals and plastics in primary form. Further, based on the EU ETS phase 4 carbon leakage criteria[33], all basic chemicals are considered at significant risk of carbon leakage. This is due to both a high emissions intensity as well as significant international trade.

[30] As the ETS also includes all countries in the European Economic Area (EU27 + Iceland, Liechtenstein and Norway), Iceland, Liechtenstein and Norway are excluded from the non-EU trade estimates.
[31] COMEXT
[32] CBS Statline
[33] European Commission (2019). Official Journal of the European Union Volume X. Products included in the EU ETS phase 4 carbon leakage list are considered to be at significant risk of carbon leakage.

The other chemical products that the Netherlands imports from outside the EU are not analysed further in this study as most make up a small fraction of Dutch imports, are considered final products and/or not considered at significant risk of carbon leakage at the EU level. While *other chemical products* (NACE 20.5) make up over a quarter of the Netherland's annual imports, most of these are final products (i.e. bottom of the value chain) and their respective sectors are not included in the EU ETS carbon leakage list. This implies that CBAM, on average, would lead to a limited cost increase for the products in these sectors.[34] Further, as final products are not the main input material for any downstream products and therefore have a limited cost impact, the impact on carbon leakage on downstream producers would be limited. Additionally, although the *manufacture of paints, varnishes and similar coatings, printing ink and mastics* (NACE 20.3) and the *manufacture of man-made fibres* (NACE 2.6) are included in the EU ETS carbon leakage list, they only account for a small fraction of Dutch imports (both 2% respectively). Products in these sectors have therefore also not been considered for further analysis in this study.

Based on available public data, non-EU imported chemical products are estimated to amount to at least 8.7 $MtCO_2$ of *imported* emissions, of which basic chemicals make up a 6.6 $MtCO_2$. The highest imported emissions are estimated to come from organic basic chemicals (5.3 $MtCO_2$), inorganic basic chemicals (1.0 $MtCO_2$) and fertilizers (0.8 $MtCO_2$). To put this in perspective, the Dutch chemical sector emitted roughly 19 $MtCO_2$ in 2021.[35] The imported emissions have been estimated using the EU average emission intensity per sector[36] and the value of non-EU imports into the Netherlands. It is important to note that this is a lower estimate, as the emission intensities are based on EU industry, where non-EU emission intensities are expected to be higher.[37] Furthermore, these only relate to production emissions of the imported products and do not include the upstream emissions related to the production of feedstock for the imported chemicals. These upstream emissions can be significant as demonstrated in Section 4.

Table 3-1 Average annual non-EU imports (and share of total chemical non-EU imports) (2018-2021) to the Netherlands and total estimated non-EU imported emissions, at 4-digit NACE sector level

NACE code	Description	Avg. annual non-EU imports by NL MEUR	% of total chemical non-EU imports	Included in EU ETS CL list?[38]	Non-EU imported emissions $ktCO_2$
20.11	Industrial gases	53	0%	Y	350
20.12	Dyes and pigments	628	3%	Y	192
20.13	Other inorganic basic chemicals	1081	5%	Y	977
20.14	Other organic basic chemicals	8989	40%	Y	5313
20.15	Fertilisers and nitrogen compounds	390	2%	Y	776
20.16	Plastics in primary forms	2481	11%	Y	459
20.17	Synthetic rubber in primary forms	180	1%	Y	47
20.20	Pesticides and other agrochemical products	188	1%	N	9
20.30	Paints, varnishes and similar coatings, printing ink and mastics	413	2%	Y*	13
20.41	Soap and detergents, cleaning and polishing preparations	386	2%	N	15
20.42	Perfumes and toilet preparations	1326	6%	N	23

[34] The impact of specific products within these sectors may vary, but have not been further investigated in this study due to their relative small value compared to basic chemicals.
[35] Emissiesregistratie (n.d.). Emissieregistratie, datareeks 1990-2020, plus voorlopige landelijke emissies 2021.
[36] The emission intensity is based on the total emissions of the sector and the production value in the Netherlands.
[37] For example, China is the leading exporter of chemicals in the world and its chemical production is highly dependent on coal, which is much more emissions-intensity than oil and gas that is mainly used in the EU. Source for the EU: Trinomics (2020). Energy prices, costs and their impact on industry and households. Source for China: RMI (2022). Transforming China's Chemicals Industry: Pathways and Outlook under the Carbon Neutrality Goal.
[38] European Commission (2019). Official Journal of the European Union Volume 62.

NACE code	Description	Avg. annual non-EU imports by NL MEUR	% of total chemical non-EU imports	Included in EU ETS CL list?[38]	Non-EU imported emissions ktCO₂
20.51	Explosives	67	0%	N	5
20.52	Glues	58	0%	N	4
20.53	Essential oils	349	1%	N	6
20.59	Other chemical products n.e.c.	5566	25%	N	416
20.60	Man-made fibres	345	2%	Y	87

*Only Vitrifiable enamels and glazes, engobes (slips) and similar preparations for ceramics, enamelling or glass (PRODCOM 20302150) and Liquid lustres and similar preparations; glass frit and other glass in powder; granules or flakes (PRODCOM 20302170).
Source: authors' calculations based on CBS, Eurostat and European Commission[39]

Most of the known Dutch importers of basic organic chemicals are manufacturers of chemicals and wholesalers of (chemical) products. From a previous Trinomics study on CBAM, CBS mapped out the Dutch importing sectors of non-EU imports of basic chemical products at a detailed level. Overall, the statistics only cover 16-46% of the total imports from these basic chemical sectors due to confidentiality reasons as well as the exclusion of re-exported products. The table below shows that of the sectors where data is available, the import of these chemical products is primarily in manufacturing of chemical products and wholesale of (chemical) products. The chemical products imported to wholesalers of chemicals are most likely sold to manufacturers in the Netherlands (as re-exports are not included), indicating that most of the imported chemical products are ultimately imported for use in the Dutch chemical sector.

Table 3-2 Top Dutch importing sectors of non-EU basic chemical products based on 2017-2019 average imports

	20.11 Industrial gases	20.14 Other organic basic chemicals	20.16 Plastics in primary forms
	Imported to:		
1	46.49 Wholesale of other household goods	20.14 Manufacture of other organic basic chemicals	20.16 Manufacture of plastics in primary forms
2	20.11 Manufacture of industrial gases	46.75 Wholesale of chemical products	46.75 Wholesale of chemical products
3	46.75 Wholesale of chemical products	20.16 Manufacture of plastics in primary forms	46.71 Wholesale of solid, liquid and gaseous fuels and related products
4	46.46 Wholesale of pharmaceutical goods	46.21 Wholesale of grain, tobacco, seeds and animal feeds	20.59 Manufacture of other chemical products n.e.c.
5		46.71 Wholesale of solid, liquid and gaseous fuels and related products	20.13 Manufacture of other inorganic basic chemicals
6		20.53 Manufacture of essential oils	22.21 Manufacture of plastic plates, sheets, tubes and profiles
7		49.41 Freight transport by road	20.14 Manufacture of other organic basic chemicals
8		46.46 Wholesale of pharmaceutical goods	20.41 Manufacture of soap and detergents, cleaning and polishing preparations
9		20.13 Manufacture of other inorganic basic chemicals	47.49 Wholesale of other household goods
10		46.38 Wholesale of other food	22.22 Manufacture of plastic packing goods

Source: CBS (2021). Handel CBAM-producten.

3.1.2 *Non-EU imports of plastics products to the Netherlands*

Almost half of the plastic products imported to the Netherlands from outside the EU are (semi-) finished products. Almost half of non-EU imports of plastic products to the Netherlands are final products (e.g. kitchenware, ornamental articles, office/school supplies, etc.) (NACE 22.29). Annex I.3 provides an overview of the top 20 imported plastic non-EU products to the Netherlands, which mainly consists of plastic products (sheets/film of plastic) and packaging materials as well as flooring and plastics for final use (e.g. kitchenware).

[39] Values of non-EU import are from CBS Statline and Eurostat Comext. Emissions per NACE 4 sector have been estimated by using emissions intensity at the EU level from European Commission (2018). EU ETS phase 4 Preliminary Carbon Leakage List, the EU average ratio between production value and gross value added from Eurostat Structural Business Statistics, and the value of non-EU imports.

The plastic products are not considered to be at significant risk of direct carbon leakage at the EU level, but inclusion in CBAM could help limit circumvention risks. Table 3-3 shows that none of the sectors for plastic products are considered at significant risk at the EU level, primarily due to the relative low emissions intensity. This implies that CBAM would lead to a relatively limited increase in cost for these products it is only applied to the production emissions. Since a significant share of the imported plastic products relate to finished products, no further processing is needed for final use. This means that there are also no circumvention risks if these products would be covered under CBAM.

Based on available public data, non-EU imported plastic products are estimated to amount to at least 0.2 $MtCO_2$ of *imported* emissions, of which final use plastics (NACE 22.29) make up a significant share. The total imported emissions are based on the estimated EU emission intensity and non-EU import values. As noted with chemical products, this is a lower estimate as the emission intensity is based on EU industry and upstream emissions are not included. The highest imported emissions are in production of final use plastics (103 $ktCO_2$) and plastic plates, sheets, tubes and profiles (66 $ktCO_2$).

Table 3-3 Average annual non-EU imports (and share of total plastic non-EU imports) (2018-2021) to the Netherlands and total estimated non-EU imported emissions, at 4-digit NACE sector level

NACE code	Description	Avg. annual non-EU imports by NL: MEUR	Avg. annual non-EU imports by NL: % of total plastic non-EU imports	Included in EU ETS CL list?[40]	Non-EU imported emissions $ktCO_2$
22.21	Plastic plates, sheets, tubes and profiles	746	23%	N	66
22.22	Plastic packing goods	507	16%	N	60
22.23	Builders' ware of plastic	429	13%	N	13
22.29	Other plastic products	1536	48%	N	103

Source: authors' calculations based on CBS, Eurostat and European Commission[39]

3.2 Production of chemical and plastic products in the Netherlands

3.2.1 *Production of chemical products in the Netherlands*

As with the non-EU imports, the analysis for production shows that basic chemicals (NACE 20.1) are the most relevant chemical subsector, which makes up 76% of all chemical production in the Netherlands. Annually, the Netherlands produces about €41.8 billion of (sold) chemical products on average, of which €31.6 billion of the sold chemical production are basic chemicals (NACE 20.1) as shown in Table 3-4. Of the basic chemicals, as with the non-EU imports, the most produced are NACE *20.14 other organic basic chemicals* and NACE *20.16 plastics in primary form* (polymers) in absolute terms. These correspond to the scope of organic chemicals and plastics as proposed by the European Parliament to be included under CBAM. Annex I.2 provides an overview of the top 20 produced chemical products in the Netherlands, of which consists mainly of organic chemicals and polymers with ethylene and styrene being the top produced.

In almost all basic chemicals sectors, a third or more of the production in the Netherlands is being exported to outside of the EU. The public statistics indicate that some sectors even export more than half of their production to countries outside of the EU) as shown in Table 3-4. This production could potentially see an increase in their carbon leakage risks compared to the status quo if covered under CBAM due to the accelerated phase out of free allowances. In absolute terms, the sectors *other organic basic chemicals* and *plastics in primary form* are also where most non-EU export occurs.

[40] European Commission (2019). Official Journal of the European Union Volume 62.

Although the Dutch chemical sector also covers other chemical divisions than basic chemicals, these products are not further investigated in this analysis. These sectors only make up a small fraction of Dutch production and/or mainly consists of final products. Therefore, the extent of the risk of carbon leakage related to these products is expected to be limited.

Almost all of the CO_2 emissions of the Dutch chemical sector come from basic chemical production (NACE 20.1).[41] Table 3-4 shows that in 2020, over 67% of all Dutch chemical sector registered emissions were derived from basic organic chemicals (NACE 20.14) and plastics in primary form (NACE 20.16), followed by 17% from fertiliser production (NACE 20.15) and 15% from other basic chemicals (e.g. industrial gases, dyes/pigments, inorganic basic chemicals). The remaining 2% come from other chemical production processes. This amounted to about 20 $MtCO_2$ in 2020.

Table 3-4 Average annual chemical production and non-EU exports (and share of production) in the Netherlands (2018-2021) and registered CO_2 emissions from production in the Netherlands, at 4-digit NACE sector level

		Avg. annual production in NL		Avg. annual non-EU exports by NL		CO_2 emissions in NL (2020)
NACE code	Description	MEUR	% of total chemical production	MEUR	% of NL production	$MtCO_2$
20.11	Industrial gases	849	2%	34	4%	1.57
20.12	Dyes and pigments	795	2%	490	62%	0.13
20.13	Other inorganic basic chemicals	1104	3%	1166	106%	1.13
20.14	Other organic basic chemicals	15334	37%	8406	55%	7.66
20.15	Fertilisers and nitrogen compounds	1627	4%	771	47%	3.17
20.16	Plastics in primary forms	11545	28%	4045	35%	4.92
20.17	Synthetic rubber in primary forms	350	1%	120	34%	.
20.20	Pesticides and other agrochemical products	298	1%	160	54%	0.00
20.30	Paints, varnishes and similar coatings, printing ink and mastics	2113	5%	774	37%	0.01
20.41	Soap and detergents, cleaning and polishing preparations	1227	3%	459	37%	0.00
20.42	Perfumes and toilet preparations	332	1%	1083	326%	.
20.51	Explosives	0	0%	12	n/a	.
20.52	Glues	401	1%	131	33%	0.00
20.53	Essential oils	761	2%	447	59%	0.01
20.59	Other chemical products n.e.c.	4330	10%	3840	89%	0.26
20.60	Man-made fibres	719	2%	132	18%	0.02

Note: "." means that the data is not available from public statistics and could be non-zero. 2020 is the latest year for which emission data is available at NACE 4-digit sector level. Emissions only include on-site emissions and not indirect emissions from consumption of electricity.
Source: Calculations based on data from CBS, Eurostat and Emissiesregistratie.

3.2.2 *Production of plastic products in the Netherlands*

The Dutch plastics sector greatly focuses on basic plastic products. Table 3-5 shows that 18% of the plastic production relates to NACE 22.29 *Other plastic products,* which is where (semi)finished plastic products fall under. This means that 82% of the plastic product production generally basic plastic products, which are used in other sectors. The non-EU export of products cannot be determined due to insufficient public data. As Annex I.4 provides an overview of the top 20 plastic products produced in the Netherlands, which include plastics across the plastics value chains (e.g. film/sheets of plastic, plastics used for construction, packaging and automobile parts and final plastics such as kitchenware).

While the direct carbon leakage risks for domestically produced plastic products are low, there could be various risks of indirect carbon leakage. If the emissions-intensive upstream materials used

[41] Emissiesregistratie (n.d.). Emissieregistratie, datareeks 1990-2020, plus voorlopige landelijke emissies 2021.

to produce plastic products (e.g. organic chemicals and polymers) are covered by CBAM, and plastic products are not, there is a possible risk of carbon leakage from passed on upstream emissions costs. This would be partly mitigated if plastic products are covered under CBAM. However, this could cause indirect carbon leakage risks in their downstream sectors that use the basic plastic products. This is not analysed further within this study due to a lack of publicly available data on the exact products plastics produced in the Netherlands are used for. Nonetheless, this could be a point of attention in the consideration for including plastic products in CBAM.

The Dutch plastics sector produced about 0.06 MtCO_2 of emissions in 2020, of which most come from production of semi-finished plastics (NACE 22.21).[42] In 2020, roughly half of all Dutch plastic sector registered emissions were derived from plastic plates, sheets, tubes and profiles (NACE 22.21), followed by 35% from plastics for construction (NACE 22.23) and 15% from plastics for packaging (NACE 22.22). The remaining 2% come from other plastic products.

Table 3-5 Average annual plastic production and non-EU exports (and share of production) in the Netherlands (2018-2021) and registered CO_2 emissions from production in the Netherlands, at 4-digit NACE sector level

NACE code	Description	Avg. annual production in NL		Avg. annual non-EU exports by NL		CO_2 emissions in NL (2020)
		MEUR	% of total plastic production	MEUR	% of total plastic production	MtCO_2
22.21	Plastic plates, sheets, tubes and profiles	2830	32%	631	22%	0.03
22.22	Plastic packing goods	.	.	318	.	0.01
22.23	Builders' ware of plastic	.	.	184	.	0.02
22.29	Other plastic products	1618	18%	648	31%	0.00

Note: "." means that the data is not available from public statistics and could be non-zero. 2020 is the latest year for which emission data is available at NACE 4-digit sector level. Emissions only include on-site emissions and not indirect emissions from consumption of electricity.
Source: Calculations based on data from CBS, Eurostat and Emissiesregistratie

3.3 Overview of the most relevant Dutch chemical value chains

The analysis of the non-EU import and Dutch production of chemicals and their downstream derivates confirmed that the most relevant value chains are related to organic chemicals and polymers (and plastics), with ammonia and hydrogen also of interest due to their proposed inclusion by the European Parliament. Section 3.1 and 3.2 show that of non-EU import and domestic production of basic chemicals potentially at the highest risk of carbon leakage are organic chemicals and polymers. This is also confirmed by the more detailed analysis of top non-EU imports and domestically produced products in Annex I; the vast majority belonging to the organic chemical and polymer sector. Based on the European Parliament's proposal and the top imported and produced chemical products, the following value chains are therefore most relevant for the Netherlands:

(A) Steam cracking refinery products;
(B) Hydrogen (SMR/ATR derivatives);
(1) Ethylene derivatives;
(2) Propylene derivatives;
(3) C4-derivatives;
(4) Aromatics derivatives; and
(5) Ammonia.

The mapping of the most relevant chemical value chains helps in identifying the intermediate and downstream products that could be most affected by inclusion of chemicals under CBAM. Figure 3-1 to

[42] Emissiesregistratie (n.d.). Emissieregistratie, datareeks 1990-2020, plus voorlopige landelijke emissies 2021.

Figure 3-7 present a schematic overview of the chemical value chains most relevant to the Netherlands in the context of CBAM. The schematic overviews are therefore not a comprehensive mapping of all chemicals and downstream products, but only the most relevant ones for the Dutch value chains, highlighting with different colours the top imported and produced chemicals.[43] The schematics also include an identification of whether the key downstream products are part of NACE *22.2 Plastic products* (the other product group that the European Parliament proposed include in CBAM). In addition, the diagrams highlight the chemicals that have 'low transportability', which is an indication of potential complexities associated to the long- distance transport of these products.[44] Besides, the mapping differentiates for which products are included in an ETS-product benchmark, and what sections of the value chains have relatively high GHG emissions in the production process.

The overview of the most relevant value chains shows that there are various interdependencies between the most imported chemicals from outside the EU and most produced chemicals in the Netherlands. Especially ethylene and benzene, both in the top 20 non-EU imported and Dutch produced lists, are key precursors for many chemical products. This includes a wide range of chemicals that are in the top 20 list of the basic chemical production in the Netherlands. Other basic chemicals that are highly produced in the Netherlands but also imported from outside the EU are styrene, acrylic ethers, aniline and polyesters. These products are generally further down in the chemical value chain as a precursor for final products. This implies that there is already significant competition between these non-EU imports and domestically produced products. CBAM would therefore potentially have a positive impact on the competitiveness of domestically produced products and with that reduce carbon leakage risks. The exposure of domestic production to competition from non-EU imports for a selection of chemical value chains is explored in Section 4.

The mapping shows that the production of various polymers in the Netherlands could see a significant increase in risk of indirect carbon leakage if their precursors are included under CBAM, irrespectively if these polymers are covered under CBAM. Table 3-5 in Annex I.2 shows that many polymers that have a relative high production in the Netherlands are also exported to outside the EU. The precursors of these polymers are key chemicals resulting from steam cracking. If organic chemicals would be included in CBAM, producers of polymers could see their feedstock costs increase. This could be directly due to CBAM costs on feedstock imported from outside the EU or indirectly from passed on ETS costs from EU produced feedstock as explained Section 2.1. Thus, even if these polymers are included in CBAM, CBAM on their precursors could increase the risk of carbon leakage for these products. This is due to the large share of exports to non-EU markets of these polymers produced in the Netherlands. The relation between domestic production and non-EU exports is further explored in Section 4 for a selection of chemical value chains.

Most of the highly imported non-EU chemicals appear further along the chemical value chain, and if the CBAM inclusion of chemicals would focus on those chemicals, the risks of indirect carbon leakage could be more confined. The only exception is methanol, an organic chemical that appears in many different value chains in the figures and is currently produced via an emission intensive process. Inclusion of methanol under CBAM could lead to indirect leakage risks for various downstream products,

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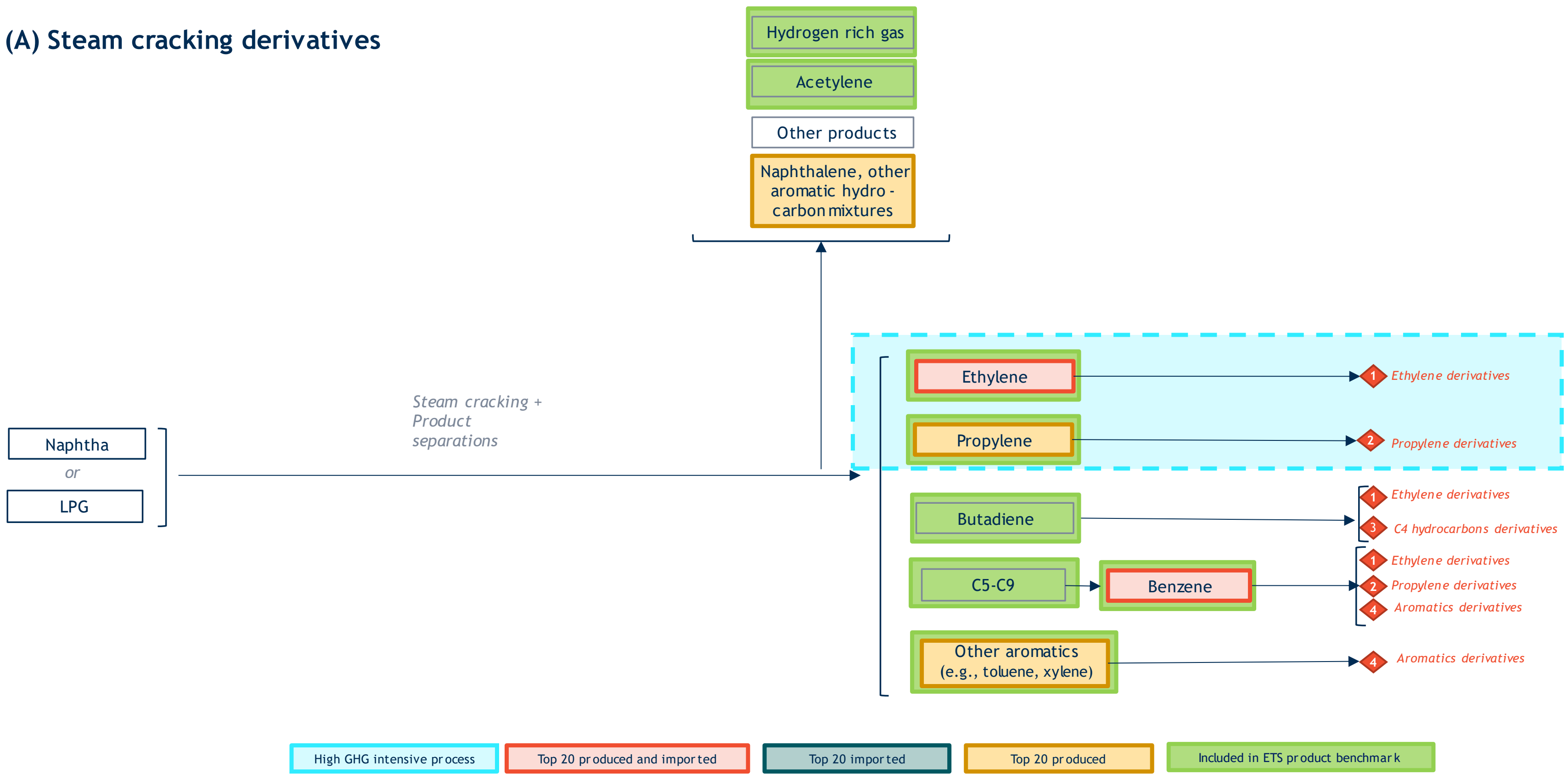
[43]Relevant products for the Dutch value chain were selected based on the publications within the MIDDEN project (Manufacturing Industry Decarbonisation Data Exchange Network) when available. In addition, the websites of the manufacturers of the identified chemicals in the Netherlands were consulted (e.g., Dow Chemical, SABIC, Linde Gas, Air Liquide), as well as the Plastics Europe database.

[44] In general, products with 'low transportability' are highly flammable or toxic, and typically not transported but used within the manufacturing site. Products with 'low transportability' are less likely to be imported from non-EU countries.

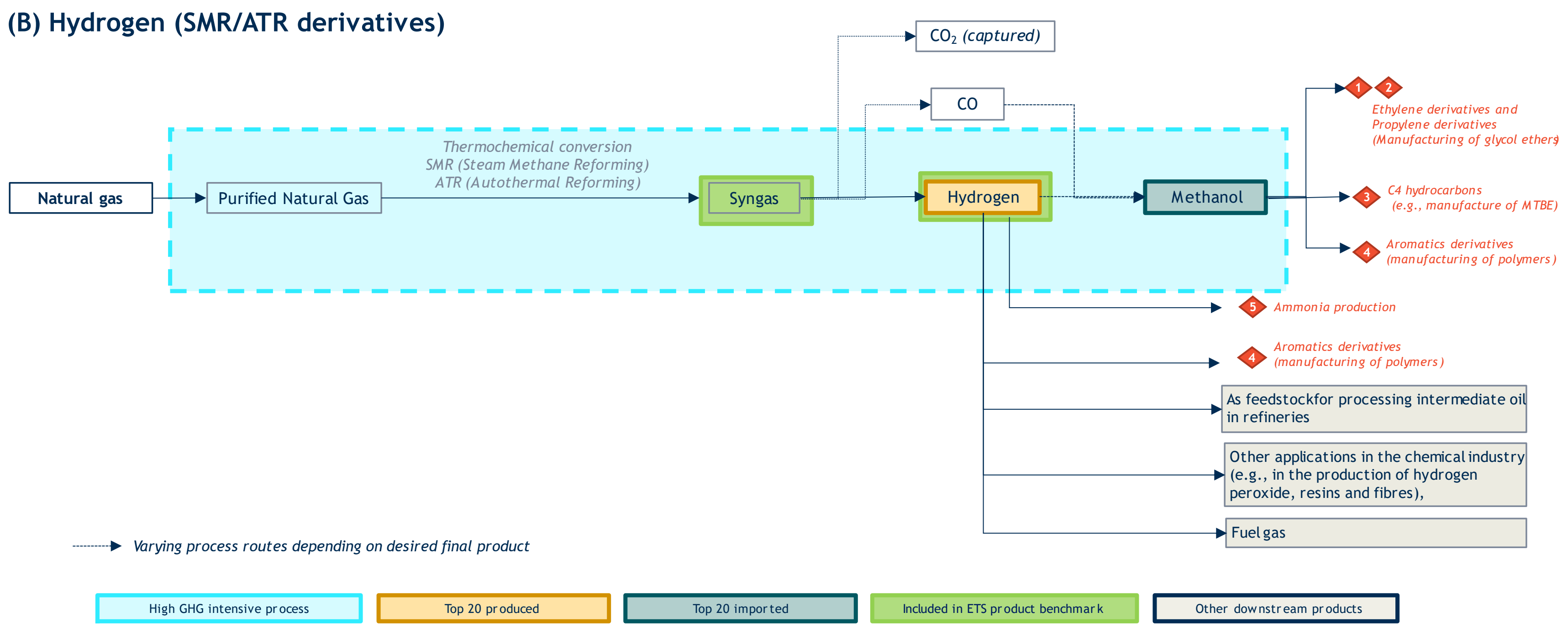
including circumvention risks from non-EU imports of these downstream products. The leakage risk related to the downstream products sold in the EU could be mitigated by including them under CBAM. The other highly imported non-EU chemicals appear further along the value chain, which means that indirect leakage risks would be more confined to specific downstream products. Nonetheless, the identification of main applications of these chemicals shows that there is still a wide range of downstream products that could be affected. The degree by which downstream products may be affected by indirect leakage risks from upstream emissions is also investigated in Section 4 for a few chemical value chains.

Figure 3-1 Value chain mapping - Steam Cracking Derivatives (non-exhaustive)[45]



Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

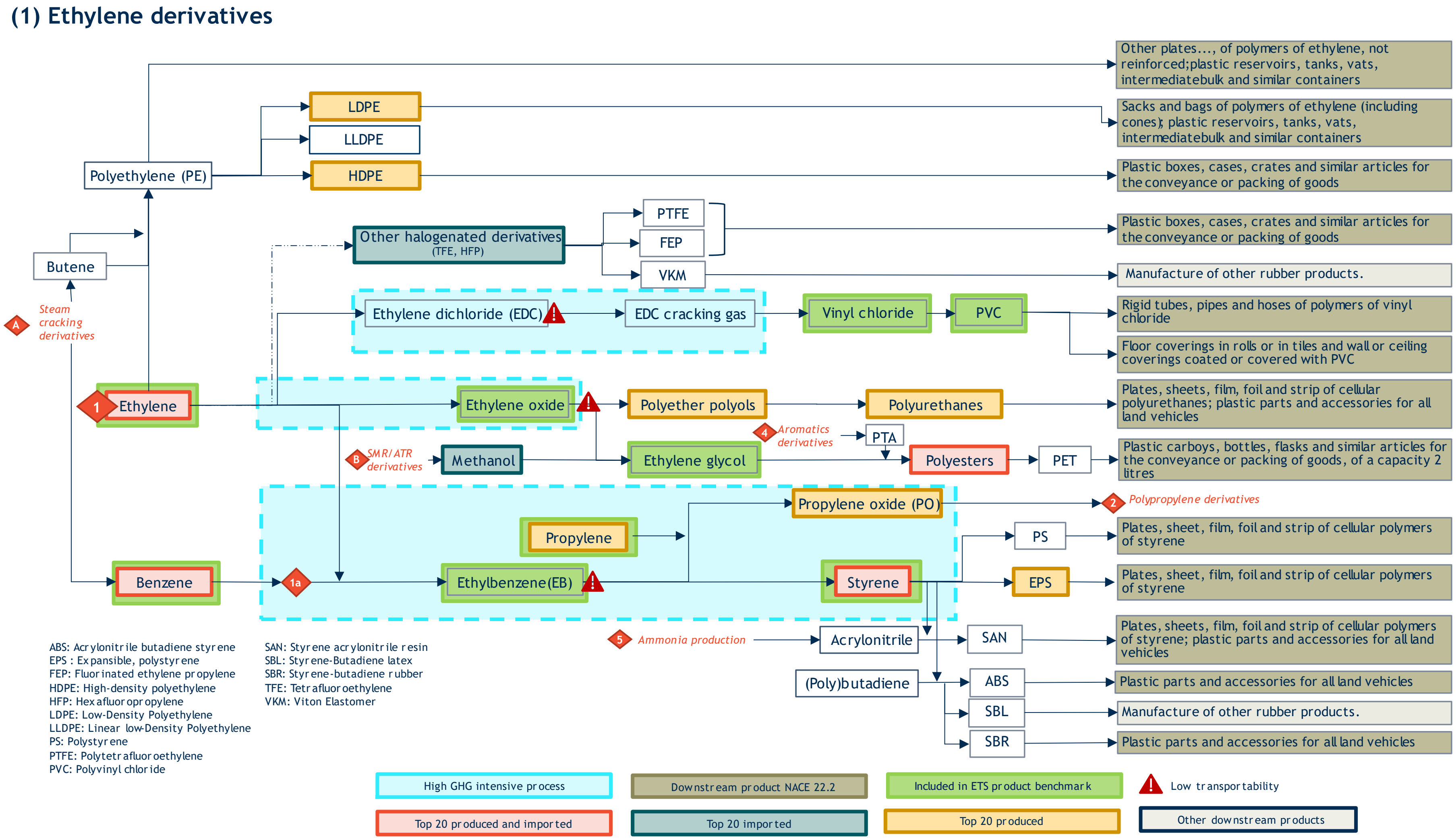
Figure 3-2 Value chain mapping - Hydrogen (SMR/ATR derivatives) (non-exhaustive)



Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

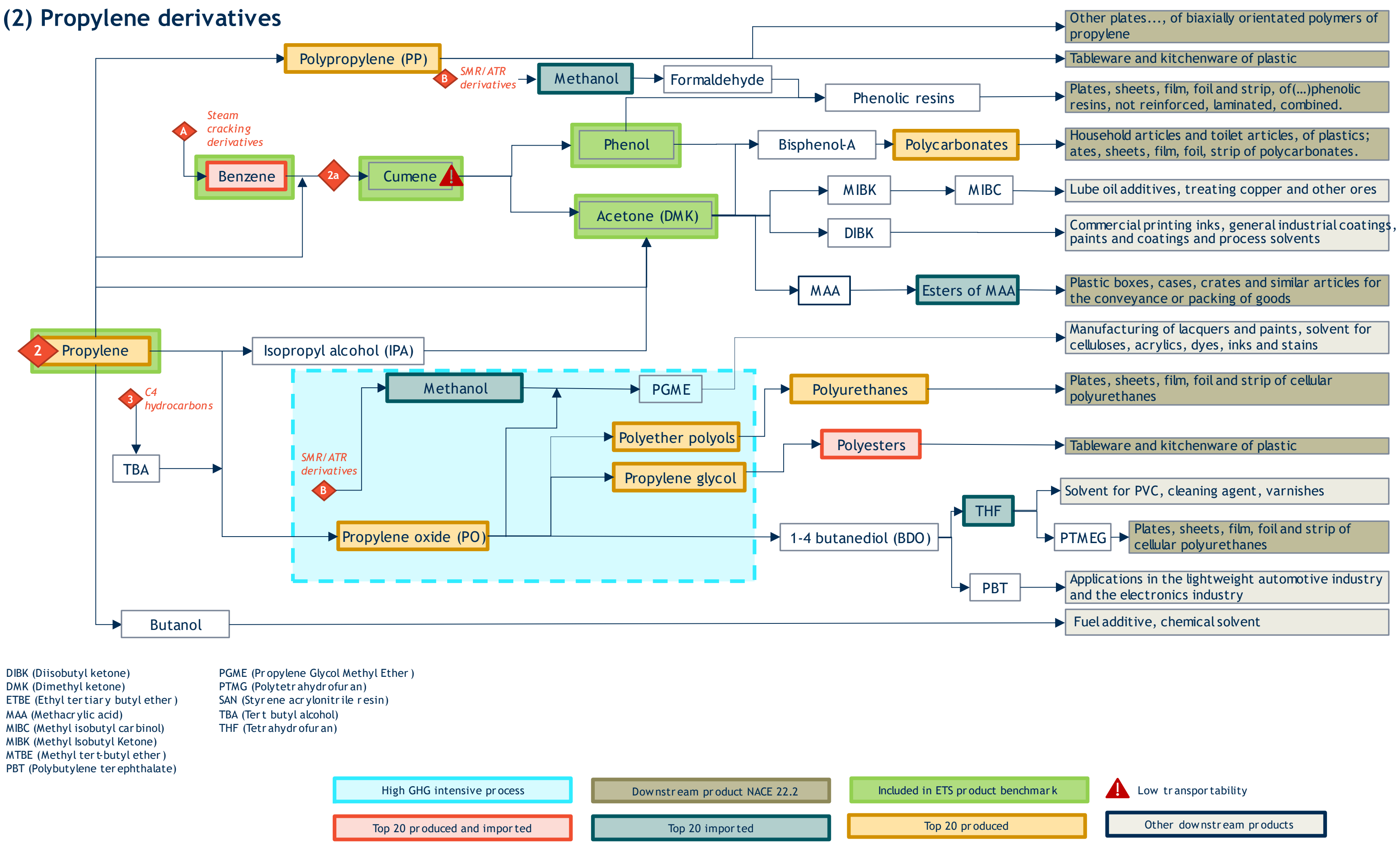
[45] The mapping does not include all the inputs used for the production of the chemical products (incl., water/steam streams, catalysts, etc.). Similarly, only the main production processes are mentioned.

Figure 3-3 Value chain mapping - Ethylene derivatives (non-exhaustive)



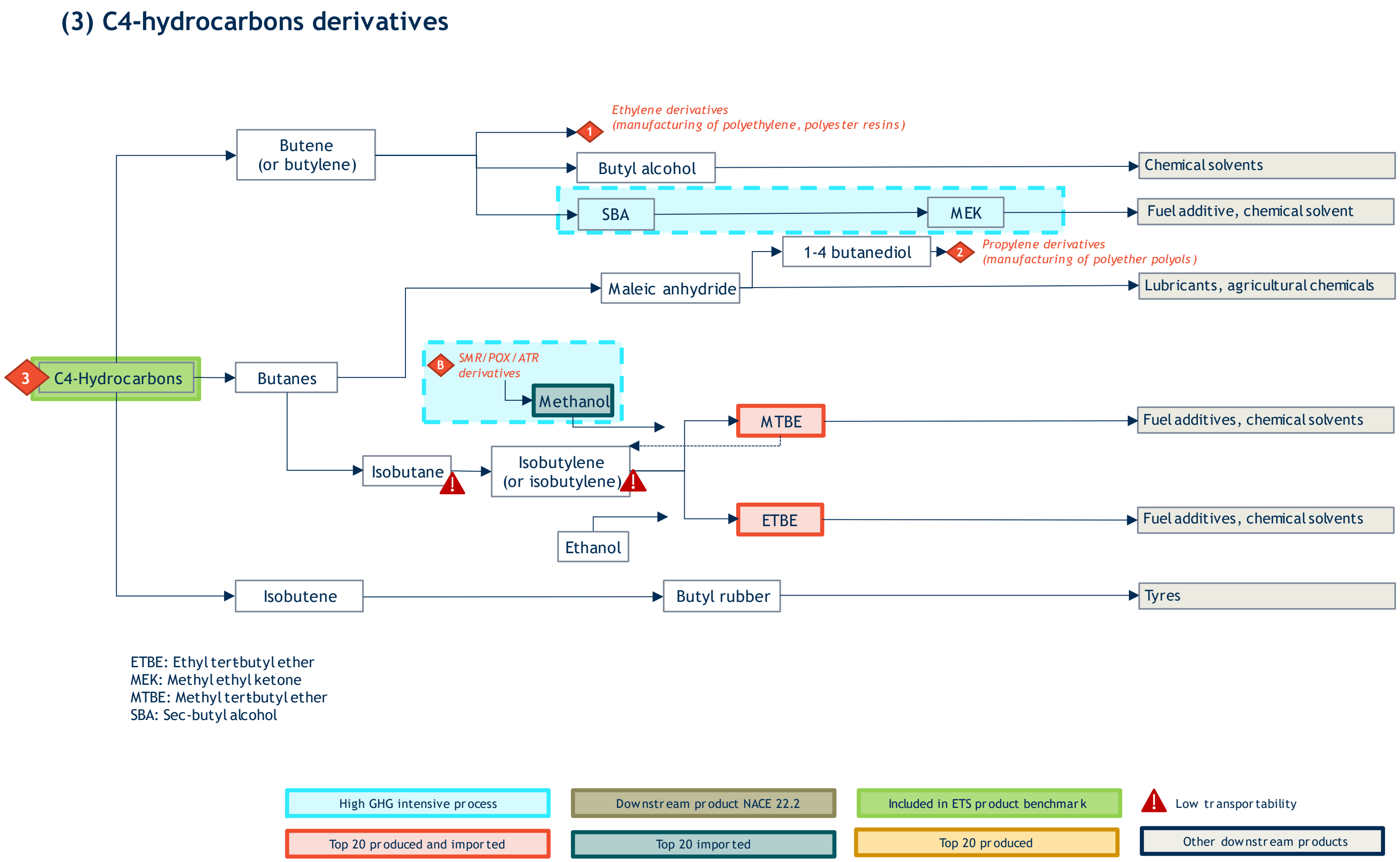
Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

Figure 3-4 Value chain mapping - Propylene derivatives (non-exhaustive)



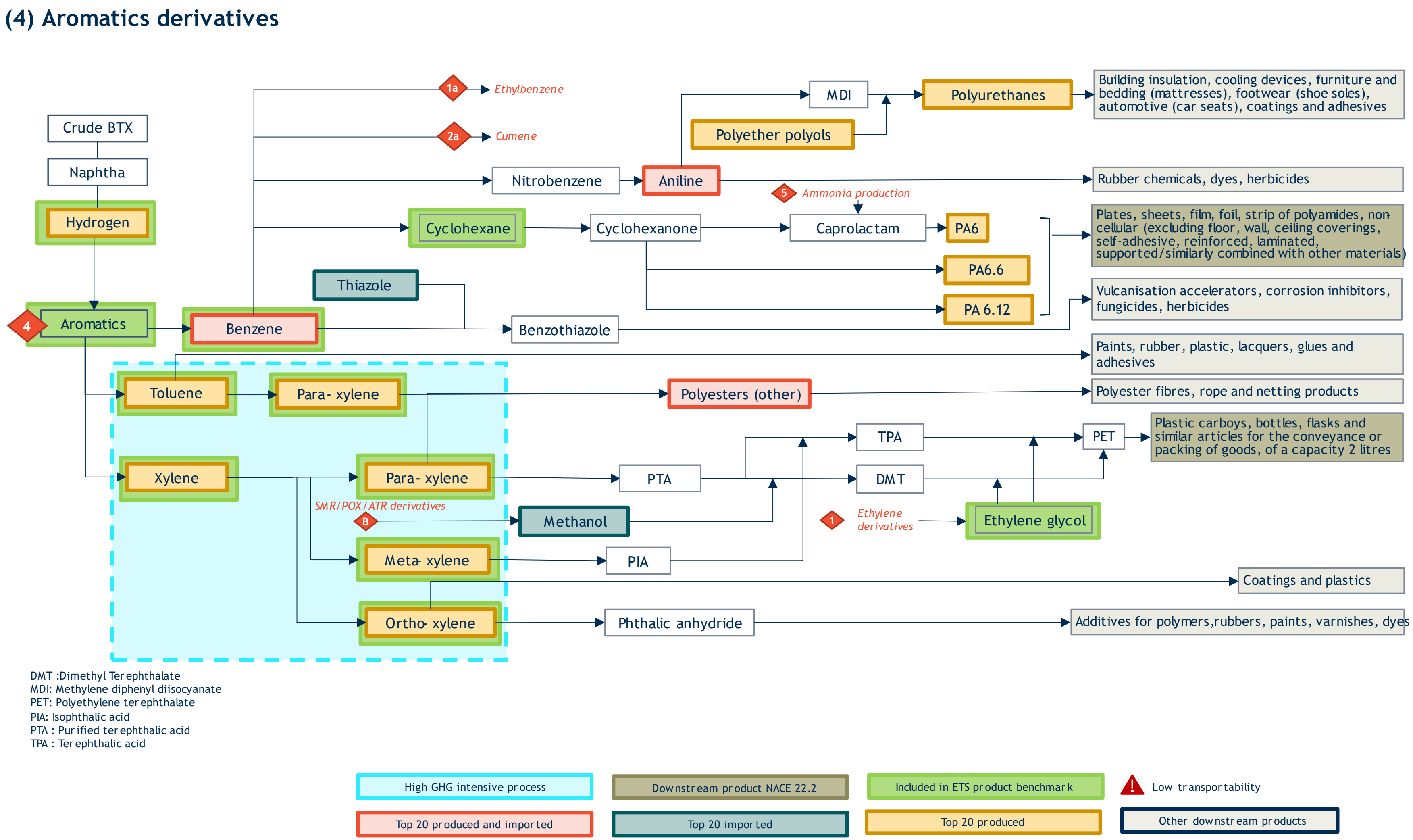
Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

Figure 3-5 Value chain mapping - C4 hydrocarbons derivatives (non-exhaustive)



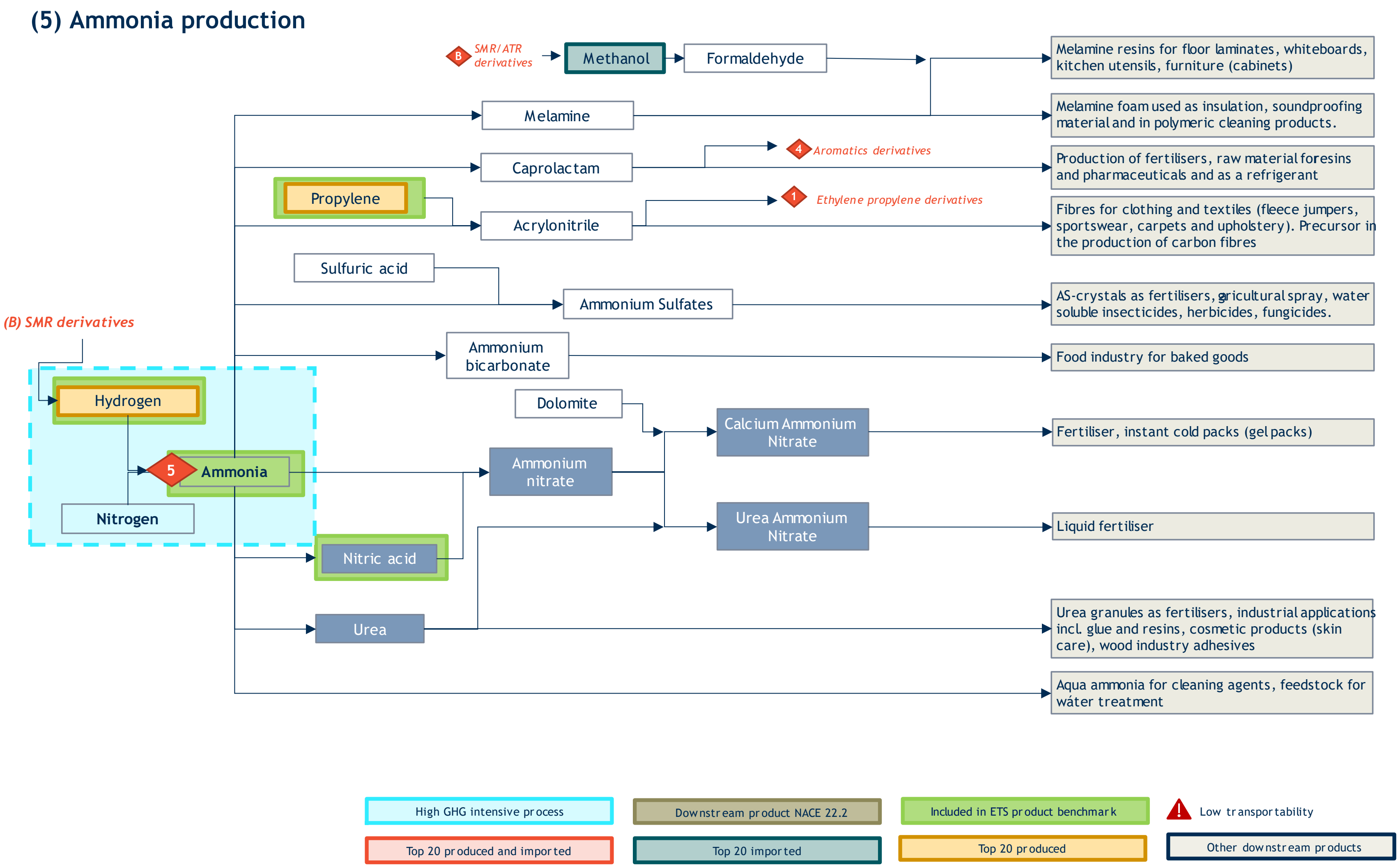
Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

Figure 3-6 Value chain mapping - Aromatics within Dutch chemical Industry (non-exhaustive)



Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

Figure 3-7 Value chain mapping - Ammonia production/derivatives within Dutch chemical Industry (non-exhaustive)



Source: Trinomics based on PBL/TNO (MIDDEN) and other public sources

4 Analysis of selected value chains

The impact of CBAM on the risk of carbon leakage of chemical and plastic products has different implications across the chemical/plastic value chains. Whether CBAM has a positive or negative impact on the carbon leakage risk of a product depends on a range of factors. As explained in Section 2, the main factors are: (i) the production emissions of a product, (ii) how extensively it is traded internationally, and (iii) whether its upstream feedstock or downstream derivatives are also covered by CBAM.

This section provides an analysis of the impacts CBAM could have on carbon leakage risks and practical challenges for a few chemical value chains selected based on relevance and data availability. The selection has been based on their relevance to the Dutch chemical sector in terms of productions and/or international trade, and availability of public data to assess carbon leakage risks. The selection also considers the product groups that the European Parliament proposed to be included in CBAM (organic chemicals, plastics, ammonia and hydrogen). This resulted in the following six products/value chains:

1. Steam cracking products;
2. Ethylene oxide and its derivatives;
3. Ethylbenzene and its derivatives;
4. Ethyl tert-butyl ether (ETBE), methyl tert-butyl ether (MTBE) and key precursors;
5. Hydrogen; and
6. Ammonia.

The analysis of the selected value chains aims to show the different considerations to be taken into account when including chemicals and plastic products under CBAM. The analysis of the first four value chain includes an overview of the value chain analysed and a quantitative analysis of the carbon leakage risk indicators. We also discuss considerations for the two main practical aspects when including the analysed value chain in CBAM: challenges for determining embedded emissions and circumvention risks. For hydrogen and ammonia, a similar analysis is conducted in a qualitative manner, but also considers the rising demand for hydrogen in the future and ammonia as a potential hydrogen carrier.

4.1 Methodology of the carbon leakage risk analysis

For the first four value chains, the impact of CBAM on their carbon leakage risk is analysed based on indicators used under the EU ETS. The carbon leakage risk in this study is estimated using the EU ETS indicators and criteria for carbon leakage risk used in Phase 4 (2021-2030), defined as:

$$Carbon\ leakage\ indicator = Emission\ intensity\ \times trade\ intensity\ \geq 0.2$$

where:

$$Emission\ intensity = \frac{emissions\ [kgCO_2]}{gross\ value\ added\ (GVA)\ [€]}$$

and

$$Trade\ intensity = \frac{(non\text{-}EU\ imports + non\text{-}EU\ exports)}{(non\text{-}EU\ imports + domestic\ production).}$$

If the carbon leakage indicator of a product or sector is greater or equal to 0.2, the product is considered at significant risk of carbon leakage in Phase 4 of the EU ETS. On the other hand, if the indicator is less than 0.2, then the risk of carbon leakage is considered limited. For the emissions intensity, data is not readily available and have been estimated based on available public data from MIDDEN, CBS and Eurostat, explained in Annex II. For the trade intensity, public data on production and non-EU[46] trade of the Netherlands have been used. However, for some chemical products, the trade intensities of the Netherlands could not be estimated due to lack of data. For these products, the trade intensities at the EU level have been used as a proxy.

To give a sense whether carbon leakage risks are primarily caused by carbon costs (emissions intensity) or international trade, the severity of trade exposure is also assessed separately. The severity of trade exposure has been analysed using the ETS Phase 3 carbon leakage criteria for trade intensity. In Phase 3 (2013-2020) of the EU ETS, sector would be considered at significant risk of carbon leakage if the trade intensity was higher than 30%. Alternatively, a sector would also be considered at significant risk of carbon leakage if the trade intensity was higher than 10% in combination with a carbon cost intensity of at least 5%. The analysis uses these thresholds to give an indication of the severity of trade exposure:

- Low trade exposure: <10%
- Medium trade exposure: 10%-30%
- High trade exposure: >30%.

The carbon leakage indicator is used to first assess the direct risk of carbon leakage with and without CBAM. In the assessment of direct carbon leakage risks, the emissions intensity only considers the production emissions of a product. These are the GHG emissions associated with the fuel and electricity use to manufacture the product from input materials.[47] For the quantitative analysis, all production emissions of basic chemicals and polymers are assumed to be covered under the EU ETS and therefore can also be covered under CBAM. Production emissions of finished plastic articles are not considered as these are generally not covered under the EU ETS, so they would not be affected by CBAM. For the analysis, CBAM is further assumed to fully mitigate the carbon leakage risk related to non-EU imports, whereas non-EU exports would be fully exposed to carbon leakage risks due to the accelerated phase out of free allowances. Thus, the trade intensity without non-EU imports provides an indication of how much exposure a product has to non-EU competition in markets outside the EU. The carbon leakage indicator is therefore calculated using two trade intensities and compared with the 0.2 threshold to assess the carbon leakage risks with and without CBAM:

- **Carbon leakage risk when *not* covered by CBAM**: indicator includes non-EU imports and non-EU exports.
- **Carbon leakage risk when covered by CBAM**: indicator includes non-EU exports only.

To understand the indirect impact of CBAM on risk of carbon leakage, the analysis also considers upstream emissions, which are the emissions from the production of the upstream feedstocks of the product. In this study, the upstream emissions are estimated for two levels: direct upstream emissions which are the production emissions related to the feedstock and further upstream emissions which are the production emissions further up the value chain. This split in upstream emissions aims to

[46] As the EU ETS also includes all countries in the European Economic Area (EU27 + Iceland, Liechtenstein and Norway), Iceland, Liechtenstein and Norway are excluded from the non-EU trade estimates.
[47] Note that in this study, the carbon leakage risk of products has been analysed for individual products and interdependencies between products, e.g. the yield pattern of steam cracking products, have not been taken into account.

illustrate complexity of chemical value chains and the relevance of emissions further upstream in the value chain to the carbon leakage risk. The upstream emissions only consider production emissions related to chemicals as other feedstocks, such as refinery products, are currently not being considered for inclusion in CBAM. For the analysis, we assume that manufacturers of products covered under CBAM can fully pass on their carbon costs (whether it be CBAM or ETS costs) to their customers in the EU. No pass through is assumed for carbon costs of products not covered under CBAM or exported to outside the EU. This shows the potential impact on the risk of carbon leakage of a product if all upstream carbon costs from covered chemical products would be passed on to downstream producers.

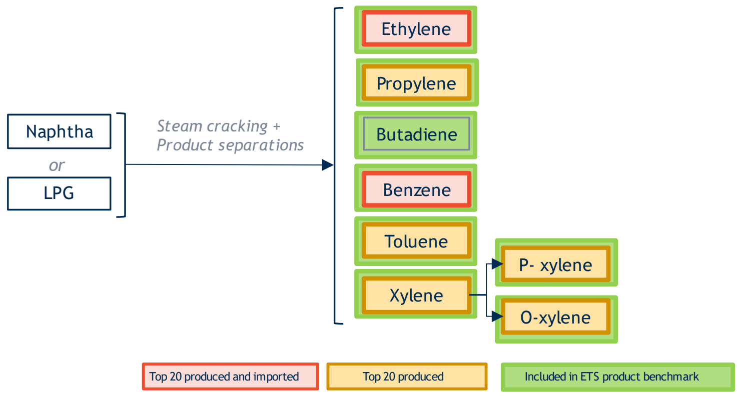
The carbon leakage indicator analysis shows the carbon leakage risk of products in the absence of any carbon leakage protection, so the reflection on carbon leakage risks compared the status quo is provided qualitatively. A quantitative comparison of the carbon leakage risk of products between CBAM inclusion and the status quo with free allowances requires data that is not publicly available. Data would be needed on the share of emissions covered by free allowances of products manufactured in the Netherlands, and how this share will develop in the future. Such data would be at most available for products under the product benchmark in the EU ETS, which is highly confidential. In addition, it requires information on the degree that carbon costs are already being passed on to downstream consumers in the status quo, which is not available. The following assumptions are therefore made for the status quo for the qualitative reflection: i) free allowances only cover a part of the production emissions, ii) producers in the Netherlands are currently not able to pass on any ETS costs to their downstream customers. In practice, some companies may already be able to pass on some of their carbon costs downstream in the status quo, so the impact of CBAM inclusion on the indirect carbon leakage risks could be overestimated.

Important to note is that the analysis of carbon leakage risks is based on historical data, while future developments could change the risk of carbon leakage. The emissions intensity and trade intensity have been calculated based on the average of the available data over 2018-2021. The assessment of carbon leakage risks is therefore only a snapshot of the current situation. However, emission intensities and trade flows are continuously changing and influenced by many different factors such as energy and materials costs, policies and technological advancements. A product meeting the criteria for carbon leakage risks based on historic data may not be at risk in the future even without CBAM if significant emission reductions would occur. At the same time, free allowances under the EU ETS continue to decrease under the status quo and ETS prices are expected to rise. Against this background, the carbon leakage risks of domestically produced products is therefore already increasing without their inclusion in CBAM.

4.2 Steam cracking products

Steam cracking is an energy-intensive process that turns refinery products into chemical building blocks. Figure 4-1 shows a diagram of the most relevant steam cracking products in the Netherlands for which data is available to analyse carbon leakage risk.

Figure 4-1 Simplified diagram of the most relevant steam cracking products in the Netherlands



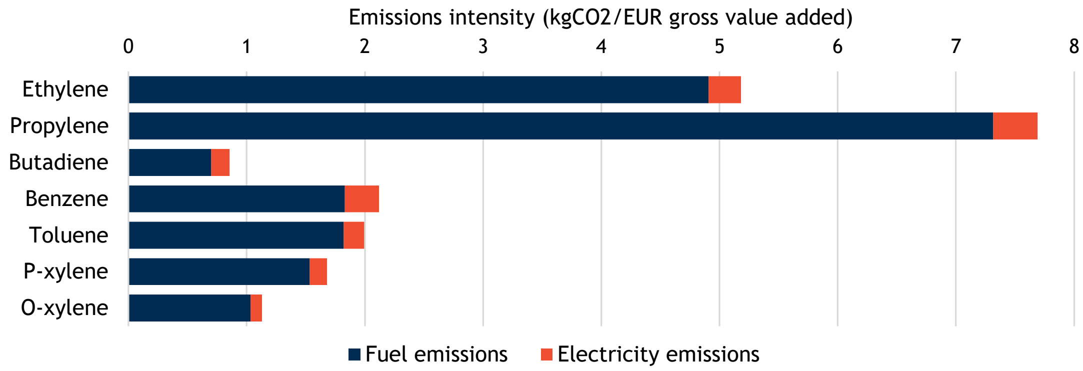
Source: Trinomics

The most important products are ethylene, propylene, butadiene, benzene, and hydrogen. These products are generally encompassed by the term *high value chemicals* (HVC)[48]. Ethylene is the main product of the steam crackers in the Netherlands.[49] Additionally, toluene and xylenes (incl. p-xylene , m-xylene, o-xylene) are also produced during the steam cracking process (usually also referred to in the chemical industry with the term *aromatics* or *BTX* chemicals). In the Netherlands, the most used feedstock for the steam cracking process is naphtha (accounting currently for 70% of the fossil feedstock used by the industry), followed by LPG (20%).[50] The steam cracking process requires a lot of energy and thus produces GHG emissions. The main downstream application of these products is the production of polymers.

4.2.1 *Analysis of carbon leakage indicators*

Our analysis finds that propylene and ethylene are the most emissions intensive steam cracking products, significantly more than butadiene and the analysed aromatics. Figure 4-2 provides the emission intensities of analysed steam cracking products. The aromatics for which sufficient data was available to estimate their emission intensity are benzene, toluene, P-xylene and O-xylene. For most steam creaking products, the GHG emissions primarily come from fuel use. The difference in the emission intensity between the products are due to the differences in estimated gross value added (GVA) for the products.

Figure 4-2 Emission intensity of steam cracking products (kgCO$_2$/€ GVA)



[48] According to free allocation rules, the covered substances under this group are acetylene, ethylene, propylene, butadiene, benzene and hydrogen
[49] In the Netherlands, there are six operating steam crackers, the largest production capacity being ethylene in all cases.
[50] Oliveira, C., & Van Dril, T. (2021). Decarbonisation options for large volume organic chemicals production, Sabic Geleen.

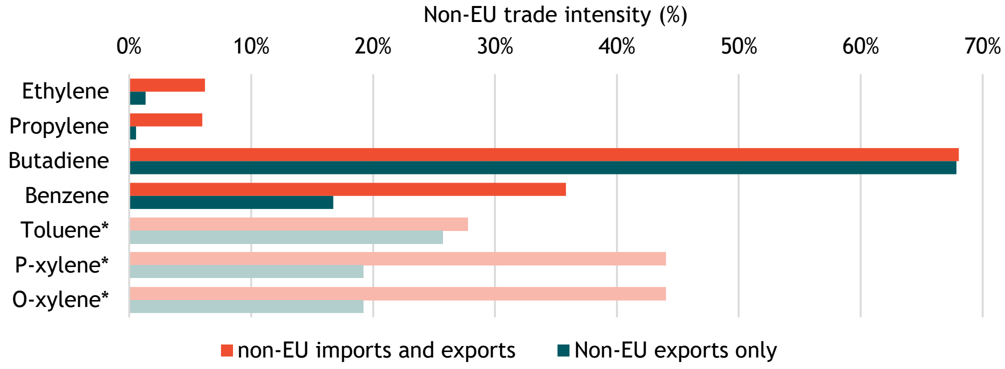
Note: Fuel emissions are the total emissions from fossil fuel combustion. Electricity emissions are the emissions from electricity use during production.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

On the other hand, ethylene and propylene have relatively low trade intensities, with most of the trade related to non-EU imports. Figure 4-3 shows the non-EU trade intensities of ethylene and propylene for the Netherlands, which were less than 10% over 2018-2021. Most of this trade was related to non-EU imports, with only 1-2% of the Dutch production being exported outside the EU. This indicates that for these products, the Dutch producers primarily produce ethylene and propylene for the intra-EU market and any competition from non-EU producers also relate to the intra-EU market.

For butadiene and the analysed aromatics, the trade intensity is significantly higher and therefore face more international competition compared to ethylene and propylene. Figure 4-3 also shows the non-EU trade intensities of for the Netherlands butadiene, benzene, toluene, P-xylene and O-xylene. As production values are missing for toluene, p-xylene and o-xylene, their trade intensity has been estimated are based on EU level data. Butadiene and the analysed aromatics can be considered highly trade-intensive with a trade intensity around 30% or more.[51] For benzene and the proxy for xylene, about half of the exposure to competition outside of the EU related imports into the Netherlands as shown in Figure 4-3. For butadiene and the proxy for toluene, the exposure of Dutch producers to international competition is almost fully related the non-EU markets they export to.

Covering steam cracking products under CBAM could reduce the risk of carbon leakage considerably for most products. Notably, for ethylene, propylene and benzene, imports make up a considerable part of the trade outside the EU, indicating that being covered by CBAM would positively impact the risk of carbon leakage for these products. However, for butadiene and toluene, the trade intensity remains fairly high even when removing non-EU imports. This means that CBAM would not lead to a significant change compared to the current situation with regards to direct carbon leakage risks of Dutch producers of these products.

Figure 4-3 Non-EU trade intensity of steam cracking products for the Netherlands (including and excluding non-EU imports) (%)



*Trade intensity values are estimated based on EU level data as a proxy because NL production values are not available for these products.
Note: Non-EU trade intensity is : (Non-EU imports + Non-EU exports)/(Non-EU imports + NL production). The trade intensity based on the average value of 2018-2021 for each parameter.
Source: authors' calculations based on CBS and Eurostat

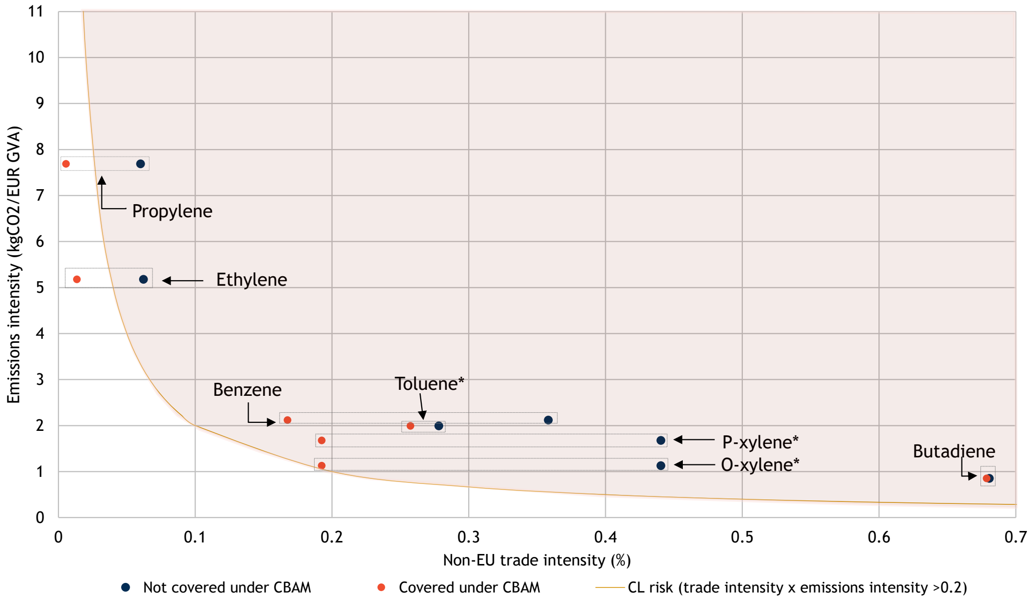
Covering steam cracking products under CBAM could significantly reduce the risk of carbon leakage of ethylene and propylene as the risk mainly relates to non-EU imports. Figure 4-4 plots the carbon leakage risk indicators for the steam cracking products. For each product, the indicator are shown for

[51] In Phase 3 of the EU ETS (2021-2030), a sector was considered highly trade-intensive and therefore at significant risk of carbon leakage if their trade intensity was higher than 30%.

the status quo of not being covered by CBAM (i.e. exposure to non-EU imports and of non-EU exports) and covered by CBAM (i.e. exposure of non-EU exports only). The figure shows that the carbon leakage indicator for ethylene and propylene, which are highly emissions intensive, but relatively less trade intensive, would drop below the 0.2 threshold. This implies that CBAM would protect the production of ethylene and propylene in the Netherlands against significant risks of carbon leakage.

Even if butadiene and the analysed aromatics are covered under CBAM, they remain at significant risk of carbon leakage due to the relative high share of non-EU exports. Figure 4-4 shows that, while covering the analysed aromatics under CBAM could reduce their carbon leakage risk, their risk indicator remains above the 0.2 threshold. The risk which would remain would concern risk of leakage via a deterioration of their competitive position in non-EU markets (i.e. non-EU exports) compared to the status quo, as a result of the accelerated phase out of free allowances for the products coverage under CBAM. This also means that for butadiene production in the Netherlands, CBAM would increase the risk of carbon leakage compared to the current situation with free allowances.

Figure 4-4 Carbon leakage risk indicators for steam cracking products



Note: Products are considered at CL risk when emission intensity x trade intensity $\geq$ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

Overall, including steam cracking products under CBAM has a primarily positive impact on reducing carbon leakage risks for Dutch producers, but risks related to non-EU exports are not negligible. For ethylene and propylene, implementing CBAM would significantly reduce their carbon leakage risks. Since ethylene is the main product of the steam crackers in the Netherlands[52], CBAM can be considered to have largely positive impact on reducing carbon leakage risks for steam cracking products. However, for butadiene and the analysed aromatics, there are concerns of carbon leakage relating to competition in non-EU markets (i.e. non-EU exports).

[52] In the Netherlands, there are six operating steam crackers, the largest production capacity being ethylene in all cases.

4.2.2 *Challenges for determining embedded emissions*

Covering specific steam cracking products (such as ethylene and propylene) under CBAM would come with some practical difficulties on determining embedded emissions. A CBAM on a product requires that embedded emissions can be determined with high robustness. However, this is challenging for steam cracking products. During the steam cracking process, all products are produced at the same time, and therefore, it is not simple to allocate the emissions for each of the products produced. In addition, the specific energy consumption and thus GHG emissions of the process depend largely on other production variables such as the feedstock composition[53], co-product use as energy source (e.g., hydrogen)[54] and the production yields or desired product mix. It is for these reasons that no agreed methodology is available currently for assigning specific emissions to each of the individual products from the steam cracking process[55], and also why the EU ETS benchmark is only available for the product mix called High-Value Chemicals (HVC), eliminating the need to allocate emissions to the individual products. Due to the absence of product specific-embedded emissions, the emission intensity presented in Figure 4-4, was calculated based on average production yields of steam crackers in the Netherlands.[56]

The lack of emissions data at the product level hinders the CBAM extension to cover steam cracking products. EU data collected on emissions for steam cracking products is not at the product level (i.e., it is only available for the HVC product mix) and thus cannot be used for attributing and determining emissions of imports of specific products (e.g., ethylene and propylene). Studies on emissions attribution of steam cracking products have suggested different methods to effectively allocate steam cracking emissions to specific products[57,58]. However, a clear proposal for solving the attribution of emissions is not yet in sight. In contrast, from a political perspective, it has been noted that the definition of the required rules may draw considerable international attention and be quite controversial[59]. This lack of consensus could delay the extension of CBAM to these products.

4.2.3 *Circumvention risks*

It is plausible that an increase of costs of ethylene following a CBAM inclusion could intensify circumvention risks via polyethylene (PE) and its derivatives. Dutch consumers of ethylene and PE include producers of sacks and bags of polymers of ethylene, as well as plastic reservoirs, tanks, vats, intermediate bulk and similar containers. The current imports of these products to the Netherlands from non-EU countries are relatively high (see

Table 5-5). Furthermore, both PE and these finished products are easy to transport. These factors render it likely that non-EU imports increase if domestic prices of PE increase considerably. This circumvention risk is strengthened by the fact that the emissions of the polymerisation of ethylene and further downstream processes are low compared to the production of ethylene. The higher carbon costs (direct CBAM or passed-on ETS costs) of ethylene could therefore become a key determinant in cost competitiveness of PE and its derivatives, and with that, the decision to import PE or its derivatives to circumvent these carbon costs.

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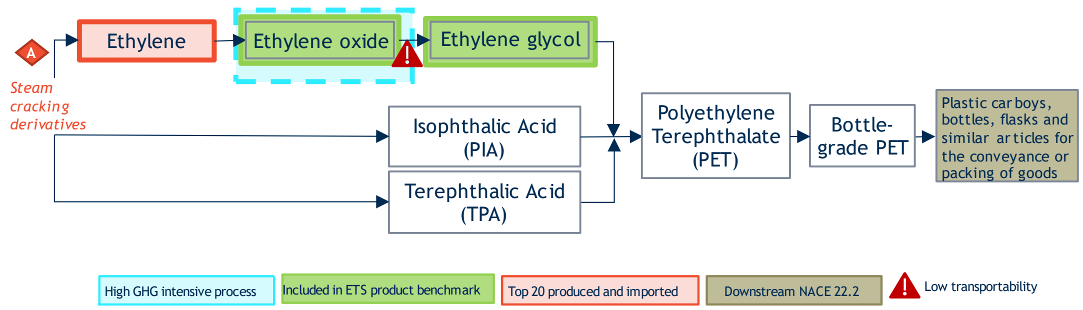
[53] For example, depending on the type of feedstock used, the weight ratio of the process steam to hydrocarbon feed can vary from 0.35 to 0.70. Oliveira, C., & Van Dril, T. (2021). Decarbonisation options for large volume organic chemicals production, Sabic Geleen.
[54] Emissions from steam cracking decrease when by-product hydrogen is consumed in the tail gas compared to when it is exported as a by-product, as recently shown by Young, B. et. al (2022). Environmental life cycle assessment of olefins and by-product hydrogen from steam cracking of natural gas liquids, naphtha, and gas oil.
[55] Also underlined in European Commission (2021). Study on the possibility to set up a carbon border adjustment mechanism on selected sectors.
[56] Available in PBL (2021). MIDDEN database.
[57] Oliveira, C., & Van Dril, T. (2021). Decarbonisation options for large volume organic chemicals production, Sabic Geleen.
[58] See, for instance Young, B. et al 2022). Environmental life cycle assessment of olefins and by-product hydrogen from steam cracking of natural gas liquids, naphtha, and gas oil. Journal of Cleaner Production, 359, 131884.
[59] European Commission (2021). Study on the possibility to set up a carbon border adjustment mechanism on selected sectors.

In line with the above, there could also be a risk of circumvention of CBAM on ethylene and propylene through the import of other derivatives. For example, in the case of ethylene, this risk might increase via the import of ethylene glycol (EG), which is easy to transport compared to other ethylene derivatives and currently imported to the Netherlands mainly from non-EU countries.[60] Similarly, in the case of a CBAM on propylene, risks of circumvention risks appear to be limited but might increase via the import of propylene oxide (PO) and tetrahydrofuran (THF) further downstream. PO is used as a chemical building block in a range of products in the Netherlands including, as shown in Figure 3-4, the production of polyether polyols for use in polyurethane applications; propylene glycols to produce polyester resins; and butanediol (BDO) for the manufacture of THF and derivatives such as polybutylene terephthalate (PBT), as well as other polyurethane applications. However, non-EU imports of PO are currently relatively low (PO is not in the top 20 of non-EU imported products), and it might thus take some time to set up the infrastructure for non-EU import flows to become significant. Circumvention risks via the import of THF might be higher as heterocyclic compounds (which include THF) are in the top 20 of non-EU imported products, and non-EU import flows of specifically THF are relevant.[61] Other circumvention risks related to ethylene and propylene derivatives are discussed in the case studies *Ethylene oxide and its derivatives* and *Ethylbenzene and its derivatives*.

4.3 Ethylene oxide and its derivatives

Ethylene oxide (EO) is a highly produced chemical in the Netherlands and one of the main chemical precursors of polyethylene terephthalate (PET), the key material for many plastic bottles. As shown in Figure 4-5 most EO is used to produce ethylene glycol (EG) and polyether polyols,[62] although EO is used to produce other derivatives as well.[63] Generally, EG and EO are produced simultaneously to allow for efficient heat integration (such as in Shell Moerdijk).[64] EG is then used as a key precursor for the production of polyethylene terephthalate (PET), together with terephthalic acid (TPA) and isophthalic acid (PIA). PET is then processed into three main products: fibre-grade PET (commonly used in the textile industry), bottle-grade PET (mainly used for the manufacturing of beverage bottles) and film-grade PET, used for the manufacturing of packaging films. [65] The focus of the following sections is the most GHG emission intensive parts relevant to the EO derivatives for which data allow a detailed analysis of carbon leakage indicators.

Figure 4-5 Simplified diagram of the most relevant ethylene oxide derivatives in the Netherlands



[60] In 2019, import origins of EG to the Netherlands were Saudi Arabia (68%) OEC.world (Dataset HS92, ethylene glycol)
[61] In 2019, over 45% of THF imports to the Netherlands came from Asia and the USA.
[62] Heavier di- and tri- ethylene glycols (DEG & TEG) are also produced.
[63] Next to the production of EG and ethylene polyols, EO is used in the production of detergent ethoxylates, ethanol amines, and as a sterilising agent and fumigation chemical. In Terneuzen polyether polyols are produced, particularly polyethylene glycol (PEG) and polypropylene glycol (PPG). Eerens, H., & van Dam, D. (2022). Decarbonisation options for Large Volume Organic Chemicals production, DOW Terneuzen.
[64] Wong, L.& van Dril, T. (2020). Decarbonisation options for large volume organic chemicals production, Shell Moerdijk.
[65] Tran, A. & West, K.J (2021) Decarbonisation options for the Dutch bottle-grade PET industry.

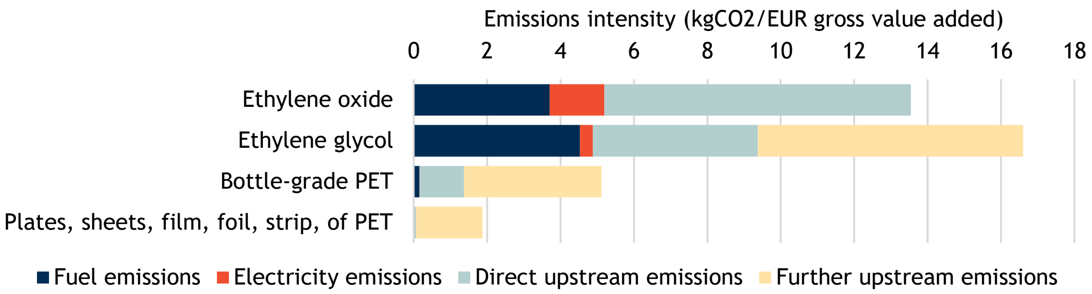
Source: Trinomics

4.3.1 Analysis of carbon leakage indicators

Of the products analysed in the ethylene oxide value chain, EO and EG are significantly more emissions intensive than their downstream products PET. Figure 4-6 provides the emission intensities of ethylene oxide, ethylene glycol and PET. The figure shows the emission intensity directly related to the production for EO and EG is significantly higher than their downstream derivatives PET, and at a similar level as their precursor ethylene at about 5 kgCO_2/€ GVA. This is the result: i) production of midstream chemicals such as EO and EG being a relative energy intensive process and ii) their downstream derivatives PET being significant less energy intensive and having greater value added.

The upstream emissions (mainly from ethylene) make up a significant part of the emission intensity of EO and its derivatives, raising concerns of indirect carbon leakage. Figure 4-6 also shows the upstream emissions considered in this study associated with the production of the feedstock of each product. The upstream emissions are split into direct emissions from the production of the feedstocks of the product, and emissions from chemical production processes further upstream of the feedstocks. The figure shows that for EO and its derivatives, the further down the value chain, the higher the relative share of the upstream emissions in the emission intensity. For EO and EG, the main source of upstream emissions is ethylene production (direct upstream for EO and further upstream for EG). This means that if the cost of emissions (whether from ETS or CBAM) of ethylene would be passed on down the value chain, this could significantly increase the carbon leakage risk of EO and its derivatives. This indirect carbon leakage risk is most profound for EO and EG. For PET, the increase in emission intensity due upstream emissions is less because of their higher GVA. Further downstream, for plastics made from PET, upstream emissions intensity is further reduced by its higher value added.

Figure 4-6 Emission intensity of ethylene oxide and its derivatives (kgCO_2/€ GVA)

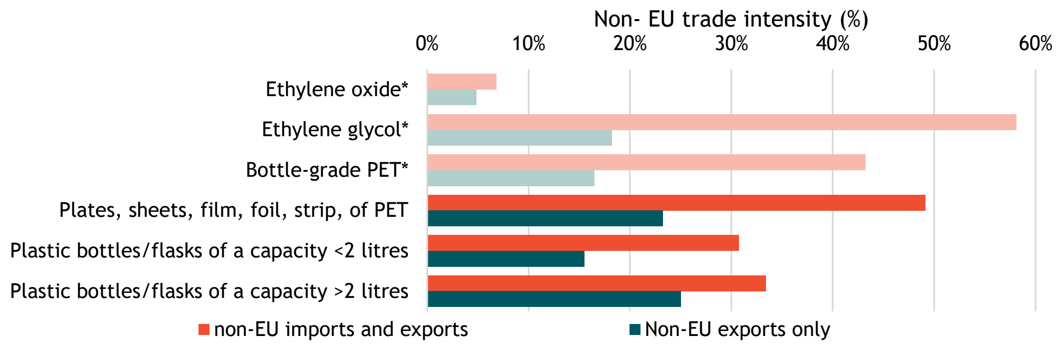


Note: Fuel emissions are the total emissions from fossil fuel combustion. Electricity emissions are the emissions from electricity use during production. Direct upstream emissions are the emissions from the production of the feedstocks of the product. Further upstream emissions are the emissions from the production of the feedstocks from further upstream chemical production processes. Upstream emissions values only consider the emissions of chemical feedstocks as other feedstock emissions do not lie within the scope of this study. Upstream emissions are lower estimates of the total upstream emissions as not all feedstocks could be included due to lack of data. Upstream emissions intensity of plates, sheets, film foil, strip of PET includes only those of thickness $\leq$ 0.35 mm and estimated based on 1kg of production requires 1kg of PET.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

EG and its derivatives is estimated to have medium to high non-EU trade intensities, meaning that they are currently exposed to non-EU competition, while EO is less exposed. Figure 4-7 provides the trade intensities of EO, EG and their derivatives. These trade intensities, except for plastic bottles, were estimated based on EU level data due to missing data. The estimated trade intensities including non-EU imports and exports are between 5-60%. The EU trade intensity of EO is considered low, meaning that it is less exposed to non-EU competition.

Covering EG and its derivates under CBAM would only mitigate a part of the non-EU trade exposure, as about half to two-thirds of the exposure relates to non-EU exports. For EG and the analysed derivatives, inclusion in CBAM would reduce the trade exposure from non-EU imports within the EU market. However, there still remains the risk of loss of competitive advantage in non-EU markets as the non-EU export intensity remains between 15-25%.

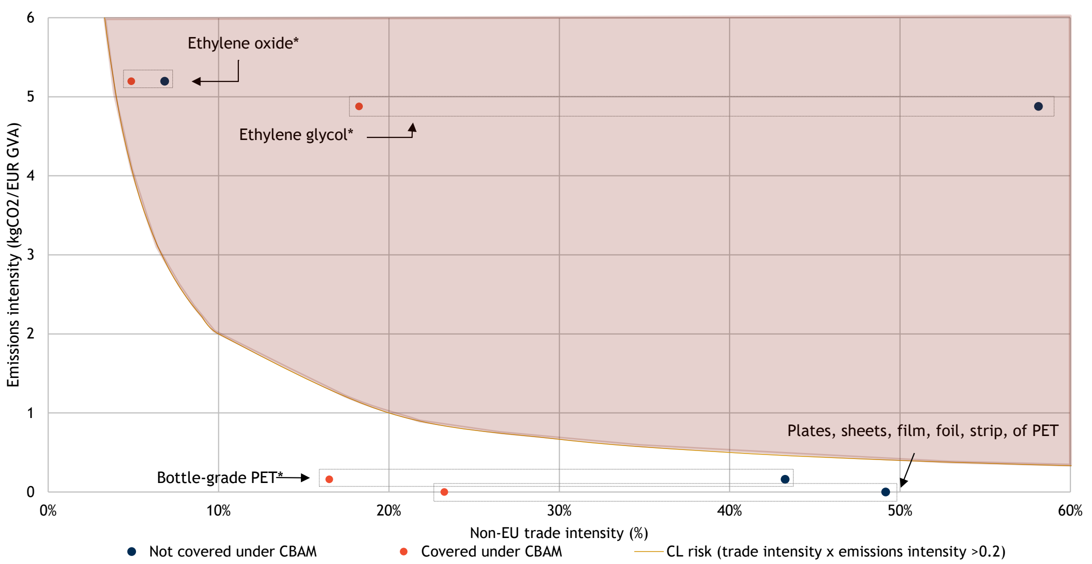
Figure 4-7 Non-EU trade intensity of ethylene oxide and its derivatives for the Netherlands (including and excluding non-EU imports) (%)



*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Note: Non-EU trade intensity is : (Non-EU imports + Non-EU exports)/(Non-EU imports + NL production). Trade intensity of plates, sheets, film foil, strip of PET includes only those of thickness ≤ 0.35 mm.
Source: authors' calculations based on CBS and Eurostat

EO and EG remain at risk of direct carbon leakage even if they are covered by CBAM due to their high emission intensity and remaining trade intensity related to non-EU exports. Figure 4-8 plots the carbon leakage indicators of EO, EG, PET and plastics of PET. Covering EO and EG under CBAM would reduce their carbon leakage risk, particularly for EG. However, their risk indicator remains above the 0.2 threshold. This is because the risk of carbon leakage from a competitive disadvantage in non-EU markets still remains. Given PET's low emissions intensity related to fuel and electricity consumption, PET is not considered at significant risk of direct carbon leakage.

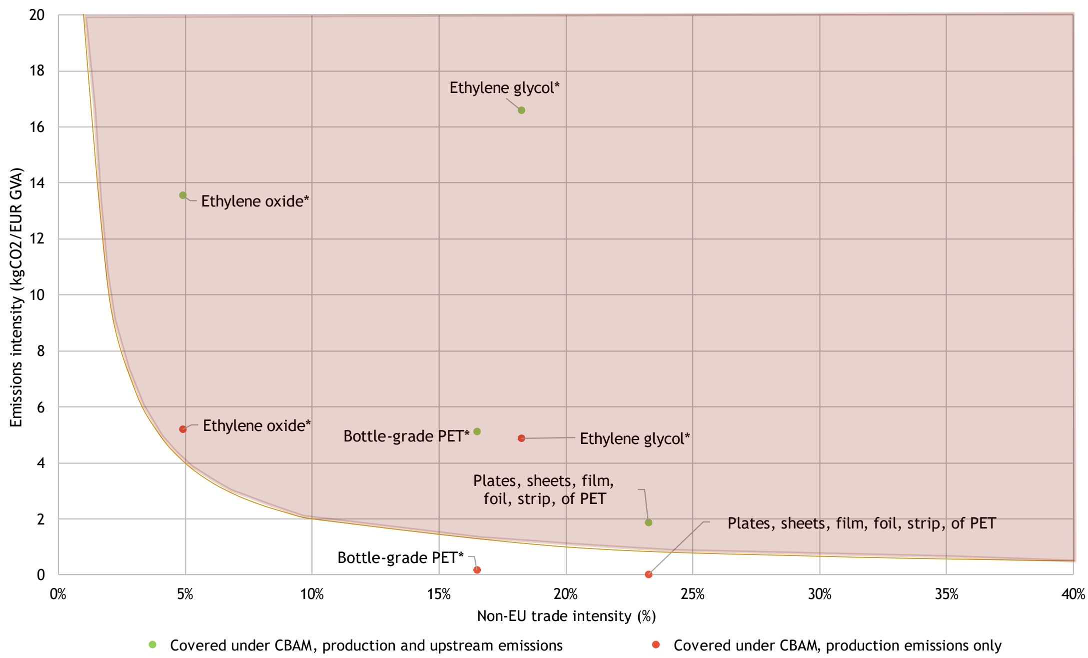
Figure 4-8 Carbon leakage indicators for EO and its derivatives



Note: Products are considered at CL risk when emission intensity x trade intensity ≥ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs. Emissions and trade intensity of plates, sheets, film foil, strip of PET includes only those of thickness ≤ 0.35 mm.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

Additionally, there is a large risk of indirect carbon leakage for EO and its derivatives, which could cause the downstream product PET and plastics of PET to become a significant risk of leakage. The extent of the upstream emission intensity can be seen in Figure 4-9, which is significantly greater than direct emissions for all analysed products. For PET, their carbon leakage indicator would even rise above the 0.2 threshold, resulting in PET becoming at significant risk of carbon leakage if upstream producers are able to pass down their carbon costs. The risks could be partially mitigated by covering both direct and upstream emissions of EO and its derivatives under CBAM. However, this would be not sufficient for the carbon leakage indicators to drop below 0.2 for the analysed products as non-EU exports are not protected against indirect carbon leakage risks under the currently proposed forms of CBAM. This risk could also be carried over to plastics of PET, which also are considered at risk of carbon leakage when taking upstream emissions into account. As plastic bottles of PET have a lower emissions intensity (due to higher GVA) and lower trade intensity than plastics of PET, the risk of carbon leakage for plastic bottles would be lower than it is for plastics of PET.

Figure 4-9 Carbon leakage indicators for EO and its derivatives, including upstream emissions



Note: Products are considered at CL risk when emission intensity x trade intensity ≥ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs. Emissions and trade intensity of plates, sheets, film foil, strip of PET includes only those of thickness ≤ 0.35 mm.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

Implementing CBAM on EO, EG and PET would reduce the risk of carbon leakage for these products, although the risk of leakage in non-EU markets and indirect leakage risks due to upstream emissions remain significant. EO and EG are considered at significant risk of direct carbon leakage, but this risk for PET is limited. For EO, EG and their plastic derivatives, the larger risk comes from the carbon cost of upstream emissions, particularly from ethylene, that could be passed down.

4.3.2 Challenges for determining embedded emissions

Determining the embedded emissions of EO and EG as separate products are not possible with the available data, therefore, a CBAM would need to cover both EO and EG to ensure practical feasibility. As pointed out throughout this report, CBAM requires embedded emissions of the specific products to be known. The emissions of the EO/EG process, however, are largely given by the product mix, which is determined by the selectivity of the process[66] and whether intermediate chemicals are produced (e.g., such as ethylene to increase EG).[67] In addition, since carbon dioxide is the main by-product of EO direct oxidation, the GHG emissions of the EO/EG process depend largely on the degree to which off gas (rich in CO_2) is utilised. In some plants, for instance, up to two-thirds of CO_2 produced in the EO process is used for other applications.[68] Depending on the EO/EG process, the consumption of steam and electricity can vary up to 20% and 10%, respectively.[69] These production variables render it difficult to estimate EO and EG separately; and for this reason, EU ETS data has been collected for EO and EG as a single product mix. This means that EU ETS data collected from the benchmarks could be directly used to estimate CBAM emissions but only if both EO and EG are covered. Alternatively, an emission attribution method would need to be developed considering specific stoichiometric factors.[70] The emission attribution method will need to be developed that is consistent with EO/EG downstream products for which ETS data is available (such as styrene) to avoid overlap or gaps in processes covered.

Due to data limitations (there is not an ETS product benchmark available for PET), the inclusion of PET under CBAM many not be feasible in the short term. Including PET under CBAM is assessed as “not possible” in the Commission’s Impact Assessment accompanying the CBAM proposal. One of the reasons for this is that depending on the final application of PET (i.e., purity grade of precursors used for bottle-grade or fibre grade applications), the final steps of the production process varies and thus the embedded emissions.[71] These processes are often carried out by a multitude of different companies across the globe making the tracing of the associated emissions of the PET’s precursors is not straightforward. In addition, the two main precursors of PET (EG and TPA) cannot be easily associated to an exact amount of embedded emissions. In particular, the emissions from the production process of terephthalic acid can vary considerably as several production processes exist.[72] A fallback approach for determining the embedded emissions could be developed, but this requires more data collection and research to determine the correct processes to be covered.

4.3.3 Circumvention risks

A risk of circumvention can become relevant if EO is covered under CBAM and EG is not. Even though the Netherlands is a net exporter of EG, a CBAM only on EO would allow EO/EG manufacturers to drive the increase in costs of these products in the domestic market. This might provide an incentive for Dutch manufacturers of EG and its derivatives to increase EG imports. Unlike EO’s high flammability and toxicity, EG is not flammable and can be transported by tank truck, rail or vessel.[73] In addition, when imported, EG mainly comes to the Netherlands from non-EU countries.[74]

Furthermore, there could be a circumvention through the imports of bottle-grade PET and other finished PET products if these are not covered under CBAM. PET is a key feedstock for some top-produced plastics within the Dutch industry (e.g., plastic carboys, bottles, flasks). Already today,

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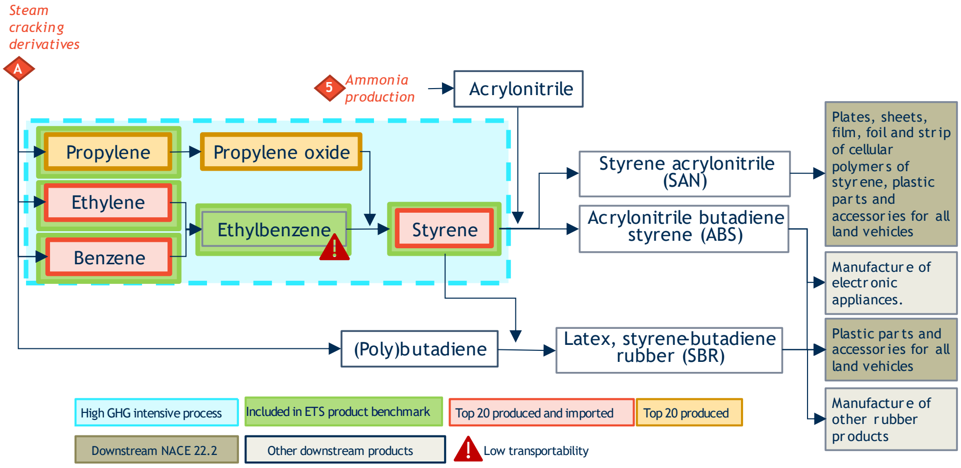
[66] In general , EO/EG processes can be designed for the production of glycols only (without high-purity EO recovery); high-purity EO only with a minimum production of unavoidable glycols; or a product mix of high-purity EO and glycols in an integrated plant. Eerens, H., & van Dam, D. (2022). Decarbonisation options for Large Volume Organic Chemicals production, DOW Terneuzen.
[67] To illustrate, an EO selectivity of 70–90 % would correspond to a ratio of 0.86–0.22 tonnes of CO_2 per tonne of EO produced (Ibid)
[68] For the 2005-2008 period, Shell obtained an opt-out for this emission under the ETS. Currently however, for the EU-ETS this remains a process emission attributed to Shell. Wong, L.& van Dril, T. (2020). Decarbonisation options for large volume organic chemicals production, Shell Moerdijk.
[69] Ibid.
[70] European Commission (2021). Study on the possibility to set up a carbon border adjustment mechanism on selected sectors.
[71] Tran, A. & West, K.J (2021) Decarbonisation options for the Dutch bottle-grade PET industry
[72] EPA (1983). AP 42, Fifth Edition, Volume I Chapter 6.11: Terephthalic Acid.
[73] Shell Chemicals (2017). Mono Ethylene Glycol (EG, MEG) Product Stewardship Summary.
[74] In 2020, import origins of EG to the Netherlands were 65% from Saudi Arabia, 20% Belgium 6% Kuwait.

almost half of PET imports come from non-EU countries.[75] This, coupled with the high transportability of PET and their end products, could be determining factors that eventual acceleration of non-EU imports if they are not covered under CBAM. When covering PET under CBAM, it would not only be important to include the EO and EG emissions but also emissions further upstream related to ethylene production if ethylene is also covered under CBAM. The carbon leakage risk analysis shows that a significant part of the leakage risks come from the potential pass-through of further upstream emissions costs.

4.4 Ethylbenzene and its derivatives

In the Netherlands, a large share of the ethylene produced is consumed as an intermediate in the manufacture of styrene from the reaction of ethylbenzene (EB) and propylene oxide (PO).[76] Styrene is the second most produced basic organic chemical in the Netherlands, on average (5.1% of total Dutch chemical production). Figure 4-10 shows a diagram of the most relevant EB and styrene-based derivatives in the Netherlands.

Figure 4-10 Simplified diagram of the most relevant ethylene benzene derivatives in the Netherlands



Source: Trinomics

In the Netherlands, styrene is widely used for the manufacture of styrene-based polymers, including styrene-acrylonitrile (SAN), acrylonitrile butadiene styrene (ABS), and styrene butadiene rubber (SBR).[77] As shown in Figure 4-10, the production of some of these polymers requires additional precursors such as acrylonitrile in the case of SAN, and polybutadiene for SBR. In general, styrene-based polymers are used in a variety of applications from packaging, kitchen utensils, and electronic equipment housing to the manufacture of automobile tyres. [78]

The production of styrene from ethylbenzene consumes a substantial amount of energy and is thus an important source of emissions. Producing styrene by this process (i.e., dehydrogenation of EB) consumes typically a substantial amount of energy because of the use of high-temperature steam. In addition, given that EB is produced by combining benzene, ethylene and PO (a direct derivative of

[75] Data source: OEC.world
[76] See, for instance. Eerens, H., & van Dam, D. (2022). Decarbonisation options for Large Volume Organic Chemicals production, DOW Terneuzen.
[77] Other polymers made from butadiene include styrene-butadiene latex, used for example in carpet backings and adhesives, among others.
[78] Shell Chemicals (2017) Ethyl Benzene Product Stewardship Summary.

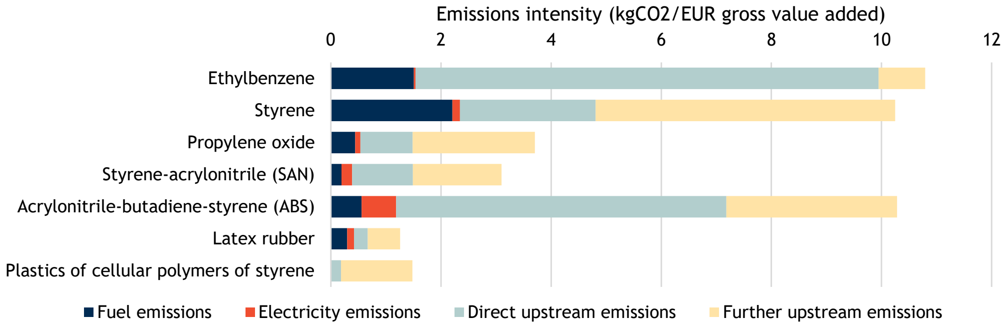
propylene), the production processes of EB and its derivatives (including styrene) are associated with high upstream emissions. The following sections focus on EB derivatives for which data is available for a quantitative analysis of carbon leakage indicators.

4.4.1 Analysis of carbon leakage indicators

In terms of production emissions, emission intensity of chemicals at the start of the ethylbenzene value chain are much higher than their downstream derivatives, with ethylbenzene (EB) and styrene being the most emissions intensive. Figure 4-11 provides the emission intensities of ethylbenzene and its derivatives. The figure shows the fuel and electricity emissions directly related to the production of ethylbenzene and styrene are 2 to 3 times higher than the analysed downstream derivatives due to their lower value added and greater energy intensity. Most of the production emissions of these products come from fossil fuel use, except for SAN and ABS production where about half of the emissions relate to electricity consumption.[79]

The upstream emissions of ethylbenzene and its derivatives are significantly higher than their production emissions, especially for ethylbenzene, styrene and ABS. The significance of the upstream emissions can be seen in Figure 4-11. Ethylene is particularly the main contributor of upstream emissions for ethylbenzene (direct upstream emissions) and its derivatives (further upstream emissions). For ABS, a significant part of the upstream emissions also come from polybutadiene and acrylonitrile production (direct upstream emissions).

Figure 4-11 Emission intensity of ethylbenzene and its derivatives (kgCO_2/€ GVA)



Note: Fuel emissions are the total emissions from fossil fuel combustion. Electricity emissions are the emissions from electricity use during production. Direct upstream emissions are the emissions from the production of the feedstocks of the product. Further upstream emissions are the emissions from the production of the feedstocks from further upstream chemical production processes. Upstream emissions values only consider the emissions of chemical feedstocks as other feedstock emissions do not lie within the scope of this study. Upstream emissions are lower estimates of the total upstream emissions as not all feedstocks can be included due to lack of data.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

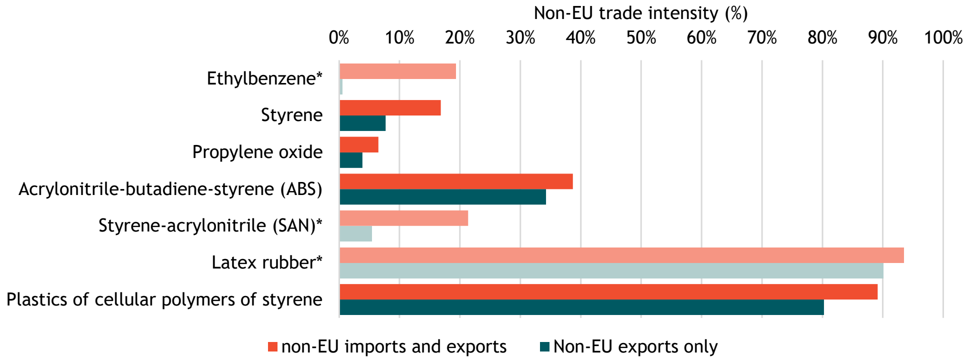
The exposure of the analysed products in the ethylbenzene value chain to non-EU competition show a mixed picture. Figure 4-12 provides the trade intensities of ethylbenzene and its analysed derivatives. For ethylbenzene, SAN and latex rubber, trade intensity is based on EU level data as a proxy. ABS, latex rubber and plastics of polymers of styrene have relatively high non-EU trade intensities with more than 30%. The trade intensities of ethylbenzene, styrene and SAN are medium

[79] Both SAN and ABS syntheses are generally big consumers of electricity . For instance, the process of continuous mass polymerization used at the DOW site Trineo requires complex machinery to handle mixing, heat transfer, melt transport, and devolatilisation. Similarly, ABS synthesis requires complex machinery to e.g., crush polybutadiene rubber into small pieces. Eerens, H., & van Dam, D. (2022). Decarbonisation options for Large Volume Organic Chemicals production, DOW Terneuzen

when considering both non-EU imports and exports. Propylene oxide has a low non-EU trade intensity of less than 10% and could therefore be considered to only have a limited exposure to non-EU competition.

Covering the analysed products under CBAM would reduce the carbon leakage exposure to non-EU competition the most for ethylbenzene, styrene, propylene oxide and SAN, while only having a limited impact on the exposure of the other downstream derivatives. For ethylbenzene, styrene, propylene oxide and SAN, about or more than half of the trade exposure is due to non-EU imports. Including these products under CBAM would therefore considerably mitigates a part of the carbon leakage risks of these products. On the other hand, for downstream chemicals and plastics, such as latex rubber, ABS and plastics of styrene, the international trade exposure primarily related to exports to outside of the EU.

Figure 4-12 Non-EU trade intensity of ethylbenzene and its derivatives for the Netherlands (including and excluding non-EU imports) (%)

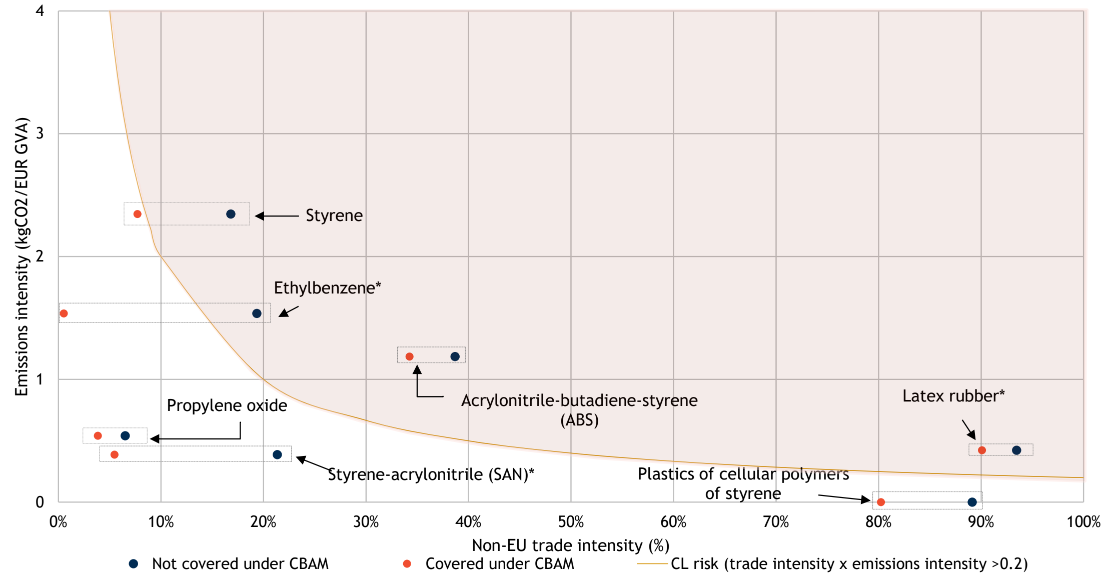


*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Note: Non-EU trade intensity is : (Non-EU imports + Non-EU exports)/(Non-EU imports + NL production).
Source: authors' calculations based on CBS and Eurostat

Inclusion of styrene and ethylbenzene in CBAM could significantly reduce the risk of direct carbon leakage, but for ABS and latex rubber, the direct carbon leakage risk remains. Figure 4-13 shows that the carbon leakage indicator of styrene and ethylbenzene, when considering production emissions only, would drop below the 0.2 threshold. On the other hand, for ABS and latex rubber, removing the risk of carbon leakage from non-EU imports lower their risk indicator. However, it still remains above the 0.2 threshold due to their exposure in non-EU markets via exports. For propylene oxide and SAN, the emissions and trade intensity are sufficiently low such that direct carbon leakage risk is limited even if it is not covered under CBAM.

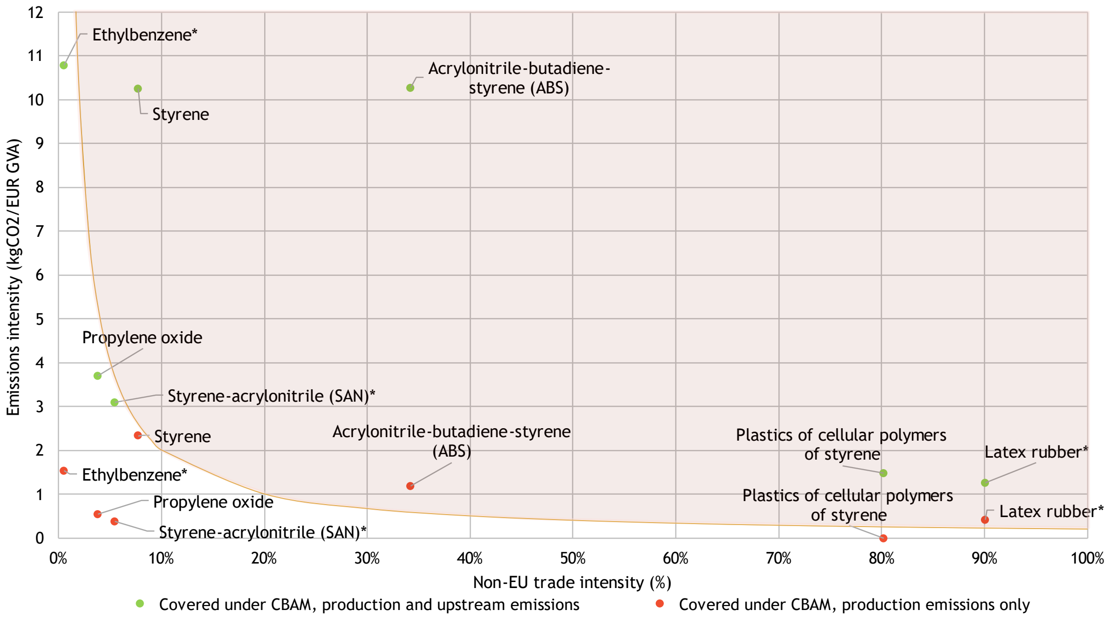
There is also a significant risk of indirect carbon leakage for the analysed products, except for ethylbenzene, propylene oxide and SAN as they have low non-EU trade exposure. The extent of their upstream emission intensity can be seen in Figure 4-14, which is significantly greater than direct emissions for all products. Particularly, when taking upstream emissions into account, the indicator of styrene rises to well beyond the 0.2 threshold and would be considered at risk of carbon leakage, even if it is covered under CBAM. Additionally, plastics of polymers of styrene are considered at risk of indirect carbon leakage if SAN and styrene are covered by CBAM. The carbon leakage indicators of propylene oxide, ethylbenzene and SAN stay below the 0.2 threshold when including upstream emissions, which mainly relates to the relative limited export of these products of producers in the Netherlands.

Figure 4-13 Carbon leakage indicators for ethylbenzene and its derivatives



Note: Products are considered at CL risk when emission intensity x trade intensity $\geq$ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

Figure 4-14 Carbon leakage indicators for ethylbenzene and its derivatives, including upstream emissions



Note: Products are considered at CL risk when emission intensity x trade intensity $\geq$ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

Including ethylbenzene and its analysed derivatives could significantly limit the direct carbon leakage risk, particularly for ethylbenzene and styrene, but the indirect leakage risks due to upstream emissions remain a particular concern for the analysed derivatives. Even when covered by CBAM, ABS and latex rubber are all considered still at risk of carbon leakage because of their high non-EU export intensity. Additionally, ethylbenzene and all of its derivatives have significant upstream emissions. If the carbon cost of upstream chemicals, such as ethylene, are passed down onto these mid/downstream products, the carbon leakage risk for some of these products would increase significantly. Of the analysed products, this increase in risk is most apparent for styrene as well as plastics of polymers of styrene, which become at significant risk of carbon leakage compared to the situation without upstream emissions.

4.4.2 Challenges for determining embedded emissions

Currently, there is no EU data available to base the emissions of imports of EB on specifically, but there is data for styrene production. EU ETS benchmark data is only available for styrene (derived from EB) but not for EB separately. The collection of ETS data for styrene (only derived from EB) responds to the fact that EB is almost exclusively used (>99%) for the production of styrene. Grouping EB and styrene is reasonable as it facilitates the ETS collection of emissions of styrene production; in practice, however, this results in data that cannot be readily used for determining emissions of imports of EB.

Difficulties in linking available EU ETS data to individual products hinder the inclusion of EB and derivatives under CBAM. In the impact assessment to the Commission's CBAM proposal, the inclusion of styrene in CBAM was assessed as 'possible' but 'onerous'. One of the reasons is that usable values of embedded emissions of the precursors of styrene (i.e., EB, and benzene and ethylene further upstream) are a pre-condition for calculating styrene embedded emissions accurately. But neither the emissions of ethylene nor benzene are easy to determine. In the case of benzene, EU ETS benchmark data is only available for "aromatics", which covers a broad range of chemicals (next to benzene) that are obtained from different fractions of oil distillation (incl. toluene, o-xylene, p-xylene, etc.). Besides, depending on the feedstock used, the EU ETS benchmark for refinery products may also apply to benzene as aromatics are produced both in the chemical and the refinery sectors. In the case of ethylene, as discussed in 4.2.2, the HVC benchmark data is only available at the moment. Linking available ETS data (i.e., aromatics, HVC) to individual products (i.e., EB) will require additional data, and possibly the involvement of experts to estimate reliable proxies that allow the allocation of emissions. The situation is not different for including other downstream products such as PO, ABS, and SAN as there is no product-specific emissions data under the EU ETS and has to be collected additionally.

4.4.3 Circumvention risks

For the analysed products in the ethylbenzene value chain, there is a circumvention risk through the import of styrene and its derivative products. Ethylbenzene (the direct precursor of styrene) is generally not transported but used within the manufacturing site.[80] On the other hand, styrene can be transported via tank truck, rail car and vessel/barge. The coverage of ethylbenzene under CBAM should therefore always be together with styrene. In addition, some of the styrene-derived products, in particular polystyrene, expansible polystyrene and other acrylonitrile-derived styrene copolymers (SAN, ABS) show a high trade intensity. Figure 4-12 also shows there is a lot of trade of plastic end products of these polymers between the Netherlands and non-EU countries. The high trade intensity corresponds to a high transportability of polymers of styrene and its end products, indicating the presence of circumvention risks if they would not be covered under CBAM. Additional circumvention risks related to styrene-derived products that use chemicals derived ammonia are described in the qualitative analysis of the ammonia value chain.

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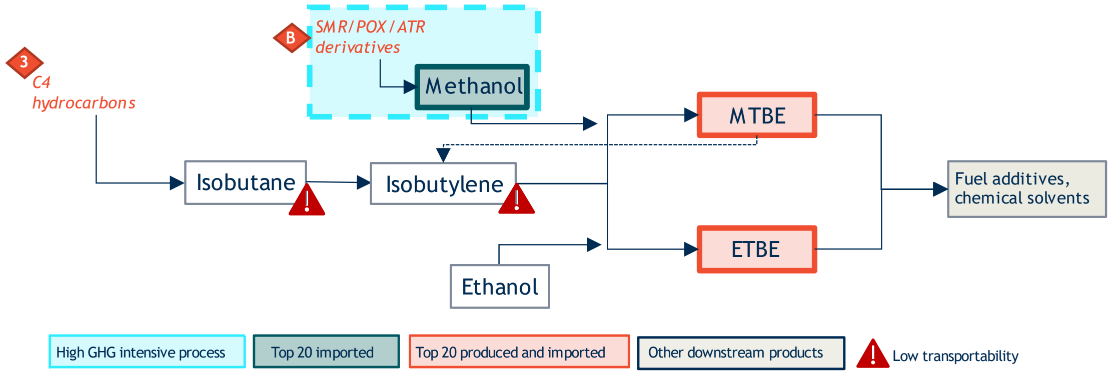
80 ShellChemicals (2017). Styrene Monomer Product Stewardship Summary.

4.5 Ethyl tert-butyl ether (ETBE), methyl tert-butyl ether (MTBE) and key precursors

ETBE and MTBE are two highly produced chemicals in the Netherlands. One of the main production processes of methyl tert-butyl ether (MTBE) and ethyl tertiary-butyl ether (ETBE) in the Netherlands is via the etherification of isobutylene.[81] As shown in Figure 4-15, MTBE can be produced through the reaction between isobutylene and methanol whereas the production of ETBE involves the use of ethanol (instead of methanol). MTBE and ETBE are among the top 20 imported and produced chemicals (Table 5-4).[82] Both chemicals are commonly used as additives for gasoline to reduce emissions. Figure 4-15 shows a diagram of the main chemical products within the MTBE/ETBE production through this route.

The MTBE production process is of particular interest as it involves the use of methanol as chemical intermediate. Methanol is the most imported product by the Netherlands from outside the EU (see Table 5-3). It is also typically manufactured from natural gas as shown in Figure 3-2 and thus its use in the production process of MTBE leads to high upstream GHG emissions. The production of MTBE is the second most important application of methanol (as a chemical intermediate).[83]

Figure 4-15 Simplified diagram of the most relevant MTBE and MTBE derivatives in the Netherlands



Source: Trinomics

4.5.1 Analysis of carbon leakage indicators

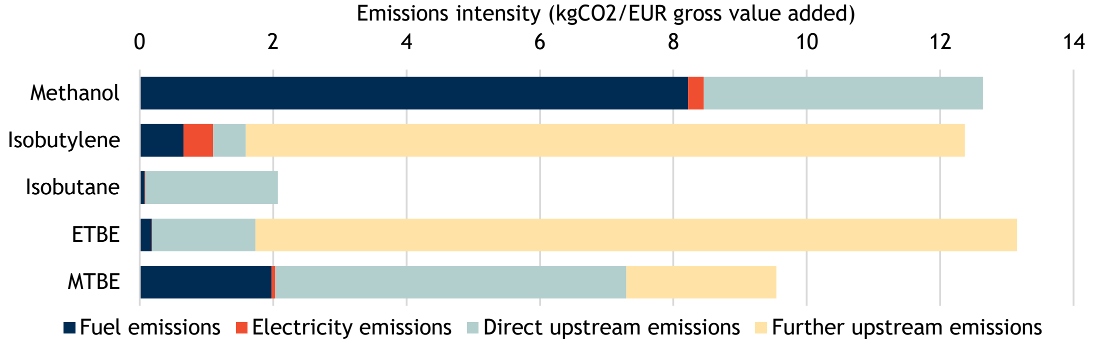
In contrast to the previous analysed value chains, the emission intensities of products in the value chain of ETBE and MTBE are much higher than some of their precursors. Figure 4-16 provides the emission intensities of ETBE and MTBE and its key precursors. In the previous analysed value chains, the production emission intensities of chemicals at the start of the value chain are generally higher than the ones further downstream. This is because of a combination of more energy intensive processes and lower value added for the more upstream chemicals. However, Figure 4-16 shows that ETBE and MTBE have a higher emission intensity related to fuel and electricity use compared to isobutane, and MTBE also higher than isobutylene. This shows that the general trend that the emission intensity lowers further along the value chain does not apply to all chemical value chains.

The upstream emissions are significantly higher than their direct emissions, particularly for ETBE. The upstream emission intensities for the analysed products can be seen in Figure 4-16. For ETBE and isobutylene, their upstream emissions mainly derive from C4 hydrocarbon production (further upstream

[81] For instance, at the LyondellBasell's Botlek site.
[82] MTBE/ETBE are categorised under the chemical group *Acyclic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives*
[83] Block, T., Gamboa, S. & Van Dril (2020) Decarbonisation options for Large Volume Organic Chemical Production, Shell

emissions). The MTBE upstream emissions mainly come from the production of its direct precursor methanol and further upstream emissions from raffinate-1 (steam cracking products).

Figure 4-16 Emission intensity of ETBE/MTBE (kgCO$_2$/€ GVA)

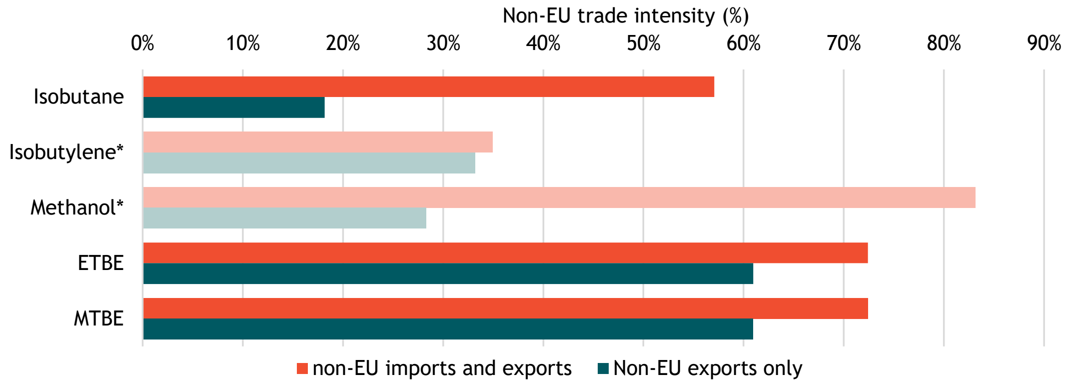


Note: Fuel emissions are the total emissions from fossil fuel combustion. Electricity emissions are the emissions from electricity use during production. Direct upstream emissions are the emissions from the production of the feedstocks of the product. Further upstream emissions are the emissions from the production of the feedstocks from further upstream chemical production processes. Upstream emissions values only consider the emissions of chemical feedstocks as other feedstock emissions do not lie within the scope of this study. Upstream emissions are lower estimates of the total upstream emissions as not all feedstocks can be included due to lack of data.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

ETBE and MTBE as well as their chemical precursors (isobutane, isobutylene and methanol) all show a high exposure to international competition from trade with outside of the EU. Figure 4-17 provides the trade intensities of these chemicals between the Netherlands and non-EU countries. Only the trade intensities of isobutylene and methanol are based on EU level values as a proxy, because Dutch production values are missing in public statistics for these chemicals.

Covering isobutane and methanol under CBAM can significantly reduce their carbon leakage exposure to non-EU competition, but for ETBE, MTBE and isobutylene the effect is limited. Including isobutane and methanol in CBAM would reduce the risk exposure by about two-thirds. On the other hand, covering non-EU imports of ETBE, MTBE and isobutylene would still leave a high non-EU trade intensity due to relatively high non-EU exports. This indicates that the producers of these chemicals in the Netherlands mainly compete heavily with non-EU producers in markets outside of the EU.

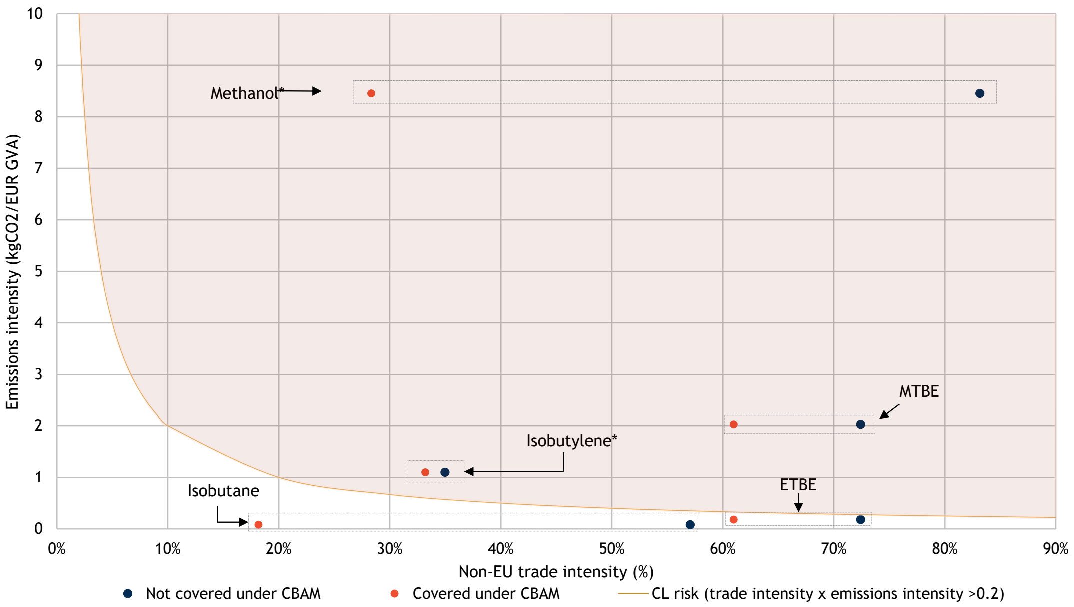
Figure 4-17 Netherlands non-EU trade intensity of ETBE/MTBE (including and excluding non-EU imports) (%)



*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Note: Non-EU trade intensity is: (Non-EU imports + Non-EU exports)/(Non-EU imports + NL production).
Source: authors' calculations based on CBS and Eurostat

While MTBE, methanol and isobutylene are considered to be at significant risk of direct carbon leakage, the direct emission intensity of ETBE and isobutane are sufficiently low not to be at significant risk. Figure 4-18 plots the carbon leakage indicator for ETBE, MTBE and their upstream feedstocks. For all of these chemicals, implementing CBAM has a positive impact on reducing the risk of carbon leakage within the EU market. However, for MTBE, methanol and isobutylene, there remains the risk of direct carbon leakage in non-EU markets due to the high non-EU export intensity combined with a high emission intensity related to fuel and electricity use. As a result, their carbon leakage indicator remains above the 0.2 threshold even if they are covered under CBAM.

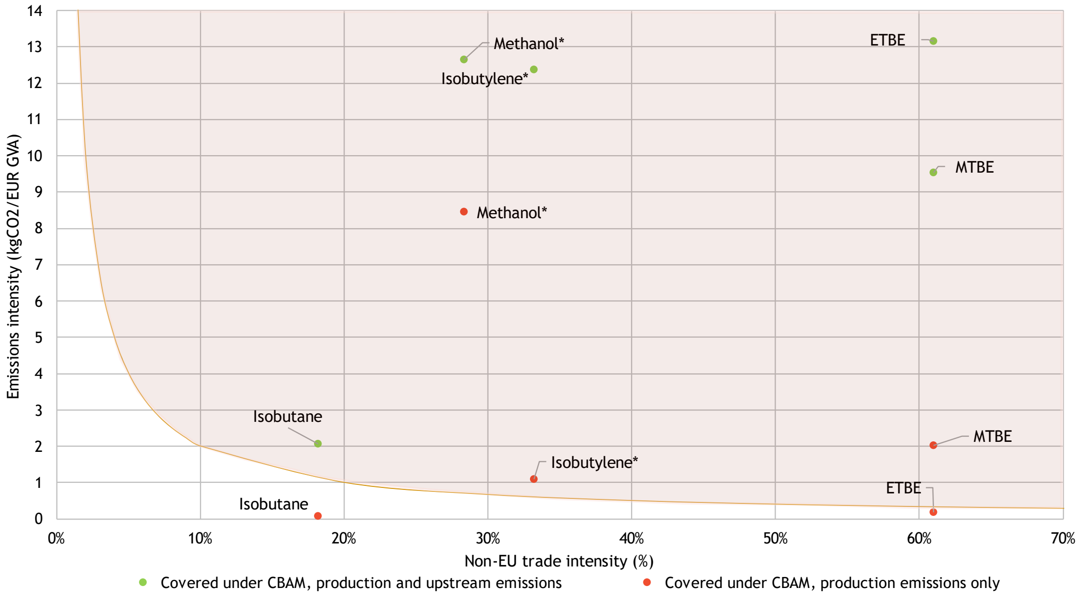
Figure 4-18 Carbon leakage indicators for ETBE/MTBE



Note: Products are considered at CL risk when emission intensity x trade intensity $\geq$ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

The indirect carbon leakage risk is much more significant for ETBE, MTBE and most of its analysed precursors. Figure 4-19 shows the extent of these upstream emission intensities. The upstream emissions of most concern are from propylene and methanol production. Particularly for isobutane and ETBE, when taking upstream emissions into account, their indicator rises beyond the 0.2 threshold to be considered at significant risk of carbon leakage.

Figure 4-19 Carbon leakage indicators for ETBE/MTBE, including upstream emissions



Note: Products are considered at CL risk when emission intensity x trade intensity ≥ 0.2. CL risk covered by CBAM uses a trade intensity without non-EU imports, as these non-EU imports face carbon costs. CL risk when not covered by CBAM includes non-EU imports in the trade intensity as these non-EU imports do not face carbon costs.
*Trade intensity values are estimated based on EU level data as production values are not available for these products.
Source: authors' calculations based on CBS, Eurostat and PBL/TNO (MIDDEN)

For MTBE, ETBE and their analysed precursors, CBAM does not appear to significantly change their risk of direct carbon leakage, but could cause isobutane and ETBE to become at significant risk of carbon leakage. Even when covered by CBAM, methanol, MTBE and isobutylene are all considered still at risk of carbon leakage because of their relative high emission intensity and/or non-EU export intensity. Additionally, all of the analysed products in this subsection have significant upstream emissions. For isobutane and ETBE, these upstream emissions are that much higher than their production emissions that these products become at significant risk of carbon leakage, if the costs of these upstream emissions would be passed down the value chain.

4.5.2 Challenges for determining embedded emissions

Additional data collection is required to include ETBE and MTBE as well as their chemical precursors (isobutane, isobutylene and methanol) under CBAM. First, even though for some of the main upstream precursors of the process ETS benchmarks are available (e.g., for butadiene as part of the HVC benchmark), the collected data cannot be linked to individual products in the absence of an emission attribution method (see also discussion under 4.2.2). Data availability is not better for methanol, for which no data has been collected yet under a standalone ETS benchmark. Data is only available from ETS installations for some of its upstream precursors such as hydrogen and syngas. In addition, the emissions of isobutylene are not easy to determine as butenes cannot be easily separated. Therefore, the separation of isobutylene from a mix of C4 hydrocarbons is usually integrated into the manufacturing of MTBE. Finally, neither an ETS product benchmark is available for ETBE nor MTBE, requiring emissions data to be collected and reference processes selected. This is not an easy task either, as there are multiple variations of processes to produce MTBE, which can range from its manufacture in petroleum refineries to plants manufacturing industrial organic chemicals such as SNC-Pernis.[84]

[84] Block, T., Gamboa, S. & Van Dril (2020) Decarbonisation options for Large Volume Organic Chemical Production, Shell

4.5.3 Circumvention risks

The MTBE/ETBE process analysed here provides an example of a potential circumvention risk through the import of chemicals that can be converted back to the original precursor covered under CBAM. There could be a circumvention risk through the import of MTBE in case a CBAM covers HVC chemicals affecting the C4-stream from the steam cracking process. A CBAM leading to a domestic cost increase of isobutene/isobutylene could lead to an increase in non-EU imports of MTBE (already among the top 20 non-EU imported chemicals as per Table 5-4).[85] This is due to the reversible nature of the MTBE production process. MTBE synthesis is an exothermic liquid phase reversible reaction. This means that MTBE can also be used reversely as a chemical intermediate to produce high-purity isobutylene, which can be used to make different polymers such as butyl rubber. If isobutylene and butyl rubber would be covered under CBAM but MTBE would not, the CBAM costs on butyl rubber could be circumvented by imported MTBE. Such circumvention risks (by importing chemicals that can be converted back to precursors covered under CBAM) were gauged as likely during the interviews conducted for this study.

Next to the above, there are no significant circumvention risks that could follow the inclusion of EBTE, MTBE and precursors under CBAM. Even though methanol appears in many different value chains and thus its inclusion under CBAM could affect various downstream products, the risks of circumvention are expected to be limited within the analysed value chain for various reasons. First, as shown in Figure 4-15, there are not many intermediate products and the few that are present have low transportability. Second, it is plausible that other market trends have a greater impact on the production of MTBE/ETBE than an increase in the costs of precursors resulting from CBAM. For example, bio-based ethanol is increasingly being used to produce bio-ETBE, which may be used as biofuel to meet the European certification requirements (gasoline containing bio-ETBE has over 66% lower greenhouse gas emissions than 100% fossil fuel-based gasoline).[86] Similarly, concerns about the toxicity of MTBE have encouraged investments in bio-based MTBE or the usage of alternative gasoline oxygenates.

4.6 Hydrogen

Hydrogen is primarily produced from natural gas in the Netherlands. Hydrogen is mostly produced as a pure hydrogen product, but also occurs as a by-product from oil refining and steam cracking processes and is present in residual gas mixtures.[87] About 70% of the hydrogen produced in the Netherlands comes from reforming natural gas according to the process depicted in Figure 3-2. Different variants of the process exist, including the steam methane reforming process (SMR- also relevant for methanol production), and autothermal reforming process (ATR), the main feedstock being natural gas in all cases. To a much lesser degree, hydrogen streams in the Netherlands are produced during steam cracking processes as shown in Figure 3-1 and refining of oil. Other processes for hydrogen production in the Netherlands include gasification (e.g., as part of the Flexicoker process of ExxonMobil), where heavy residues of oil refining are used as feedstock; Chlor-alkali process (e.g., by Nouryon), where hydrogen is produced as an electrolysis by-product with chlorine and sodium hydroxide (i.e., non-organic chemicals) as feedstocks; and cokes production, where hydrogen is produced from coke oven gas.

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[85] MTBE/ETBE are categorised under the chemical group *Acyclic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives*

[86]

[87] Based on estimations mainly from 2019 from Weeda, M. and Segers, R (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics.

Most of the hydrogen produced in the Netherlands is consumed domestically in oil refineries and the chemical industry. In the Netherlands, most of the hydrogen used is produced on-site for own use (captive). Oil refineries use the largest share of produced hydrogen (37%), with the ammonia industry following closely (32%). Further, hydrogen is also used as fuel gas (15%) and for methanol production via SMR-natural gas process (7%), as shown in Figure 3-2. The rest of the hydrogen (9%) is used in a wide variety of smaller applications in the chemical industry (e.g., in the production of hydrogen peroxide, resins and fibres), the biofuels industry, the food industry, the glass industry, the metallurgical industry, and the electronics industry.[88] Trade of hydrogen in pure form occurs via pipelines from the Netherlands to Belgium and Northern France, but on average the balance is zero; in contrast, hydrogen-rich residual gas is often delivered as a by-product to neighbouring plants.

4.6.1 *Qualitative analysis of carbon leakage risks*

The inclusion of hydrogen in CBAM would have practically no direct impact on carbon leakage risks in the short-term as the Netherlands currently has very little non-EU trade of hydrogen. Public statistics show that over 2018-2021, the Netherlands exported less than 0.4% of hydrogen in terms of value to countries outside of the EU. Over the same period, the non-EU import of hydrogen was practically zero. Since the refinery products such as natural gas, naphtha and LPG are currently not considered under CBAM, there is no additional indirect carbon leakage risk for hydrogen via upstream emissions.

Hydrogen under CBAM would accelerate the phase-out of free allowances for hydrogen producers, which needs to be applied consistently to avoid competition distortion among EU producers. Hydrogen production receives free allowances under a variety of product benchmarks in the EU ETS: hydrogen, syngas, refinery products, and high value chemicals (steam cracking products). In addition, hydrogen produced for ammonia production also receives free allowances as part of the ammonia benchmark. Should hydrogen be included in CBAM, the accelerated phase out of free allowances for hydrogen production should be applied consistently across all benchmarks to avoid competitive distortion.

The resulting cost increase due to passed on CBAM/ETS costs would mainly introduce indirect carbon leakage risks on products downstream of hydrogen production, similar to the other value chains analysed. This would be mainly on products from oil refineries, ammonia and methanol as those are the products consuming the largest share of hydrogen in the Netherlands. The leakage risks of methanol have been analysed in Section 4.5, and for ammonia, this is qualitatively discussed in Section 4.7. Oil refinery products have not been analysed in this study. However, they may be relevant when covering hydrogen under CBAM, not only with regards to indirect carbon leakage risks but also on circumvention risks discussed in Section 4.6.3.

In the long term, the inclusion of hydrogen in CBAM could mitigate future carbon leakage risks with the demand for hydrogen expected to rapidly rise in the EU. The Netherlands has a well-established market for hydrogen and is currently Europe's second-largest hydrogen producer.[89] This market is projected to grow as hydrogen demand increases in part due to the current policy agenda that includes

[88] Ibid
[89] RVO,FME & TNKI (2021). Excelling in Hydrogen Dutch technology for a climate-neutral world, pg. 12.

the Government Strategy on Hydrogen[90] and the EU hydrogen strategy for a climate-neutral Europe.[91] Under this scenario, CBAM could limit the imports of emissions-intensive hydrogen from outside of the EU. At the same time, this would incentivise the development of the infrastructure in the EU with a focus on domestic production also integrating technologies to accelerate the emissions reduction of fossil-based hydrogen (such as carbon capture).

4.6.2 Challenges for determining embedded emissions

Hydrogen can be produced through a variety of processes, making it a challenge to determine the actual embedded emissions. For production processes where hydrogen is produced as a by-product or a part of different products such as in steam cracking, there is a challenge of attribution of emissions as discussed in Section 4.2.2. In addition, the emissions related to hydrogen production strongly depend on the feedstock, production method, and the quality of the hydrogen produced (ranging from 'pure' to 'residual gas'). The overview of production processes for hydrogen above assumes the use of fossil fuels as feedstock, but biomass-derived biogas and biomethane could also be used instead to make renewable (or green) hydrogen. Furthermore, hydrogen can also be produced via the electrolysis of water. If this electricity comes from renewable sources, the hydrogen produced is also considered renewable. While CBAM should mitigate carbon leakage risks that occur through imports of fossil-based hydrogen, the import of renewable hydrogen should not be discouraged from a climate perspective. Provisions will need to be made to identify renewable hydrogen, which could be through the use of certification schemes such as CertifHy.[92] These are being developed in the context of the proposed revision of the Renewable Energy Directive and proposed directive on the internal market in hydrogen.

Emission data of hydrogen production collected under the EU ETS could be used for estimating embedded emissions, but these do not include all emissions relevant to hydrogen imports. The emission data collected under the EU ETS for hydrogen relate to the production emissions only. However, these relate to gaseous hydrogen only and do not include emissions relating to liquified hydrogen. Liquid hydrogen is one of the ways that hydrogen could be imported in the absence of pipelines.[93] Hydrogen liquefaction process is an energy-intensive process with an estimated 10-15 kWh/kgH_2,[94] which is equivalent to 42-64% of the average GHG emissions to produce 1 kg of hydrogen in the EU.[95] Additional data collection would be necessary to determine these emissions.

4.6.3 Circumvention risks

Considering the challenges related to the transportability of hydrogen, the circumvention risks of hydrogen lie mainly with the non-EU import of hydrogen carriers such as ammonia, methanol and liquid organic hydrogen carriers (LOHCs). First, hydrogen can be transported via pipelines, but current networks do not connect markets outside the EU.[96] For example, the Port of Rotterdam indicated that hydrogen imports from North Africa via pipelines are an attractive option only in the long term and if the volume is 'big enough'.[97] Next to pipelines, hydrogen can also be delivered by truck as compressed gas or liquid, but this type of transport takes place in small quantities and over limited

[90] Available under: Government of Netherlands (2020). Government Strategy on Hydrogen.
[91] European Commission (2020). COM/2020/301 final.
[92] Certifhy.
[93] IEA (2019). The future of hydrogen, seizing today's opportunity.
[94] Al Ghafri, S. et. al (2022). Hydrogen liquefaction: a review of the fundamental physics, engineering practice and future opportunities.
[95] Authors' calculation based on an electricity emission factor of 0.376 tCO_2/MWh and the average GHG emission intensity in 2016-2017 of EU ETS installations under the hydrogen benchmark of 8.88 tCO_2/tonne hydrogen. European Commission (2021). Update of benchmark values for the years 2021 – 2025 of phase 4 of the EU ETS.
[96] Main Dutch producers of pure hydrogen (Air Products and Air Liquid) operate their own pipeline, one in the Rotterdam harbour region (from the Botlek to Moerdijk and Zwijndrecht), and the second connecting Northern France with Rotterdam. Weeda, M. and Segers, R (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics.
[97] Port of Rotterdam (2022). Hydrogen comes in different packages.

distances.[98] In contrast, some downstream products of hydrogen could be used as a carrier and reconverted back to hydrogen once imported. The hydrogen carriers that are considered most promising are ammonia, methanol and LOHCs.[99]

Since there is a consensus on the EU level to cover ammonia under CBAM, there would be no circumvention risks of hydrogen using ammonia as a hydrogen carrier. Ammonia is considered to be a potential medium for hydrogen storage due to, among others, its high volumetric hydrogen density, low storage pressure and stability for long-term storage. [100] Once on site, ammonia can substitute hydrogen by being used directly as fuel or reconverted to hydrogen.[101] The EC's CBAM proposal and proposed amendments of the European Parliament and Council all list ammonia as a product to be covered under CBAM. As long as the embedded emissions of imported ammonia from outside the EU include the production emissions of hydrogen, there would not be a circumvention risk.

There are also circumvention risks through the import of methanol as a hydrogen carrier if it is not included under CBAM given the high non-EU import of methanol. Public statistics show that methanol is the most imported product by the Netherlands over 2018-2021. If not included under CBAM, the Dutch broad experience with methanol imports (including transport and storage) may render it a potentially attractive hydrogen carrier, even if the costs of producing hydrogen from methanol are still relatively high. Just like ammonia, methanol is ready for immediate use in various production processes and as marine fuel but the disadvantage being the high costs of "unloading" hydrogen from the methanol carrier.[102] Since methanol is currently used in the Netherlands for a variety of applications (including solvents, antifreeze and fuel additives)[103] and the manufacturing of different chemicals (it is present in most value chains relevant to the Netherlands depicted in Section 3.3), its use as a hydrogen carrier may be exploited only once the domestic demand is covered.

The circumvention risk of hydrogen with LOHCs may be lower compared to methanol as LOHCs are mainly produced domestically, but cannot be ruled out as the Netherlands has the infrastructure to handle it. LOHCs are organic molecules containing aromatic rings, such as toluene, naphthalene, or dibenzyl-toluene. LOHCs, therefore, fall under the classification of *organic basic chemicals*, one of the product groups proposed by the European Parliament to be covered under CBAM. LOHCs are considered an attractive option for the long-distance transport of hydrogen as an alternative to ammonia and methanol due to costs. Most of the common LOHCs[104] are part of the top-produced basic chemicals in the Netherlands but not heavily imported from outside the EU as listed in Annex I. However, these carriers are considered relatively easy to handle and the existing chemical infrastructure in the Netherlands can be used for this.[105] If LOHCs would not be covered under CBAM, the CBAM costs on hydrogen could therefore be circumvented using LOHCs. A key disadvantage of LOHCs is, however, that the carrier molecule generally has to be shipped back to pick up a new cargo of hydrogen, which adds to transportation costs.

Finally, the circumvention risks of hydrogen should also be considered in the context of synthetically derived fuels, which is not part of the products that have been proposed to be

[98] Weeda, M. and Segers, R (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics.
[99] Joint Research Centre (2021). Assessment of hydrogen delivery options.
[100] Aziz, M. et. al (2020). Ammonia as Effective Hydrogen Storage: A Review on Production, Storage and Utilization.
[101] Ibid
[102] Port of Rotterdam (2022). Hydrogen comes in different packages.
[103] Yong, C. & Keys, A. (2021). Decarbonisation options for Large Volume Organic Chemicals Production, LyondellBasell Rotterdam.
[104] Naphthalene and other aromatic hydrocarbon mixtures; benzol (benzene), toluol (toluene) and xylol (xylenes).
[105] Port of Rotterdam (2022) Hydrogen comes in different packages.

covered under CBAM. Currently, most fuels are produced from refining fossil resources. However, hydrogen-derived synthetic fuels could play an increasingly important role as the use of fossil fuels is phased out.[106] Synthetic fuels have the same chemical composition as their chemical alternative and could replace them completely. These synthetic fuels are produced from syngas (hydrogen + CO_2) using electricity. Only if the electricity used to produce the hydrogen and the subsequent fuel is renewable, can synthetic fuels be considered renewable. Imports of non-renewable synthetic fuels from outside the EU should therefore be considered under CBAM to prevent future circumvention risks when hydrogen-derived synthetic fuels take off.

4.7 Ammonia

Natural gas is currently the main feedstock for ammonia production in the Netherlands. Natural gas is turned into syngas and hydrogen, from which ammonia is made, as shown in Figure 3-7. Hydrogen could therefore also be used directly as a feedstock in the production of ammonia.[107]

Most of the ammonia in the Netherlands is used to produce fertilisers, with the rest going to the production of organic basic chemicals mainly to make synthetic materials. In the Netherlands, it is estimated that 60-70% of the ammonia produced is used for products for the (nitrogen-based)[108] fertiliser industry such as nitric acid, ammonium nitrate, calcium ammonium nitrate, urea, urea ammonium nitrate, and other compound fertilisers.[109] After the fertiliser domestic market is supplied, the remaining ammonia (30-40%) is used to produce organic basic chemicals such as melamine, caprolactam, and acrylonitrile, which are used to make synthetic materials.

4.7.1 Qualitative analysis of carbon leakage risks

CBAM will likely reduce direct carbon leakage risks of ammonia as the Netherlands mainly imports ammonia from non-EU countries and exports it to EU countries. Ammonia is traded internationally as a commodity and shipped by tankers to the Netherlands,[110] mainly from non-EU countries. In 2021, about 40% of imports to the Netherlands came from outside of the EU (mainly from Egypt and the United States).[111] In the same year, practically all ammonia produced in the Netherlands was exported to EU countries.

The limited export to outside the EU also means that upstream emissions would also not lead to significant indirect leakage risks for ammonia. In the Netherlands, the hydrogen required for ammonia production is generally produced on-site from natural gas, but some ammonia production also uses hydrogen from neighbouring sites.[112] Emissions related to hydrogen production could therefore be considered the main upstream emissions of ammonia. If the carbon costs of hydrogen production would be passed on downstream, this could affect the competitiveness of ammonia producers in markets outside the EU and increase their carbon leakage risk. However, since statistics show very little export of ammonia to countries outside the EU, this risk is limited.

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[106] Davies, J., Dolci, F., Klassek-Bajorek, D., Ortiz Cebolla, R. and Weidner Ronnefeld, E. (2020). Current Status of Chemical Energy Storage Technologies.
[107] Batool, M & Wetzels, W. (2019) Decarbonisation options for the Dutch fertiliser industry.
[108] Next to ammonia-based mineral fertilisers, it also includes the production of phosphate-based and potassium-based fertilisers. In the Netherlands, the nitrogen (i.e., ammonia-based) fertilisers are the most important in terms of production volumes and energy consumption (Ibid).
[109] Batool, M & Wetzels, W. (2019) Decarbonisation options for the Dutch fertiliser industry.
[110] Weeda, M. and Segers, R (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics.
[111] Source: TrendEconomy data. Annual International Trade Statistics by Country (HS 2814)
[112] Weeda, M. and Segers, R (2020). The Dutch hydrogen balance, and the current and future representation of hydrogen in the energy statistics.

4.7.2 Challenges for determining embedded emissions

Since ammonia has a product benchmark under the EU ETS, EU data for the ammonia benchmark can in principle be used as a basis for determining embedded emissions. In the EU ETS, the system boundaries of the ammonia benchmark are clearly defined and include hydrogen production for ammonia. The data collected from EU producers of ammonia could therefore be used to estimate the embedded emissions of non-EU imports of ammonia.

A complication could arise for ammonia that is not produced from on-site hydrogen but from external sources. While the integrated production of ammonia and hydrogen is most common, ammonia production from hydrogen produced elsewhere also occurs. As discussed in Section 4.6.2, this hydrogen can be produced from a variety of processes, each with different embedded emissions. In addition, there could be emissions associated with the transport of hydrogen, which also has to be taken into account. This means that the embedded emissions for the ammonia production step would need to be determined separately from the hydrogen production step. For the EU ETS product benchmarks, emission data has only been collected for ammonia production with integrated hydrogen production. Emission data for solely the ammonia production step is not readily available and would therefore have to be additionally collected.

4.7.3 Circumvention risks

The consensus on the EU level to cover fertilisers under CBAM means that there would be no circumvention risks from fertilisers, the largest downstream product group of ammonia. In addition to ammonia, fertilisers (including fertilisers produced from ammonia) have been proposed as products to be covered under CBAM by the European Commission, which is supported by the European Council and Parliament. If the embedded emissions of non-EU imports of fertilisers include the upstream emissions related to the production of hydrogen and ammonia, there would not be a circumvention risk.

Of the downstream ammonia products, acrylonitrile and its derivatives are of particular interest for circumvention risks, as it is used for a wide variety of applications in the Netherlands. As reflected in Figure 3-7, acrylonitrile is used for a variety of applications both directly and as a feedstock to other production processes. It can be used directly in the manufacture of acrylic and fibers for use in clothing and textiles, and also as a feedstock for the production of styrene-derived products. Since styrene is both largely produced in the Netherlands and imported from outside the EU, a CBAM on styrene and acrylonitrile would prevent circumvention risks through further downstream products derived from the combination of styrene and acrylonitrile.

Melamine, another downstream product of ammonia, could also be relevant for circumvention risks, although to a lesser degree than acrylonitrile. Melamine is a vital raw material in wood adhesives, laminates, coatings and halogen-free fire retardants.[113] An eventual cost increase of ammonia in the EU could provide non-EU melamine manufacturers a competitive advantage in the EU market. However, within the international melamine market, the Dutch chemical sector plays a key role (OCI Nitrogen in Geleen is the world's largest melamine producer).[114] In addition, anti-dumping measures against Chinese melamine imports would hamper the increase in melamine imports.[115] These factors lower the risks of circumvention related to melamine.

[113] PDM (n.d.). Develop and implement a flange integrity management system at the Chemelot site.
[114] OCI (n.d.). OCI Nitrogen.
[115] OCI N.V (2018) OCI N.V. Investor Presentation.

In addition, there could be a circumvention risk if caprolactam (derived from ammonia) is not covered under CBAM. Figure 3-6 shows that caprolactam is used to produce nylon-6 (polyamide 6), which is among the top 20 most produced basic chemicals in the Netherlands as shown in Annex I.2. Among others, consumers of nylon-6 include the manufacturers of clothing, ropes, fishing nets, packaging films and engineering plastics (plates, rods, molded parts). These products downstream of caprolactam would be part of the product category *Plates, sheets, film, foil, strip of polyamides*, which is among the top 20 imported plastic products. This means that if domestic prices of nylon-6 would increase due to passed on costs from upstream emissions related to ammonia production, end-consumers may also opt for importing the finished products instead.

5 Key conclusions and considerations

Several commonalities between the value chains analysis in the previous section can be observed on carbon leakage risks, challenges in determining embedded emissions and circumvention risks. Combined with the findings from Section 3, some general conclusions can be drawn, which are discussed in Section 5.1. These general conclusions may not be valid for all chemical value chains. Nonetheless, this helps in bringing out the risks and challenges to consider with the inclusion of chemicals under CBAM.

The commonalities on risks and challenges are used to inform the considerations on the different options to include chemicals in the scope of CBAM. Section 5.2 summarises the key findings from Section 4 as a basis to discuss the considerations on the different scope options.

5.1 Key conclusions

5.1.1 Carbon leakage risks

Including upstream chemicals[116] under CBAM shows a mainly positive picture on reducing carbon leakage risk for Dutch producers, although concerns on non-EU exports remain. For ethylene and propylene, CBAM inclusion would have a largely positive impact on reducing carbon leakage risks due to their relatively high non-EU import into the Netherlands compared to the non-EU export out of the Netherlands. The same goes for ammonia, which can be considered an upstream chemical as the hydrogen required for ammonia production is generally produced on-site from natural gas. For butadiene and some analysed aromatics, the remaining concerns relating to competition in non-EU markets due to the accelerated phase out of free allowances could result in them still being at significant risk of carbon leakage. In the case of methanol, the top upstream chemical imported to the Netherlands from outside the EU, its CBAM inclusion could lead to indirect leakage risks for various downstream products, as it is widely used in many different value chains and associated with relatively high emissions.

For Dutch producers of many midstream chemicals,[117] the inclusion of their chemical precursors in CBAM could increase their overall carbon leakage risk even if the midstream chemicals are also covered under CBAM. For many midstream chemicals analysed, the upstream emissions are significantly higher than their production emissions. This is even the case for chemicals with an emissions intensity production process such as ethylene glycol, styrene and ABS. The potential passthrough of the costs of these upstream emissions (CBAM and/or ETS costs) to the midstream chemicals can cause indirect carbon leakage risks. For many analysed midstream chemicals, the increase in indirect leakage risks related to non-EU exports is higher than the reduction in direct carbon leakage risks from inclusion of non-EU imports.

The significance of the potential passthrough of upstream emissions costs to downstream producers could introduce new carbon leakage risks to producers of (semi)finished plastic products, which could be partly mitigated by also included them under CBAM. The production of (semi)finished plastics tend to be less emissions intensive due to being less energy intensive and having a higher value

[116] In this study, upstream chemicals refer to chemicals for which the precursors do not fall under the chemical sector. This means that the production emissions of their precursors are not in scope of this study as potential products to be included under CBAM, so any risks of carbon costs pass through is not considered.
[117] In this study, midstream chemicals refer to chemicals including polymers for which the precursors are also part of the chemical industry and may therefore potentially be covered under CBAM, which could result in carbon costs being passed on.

added. Furthermore, these plastic producers are generally not included in the EU ETS due to their low emission and would currently therefore not have any carbon leakage risks. However, if the producers of all chemicals upstream of those plastic products can pass down their carbon costs, the analysis of some plastic products such as polystyrene plastics and PET found they would become at significant risk of carbon leakage, even if they are also covered under CBAM. This is because some of these plastic producers in the Netherlands export a lot of their products to markets outside the EU where they compete with non-EU producers that do not have these passed down carbon costs. This shows that the indirect carbon leakage risk can be even significant for (semi)finished plastic products at the end of the chemical value chain.

The direct carbon leakage risks could be mitigated by maintaining free allowances relating to non-EU exports, but it would not be able to address indirect carbon leakage risks. The European Parliament proposed to maintain free allowances for non-EU exports. However, such a measure risks non-compliance with WTO rules on non-discrimination and/or export subsidies. Furthermore, the current system of free allowances would be unable to mitigate indirect carbon leakage risks. Free allowances are designed to only cover direct ETS emissions and do not compensate for upstream emission costs.

By focussing on chemicals and their derivatives that are heavily imported from outside the EU and have limited non-EU exports, the positive impact of CBAM to reduce carbon leakage risks can be optimised. To identify which chemical value chains in the Netherlands fulfil these conditions, a more extensive analysis is required, for which this study can serve as a basis. It would also access to the complete dataset on domestic production and non-EU trade for all products, which is not publicly available for data confidentiality reasons.[118] The positive impact of CBAM could also be optimised by including some midstream chemicals without their chemical precursors that are not at risk of carbon leakage to limit indirect leakage risks. This would require further analysis beyond the analysed value chains in this study, because steam cracking products (a chemical precursor for all products analysed in this study) are considered to be at significant risk of carbon leakage themselves.

Specifically for hydrogen, its inclusion in CBAM practically has no impact on its carbon leakage risks in the short-term but it could mitigate future carbon leakage risks. The Netherlands currently has very little non-EU trade of hydrogen, but a well-established market for hydrogen. As the demand for hydrogen is expected to grow, CBAM could limit the imports of emissions-intensive hydrogen from outside of the EU. At the same time, this would incentivise the development of the infrastructure in the EU with a focus on domestic production, also integrating technologies to accelerate the emissions reduction of fossil-based hydrogen (such as carbon capture). However, the passed on CBAM/ETS costs from hydrogen inclusion could introduce indirect carbon leakage risks on hydrogen derivatives and carbon leakage risks via hydrogen carriers. If hydrogen is covered under CBAM, covering methanol and LHOCs should therefore also be considered, which are discussed below under *Circumvention risks*.

5.1.2 Determining embedded emissions

Determining the embedded emissions of imported products could be based on existing methodologies and data from the EU ETS where there are product-specific benchmarks. There are several ETS product benchmarks for chemical products to determine the free allowances that EU producers of these products will receive (see Table 5-1 for an overview of the availability of ETS

[118] In the publicly available datasets from the CBS and Eurostat, many datapoints have been marked as confidential.

benchmarks for the products analysed). For these products, there is an existing definition which production processes and emissions associated with processes are considered part of the production emissions. These definitions could be used as a basis for setting the rules how the actual emissions of the same imported products need to be determined. The data collected to determine the product benchmarks could also be used to determine a default value in case importers are unable to report actual emissions.

However, for several chemical products the rules and data of the product benchmarks cannot be directly used due to challenges with emission attribution. For steam cracking products, the product benchmark is only available for the resulting product mix from steam cracking called *High-Value Chemicals*. A commonly accepted methodology would therefore need to be developed to attribute specific emissions to each of the individual products from the steam cracking process. Furthermore, some product benchmarks are only available for product mixes (aromatics) or include the production processes of precursors of the chemical product (EO/EG process, and EB/styrene). Methodologies would therefore need to be developed on the attribution of emissions to take into account separate import of EO, EB and individual aromatics. For some of these products, such as EO and EG, where determining separate embedded emissions is not possible with the available data, CBAM would need to cover all products under the mix to ensure practical feasibility.

For products without a product benchmark, the challenge for determining embedded emissions is even greater as clear methodologies are yet to be established. These rules need to define which processes need to be included for determining the embedded emissions of each imported product. If the importers are unable to report actual emissions for products without a product benchmark, default values could potentially be established using the data collected from EU ETS installations for updating the fallback benchmarks (heat and fuel benchmarks). However, this data is unlikely to be directly usable to establish default values. Each installation only had to report their total heat and fuel consumption related to the production of products not covered under a product benchmark. The heat and fuel consumption would therefore first need to be attributed to specific products.

Emission attribution rules also need to be established for upstream emissions from precursors that are also covered under CBAM, which becomes increasingly difficult the more precursors are involved such as in chemical value chains. For each imported product that contains precursors also covered under CBAM, rules would need to be established to determine the upstream emissions related to that product. This requires the importer to report the quantity of a precursor that has been used to produce one kg of the imported chemical (conversion factors), and what the actual emissions were associated with the production of that precursor. This becomes increasingly difficult to trace as more precursors are involved, especially if this relates to precursors several production steps upstream as shown for the chemical value chain. The alternative would be to collect additional data from installations in the EU or use collected data from other imports to establish default conversion factors. Otherwise, conservative estimates from literature could be used where available.

5.1.3 Circumvention risks

Circumvention risks vary for each of the value chains, with multiple determinants for high circumvention risks. The transportability of products, availability of established import partners from outside the EU to the Netherlands, and usable transport infrastructure, are all factors that may reinforce or prevent circumvention risks. For most of the value chains analysed, circumvention risks are intensified downstream (e.g., after polymerisation processes) as the nearly finished products are easier to transport and already show a high non-EU trade intensity. Circumvention risks are also intensified via top non-EU imported chemicals (such as EG and methanol) if they are not included under CBAM but their (highly GHG-intensive) precursors are (such as ethylene and hydrogen, respectively). In addition, for some of these chemicals (largely imported from non-EU countries), there may be high circumvention risks through the non-EU import of their downstream products, in particular for those used for many different applications, such as a methanol.

There are also circumvention risks through the import of non-CBAM chemicals that can be converted back to the original precursor that are covered under CBAM to make other products. The MTBE/ETBE process analysed provides an example of this potential circumvention risk. The synthesis of MTBE can be relatively easily reversed to produce high-purity isobutylene, which can be used to make different polymers such as butyl rubber. If isobutylene and butyl rubber would be covered under CBAM but MTBE would not, the CBAM costs on butyl rubber could be circumvented by imported MTBE. Such circumvention risks were gauged as likely during the interviews conducted for this study. At the same time, input from companies for this study indicated that whether such circumvention risk will materialise depends on the presence of or required investment for the infrastructure for conversion.

Circumvention risks can be reduced by covering products down the value chain in return for increased complexities in determining embedded emissions. The analysis of ethylene and propylene value chains show that there are many opportunities to circumvent a CBAM on ethylene and propylene via its derivatives. Similarly, the analysis of ammonia derivatives shows the presence of circumventing CBAM on ammonia via melamine, caprolactam, and acrylonitrile. A CBAM on acrylonitrile could in turn be circumvented by importing SAN, which is made from styrene and acrylonitrile. Covering all these further downstream products would prevent circumvention risks. However, determining the embedded emissions of these downstream products is much more complex than more upstream chemicals as discussed in Section 5.1.2.

Specifically for hydrogen, the carbon leakage risks mainly lie with the circumvention risks via non-EU imports of hydrogen carriers such as methanol and LOHCs. The transportability of hydrogen over long distances shows considerable challenges due to the absence of pipelines with non-EU countries and the liquefaction of hydrogen being an energy intensive process. Methanol, LOHCs and ammonia are therefore considered promising alternatives as hydrogen carriers. Methanol is already the top imported chemical from outside the EU by the Netherlands and the Netherlands has the infrastructure to handle LOHCs. If they would not be covered under CBAM, hydrogen could be subject to circumvention risks. Since there is a consensus on the EU level to cover ammonia under CBAM, there would be no circumvention risks of hydrogen using ammonia as a hydrogen carrier.

5.2 CBAM scope considerations

The considerations for including a chemical or plastic product in the scope of CBAM depends on the resulting direct and indirect carbon leakage risks, the feasibility of determining a product's embedded emissions and circumvention risks. Table 5-1 summarises the findings for the products analysed in the value chain case studies in Section 4. This includes whether a significant risk of carbon leakage would be remaining after CBAM inclusion due to non-EU exports, and whether the product would be exposed to significant risks of indirect carbon leakage if their upstream chemical precursors would be included in CBAM. The table also gives a summary of the type of challenges presence for determining embedded emissions and circumvention risks found for the analysed value chains.

The results show that the inclusion of CBAM does not mitigate carbon leakage risks for every analysed product while at the same time new issues could arise. This is because for some of the analysed products, a significant share of the production in the Netherlands is exported to outside the EU. In addition, many analysed midstream and downstream products observe a significant risk of indirect carbon leakage if their chemical precursors are also covered under CBAM, even if the products themselves are covered under CBAM. At the same time, almost every analysed product has issues regarding the determination of embedded emissions and circumvention risk that need to be considered.

Table 5-1 Overview of carbon leakage risk after CBAM inclusion, challenges for determining embedded emissions and circumvention risks for analysed products in the Dutch chemical value chains

Value chain	Product	Significant carbon leakage risk after CBAM inclusion		Determining of embedded emissions		Circumvention risks within the value chain
		Direct[119]	Indirect[120]	ETS product benchmark available	Main emission attribution issues[121]	
Steam cracking	Ethylene & propylene	No	No	Included in product mix 'HVC'	Production	• High for ethelene via the import of polyethylene (PE), EG and other PE-finished products • Limited for propylene but might increase via the import of PO and tetrahydrofuran
	Butadiene	Yes	No			• *Circumvention risks were not analysed for butadiene derivatives*
	Aromatics[122]	Yes	No	Only for product mix 'aromatics'	Production	• *Circumvention risks were not analysed for aromatics' derivatives*
Ethylene oxide	Ethylene oxide (EO) & Ethylene glycol (EG)	Yes	Yes	Only for product mix 'EO/EG'	Production	• High via the import of EG if EO is covered under CBAM and EG is not. • High via the import of bottle-grade PET and other finished products
	PET and derivatives	No	Yes	No	Upstream and production	
Ethylbenzene	Ethylbenzene (EB)	No	No	Only for production route EB/styrene	Upstream	• High via the import of styrene and its derivative products if only EB is covered under CBAM. • High via the import of SAN if acrylonitrile is covered under CBAM
	Styrene	No	Yes			
	Propylene oxide (PO)	No	No	No	Upstream	
	SAN	No	No			
	ABS & latex rubber	Yes	Yes			
	Plastics of styrene	No	Yes		Upstream and production	
ETBE/ MTBE	Methanol	Yes	Yes	No	Production	• High via the import of MTBE in case a CBAM covers HVC chemicals affecting the production costs of isobutene/ isobutylene from the steam cracking process
	Isobutylene	Yes	Yes	No	Upstream	
	Isobutane	No	Yes			
	ETBE	No	Yes			
	MTBE	Yes	Yes			
Hydrogen (H_2)		No	No	Yes, but may not include all emissions relevant to H_2 imports	Production	• High via the import of H_2 carriers such as methanol and further downstream products • Limited via the import of LOHC • None via import of NH_3 as there is EU level consensus for it to be included under CBAM
Ammonia (NH_3)		No	No	Yes, but only for NH_3 production with integrated H_2 production	None	• High via the import of acrylonitrile, caprolactam, and nylon (polyamide-6) derived products. • Limited via the import of melamine

However, the commonalities between the analysed products show that upstream basic chemicals (steam cracking products and hydrogen) can be considered the most relevant group of chemicals for inclusion in CBAM and would likely see an overall reduction of direct carbon leakage risks.

[119] This refers to the presence of significant risks of direct carbon leakage after inclusion of the product under CBAM due to relatively high non-EU export intensity.

[120] This refers to the presence of significant risks of indirect carbon leakage after inclusion of the product under CBAM due to the cost pass through of carbon costs from upstream chemical precursors in combination with a relatively high non-EU export intensity, assuming that the upstream chemical precursors are also covered under CBAM.

[121] Main emission attribution issues can be due to a) upstream (i.e., attributing the upstream emissions to the embedded emissions of the product is complex) or b) production (i.e., different process conditions affect the embedded emissions related to the production and/or multiple products are produced from the same production process, making attribution of emissions complex). Table 5-1 differentiates the *main* attribution issues, but it is noted that in most cases both types of issues are present to varying extents. More information is provided in the respective case studies.

[122] Benzene, toluene, xylenes

Upstream basic organic chemicals are part of the most heavily non-EU imported and domestically produced products in the Netherlands. Upstream chemicals with a relatively large exposure to non-EU import compared to non-EU exports, such as ethylene and propylene, would see their carbon leakage risks reduce. Hydrogen, another upstream chemical, would likely benefit from CBAM inclusion with regards to a potential reduction of future carbon leakage risks. However, for upstream aromatic chemicals (benzene, toluene and xylenes), which more exposed to non-EU exports than imports, their carbon leakage risk would remain high. Furthermore, the inclusion of upstream chemicals increases indirect carbon leakage risks for downstream products, with circumvention risks as one of the consequences.

For the midstream organic chemicals (including polymers) and downstream plastics, their inclusion of CBAM shows a mixed picture due to their relatively high non-EU export share of some of these products. In addition, some midstream chemicals and downstream plastics show relatively high indirect carbon leakage risks when their upstream chemical precursors are covered under CBAM, such as those in the ethylene oxide, ethylbenzene and ETBE/MTBE value chains. Inclusion of these midstream chemicals and downstream plastics can reduce their indirect carbon leakage risks as long as the embedded emissions of non-EU imports also cover the upstream emissions from the chemical precursors. This does expose the midstream chemicals to circumvention risks, which can be mitigated by including downstream plastic products under CBAM as proposed by the European Parliament. However, including downstream plastic products under CBAM could also trigger indirect carbon leakage risks in further downstream sectors (e.g. food packaging, construction, electronics, etc.). Further, extending the scope further downstream does add more challenges to the practical feasibility with regards to determining embedded emissions.

Instead of including an entire group of organic chemicals, polymers or plastics, an alternative is to include specific chemical value chains where the positive impact of CBAM to reduce carbon leakage risks is optimised. This could be a certain value chain from upstream chemical emissions to the downstream finished plastic product, where products throughout the value chain have a relatively high non-EU import and low non-EU export. This could serve as a pilot to work out the issues related to the attribution of emissions throughout the value chain and test this in practice, which is particularly relevant to the chemical value chain. It could also help in identifying to what degree indirect carbon leakage risks and circumvention risks are of particular concern. The key challenge will be identifying the most suitable chemical value chains for initial inclusion, especially since steam cracking products are an integral part of many chemical value chain. Selecting an appropriate value chain without introducing significant circumvention risk will therefore be difficult. Lessons could also be learned from the CBAM inclusion of fertilisers as the fertiliser value chain covers various chemicals.

More chemical value chains could be added in the future, especially since the carbon leakage risks in the status quo are already increasing, meaning that the relative negative impact of CBAM inclusion on increasing carbon leakage risk for non-EU exports reduces over time. Even without CBAM inclusion, the carbon leakage risks are already increasing, not only for non-EU exports but also for non-EU imports. Free allowances under the EU ETS continue to decrease under the status quo and ETS prices are expected to rise. An accelerated phase out of free allowances due to CBAM inclusion would therefore have a relatively more limited impact on the carbon leakage risk of non-EU exports in the future than it would have now. Furthermore, the positive impact of including products under CBAM to mitigate carbon leakage risks from non-EU imports increases over time. As time progresses, the positive impacts of CBAM inclusion start to outweigh the negative impact for more and more products.

Table 5-2 provides an overview of the potential scopes for CBAM and a summary of the pros and cons identified in this study.

Table 5-2 Overview of potential CBAM scopes for considerations and their relative pros and cons compared to each other

Potential CBAM scope	Pros	Cons
Upstream organic basic chemicals + hydrogen	• Mainly positive CL impact of CBAM due to relative high non-EU imports compared to non-EU exports • Limited complexity to determine embedded emissions	• Some negative CL impact for specific products with high non-EU exports • Indirect CL risks downstream • High circumvention risks
All organic basic chemicals and polymers + hydrogen	• Positive CL impact with high non-EU imports	• Indirect CL risks downstream • Negative CL impact for high non-EU exports • Complex to determine embedded emissions • High circumvention risks
All organic basic chemicals, polymers and plastics + hydrogen (EP proposal)	• Limited circumvention risks • More limited indirect CL risks	• Negative CL impact for high non-EU exports • Highly complex to determine embedded emissions
Specific chemical value chains	• Can be optimised for positive CL impacts of CBAM • Can be optimised to limited indirect CL risks downstream • Limited circumvention risks	• Challenge to select the appropriate value chains for CBAM

CL = carbon leakage

Annex I Non-EU imports and Dutch production of chemical and plastic products at product level

I.1 Non-EU imports of chemical products to the Netherlands

The majority of the most imported basic chemical products from outside the EU belong to the sectors *other organic basic chemicals* (NACE 20.14) or *plastics in primary form* (NACE 20.16), with methanol being the most imported product on average (2.4% of total chemical product imports) as shown in Table 5-3. As plastics in primary form, or polymers, are derived from organic basic chemicals such as ethylene and propylene (see also Section 3.3), these belong to the organic chemical value chain. Other basic chemicals such as industrial gases, dyes, fertilisers, synthetic rubber and other inorganic basic chemicals do not appear in the top imported non-EU chemicals or more sparingly.

Table 5-3 Total production and imports (2018-2021 average) of the top 20 imported basic chemical products to the Netherlands (NACE 20.1)

#	PRODCOM	Product	Annual non-EU imports by NL (Avg. 2018-2021)		Annual production in NL (Avg. 2018-2021)	
			MEUR	% of total basic chemical non-EU imports	MEUR	% of total basic chemical production
1	20.14.22.10	Methanol (methyl alcohol)	540	2.4%	.	.
2	20.14.31.97	Industrial monocarboxylic fatty acids (excluding stearic, oleic, tall oil, distilled)	396	1.8%	47	0.1%
3	20.14.19.10	Fluorinated; brominated or iodinated derivatives of acyclic hydrocarbons	343	1.5%	.	.
4	20.16.40.90	Polyesters, in primary forms (excluding polyacetals, polyethers, epoxide resins, polycarbonates, alkyd resins, polyethylene terephthalate, other unsaturated polyesters)	299	1.3%	461	1.1%
5	20.14.21.00	Industrial fatty alcohols	292	1.3%	.	.
6	20.14.12.50	Styrene	235	1.0%	2141	5.1%
7	20.14.41.51	Aniline and its salts (excluding derivatives)	212	0.9%	0	0.0%
8	20.14.52.90	Nucleic acids and other heterocyclic compounds - thiazole, benzothiazole, other cycles	187	0.8%	10	0.0%
9	20.13.21.70	Silicon. Other than containing by weight not less than 99,99 % of silicon	186	0.8%	0	0.0%
10	20.16.10.90	Polymers of ethylene, in primary forms (excluding polyethylene, ethylene-vinyl acetate copolymers)	175	0.8%	.	.
11	20.14.52.25	Heterocyclic compounds with oxygen only hetero-atom(s) (excluding other lactones)	164	0.7%	12	0.0%
12	20.13.24.55	Phosphoric acid and polyphosphoric acids	156	0.7%	.	.
13	20.14.63.10	Acyclic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives	154	0.7%	370	0.9%
14	20.14.32.80	Lauric acid and others; salts and esters	153	0.7%	181	0.4%
15	20.14.33.40	Esters of methacrylic acid	149	0.7%	7	0.0%
16	20.17.10.90	Synthetic rubber (excluding latex)	141	0.6%	.	.
17	20.14.12.23	Benzene	136	0.6%	457	1.1%
18	20.16.51.30	Polypropylene, in primary forms	134	0.6%	924	2.2%
19	20.14.11.30	Ethylene	132	0.6%	2543	6.1%
20	20.12.21.50	Other synthetic organic colouring matters	130	0.6%	36	0.1%

Note: "." means that the data is not available from public statistics and could be non-zero. Non-EU imported products for which no public data was available have not been included in the top 20 list.
Source: CBS and Eurostat.

I.2 Production of chemical products in the Netherlands

As with the non-EU imports, the top basic chemical production in the Netherlands also emphasises the relevance of organic chemicals and polymers for the Dutch chemical industry. The majority of the most produced basic chemical products are organic, with ethylene and styrene being the most produced on average (6.1% and 5.1% of total Dutch chemical production, respectively). All of these top produced chemicals are either under the category of *other organic basic chemicals* (NACE 20.14) or *plastics in primary form* (NACE 20.16).

Table 5-4 Total production and exports (2018-2021 average) of the top 20 produced basic chemicals in the Netherlands (NACE 20.1)

#	PRODCOM	Product	Annual production in NL (Avg. 2018-2021) MEUR	Annual production in NL (Avg. 2018-2021) % of total chemical production	Annual non-EU exports by NL (Avg. 2018-2021) MEUR	Annual non-EU exports by NL (Avg. 2018-2021) % of NL production
1	20.14.11.30	Ethylene	2543	6.1%	34	1.3%
2	20.14.12.50	Styrene	2141	5.1%	165	7.7%
3	20.14.11.40	Propene (propylene)	1754	4.2%	10	0.5%
4	20.16.40.40	Polycarbonates, in primary forms	1195	2.9%	209	17.5%
5	20.16.40.15	Polyethylene glycols and other polyether alcohols, in primary forms	1183	2.8%	530	44.8%
6	20.14.63.75	Methyloxirane (propylene oxide)	928	2.2%	36	3.8%
7	20.16.51.30	Polypropylene, in primary forms	924	2.2%	111	12.1%
8	20.16.10.39	Polyethylene having a specific gravity < 0,94, in primary forms (excluding linear)	847	2.0%	110	12.9%
9	20.14.73.40	Naphthalene and other aromatic hydrocarbon mixtures (excluding benzene, toluene, xylene)	654	1.6%	.	n/a
10	20.16.53.90	Acrylic polymers, in primary forms (excluding polymethyl methacrylate)	588	1.4%	242	41.2%
11	20.16.40.90	Polyesters, in primary forms (excluding polyacetals, polyethers, epoxide resins, polycarbonates, alkyd resins, polyethylene terephthalate, other unsaturated polyesters)	461	1.1%	197	42.8%
12	20.14.12.23	Benzene	457	1.1%	76	16.7%
13	20.16.20.35	Expansible polystyrene, in primary forms	399	1.0%	36	9.0%
14	20.11.11.50	Hydrogen	395	0.9%	1	0.3%
15	20.14.63.10	Acyclic ethers and their halogenated, sulphonated, nitrated or nitrosated derivatives	370	0.9%	226	61.0%
16	20.16.51.50	Polymers of propylene or of other olefins, in primary forms (excluding polypropylene)	354	0.8%	327	92.3%
17	20.16.54.50	Polyamide -6, -11, -12, -6,6, -6,9, -6,10 or -6,12, in primary forms	352	0.8%	100	28.4%
18	20.16.10.50	Polyethylene having a specific gravity of >= 0.94, in primary forms	351	0.8%	125	35.6%
19	20.16.56.70	Polyurethanes, in primary forms	341	0.8%	172	50.5%
20	20.14.73.20	Benzol (benzene), toluol (toluene) and xylol (xylenes)	332	0.8%	.	n/a

Note: "." means that the data is not available from public statistics and could be non-zero. Production in the Netherlands for which no public data was available have not been included in the top 20 list.
Source: CBS and Eurostat

I.3 Non-EU imports of plastic products to the Netherlands

The top 20 imported products from outside the EU, based on available statistics, mainly consists of plates/sheets/film and packaging materials, although plastics for flooring and final uses (e.g. kitchenware and household uses) are also highly imported. Several of the listed non-EU imported plastic products are specific derivatives of the most relevant value chains in the Netherlands, namely ethylene (e.g. vinyl chloride, PVC), propylene (e.g. polycarbonates, phenolic resins) and aromatics (e.g. polyesters).

Table 5-5 Total production and imports (2018-2021 average) of the top 20 imported plastic products to the Netherlands (NACE 22.2)

#	PRODCOM	Product	Annual non-EU imports by NL (Avg. 2018-2021)		Annual production in NL (Avg. 2018-2021)	
			MEUR	% of total plastics non-EU imports	MEUR	% of total plastic production
1	22.23.11.55	Floor coverings in rolls or in tiles and wall or ceiling coverings consisting of a support impregnated, coated or covered with polyvinyl chloride	297	9%	188	2.1%
2	22.22.13.00	Plastic boxes, cases, crates and similar articles for the conveyance or packing of goods	291	9%	598	6.8%
3	22.29.23.20	Tableware and kitchenware of plastic	219	7%	40	0.5%
4	22.22.11.00	Sacks and bags of polymers of ethylene (including cones)	216	7%	147	1.7%
5	22.21.30.82	Plates, sheets, film, foil, strip of polyamides, non-cellular (excluding floor, wall, ceiling coverings, self-adhesive, reinforced, laminated, supported/similarly combined with other materials)	167	5%	0	0.0%
6	22.21.30.86	Plates, sheets, film, foil and strip, of non-cellular poly(vinyl butyral), amino-resins, phenolic resins or polymerisation products, not reinforced, laminated, supported or similarly combined with other materials (excluding self-adhesive products as well as and floor, wall and ceiling coverings of HS 3918)	148	5%	0	0.0%
7	22.29.22.40	Self-adhesive plates, sheets, film, foil, tape, strip and other flat shapes, of plastics, whether or not in rolls > 20 cm wide (excluding floor, wall and ceiling coverings of HS 3918)	111	3%	45	0.5%
8	22.21.42.30	Non-cellular plates, sheets, film, foil, strip of condensation or rearrangement polymerisation products, polyesters, reinforced, laminated, supported/similarly comb. with other materials	94	3%	10	0.1%
9	22.22.19.50	Articles for the conveyance or packaging of goods, of plastics (excluding boxes, cases, crates and similar articles; sacks and bags, including cones; carboys, bottles, flasks and similar articles; spools, spindles, bobbins and similar supports; stoppers, lids, caps and other closures)	80	2%	402	4.6%
10	22.21.30.21	Other plates..., of biaxially orientated polymers of propylene, thickness ≤ 0,10 mm	78	2%	113	1.3%
11	22.21.30.10	Other plates..., of polymers of ethylene, not reinforced, thickness ≤ 0,125 mm	77	2%	398	4.5%
12	22.29.26.20	Statuettes and other ornamental articles of plastic (including photograph, picture and similar frames)	76	2%	0	0.0%
13	22.23.13.00	Plastic reservoirs, tanks, vats, intermediate bulk and similar containers, of a capacity > 300 litres	76	2%	51	0.6%
14	22.22.12.00	Plastic sacks and bags (including cones) (excluding of polymers of ethylene)	71	2%	.	.
15	22.29.23.40	Household articles and toilet articles, of plastics (excluding tableware, kitchenware, baths, shower-baths, washbasins, bidets, lavatory pans, seats and covers, flushing cisterns and similar sanitary ware)	67	2%	94	1.1%
16	22.23.11.59	Other floor, wall, ceiling... coverings of polymers of vinyl chloride	58	2%	.	.
17	22.21.30.61	Plates, sheets, film, foil, strip of polycarbonates, non-cellular excluding floor, wall, ceiling coverings - self-adhesive, reinforced, laminated, supported/similarly combined with other materials	58	2%	.	.
18	22.21.29.50	Plastic tubes, pipes and hoses (excluding artificial guts, sausage skins, rigid, flexible tubes and pipes	58	2%	26	0.3%

		having a minimum burst pressure of 27,6 MPa)				
19	22.22.19.25	Plastic stoppers, lids, caps, capsules and other closures	57	2%	136	1.5%
20	22.22.14.50	Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity 2 litres	55	2%	250	2.8%

Note: "." means that the data is not available from public statistics and could be non-zero. Non-EU imported products for which no public data was available have not been included in the top 20 list. The values per product are based on available data from CBS or Eurostat. Therefore, the sum of the values per product group may not align with the values in Table 3-3, as this data is from Eurostat (not available from CBS).
Source: CBS and Eurostat.

I.4 Production of plastic products in the Netherlands

The top 20 plastic products produced in the Netherlands consists of plastics across the value chain, from upstream plastics (film/sheets/plates), mid-stream (construction/packaging plastics/auto parts) to final plastic products(household articles). For upstream plastics and mid-stream, implementing CBAM on their precursors (organic chemicals and polymers) could lead to carbon leakage via indirect carbon costs if they are not also covered by CBAM as well as passed down costs on their downstream products. Final plastic products face similar risks, although the risk of a downstream effect are not a concern.

Table 5-6 Total production (2018-2021 average) of the top 20 plastic products produced in the Netherlands (NACE 22.2)

#	PRODCOM	Product	Annual production in NL (Avg. 2018-2021)	
			MEUR	% of total plastic production
1	22.29.29.95	Other articles of plastic n.e.c (excluding appliances identifiable for ostomy use)	872	10%
2	22.22.13.00	Plastic boxes, cases, crates and similar articles for the conveyance or packing of goods	598	6.8%
3	22.22.19.50	Articles for the conveyance or packaging of goods, of plastics (excluding boxes, cases, crates and similar articles; sacks and bags, including cones; carboys, bottles, flasks and similar articles; spools, spindles, bobbins and similar supports; stoppers, lids, caps and other closures)	402	4.6%
4	22.21.30.10	Other plates..., of polymers of ethylene, not reinforced, thickness ≤ 0,125 mm	398	4.5%
5	22.23.14.50	Plastic doors, windows and their frames and thresholds for doors	342	3.9%
6	22.21.41.50	Plates, sheets, film, foil and strip of cellular polyurethanes	320	3.6%
7	22.22.14.50	Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity ≤ 2 litres	250	2.8%
8	22.21.30.35	Other plates, sheets, film, foil and strip, of polymers of vinyl chloride, containing ≥ 6% of plasticisers, thickness ≤ 1 mm	231	2.6%
9	22.21.21.57	Rigid tubes, pipes and hoses of polymers of vinyl chloride	220	2.5%
10	22.29.91.60	Plastic parts and accessories for all land vehicles (excluding for locomotives or rolling stock)	215	2%
11	22.21.29.70	Fittings, e.g. joints, elbows, flanges, of plastics, for tubes, pipes and hoses	196	2.2%
12	22.23.11.55	Floor coverings in rolls or in tiles and wall or ceiling coverings consisting of a support impregnated, coated or covered with polyvinyl chloride	188	2.1%
13	22.23.19.90	Builders' ware for the manufacture of flooring, walls, partition walls, ceilings, roofing, etc., guttering and accessories, banisters, fences and the like, fitted shelving for shops, factories, warehouses, storerooms, etc., architectural ornaments such as fluting, vaulting and friezes, of plastics, n.e.c.	172	2.0%
14	22.22.11.00	Sacks and bags of polymers of ethylene (including cones)	147	1.7%
15	22.22.19.25	Plastic stoppers, lids, caps, capsules and other closures	136	1.5%
16	22.21.30.21	Other plates..., of biaxially orientated polymers of propylene, thickness ≤ 0,10 mm	113	1.3%
17	22.29.23.40	Household articles and toilet articles, of plastics (excluding tableware, kitchenware, baths, shower-baths, washbasins, bidets, lavatory pans, seats and covers, flushing cisterns and similar sanitary ware)	94	1.1%
18	22.21.42.79	Other plates, sheets, films, foil and strip, of polymerisation products	86	1.0%
19	22.22.14.70	Plastic carboys, bottles, flasks and similar articles for the conveyance or packing of goods, of a capacity > 2 litres	82	0.9%
20	22.21.42.80	Other plates..., non-cellular of plastics other than made by polymerisation	81	0.9%

Note: "." means that the data is not available from public statistics and could be non-zero. Production in the Netherlands for which no public data was available have not been included in the top 20 list.
Source: CBS and Eurostat

Annex II Detailed methodology of carbon leakage risk indicators

II.1.1 Data sources

Table 5-7 Relevant data sources and sector level coverage

Data type	Source(s) (in order of preference)	Sector level coverage
Non-EU imports and exports to the Netherlands	CBS (2022). Goederensoorten naar EU, niet-EU; minerale brandstoffen en chemie.	HS 10-digit level
	Eurostat (2022). EU trade since 2002 by CPA 2.1.	NACE 2-4 digit level
	Eurostat (2022). EU trade since 1999 by SITC.	SITC 1-3 and 5 digit level
	CBS (2021). Handel CBAM-producten.	NACE 4-digit level
Dutch production (value and volume)	CBS (2021). Verkopen; industriële producten naar productgroep (ProdCom).	PRODCOM 2,4, 8-digit level
	Eurostat (2022). Sold production, exports and imports.	PRODCOM 8-digit level
	Eurostat (2022). Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E).	NACE 3 and 4-digit level
Product emissions, feedstocks, electricity consumption	PBL (2021). MIDDEN database.	PRODCOM 8-digit level for a selection of products

II.1.2 Carbon leakage indicator

The carbon leakage risk in this study is estimated considering the EU ETS Phase 4 criteria for carbon leakage risk, defined as:

$$\textit{Emission intensity} * \textit{Trade intensity} \geq 0.2$$

where:

$$\textit{Emission intensity} = \textit{emissions } (kgCO_2) \ / \ \textit{gross value added } (€)$$

$$\textit{Trade intensity} = [(imports+exports)/(imports+production)].$$

Under this definition, if the carbon leakage indicator is greater or equal to 0.2, the product is considered at risk of carbon leakage. On the other hand, if the indicator is less than 0.2, then the risk of carbon leakage is considered limited.

II.1.3 Emission intensity: Product emissions and gross value added

The emission intensity is based on the emissions attributed to the product and the product's gross value added. To estimate these values for chemical products, the MIDDEN database is used primarily.

Direct CO_2 emissions

The CO_2 emissions emitted per kt of product is provided by MIDDEN. However, this value does not take into account emissions from electricity use. Electricity emissions are estimated based off the level of electricity use and the emission intensity of electricity (0.376 tCO_2/MWh). For some product processes, multiple products are produced. In these cases, the emissions are divided across the different chemical products based off of the share of their weight of the total production weight.

Upstream emissions

In order to estimate the upstream emissions, the emissions attributed to each feedstock is estimated based on emissions data from MIDDEN or PlasticsEurope. The upstream emissions only consider the emissions of chemical/plastic products which are within the scope of the products analysed in this study. The upstream emission intensity is estimated as follows:

Upstream emission intensity =

[Sum of direct upstream emissions and further upstream emissions of all inputs] ($ktCO_2$/kt) / gross value added per kt of product (€/kt).

The direct and further upstream emissions are estimated as follows:

Direct upstream emissions$_f$ ($ktCO_2$ per kt output)=

Input$_f$ (kt input per kt output) x emission intensity of input$_f$ (ktCO2 per kt input)

Further upstream emissions$_f$ ($ktCO_2$ per kt output)=

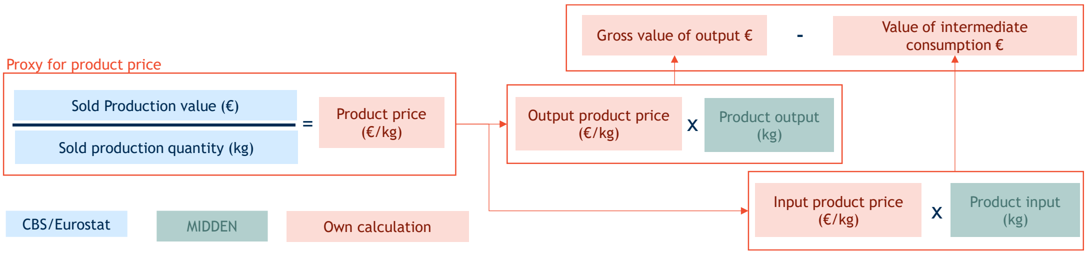
Input$_f$ (kt input per kt output) x upstream emission intensity of input$_f$ ($ktCO_2$per kt input).

Where f is the feedstock (input) of a product.

Gross value added

Figure II-1 provides an overview of how gross value added at product level is estimated. Gross value added is the revenue minus the intermediate consumption cost, i.e. value of outputs minus value of inputs. The estimate the value of the inputs and outputs, the values are based on the amount of input/outputs in the production process (kg) and the product price. To estimate the product price, total Dutch sold production value is divided by the total sold production quantity.

Figure II-1 Estimation of gross value added at product level



As with emissions, for processes with multiple outputs, the gross value added is divided amongst the output products based off of their share of the total revenue of the process.

II.1.4 Trade intensity

Trade intensity per product is based on available data from CBS and Eurostat on non-EU imports/exports and Dutch production. For some chemical products, the trade intensities cannot be estimated due to lack of data. To fill in these gaps, the trade intensities for these products are proxied based on the available EU level data. In this study, trade intensities at the EU product level are a better estimate than trade intensities at the Dutch, aggregated sector level, as the sector level does not take specific product characteristics into account which impact trade, such as transportability.

Trinomics B.V.
Westersingel 34
3014 GS Rotterdam
The Netherlands

T +31 (0) 10 3414 592
www.trinomics.eu

KvK n°: 56028016
VAT n°: NL8519.48.662.B01