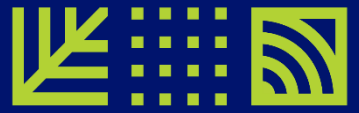
SYSTEMIQ

Fertilizer decarbonization

Rupert Simons, 26 October 2023



AGENDA

- Key facts about fertilizer
- Emissions and decarbonization pathways
- Tipping the system

SYSTEMIQ – WHO WE ARE

Systemiq is the world's only 'pure play' climate and systems change company. Our mission is to accelerate the transition to a net-zero, nature-positive and more inclusive economy.

390 EMPLOYEES

OVER 300 PROJECTS

15 INVESTMENTS

3 EXITS

5 PLATFORMS:

ENERGY

MATERIALS

NATURE-FOOD

SUSTAINABLE FINANCE

URBAN

AGENDA

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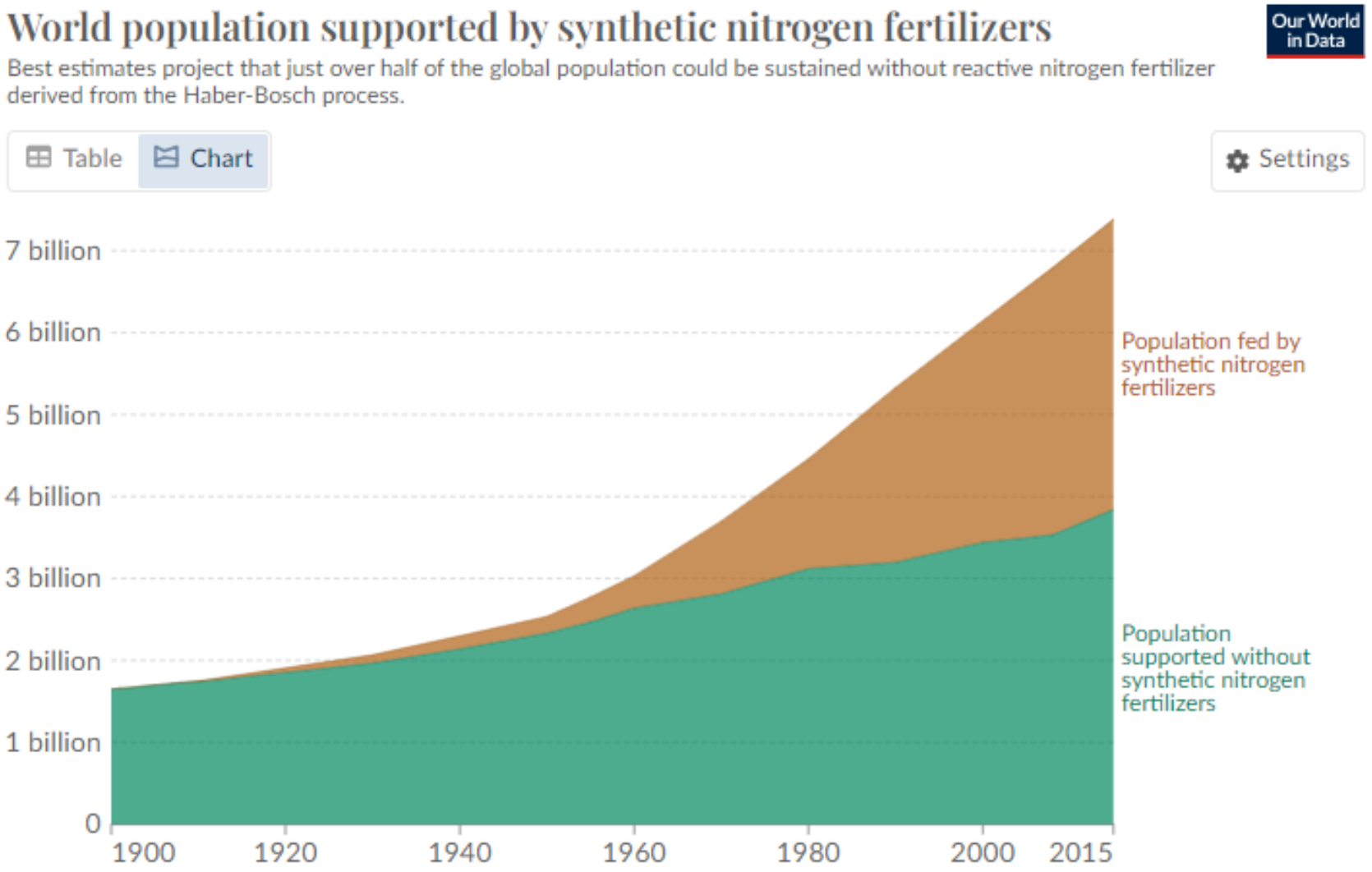
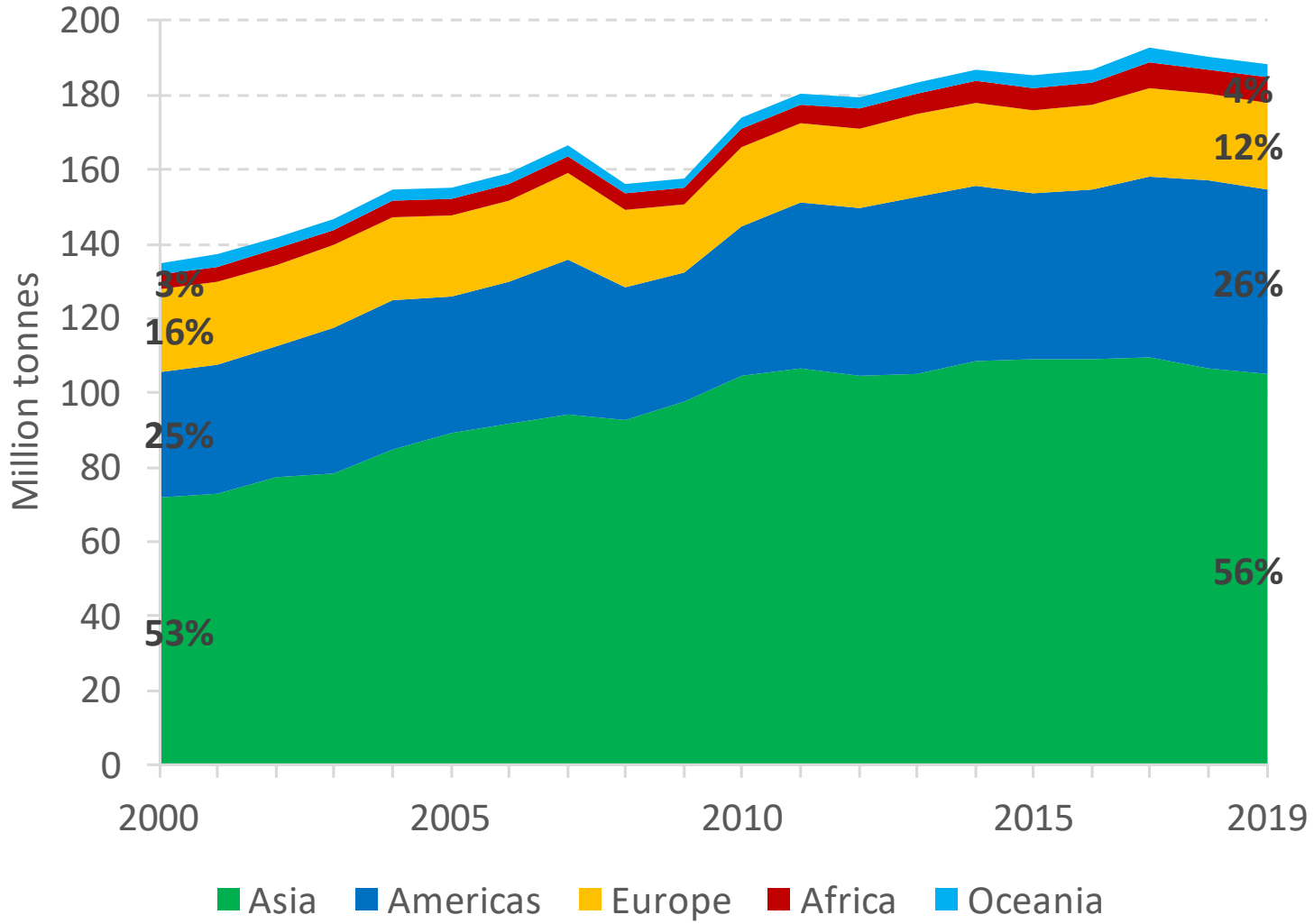
FERTILIZER FEEDS HALF THE WORLD POPULATION



Source: Our World in Data, based on Erisman et (al) 2008; Smil (2002); Stewart (2005)

THE WORLD USES JUST UNDER 200 MILLION TONNES OF MINERAL FERTILIZER EVERY YEAR, HALF OF IT IN ASIA, JUST 4% IN AFRICA



Total global fertilizer sales ~$200 billion per year

Animal manure accounts for >10x the volume of mineral fertilizer, but a similar volume of nutrients owing to its lower nutrient density

Source: IFAStat, FAOStat

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SCOPE 1 FERTILIZER EMISSIONS ARE SCOPE 3 FOR THE FOOD INDUSTRY

Fertilizer production | **Food production** | **Food manufacturing and trade**

Fertilizer companies

Scopes 1 & 2

Downstream scope 3

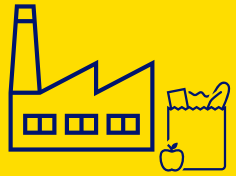
Upstream scope 3

Farmers

Scopes 1 & 2

Downstream scope 3

Upstream scope 3



Food manufacturers, retailers, commodity traders

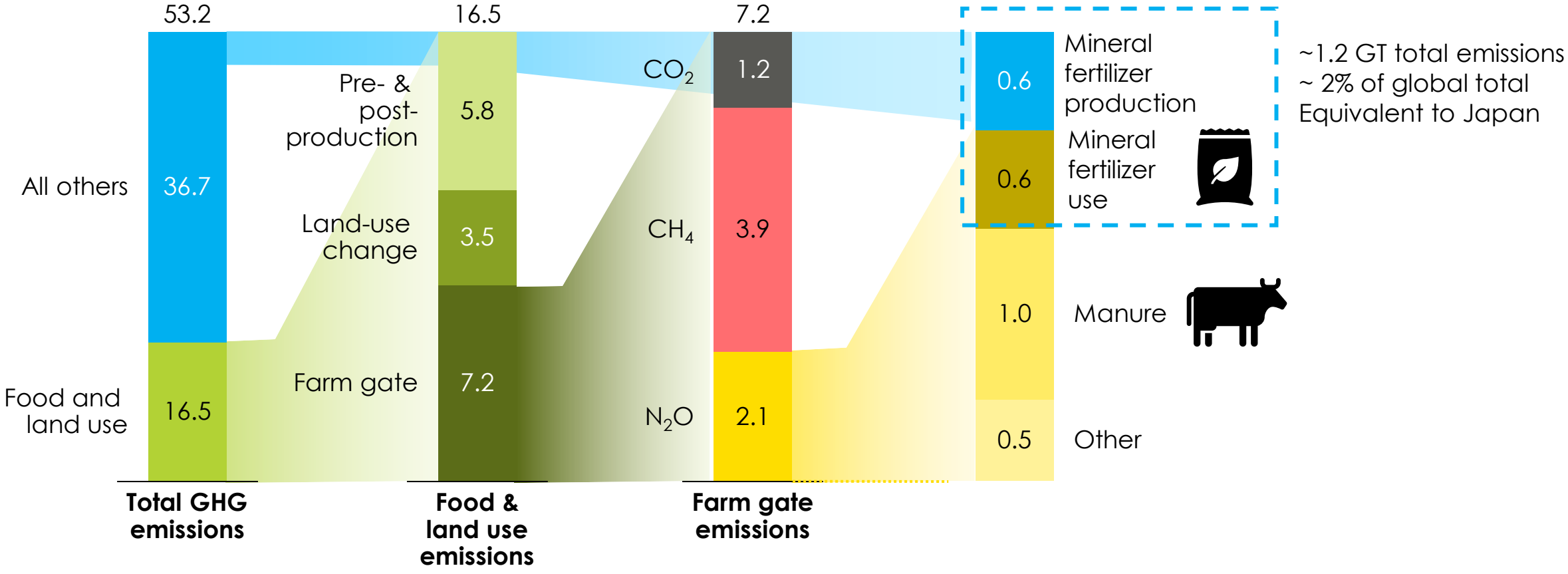
Scopes 1 & 2

Flow of goods and services

Source: WWF, WRI, SYSTEMIQ analysis

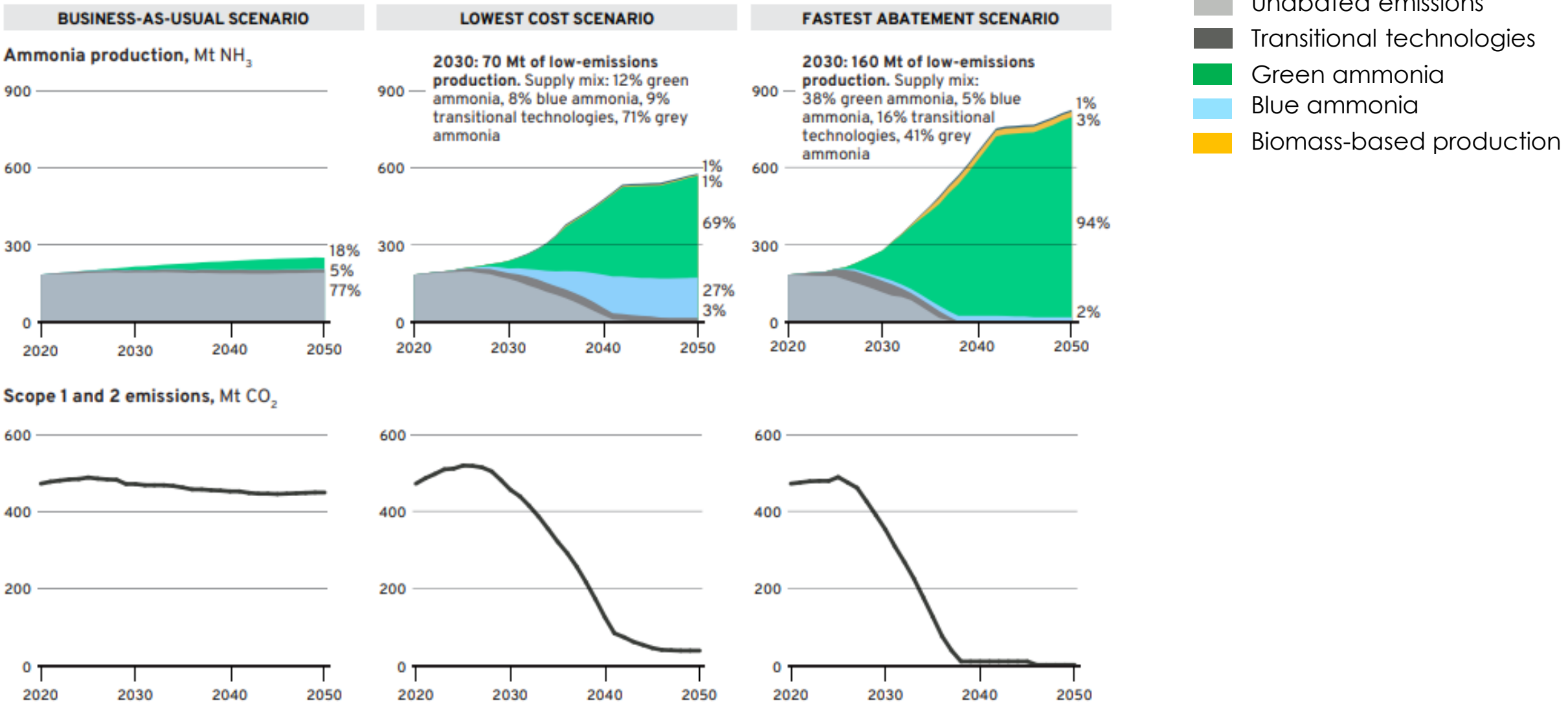
AGRI-FOOD IS RESPONSIBLE FOR 30% GREENHOUSE GAS EMISSIONS, WITH FERTILIZER AROUND 2% OF THE TOTAL

Total emissions ($GtCO_2e$) for agri-food by greenhouse gas (GHG) and primary source



Source: FAO 2019 data released Nov 2021. Other N_2O and CO_2 farm gate emissions come from crop residues, soil drainage, fires and on-farm energy use

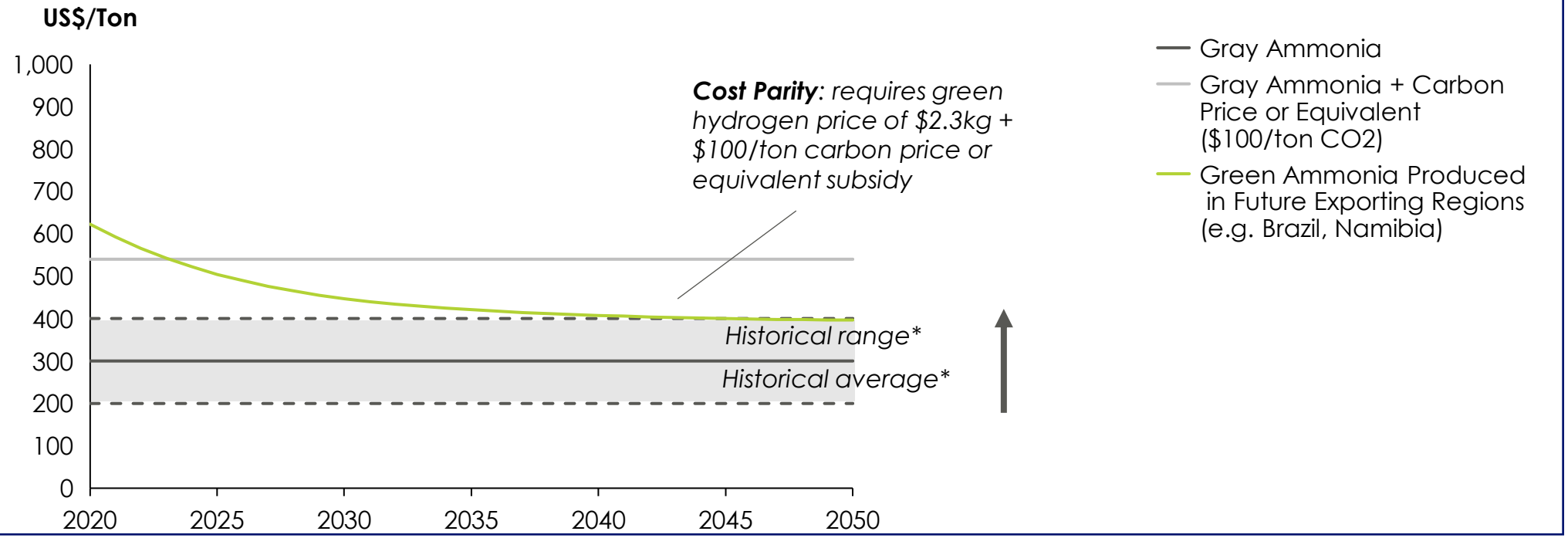
GREEN AMMONIA DELIVERS THE FASTEST EMISSIONS REDUCTIONS



Source: Making net zero ammonia possible

HOWEVER GREEN AMMONIA WILL NOT AUTOMATICALLY REACH COST PARITY

PROJECTED COST PER TON GRAY VS. GREEN AMMONIA FOR FERTILISER PRODUCTION[2]



SOLUTION STATUS

- Major fertilizer producers such as Yara, CF Industries, Unigel have begun construction on green ammonia plants, with **commercial launch scheduled for 2023**
- Three green ammonia **projects are operational** (up to 20 MW electrolysers) with seven more **reaching the final investment decision** stage[2]
- Green ammonia production projected to be both **economically viable and technologically mature** within the decade[3]

Note: * Last 10 years from 2011 to 2020 excluding 2021 due to energy price spikes [2] Refers to project range for green ammonia production from electrolysis with dedicated VREs and pipeline H2 storage plus ammonia synthesis (lowest cost scenario); Grey ammonia production cost assumes natural gas via steam methane reforming taking historic average gas price of $5/MMBtu. [3] The point at which a technology is considered to reach maturity is the year in which it is estimated to reach TRL 9 and thus commercial scale, which is 2025 for electrolysis-based ammonia production.
Sources: [1] IFA (2022), Reducing Emissions From Fertiliser Use ; [2] Mission Possible Partnership (2022), Making 1.5-Aligned Ammonia Possible

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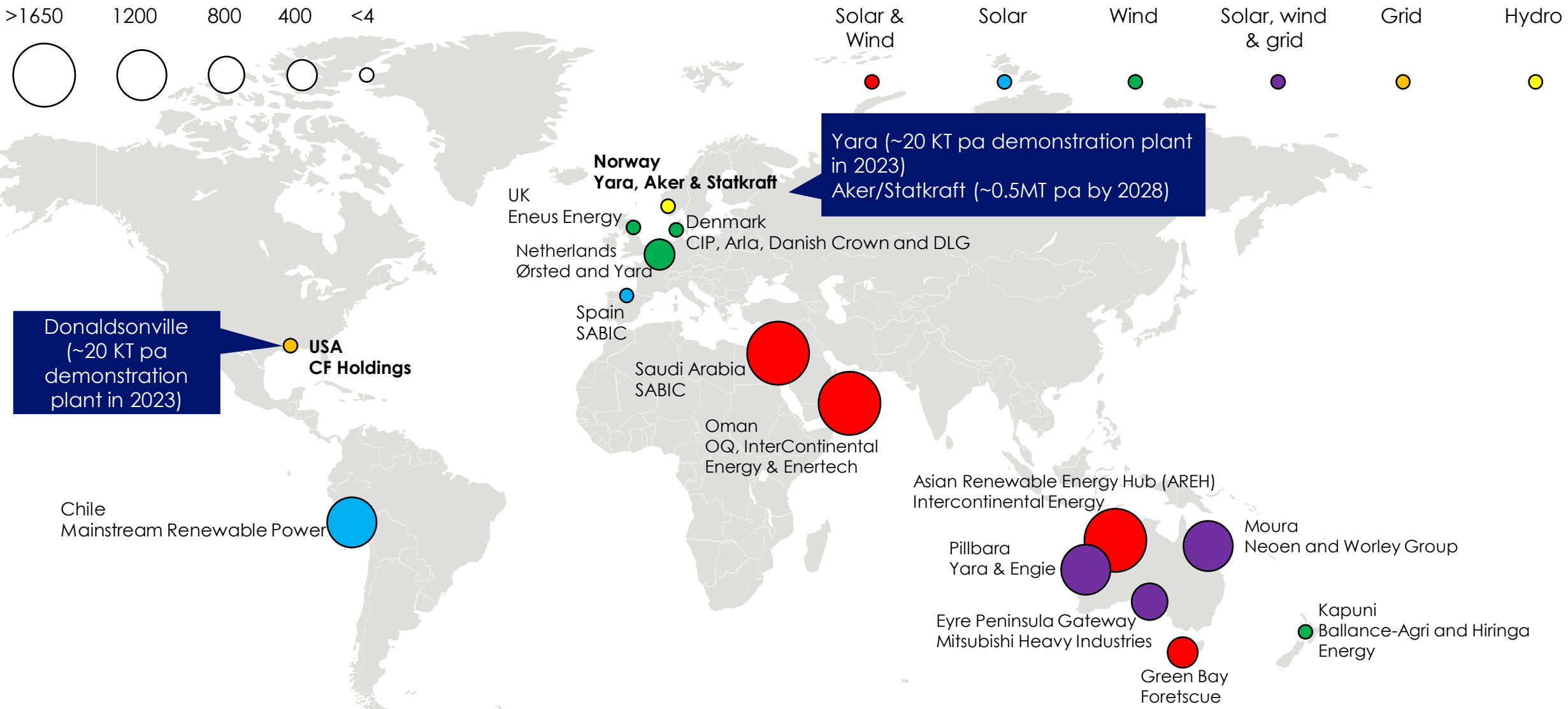
GREEN AMMONIA PLANTS BEING SCOPED ADD UP TO 15MT OF POTENTIAL SUPPLY, JUST UNDER 10% OF GLOBAL AMMONIA PRODUCTION

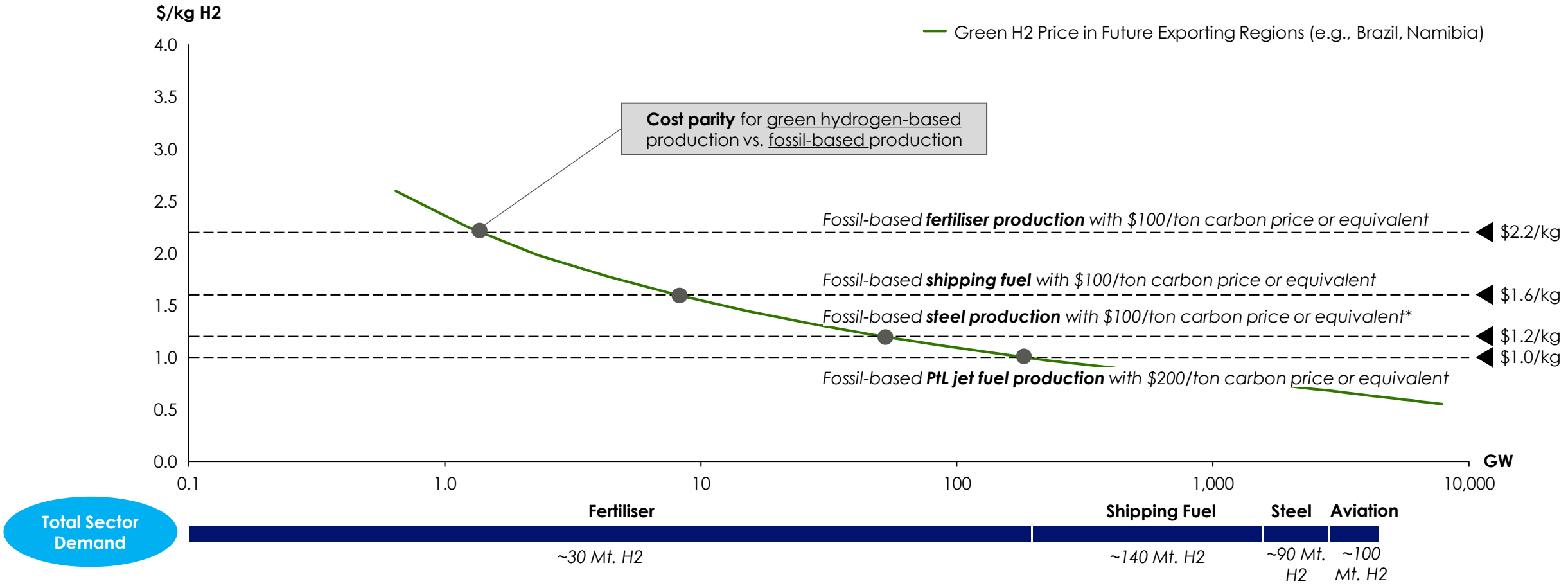


Source: Mission Possible Partnership – source data 2021

FERTILISER DEMAND FOR GREEN H2 COULD DRIVE SCALE ECONOMIES UNLOCKING COST PARITY IN OTHER HARD-TO-ABATE SECTORS

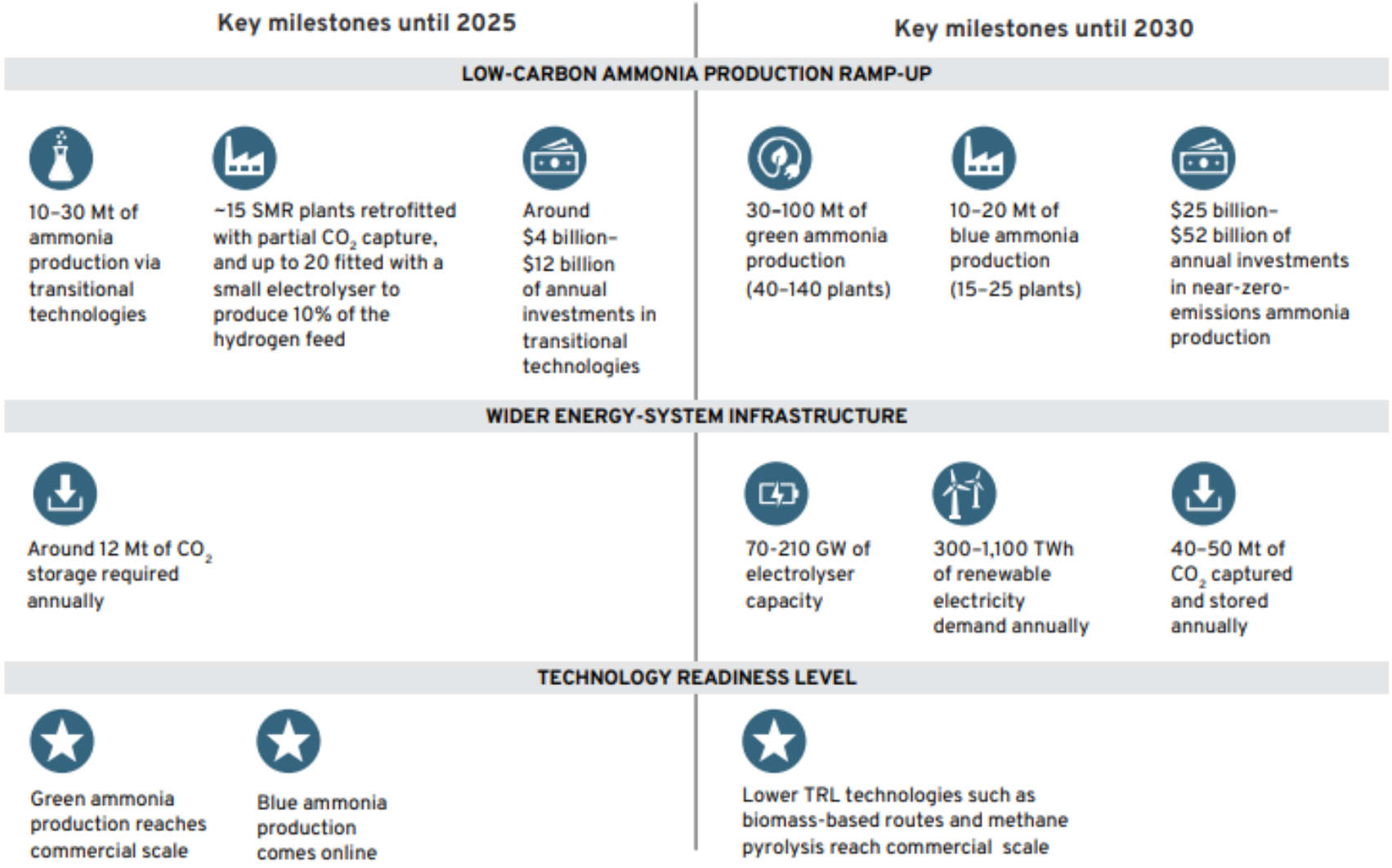
We estimate the price of electrolysers falls by ~18% for every doubling of capacity – so reaching scale in fertiliser helps tip other systems like fuel, steel, avaiation

Cumulative Installed Electrolyser Capacity vs. Green Hydrogen Production Cost



Note: * Across all major producing regions (EU, US, China India). Green hydrogen production – i) favourable scenario assumes average LCOE of PV and onshore wind of lowest 33% locations (falling from $22/MWh in 2020 to $10/MWh in 2050) and average scenarios assumes median LCOE from lowest 75% locations (falling from $39/MWh in 2020 to $17/MWh in 2050) from BloombergNEF forecasts, ii) additional 20% (favourable) and 10% (average) LCOE savings included due to directly connecting dedicated renewables to electrolyser, iii) 18 % learning rate for favourable & 13 % for average scenario. Electrolyser capacity utilization factor: 45%. Comparison to BloombergNEF most favourable ($0.55/kg) and average ($0.86/kg) and Hydrogen Council favourable (ca. $0.85/kg) and average (ca. $1.45/kg) in 2050.
Source: Systemiq Analysis based on [1] BloombergNEF (2021), Natural Gas Price Database; [2] BloombergNEF (2020), 2H 2020 LCOE Data Viewer; [3] BloombergNEF (2021), 1H2021 Hydrogen Levelized Cost Update; [4] Hydrogen Council (2021), Hydrogen Insights.

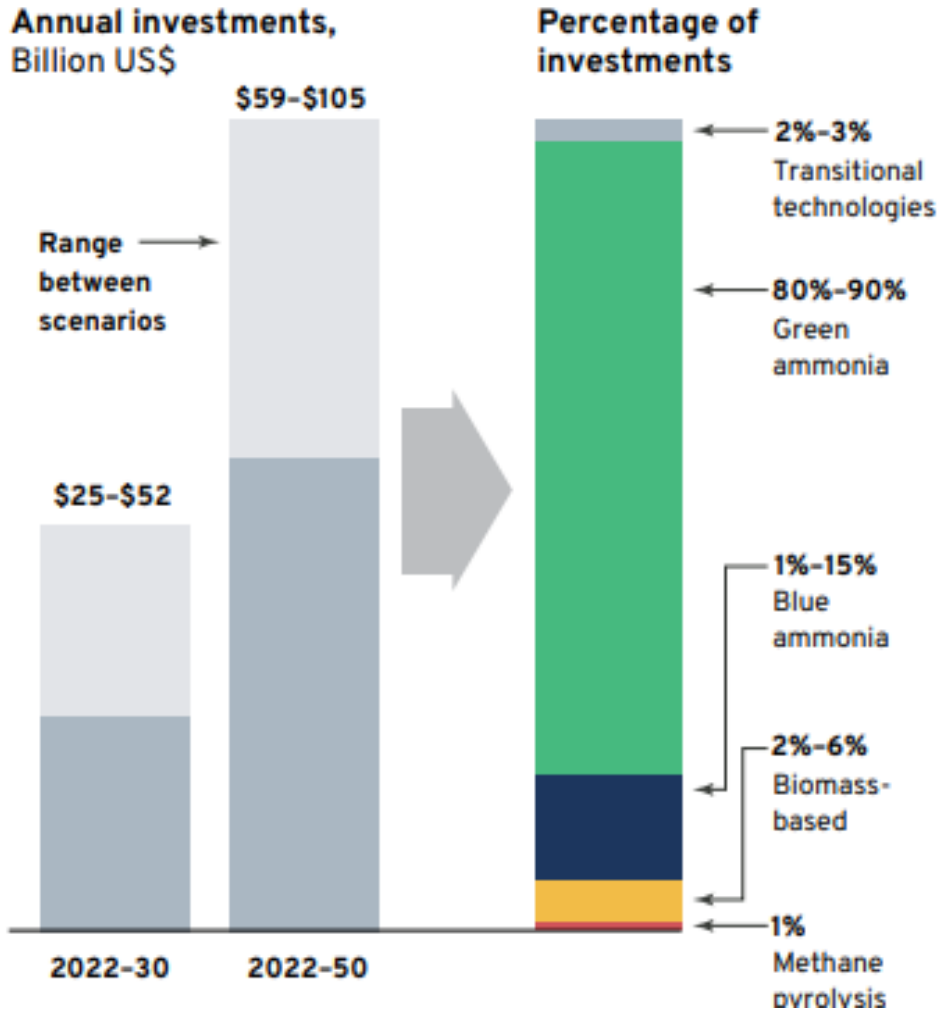
MILESTONES TO BE MET BY 2025 AND 2030



 Source: Making net zero ammonia possible

INVESTMENTS REQUIRED ARE IN THE RANGE OF 15-30% OF INDUSTRY REVENUE PER YEAR

Investments required by technology type



Comparators:

- Fertilizer market $200 billion pa
- Shipping fuel market ~$140 billion pa
- Global food market $10 trillion pa

Source: Making net zero ammonia possible, 2022

SYSTEMIQ

THANK YOU!

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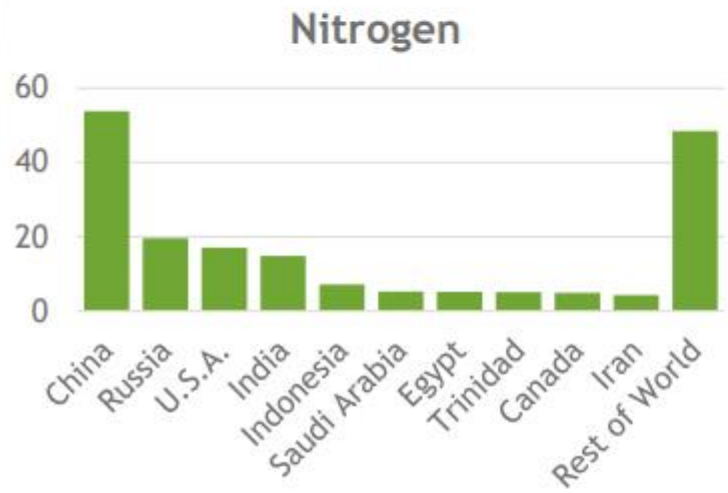
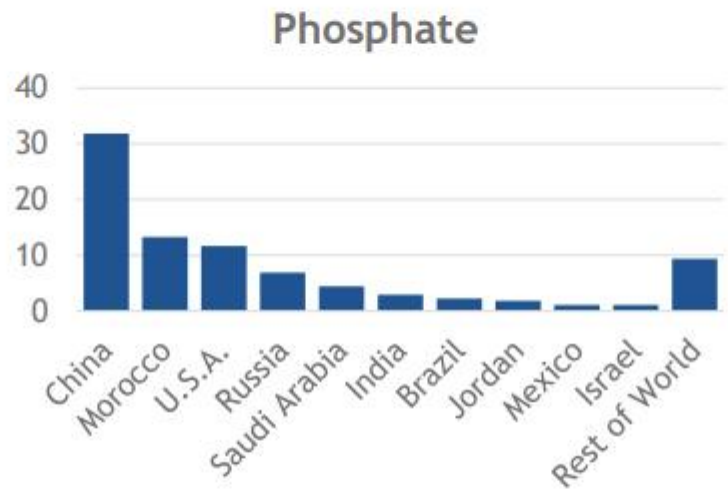
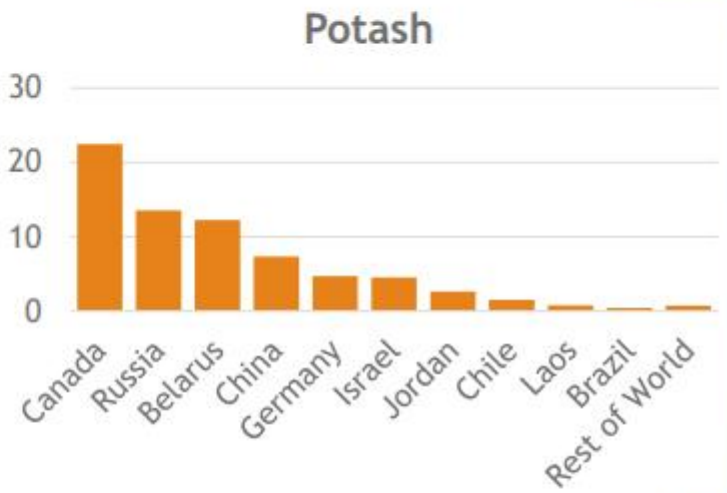
BACKUP PAGES IF NEEDED

Product market structure and price elasticity matters

Production by country, Mt product







Energy-intensive

Marginal producers in Europe

Crop price inelastic

Exposed to energy-derived products

Use correlated with affordability

40% of global trade from sanctions countries

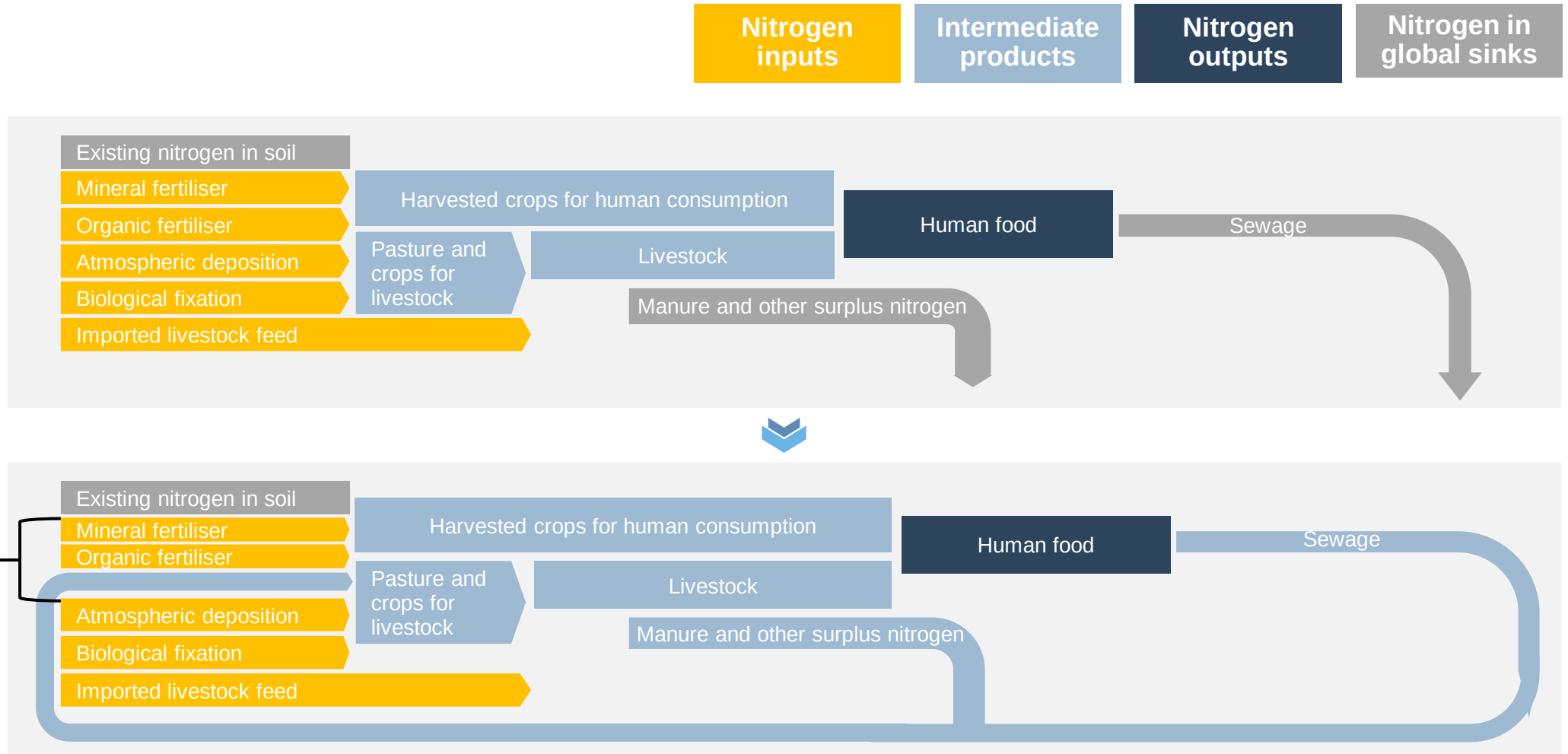
Use correlated with affordability, capped by availability

Source: IFA

ifa
INTERNATIONAL FERTILIZER ASSOCIATION
Helping to feed the world sustainably

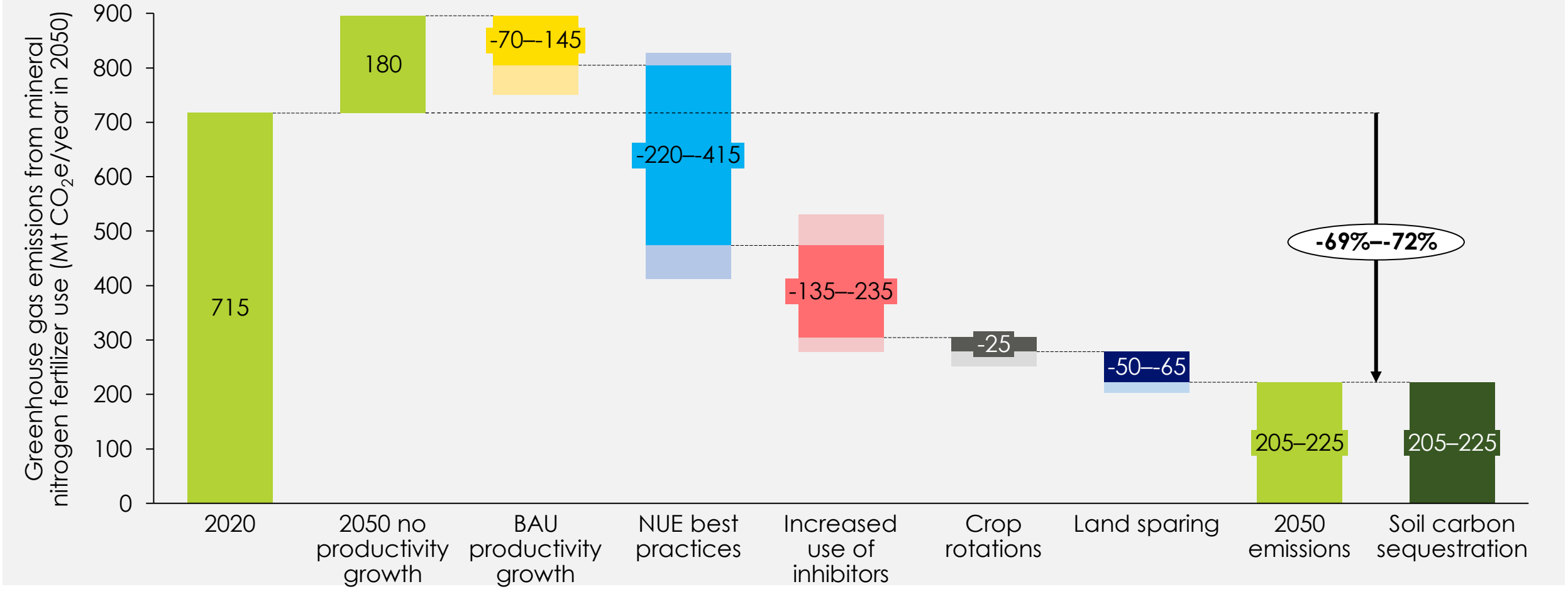
MAJOR GLOBAL FERTILIZER SUPPLIERS

Nutrient upcycling: Using these nutrients on farmland would raise regional NUE by reducing losses to global sinks



SCOPE 3 EMISSIONS FROM THE USE OF FERTILIZER CAN BE MORE THAN HALVED BY 2050 – MOSTLY UNDER INFLUENCE OF THE SECTOR

Decarbonising mineral fertilizer use Scope 3 - Annual GHG emissions - Mt CO_2e

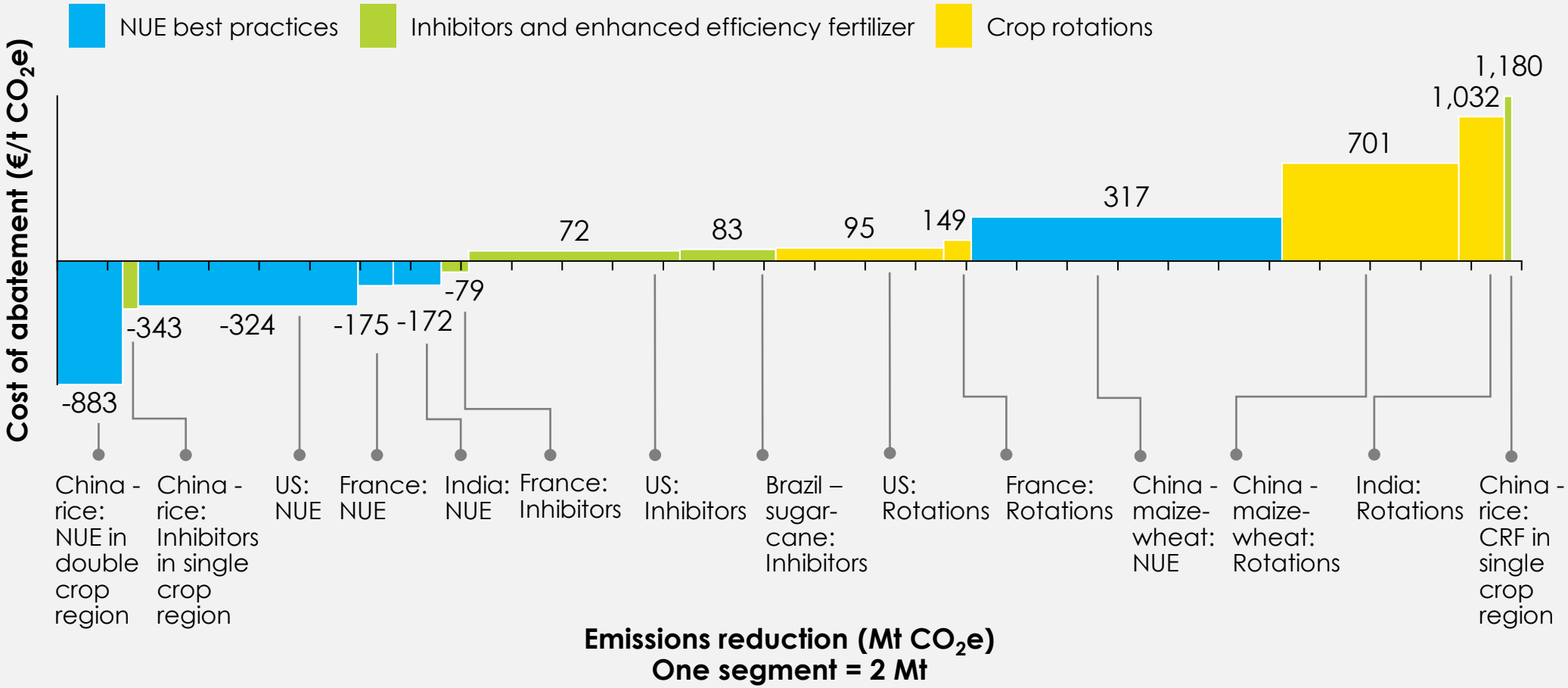


NB: Numbers may not sum perfectly due to rounding, BAU = Business as usual. NUE = Nitrogen Use Efficiency.

Source: Systemiq and IFA(2022)

REGIONAL DEEP DIVES SUGGEST ~25% OF MEASURES ARE COST SAVING FOR FARMERS

Marginal abatement cost curve – Mineral fertilizer scope 3 decarbonisation



- Illustrative examples for six regional case studies only (US, 2x China, France, India, Brazil)
- Net implementation cost for farmers, based on long term, pre-2020 pricing
- Average abatement cost = €26/t CO_2e

The regional analysis is not comparable with the analysis on slide 4. The regional analysis is relative to a 2015-2020 baseline, depending on data availability, and has different underlying assumptions. Source: SYSTEMIQ analysis

TIPPING POINTS: GREEN AMMONIA FOR FERTILISERS

TIPPING POINT

- Tipping point possible after **1st wave of greens ammonia plants for fertilisers developed** (~50 plants, ~45-50 Mt production p.a.*) to kick-off large-scale adoption – 2nd wave to benefit from de-risked investment.
- This can close the **initial cost premium for** green ammonia vs. grey ammonia through scale economies in H2 production, targeting **<$500/ton green ammonia with hydrogen price of <$2.2/kg H2.** $500/t is competitive with grey ammonia under pre-crisis natural gas prices + **carbon price or equivalent of ~$100/ton** CO2 applied.
- High confidence in strength of reinforcing feedback loops: Learning curves & economies of scale: as more electrolysers are deployed; we experience 18% cost reduction per doubling of output, and lower costs encourage greater deployment

	TARGET CONDITIONS TO TRIGGER TIPPING POINT	PROGRESS**
AFFORDABILITY	• Achieve **cost parity for green ammonia** vs conventional grey ammonia – at **$200-400/ton**[2] (20-year long-term average: currently $1,000–$1,500/ton[2] due to current high gas prices)	• Current green ammonia production costs of **>$600-900/ton uncompetitive with grey ammonia**[3] • **Cost parity of green ammonia vs. grey ammonia** within reach by 2024 in favourable locations through combination of **green H2 price <$2.2/kg** (vs. ~$2.5-4.5/kg today) and subject to carbon price or equivalent subsidy of **$100/ton CO2 across several major producing regions**[2]
ATTRACTIVENESS	• N/A – grey and green ammonia are **chemically identical.** There is **no difference in downstream use** of grey or green ammonia for fertiliser input.	• N/A
ACCESSIBILITY	• Mass Market: large **expansion in renewables and hydrogen production** capacity to drive down costs; focussing on favourable locations with low-cost renewables • Scale **trading infrastructure** required to transport from **new producers** to demand centres*** i.e., more ammonia storage at ports + more ammonia-carrying ships.	• Can be **transported and stored** relatively cheaply and easily, but infrastructure expansion required in new producing regions (e.g., Namibia, Mauritania) and expanded infrastructure in importing regions (e.g., Europe)

Notes: * 1Mtpa plants, running at ~95% CUF ; **Affordability: green - no cost disadvantage, amber - point of parity is <5Y away, red – point of parity is >5Y away (incl. policy support measures equivalent to <$100/ton CO2). Attractiveness + accessibility: green – no barrier to tipping point, amber – currently impeding tipping point but strong progress underway, red – currently impeding tipping point with limited progress to date ; ** Grey ammonia is currently produced near to points of use with only 10% of global production being exported[4]. As new supply chains emerge in low-cost producer regions that do not always equate to demand centers, greater quantities of green ammonia will need to be shipped to fertilizer manufacturing plants. Supporting trade flows from new producers (e.g., Namibia + Mauritania) to consumer markets (e.g., Europe) requires a scale up in infrastructure such as storage tanks and import infrastructure.

Sources: [1] IRENA (2020), Green Hydrogen Cost Reduction: Scaling Up Electrolysers to meet the 1.5°c Climate Goal; [2] Mission Possible Partnership (2022), Making 1.5-Aligned Ammonia Possible ; [3] Argus (2021), Inside Fertiliser Analytics: Green Ammonia ; [4] Yara (2021), Renewable Hydrogen and Ammonia Production ; [5] IEA (2021), Ammonia Technology Roadmap