# Circularity in Climate Logistics

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*Kühne Logistics University*
*Hamburg*

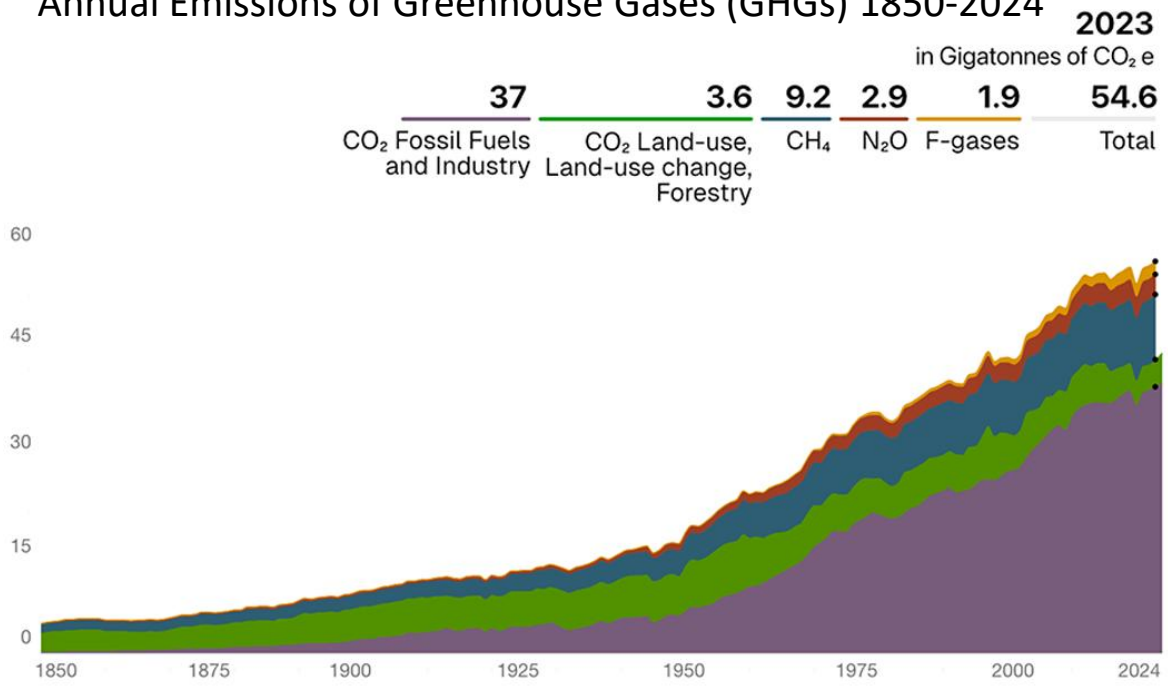
29th International Symposium on Logistics
*Wiesbaden*

7 July 2025

Circularity in Climate Logistics

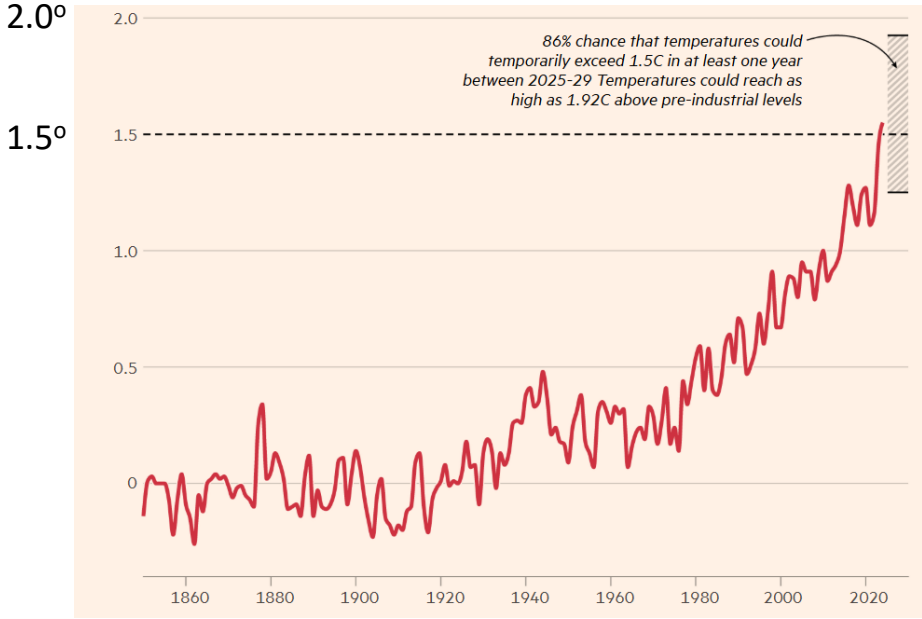
# Brief Update on the Climate Science I

## Annual Emissions of Greenhouse Gases (GHGs) 1850-2024

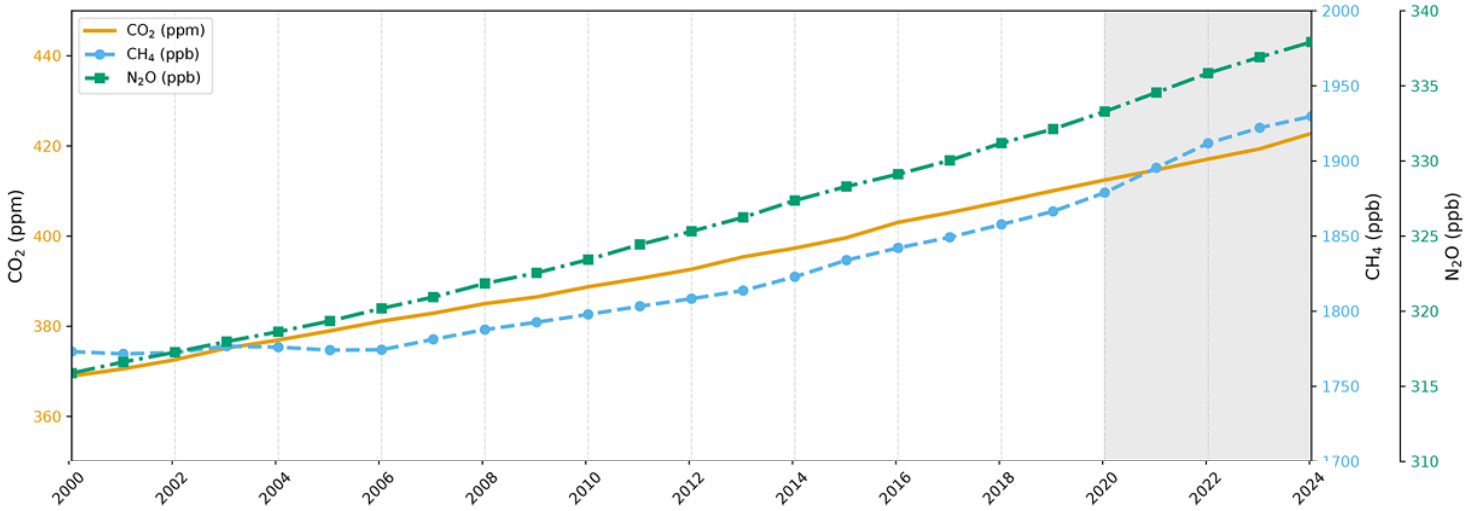



## Global Annual Mean Temperature Anomalies

relative to 1850-1900 baseline




## Atmospheric Concentration of GHGs 2000-2024





Hansen et al (2025)

- rate of climate change accelerating
- ability of natural and geophysical systems to absorb $CO_2$ is degrading

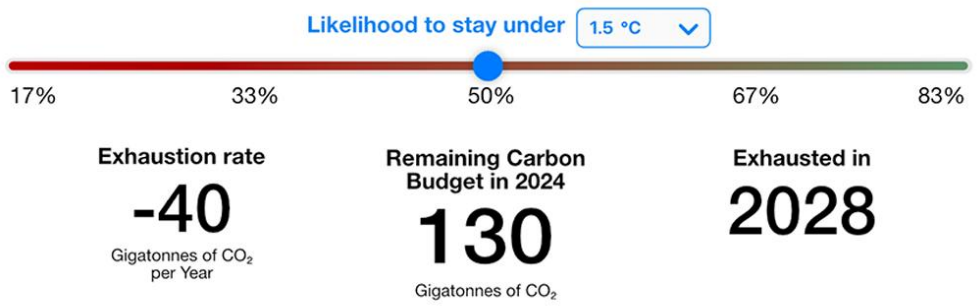
# Brief Update on the Climate Science II – *and Climate Politics*

'*We are on the brink of an irreversible climate disaster. This is a global emergency beyond any doubt. Much of the fabric of life on Earth is imperilled. We are stepping into a critical and unpredictable new phase of the climate crisis.*'

2024 State of the Climate Report (Oct 2024)

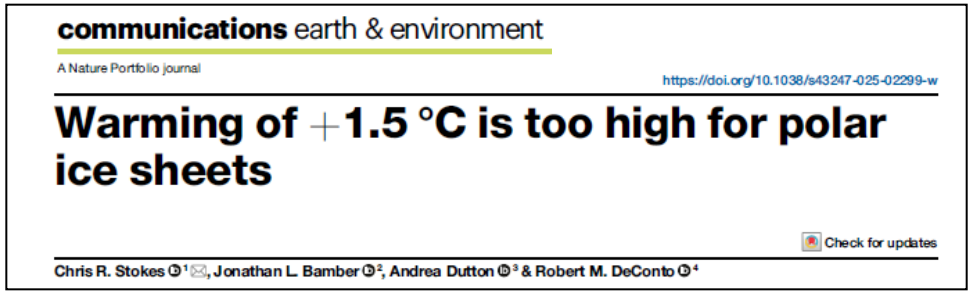
Climate Change Tracker

remaining carbon budget for 1.5°C temperature increase




Budget for 83% probability of staying within 1.5°C global temperature increase: **30 Gtonnes of $CO_2$**

**exhausted this year**


communications earth & environment

A Nature Portfolio journal

https://doi.org/10.1038/s43247-025-02299-w

**Warming of +1.5 °C is too high for polar ice sheets**

Check for updates

Chris R. Stokes, Jonathan L. Bamber, Andrea Dutton & Robert M. DeConto

Physical evidence of climate change steadily accumulates

WMO: 5-fold increase in weather disasters since 1970

Valencia Oct 2024


Lee Zeldin, head of US Environmental Protection Agency

*'driving a dagger straight into the heart of the climate change religion'*

US government assault on climate science

Politics and Government News

The Associated Press · Washington · March 12, 2025 11:22 AM · **UPDATED:** MARCH 12, 2025 11:49 AM

**The U.S. agency that monitors weather will cut another 1,000 jobs, AP sources say**

**Tracking sea ice is 'early warning system' for global heating – but the US is halting data sharing**

political, financial and industrial 'push-back' on decarbonisation efforts

# Climate Logistics: *Multiple Roles of Logistics in the Climate Crisis*

GHG emissions

logistics

Cause

Decarboniser

Beneficiary

Victim

Geo-engineer

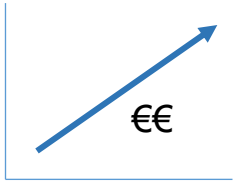
CLIMATE CRISIS

Remover

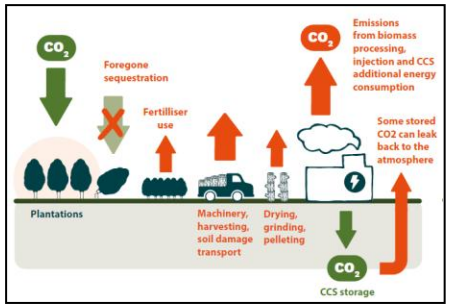
Adaptor

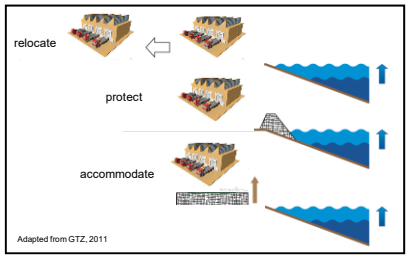
Facilitator

Rescuer



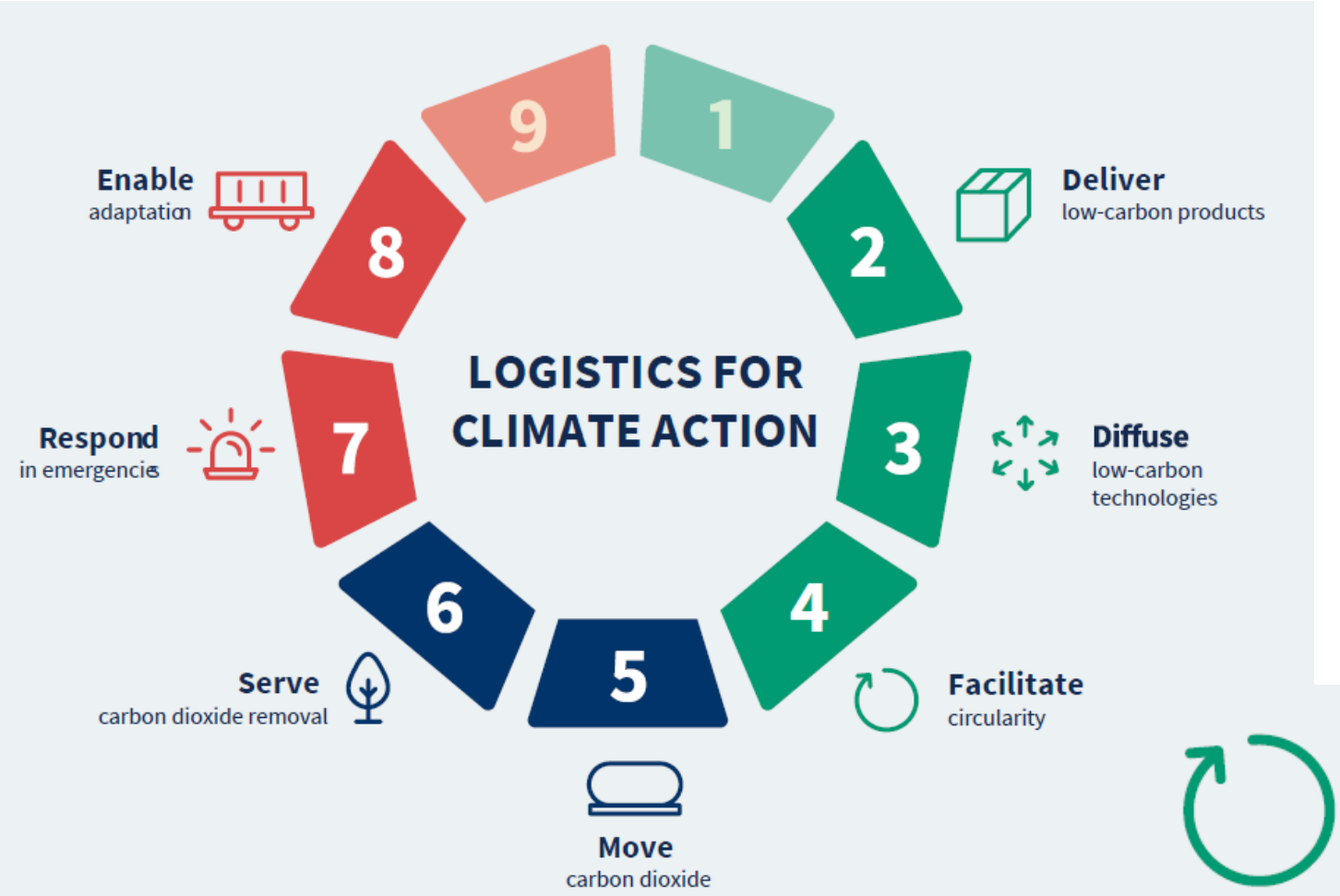



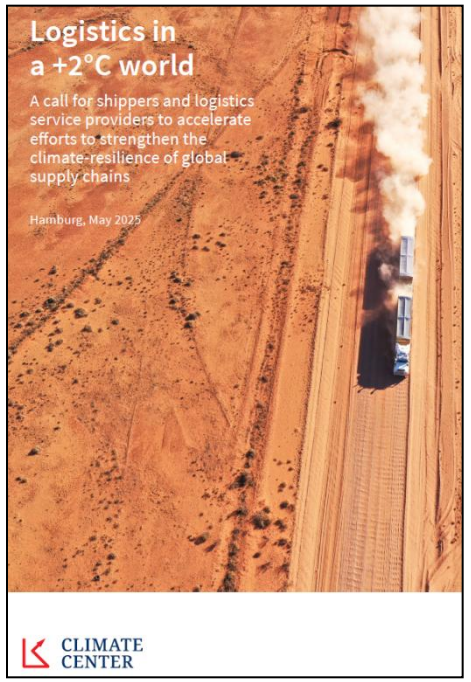




**Logistics and climate: an assessment of logistics' multiple roles in the climate crisis**

Alan C. McKinnon

# Kuehne Climate Centre perspective



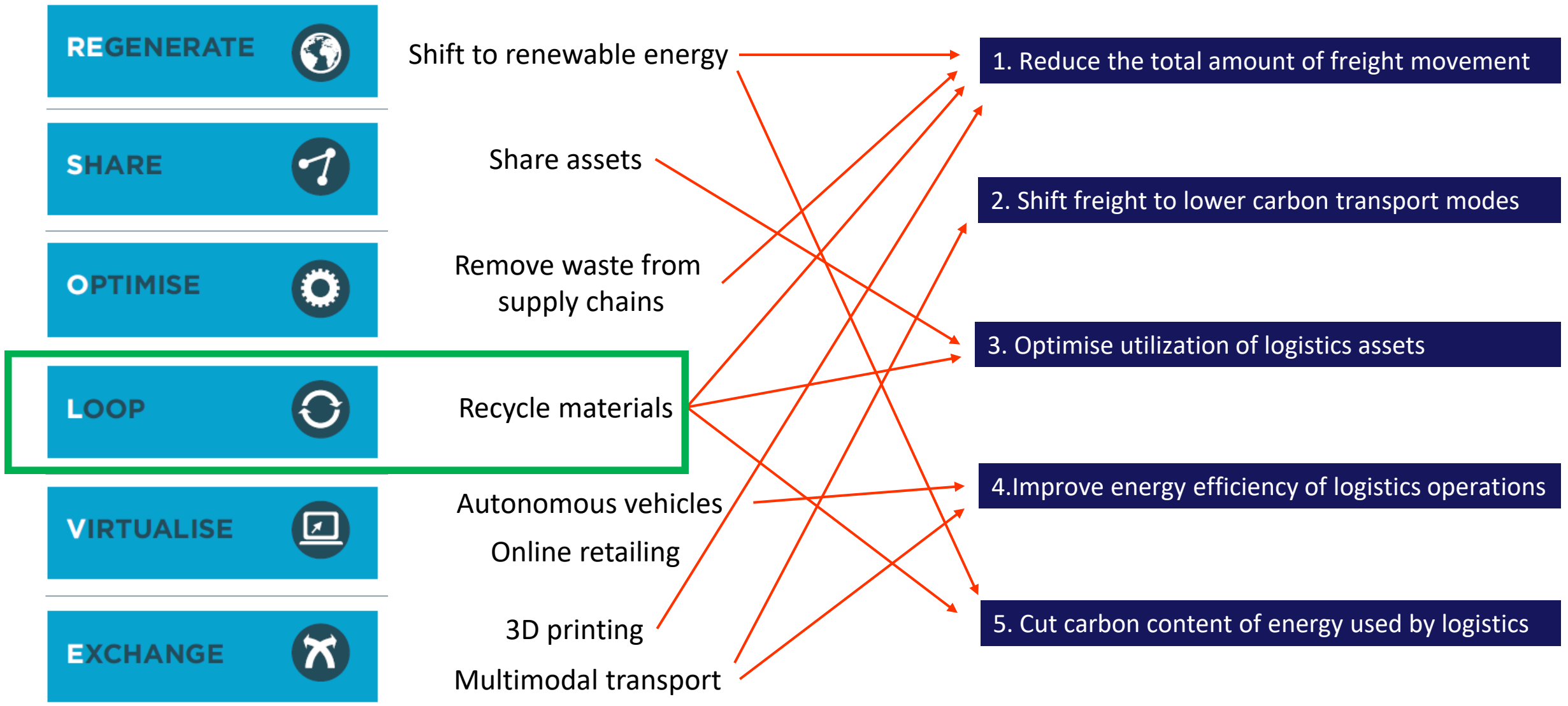




**Facilitate**
circularity

Need broader review of the relevance of circularity to climate logistics

Circularity: *ReSOLVE framework*

Logistics Decarbonisation: *5 Lever Framework*




Source: Ellen MacArthur Foundation / McKinsey 2015

Source: McKinnon 2018

# Impact of Circularity on the Freight Transport Intensity of the Global Economy

Does circularity localize supply chains?

*Google AI*: Yes, circularity can contribute to localizing supply chains. By focusing on reuse, recycling, and remanufacturing, circular practices can **reduce the need for long-distance sourcing** of raw materials and components, potentially **shortening and regionalizing supply chains**.

International Transport Forum

*'.. the potential impact of increased trade regionalisation, spurred by geopolitical reasons and increasing **economic circularity**, could also **limit freight growth for all modes**. A more resource-efficient **circular economy** can therefore **contribute to a less resource-intensive transport sector.'***

No attempts to measure the net effect of circularity on freight traffic volumes and the related emissions at national or global scales

Analysis complicated by relationship between circularity and other supply chain megatrends.

**Circular Economy and Deglobalization**

Enterprise Strategy for a Changing World

PETER C. EVANS

NOV 11, 2024

*'Companies are finding that their efforts to close material loops and extend product lifecycles are simultaneously **reducing their dependence on global supply chains** and mitigating risks associated with trade barriers and resource scarcity.'*

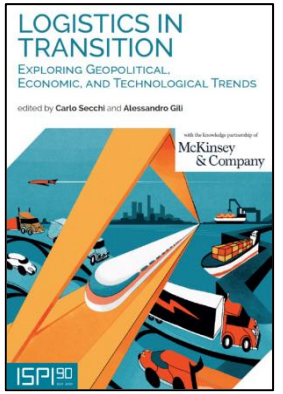
examples of companies using circularity strategies to localise their supply chains

PHILIPS

RENAULT

STELLANTIS

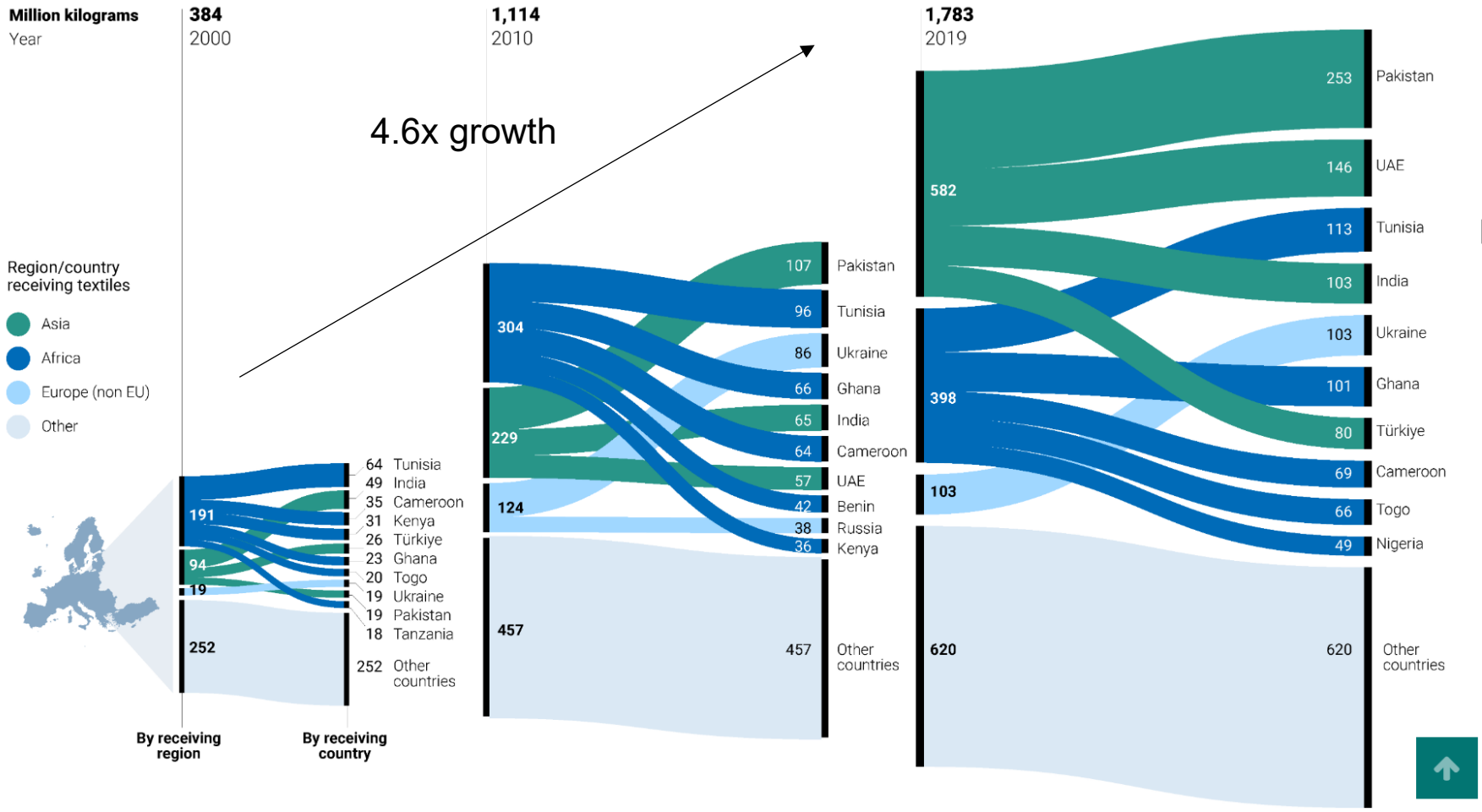
BMW




4. **Deglobalization: Could It Help to Decarbonize Global Supply Chains?**

   Alan McKinnon

# Growth and Widening Geographical Dispersal of EU Used-Textile Exports 2000-2019




EU used textile exports to Africa
60% for re-use
40% for waste disposal

Growth of international trade in used products – *mixture of products for recycling, re-use and waste disposal*

Circularity should reduce the waste content – *but at expense of increasing international flows for recycling*

# Liberalisation of the Global Market in Secondary Materials for Re-use and Recycling

WORLD TRADE ORGANIZATION

**TRADE POLICIES FOR A CIRCULAR ECONOMY:**

**WHAT CAN WE LEARN FROM WTO EXPERIENCE?**

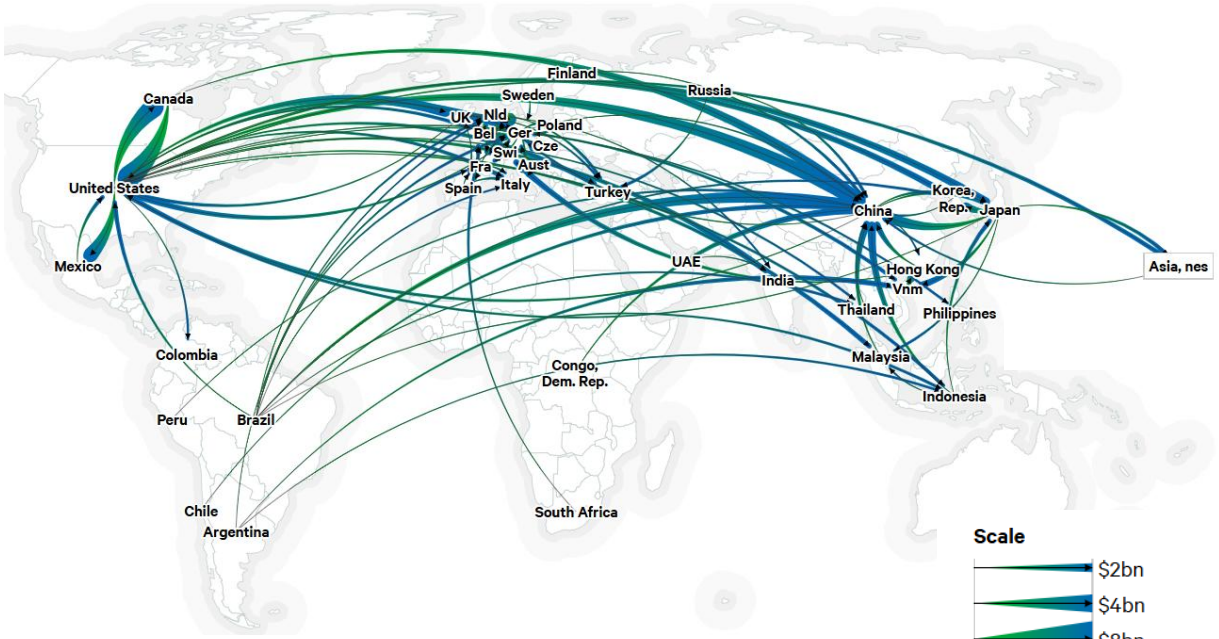
OECD BETTER POLICIES FOR BETTER LIVES

**Synergies and trade-offs in the transition to a Resource-Efficient and Circular Economy**

*'opening and facilitating trade in goods, components, materials and services related to key circular economy activities (such as reuse, repair, refurbishment, remanufacturing and recycling) would help to ensure that these activities happen in the best possible locations in terms of cost, quality, skills and other location-specific advantages'*

- conflicts with the traditional view of circularity as promoting localisation and a net reduction in freight traffic volumes

already a substantial and growing trade in secondary materials




Global trade in 'secondary materials' (2020) $ billion

**Is 3D Printing a Threat to Global Trade?**

**The Trade Effects You Didn't Hear About**

*'The results counter widespread views that 3D printing will shorten supply chains and reduce trade'*

THE WORLD BANK

# Effect of Circularity on the Potential Impact of other Logistics Decarbonisation Levers

## Shift freight to lower carbon transport modes

- '*multimodal transport*' key element in ReSOLVE framework

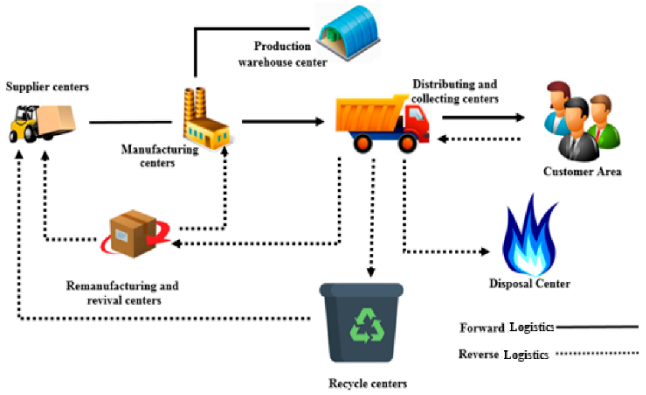
- not clear how lower carbon transport modes can capture a larger share of freight in circular supply chains

## Optimise utilization of logistics assets

more balanced freight flows in a circular economy

should be easier to obtain backloads and reduce empty running

but requires integration / coordination of forward and reverse channels




improved vehicle loading in closed loop supply chains conditional on several factors – *similar to other supply chains (Harris et al, 2024)*

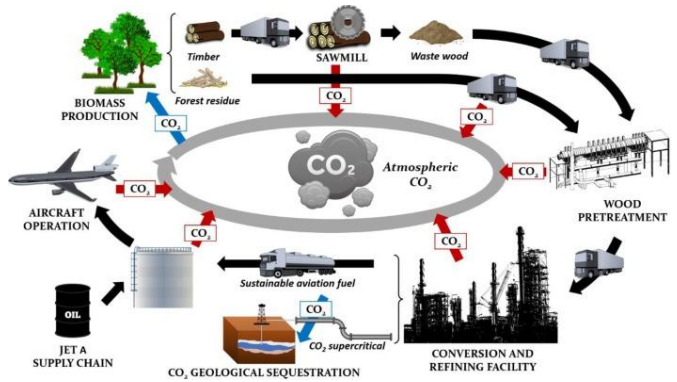
## Improve energy efficiency of logistics operations

- '*autonomous vehicles*' key element in ReSOLVE framework
- likely to achieve higher energy efficiency

- energy efficiency benefits of preventive maintenance

## Cut carbon content of energy used by logistics

- transition from fossil to renewable energy
- recycled material and biomass in low carbon fuel e.g. HVO, SAF

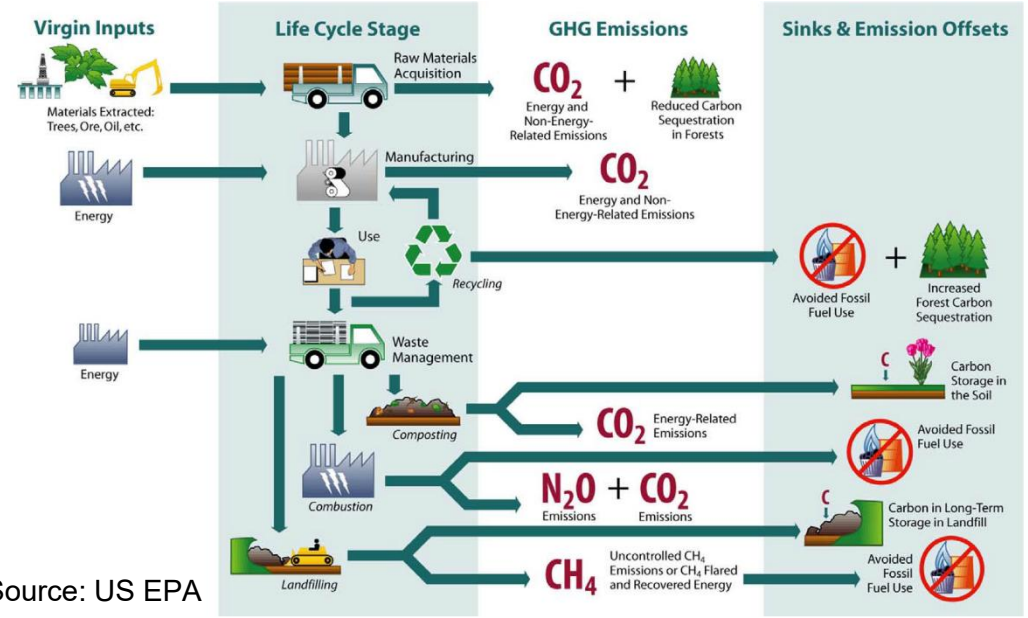



- longer-term reconditioning and recycling of truck batteries

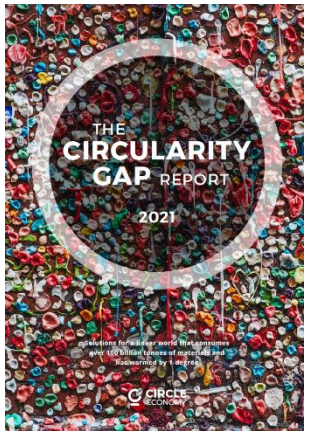
# Logistics as a FACILITATOR

## In the Creation of a more Circular and Lower-Carbon Economy

Material Life Cycle and Greenhouse Gas Emissions




Source: US EPA



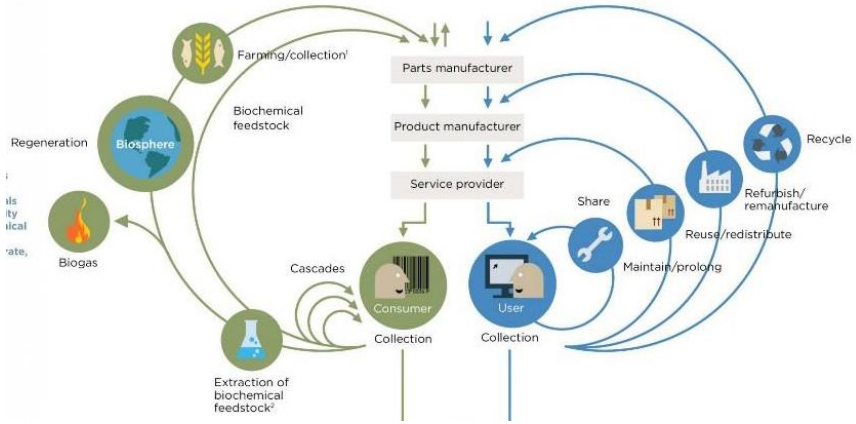


70% of greenhouse gas emissions are linked to the handling and use of materials

Cutting material use by 28% could cut GHG emissions by 39%

Decline in circularity of world economy from 9.1% (2018) to 6.9% (2025)

Logistics is fundamental to re-use, recycling and remanufacturing processes




- reconfiguring logistics systems
- increasing capacity of reverse logistics channels
- designing products for reverse logistics
- deploying new technologies in returns process
- **decarbonising reverse logistics operations**

overcoming barriers to the adoption of reverse logistics

| | |
|---|---|
| 1 | Lack of top management initiation |
| 2 | Lack of visibility for recycling/ reuse |
| 3 | Difficulty in deciding 3PL to partner with |
| 4 | Lack of resources |
| 5 | Difficulty in segregating waste/ returns at collection points |
| 6 | Less Return on investment |
| 7 | Lack of government policies on recycling |
| 8 | Lack of KPIs to track the reverse logistics activities |
| 9 | Lack of regulatory compliances |
| 10 | Demand uncertainty for return products |
| 11 | Lack of strategic plans for returns |
| 12 | Lack of information on RL for stakeholders |
| 13 | Lack of support from other supply chain members |

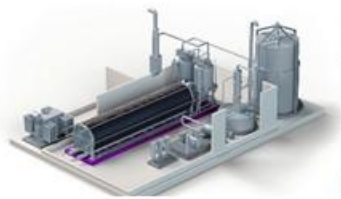
Source: Sonar et al (2024)

Logistics as a FACILITATOR

# Logistics of Transitioning from Fossil to Renewable Energy

## Creation of new renewable energy infrastructure






**renewal energy infrastructure more material-intensive in *tonnes per megawatt***

| | steel | concrete |
|---|---|---|
| wind | 460 | 870 |
| coal | 100 | 270 |
| nuclear | 40 | 195 |
| natural gas | 5 | 25 |

Source: Petersen (2006)

2030 forecast: 60m tonnes of 'structural materials' needed for wind turbines in EU

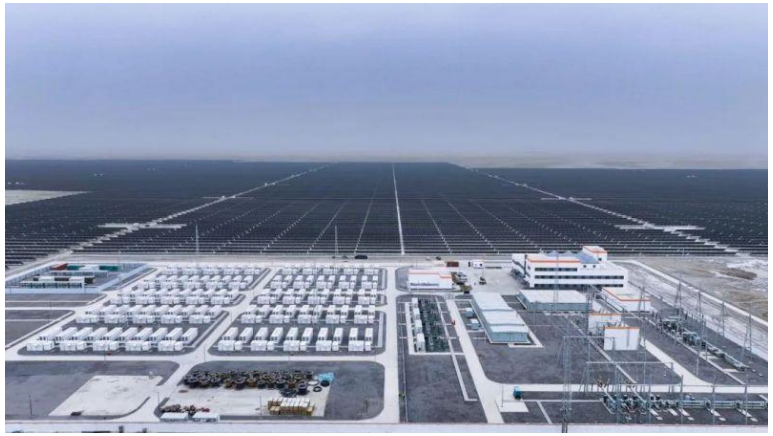
**generation of renewable energy is more geographically dispersed than generation of 'fossil' energy**

*Germany 2022*: 1055 wind turbines to produce as much electrical power as the country's largest coal-fired power station

China (2022)

390 GW of solar power

800,000 sq.km of land



**complex global supply chains for renewable energy materials and equipment (*lithium, cobalt, batteries, solar panels etc.*)**

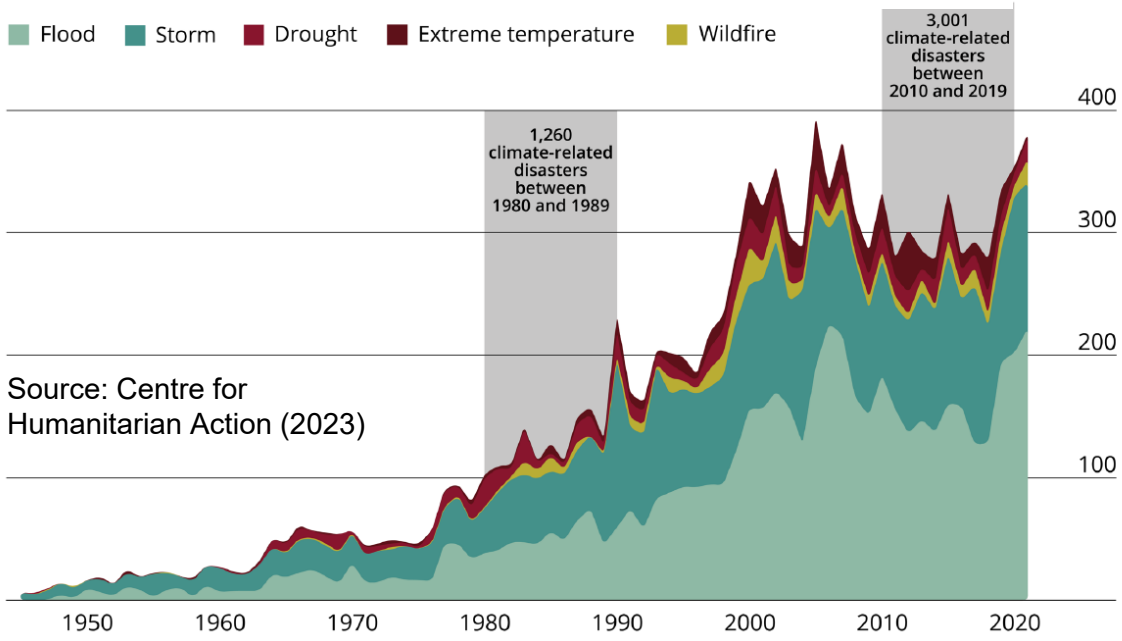
**much renewable power generation equipment '*out-of-gauge*' requiring specialist transport and handling**

# Logistics as a RESCUER

## Providing Humanitarian Relief to Communities Suffering Climate-related Disasters

*Logistics costs represent 60-80% of expenditure on humanitarian aid*

Climate-related disasters 1950-2020



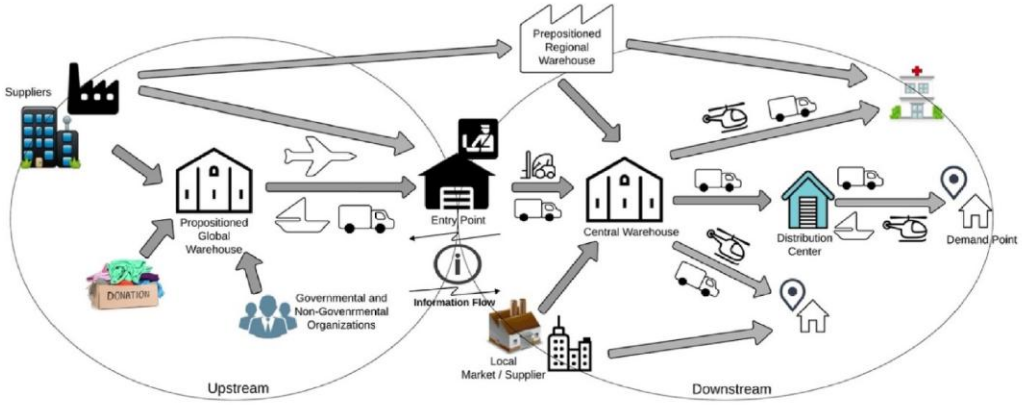

Source: Centre for Humanitarian Action (2023)

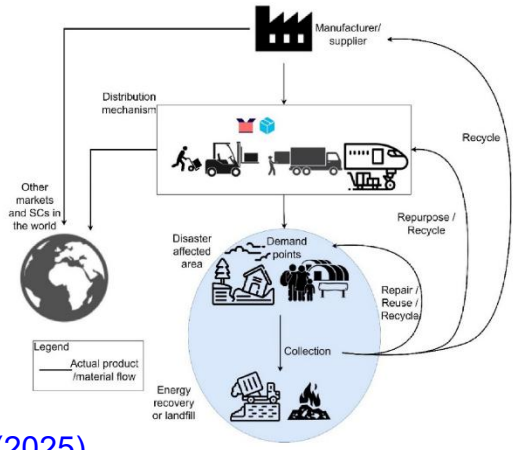
INTERNATIONAL FEDERATION

In 2019 **94.7 million people** required humanitarian aid as a result of weather-related disasters

Forecast that **200 million** will need such aid annually as a result of climate change by 2050

from linear to circular humanitarian supply chains →




source: Baharmand (2025)

application of circularity to humanitarian logistics transport fleets

LOGISTICS CLUSTER WREC DRC DANISH REFUGEE COUNCIL IFRC Save the Children WFP

**How to make your fleet more circular and environmentally sustainable**

Circular fleet management aligns with circular economy principles, emphasizing responsible sourcing, efficiency, eco-friendly technologies, optimized utilization, and focuses on minimizing waste throughout the vehicle lifecycle.

# Pursuit of **Net Zero:** *key role of carbon sequestration*

NET ZERO TRACKER

Proportion of Global GDP covered by Net Zero pledges: 2019 **16%** → 2024 **93%**

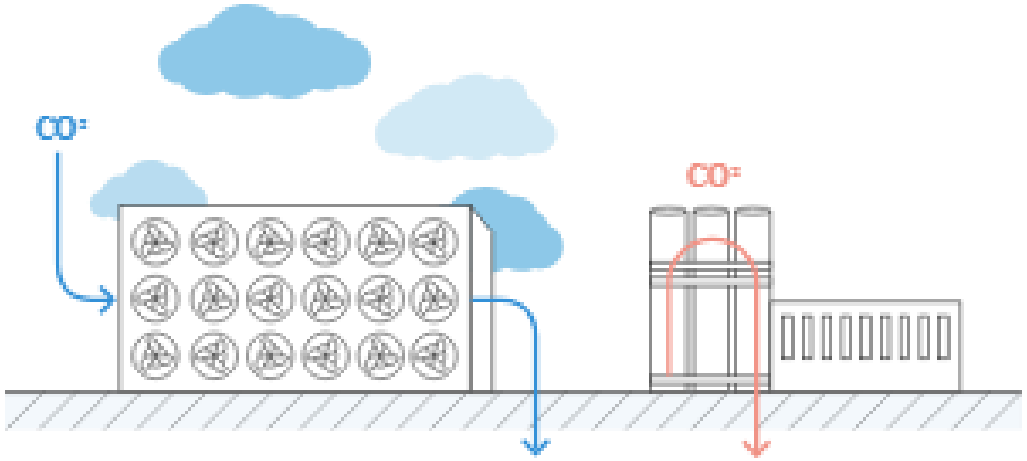
**Net Zero**: reduce emissions as much as possible by **mitigation** measures with any surplus balanced by the removal of $CO_2$ from the atmosphere by carbon **sequestration** processes

European Scientific Advisory Board on Climate Change

EU **Residual Gross Emissions** in 2050: between **390 and 1165 million tonnes of $CO_{2e}$** will need to be removed **annually** from the atmosphere. **(Germany emitted 674 Mt of $CO_{2e}$ in 2023)**

carbon sequestration
carbon dioxide removal
negative emissions

carbon capture and storage
point-source carbon capture




**concentration of $CO_2$ in the atmosphere**

426 parts per million

**0.04% of the air**

*'Removing $CO_2$ from ambient air is a thermodynamic slog'* Barnard (2025)

**typical concentrations of $CO_2$ in exhaust / chimney gases**

| | |
|---|---|
| gas boilers: | 4% |
| coal-fired power plants: | 10-12% |
| chemical plants: | 10% |
| cement kilns / blast furnaces: | 10-40% |
| liquid natural gas plants: | 90-100% |

**Concept of net zero is a dangerous trap** *'Within a few decades, we will need to transform our civilisation from one that currently pumps out 40 billion tons of carbon dioxide into the atmosphere each year, to one that produces a net removal of tens of billions. Net zero has licensed a recklessly cavalier "burn now, pay later" approach which has seen carbon emissions continue to soar'* (Dyke et al, 2021)

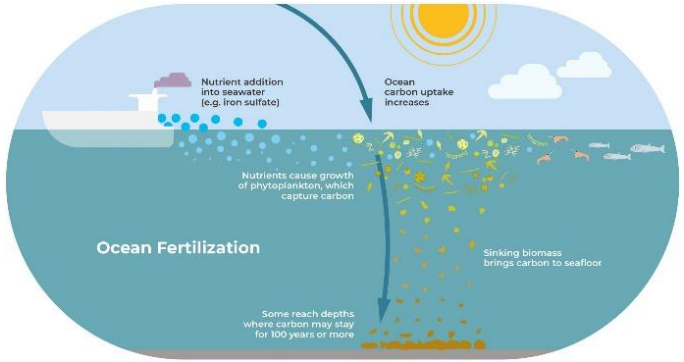
Logistics as a REMOVER

# Main Methods of Carbon Sequestration

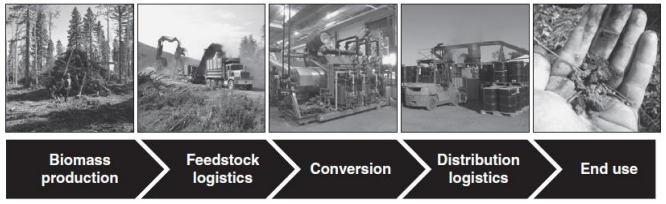
## Nature-based methods

### Afforestation

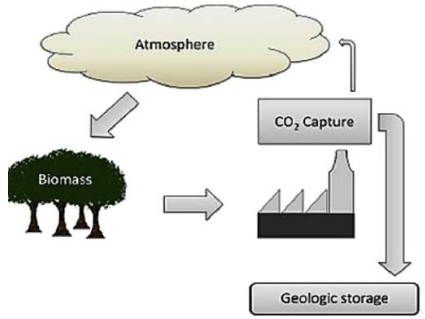
### Ocean fertilisation




## Hybrid nature-based and engineered sequestration




Biochar (charcoal-like substance produced by the pyrolysis of biomass, scattered on the land)

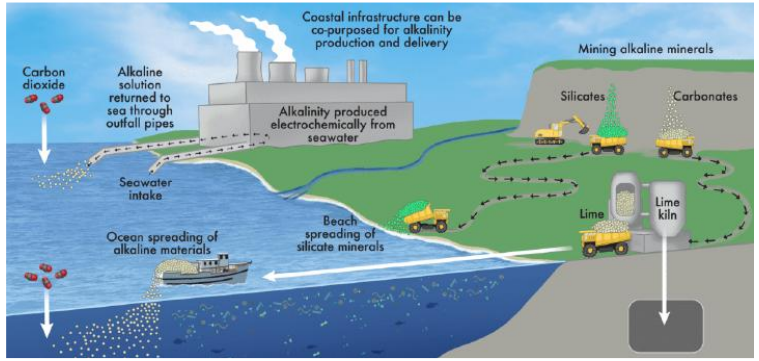



Bio-energy carbon capture and storage BECCS

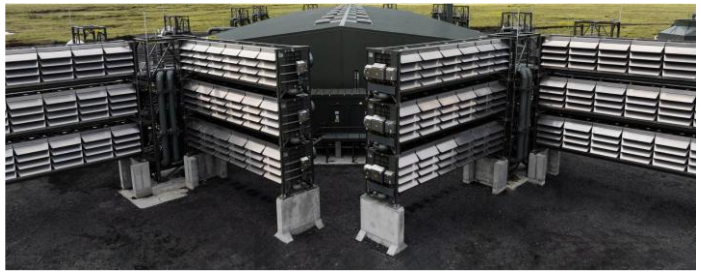
## Mechanical-chemical methods

'*engineered $CO_2$ removal*'

### Enhanced rock weathering / Ocean Alkalinity Enhancement (OAE)




### Direct air carbon capture and storage (DACCS)



Climeworks Mammoth plant, Iceland

logistical requirements vary widely, many as yet unquantified, but likely to be very freight transport-intensive

# Carbon Sequestration: *Existential Circularity?*

INTERFACE FOCUS

royalsocietypublishing.org/journal/rsfs

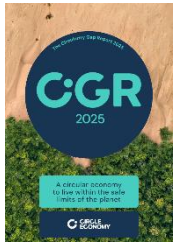
Should carbon removal be treated as waste management? Lessons from the cultural history of waste

Holly Jean Buck

European Commission

Horizon
The EU Research & Innovation Magazine

How carbon-intensive industries can scale up CO2 recycling




Flows of fossil fuel '*are inherently non-circular: as they are combusted, they release greenhouse gas emissions into the atmosphere. Once released, these emissions are* ***almost impossible*** *to recapture or reuse at the speed, scope and scale necessary to limit warming to 1.5-degrees*'

nature reviews earth & environment

Controversies of carbon dioxide removal

Institute for Energy Economics and Financial Analysis

Carbon capture: a decarbonisation pipe dream



**criticisms of carbon capture and storage**

technological complexity

very high cost

diversion of attention and resources from carbon mitigation

gives fossil fuel industry 'license' to continue exploitation

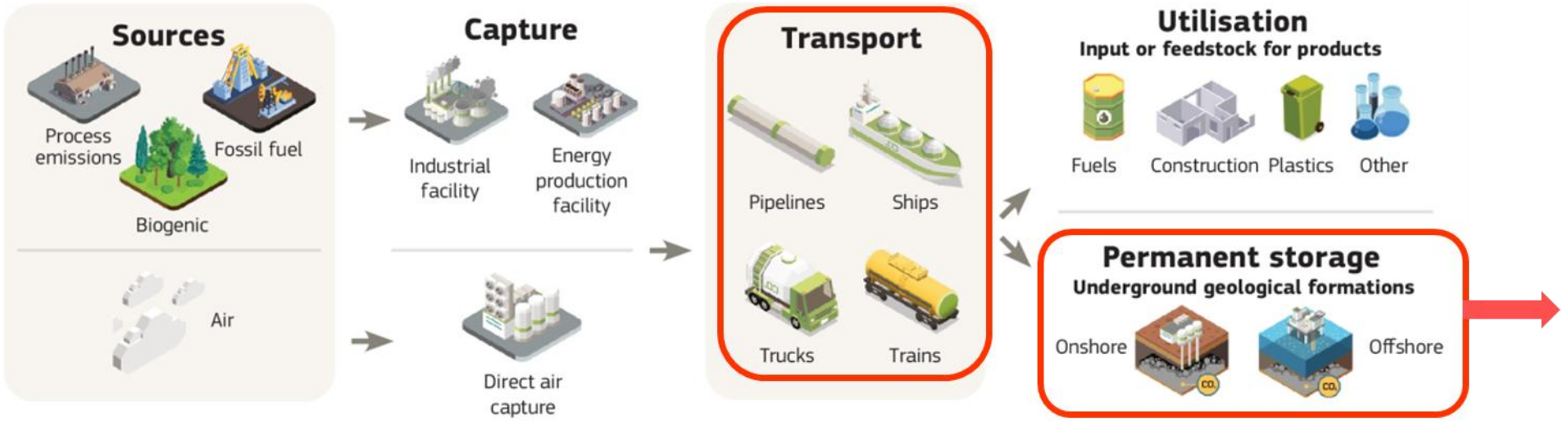
excessive energy requirements

past record of meeting targets very poor

scale of the logistical challenge

But huge amounts of CCS now factored into climate models for Net Zero

# Logistical Demands of Carbon Capture and Storage



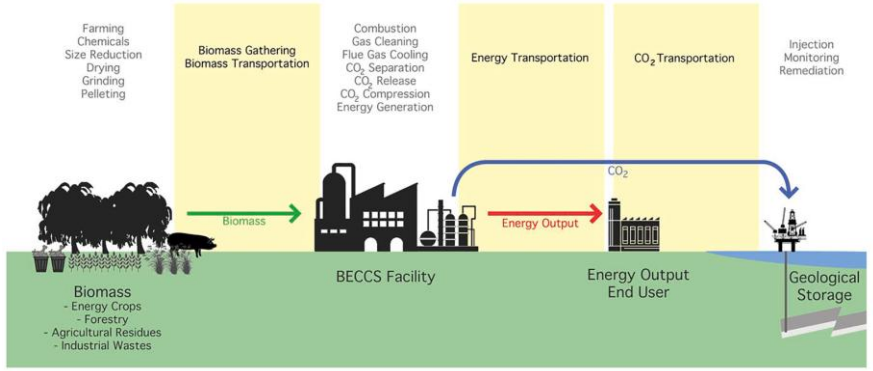

EU Carbon Capture and Storage targets (million tonnes):

2030 **50**
2040 **280**
2050 **450**

Carbon optimal bioenergy with carbon capture and storage supply chain modelling: How far is too far?

Muir Freer [a,*], Clair Gough [a], Andrew Welfle [a,b], Amanda Lea-Langton [a]

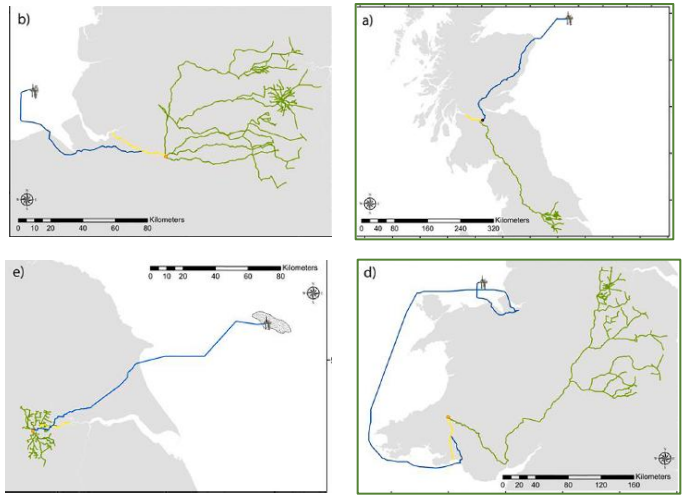
[a] Tyndall Centre, Department of Mechanical, Aerospace and Civil Engineering, University of Manchester, Oxford Road, Manchester M13 9PL, UK
[b] UK Supergen Bioenergy Hub, Birmingham, B4 7ET, UK




## Carbon Navigation System

Optimise BECCS supply chains by:

- types, amounts and sources of biomass
- type of conversion facility
- types and amount of energy produced
- output of $CO_2$
- methods of transport




sequestration efficiency – *a new optimisation criterion for supply chain modelling*

# Freight Transport Requirements of Carbon Dioxide Removal: *new business opportunities for logistics providers?*

**infrastructure**

construction of $CO_2$ removal and storage facilities

electrical grid infrastructure for CDR facilities

pipeline networks for captured $CO_2$

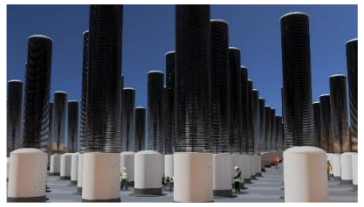
EU will need **15,000-19,000 km transport network** by 2050 to move $CO_2$ between '***100-120 potential $CO_2$ capture clusters and about 100 storage sites.'***

**equipment**

supply chains for production of $CO_2$ removal devices and vessels and vehicles to transport captured $CO_2$

Climeworks

*'mechanical trees'*
Prof Klaus Lackner




**inputs**

solvents and sorbents for the $CO_2$ removal process
biomass for Bio Energy Carbon Capture and Storage BECCS
biochar, enhanced weathering rocks, ocean fertilisation chemicals

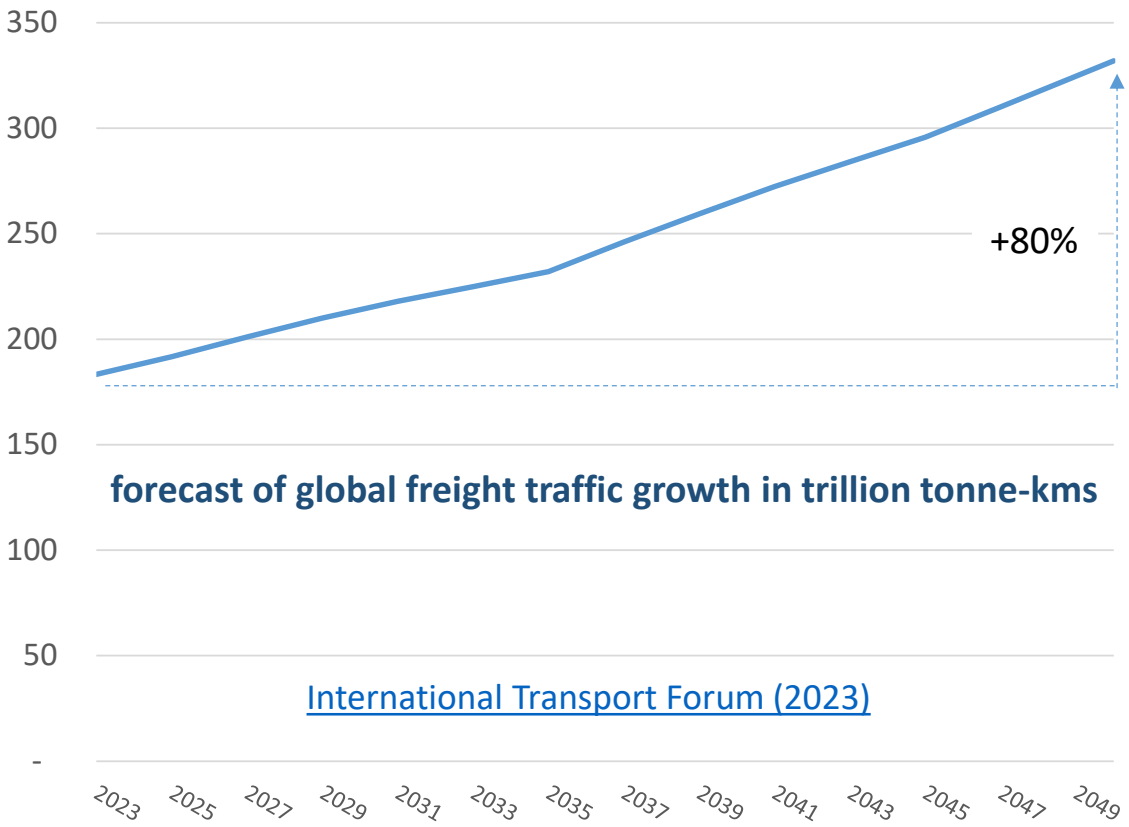
removal of 30 billion tonnes of $CO_2$ might need **22 billion tonnes of ammonia**, **6.9 billion tonnes of sodium hydroxide** and **4.4 billion tonnes of ethylene oxide**

**outputs**

captured $CO_2$ for storage or use in chemical processes
by-products of the sequestration process

moved mainly by pipeline, but with some use of '*non-pipeline modes*' (ships and rail)

# Long-term Growth in Demand for Climate Logistics Services




**forecast of global freight traffic growth in trillion tonne-kms**

International Transport Forum (2023)

**forecast excludes additional freight movement generated by:**

creation of renewable energy infrastructure

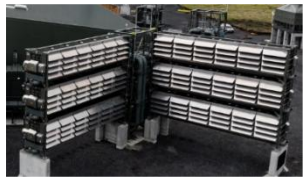
climate change adaptation

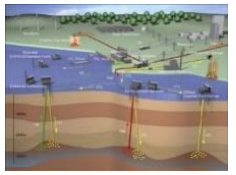
population resettlement

rebuilding after climate disasters

climate-related humanitarian logistics

carbon capture and storage





To what extent might wide adoption of economic circularity constrain the growth of freight movement?

With or without such a constraint, *Climate Logistics* is likely to substantially increase the total amount of freight movement

Feasibility of reducing the carbon intensity of freight movement sufficiently to compensate for this traffic growth?

Should '*climate logistics*' be exempted from Net Zero targets, given longer to reach them and / or be awarded carbon credits for the key role it will play in the overall management of the climate crisis?

# Professor Alan McKinnon

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**Logistics and climate: an assessment of logistics' multiple roles in the climate crisis**

Alan C. McKinnon

CarbonBrief
CLEAR ON CLIMATE

Guest post: The forgotten role of logistics in achieving net-zero

THE LOGISTICS BLOG

Circularity in Climate Logistics