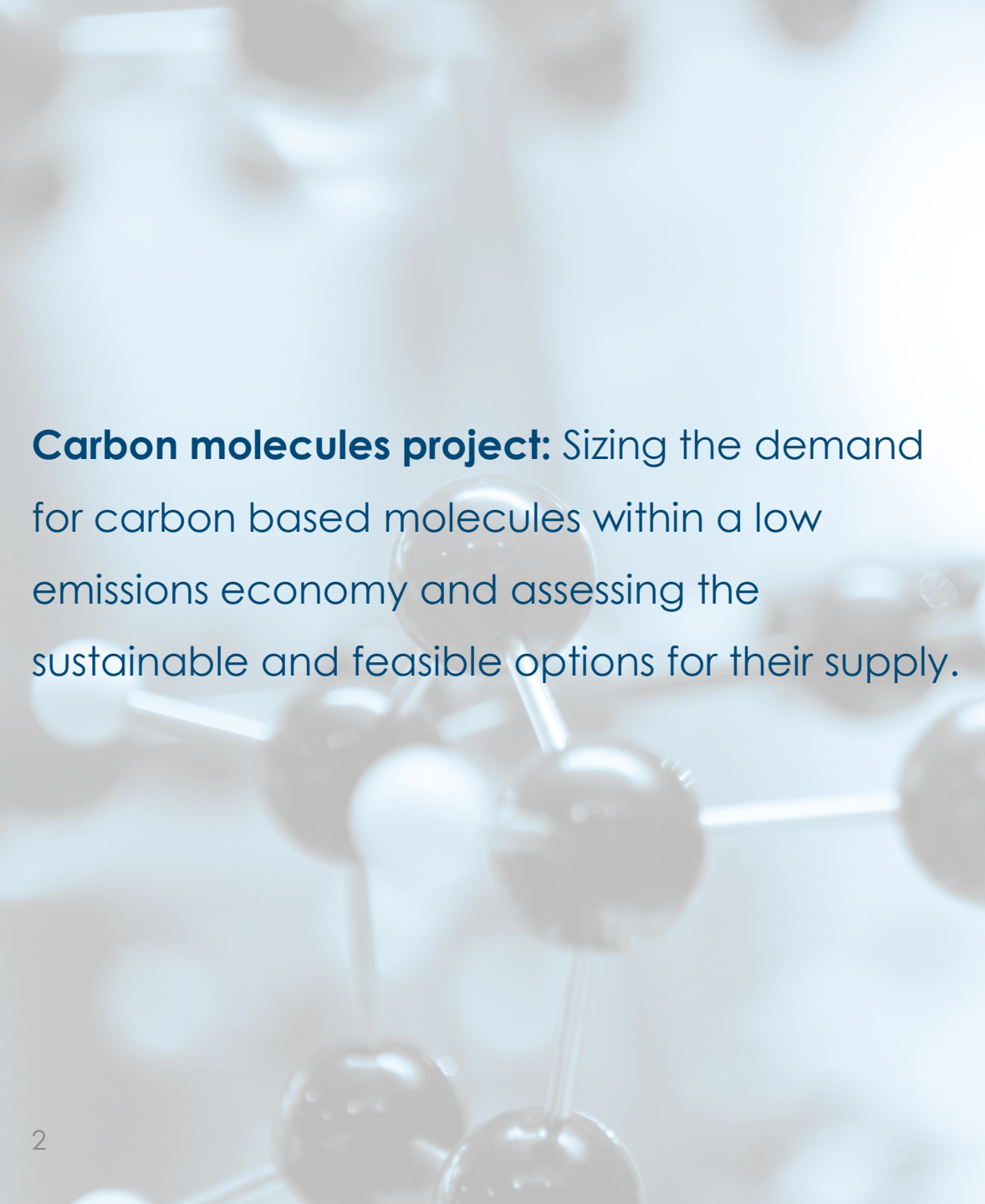




Energy
Transitions
Commission

Low Carbon Molecules

ETC Representatives Meeting
15th May 2025



Carbon molecules project: Sizing the demand for carbon based molecules within a low emissions economy and assessing the sustainable and feasible options for their supply.

Aim:

Shape the narrative and conversation around low-carbon emission molecules in the lead-up to COP30

Organised in four phases / questions

1. How large a role can and should direct electrification play in a zero emission economy?
2. The role of hydrogen and non-carbon H₂ derivatives
3. The potential to recycle and reuse carbon molecules
4. Sources of primary carbon: costs and sustainability and end-of life carbon *Our topic today* management

Phase 3: Sources of primary carbon: costs and sustainability

Integration in broader carbon molecule project

Having understood how maximum electrification and circularity of carbon to reduce reliance on primary carbon molecules, the last phase of work focuses on how we can meet the remaining demand for carbon molecules and manage end of life carbon

	2024		2025	
	Q4	Q1	Q2	Q3
Workplan	<p>Phase 1A How large can and should the role of direct electrification be in a zero-emission economy</p> <p>Phase 1B The role of hydrogen and derivatives (i.e., ammonia) in a zero-emission economy?</p>	<p>Phase 2 The potential to recycle and reuse carbon molecules</p>	<p>Phase 3 Sources of primary carbon: costs and sustainability and end-of life carbon management</p>	<p>Phase 4 Report production and communication campaign running into COP30</p>
Deliverables	<ul style="list-style-type: none"> A 5-pager published externally A series of short innovation briefs for publication 	<ul style="list-style-type: none"> A 5-pager published externally Report chapter Innovation brief(s) 	<ul style="list-style-type: none"> A 5-pager published externally Report chapter Innovation brief(s) 1-2 workshop with ETC reps/ commissioners 	<ul style="list-style-type: none"> Publication of the ETC report ahead of COP A series of short innovation briefs for publication Workshop Report reviews Report launch at COP
Key interactions	<ul style="list-style-type: none"> 1-2 workshops with ETC Commissioners 	<ul style="list-style-type: none"> 1-2 workshop with ETC reps/ commissioners 	<ul style="list-style-type: none"> 1-2 workshop with ETC reps/ commissioners 	<ul style="list-style-type: none"> Workshop Report reviews Report launch at COP



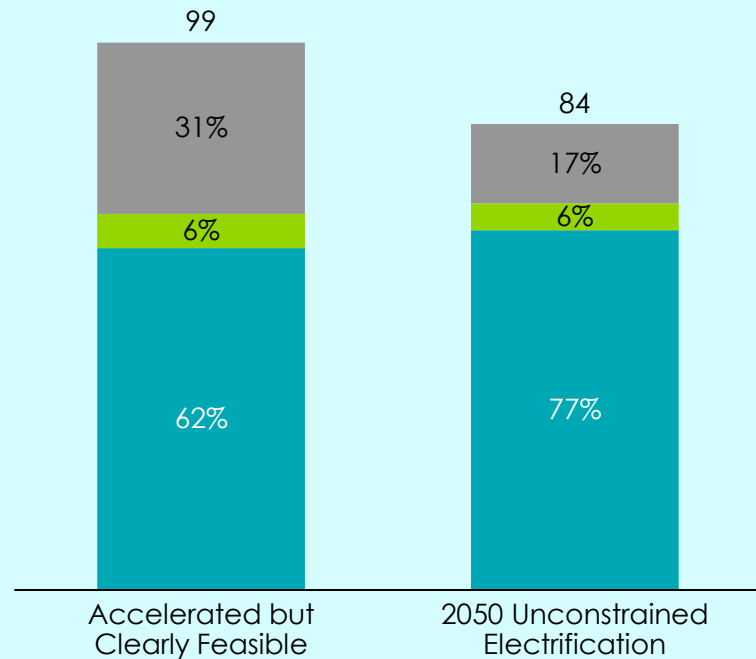
Outputs of the first two phases of work inform phase 3 analysis

Phase 1 How much can we reduce carbon energy by maximising electrification



Final Energy Demand for ETC's ACF scenario in 2050 Thousand of TWh

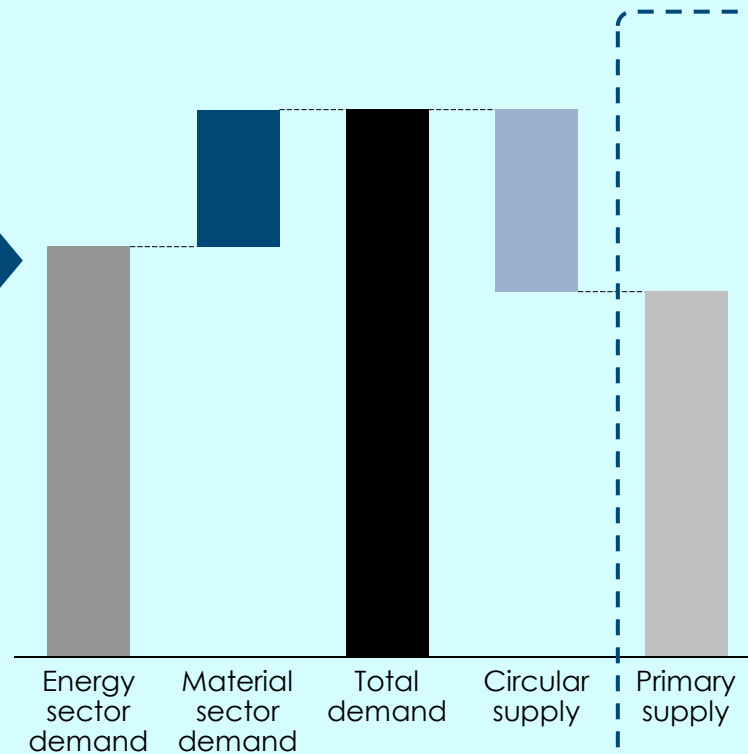
Carbon based fuels Electricity and other renewables
H2 and e-ammonia



Phase 2 What is total carbon demand and how much of it can be circular



Carbon demand and supply, 2050 Gigatons of carbon (C)

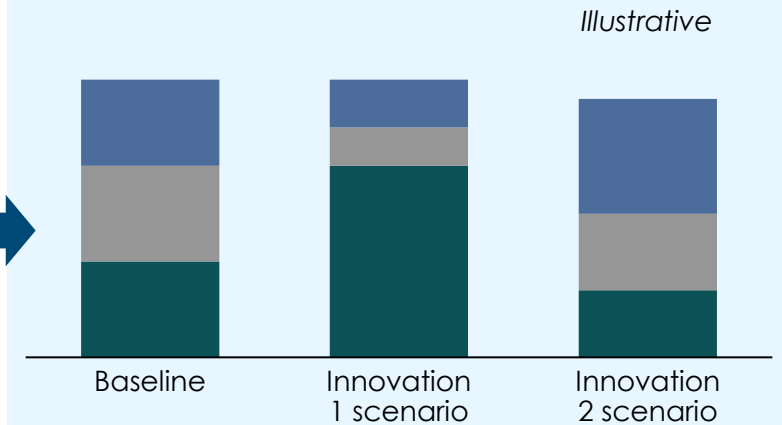


Phase 3 How do we sustainably source primary carbon & manage carbon at end of life



Scenarios for sourcing primary carbon supply Gigatons of carbon (C)

Atmospheric/Oceanic Ground Biomass



Plus – system trade-offs using cross-phase outputs

Examples conclusions

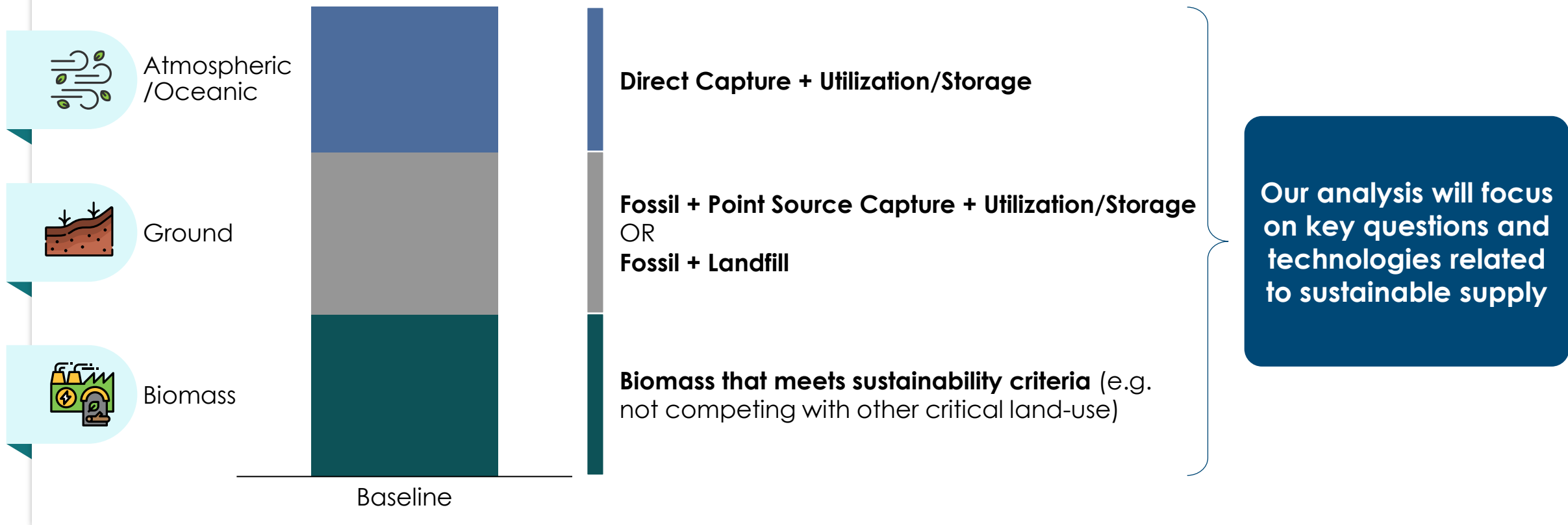
- Pushing circularity as far as we can will saving X million tonnes of primary carbon
- This will save DAC requirements of X tonnes of CO₂/y
- Investment requirements for such as system are X



The analysis will focus on sustainable pathways for primary carbon sourcing and end-of-life carbon management

Sources of primary carbon supply

Illustrative



Analysis will focus on key questions to assess available volumes, levers and technologies to understand sustainable supply of carbon

Primary carbon source

Key questions

End of life management

1. Atmospheric /Oceanic



- What are the latest technology developments for Direct Capture?
- How can Direct Capture be more cost effective?

Key questions

(cross-cutting sources of carbon)

- What are the latest technology developments to store and manage carbon?
- What is the feasible capacity and scalability of storing/management technologies?

2. Ground



- What are the latest technology developments for point source capture?
- What are the scope 1 and 2 emissions in fossil fuel production and how can emerging capture technologies reduce them close to net zero?

3. Bioresources

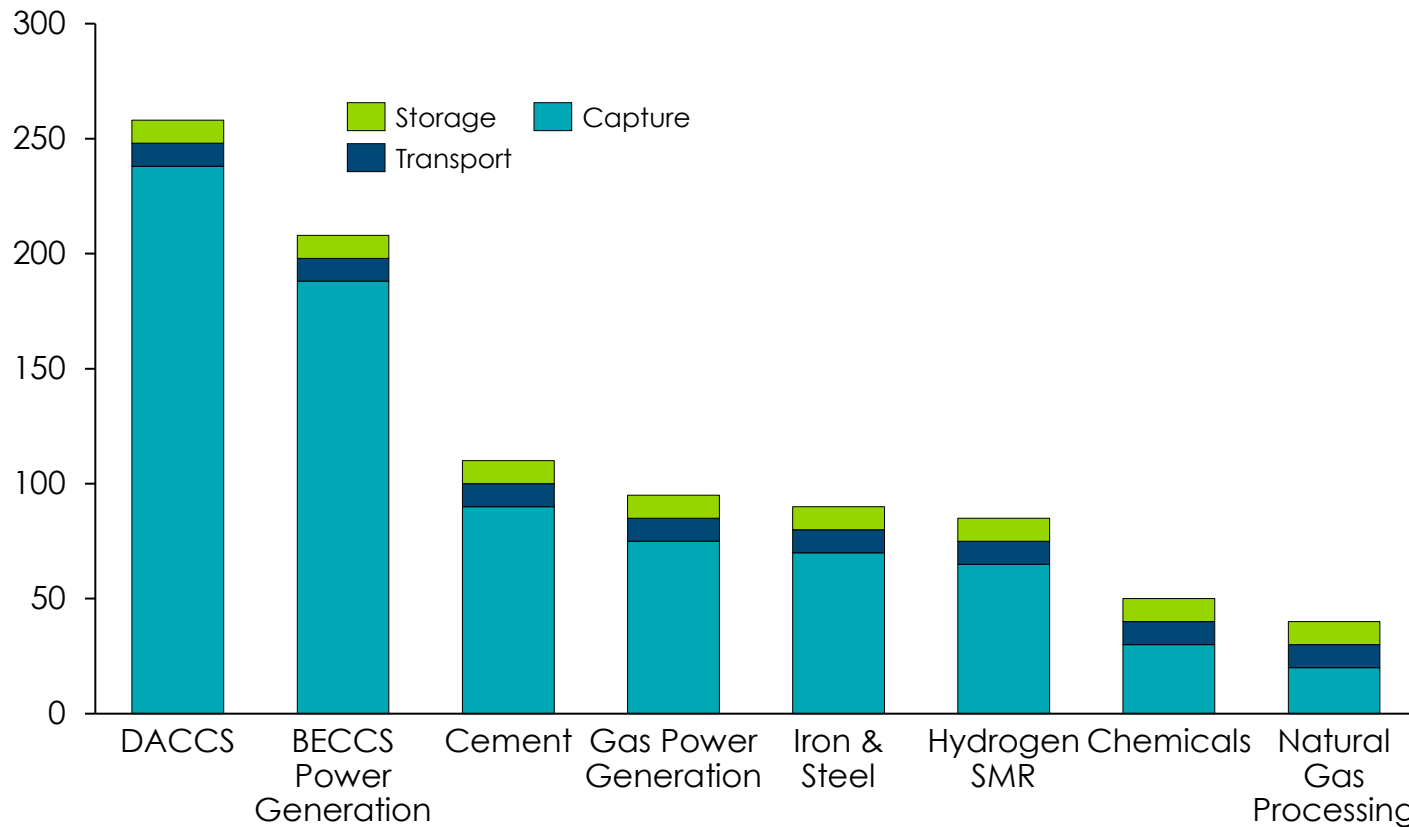


- How could conversion efficiency of biomass be improved?
- How much more biomass could be made available through:
 1. More available land
 2. More productivity from land
 3. New sources of biomass

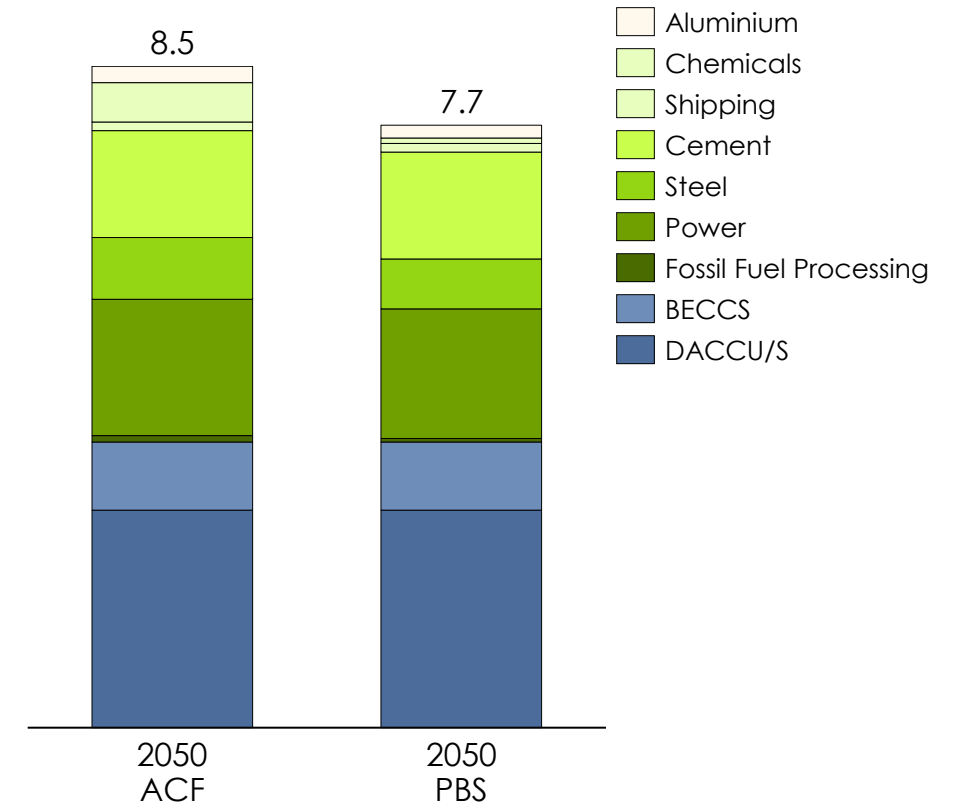


Recap on carbon capture: ETC has previously explored costs of carbon capture and expected volumes through to 2050

Levelised cost of capture, transport and storage by application today
\$/tCO₂



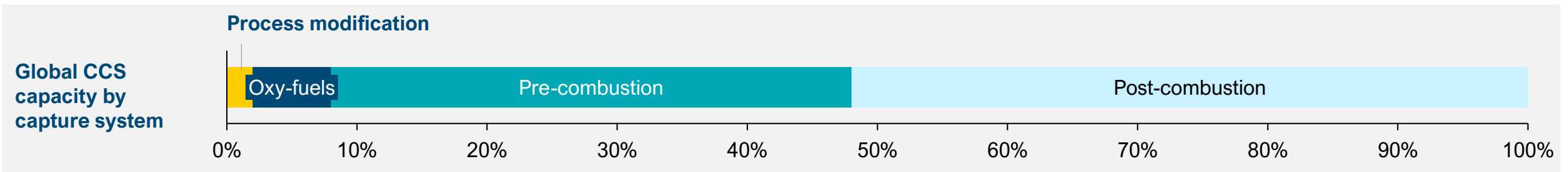
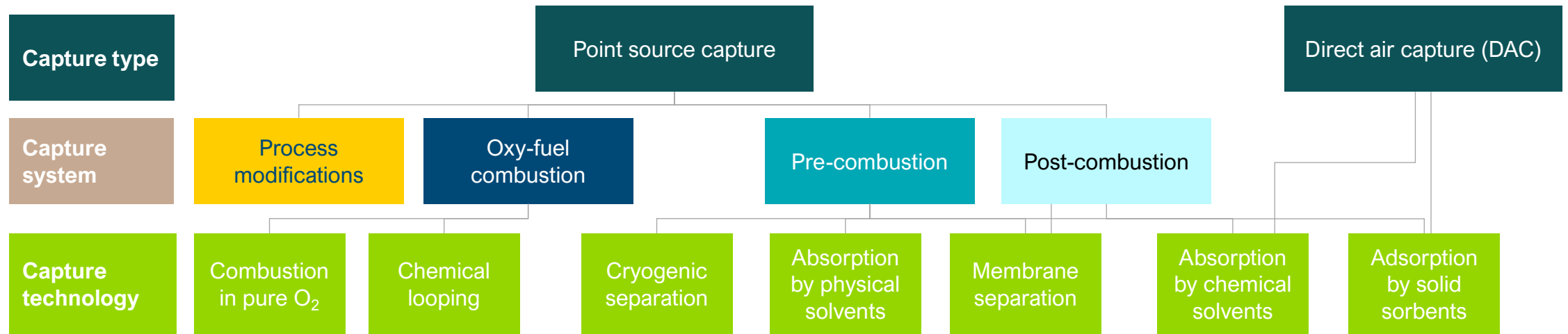
Scenarios for CCUS volumes in 2050 – by source of capture
GtCO₂/year



Note: ACF= Accelerated but Clearly Feasible scenario. PBS=Plausible But Stretching Scenario. Source: ETC (2022) *Carbon Capture, Utilisation and Storage in the Energy transition: Vital but limited* and ETC (2023) *Fossil Fuels In Transition*

Carbon capture technologies can be categorised according to capture type, system and technology, and advancements are being made..

Standard Carbon capture technologies



Source: Systemiq for the ETC (2022), Cancawe (2018) Technology scouting – carbon capture



Atmospheric/Oceanic – new liquids and sorbents in DAC and Direct Water Capture are innovations to be explored in the new analysis




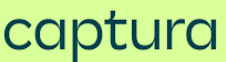




Key questions in focus

- What are the latest technology developments for Direct Capture?
- How can Direct Capture be more cost effective?



Technologies in focus

Technology	Description	TRL	Companies
Direct Air Capture (liquid and solid sorbents)	Liquid DAC uses a strong hydroxide solution to capture CO ₂ . Solid DAC uses fans to pass air over chemicals on a solid surface that bind CO ₂ .	6-9	  Heirloom 
Direct Water Capture	Electrochemical processes to extract CO ₂ directly from seawater. The seawater returns to the ocean with increased capacity to absorb more atmospheric CO ₂ .	5-6	  

NOTES: LCOH/E = levelised cost of heat/electricity; Levelised Cost of CO₂ Direct Air Capture breakdown refers to a fully electrified high temperature DAC system for 5,000 Full Load Hours per annum. Assumes overnight cost of capital for 1MtCO₂ plant in 2020 of \$1,470m, weighted average cost of capital of 7% and plant lifetime of 20 years, growing to 30 years by 2050. Capital, heat and electricity costs refer to an advantaged region with abundant wind and solar resources.

SOURCE: SYSTEMIQ for the ETC (2022) based on models developed by Fasihi et al. (2019) Techno-economic assessment of CO₂ direct air capture plants; Keith et al. (2018) A Process for Capturing CO₂ from the Atmosphere.



Ground – Point source capture is a core technology to allow a sustainable pathway with fossil carbon sources, and advancements continue to be made






Key questions in focus

- What are the latest technology developments for point source capture?
- What are the scope 1 and 2 emissions in fossil fuel production and how can emerging technologies reduce these close to net zero?

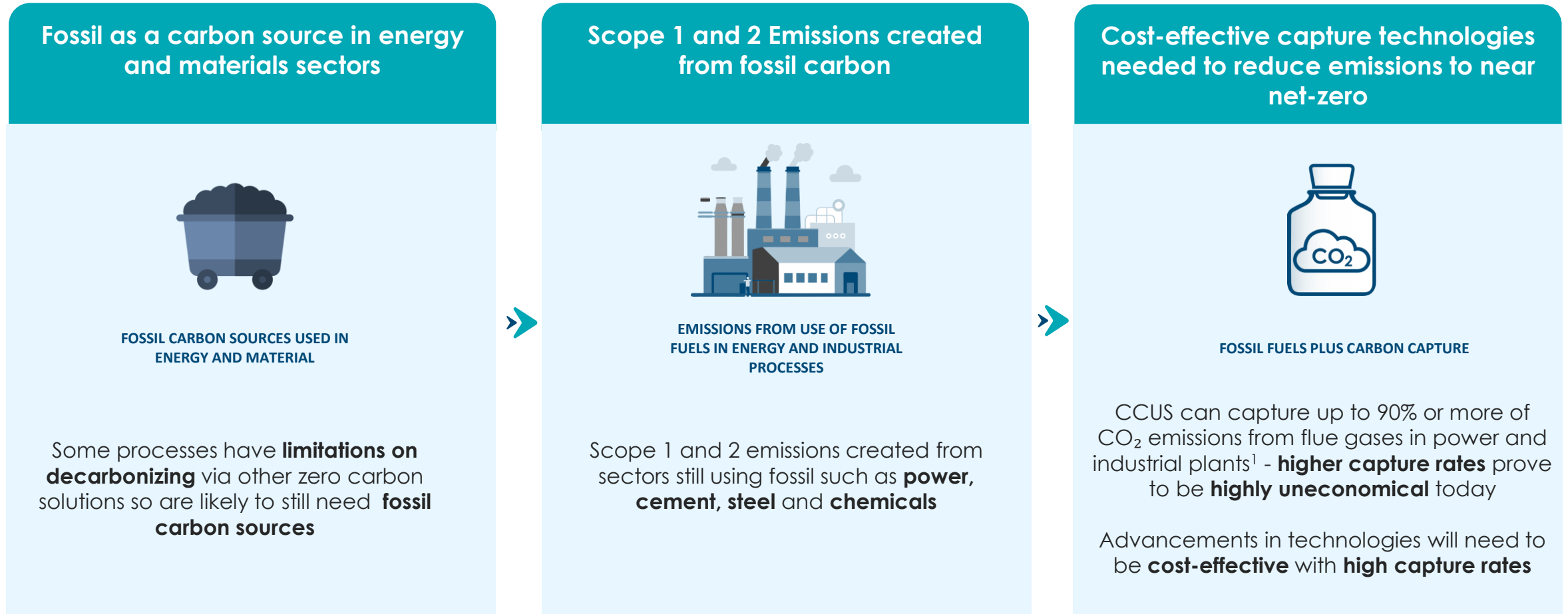
Technologies in focus



Technology	Description	TRL	Companies
Point source capture	Process modification (Allam-Fetvett Cycle)	7	
	Calcium looping	6-7	 



Ground – Scope 1 and 2 emissions from fossil fuels would need to be reduced to close to zero by cost-effective technologies



1. ETC (2022) Carbon Capture, Utilisation & Storage in the Energy Transition: Vital but Limited

Bioresources – Better conversion technologies could reduce the required primary biomass required to meet final energy demand

Key question: Can biomass conversion to energy be more efficient?



Global final energy demand by energy source and scenario

Thousand TWh (%), 2050



Equivalent to 12 Thousand TWh of primary demand



Technologies in focus



Technology	Description	TRL	Companies
Biofuels conversion	Advanced catalysts	6-7	<p>We create chemistry</p>
	Advanced reactor designs	6-7	



Source: Systemiq analysis for ETC (2024) based on Fossil Fuels in Transition analysis by the ETC (2023)

Bioresources – ETC has previously estimated global supply of sustainable biomass at ~40-60 EJ/year, but disruptive innovation could change this

Global sustainable biomass¹ supply (2050) – illustrative scenario
EJ/year (primary energy)



Extra Bioresource if radical change can happen



Dedicated land use

Non-food crops

Waste & residues

Woody biomass from forestry²

Agricultural residues

Municipal & Industrial Waste

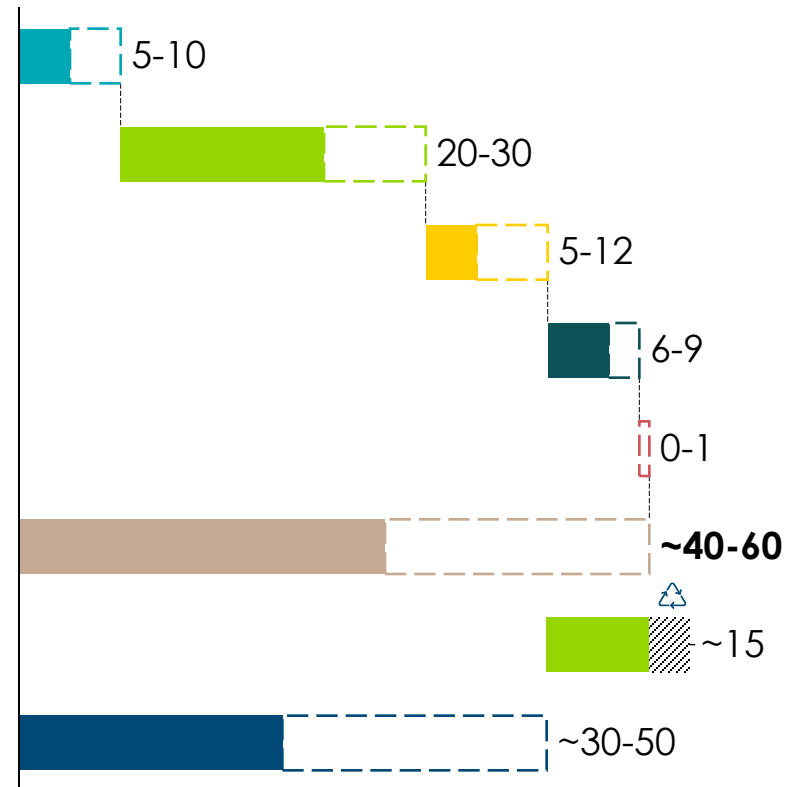
Aquatic sources

Microalgae

Total biomass production

Woody biomass from forestry used as a material^{3,4}

Available for energy and industry



1 More available land (more ha)

Dietary shifts from animal based-protein

Less food waste

2 More productive land (more MJ/ha)

More productive plants (traditional crops, algae)

3 New Sources (more MJ)

Development of macroalgae

Increased collection to organic waste

(1) The term 'sustainable biomass' is used to describe organic material that is renewable, has a lifecycle carbon footprint equal or close to zero (including considerations for the opportunity cost of land), and for which the cultivation and harvesting practices used are mindful of ecological considerations such as biodiversity and health of the land and soil. (2) Includes high-quality stemwood from forestry suitable for the timber and pulp & paper sectors (~10 EJ/year today, FAO Industrial Roundwood production less by-products used for energy). This category also includes residues from forestry but excludes traditional fuelwood (~25 EJ/year today, assumed to reduce with modernisation) due to collection and sustainability assurance challenges. (3) E.g., timber, pulp & paper. Based on current harvests from commercial forestry; additional high-quality stemwood could be made available if freed up land were dedicated to forestry. (4) Additional supply from recycled materials (~4 EJ/year today). Source: SYSTEMIQ analysis for ETC (2021).















Bioresources – technologies that allow reduction in land-use for food production, more land productivity and new sources of biomass are in focus

Key question: How much more biomass might be made available?



Technologies in focus



	Technology	Description	TRL	Companies	
1 More available land	Alternative foods	Precision fermentation	Uses genetically modified yeast or fungi to produce functional ingredients (e.g. casein, collagen, egg white) with high efficiency	7	  
		Biomass fermentation	Single-cell proteins grown using CO ₂ and hydrogen in bioreactors	6-8	 
		Cultivated meat	Grows animal muscle cells in bioreactors, bypassing livestock farming.	3-5	  
2 More productive land	More productive plants	Energy Cane	Energy cane is a type of sugarcane specifically bred for its high biomass production	6-7	   
3 New Sources	New sources of supply	Macro algae (biofuels/bio materials)	Open-ocean farming of kelp/seaweed for feed, biomaterials, or fuels with high CO ₂ uptake and fast growth, increasing supply of total available biomass.	5-7	 



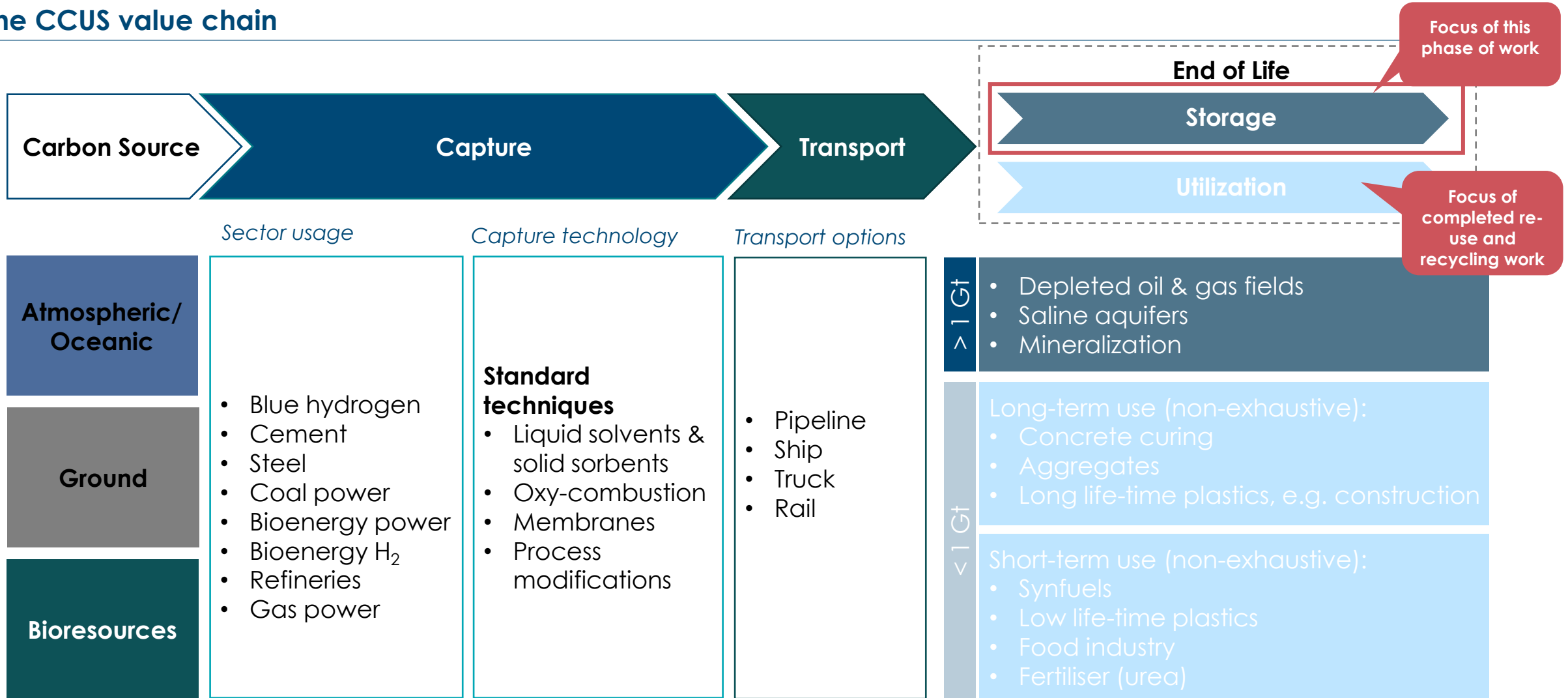
Beyond technologies, trends are considered

- Dietary shifts (enabled by technologies shown)
- Uptake of farming practices with higher yield potential (precision and regenerative agriculture)
- Increased waste collection rates



End of life management: Phase 2 focused on utilization of carbon; Phase 3 will focus on non-circular carbon at end of life

The CCUS value chain



End of life management – Advancements in emerging technologies for carbon storage and end-of-life management will be explored







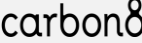




Key questions in focus

- What are the latest technology developments for carbon capture and storage?
- What is the feasible capacity and scalability of storing/management technologies?

Emerging technologies in focus



Technology	Description	TRL	Companies
Storage	Advanced landfill	7-9	  
	Sub-sea CO ₂ injection	6-7	 
	CO ₂ to stone	4-7	   



Outputs from the all the phases will be used to quantify scenarios, trade-offs and provide recommendations

Quantification and conclusions workflow

01

Primary carbon scenarios

Develop 2-5 'what if' scenarios where disruptive technologies stretch or disrupt the way we source primary carbon



02

Trade-off analysis

Quantify trade-offs between carbon management routes at a technology and at a system level (costs, GHG's etc., bang for buck)



03

Recommendations and conclusions

Develop recommendations for the coming decade, for policy makers, producers, buyers, financier players and consumers to ensure availability of carbon molecules in a net-zero system.



Next steps



Deep-dives on technologies in focus



Develop innovation scenarios and explore trade-offs



Workshop on 13th of June

