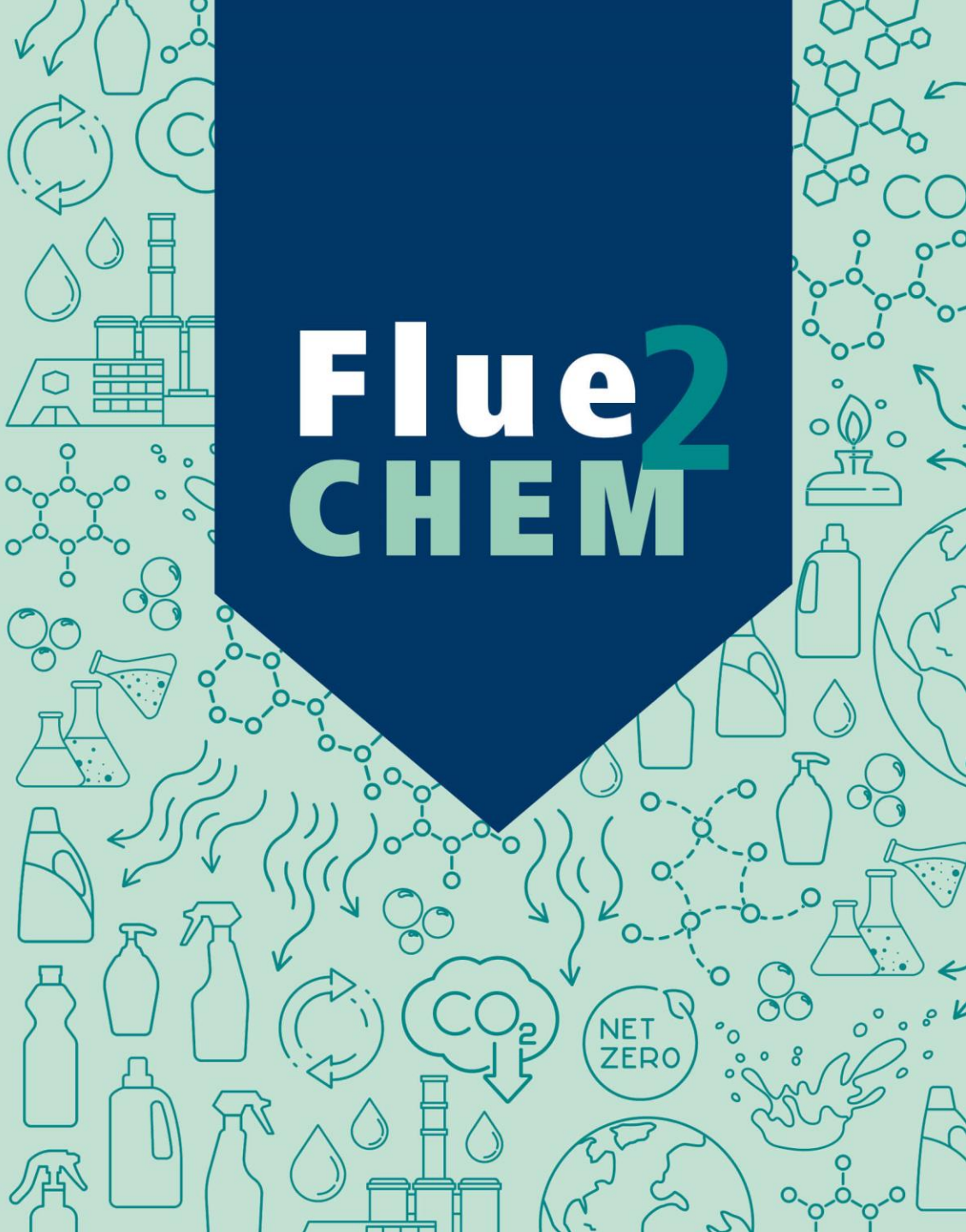
Flue2CHEM

The foundations of the post 2050 chemicals industry

Dr Alastair Sanderson and Dr David Bott

5th December 2023, TFIN+ Christmas Conference, Sheffield

1. Does chemistry have a future ?
2. What is Flue2Chem ?
3. Why carbon provenance matters
4. Next Steps
5. Forming Collaborative Partnerships



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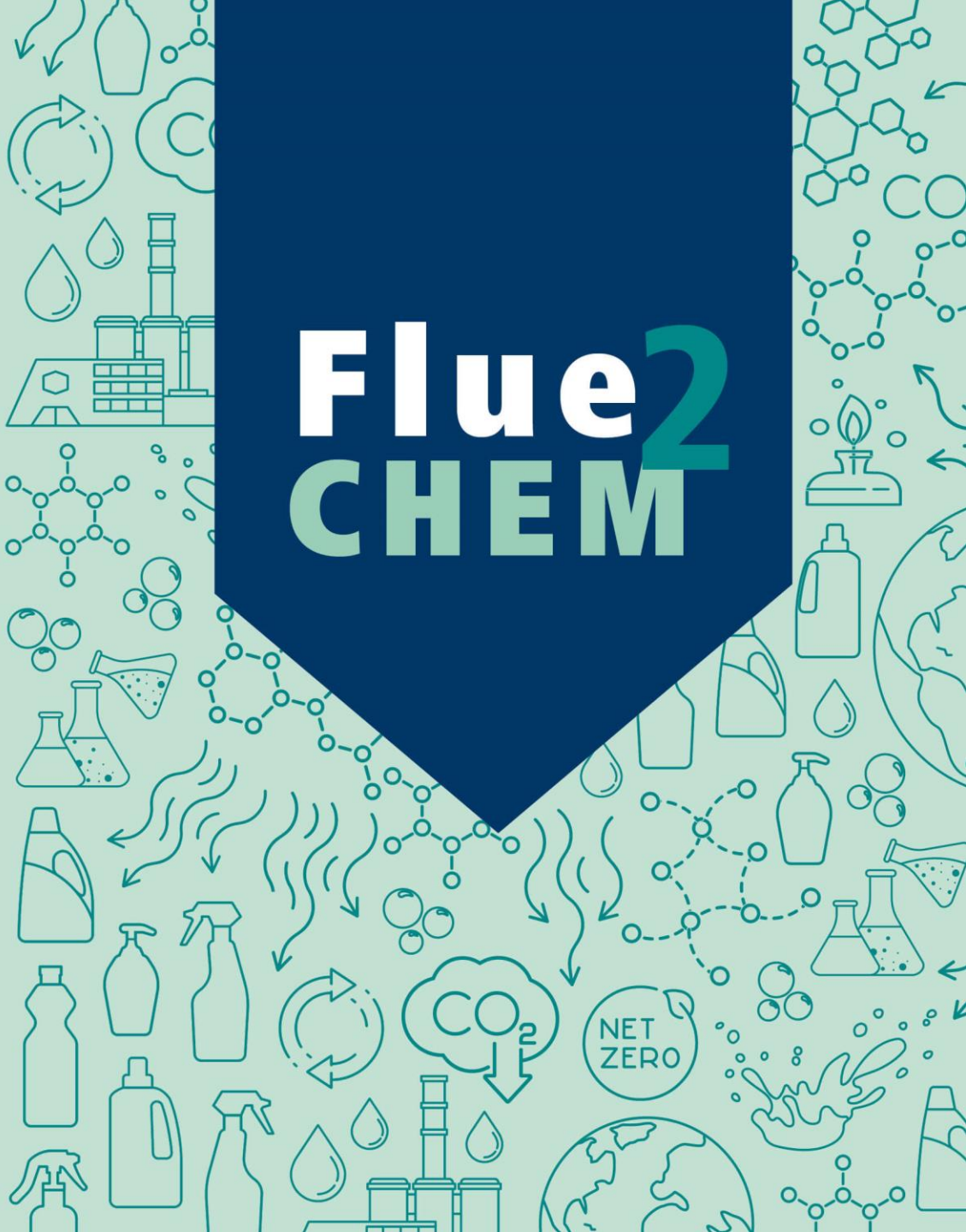


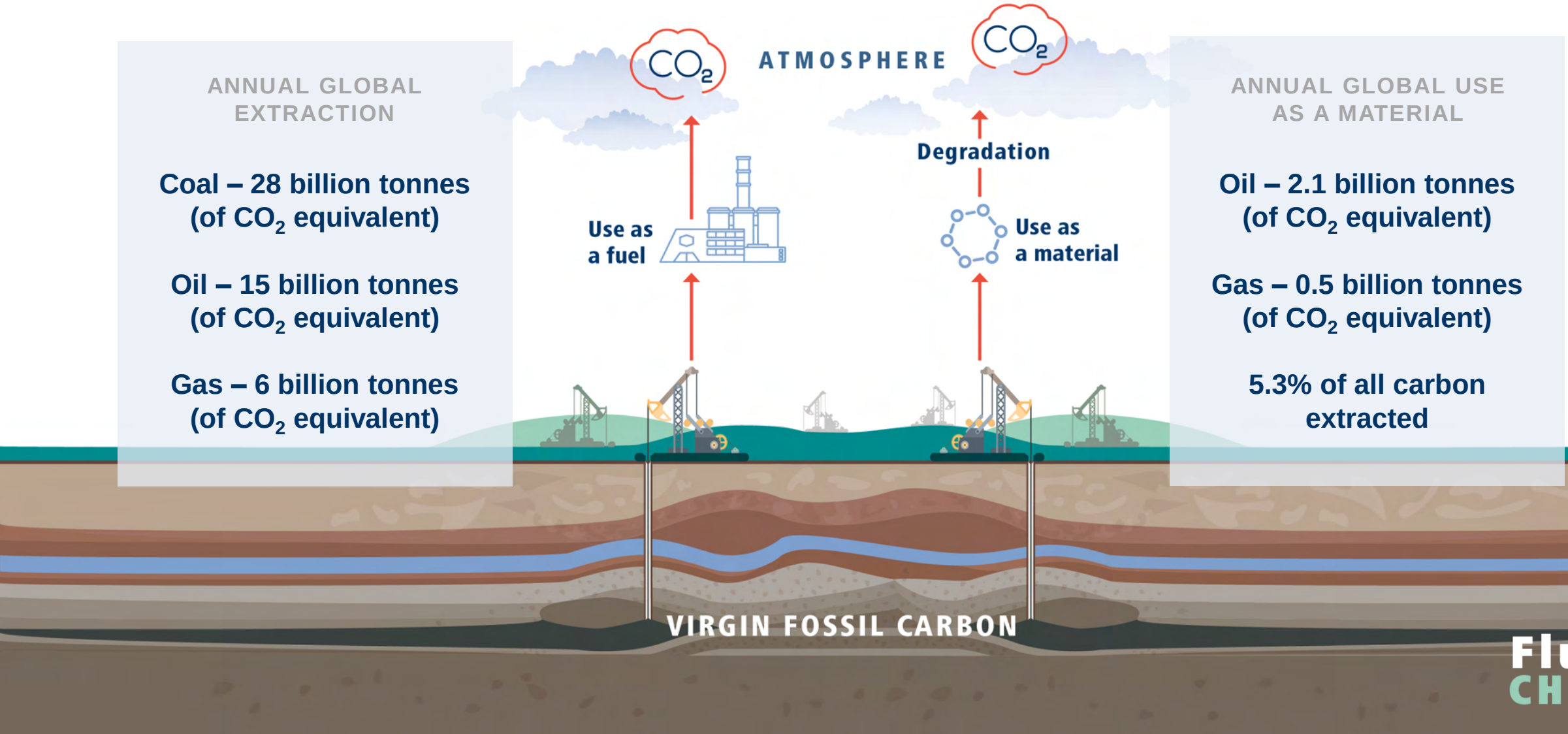
1 Virgin Fossil Carbon Flows

ANNUAL GLOBAL EXTRACTION

Coal – 28 billion tonnes (of CO_2 equivalent)

Oil – 15 billion tonnes (of CO_2 equivalent)

Gas – 6 billion tonnes (of CO_2 equivalent)



ANNUAL GLOBAL USE AS A MATERIAL

Oil – 2.1 billion tonnes (of CO_2 equivalent)

Gas – 0.5 billion tonnes (of CO_2 equivalent)

5.3% of all carbon extracted

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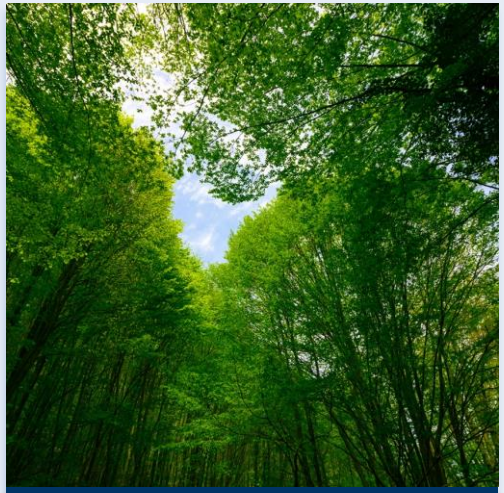
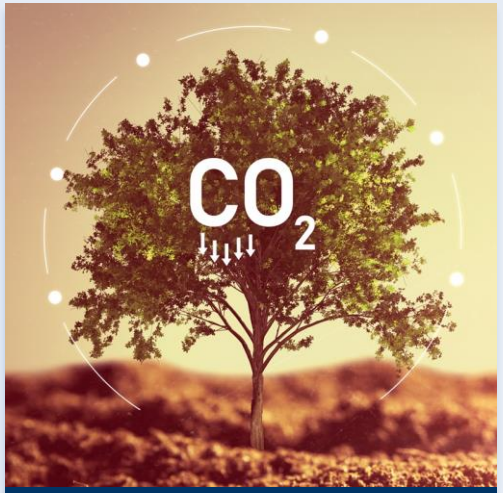
1 Why Flue2Chem ?



We will *not reach Net Zero* unless we find another source for carbon as a material



The science is well known, but the question is whether it can be made to work *at scale* and the *right cost*

The consumer market has the most *immediate driver for change*

Other uses of carbon as a feedstock (plastics, paints, adhesives, insulation, fabrics, textiles and so on) would be able to use similar supply chains to *move away from fossil carbon* in time

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Where will we get the carbon from?

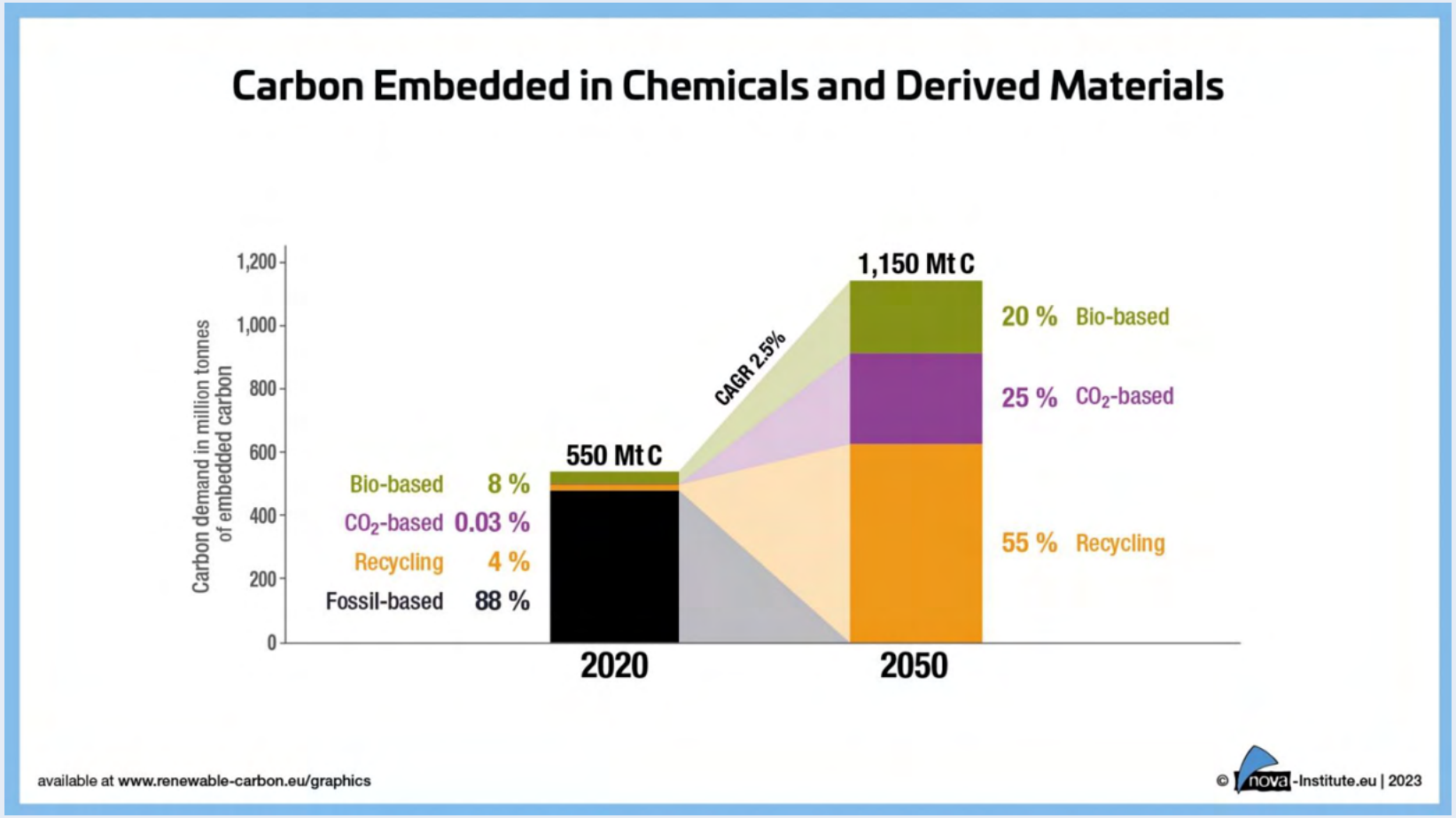
- If we stop using carbon from virgin fossil feedstocks, we are going to need another source of carbon - and lots of it
  - 2.6 billion tonnes of carbon dioxide equivalent now…
  - …with a CAGR of 5% will be 12.5 billion tonnes of carbon dioxide equivalent by 2050
- There are several sources currently being discussed and evaluated
  - Biomass
  - Recycled plastics, oils and other easily collected chemicals
  - Carbon dioxide from flue gases (while we still have them) and the atmosphere

Balancing the options – or combining them?

- Biomass
  - Established but not yet scaled sufficiently
  - Collection of raw materials favours distributed first steps
- Recycled plastics, oils and other easily collected chemicals
  - Collection of materials to be recycled needs sorting
- Carbon dioxide from flue gases and the atmosphere
  - We should be phasing out flue gases as we approach 2050
  - Least well developed but offers the hope of atmospheric remediation

- The proportion each process can supply depends on how we invest…
- ,,,but many agree no single process will supply enough to satisfy needs

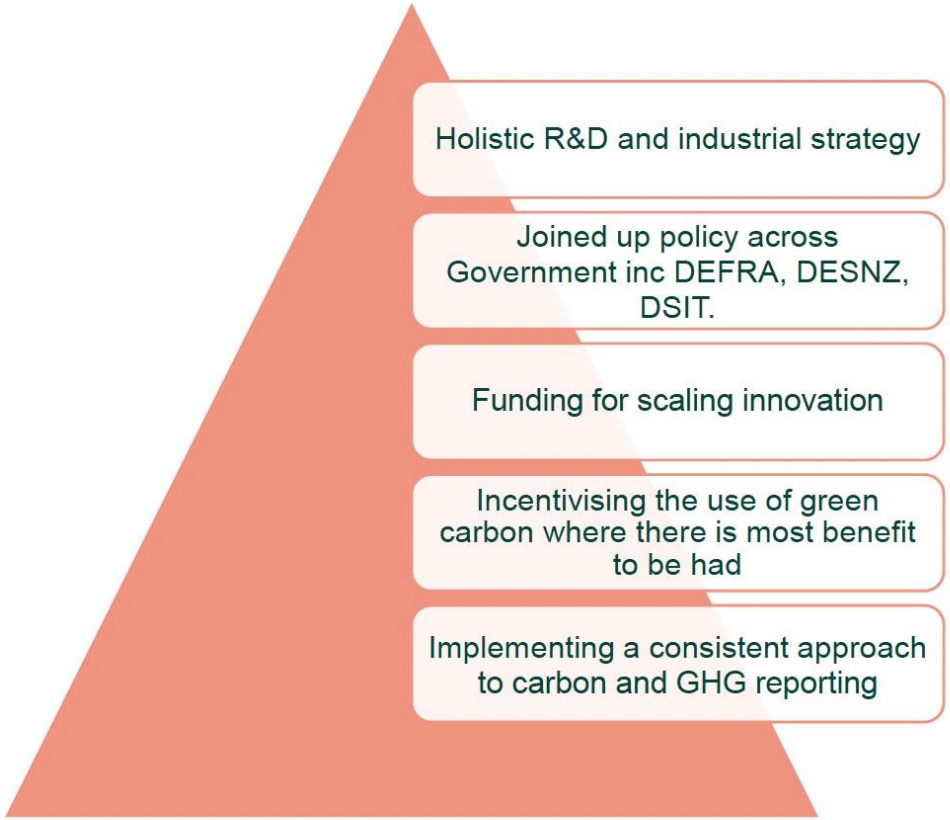
The Nova “view” of future sourcing



Atmospheric or biogenic carbon can help reduce product carbon footprint. If there is not sufficient biobased carbon, using CO_2 is unavoidable if society is to access the chemicals it so demands.

Recycling fossil carbon does not help reduce product carbon footprint.

It needs policy as well as technology



SM4CP & Dr R Miller, October 2023, Outputs of the Workshop on Sustainable Materials for Consumer Products

- Policy has a role in driving the transition to increased use of green carbon.
  - This can be done through **incentivisation** or **penalty**.
- There are several fundamental asks from industry to support this. these including
  - Creating a clearer vision for an industrial Net Zero pathway that is aligned across government.
  - Backing the use of sustainable resources and helping scale enabling technologies.
  - Employing consistent reporting of carbon impact across sectors.

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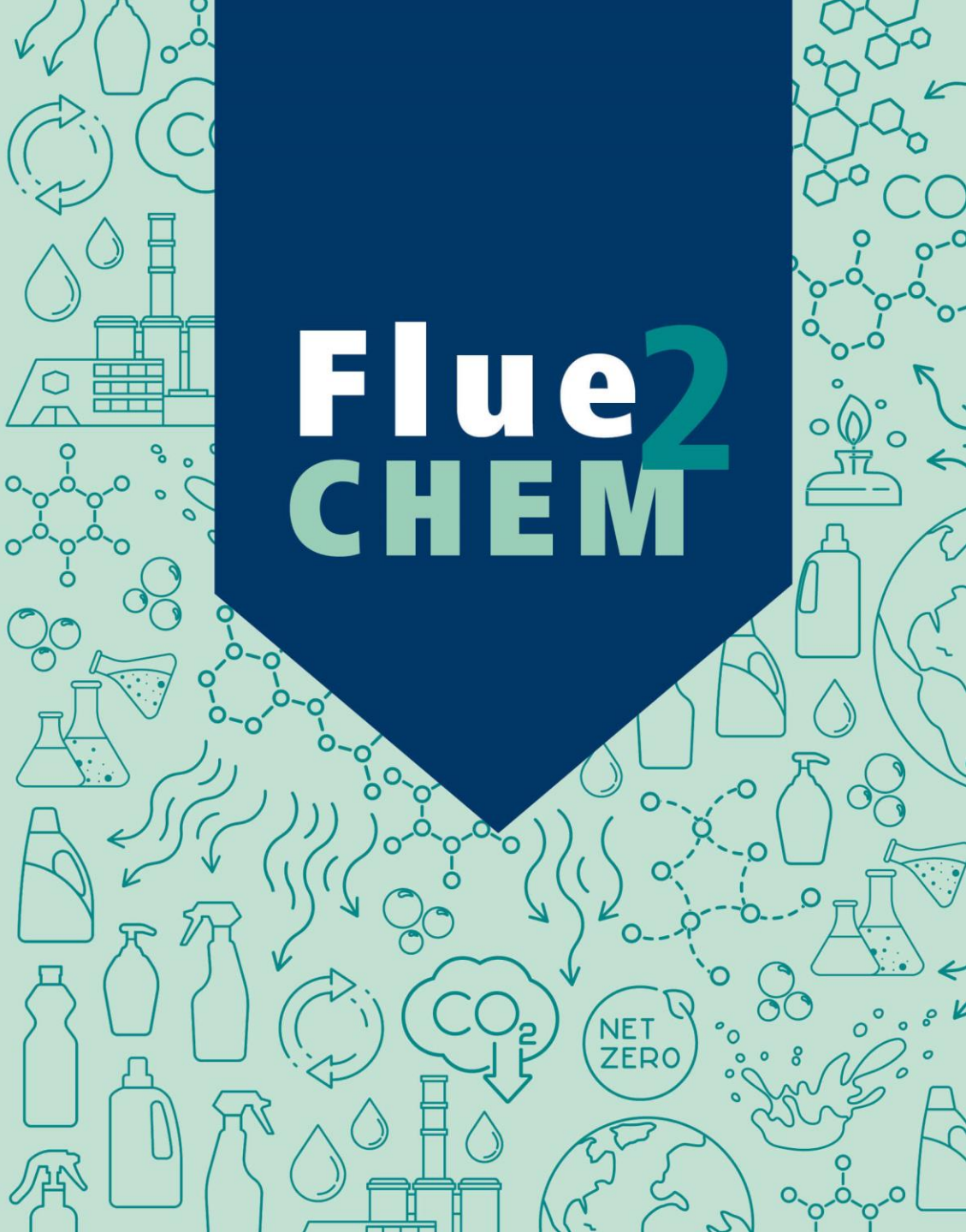
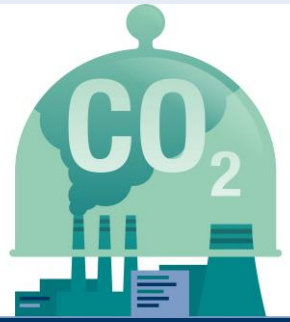


Flue2Chem: Transforming the Foundation Industries Challenge

Make sustainable materials for consumer products (Alkoxylated Surfactants) from UK emissions



Entire value chain is in scope

- Source of emissions (second use black & biogenic carbon),
- Capture and purification of emissions,
- Conversion of CO_2 to hydrocarbons and ethylene oxide,
- Manufacture and application of alkoxylated surfactants.

Consortium of 16 partners

- Evaluate the full end-to-end business & environmental impacts,
- Build the case to create a chemicals infrastructure to implement CCU in the UK.

Start 1st December 2022: 2-year project

- Unilever lead partner
- £5.4m project, £2.7m grant

UKRI Innovate UK

Why Alkoxylated Surfactants?

Global production > 6 million T /yr and £10 billion | Wide range of consumer applications

- **Fossil Carbon increases GHG**
- **Palm Kernel Oil can lead to Deforestation and associated GHG increase**
- **Generally imported to the UK**

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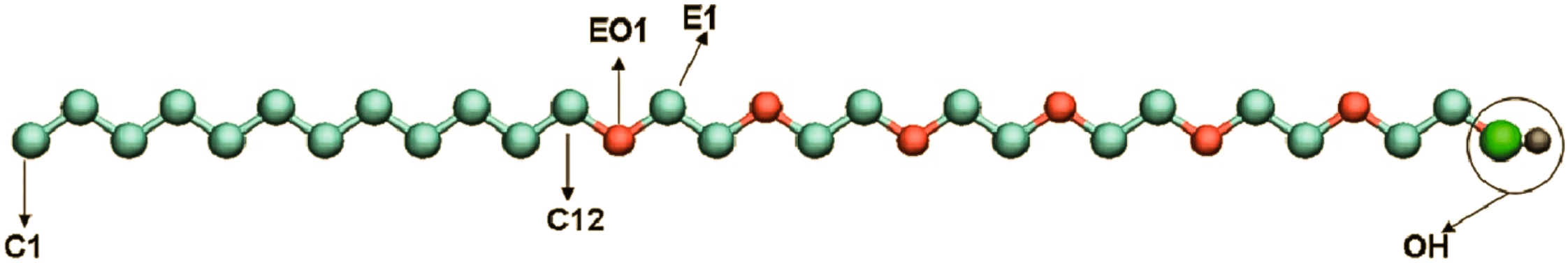
Target Molecule: an Alkoxylated Surfactant



Fatty Alcohol ↑ Fatty Acid ↑ Palm Kernel Oil

Synthetic Alcohol

Ethylene Oxide

Ethylene ↑ Oil

Ethylene Oxide ↑ Ethylene ↑ Ethanol ↑ Sugar

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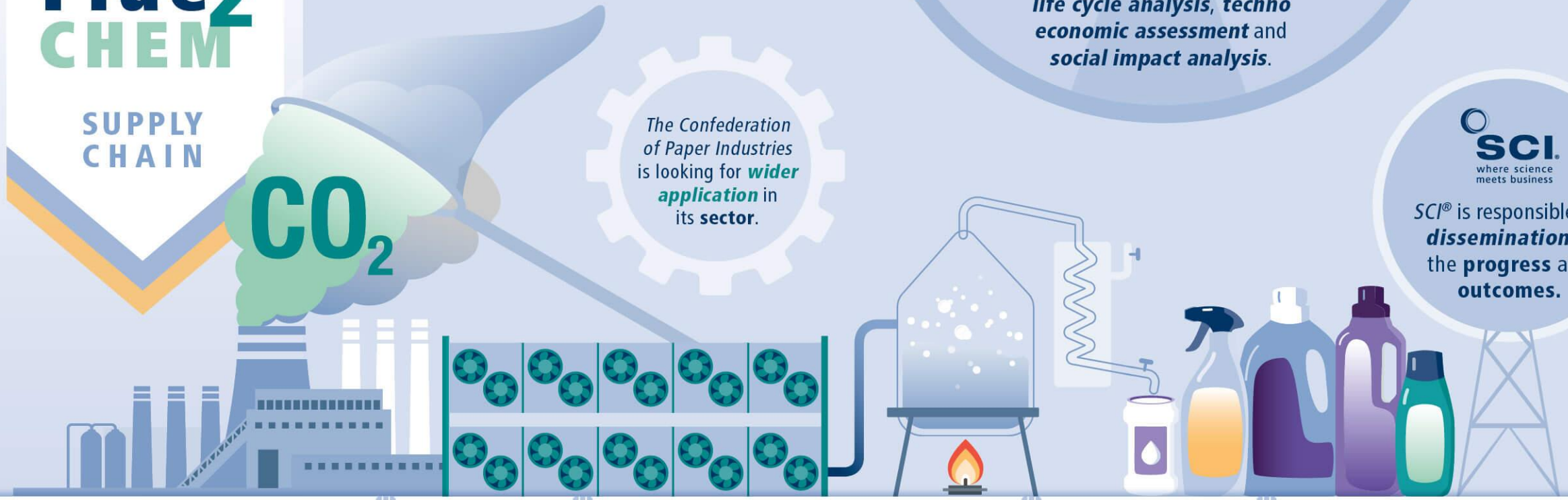
SUPPLY CHAIN



The University of Surrey is ***leading life cycle analysis, techno economic assessment*** and ***social impact analysis***.

The Confederation of Paper Industries is looking for ***wider application*** in its **sector**.

SCI where science meets business

SCI® is responsible for ***dissemination*** of the **progress** and **outcomes.**

Foundation Industries *emit* valuable CO_2

HOLMEN · UPM BIOFORE BEYOND FOSSILS · TATA STEEL

CO_2 is ***captured***

carbon clean · University of Sheffield

CO_2 is ***converted*** into **key intermediates** used widely in the chemical industry

BASF · JM · University of Sheffield · cpi · LanzaTech

Intermediates ***converted*** into **surfactants**

CRODA

Surfactants are ***formulated*** into **cleaning products** and **coatings**.

Unilever · reckitt · P&G · TATA STEEL

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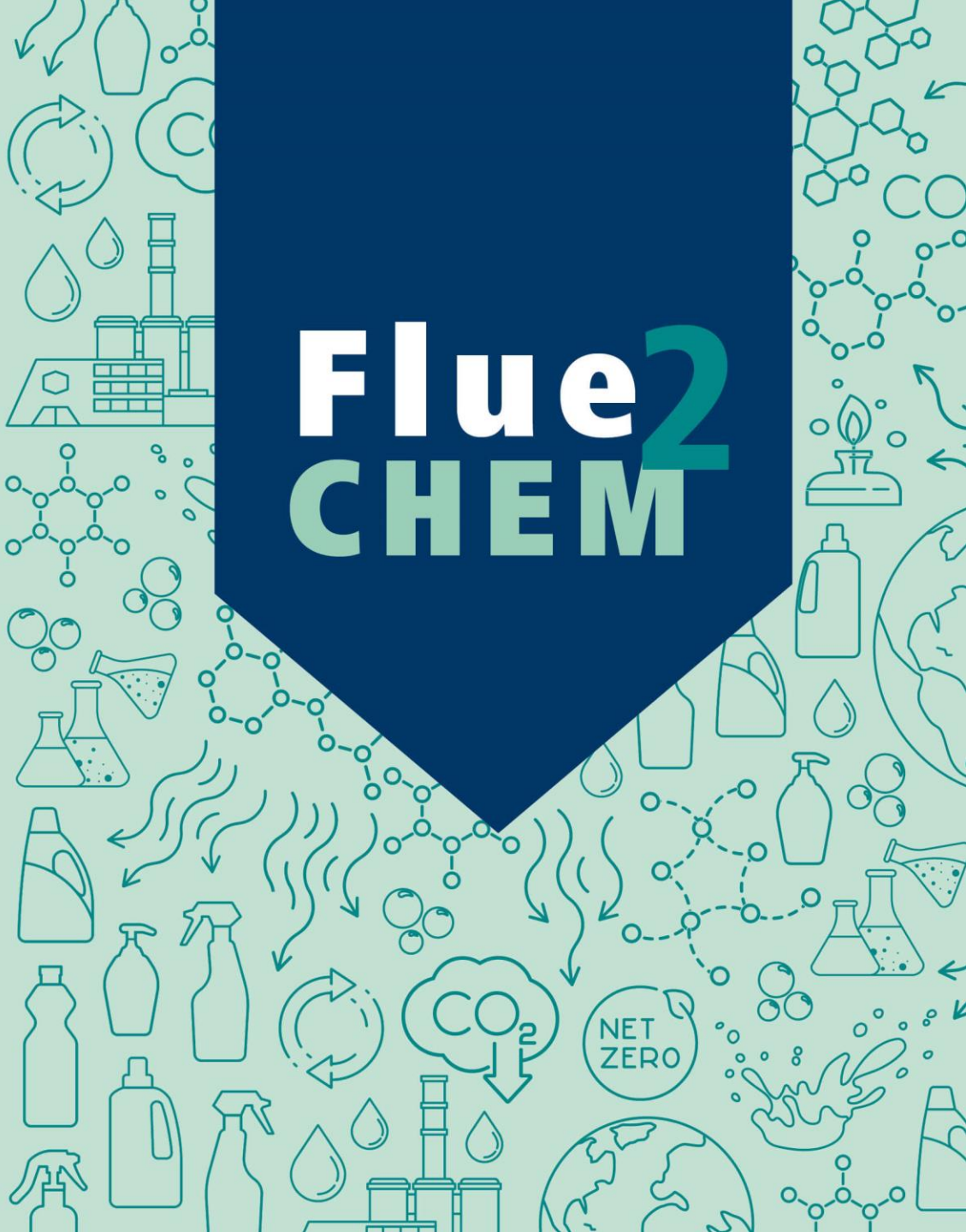
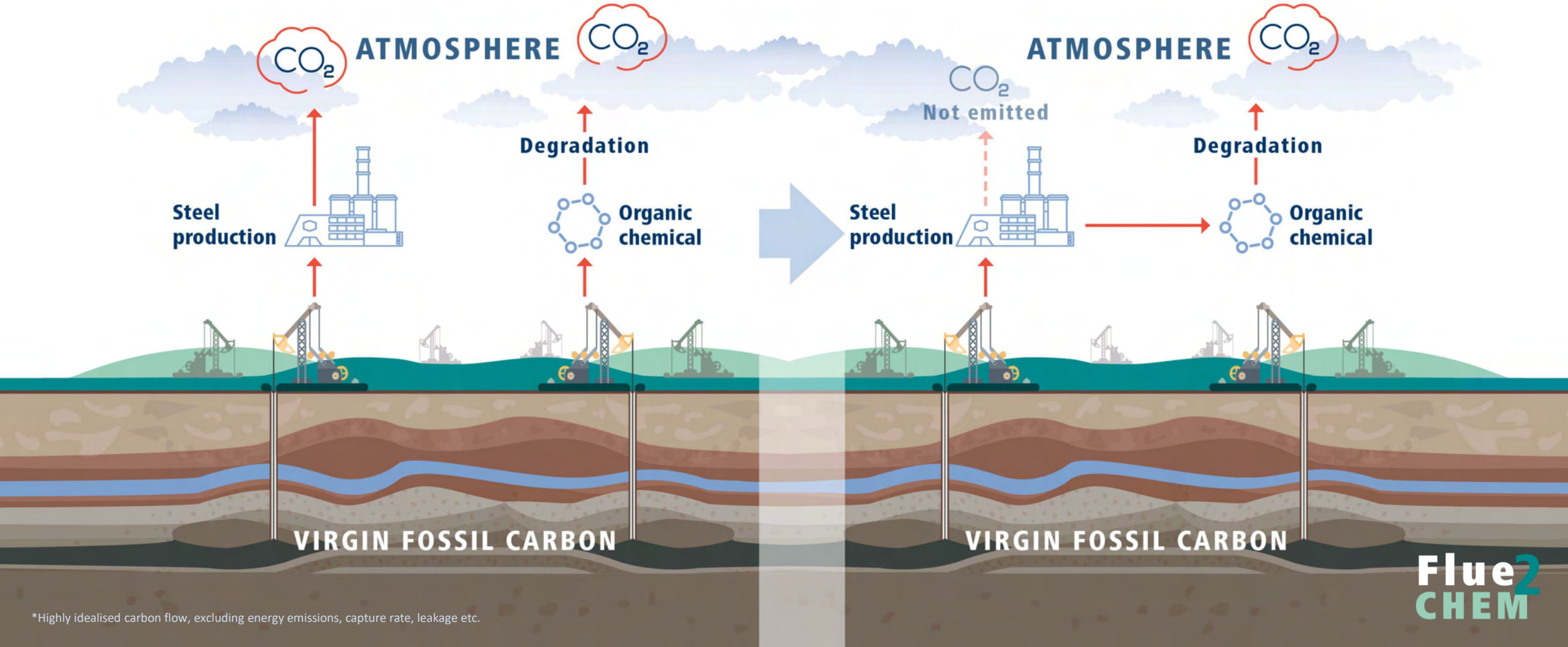


3

Carbon Flows*: Reusing Fossil Carbon

Reusing point source **fossil** CO_2 emissions can lead to **emissions reduction (<50%)** of the system



*Highly idealised carbon flow, excluding energy emissions, capture rate, leakage etc.

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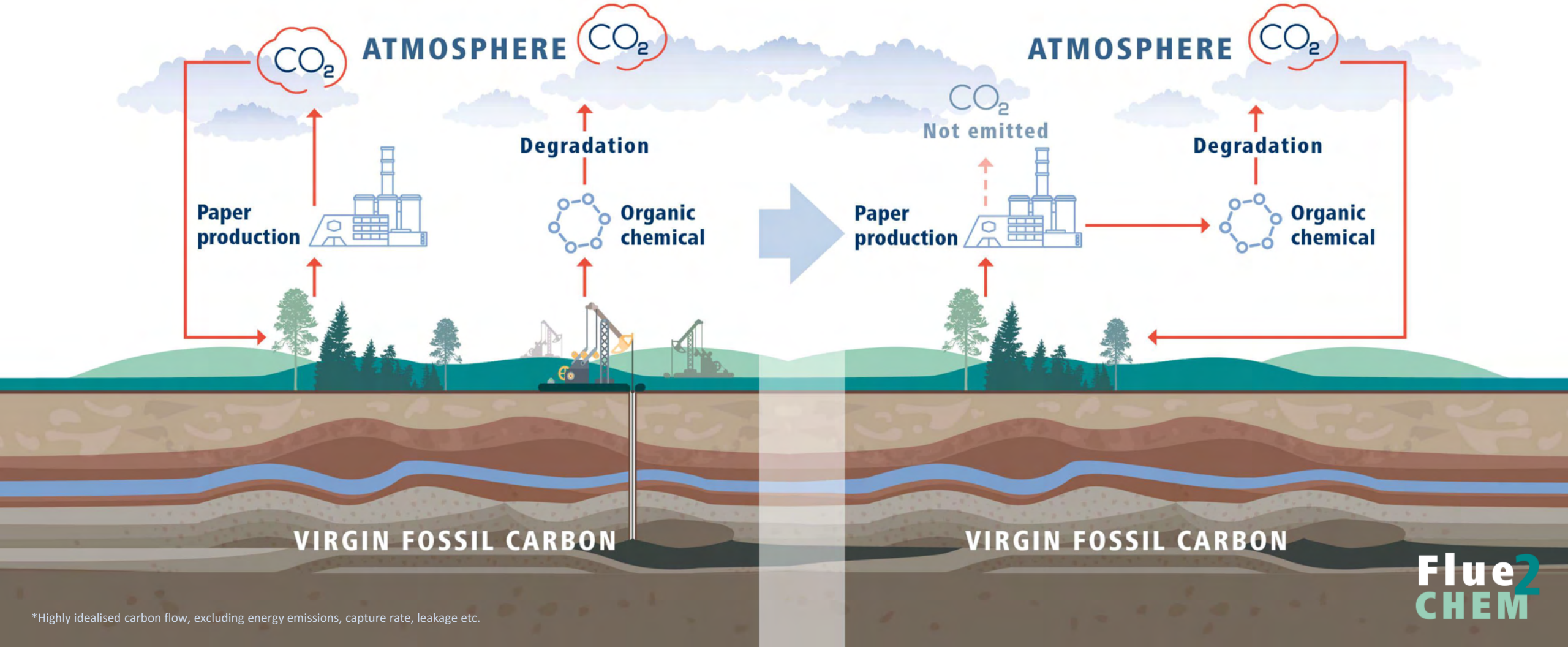
3 Carbon Flows*: Circular Atmospheric / Biogenic Carbon

Re-using point source **biogenic** CO_2 emissions can lead to **zero emissions** of the system



*Highly idealised carbon flow, excluding energy emissions, capture rate, leakage etc.

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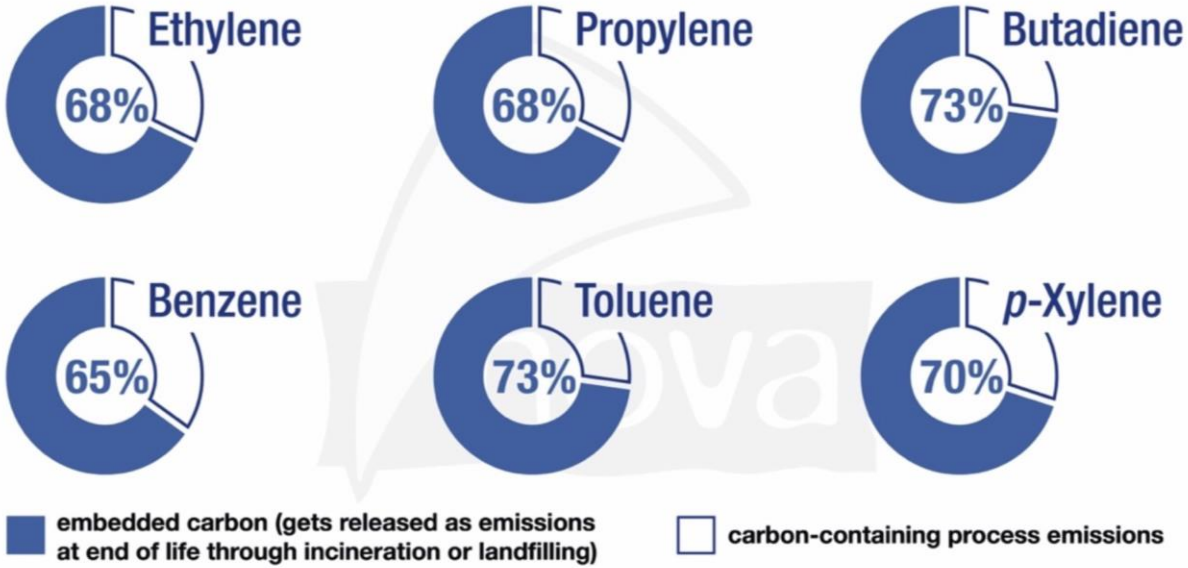
3 The Hidden Carbon Footprint

- PACKAGING
- TEXTILES
- PAINTS/ADHESIVES
- CONSTRUCTION

- PACKAGING
- PHARMACEUTICALS
- PAINTS/ADHESIVES
- CLEANING PRODUCTS



- AUTOMOTIVE
- TYRES
- PAPER

- PACKAGING
- SPORTS EQUIPMENT
- ELECTRICAL
- FURNITURE

> *"We must not stop using carbon, but start using the right carbon that avoids adding more carbon into the atmosphere."*
>
> Michael Carus, *Nova Institute*

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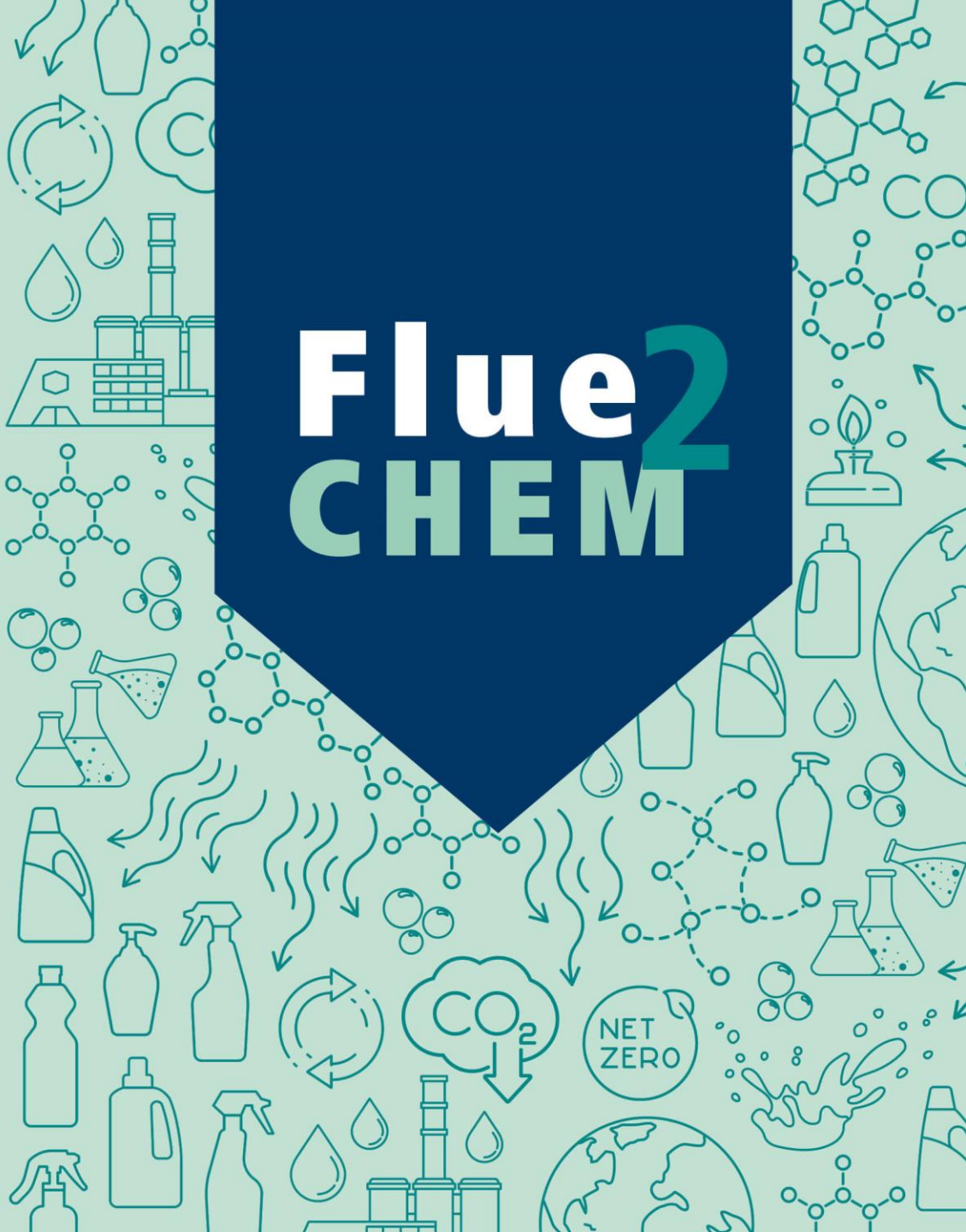

What are we aiming for as outputs?

- Demonstrator Products
  - We are aiming to produce a series of cleaning products based on the surfactant where the carbon has a straight supply line from carbon dioxide collected from flue gases

- A detailed paper that…
  - Describes all the mistakes we made, learning we had and recommendations to make it easier for anyone else going down this path
  - Makes recommendations to governments about how to “develop” standards and regulations that support the move from fossil carbon feedstocks to circular supply chains

4 Flue2Chem – Next steps...and beyond

1. ***Design*** and ***demonstrate*** value chain to **capture valuable CO_2 emissions** and ***convert*** these into **sustainable chemicals**.

2. ***Complete*** **environmental, techno-economic** and **social impact** in comparison to current processes.

3. ***Frame developments*** and ***interventions*** **required** to make the **business model work**.

4. ***Build*** **value chain** to ***utilise*** **foundation industry emissions** to ***displace*** import of **non-sustainable materials** from outside of the UK

Flue2Chem → **Flue2Chem2,3....n**

We will use this to create the blueprint for driving change in other countries.

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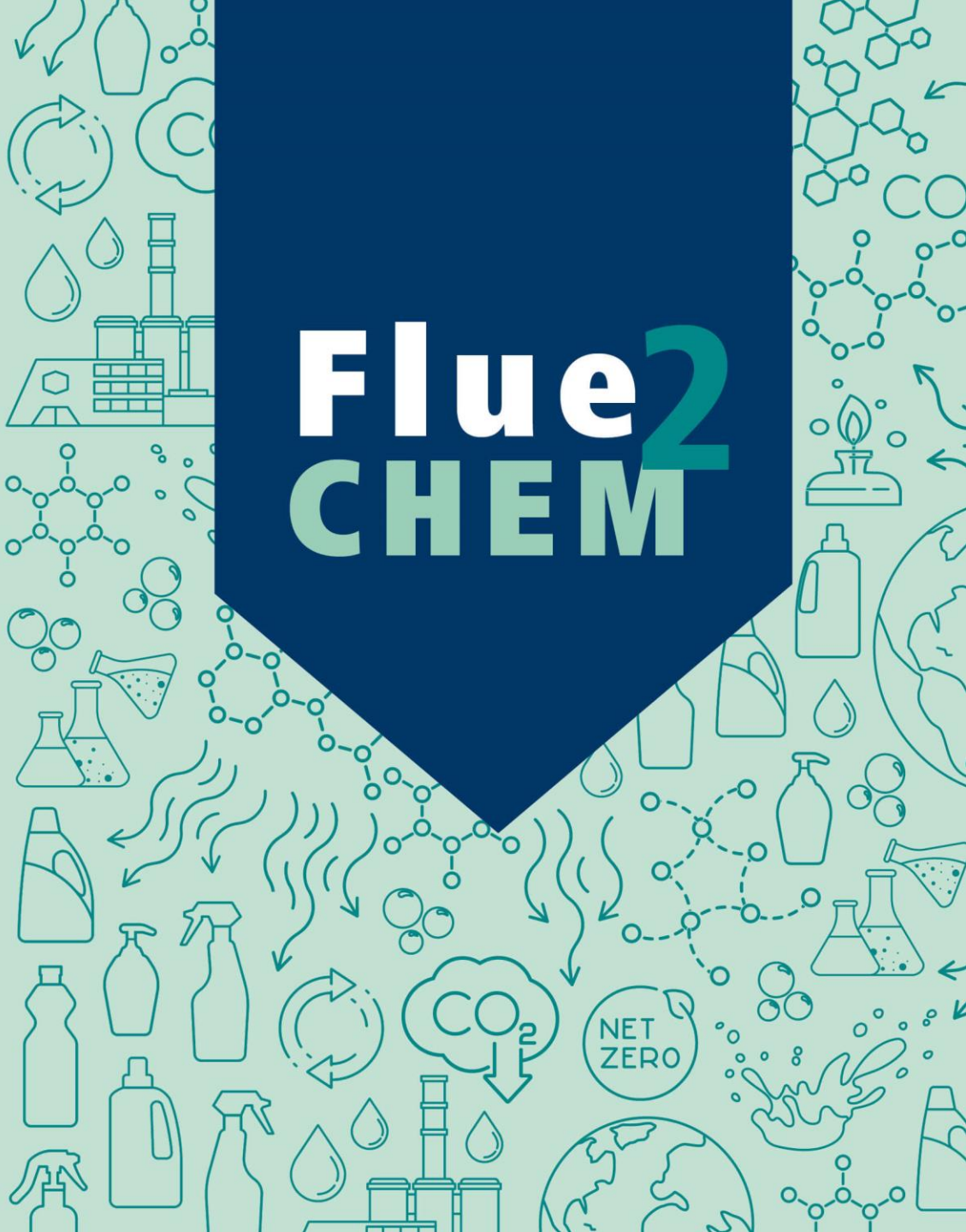

Forming Collaborative Partnerships

How we built the team.

“How did you assemble such a large project so quickly?” ……..**“we didn’t, it took years!”**

Goal of **replacing fossil carbon feedstocks** was identified in the **2018 UK Chemistry Council Strategy**

It was part of a ***“Sector Deal”*** **proposed to UK Government** in **late 2019** – just as the government abandoned that mechanism

The first workshop was held at the **SCI®** in **February 2020** – it launched a **committee** made up of **interested companies** which then met (virtually) through lockdown

UKRI Innovate UK

They recognised that an **InnovateUK competition** (Transforming the Foundation Industries) in **late 2021** covered what they wanted to do

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Assembling the Consortium

1. Time, and lots of interaction.

Unilever, P&G, Reckitt, Croda, BASF, Johnson Matthey and the SCI – had all been sharing ideas, challenges, opportunities and frustrations for over 3 years. Individually some had also worked with the others we invited to join: personal recommendations and shared experiences.

2. Transparency and honesty.

The relationships we have built over those years are strong. We have disagreed (a fair amount) on the way, but we have always shared a commitment to move from fossil carbon feedstocks to a sustainable chemistry based industry.

3. Shared commitment and understanding.

How the different organisations fitted into what will be a wholly new supply chain.

4. Tireless advocacy

Within our own organisations – and to anyone who will listen outside them!

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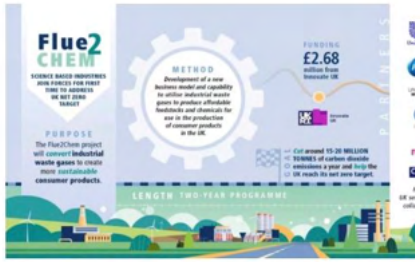
Follow us on LinkedIn



#Flue2Chem - a story - pa

David Bott
Principal Fellow at WMG

July 18, 2023

Open Immersive Reader

The backstory to #Flue2Chem – 1. What good is chemistry?

A collaboration of 15 organisations is part way through an Inno project to turn the carbon dioxide in flue gases into non-ionic s cleaning products. Many have asked: why we are doing it? hov the team? and how things are going? This is the first part of th will follow...

No-one really thinks about the role of chemistry in society. Alt everything around us is chemistry – life itself, the natural world material world we have created to add to the natural world – w about "chemicals" in a derogatory way. Does society understa

#Flue2Chem – a story - pa (But what should we do?)

David Bott
Principal Fellow at WMG

August 1, 2023

Open Immersive Reader

If you look carefully in the top right hand corner of the graphic the Chemistry Council Strategyyou will find the phrase "Susta for Consumer Products". This is (we think) the first time the ph in this context and so was effectively the beginning of the story

Technically, there is prehistory. The UK Government had tried understand and support the "chemistry using" industries but h capture the breadth and scale of their impact on the economy engagement. They had included the pharmaceutical companie

Like Comment Share

#Flue2Chem - a story - par

David Bott
Principal Fellow at WMG

November 22, 2023

Open Immersive Reader

It's not easy being green

There is much talk of "decarbonisation" these days, and you co for thinking this means eliminating carbon from all human activi are lots of things that need carbon to exist. The chemistry of ca and nature relies on it for many things. Carbon has direct influe conditions for life on our planet, whether or not you factor in the of human beings! And we depend on carbon chemistry for life t burn carbon based fuels ourselves (grains, vegetables and mea based materials).

A large petrochemical plant!

#Flue2Chem - a story - part 4

David Bott
Principal Fellow at WMG

6 articles

November 7, 2023

Open Immersive Reader

We're going to need a bigger test tube

Science is hard work. Understanding the world around us well enough to predict the behaviour of everything from sub-atomic particles to planets requires insight, patience, imagination and rigour. But science also lays the foundations of many of the industries that have changed our world – from pharmaceuticals to airplanes.

It is this application of science to address societal challenges that benefits people. And one of the biggest challenges is moving away from using virgin fossil carbon to feed the chemical supply chain!

We hold these truths to be self-evident

- Chemistry forms the basis of many supply chains
- Chemistry is largely based on carbon
  - Though other elements are quite useful!
- We have to change the source of that carbon
  - But 150 years of cheap carbon has spoiled us
- There are options – we need them all
- We need a strategic plan for implementation and roll-out
- We need a fiscal and regulatory environment that supports this change

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THANK YOU

Innovate UK

SCI where science meets business

Unilever

P&G

BASF We create chemistry

JM

UPM BIOFORE BEYOND FOSSILS

carbon clean

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HOLMEN