Soda Ash Carbon Intensity

Carbon Footprint Report - *Final*
(External)

23 January 2026

Prepared for WE Soda

Contents

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Section 1: Executive Summary

WE Soda is publishing a Sustainability Plan and Evidence Book to strengthen its positioning as the most sustainable producer of natural soda ash globally, based on fact-based support provided by FGE NexantECA

WE Soda Overview

WE Soda is positioning itself as the global leader in sustainable natural soda ash production

- WE Soda aim to leverage sustainability as a strategic commercial differentiator
- Due to its patented solution extraction-based process, WE Soda is already well placed within the industry in terms of carbon efficiency as the production process used at Eti and Kazan sites has an inherently low carbon footprint

Eti and Kazan, WE Soda's soda ash assets in Türkiye, have the lowest CO_2 emissions, water, and energy intensity in the sector

CO_2 emissions intensity of soda ash in 2024 was 0.29 mt CO_2e per mt of soda ash for Eti[1] and 0.35 for Kazan[1] (average 0.33), and approximately 0.51 mt CO_2e per mt of soda ash including Scope 3 emissions[1]

Water intensity in 2024 was 1.67 mt per mt of product for Eti, and 2.24 for Kazan[2], less than one-quarter of synthetic producers (average ca. 11.26 for Ammonia-Solvay processes)

Near-zero waste generation, with a circular approach to waste management, including the reuse of process streams and sale of other process outputs where feasible

Carbon Intensity Public Report Overview

WE Soda is publishing a trilogy of documents in early 2026 to underpin its sustainability positioning

Sustainability Plan: A roadmap to 2050 with concrete targets, milestones, and actions which will explore a range of sustainability issues

The Case for Change: A document outlining the global trends that shape the sustainability landscape based in scientific evidence (beyond carbon)

Evidence Book: Presenting the evidence behind WE Soda's sustainability strategy while setting a benchmark for environmentally responsible production

FGE NexantECA has refreshed their existing report on soda ash carbon intensity to be made available in the public domain as a supporting document to the Evidence Book

- *The refreshed report assesses the carbon intensity of the major commercialised soda ash technologies*
- Soda ash players around the globe have been modelled, representing all major production processes, including natural and synthetic pathways
- FGE NexantECA has benchmarked the carbon intensity of WE Soda's assets in Türkiye and Wyoming against its peers to support the sustainability claims made in the Evidence Book

(1) WE Soda Annual Report, 2024
(2) WE Soda Ltd.

WE Soda facilities are positioned at the most competitive end of the carbon intensity curve, with its Turkish assets emitting around 55% fewer *Scope 1 & 2* emissions compared to a typical European plant

Ex-works soda ash carbon intensity curve, *mt CO_2e per mt product (2024)*

Ex-works†	0.40	0.44	0.61	0.61	0.63	0.73	0.91	0.92	0.97	0.58	0.97	1.00	1.04	1.08	1.17	1.25	1.28	1.40	1.50	1.68	2.24	1.19
Scopes 1 + 2	0.30	0.35	0.56	0.53	0.53	0.73	0.81	0.84	0.90	0.44	0.78	0.80	0.82	0.95	0.95	1.01	1.05	1.14	1.16	1.38	1.06	0.53

Natural | *Synthetic*

Callouts in figure:
- Incl. sodium bicarbonate co-product (Eti & Kazan)§
- High Scope 1 emissions due to use of coal
- Incl. co-products§
- High Scope 3 emissions driven by high relative ammonia consumption
- Per mt soda ash only
- Incl. NH_4Cl
- 55%

Bar values and labels:
- WE Soda Eti: 0.40 (0.10 / 0.22)
- WE Soda Kazan: 0.44 (0.09 / 0.35)
- Wyoming Leader: 0.61 (0.04 / 0.44)
- Natural Kenya: 0.61 (0.08 / 0.51)
- WE Soda Granger: 0.63 (0.09 / 0.40)
- Natural China Leader: 0.73 (0.01 / 0.63)
- WE Soda Westvaco: 0.91 (0.10 / 0.73)
- Natural China Laggard: 0.92 (0.08 / 0.63)
- Wyoming Laggard: 0.97 (0.07 / 0.63)
- Ammonia-Solvay Process 100% Biomass: 0.58 (0.14 / 0.43)
- Ammonia-Solvay Process Nat Gas Cogen: 0.97 (0.19 / 0.76)
- Ammonia-Solvay Process Nat Gas Cogen: 1.00 (0.20 / 0.76)
- Ammonia-Solvay Process Nat Gas: 1.04 (0.22 / 0.76)
- Ammonia-Solvay Process 80:20 Waste Coal: 1.08 (0.14 / 0.93)
- Ammonia-Solvay Process 50:50 Gas Coal: 1.17 (0.22 / 0.93)
- Ammonia-Solvay Process 40:60 Gas Coal: 1.25 (0.24 / 0.97)
- Ammonia-Solvay Process 20:80 Gas Coal: 1.28 (0.23 / 1.03)
- Ammonia-Solvay Process 100% Coal: 1.40 (0.26 / 1.10)
- Ammonia-Solvay Process 100% Coal: 1.50 (0.34 / 1.10)
- Ammonia-Solvay Process 100% Coal: 1.68 (0.31 / 1.29)
- Hou Process 100% Coal: 2.24 (1.18 / 0.98)
- Hou Process (Coproduct) 100% Coal: 1.19 (0.67 / 0.49)

Legend: Scope 1 | Scope 2 | Scope 3 - Upstream*

† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
*Scope 3 – Upstream includes raw material, water and fuel; Upstream raw material transportation emissions are excluded from calculations
§ Co-products account for all economically valuable products produced on site; at Westvaco this includes sesqui, sodium bicarbonate and caustic soda (all products produced onsite)
$NaHCO_3$ = Sodium bicarbonate; NH_4Cl = Ammonium chloride, produced on a 1:1 ratio with soda ash in the Hou process which offsets the emissions per mt product (see Slide 41)
Source: WE Soda Ltd., FGE NexantECA analysis

Note: Due to rounding, totals in figure may differ from table. For specific data refer to table
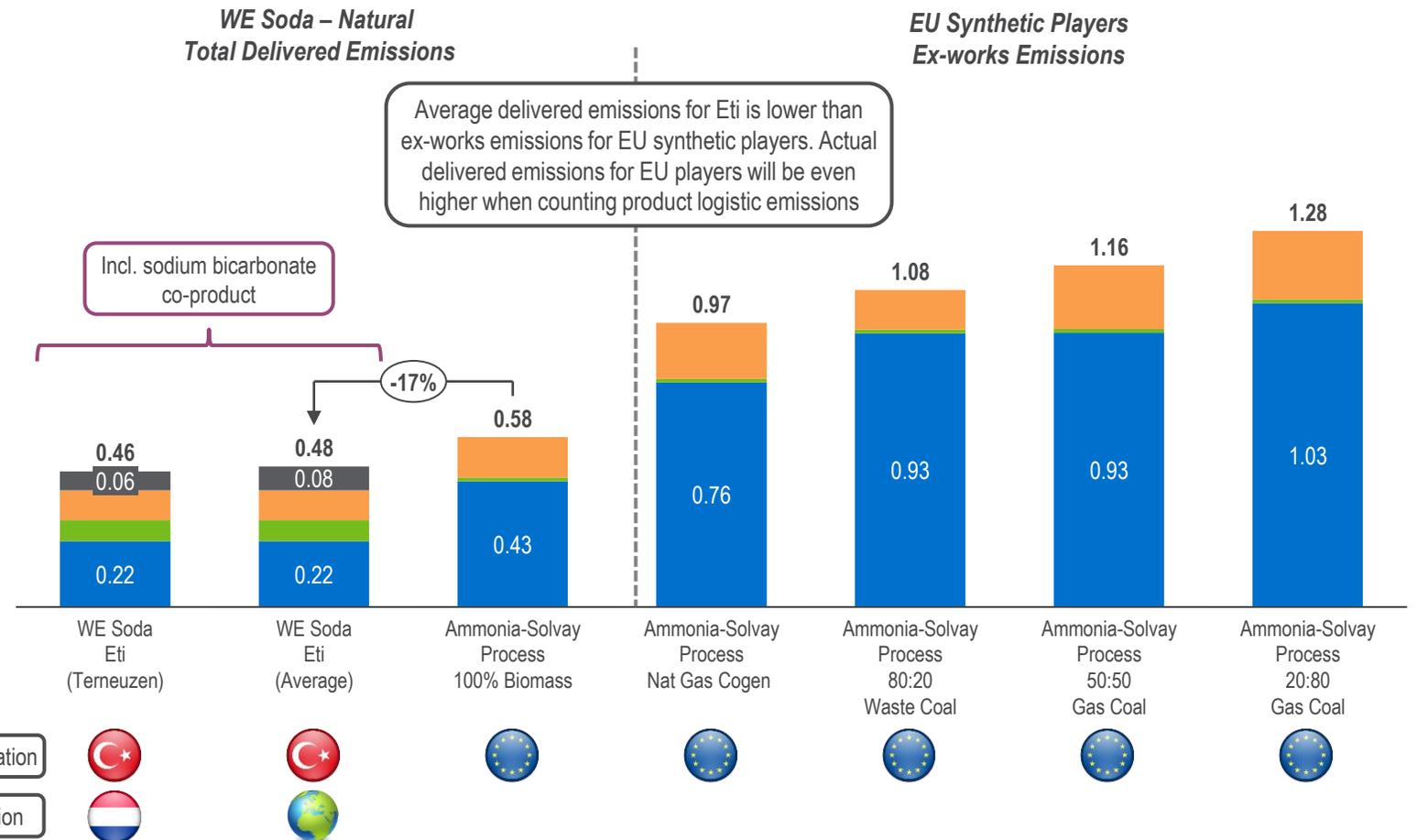
FGE NexantECA
POWERED BY FUNDAMENTALS

Delivered emissions for soda ash from Eti are lower on average than ex-works emissions for synthetic EU players
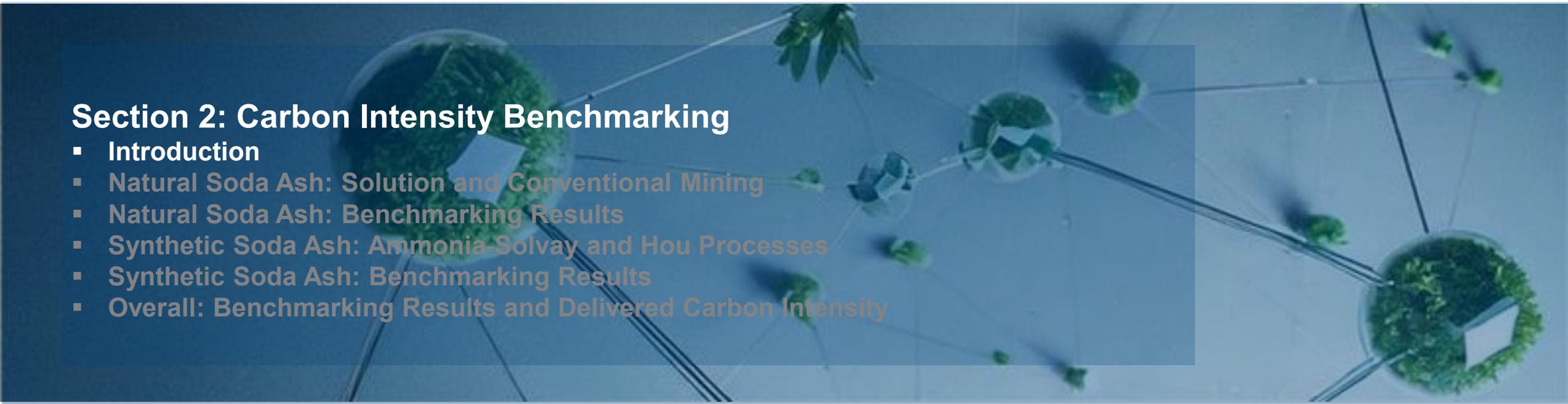
Delivered emissions for Eti were modelled using actual sales data from WE Soda

- Delivered emissions to Terneuzen, Netherlands were modelled due to its position as a key distribution hub for soda ash for Eti

- Delivered emissions for Eti (average and to Terneuzen) are lower than ex-works emissions for EU players, further supporting WE Soda's low-carbon competitive positioning

- Actual delivered emissions for EU players will be higher than ex-works when accounting for downstream freight emissions

- Freight emissions contribute a relatively small amount to total delivered emissions

- Downstream freight emissions to some customer destinations will be higher than the average case shown, however the increase will be relatively minor

- For further details refer to Methodology & Assumptions section

Soda ash carbon intensity curve, *mt CO$_2$e per mt product (2024)*

WE Soda – Natural Total Delivered Emissions

EU Synthetic Players Ex-works Emissions

> Average delivered emissions for Eti is lower than ex-works emissions for EU synthetic players. Actual delivered emissions for EU players will be even higher when counting product logistic emissions

Incl. sodium bicarbonate co-product

-17%

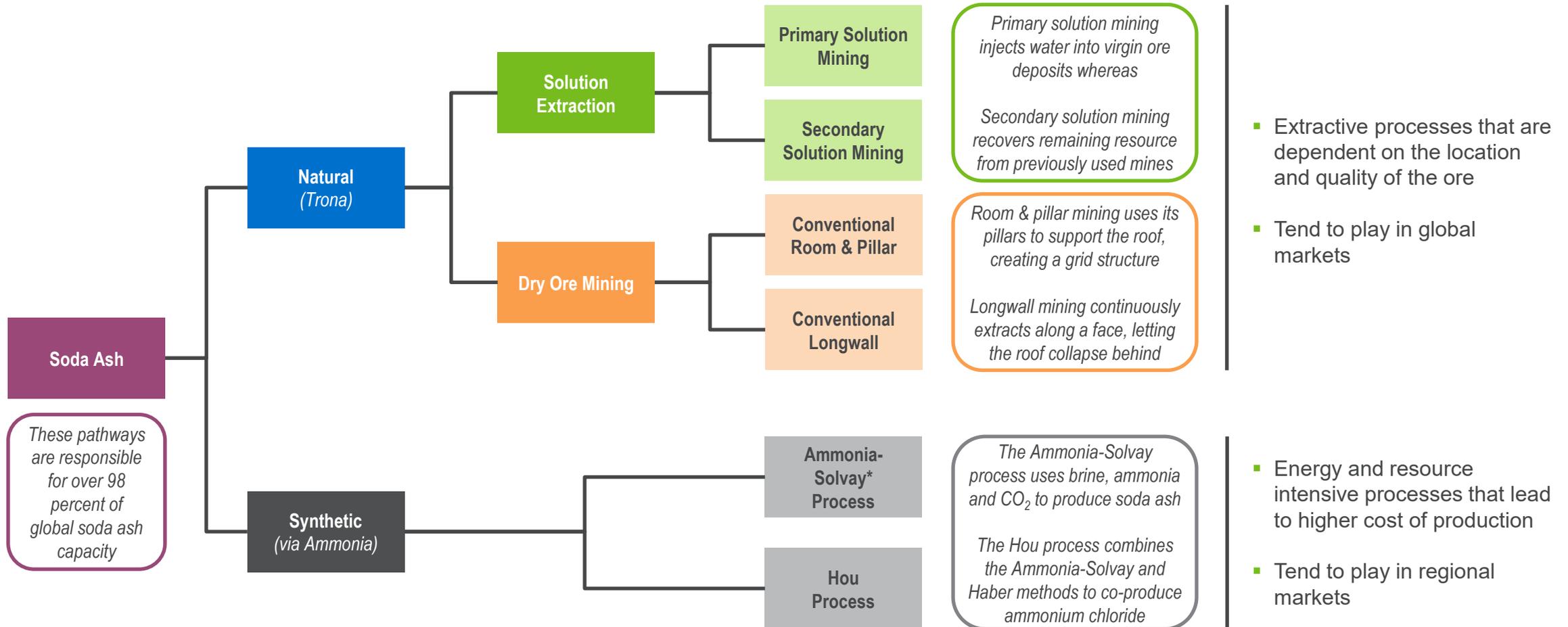| Category	Scope 1	Scope 2	Scope 3 - Upstream*	Scope 3 - Downstream Freight	Total
WE Soda Eti (Terneuzen)	0.22			0.06	0.46
WE Soda Eti (Average)	0.22			0.08	0.48
Ammonia-Solvay Process 100% Biomass	0.43				0.58
Ammonia-Solvay Process Nat Gas Cogen	0.76				0.97
Ammonia-Solvay Process 80:20 Waste Coal	0.93				1.08
Ammonia-Solvay Process 50:50 Gas Coal	0.93				1.16
Ammonia-Solvay Process 20:80 Gas Coal	1.03				1.28

Plant Location

Destination

*Scope 3 – Upstream includes raw material, water and fuel; Upstream raw material transportation emissions are excluded from calculations
† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
§WE Soda average cases based on weighted average using actual sales data to port destinations (see Methodology & Assumptions)
Source: WE Soda Ltd., FGE NexantECA analysis

■ Scope 1   ■ Scope 2   ■ Scope 3 - Upstream*   ■ Scope 3 - Downstream Freight

Section 2: Carbon Intensity Benchmarking

- **Introduction**
- Natural Soda Ash: Solution and Conventional Mining
- Natural Soda Ash: Benchmarking Results
- Synthetic Soda Ash: Ammonia-Solvay and Hou Processes
- Synthetic Soda Ash: Benchmarking Results
- Overall: Benchmarking Results and Delivered Carbon Intensity

There are six major pathways to producing soda ash globally, four natural and two synthetic. These routes determine the operational and go-to market strategies of soda ash players

Soda Ash

These pathways are responsible for over 98 percent of global soda ash capacity

Natural
(Trona)

Solution Extraction

Primary Solution Mining

Secondary Solution Mining

Primary solution mining injects water into virgin ore deposits whereas

Secondary solution mining recovers remaining resource from previously used mines

Dry Ore Mining

Conventional Room & Pillar

Conventional Longwall

Room & pillar mining uses its pillars to support the roof, creating a grid structure

Longwall mining continuously extracts along a face, letting the roof collapse behind

- Extractive processes that are dependent on the location and quality of the ore

- Tend to play in global markets

Synthetic
(via Ammonia)

Ammonia-Solvay* Process

Hou Process

The Ammonia-Solvay process uses brine, ammonia and CO_2 to produce soda ash

The Hou process combines the Ammonia-Solvay and Haber methods to co-produce ammonium chloride

- Energy and resource intensive processes that lead to higher cost of production

- Tend to play in regional markets

*The "Ammonia-Solvay Process" can be referred to as the "Ammonia Process". For the purpose of this report, the Ammonia-Solvay nomenclature will be used to avoid confusion with the "Hou Process" where ammonia is a key feedstock

Section 2: Carbon Intensity Benchmarking

Natural soda ash is obtained from trona and sodium carbonate-rich brines
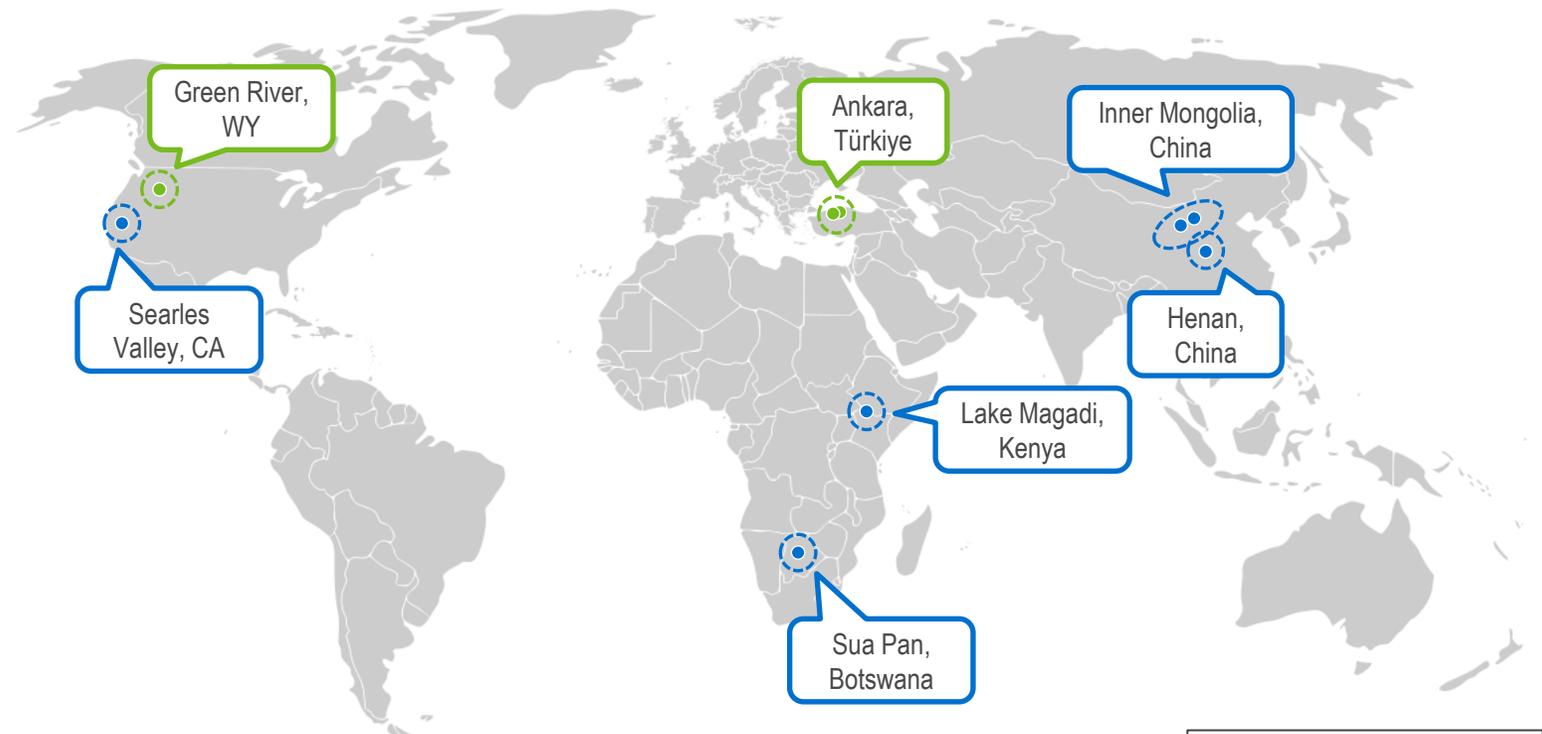
Trona minerals are in located in only a few regions globally

- The world's largest deposit of trona is in the Green River Basin in Wyoming, with around 47 Gt of identified and recoverable reserves
- Elsewhere in the US, the Searles Valley deposits are dried trona lakes
  - There are estimated to be 0.8 Gt of soda ash reserves
- China's underground deposits are reportedly of lower grade
- The Botswana trona lakes' reserves are the largest in Africa, with others located in Kenya and Ethiopia

The Ankara trona deposits in Türkiye are the second largest reserves globally

- WE Soda is the only producer of trona-based soda ash in Türkiye

**Location of the Major Trona Reserves and Trona-Based Soda Ash Plants**

Green River, WY

Ankara, Türkiye

Inner Mongolia, China

Searles Valley, CA

Henan, China

Lake Magadi, Kenya

Sua Pan, Botswana

Key

● *Natural trona deposits – Utilised by WE Soda*

● *Other natural trona deposits*

Source: WE Soda Ltd., USGS, FGE NexantECA analysis

WE Soda's patented solution extraction-based process used at Eti & Kazan is a source of sustainable competitive advantage in the global market

Simplified WE Soda solution extraction process: Scope 1 perimeter
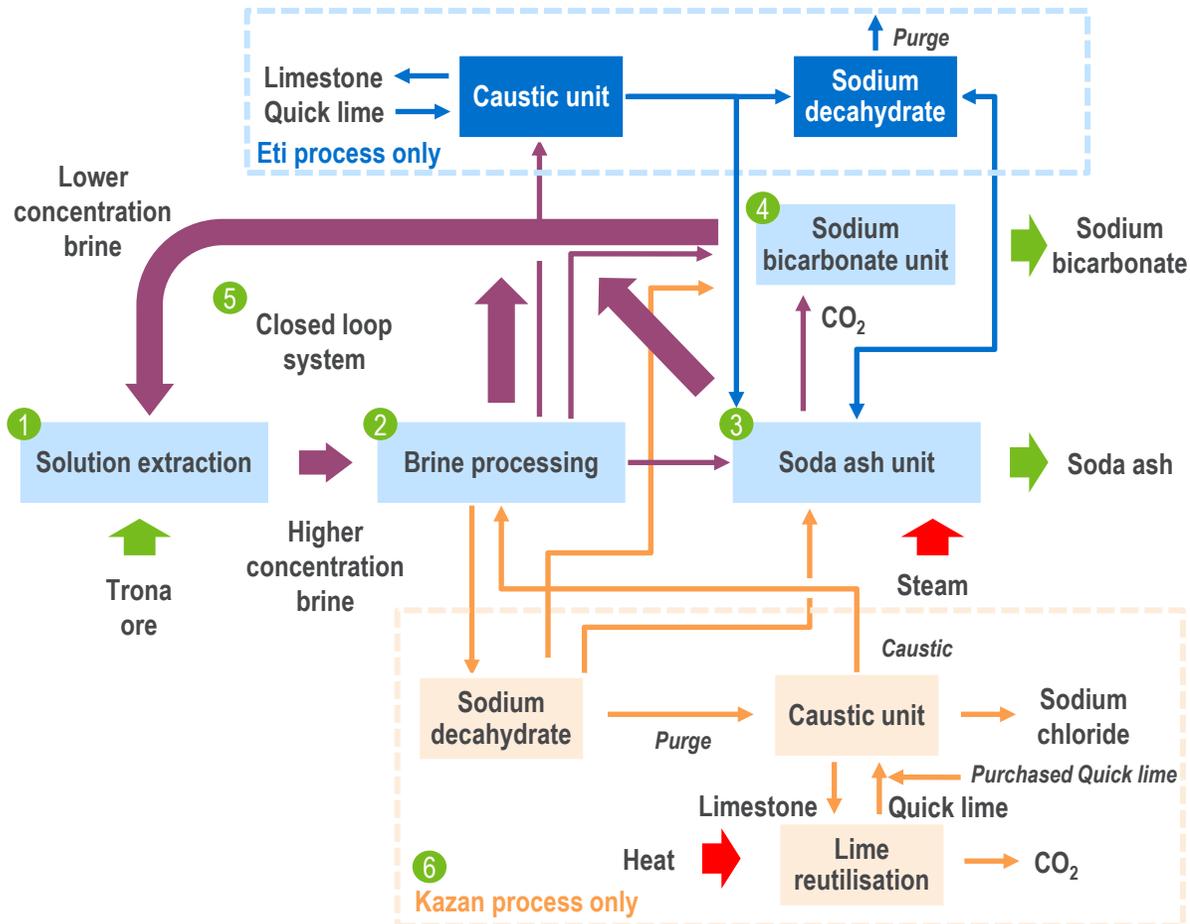
At Eti & Kazan, natural trona is used to produce soda ash, as well as sodium bicarbonate

- The solution extraction-based process has a low environmental footprint and provides WE Soda with a cost advantage

- The trona ore is dissolved in wells and extracted (1) while leaving insoluble impurities underground in the mine

- The trona brine is filtered, stripped and evaporated (2) to crystallise the sodium carbonate from the solution to form a slurry

- This is then separated using centrifuges and then dried to produce soda ash (3)

- Sodium bicarbonate is produced by reacting CO_2 with sodium carbonate (4)
  - This step is not intrinsic to the trona process chemistry, so the sequestration of carbon in the product can be viewed as an upside to Scope 1 emissions

- A reported advantage of the process is that it is a closed loop system (5), which minimises water consumption and waste

- At Kazan, the sodium decahydrate section (6) is required before brine processing to purify the trona due to its intrinsic impurities

## The recovery of solution extraction is reported to be 30%[1]

- The implementation of improved mining techniques are capable of improving yields and, hence, CO_2 emissions per mt soda ash

Source: WE Soda Ltd., FGE NexantECA analysis
(1) US Geological Survey, Mineral Commodity Summaries, January 2025

WE Soda's facility in Westvaco makes use of multiple production pathways to produce soda ash and co-products from natural trona deposits, while Granger produces natural soda ash via the ELDM process

Simplified mining and processing at Westvaco and Granger
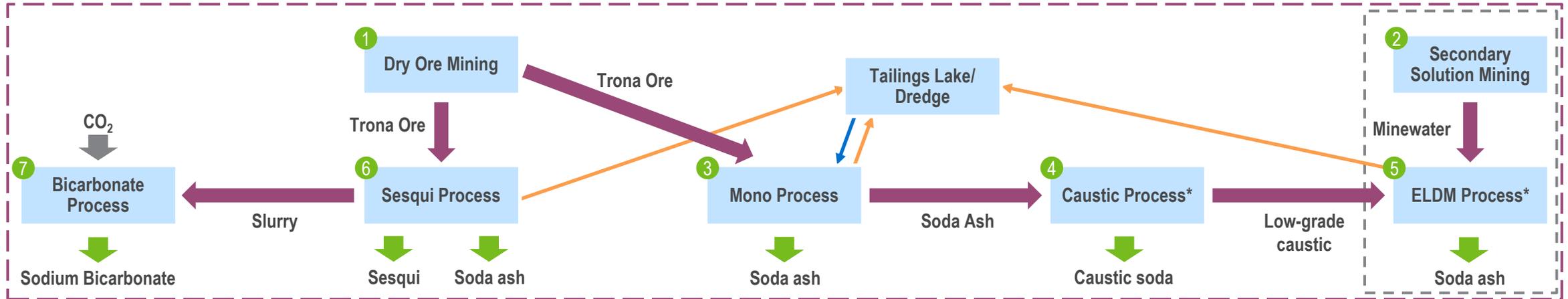
At the Westvaco site, natural trona is used to produce soda ash and three other valuable co-products: sesqui, caustic soda and sodium bicarbonate

- Trona is mined via two processes, dry ore mining which utilises longwall mining (1), and solution mining (2) which recovers trona from old underground mine workings through dissolution

- At Granger, natural soda ash is produced via secondary solution mining (2), followed by the ELDM process (5)

- Sodium bicarbonate is used mainly in food and industrial applications

- Sesqui is mostly used in bath salts, detergents, and water treatment

- Caustic soda is used as a chemical building block in processes such as pulp and paper production, chemical production, detergents, and food processing

Multiple pathways are employed to produce Westvaco's product portfolio

- The monohydrate (Mono) process (3) converts dry trona ore to soda ash

- The caustic process (4) uses a soda ash feed from the Mono process to produce product-grade caustic (50% NaOH)

- Low-grade caustic (ca. 10% NaOH) is sent to the ELDM process (5) where it is combined with trona from solution mining to produce soda

- The sesquicarbonate process (6) produces sesqui product and soda ash using dry trona ore. The slurry from this process is reacted with purchased carbon dioxide (7) to produce sodium bicarbonate

- Tailings from Sesqui, Mono and ELDM processes are sent to a lake, where the liquor is then dredged and recovered via the Mono process

ELDM = Evaporation Lime Deca Mono process
*ELDM and Caustic have a feedback loop to the Mono process that has been left out of the diagram for simplification purposes
Source: WE Soda Ltd., FGE NexantECA Analysis

At Westvaco, soda ash is produced by three distinct pathways: the Mono, Sesqui, and ELDM processes, allowing full optimisation of the natural trona resource available
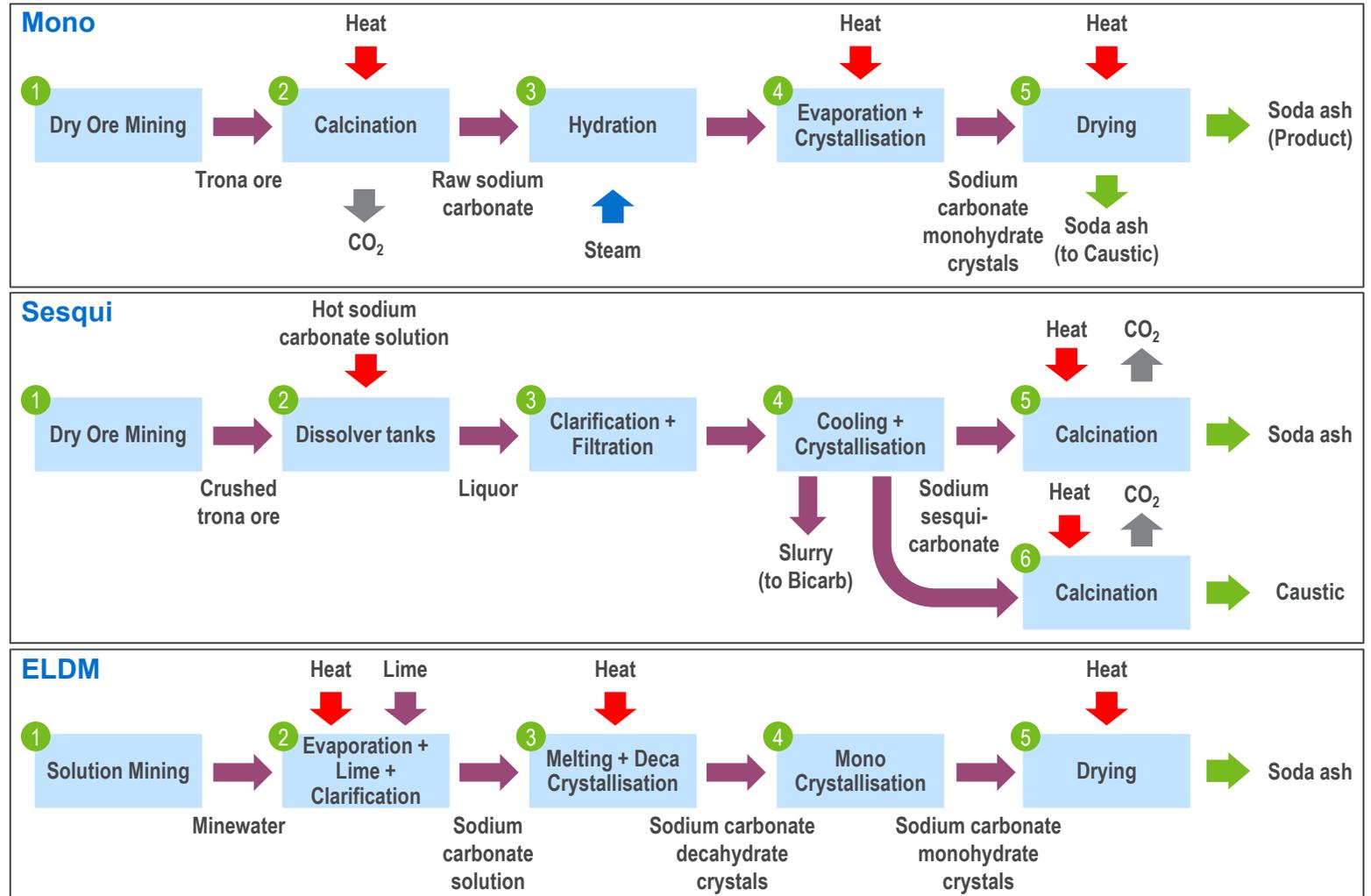
Monohydrate (Mono) Process

- Utilises trona ore to produce soda ash
- Produces product grade soda ash as well as soda ash feed for caustic unit
- Calcination step occurs before crystallisation

Sesquicarbonate (Sesqui) Process

- Crushed trona ore is fed into a series of dissolver tanks where it is mixed with hot water
- This liquor is clarified and filtered to remove insoluble material
- Unlike the Mono process, calcination occurs after crystallisation
- Sesqui process produces soda ash, caustic soda and a slurry to be used in the Bicarb unit

Evaporation Lime Deca Mono (ELDM) Process

- ELDM does not have a calcination step but instead has two crystallisation steps
- Residue brines from Sesqui/ Mono processes are pumped into used dry ore mines where tailings are decanted out, and leftover minewater is pumped up to the surface for processing
- The ELDM process is utilised by WE Soda at the Granger site with trona from solution mining

Mono

1. Dry Ore Mining → (Trona ore) → 2. Calcination (Heat) → (CO₂ down) (Raw sodium carbonate) → 3. Hydration (Steam up) → 4. Evaporation + Crystallisation (Heat) → (Sodium carbonate monohydrate crystals) → 5. Drying (Heat) → Soda ash (Product) / Soda ash (to Caustic)

Sesqui

1. Dry Ore Mining → (Crushed trona ore) → 2. Dissolver tanks (Hot sodium carbonate solution) → (Liquor) → 3. Clarification + Filtration → 4. Cooling + Crystallisation → (Slurry to Bicarb) (Sodium sesqui-carbonate) → 5. Calcination (Heat, CO₂) → Soda ash / 6. Calcination (Heat, CO₂) → Caustic

ELDM

1. Solution Mining → (Minewater) → 2. Evaporation + Lime + Clarification (Heat, Lime) → (Sodium carbonate solution) → 3. Melting + Deca Crystallisation (Heat) → (Sodium carbonate decahydrate crystals) → 4. Mono Crystallisation → (Sodium carbonate monohydrate crystals) → 5. Drying (Heat) → Soda ash

Section 2: Carbon Intensity Benchmarking

Conventional mining involves physically removing solid trona ore from underground deposits by mechanical means. Room & pillar and longwall techniques are commonly utilised at trona deposits in Green River WY

Simplified conventional mining and processing: Scope 1 perimeter

Reacting with CO_2 can result in sodium bicarbonate
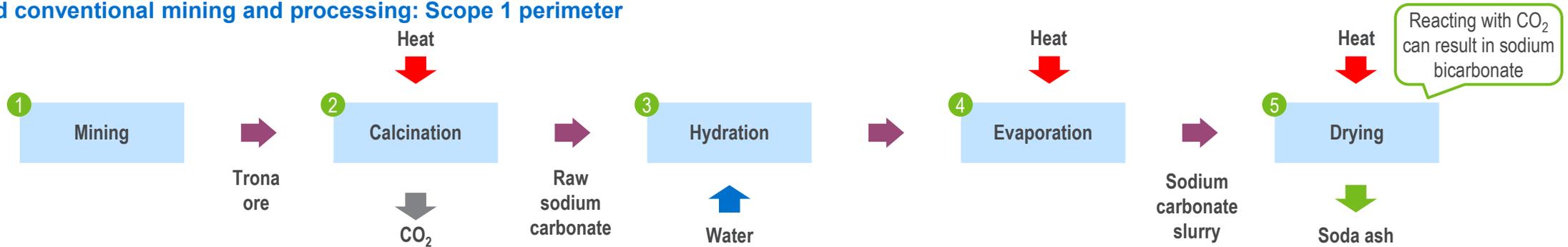
Room and pillar mining involves excavating a network of alternating open spaces and leaving behind large pillars of ore to support the roof

- Heavy machinery, such as continuous miners, carve a network of drifts throughout the deposit
- Connections are made between the drifts at regular intervals, which creates a checkerboard pattern of rooms and pillars
- The pillars are left to support the overlying rock, and the mineral is then cut from the mining face and processed

Longwall mining continuously excavates trona ore from a long wall

- The longwalls are typically several hundred metres wide and can extend up to kilometres long
- Hydraulic roof supports are used during excavation to protect workers and machinery
- Post-excavation, the roof behind the hydraulic supports is left to collapse

The trona ore is then transported to an adjacent processing plant for purification to marketable soda ash
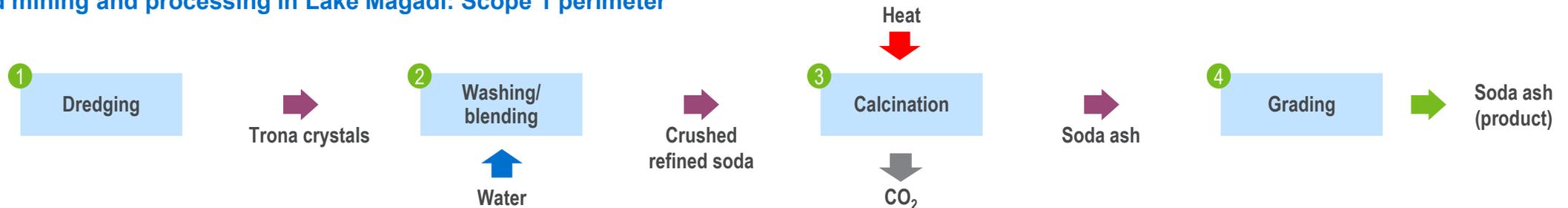
- The trona ore is crushed and calcined (2) to drive off unwanted gases and transforms the trona into a sodium carbonate
- This is then hydrated and filtered to remove impurities (3) and then sent to a series of large outdoor evaporation ponds (4) (right)
- The resulting slurry is placed into a centrifuge to separate the remaining water from the soda ash monohydrate crystals, which are sent to driers, screened, and sent to storage bins for transport (5)

The use of the energy-intensive calcination step in the processing of mined trona into soda ash is a major source of CO_2 emissions

- The choice of primary fuel used to generate heat to drive processes such as evaporation and calcination steps has a significant impact on emissions
- The decomposition of trona ore also release process CO_2 emissions, although this is less than in the case of synthetic soda ash production

Source: European Commission BREF on LVIC-S Industries (2007), Wyoming Mining Association, FGE NexantECA analysis

Soda ash production at Lake Magadi (Kenya) takes advantage of the natural trona crystals found at the lakebed

Simplified mining and processing in Lake Magadi: Scope 1 perimeter

Heat

① Dredging → Trona crystals → ② Washing/blending → Crushed refined soda → ③ Calcination → Soda ash → ④ Grading → Soda ash (product)

Water (into Washing/blending)

CO_2 (out of Calcination)

The soda ash manufacturing facility in Lake Magadi utilises naturally forming trona deposits on the lakebed

- Lake Magadi is situated in the Great Rift Valley of East Africa. Rainfall in and around the Rift Valley drains underground and is heated geothermally

- Sodium compounds (including trona) are dissolved into the geothermal water and rises to the surface in hot, alkaline springs around the perimeter of the lake

- The solution is naturally concentrated via evaporation and leads to the production of more trona crystals

- Lake Magadi renews its trona deposits approximately every 10-15 years

Trona crystals deposited in Lake Magadi are extracted, washed, and calcined to produce soda ash

- The trona crystals with the interstitial saturated alkaline solution are extracted (①) from the lakebed by dredging – a combination of crushing, slurrying and pumping to the washery plant

- At the washery plant (②), the trona crystals are washed and blended and the interstitial fluid is displaced by process water to reduce sodium chloride content from 11.5% to 0.3%

- The crushed refined soda is then calcinated (③) to decompose into soda ash, carbon dioxide, and water vapour

- Soda ash is then ground and screened (④) into the desired grade before storage in silos

At Lake Magadi, the natural production of trona crystals indicates that the process may have a very competitive carbon intensity

- However, the fuel used at Lake Magadi is heavy fuel oil which is considerably more carbon intensive than natural gas and coal, increasing the Scope 1 emissions of this natural process compared to mining practices seen elsewhere

- The facility has recently commissioned a 5 MW solar plant to supply their first-of-a-kind electric calciner, as part of their expansion plans, however the output of this solar installation will only provide a minor proportion of the plant's overall energy consumption, and thereby have a limited impact on emission intensity

Source: Tata Chemicals Magadi, FGE NexantECA analysis

All three natural producers in China, located in Henan and Inner Mongolia, utilise solution mining techniques for soda ash production

FGE NexantECA has identified three natural soda ash producers in China

- The three natural soda ash facilities are located in Inner Mongolia and Henan
  - The Berun Yingen plant in Inner Mongolia currently produces ca. 5 million mt of natural soda ash per year, with a planned expansion to 7.8 million mt per year by 2026
  - The method of trona mining has not been definitively identified, however given that the Chaganor deposit where the plant's trona is sources is a modern alkaline lake deposit, there is evidence to suggest that solution mining is employed
- The Zhongyuan Chemical plant in Henan has an annual capacity of 1.4 million tons of soda ash
  - The facility sources its trona from the Anpeng trona deposit, which is extracted via solution mining
- The Tongbai Haijing Alkali plant in Henan is the smallest of China's natural soda ash plants, with an annual capacity of 300 thousand mt per year, with evidence also strongly suggests that trona is extracted via solution mining

Despite the use of natural production routes and solution mining, industrial manufacturing practices – most notably the extensive use of coal in heat and power generation – make natural soda ash production in China comparably carbon intensive

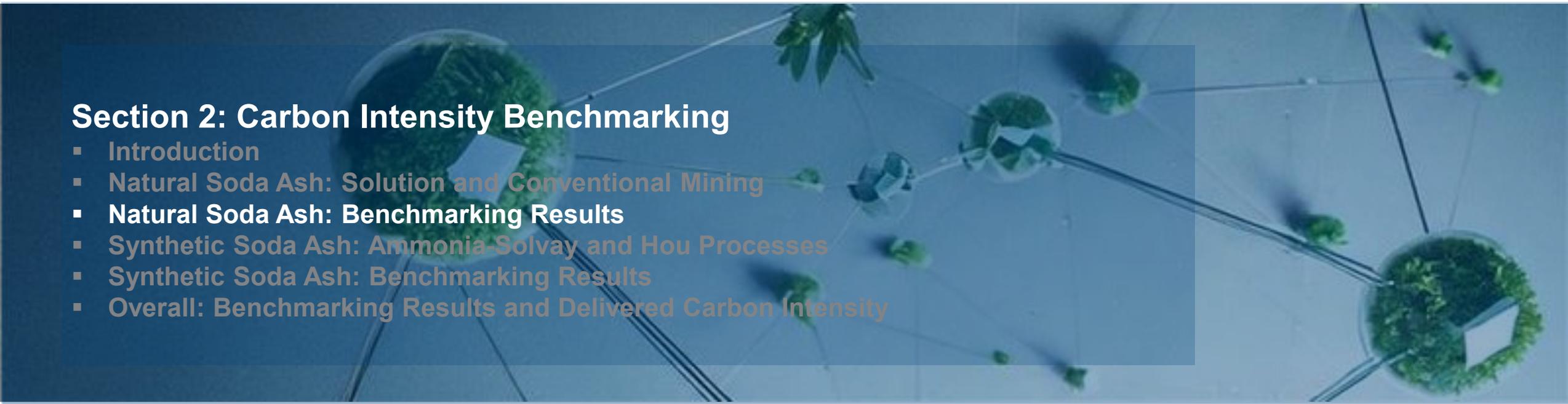- The use of coal to drive processes including evaporation and calcination steps contribute significantly to overall emissions, which also emits a material quantity of process CO_2 through decomposition of trona

Map of China Natural Trona Plants

Simplified Overview of China Natural Soda Ash Production
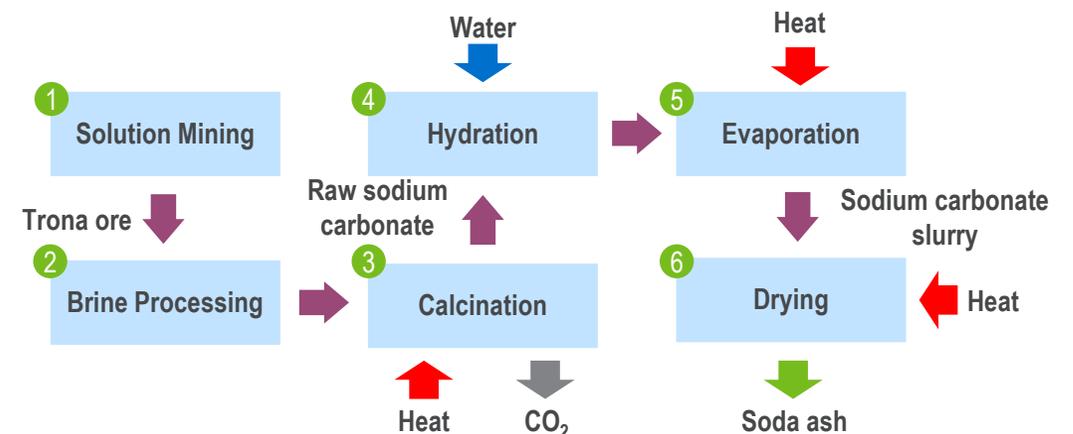
Source: FGE NexantECA analysis

Section 2: Carbon Intensity Benchmarking

The solution extraction-based process utilised at WE Soda's Eti & Kazan sites is considerably less carbon intensive than traditional mining-based plants, giving a competitive advantage in terms of emissions intensity

Ex-works natural soda ash carbon intensity curve, *mt CO$_2$e per mt product (2024)*

Ex-works†			0.40	0.44	0.61	0.61	0.63	0.73	0.91	0.92	0.97
Scopes 1 + 2			0.30	0.35	0.56	0.53	0.53	0.73	0.81	0.84	0.90

- Solution-based extraction used **at Eti and Kazan** is less energy and carbon intensive than conventional mining, and overall processing is *generally* less energy intensive than alternative routes
- Scope 1 emissions at Kazan are higher than at Eti because at Kazan, all electricity requirements are met via a natural gas-fed cogeneration unit and there are extra processing facilities, while Eti meets part of its electricity requirement via the grid and procures nearly 50 percent under renewable certificates
- The **Wyoming** Leader uses natural gas as the primary fuel and has more efficient solar evaporation ponds for sodium carbonate decahydrate preparation, while the Wyoming Laggard uses coal as the primary fuel and prepares the decahydrate via energy-intensive forced crystallisation
- Both **China** plants use coal as a fuel, but differ in electricity intensity: the Leader uses a more efficient evaporation process than the Laggard

Soda ash plants in China and Wyoming tend to have high Scope 1 emissions due to use of coal as primary fuel

Scope 2 affected by high coal mix for generating electricity

Incl. co-products§

Incl. NaHCO$_3$ co-product (Eti & Kazan)§

† = Ex-works carbon emissions defined as Scope 3* (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
§ Co-products account for all economically valuable products produced on site; at Westvaco this includes sesqui, NaHCO$_3$ and caustic soda (all products produced onsite)
*Scope 3 – Upstream includes raw material, water and fuel
Source: WE Soda Ltd., FGE NexantECA analysis

Scope 1   Scope 2   Scope 3 - Upstream*

Note: Due to rounding, totals in figure may differ from table. For specific data refer to table
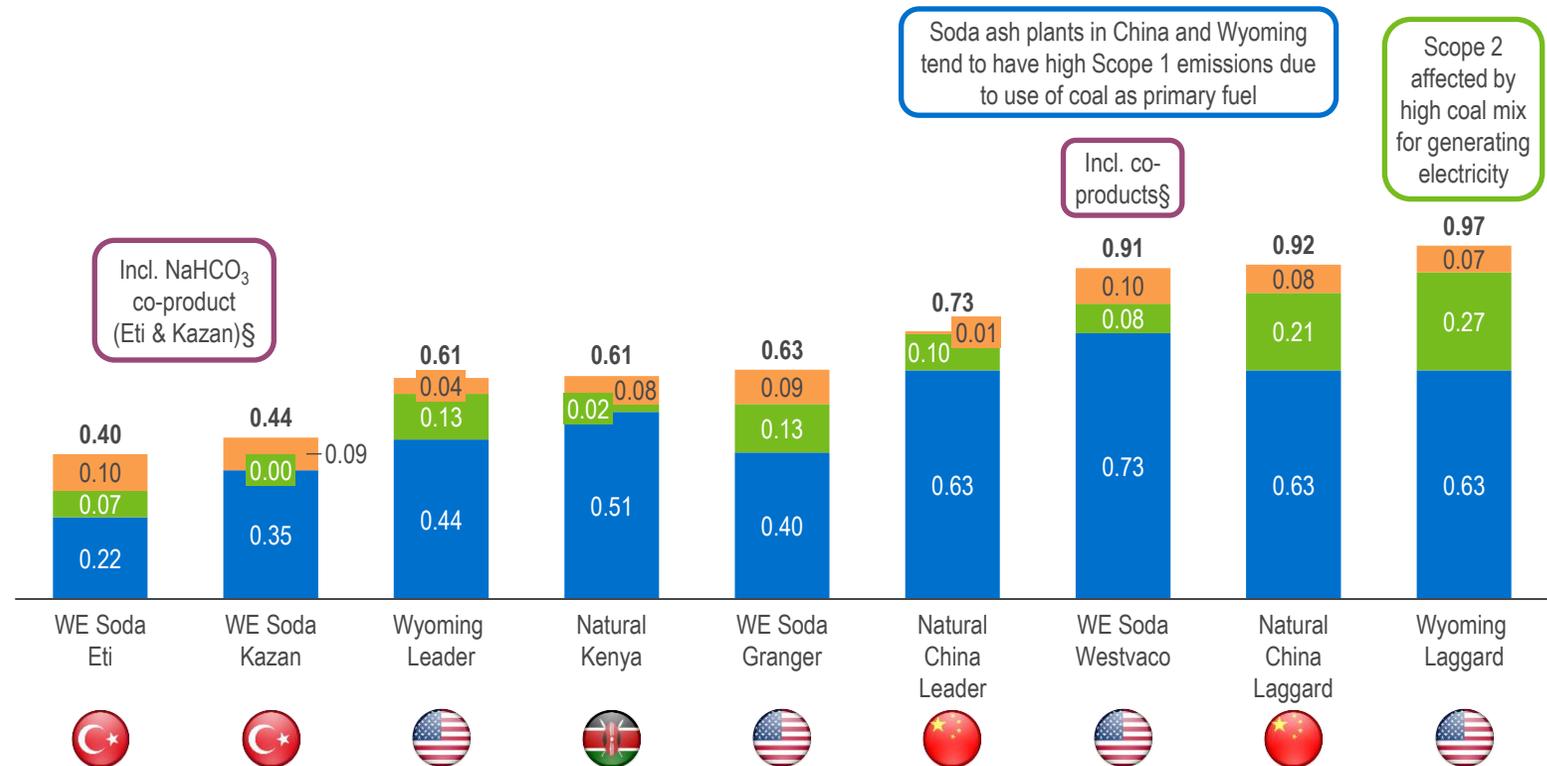
Section 2: Carbon Intensity Benchmarking

- Introduction
- Natural Soda Ash: Solution and Conventional Mining
- Natural Soda Ash: Benchmarking Results
- **Synthetic Soda Ash: Ammonia-Solvay and Hou Processes**
- Synthetic Soda Ash: Benchmarking Results
- Overall: Benchmarking Results and Delivered Carbon Intensity

The synthetic routes to soda ash are characterised by energy intensive and mature assets that still utilise a high proportion of coal in the Scope 1 process fuel mix

Ammonia-Solvay process plant locations are generally constrained by the proximity to demand centres rather than feedstocks

- Limestone and brine are widely available

- High cost of production relative to trona means that synthetic players are the marginal producers
  - Netbacks depend on customer logistics costs
  - In practice this results in a max distance of 300-500 km, typically by truck

- The location of Chinese Hou plants is determined by the access to ammonia and CO_2 gases

Both major synthetic process technologies are over 75 years old

- Many European Ammonia-Solvay plants have been operational for over 50 years and utilise legacy technologies that impact carbon emissions

Synthetic plant emissions are driven by the source of heat and power for breaking strong inorganic chemical bonds & process emissions

- Coal is still a large component of the fuel mix for European plants

- Coal is also the main source of energy for the Chinese chemicals industry

Source: WE Soda Ltd., FGE NexantECA analysis

Location of synthetic soda ash plants utilising the Ammonia-Solvay and Hou processes

100% Ammonia-Solvay process

Capacity approx. 50:50 Ammonia-Solvay : Hou
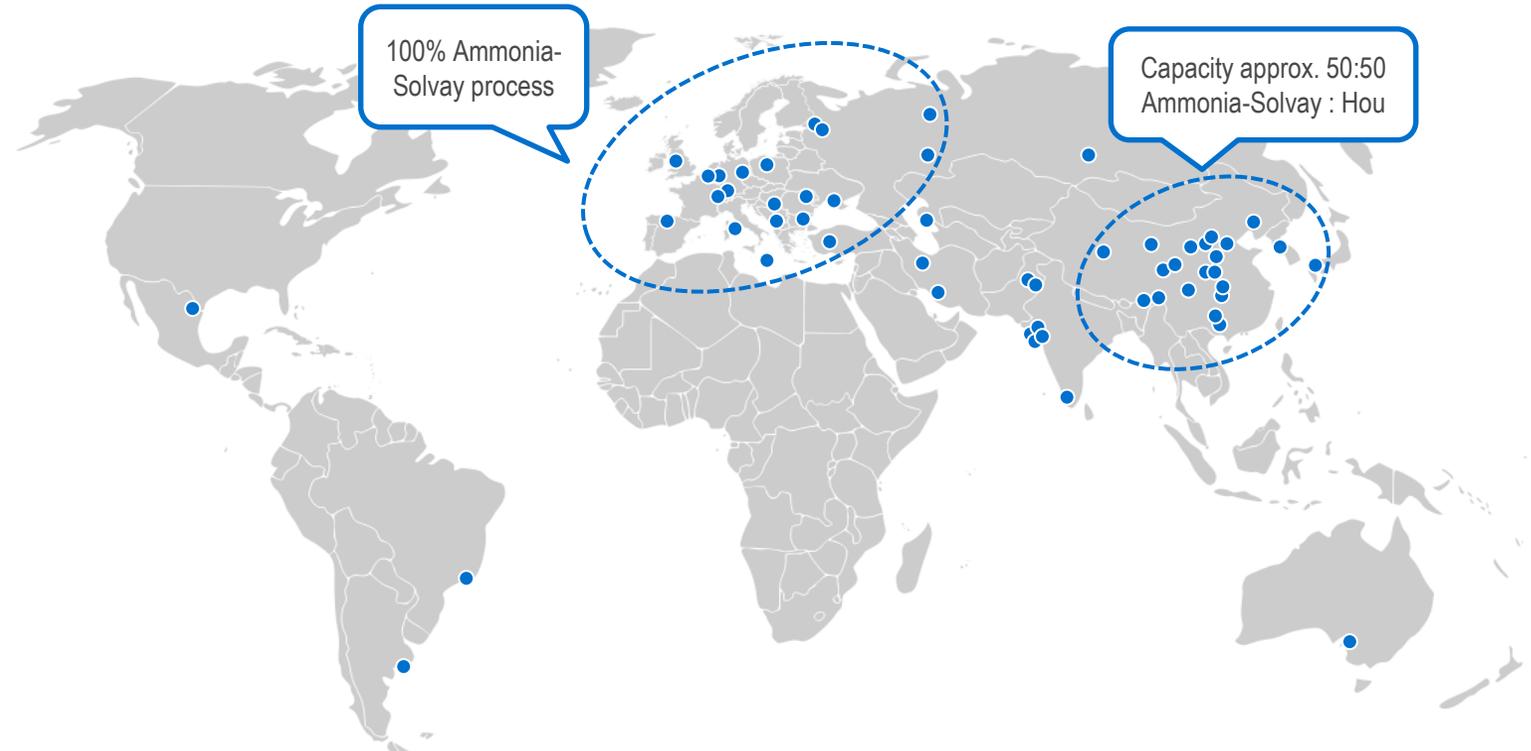
Developed in 1861, the Ammonia-Solvay process is complex as well as being energy and water intensive

Simplified Ammonia-Solvay process: Scope 1 perimeter

The Ammonia-Solvay process uses limestone (calcium carbonate) and brine as raw materials

- The calcination step (1) occurs at high temperature (1050-1100ºC) supplied through direct combustion of fuel, typically coal

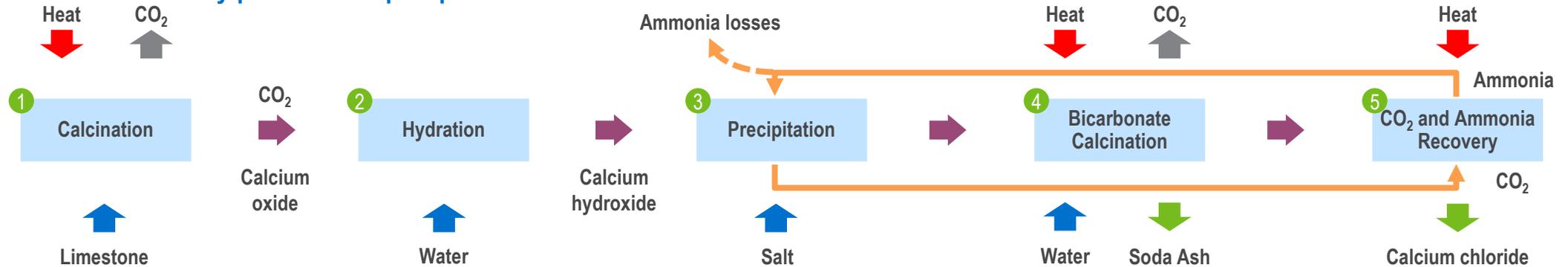- Ammonia is used during the precipitation stage (3) and then reformed, using steam in the ammonia recovery stage (5), and recycled to the precipitation stage

  - A small amount is purged during each cycle and as such a small amount of ammonia is required to replace these losses

- 1.9 to 2.4 m^3 of water per mt of soda ash is required for the slaking process (2) with a top-up of 0.6 to 1.2 m^3 per mt of soda ash required for washing the sodium bicarbonate (4)

  - Up to 100 m^3 per mt soda is required as cooling water, either in a closed or open loop

- The calcium chloride co-product can be sold as road salt; however demand is generally far lower than for soda ash

  - Depending on demand typically all or most of calcium chloride is disposed of with wastewater because of its minimal monetary value

The major source of carbon dioxide emissions from the process is to produce the heat required to break the strong chemical bonds in during the calcination steps (1, 4)

- Other carbon dioxide sources derive from process emissions from calcination and emissions associated with raw materials, so some emissions remain even when switching to a biomass fuel

- A proportion of carbon dioxide emissions from the first calcination (1) is consumed in the precipitation stage

Source: European Commission BREF on LVIC-S Industries (2007), FGE NexantECA analysis

The Hou process was developed in the 1940s as a combination of the Ammonia-Solvay and Haber (ammonia) processes with the aim to improve feedstock yields, minimise water use and lower CAPEX

Simplified Hou process: Scope 1 perimeter
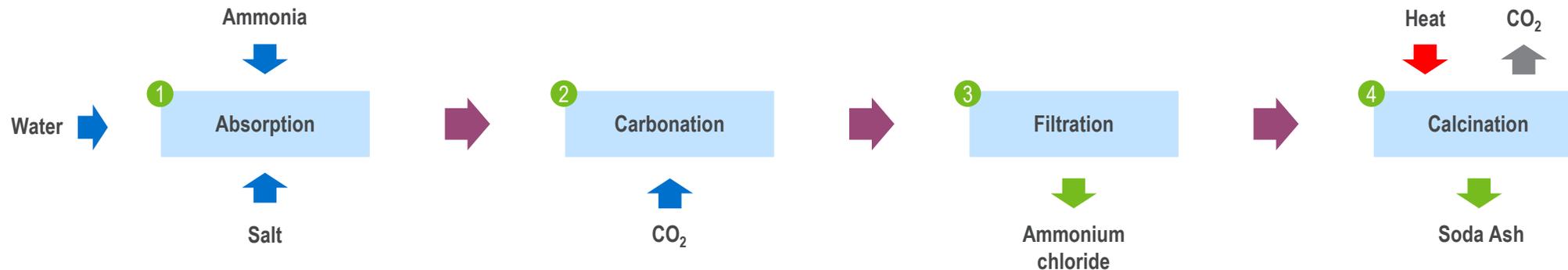
The Hou process uses a different approach to the Ammonia-Solvay process in using ammonia and carbon dioxide as feedstocks (instead of limestone) and produces ammonium chloride as a valuable co-product

- A super saturated solution from imported ammonia gas, from an adjacent ammonia plant, and brine (**1**) are reacted with CO_2 (**2**)
- Ammonium chloride precipitates outs (**3**), which is usually sold as a fertiliser
- The sodium carbonate slurry is subsequently calcined to yield soda ash (**4**)

Despite utilising carbon dioxide as a feedstock, emission for the Hou process arise from the use of coal for heat and power generation as well as the use of ammonia which is a carbon intensive feedstock

- The major source of carbon dioxide emissions from the process is from the Scope 1 energy use as well as the production of the ammonia feedstock (Scope 3), the majority of which is coal based
- The CO_2 utilised in the carbonation step is fossil-fuel derived, often sourced from neighbouring ammonia plants, further contributing to emission intensity

Source: FGE NexantECA analysis

Section 2: Carbon Intensity Benchmarking

The carbon emissions in synthetic processes are driven by the type of fuel used in the calcination and cogeneration units

Ex-works soda ash carbon intensity curve, *mt CO$_2$e per mt product (2024)*

Ex-works†	0.58	0.97	1.00	1.04	1.08	1.17	1.25	1.28	1.40	1.50	1.68	2.24	1.19
Scopes 1 + 2	0.44	0.78	0.80	0.82	0.95	0.95	1.01	1.05	1.14	1.16	1.38	1.06	0.53

- Due to the energy intensive nature of the synthetic processes, carbon intensity is largely defined by fuel type used at the facility
- Current players use carbon intensive coke fired kilns with varied fuel mix observed in boilers and cogeneration units
- Hou process players are generally integrated with coal-based Ammonia plants
  - In this case, Scope 3 – Feedstock emissions could be re-allocated to Scope 1 & 2 if the company owns both facilities
- **Hou emissions are effectively halved if ammonium chloride (NH$_4$Cl) is considered** on a CO$_2$e per mt marketable product basis (methodology on Page 40)
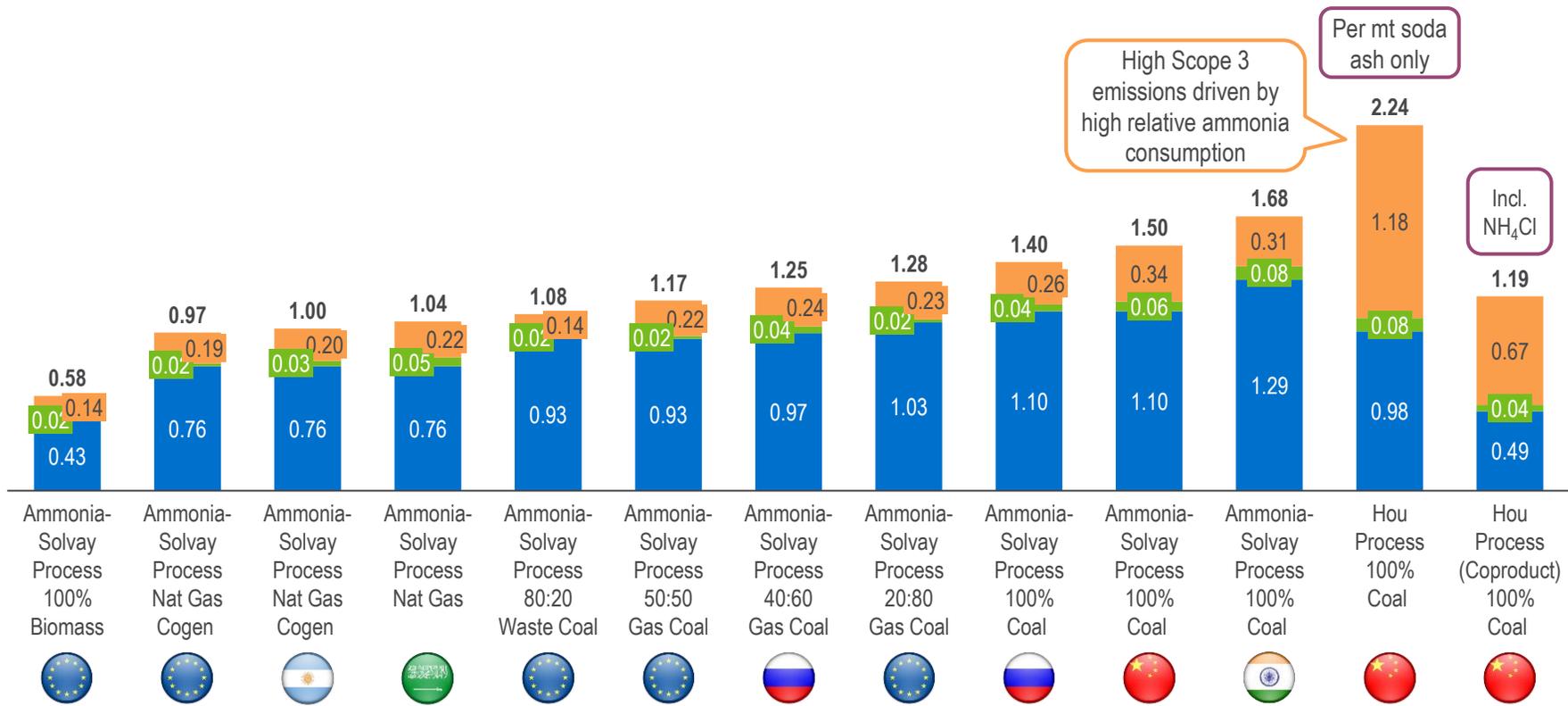
† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2
*Scope 3 – Upstream includes raw material, water and fuel
Source: WE Soda Ltd., FGE NexantECA analysis

Note: Due to rounding, totals in figure may differ from table. For specific data refer to table

FGE NexantECA has benchmarked modelled results against EU ETS reported data for EU soda ash producers

FGE NexantECA has developed 'bottom-up' carbon intensity models for soda ash production, using publicly available data

- This includes raw material, utility consumption & emission factors, in addition to other components (see Appendix A for detailed methodology)

In order to validate this modelling approach, FGE NexantECA has benchmarked results against reputable public data

- As part of the EU-ETS, the European Commission publishes benchmark curves based on data delivered by the respective European industry associations[1]

- These benchmark curves are based on actual reported emissions from plants in Europe, accounting for Scope 1 and Scope 2 emissions, for various chemicals including soda ash

- The EU-ETS reported emissions curve for soda ash can be used to validate FGE NexantECA's emission intensity modelling, by comparing results for EU plants represented in the EU-ETS dataset

- Comparison of FGE NexantECA results for EU plants with the EU-ETS dataset show a close alignment of Scope 1 & 2 emissions

- Modelled results are intended to be representative of the range of EU soda ash plants, as opposed to modelling specific installations

- For plants relevant to the EU-ETS benchmark, the maximum deviation of the modelled plant from reported data is -2% (Ammonia-Solvay Natural Gas Cogeneration)

- Solvay's Rheinberg plant shifted to a 100% biomass boiler in November 2024 and therefore is not included in the EU-ETS benchmark curve (published 2021)

(1) European Commission 2021, 'Update of benchmark values for the years 2021-2025 of phase 4 of the EU ETS'

Comparison of FGE NexantECA Modelling Results for EU-Players against Soda Ash EU-ETS Installations Reported Emissions[1], *mt CO_2e / mt*

Ammonia-Solvay 100% Biomass plant not included in EU-ETS data

| | Scope 1 | Scope 2 | EU-ETS Installations Reported Emissions |

Section 2: Carbon Intensity Benchmarking

FGE Nexant ECA
POWERED BY FUNDAMENTALS

WE Soda facilities are positioned at the most competitive end of the carbon intensity curve, with its Turkish assets emitting around 55% fewer *Scope 1 & 2* emissions compared to a typical European plant

Ex-works soda ash carbon intensity curve, *mt CO_2e per mt product (2024)*

Ex-works†	0.40	0.44	0.61	0.61	0.63	0.73	0.91	0.92	0.97	0.58	0.97	1.00	1.04	1.08	1.17	1.25	1.28	1.40	1.50	1.68	2.24	1.19
Scopes 1 + 2	0.30	0.35	0.56	0.53	0.53	0.73	0.81	0.84	0.90	0.44	0.78	0.80	0.82	0.95	0.95	1.01	1.05	1.14	1.16	1.38	1.06	0.53

Natural | *Synthetic*

Incl. sodium bicarbonate co-product (Eti & Kazan)§

High Scope 1 emissions due to use of coal

Incl. co-products§

Per mt soda ash only

Incl. NH_4Cl

55%

| | WE Soda Eti | WE Soda Kazan | Wyoming Leader | Natural Kenya | WE Soda Granger | Natural China Leader | WE Soda Westvaco | Natural China Laggard | Wyoming Laggard | Ammonia-Solvay Process 100% Biomass | Ammonia-Solvay Process Nat Gas Cogen | Ammonia-Solvay Process Nat Gas Cogen | Ammonia-Solvay Process Nat Gas | Ammonia-Solvay Process 80:20 Waste Coal | Ammonia-Solvay Process 50:50 Gas Coal | Ammonia-Solvay Process 40:60 Gas Coal | Ammonia-Solvay Process 20:80 Gas Coal | Ammonia-Solvay Process 100% Coal | Ammonia-Solvay Process 100% Coal | Ammonia-Solvay Process 100% Coal | Hou Process 100% Coal | Hou Process (Coproduct) 100% Coal |

Legend: Scope 1 (blue) | Scope 2 (green) | Scope 3 - Upstream* (orange)

† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
*Scope 3 – Upstream includes raw material, water and fuel; Upstream raw material transportation emissions are excluded from calculations
§ Co-products account for all economically valuable products produced on site; at Westvaco this includes sesqui, $NaHCO_3$ and caustic soda (all products produced onsite)
$NaHCO_3$ = Sodium bicarbonate; NH_4Cl = Ammonium chloride, produced on a 1:1 ratio with soda ash in the Hou process which offsets the emissions per mt product (see Slide 41)
Source: WE Soda Ltd., FGE NexantECA analysis

Note: Due to rounding, totals in figure may differ from table. For specific data refer to table

FGE NexantECA
POWERED BY FUNDAMENTALS

Delivered emissions for soda ash from Eti are lower on average than ex-works emissions for synthetic EU players

Delivered emissions for Eti were modelled using actual sales data from WE Soda
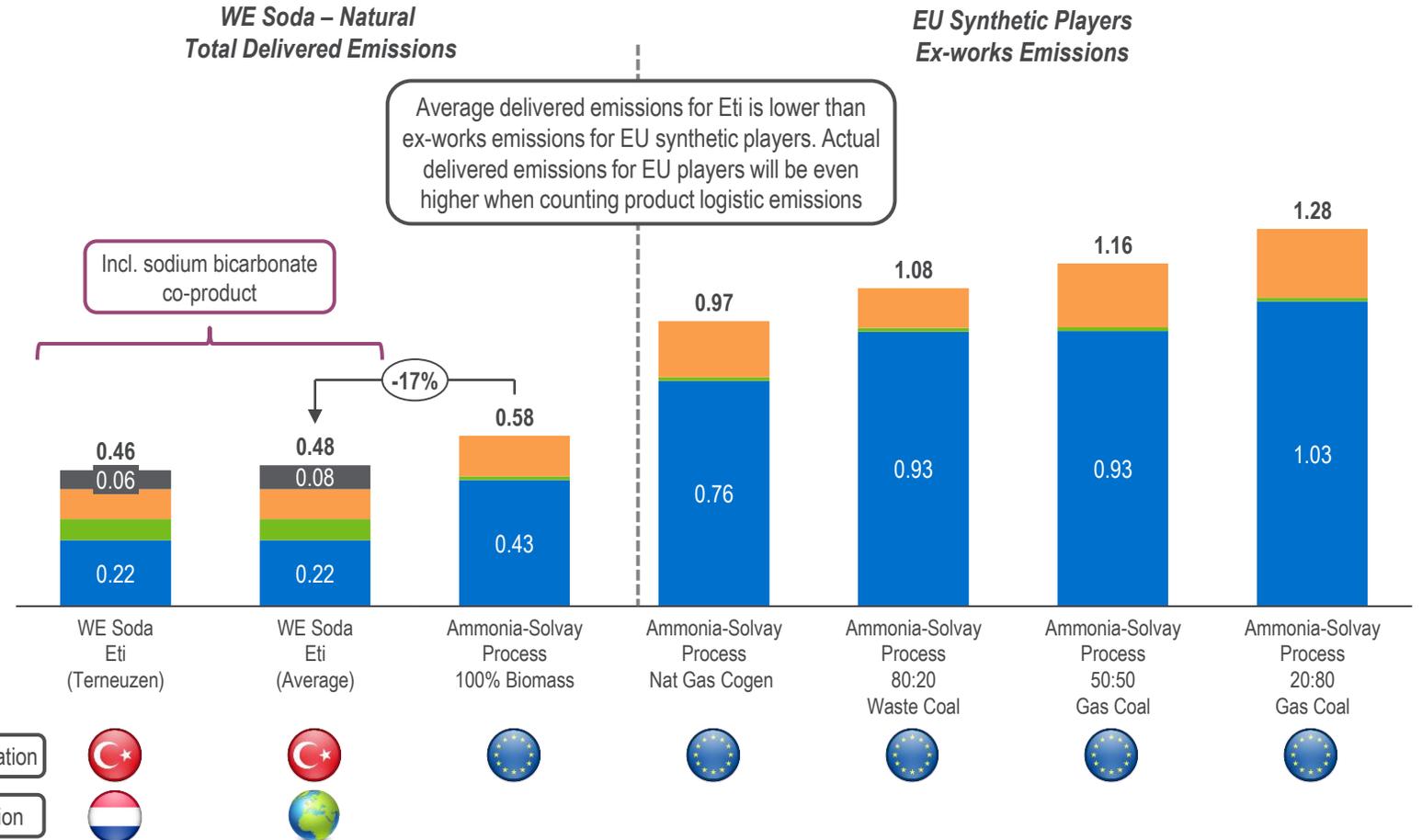
- Delivered emissions to Terneuzen, Netherlands were modelled due to its position as a key distribution hub for soda ash for Eti

- Delivered emissions for Eti (average and to Terneuzen) are lower than ex-works emissions for EU players, further supporting WE Soda's low-carbon competitive positioning

- Actual delivered emissions for EU players will be higher than ex-works when accounting for downstream freight emissions

- Freight emissions contribute a relatively small amount to total delivered emissions

- Downstream freight emissions to some customer destinations will be higher than the average case shown, however the increase will be relatively minor

- For further details refer to Methodology & Assumptions section

Soda ash carbon intensity curve, *mt CO$_2$e per mt product (2024)*

WE Soda – Natural Total Delivered Emissions

EU Synthetic Players Ex-works Emissions

Average delivered emissions for Eti is lower than ex-works emissions for EU synthetic players. Actual delivered emissions for EU players will be even higher when counting product logistic emissions

Incl. sodium bicarbonate co-product

-17%

	WE Soda Eti (Terneuzen)	WE Soda Eti (Average)	Ammonia-Solvay Process 100% Biomass	Ammonia-Solvay Process Nat Gas Cogen	Ammonia-Solvay Process 80:20 Waste Coal	Ammonia-Solvay Process 50:50 Gas Coal	Ammonia-Solvay Process 20:80 Gas Coal
Total	0.46	0.48	0.58	0.97	1.08	1.16	1.28
Scope 3 - Downstream Freight	0.06	0.08					
Scope 1	0.22	0.22	0.43	0.76	0.93	0.93	1.03

Plant Location

Destination

*Scope 3 – Upstream includes raw material, water and fuel; Upstream raw material transportation emissions are excluded from calculations
† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
§WE Soda average cases based on weighted average using actual sales data to port destinations (see Methodology & Assumptions)
Source: WE Soda Ltd., FGE NexantECA analysis*

■ Scope 1   ■ Scope 2   ■ Scope 3 - Upstream*   ■ Scope 3 - Downstream Freight

Appendix A: Carbon Intensity Methodology and Model Assumptions

- **Scope Definitions**
- Ex-works Emissions
- Distribution Emissions
- References

FGE NexantECA considered the more material carbon intensive elements across the value chain from feedstock to the customer

Definition of Scopes 1, 2, 3

Scope 1 are direct carbon emissions that occur from sources owned or controlled by the entity producing soda ash

- It was assumed that all heat demand and steam required for each of the processes are produced onsite

Scope 2 are the indirect carbon emissions associated with the purchase of electricity

- It was assumed that electrical demand is either imported from the grid or generated onsite based available information

Scope 3 carbon emissions include all associated those not included in the Scope 1 or Scope 2 boundary, either upstream or downstream

- No emissions arising from customer activities were modelled

	Modelled by FGE NexantECA			Not Modelled by FGE NexantECA	
Upstream Scope 3	Feedstocks: Ammonia, Salt, Limestone (Ammonia-Solvay), Carbon Dioxide (Hou & Ammonia-Solvay), Trona (Natural)	Water	Upstream fuel emissions (extraction, processing etc.)	Purchased services / Operational waste / Business travel / commuting	Capital goods / Transportation of feedstocks / Leased assets
Scope 1	Process emissions	Fuels: Lignite, Coal, Natural Gas, Biomass	Onsite vehicle emissions / Fugitive emissions	Emissions from offices and ancillary business activities	
Scope 2	Electrical demand of plant: pumps, motors etc.		Ex-works		
Downstream Scope 3	Trading and transportation of soda ash		Delivered	Transportation of by-product / Sale of product / Use of product	Product manufacturing / Investments / End of life of product

Source: based on GHG Protocol definitions and guidance

A differentiated approach to feedstock, process and utility streams was applied for the natural trona and synthetic Ammonia-Solvay and Hou processes

Trona

Quick lime, Water, Antifoam → Trona Processes (Solution and Conventional) → Soda Ash

Coal, Gas or Biomass; Electricity (inputs)
Caustic soda (Kazan only); Vehicular Movements (Room & Pillar) (inputs)
Carbon Dioxide (output)

Hou Process

Water → Hou Process → Soda Ash

Salt, Ammonia, Carbon Dioxide (inputs)
Coke, Gas or Biomass; Electricity (inputs)
Ammonium Chloride (output)

Ammonia-Solvay Process

Limestone → Calcination → Ammonia-Solvay Process → Soda Ash

Water, Electricity (Calcination inputs)
Coke, Gas or Biomass; Carbon Dioxide (Calcination)
Coke, Gas or Biomass; Electricity (Ammonia-Solvay inputs)
Salt, Ammonia (inputs); Calcium Chloride (output)

Carbon intensity of soda ash is modelled on an asset basis, where total emissions crossing a specific asset boundary have been allocated over all valuable products. As such, no distinction has been made between specific grades of soda ash

Scope 1: Process
Scope 2: Utilities
Scope 3: Upstream

Source: FGE NexantECA analysis

Appendix A: Carbon Intensity Methodology and Model Assumptions

- Scope Definitions
- **Ex-works Emissions**
- Distribution Emissions
- References

Emissions data for Eti & Kazan sites has been provided by WE Soda, and has been incorporated into the FGE NexantECA carbon intensity model

WE Soda Emissions for Eti Soda & Kazan Soda

	Units	2024
WE Soda: Eti		
Scope 1 emissions	mt CO_2e	449 618
Scope 2 market-based emissions	mt CO_2e	144 416
Scope 2 location-based emissions	mt CO_2e	237 236
Scope 3 feedstock emissions	mt CO_2e	190 016
Total production	mt	2 000 100
Scope 1 carbon intensity	**mt CO_2e / mt**	**0.22**
Scope 2 (market) carbon intensity	**mt CO_2e / mt**	**0.07**
Scope 3 feedstock carbon intensity	**mt CO_2e / mt**	**0.10**
WE Soda: Kazan		
Scope 1 emissions	mt CO_2e	1 094 578
Scope 2 market-based emissions	mt CO_2e	-
Scope 2 location-based emissions	mt CO_2e	91 631
Scope 3 feedstock emissions	mt CO_2e	282 198
Total production	mt	3 100 000
Scope 1 carbon intensity	**mt CO_2e / mt**	**0.35**
Scope 2 (market) carbon intensity	**mt CO_2e / mt**	**0.00**
Scope 3 feedstock carbon intensity	**mt CO_2e / mt**	**0.09**

Source: WE Soda Ltd. Annual Report 2024, Assured by ERM CVS

Emissions data has been provided by WE Soda:

- The total emissions from operating data supplied by WE Soda has been divided by the production to give the carbon intensity per mt of product

- FGE NexantECA has utilised 2024 emissions and production data which aligns to the other carbon intensity inputs detailed in the report appendix

- Previous editions of this study had excluded fugitive emissions from Scope 1 emissions results, however FGE NexantECA's Scope 1 emissions modelling methodology has now been revised to include fugitive emissions, as these have been deemed material for the purposes of this study

- Market-based Scope 2 emissions have been selected for comparison with European soda ash players

- Total Scope 3 emissions expressed by WE Soda include raw material transport and other emissions excluded by FGE NexantECA as part of the carbon intensity study (detailed in Appendix)

  - To determine the feedstock & product distribution Scope 3 emissions FGE NexantECA has excluded emissions associated with the sale and use of product, product manufacturing, investments and end of life product, among other categories (see Appendix) from the total scope three emissions data provided by WE Soda

Emissions data for Westvaco & Granger sites has been provided by WE Soda, and has been incorporated into the FGE NexantECA carbon intensity model

WE Soda Emissions for Granger & Westvaco, Wyoming

	Units	2024
WE Soda: Westvaco		
Scope 1 emissions	mt CO$_2$e	2 248 570
Scope 2 emissions	mt CO$_2$e	248 784
Scope 3 feedstock emissions[1]	mt CO$_2$e	297 875
Total production	mt	3 085 857
Scope 1 carbon intensity	mt CO$_2$e / mt	**0.73**
Scope 2 (market) carbon intensity	mt CO$_2$e / mt	**0.08**
Scope 3 feedstock carbon intensity[1]	mt CO$_2$e / mt	**0.10**
WE Soda: Granger		
Scope 1 emissions	mt CO$_2$e	365 600
Scope 2 emissions	mt CO$_2$e	121 415
Scope 3 feedstock emissions[1]	mt CO$_2$e	85 882
Total production	mt	910 327
Scope 1 carbon intensity	mt CO$_2$e / mt	**0.40**
Scope 2 (market) carbon intensity	mt CO$_2$e / mt	**0.13**
Scope 3 feedstock carbon intensity[1]	mt CO$_2$e / mt	**0.09**

[1]Calculated based on energy & feedstock consumption data provided by WE Soda
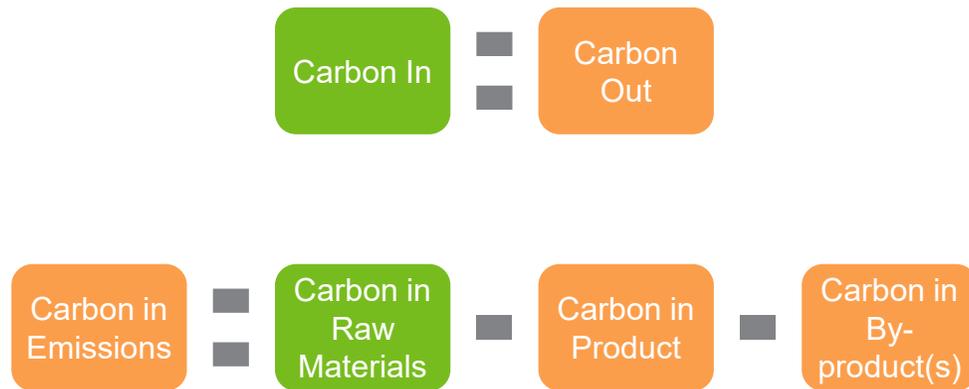
Source: WE Soda Ltd.

Emissions data has been provided by WE Soda:

- The total emissions from operating data supplied by WE Soda has been divided by the production to give the carbon intensity per mt of product

- FGE NexantECA has utilised 2024 emissions and production data which aligns to the other carbon intensity inputs detailed in the report appendix

- Previous editions of this study had excluded fugitive emissions from Scope 1 emissions results, however FGE NexantECA's Scope 1 emissions modelling methodology has now been revised to include fugitive emissions, as these have been deemed material for the purposes of this study

- Total Scope 3 emissions expressed by WE Soda include raw material transport and other emissions excluded by FGE NexantECA as part of the carbon intensity study (detailed in Appendix)

  - To determine the feedstock & product distribution Scope 3 emissions FGE NexantECA has excluded emissions associated with the sale and use of product, product manufacturing, investments and end of life product, among other categories (see Appendix) from the total scope three emissions data provided by WE Soda

FGE NexantECA's methodology for calculating process emissions of the competing technologies is aligned with international guidelines

Process emissions schematic

```
┌─────────────┐   ■   ┌─────────────┐
│  Carbon In  │   =   │   Carbon    │
│             │   ■   │    Out      │
└─────────────┘       └─────────────┘
```

```
┌───────────┐  ■  ┌───────────┐  ■  ┌───────────┐  ■  ┌───────────┐
│ Carbon in │  =  │ Carbon in │  -  │ Carbon in │  -  │ Carbon in │
│ Emissions │  ■  │    Raw    │     │  Product  │     │    By-    │
│           │     │ Materials │     │           │     │ product(s)│
└───────────┘     └───────────┘     └───────────┘     └───────────┘
```

Key assumptions

- Negligible amounts of raw materials in the product streams for the Ammonia-Solvay and Hou processes – i.e. perfect conversion
- Calcination kilns at Ammonia-Solvay process facilities are assumed to be fired by coke unless stated
- FGE NexantECA has not included existing stock as part of the carbon balance

Process emissions utilise FGE NexantECA's process technology insights and a *carbon balance* methodology to calculate carbon dioxide emissions inherent to a process technology

- It is based on the fact that all carbon entering a manufacturing process as raw materials must leave either as products, by-products or emissions to air
- It is assumed that carbon leaving through other means such as solid or liquid waste is negligible
  - For example, organic content in wastewater is minimal given the strict requirements that industrial facilities must uphold to meet total organic carbon content in water
- The molar carbon content in raw materials or products/by-products is calculated
  - The difference between the two is then assumed to be the carbon present in carbon dioxide emissions – i.e. process emissions
- The carbon content associated with process emissions has been calculated using public data sources for unit consumption factors and definitions of stream compositions, where necessary
- Counterfactual emissions have not been modelled

Generic industry standard compositions for key process streams of competing processes were used rather than applying site specific characteristics

Assumed compositions for key hydrocarbon process streams
Weight percent

Component	Coke	Natural gas	Limestone
Compound			
Fix Carbon	85.0		
Ash	8.5		
Water	5.5		
Volatiles	1.5		
Carbon Dioxide		1.8	
Nitrogen		2.7	
Oxygen		0.04	
Methane		90.2	
C$_{2+}$		5.3	
Calcium Carbonate			94.6
Magnesium Carbonate			1.4
Other Limestone [1]			4.0

FGE NexantECA has used compositions to define the carbon content of the inlet and outlet streams for the carbon balance

- Compositions are representative and do not reflect individual cases for each technology
  - This basis is sufficient for generic analysis of competing technologies

(1) Other limestone components assumed not to contain carbon
Sources: Soda Ash IPPC BAT Report, North American Energy Standards Board, Soda Ash IPPC BAT Report, FGE NexantECA analysis

Upstream emissions for the production of raw materials were calculated as the product of their consumption and emission factor

Raw material emissions

$$\sum \boxed{\text{Raw Material Emissions}} = \sum \boxed{\text{Consumption Factor}} \times \boxed{\text{Emission Factor}}$$

mt CO$_2$e per mt product   *Unit per mt product*   *mt CO$_2$e per unit of raw material*

Scope 3 raw material emissions account for the process and utility emissions released during their production

- To calculate raw materials emissions on a per mt of product basis requires knowledge of the unit consumption factor for the raw material and the emission factor, in mt CO$_2$e per unit of raw material

- Where possible FGE NexantECA has used emissions factors based on reputable public data sources

- FGE NexantECA has modelled the production of raw materials to produce emissions factors where public data is not available

- The transport of raw material to the soda ash production site was not considered
  - Therefore, raw material emission factors are not effected by geography if the feedstock and process are alike

- All emissions associated with mining and supply of trona are captured in the process and utility emissions

- This emission factors for coke and natural gas are for the supply of the fuel only and do not include emissions for combustion considered in the process emissions (Scope 1)

Raw material emission factors

Raw Material	Units	Emission Factor	*Source*
Trona	mt CO$_2$e per mt	-	-
Brine	mt CO$_2$e per mt	0.002	*(4)*
Coke – US & Europe	mt CO$_2$e per mt	0.713	*(2)*
Coke – China	mt CO$_2$e per mt	1.395	*(2)*
Natural Gas	mt CO$_2$e per mt	0.423	*(3)*
Limestone	mt CO$_2$e per mt	0.039	*(2)*
Ammonia: Natural Gas, Europe	mt CO$_2$e per mt	2.351	*(2)*
Ammonia: Coal, China	mt CO$_2$e per mt	4.368	*(2)*
Caustic (100 wt%)	mt CO$_2$e per mt	0.530	*(2)*
Lime	mt CO$_2$e per mt	1.193	*(2)*
Anthracite	mt CO$_2$e per mt	0.418	*(5)*
Carbon Dioxide	mt CO$_2$e per mt	(1.00)	*(2)*

Raw materials consumption factors were based on reputable public data sources. WE Soda has provided emissions data for its own processes, and as such is not included in the below dataset

Raw material consumption factors, *mt per mt product (2024)*

Raw Material	Units	Natural Wyoming	Natural China	Natural Kenya	Ammonia-Solvay Process (Coke Kiln)	Ammonia-Solvay Process (Natural Gas Kiln)	Hou Process (Coal)
Trona Solution	mt per mt						
Trona	mt per mt	1.54	1.54	1.54			
Brine	mt per mt				1.60	1.60	1.60
Coke	mt per mt				0.09*		
Natural Gas	mt per mt					0.06*	
Limestone	mt per mt				1.10	1.10	
Ammonia	mt per mt					0.001	0.32
Caustic (100 wt%)	mt per mt						
Lime	mt per mt						
Carbon Dioxide	mt per mt						0.42
Source		(6)	(6)	(6)	(1)	(1)	(1) (12)

Raw material consumption factors were used for calculating process emissions (Scope 1) and upstream emissions due to raw materials (Scope 3)

- Trona ore consumption is based on the SEC-filed 2021 Annual Report by Ciner Wyoming. The consumption of processing chemicals in the Wyoming mining sites was assumed to have a negligible impact

- The models and consumption factors used by FGE NexantECA align with the *AACE Class 4 definition for Cost Estimates*

* For chemical conversion and heat in lime kiln only and do not include fuel for other process stages

Co-, by- and waste production factors were based on reputable public data sources and FGE NexantECA analysis and have been used to determine emission allocation

Co- and by-production factors, *mt per mt product (2024)*

Raw Material	Units	Natural Wyoming	Natural China	Natural Kenya	Ammonia-Solvay Process (Coke Kiln)	Ammonia-Solvay Process (Natural Gas Kiln)	Hou Process (Coal)
Calcium Chloride	mt per mt				1.04 §	1.04 §	
Ammonium Chloride	mt per mt						1.01 ‡
Source					*(1)*	*(1)*	*(1) (12)*

Co-, by- and waste product consumption factors were also considered for the emissions calculations

- **Sodium bicarbonate** is considered a valuable co-product for the soda ash process (in the Ammonia-Solvay process it is produced as precursor to soda ash)
  - The use of carbon dioxide to produce sodium bicarbonate from sodium carbonate is a sequestration method to mitigate emissions
  - However, it is assumed that sodium bicarbonate is not readily produced by other trona-based players as a function of:
    - Legacy assets that have not been configured to utilise carbon dioxide emissions from steps that release it
    - WE Soda's solution extraction technology is more recent and has been designed with carbon dioxide utilisation at its core
- While **calcium chloride** is produced along with soda ash in the Ammonia-Solvay process, it has been considered as a waste by-product in this analysis due its low monetary value and general purging in effluent water streams
  - It therefore does not affect the quantification of emissions performance
- While **ammonium chloride** is often considered a waste product, in China it can be considered a by-product as it may be monetised as a fertiliser
  - FGE NexantECA therefore shows Hou process emissions on **both** a per mt soda ash (i.e., allocating emissions only to soda ash) and on a per mt marketable product basis (i.e., allocating emissions over both soda ash and ammonium chloride)
  - In the latter case, emissions are effectively halved due to the ~1:1 ratio with soda ash compared to the emissions on a per mt soda ash basis. Both allocation cases are considered given the ability to consider ammonium chloride as a waste product or valuable by-product dependent on the specific plant

Source: US Geological Survey, (12), FGE NexantECA; † *Co-product;* ‡ *By-product;* § *Waste*

Utility emissions for the competing technology scenarios were calculated as the product of their consumption and emission factors

Utility emissions

$$\sum \boxed{\text{Utility Emission}} = \sum \boxed{\text{Consumption Factor}} \times \boxed{\text{Emission Factor}}$$

mt CO_2e per mt product   *Unit per mt product*   *mt CO_2e per unit of utility*

Utility emissions account for using carbon-intensive fuels in producing process utilities such as electricity, water, steam, inert gas or heat

- To calculate utility emissions on a per mt of product basis requires knowledge of the unit consumption factor for the utility and the emission factor in mt CO_2e per unit of utility
  - The product of these two factors gives each utility emission
- The sum of all individual utility emissions gives the total utility emissions for a particular technology
- Consumption and emission factors are based on publicly available sources where available, as well as FGE NexantECA's internal technology database

The impact of geography is relevant for electricity sourced from the grid due to the fuel mix used to produce the energy in any given country

- Also, electricity intensity from the grid is expected to change over time
- Emissions from water utilities and inert gas change over time and geography as the emissions in their production are due to electricity

Fuel gas emissions are dependent on the type of fuel used as the utility, i.e. natural gas, fuel oil, coal, hydrogen, biogas

- Steam emissions change negligibly over time and geography but depend on the production technology selected and fuel used

In theory, it is possible to reduce reported utility emissions to effectively zero as they only occur due to hydrocarbon fuels consumption, and they could be electrified to utilise 100% renewable electricity

- The use of renewables for electricity or alternative fuels, such as biogas or hydrogen, can reduce emission intensity. However, it could lead to higher manufacturing costs

Emissions from the combustion of carbon intensive fuels (to generate process utilities) classified as Scope 1

The emissions from imported 3rd party utilities are classified as Scope 2

Utility emission factors were based on reputable third-party resources, which vary by region

Utility emission factors (2024)

Utility	Scope	Units	EU	Wyoming	Russia	China	KSA	India	Argentina	Kenya	Source
Electricity	2	mt CO_2e per MWh	0.187	0.838	0.464	0.661	0.595	0.934	0.376	0.063	(7) (8) (9) (11) (12)
Cooling Water	3	mt CO_2e per kt	0.059	0.161	0.156	0.271	0.238	0.295	0.103	0.149	(5) (12)
Process/ Boiler Water	3	mt CO_2e per mt	0.001	0.003	0.003	0.005	0.004	0.005	0.002	0.003	(5) (12)
Natural Gas	1	mt CO_2e per MWh	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	(5)
Natural Gas	3	mt CO_2e per MWh	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	(5)
Coal	1	mt CO_2e per MWh	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	(5)
Coal	3	mt CO_2e per MWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	(5)
Lignite	1	mt CO_2e per MWh	0.379	0.379	0.379	0.379	0.379	0.379	0.379	0.379	(5)
Lignite	3	mt CO_2e per MWh	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	(5)
Diesel	1	mt CO_2e per MWh	0.304	0.304	0.304	0.304	0.304	0.304	0.304	0.304	(5)
Diesel	3	mt CO_2e per MWh	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	(5)
Heavy Fuel Oil	1	mt CO_2e per MWh	0.280	0.280	0.280	0.280	0.280	0.280	0.280	0.280	(5)
Heavy Fuel Oil	3	mt CO_2e per MWh	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061	(5)
Municipal Waste	1	mt CO_2e per MWh	0.311	0.311	0.311	0.311	0.311	0.311	0.311	0.311	(9)
Biomass (Wood Pellets)	1	mt CO_2e per MWh	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	(5)
Biomass (Wood Pellets)	3	mt CO_2e per MWh	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	(5)

Electricity emission factors vary by location and were sourced from the latest publication of electricity generation from independent bodies

- The EU electricity emission factor is the average reported by the European Environment Agency (2024). The factor for individual member states depends on their fuel mix
  - France has a lower emission factor (0.071 mt CO_2e per MWh, 2024) due to the higher share of nuclear power
  - Conversely, Germany and Poland (0.380 and 0.708 mt CO_2e per MWh, 2024, respectively) are higher due to a greater proportion of coal
- Emission factor for cooling water was based on the electricity requirements for raw water supply
  - As well as pumping, process and boiler feed water require additional electricity in treatment plants to remove impurities
- Emission factors for coal, fuel oil and natural gas and other fuels are assumed to be fixed by geography and time
- Biomass fuel modelled as wood pellets. Methane and NOx emissions considered only – carbon dioxide is offset by absorption during fuel growth

Utility consumption factors were sourced from WE Soda along with reputable public data sources to calculate and compare energy and water intensities

Utility consumption factors, *unit per mt product (2024)*

Scope	Utility	Units	WE Soda Eti	WE Soda Kazan	WE Soda Westvaco	WE Soda Granger	Wyoming Leader	Wyoming Laggard	Natural China Leader	Natural China Laggard	Natural Kenya	Ammonia-Solvay (Natural Gas)	Ammonia-Solvay (Coal)	Ammonia-Solvay (Waste)	Ammonia-Solvay (Biomass)	Hou Process (Coal)
Scope 1	Natural Gas	MWh per mt		1.716	0.816	1.839	1.172					2.081				
	Coal	MWh per mt			0.887			1.172	1.172	1.172			2.081			2.594
	Lignite	MWh per mt	0.459													
	Diesel	MWh per mt	0.006	0.014	0.008	0.002	0.006	0.006	0.006	0.006	0.003					
	Gasoline	MWh per mt			0.001	0.001										
	Heavy Fuel Oil	MWh per mt									1.172					
	Municipal Waste	MWh per mt												2.081		
	Biomass	MWh per mt	0.053												2.081	
	Steam, Cogen	MWh per mt														
Scope 2	Electricity	MWh per mt	0.270	0.067[a]	0.129	0.214	0.151	0.321	0.151	0.321	0.321	0.090	0.090	0.090	0.090	0.122
Scope 3	Cooling Water	mt per mt										6.460	6.460	6.460	6.460	6.371
	Process / Boiler Water	mt per mt					1.622	1.622	1.622	1.622	1.622	4.800	4.800	4.800	4.800	3.050
Source							(6)	(6)	(6)	(6)	(6) (12)	(1)	(1)	(1)	(1)	(1) (12)
Scope 1	Total Energy Intensity	MWh per mt	0.518	1.730	1.703	1.842	1.179	1.179	1.179	1.179	1.175	2.081	2.081	2.081	2.081	2.594
Scope 1 + 2	Total Energy Intensity	MWh per mt	0.788	1.797[b]	1.841	2.056	1.330	1.500	1.330	1.500	1.496	2.171	2.171	2.171	2.171	2.716
	Total Water Intensity	mt per mt	1.671	2.243	2.105	3.190	1.622	1.622	1.622	1.622	1.622	11.260	11.260	11.260	11.260	9.421

(a)   *Accounts for purchased electricity. Note that Kazan Soda is a net exporter of electricity as it sells approximately 0.3 MWh per mt back to the grid. This export is considered as a reduction in Scope 1 energy intensity*
(b)   *Total energy intensity for Kazan is 1.800, however energy consumption of renewable sources has been excluded in Table as they do not contribute to emissions.*
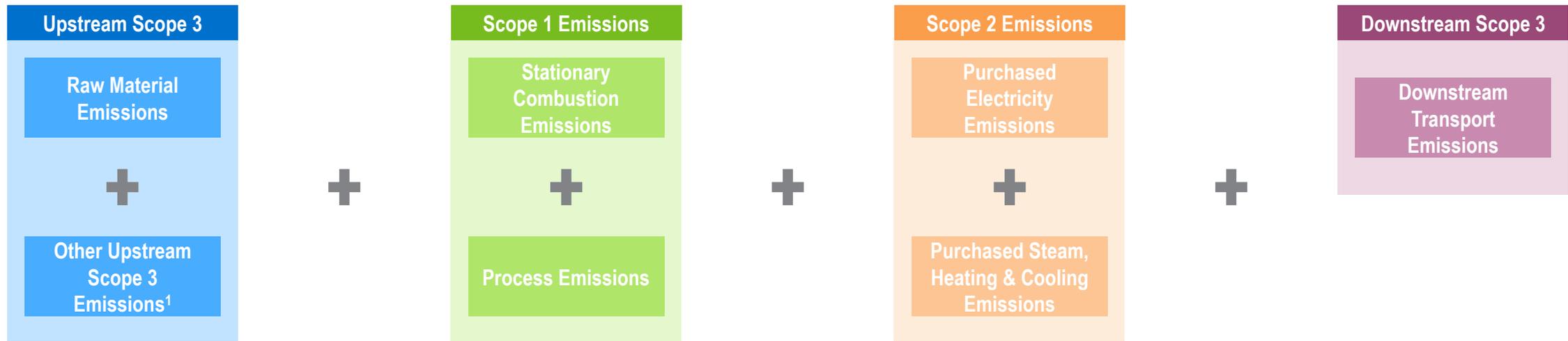*Note: Individual components may not sum exactly to totals due to rounding*

FGE Nexant ECA
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Overall emission intensities are calculated by combining all individual material, resource or activity emission intensities, to produce a total per tonne emission value, broken into Scope 1, 2 and 3 emission categories

Emission Calculation

| Emissions | = | Consumption Factor | × | Emission Factor |

Overall Emission Model

Upstream Scope 3	Scope 1 Emissions	Scope 2 Emissions	Downstream Scope 3
Raw Material Emissions	Stationary Combustion Emissions	Purchased Electricity Emissions	Downstream Transport Emissions
+	+	+	
Other Upstream Scope 3 Emissions[1]	Process Emissions	Purchased Steam, Heating & Cooling Emissions	

[1]*Such as upstream extraction emissions For more details please refer to Appendix A: Carbon Intensity Methodology and Assumptions*

Appendix A: Carbon Intensity Methodology and Model Assumptions
- Scope Definitions
- Ex-works Emissions
- **Distribution Emissions**
- References

WE Soda's Scope 3 downstream freight emissions for product transportation from Eti & Kazan sites were calculated using a simplified mixed mode distribution model using actual sales data
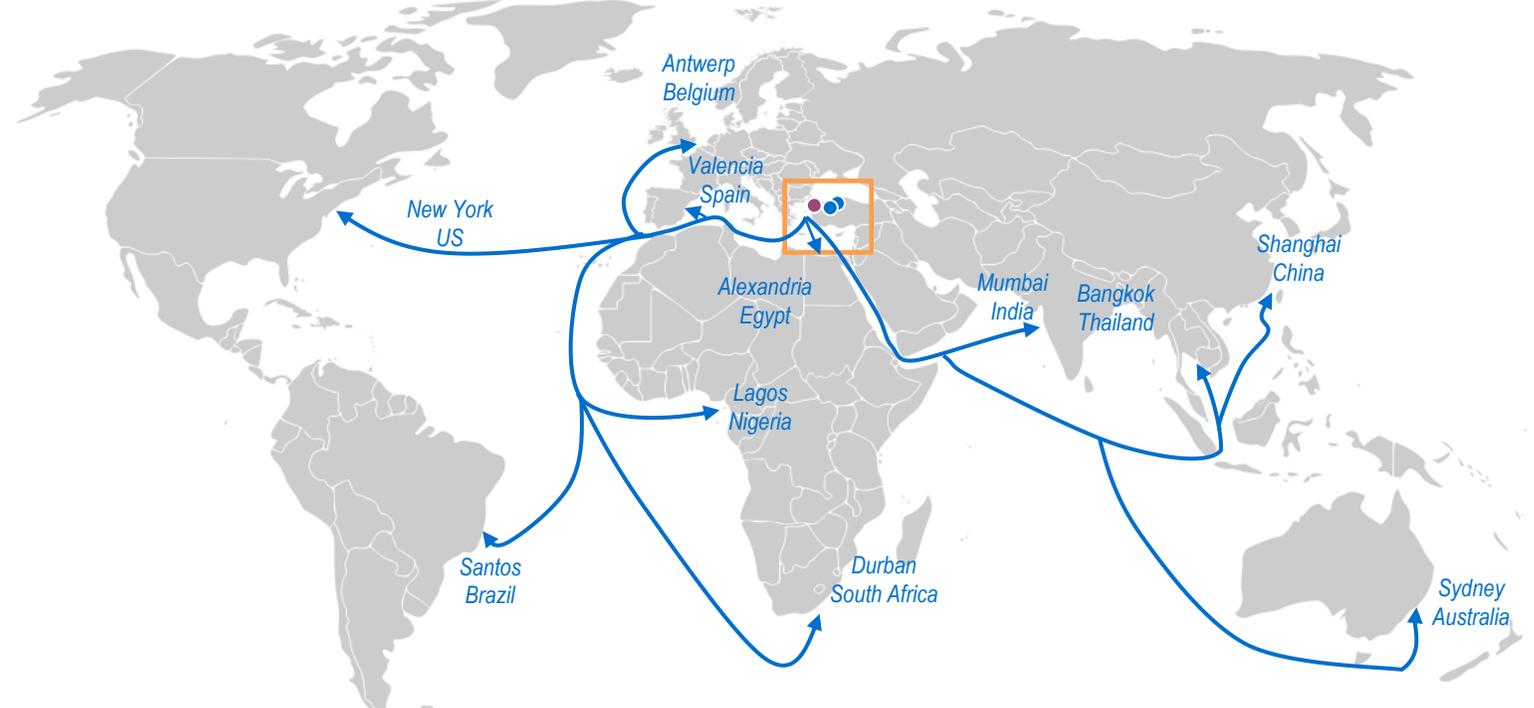
WE Soda distribution in Türkiye

Assumed Eti & Kazan distribution volumes

Destination	Mode
Türkiye	Truck
Europe	Truck & Sea
Asia	Truck & Sea
South America	Truck & Sea
Africa	Truck & Sea
North America	Truck & Sea
Oceania	Truck & Sea

Illustrative WE Soda Eti & Kazan global distribution

Mean sea freight
Eti: ~5 200 km
Kazan: ~5 700 km

Emissions factors
Truck: 0.1244 kg CO_2e per mt per km
Sea: 0.0076 kg CO_2e per mt per km

Mean Scope 3 downstream freight emissions:
Eti: 0.081 mt CO_2e per mt soda ash
Kazan: 0.105 mt CO_2e per mt soda ash

→ *Transport to export port*   → *Exports*

WE Soda's Scope 3 downstream freight emissions for product transportation from Granger & Westvaco sites were calculated using an equivalent mixed mode distribution model using actual sales data
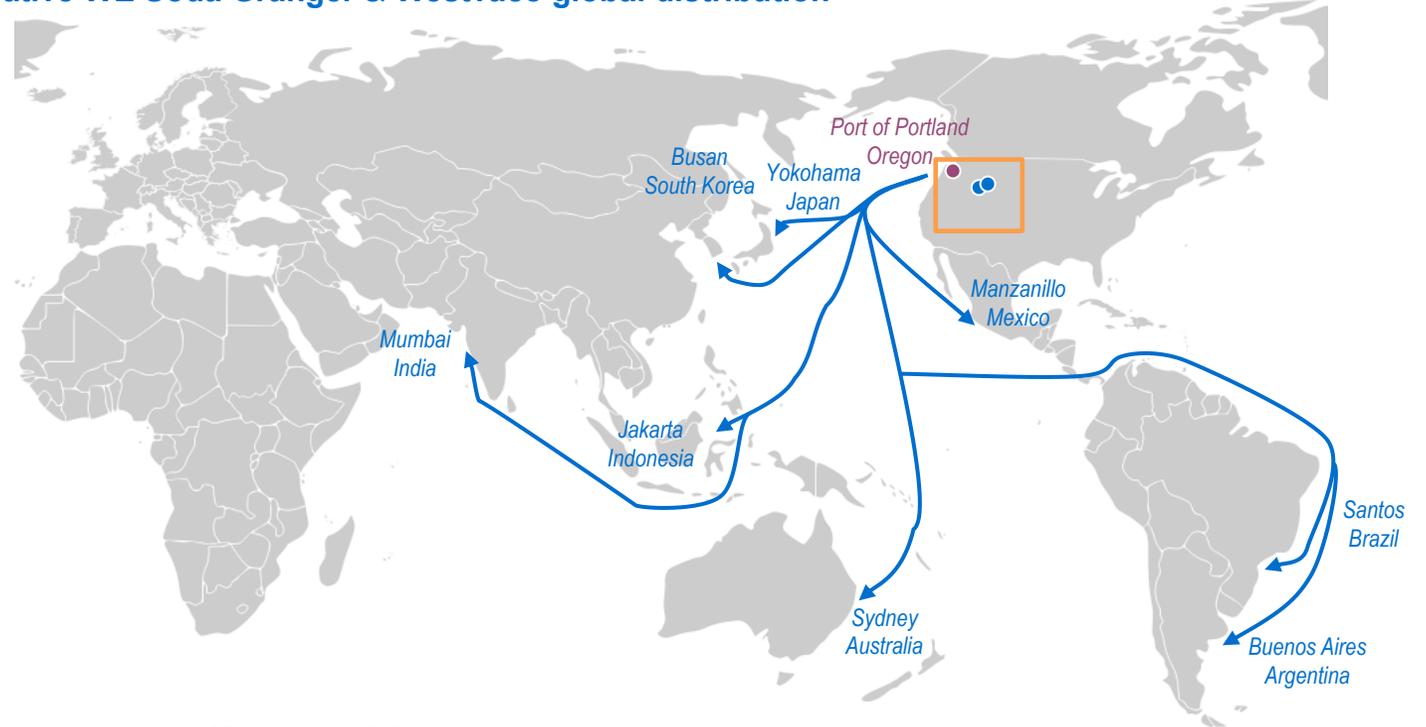
WE Soda distribution in US

Export Point
Portland, Oregon

Westvaco
Granger

Assumed US distribution distance[1]
~2 500 km

Assumed Granger & Westvaco distribution volumes

Destination	Mode
US	Rail
Europe	Rail & Sea
Asia	Rail & Sea
South America	Rail & Sea
India	Rail & Sea
Oceania	Rail & Sea

Illustrative WE Soda Granger & Westvaco global distribution

Busan
South Korea

Yokohama
Japan

Port of Portland
Oregon

Manzanillo
Mexico

Mumbai
India

Jakarta
Indonesia

Santos
Brazil

Sydney
Australia

Buenos Aires
Argentina

Mean sea freight
Granger: ~11 700 km
Westvaco: ~11 700 km

Emissions factors
Rail: 0.0278 kg CO_2e per mt per km
Sea: 0.0104 kg CO_2e per mt per km

Mean Scope 3 downstream freight emissions:
Granger: 0.124 mt CO_2e per mt soda ash
Westvaco: 0.098 mt CO_2e per mt soda ash

➤ *Transport to export port*　　➤ *Exports*　　[1]*Not to scale*

Wyoming Leader & Laggard downstream freight emissions used a simplified distribution model, transporting product via rail to US customers or to two export locations, before shipping to Asia or South America
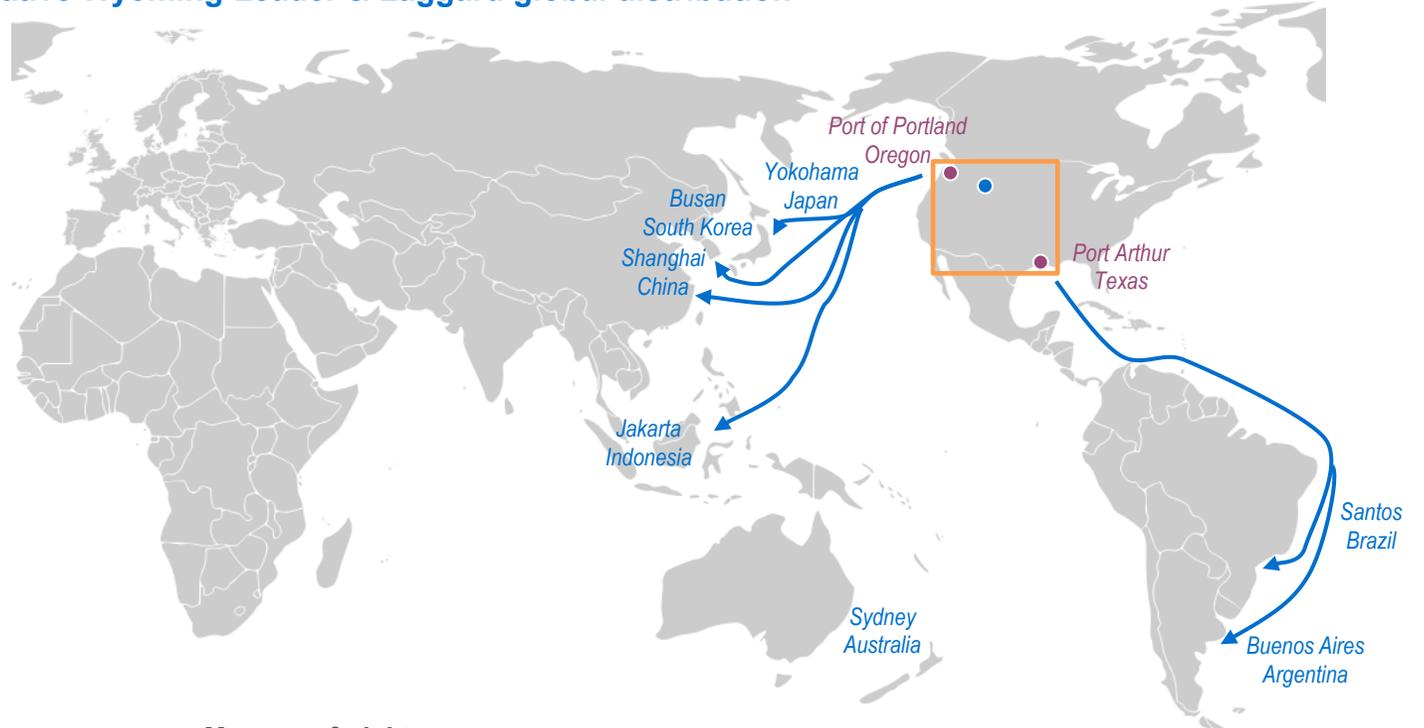
Wyoming Leader & Laggard distribution in US

Export Point
Portland, Oregon

Wyoming Leader
& Laggard

Assumed US distribution distance[1]
~2 500 km

Export Point
Port Arthur, Texas

Assumed Wyoming Leader & Laggard distribution volumes

Destination	Mode	Wyoming Leader & Laggard Sales
US	Rail	40%
Europe	Rail & Sea	0%
Asia	Rail & Sea	36%
South America	Rail & Sea	24%
India	Rail & Sea	0%
Oceania	Rail & Sea	0%

Note: May not add to 100% due to rounding
Source: FGE NexantECA analysis

Illustrative Wyoming Leader & Laggard global distribution

Port of Portland Oregon
Yokohama Japan
Busan South Korea
Shanghai China
Port Arthur Texas
Jakarta Indonesia
Santos Brazil
Sydney Australia
Buenos Aires Argentina

Mean sea freight
*Wyoming Leader & Laggard: ~ 9 700 km*

Emissions factors
Rail: 0.0278 kg CO_2e per mt per km
Sea: 0.0104 kg CO_2e per mt per km

Mean Scope 3 downstream freight emissions:
Wyoming Leader & Laggard: 0.112 mt CO_2e per mt soda ash

→ *Transport to export port*   → *Exports*   [1]*Not to scale*

Synthetic producers are assumed to ship product an average of 300 km, due to end-market proximity
China and Kenya natural producers have assumed a mixed mode freight models using market and trade data

Synthetic producers, e.g. Europe[1,2]

Mean Scope 3 downstream freight emissions:
0.023 mt CO_2e per mt soda ash
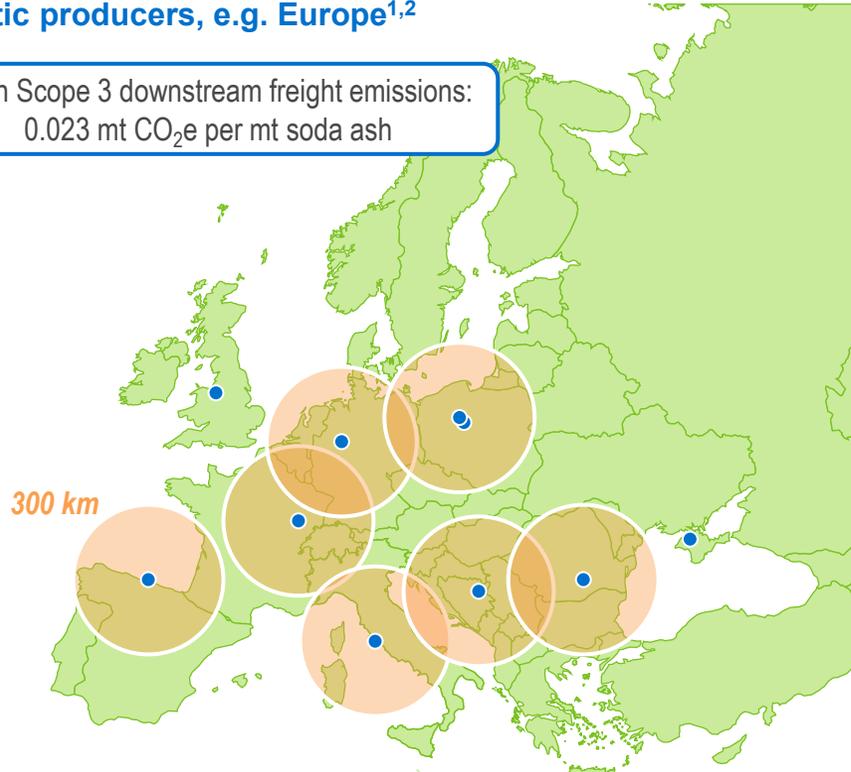
300 km

On average, it is assumed that synthetic soda ash producers ship product an average ~300 km via 33 mt trucks

- The applied emission factor was 0.0767 kg CO_2e per mt per km

- In practice, it would be expected that soda ash produced by synthetic players could travel further

Source: Industrial Minerals, DESNZ (2025 GHG conversion factors), USGS, UN Comtrade, FGE NexantECA analysis

Natural soda ash producers: Kenya *(left)*, China *(right)*[2]

Mean Scope 3 downstream freight emissions:
0.096 mt CO_2e per mt soda ash

1 000 km

300 km

Mombasa

5 900 km

Up to 1 200 km

Mean Scope 3 downstream freight emissions:
0.026 mt CO_2e per mt soda ash
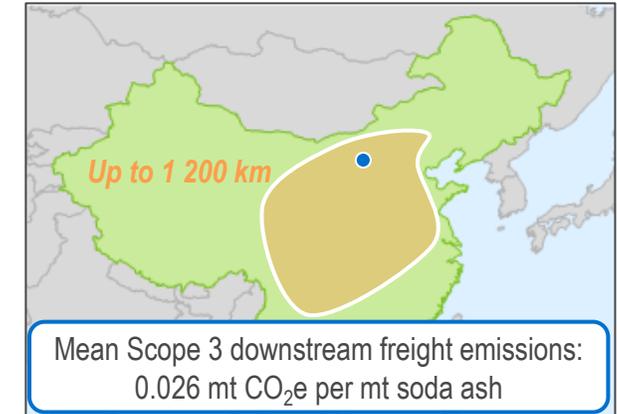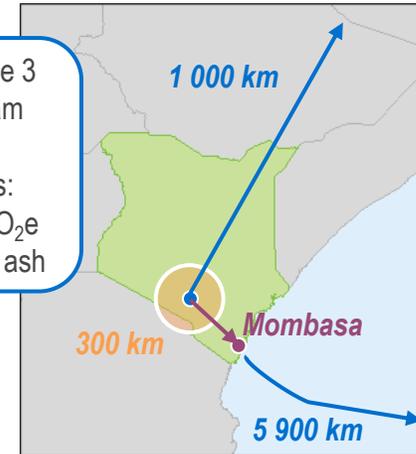
Destination	Mode	Kenya Sales	China Sales
Domestic[3]	Road (ca. 300 km)	10%	0%
Domestic[4]	Rail & Road (up to 1 200 km)	0%	100%
Local Africa[3]	Road (up to 1 000 km)	10%	0%
Southeast Asia & India[3]	Road and Sea (weighted 5 900 km)	80%	0%

Through trade data and market analysis, a mixed mode freight model has been developed for Kenya and China natural producers

- It is assumed that a proportion of sales are for local distribution (ca. 300 km)

- Around 10% of Kenyan soda ash is sold to neighbouring African countries[3]

- All of the modelled China producer's product is sold within China[4]

[1]Non-exhaustive   [2]Not to scale   [3]Determined through trade data analysis   [4]Determined through market analysis

█ *Local distribution range*   ➤ *Transport to export port*   ➤ *Exports*

Appendix A: Carbon Intensity Methodology and Model Assumptions
- Scope Definitions
- Ex-works Emissions
- Distribution Emissions
- **References**

References for Carbon Intensity Analysis

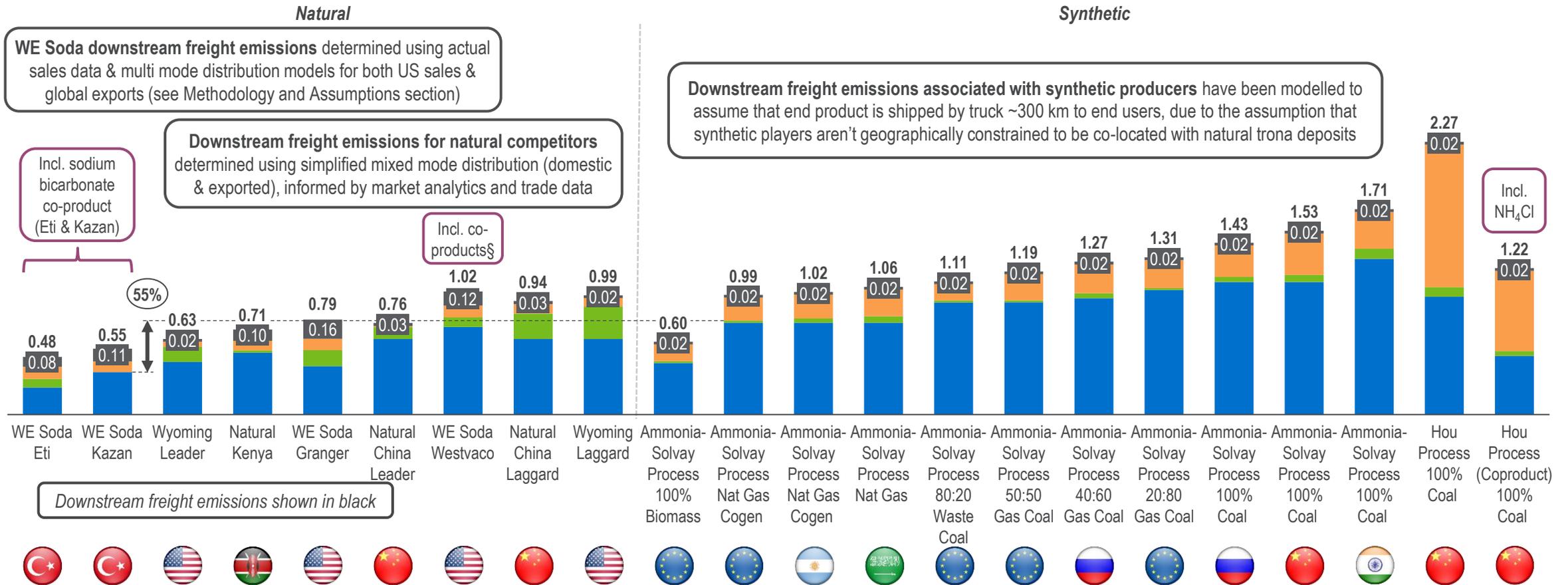| Source number	Reference
(1)	Integrated Pollution Prevention and Control - Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals -Solids and Others industry - August 2007, Table 2.11
(2)	JRC Science for Policy Report - Definition of Input Data to Assess GHG default emissions from biofuels in EU legislation - Version 1C - July 2017
(3)	JRC Reference Report - Best Available Techniques (BAT) Reference Document for Iron and Steel Production -Industrial Emissions Directive 2010/75/EU - 2013
(4)	European Commission Directorate-General for Agriculture and Rural Development - Expert Group for Technical Advice on Organic Production - Organic sea salt and other salts for food and feed - 2021
(5)	UK Government GHG Conversion Factors for Company Reporting
(6)	Ciner Wyoming SEC Filing - Annual Report 2021
(7)	CaDI 2024, Greenhouse Gas Emissions Factors for International Grid Electricity
(8)	United States Environmental Protection Agency (EPA) 2023, Emissions & Generation Resource Integrated Database (eGRID),
(9)	European Environment Agency 2025, Greenhouse gas emission intensity of electricity generation in Europe
(10)	Federal Register EPA; 40 CFR Part 98; e-CFR. Table C-1, Table C-2 (as amended at 81 FR 89252, Dec. 9, 2016), Table AA-1 (78 FR 71965, Nov. 29, 2013).
(11)	IPCC Guidelines for National Greenhouse Gas Inventories - Chapter 3 - Chemistry Industry Emissions - 2006
(12)	FGE NexantECA Analysis

Note: *WE Soda data for Eti & Kazan sourced via WE Soda Ltd. Annual Report 2024 (assured by ERM CVS)*

WE Soda data for Granger & Westvaco sourced via WE Soda Ltd.

Appendix B: Delivered Soda Ash Carbon Intensity Curve

When accounting for downstream freight emissions, WE Soda's facilities maintain a leading position on the carbon intensity curve, particularly Eti & Kazan, reinforcing its competitive advantage

Delivered soda ash carbon intensity curve, *mt CO_2e per mt product (2024)*

Natural

Synthetic

WE Soda downstream freight emissions determined using actual sales data & multi mode distribution models for both US sales & global exports (see Methodology and Assumptions section)

Downstream freight emissions associated with synthetic producers have been modelled to assume that end product is shipped by truck ~300 km to end users, due to the assumption that synthetic players aren't geographically constrained to be co-located with natural trona deposits

Downstream freight emissions for natural competitors determined using simplified mixed mode distribution (domestic & exported), informed by market analytics and trade data

Incl. sodium bicarbonate co-product (Eti & Kazan)

Incl. co-products§

Incl. NH_4Cl

55%

Downstream freight emissions shown in black

Facility	Value	Downstream
WE Soda Eti	0.48	0.08
WE Soda Kazan	0.55	0.11
Wyoming Leader	0.63	0.02
Natural Kenya	0.71	0.10
WE Soda Granger	0.79	0.16
Natural China Leader	0.76	0.03
WE Soda Westvaco	1.02	0.12
Natural China Laggard	0.94	0.03
Wyoming Laggard	0.99	0.02
Ammonia-Solvay Process 100% Biomass	0.60	0.02
Ammonia-Solvay Process Nat Gas Cogen	0.99	0.02
Ammonia-Solvay Process Nat Gas Cogen	1.02	0.02
Ammonia-Solvay Process Nat Gas	1.06	0.02
Ammonia-Solvay Process 80:20 Waste Coal	1.11	0.02
Ammonia-Solvay Process 50:50 Gas Coal	1.19	0.02
Ammonia-Solvay Process 40:60 Gas Coal	1.27	0.02
Ammonia-Solvay Process 20:80 Gas Coal	1.31	0.02
Ammonia-Solvay Process 100% Coal	1.43	0.02
Ammonia-Solvay Process 100% Coal	1.53	0.02
Ammonia-Solvay Process 100% Coal	1.71	0.02
Hou Process 100% Coal	2.27	0.02
Hou Process (Coproduct) 100% Coal	1.22	0.02

† = Ex-works carbon emissions defined as Scope 3 (upstream) + Scope 1 + Scope 2 (market-based for WE Soda)
*Scope 3 – Upstream includes raw material, water and fuel; Upstream raw material transportation emissions are excluded from calculations
§ Co-products at Westvaco include sesqui, $NaHCO_3$ and caustic soda
$NaHCO_3$ = Sodium bicarbonate; NH_4Cl = Ammonium chloride, produced on a 1:1 ratio with soda ash in the Hou process which offsets the emissions per mt product (see Page 40)
Source: WE Soda Ltd., FGE NexantECA analysis

Legend: ■ Scope 1 ■ Scope 2 ■ Scope 3 - Upstream* ■ Scope 3 - Downstream Freight

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