

An illustration of a sustainable city skyline with green buildings and trees, set against a background of a glowing sun. Below the skyline is a stylized map of the European Union on a globe, all in shades of green and yellow.

# SUSTAINABLE AND COMPETITIVE: THE BIOECONOMIC FUTURE OF THE EU

Expert workshop on Fraunhofer-Roadmap Circular Bioeconomy

September 20, 2023 | 12-16 CEST | Brussels

# Sustainable and Competitive: The Bioeconomic Future of the EU

## Agenda

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### Slides

#### Introduction:

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*Markus Wolperdinger und Alexander Böker (Fraunhofer Strategic Research Field Bioeconomy)*

#### Keynote:

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*Peter Wehrheim (DG Research and Innovation, European Commission)*

#### Parallel workshops - Part I

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Download roadmap  
and brochure





# Introduction

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## **Fraunhofer roadmap for the Future Development of the Circular Bioeconomy**

Markus Wolperdinger and Alexander Böker

# Introduction

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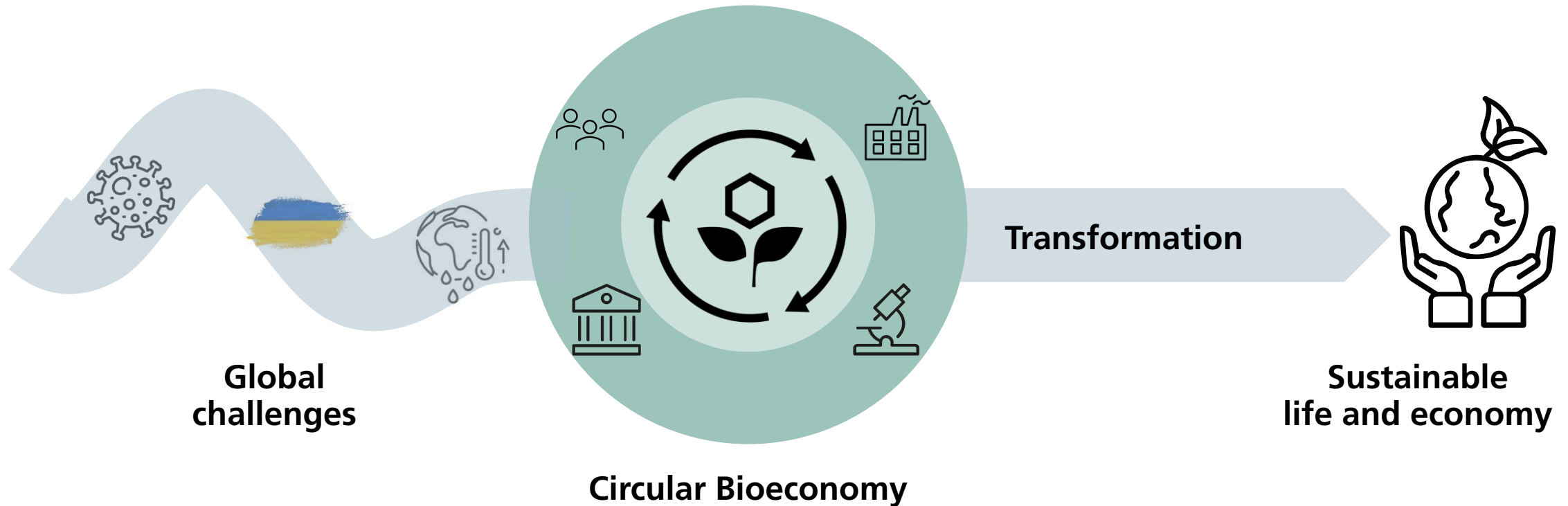


## Circular Bioeconomy for Germany

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A roadmap by the Fraunhofer-Gesellschaft for implementing the bioeconomy in Germany

# Global challenges demand a new era



© Fraunhofer-Gesellschaft

# Policy framework opens new opportunities

EU  
Germany  
Federal states



EU Bioeconomy Strategy  
2012



Revised EU Bioeconomy Strategy  
2018



Sustainable Bioeconomy BaWue



EU Green Deal  
2019



National Bioeconomy Strategy  
2020



Farm to Fork Strategy  
2020



Further development German Sustainability Strategy  
2021



Bioeconomy Strategy Paper Saxony-Anhalt  
2021



European Climate Law  
2021



10 years EU Bioeconomy Strategy



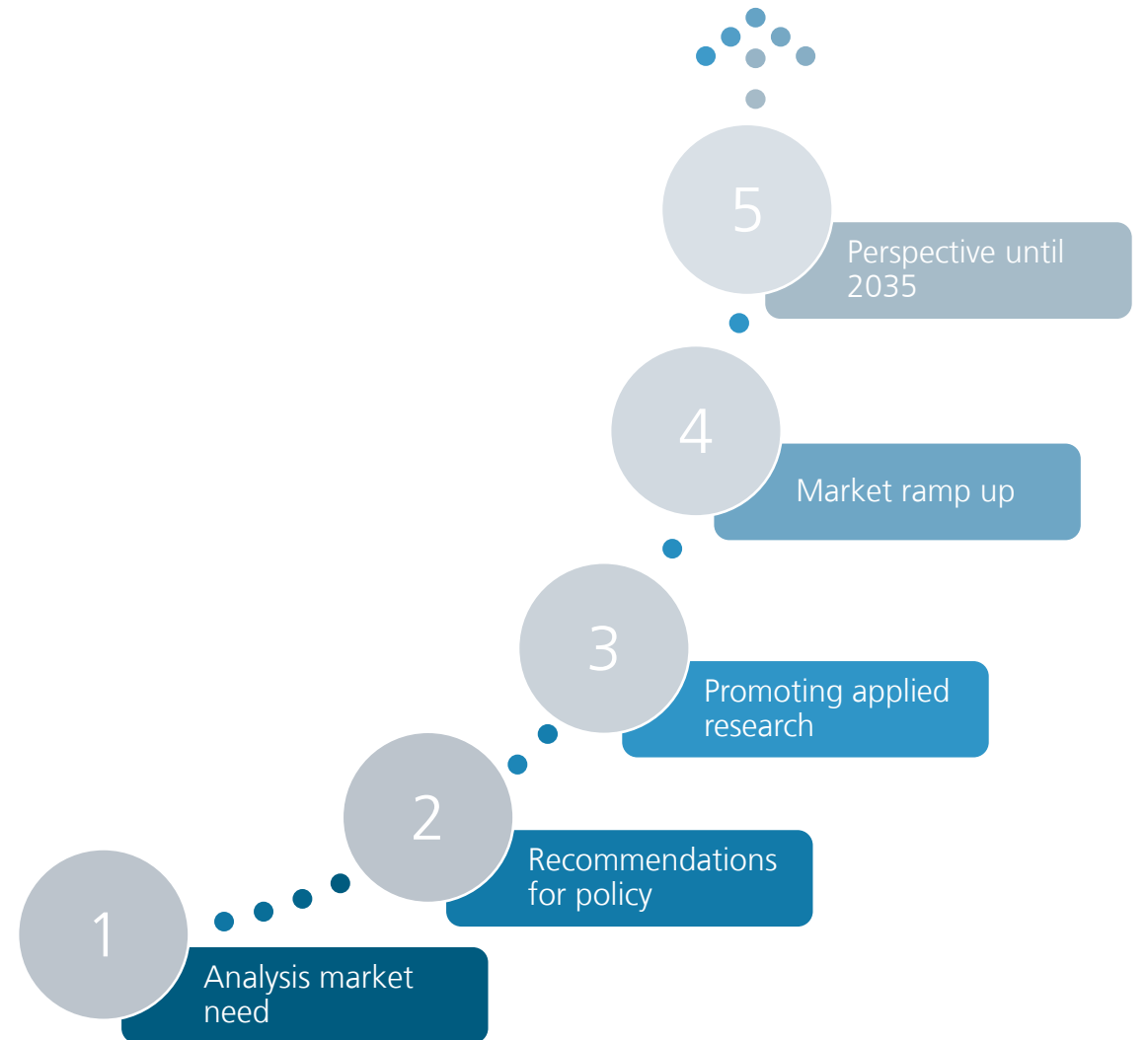
BMWK Annual Economic Report  
2022



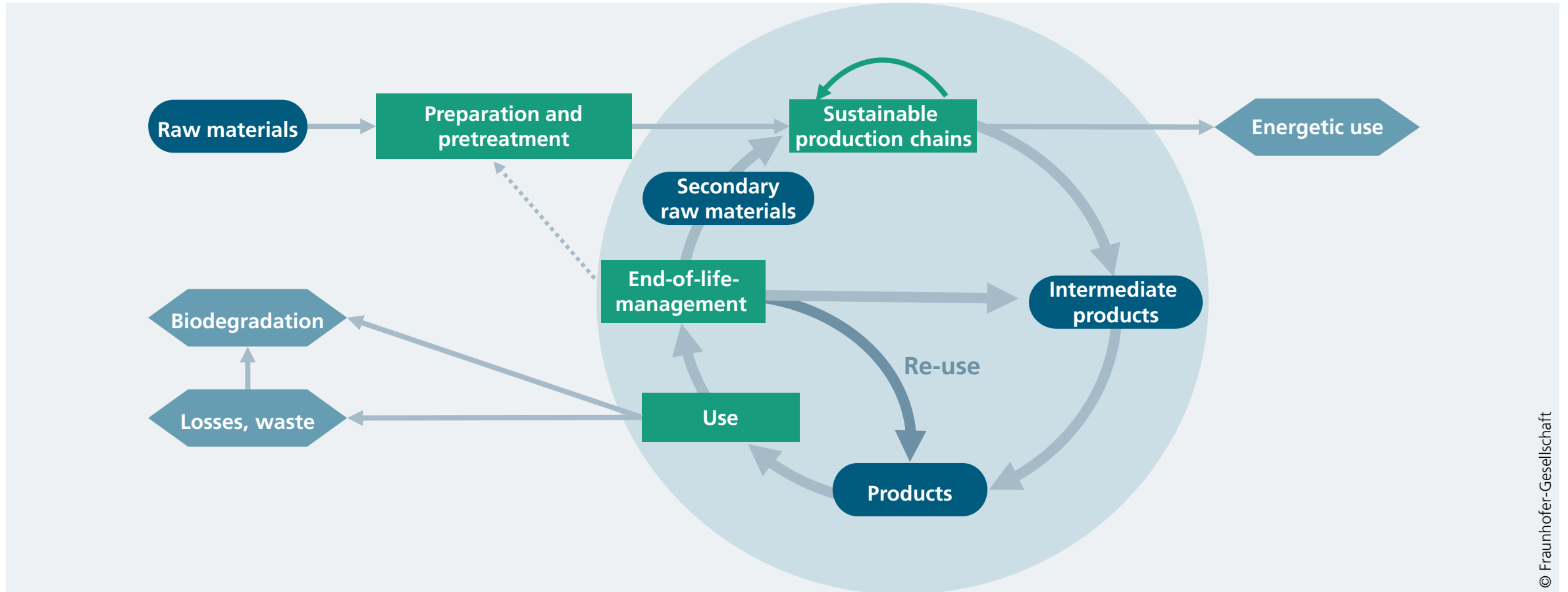
Bioeconomy Strategy Brandenburg  
2022

# Objective

- **Recommendations** to federal policymakers from the perspective of the Fraunhofer-Gesellschaft
- **Further development** of the German bioeconomy in the European economic area until 2035
- Presentation of key **scientific-technological aspects**
- Strengthening Germany as a **business location** and helping solve **global social challenges**



# Concept of the circular bioeconomy





# Biomass: limited raw material for the bioeconomy



**Increased demand** for biogenic raw materials vs. **limited supply**



**Sustainable supply** as critical factor



**Competition** for land and use



Primary goal is **food security**



**Assign recovery paths**



**Material:** high raw material efficiency and low competition

**Energetic:** neither nutrition nor material recycling

# Alternative raw material sources for the bioeconomy



## Biogenic residual materials

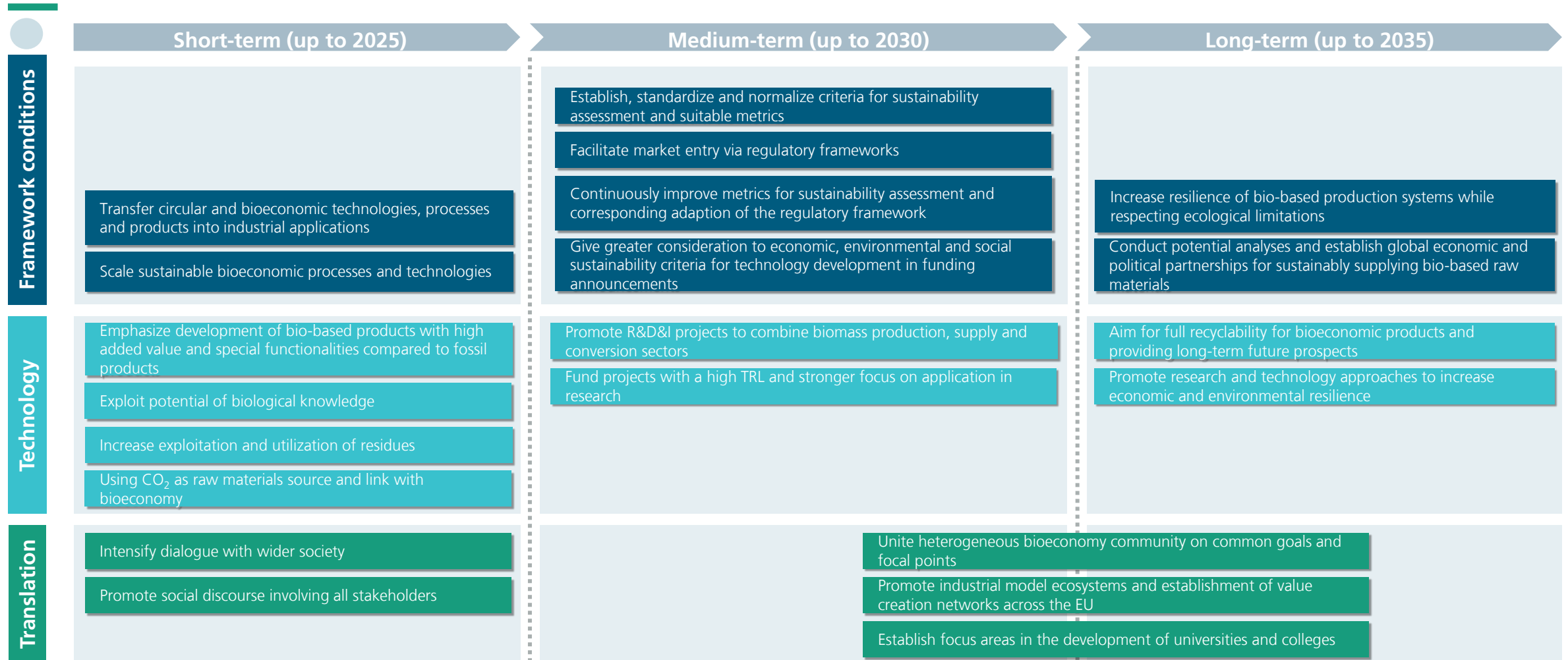
- No competition with food and feed production
- Reduced risks for ecosystems
- Significant biomass potential for various uses



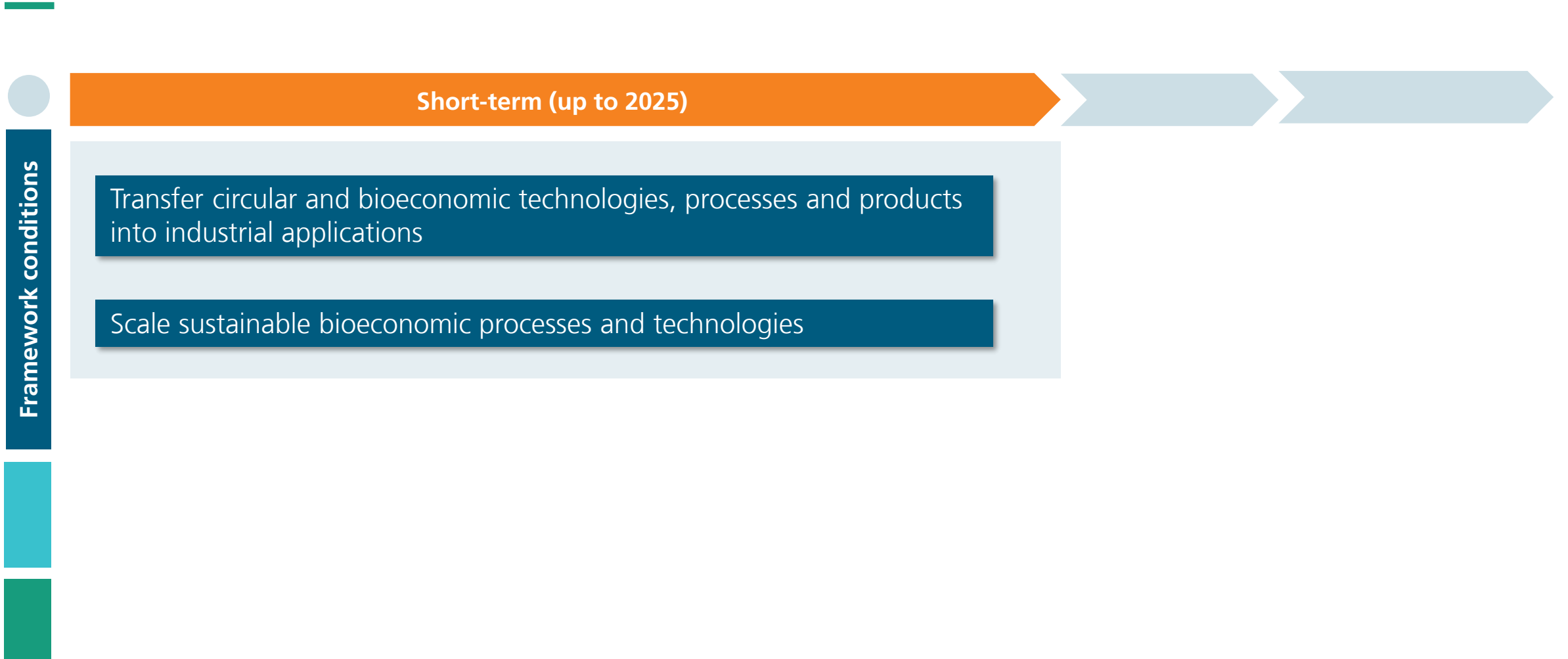
## Ressource CO<sub>2</sub>

- Carbon Capture and Usage (CCU) to recycle CO<sub>2</sub> as raw material
- Technologically possible, but high (energy) expenditure
- Many questions for further development of CCU technology

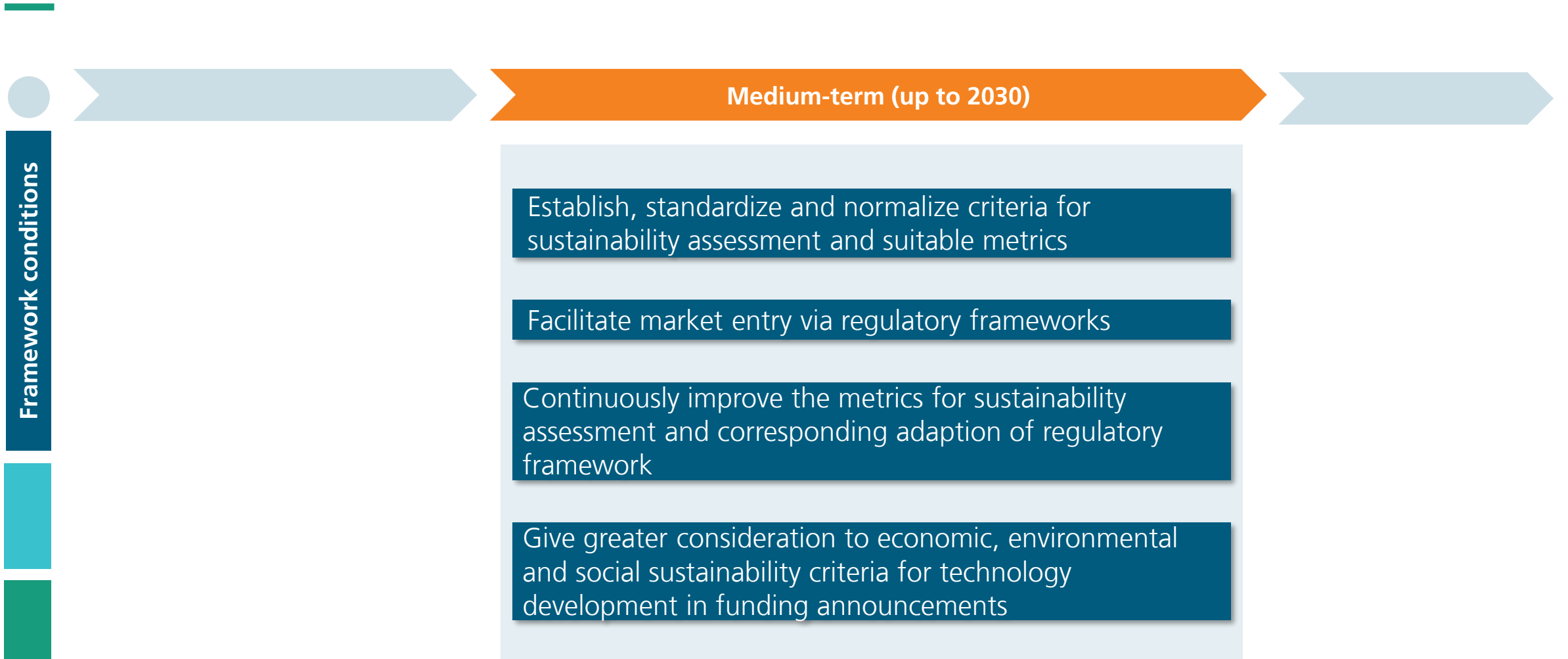
# Recommendations for action



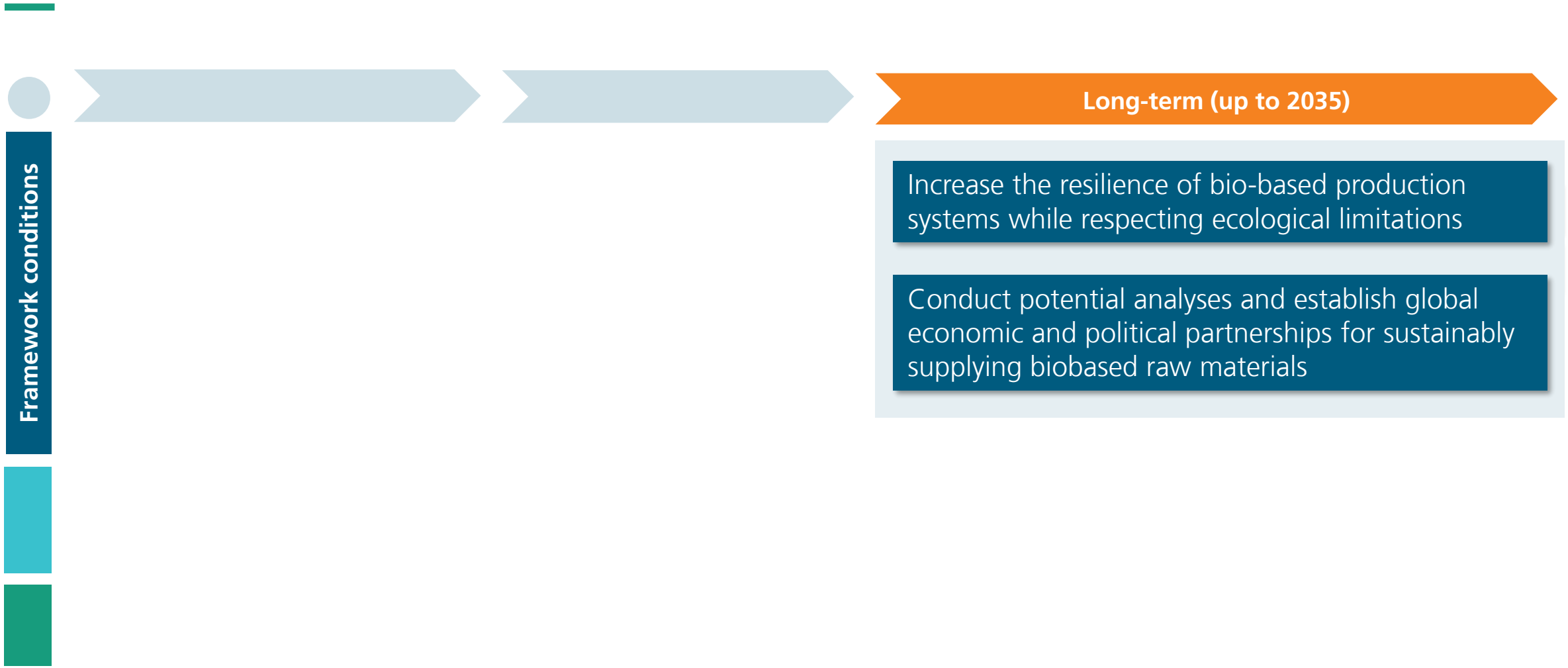
# Recommendations for action – Short-term



# Recommendations for action – Medium-term



# Recommendations for action – Long-term



# Recommendations for action – Short-term

Short-term (up to 2025)

Emphasize development of bio-based products with high added value and special functionalities compared to fossil products

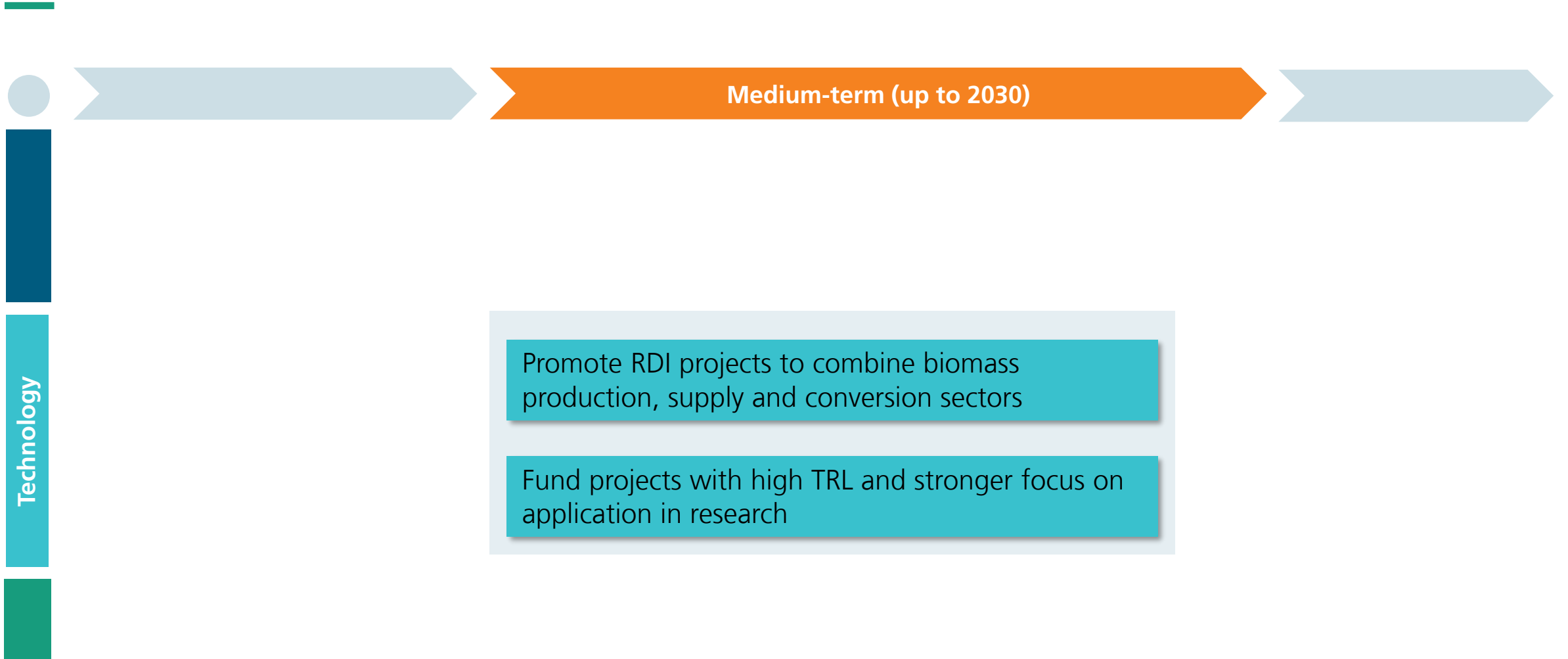
Exploit potential of biological knowledge

Increase exploitation and utilization of residues

Using CO<sub>2</sub> as raw materials source and link with bioeconomy

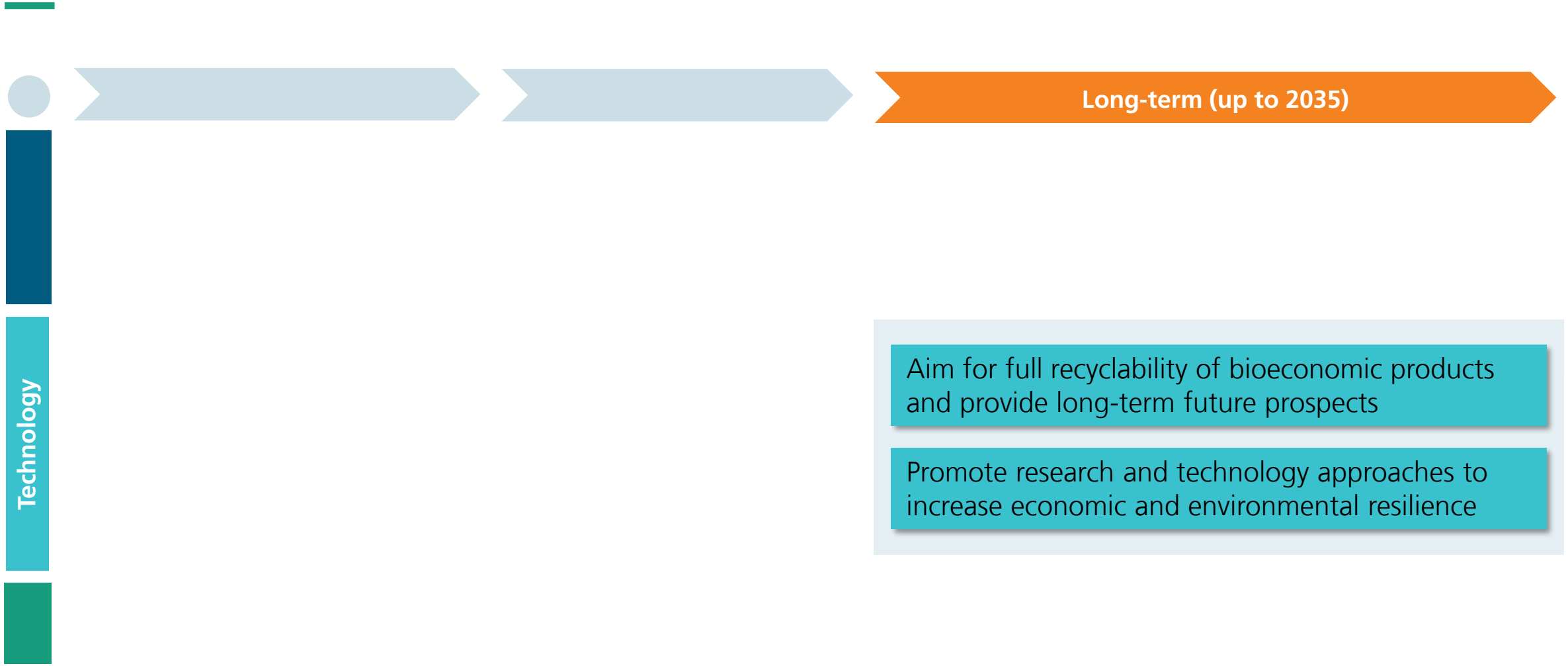
Technology

# Recommendations for action – Medium-term

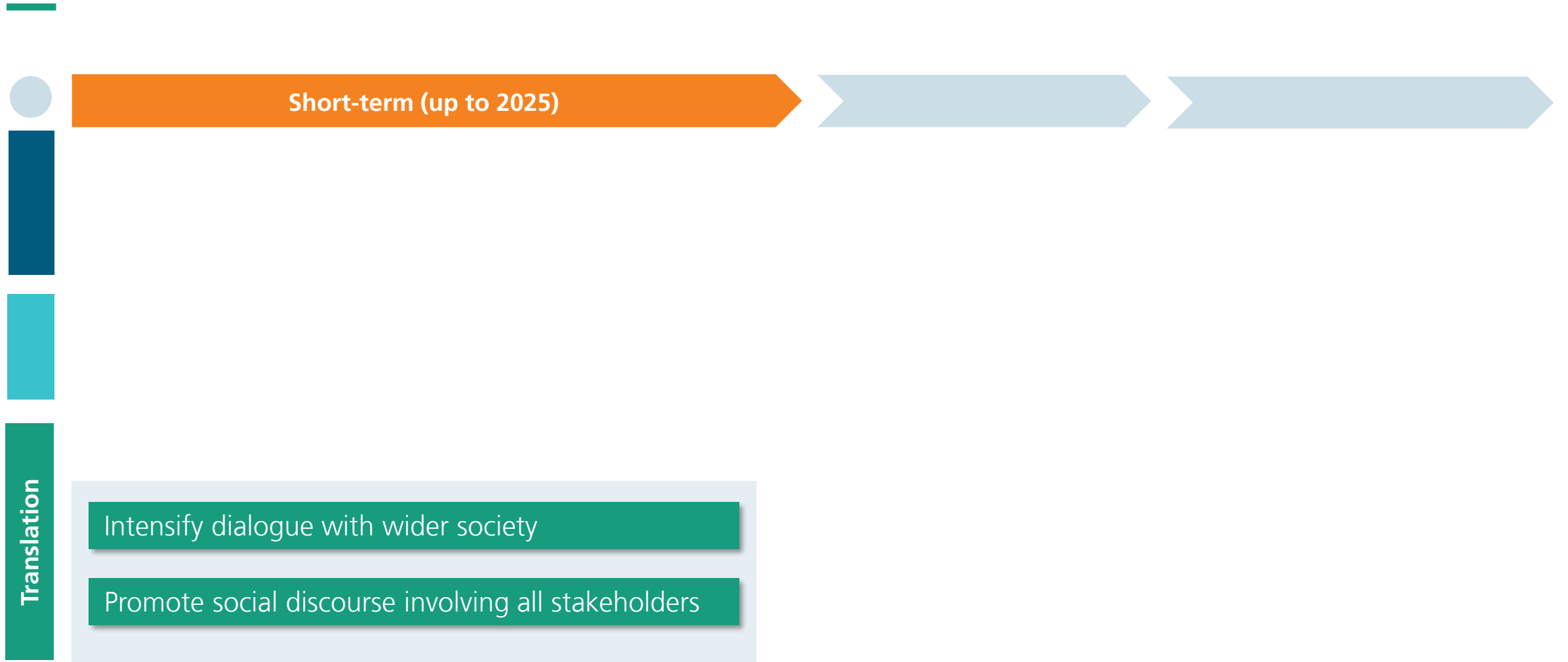




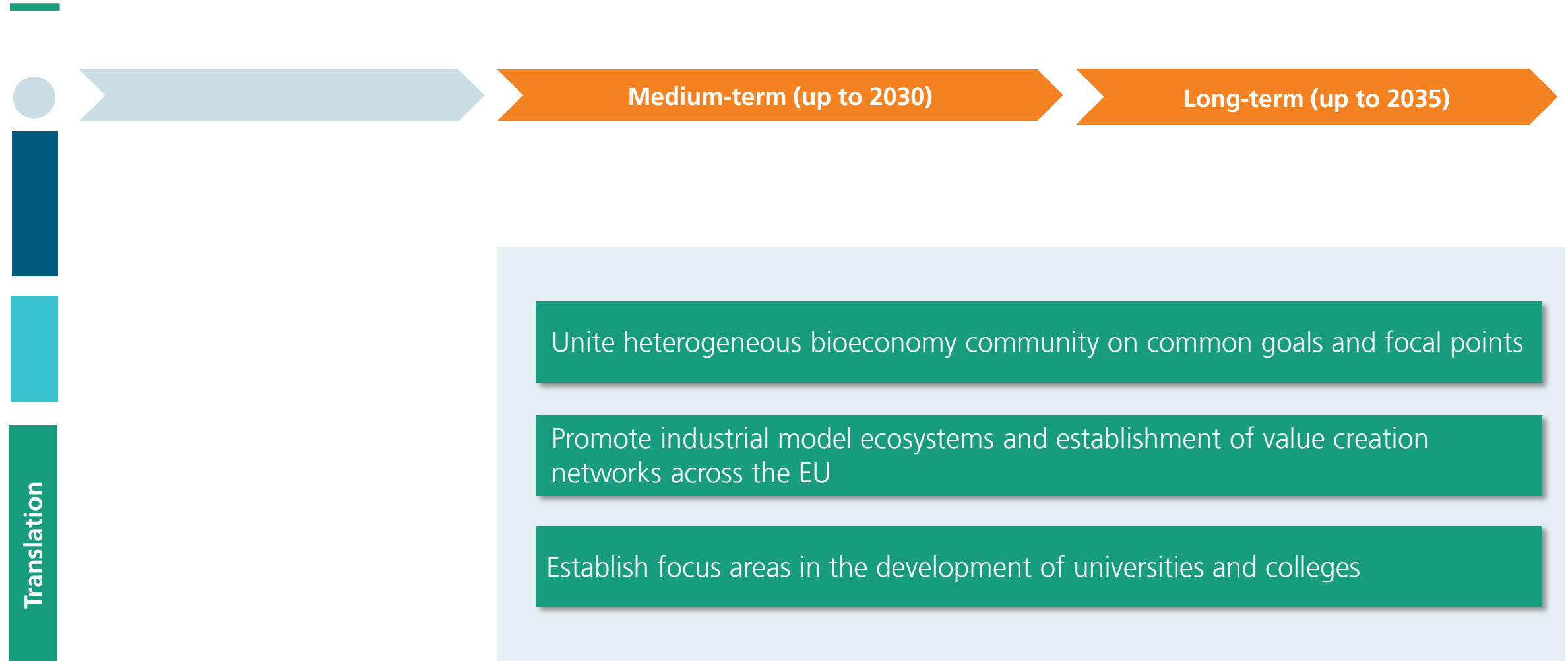
# Recommendations for action – Long-term



# Recommendations for action – Short-term



# Recommendations for action – Medium- and long-term





# Keynote

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**Bioeconomy in the EU - a key strategic priority**

Peter Wehrheim

Fraunhofer-Gesellschaft

Sustainable and competitive:  
The Bioeconomic Future of the EU

20 Sept 2023, Brussels

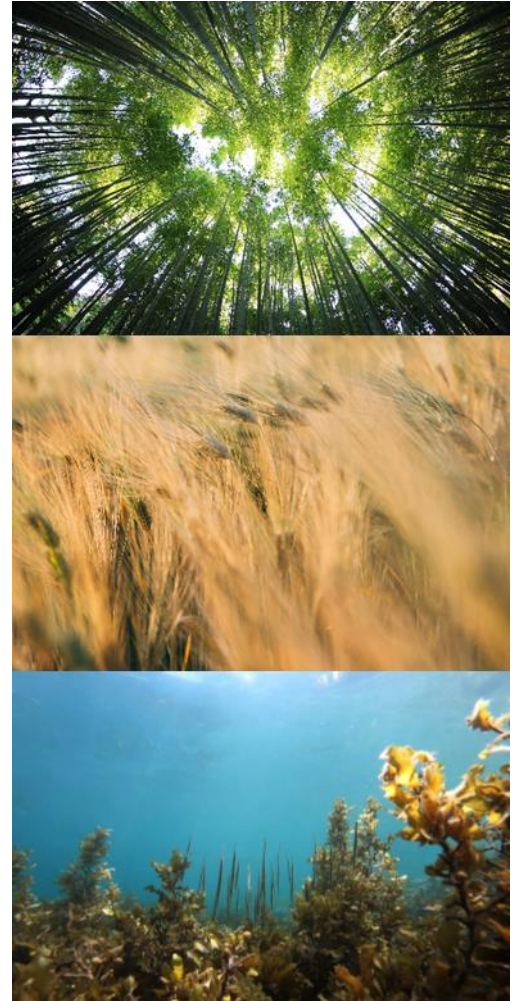
**The bioeconomy in the EU -  
A key strategic priority for the EU**

Peter Wehrheim, Head of Unit for Bioeconomy and Food Systems  
Directorate General for Research & Innovation, European Commission

# The EU's understanding of *the Bioeconomy*

All sectors and associated services and investments that produce, use, process, distribute or consume biological resources (animals, plants, micro-organisms, including organic waste), including nature-based solutions and ecosystem services.

- Primary production systems - agriculture, forestry, aquaculture / fisheries – incl. waste/side streams
- Food, feed, fibre, bio-based industry, fuels and bioenergy
- services on land and sea





# EU BIOECONOMY

European Commission's Knowledge Centre for Bioeconomy

EMPLOYMENT  
(MILLION JOBS)  
**17.4**

VALUE ADDED  
(BILLION EUR)  
**657**

	EMPLOYMENT (MILLION JOBS)	VALUE ADDED (BILLION EUR)	VALUE ADDED (SHARE TOT)
--	------------------------------	------------------------------	----------------------------

	AGRICULTURE	8.8	193	29%
	FORESTRY	0.5	25	4%



## A key sector of the EU's economy

- Based on this definition the **bioeconomy is an important sector in the EU: 8.3%** of the EU's workforce and **4.7%** of GDP; agriculture and the manufacture of food, beverage **65%** of the total value added
- The **bioeconomy's share in GDP is much higher** (10.4% for EU-28 in 2020), when including **bioeconomy services** (Ronzon WUR 2023)
- **High innovation potential** for sustainable / new biobased products through **biomanufacturing** (e.g. textiles, packaging, cosmetics, building material and services e.g. carbon farming)
- **High job creation potential**, in rural and coastal areas, through the growing participation of primary producers and deployment of bio-based solutions

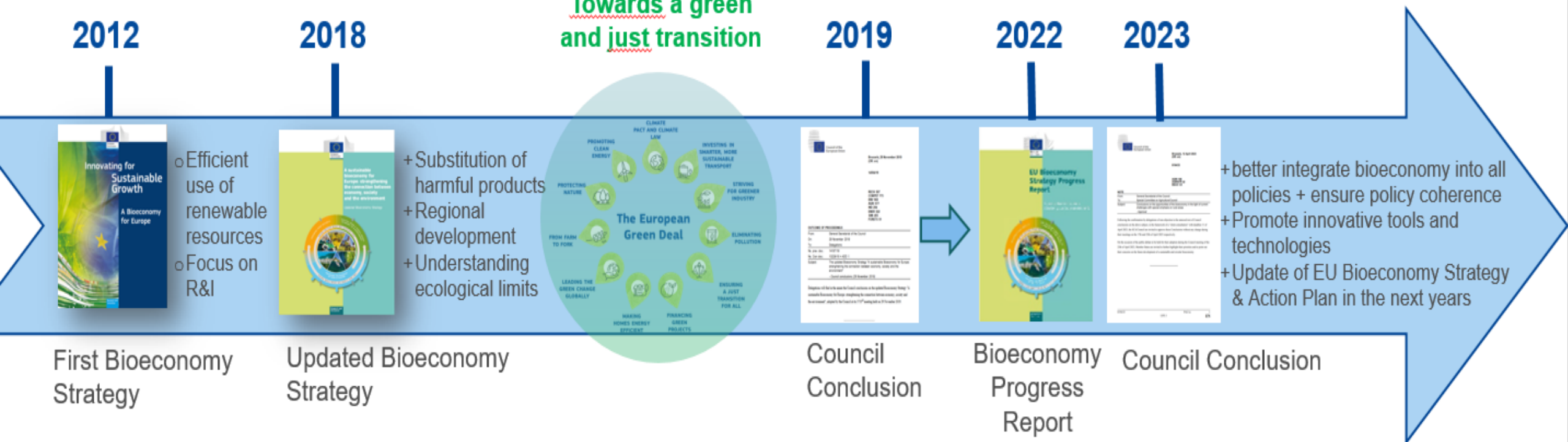
# Examples of innovative bioeconomy products

- [Woodio](#): combination of wood (80%) and resin based adhesives
- **Up-cycling** of woodchips to make long-lived wood products
- Produced from wood chips usually used for pulp, energy
- **Lower carbon footprint** on the lifecycle than for similar traditional ceramic bathroom fixtures
- Received acceleration funding (7,5 million euros) in 2021 from the [European Innovation Council](#)





# The EU Bioeconomy Strategy

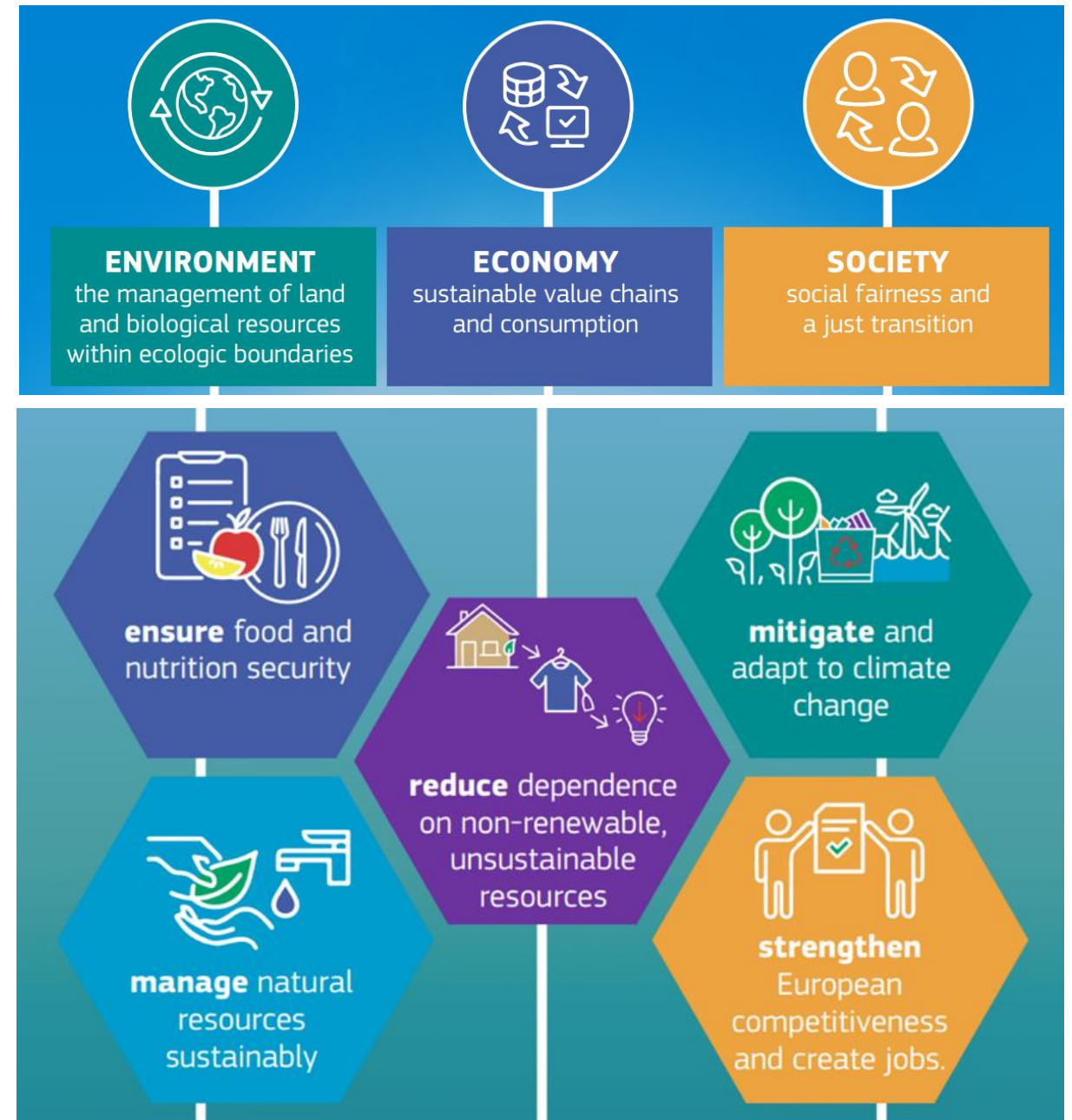


**Council Conclusions**  
 On the opportunities of the bioeconomy in the light of current challenges with special emphasis on rural areas

AgriFish Council 25/4/2023

# EU Bioeconomy policy...

- addressing all three dimensions of sustainability
- addressing five different objectives, policies across sectors, strategic view on trade-offs (e.g. scarce biomass), co-benefits (e.g. for biodiversity)
- Holistic perspective, identify win-win-win solutions



# The updated EU Bioeconomy Strategy (2018)

- **Key principles:**
  - Sustainability, circularity, cross-sectoral/holistic
- **Three priorities:**
  - Strengthening the **biobased sectors**
  - **Deploy local bioeconomies**
  - Understand the **ecological boundaries**/ protect the biosphere
- A set of **14 well-defined actions**





1

## STRENGTHEN AND SCALE-UP THE BIO-BASED SECTORS, UNLOCK INVESTMENTS AND MARKETS

-  Mobilise stakeholders in development and deployment of sustainable bio-based solutions
-  Launch the EUR 100 million Circular Bioeconomy Thematic Investment Platform
-  Analyse enablers and bottlenecks for the deployment of bio-based innovations
-  Promote and develop standards, labels and market uptake of bio-based products
-  Facilitate the development of new sustainable biorefineries
-  Develop new biodegradable products, including bio-based plastic substitutes

2

## DEPLOY LOCAL BIOECONOMIES RAPIDLY ACROSS EUROPE

-  Launch a Strategic Deployment Agenda for sustainable food and farming systems, forestry and bio-based products
-  Launch pilot actions for the development of bioeconomies in rural, coastal and urban areas
-  Support regions and Member States to develop Bioeconomy Strategies
-  Promote education, training and skills across the bioeconomy

3

## UNDERSTAND THE ECOLOGICAL BOUNDARIES OF THE BIOECONOMY

-  Enhance knowledge on biodiversity and ecosystems
-  Monitor progress towards a sustainable bioeconomy
-  Promote good practices to operate the bioeconomy within safe ecological limits
-  Enhance the benefits of biodiversity in primary production



***“The European Green Deal is Europe’s Man on the Moon Moment”***

*December 2020*

***“The fossil fuel economy has reached its limits!”*** *July 2021*

It is a new growth strategy that aims to transform the EU into a **fair and prosperous society**, with a modern, **resource-efficient and competitive** economy, where there are **no net emissions of greenhouse gases in 2050** and where **economic growth is decoupled from resource use.** »

**#EUGreenDeal**



“ *With its potential to connect and implement transformative policies holistically, the bioeconomy will contribute to all dimensions and objectives of the European Green Deal. Research and innovation will enable Europe to lead the green and digital transition.* ”

*Mariya Gabriel, EU Commissioner for Innovation, Research, Culture, Education and Youth*

Research and  
Innovation

## Bioeconomy - a blueprint for green growth :

- Holistically addresses the economic, social and environmental aspects
- Contributes to a climate-neutral future
- Promotes resource efficiency and circularity
- Reduces dependence on non-renewable resources
- Protects nature and safeguards biodiversity and ecosystems
- Provides opportunities for fair and just transition
- Green business opportunities for SMEs

See Factsheet on **How the bioeconomy contributes to the Green Deal** (<https://op.europa.eu/en/web/eu-law-and-publications/publication-detail/-/publication/66722c8d-2e03-11eb-b27b-01aa75ed71a1>)

Priority 1: Strengthening the **biobased sectors e.g.**  
Support for biobased innovation in the EU:  
**Circular Biobased Europe (CBE)**



- **Horizon Europe** (the EU's framework program for Research and Innovation) supports the **Circular Biobased Europe CBE** (public-private)
- CBE is a **€2 billion** partnership between the EU and the **Bio-based Industries Consortium (BIC)**: funding projects that advance competitive **circular bio-based industries in Europe** (e.g. [Carlsberg makes bio-based and fully recyclable bottles ..](#))

**General objectives of CBE:**

- Accelerate the **innovation** process and development of bio-based innovative solutions
- Ensure a high level of **environmental performance** of bio-based industrial systems
- Accelerate **market deployment** of the existing mature bio-based innovative solutions

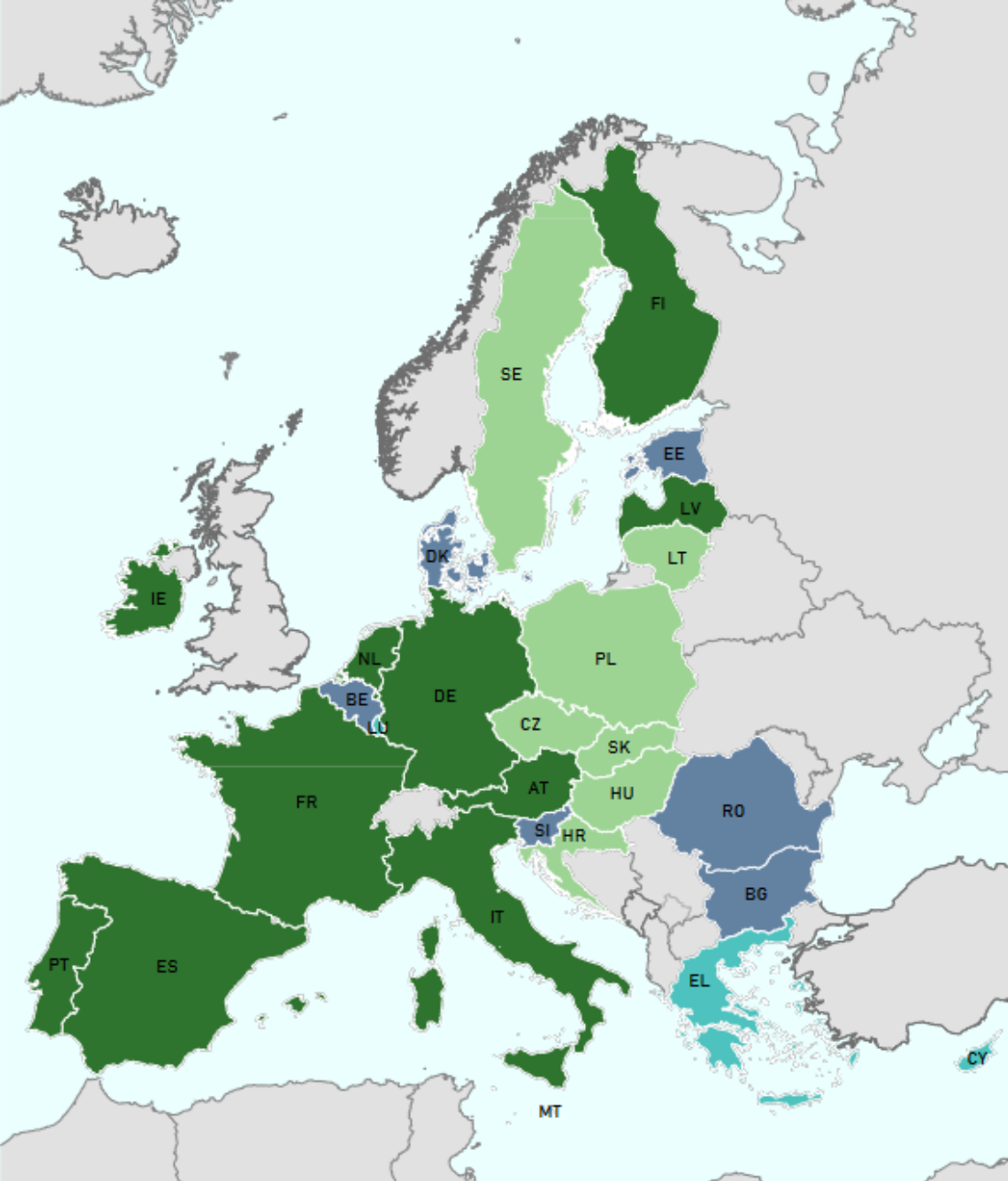
**Open calls:**

- Two 2023 calls are currently open: [Home | Circular Bio-based Europe Joint Undertaking \(CBE JU\) \(europa.eu\)](#)”

## Priority 2: Deploy local bioeconomies e.g. Status of the national bioeconomy policies in the EU-27

(as of Dec 2022)

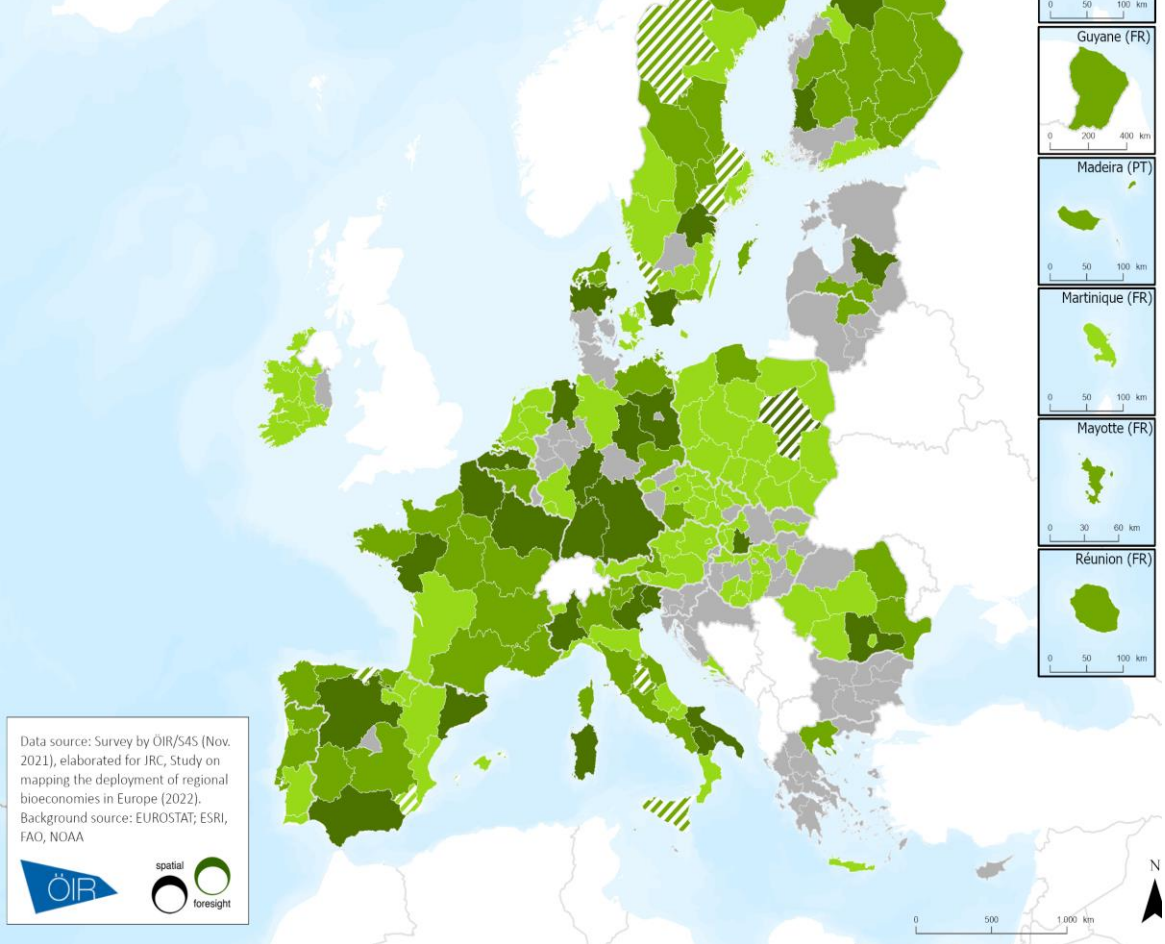
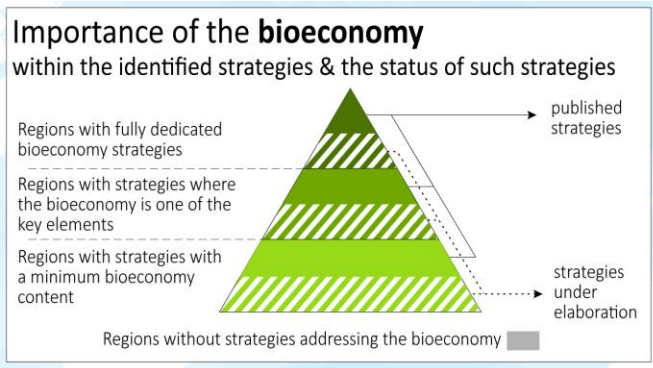
- **10 Member** states with **dedicated bioeconomy strategies** at national level (AT, DE, ES, FI, FR, IE, IT, LV, NL, PT)
- **7 MS** in the process of **developing their respective dedicated national strategies** (CZ, **HR**, HU, LT, PL, **SE**, SK)
- **6 MS** are involved in other **macro-regional** (BG, DK, EE, RO, SI) or **sub-national** (BE) policy initiatives dedicated to the bioeconomy



### Status of national bioeconomy strategies:

- Dedicated bioeconomy strategy at national level
- Dedicated bioeconomy strategy at national level under development
- Other policy initiatives dedicated to the bioeconomy
- Other related strategies at national level

Source: EC's Knowledge Centre for Bioeconomy  
Administrative Boundaries:  
© EuroGeographics © UN-FAO © Turkstat



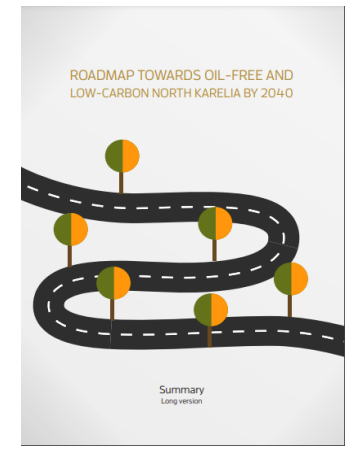
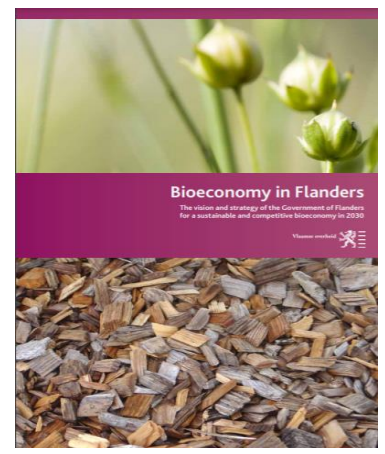
- Açores (PT)
- Canarias (ES)
- Guadeloupe (FR)
- Guyane (FR)
- Madeira (PT)
- Martinique (FR)
- Mayotte (FR)
- Réunion (FR)

Data source: Survey by ÖIR/S4S (Nov. 2021), elaborated for JRC, Study on mapping the deployment of regional bioeconomies in Europe (2022).  
Background source: EUROSTAT; ESRI, FAO, NOAA

# Status of the regional bioeconomy policies in the EU-27

(as of Nov 2021)

- **28 EU** regions have dedicated strategies



- **68 EU** regions have adopted policies where bioeconomy is a key element while in **7 additional regions** such strategy is under development.





# The EU's Bioeconomy Strategy

A policy framework for sustainability

## Findings of the Progress Report

<https://op.europa.eu/s/wmT4>

Bioeconomy continues to be a **crucial policy** for the EC

- Contributes to the European Green Deal objectives
- Enables sustainable and just transition pathways to a climate-neutral & nature-positive Europe 2050.

**Mainstreaming** and **up-scaling** of sustainable bioeconomy ever more important in view of the current food and energy price crisis

- Transition to resilient and sustainable food systems & clean energy within ecosystem boundaries
- Managing potential trade-offs from a holistic perspective



Additional focus needed: risks and opportunities



### Biosphere stewardship strategy

Focus on resolving multiple pressures on land and sea



### Consumption-based framework

Focus on the overall consumption of biological resources

# **Bioeconomy Council conclusions (position of Member States, Ministers for Agriculture and Fisheries) - April 2023**

- EMPHASISES the **central role of a sustainable and circular bioeconomy** for the climate and the environment, and **for achieving the objectives of the European Green Deal and its strategies.**
- Invites EC to provide an overview and follow-up on **how the bioeconomy has been addressed in national plans for the Common Agricultural Policy.**
- Calls on the EC to **better integrate bioeconomy in all EU policies** and support the development of the bioeconomy across the whole value chain while addressing regulatory barriers.
- Calls on the Commission to present an updated Bioeconomy Strategy and Action Plan

# The Bioeconomy – Youth Ambassadors and next steps

- The EU **Bioeconomy Youth Ambassadors**
- **March 2024: Bioeconomy Youth & Innovation Festival**, Brussels
- **October 13<sup>th</sup> 2023**: Conference at the Agricultural University of Plovdiv, Bulgaria on **Innovation Valleys for Bioeconomy and Food Systems**
- **European elections in May 2024** a new Commission expected to take office towards end of 2024



# Conclusions – The **EU Bioeconomy** is a

- **thriving sector in the EU** with growing number of national and regional strategies
- a **problem solver** to meet the ambition of the European Green Deal and a **complement to the circular economy** e.g. by offering solutions for biomanufacturing/”defossilisation” of the chemical industry
- a research intensive sector, **cutting edge bioeconomy research from Institutes like the Fraunhofer-Gesellschaft** is key to develop/deploy/scale innovative sustainable biobased solutions
- **Horizon Europe supports research and innovation related to the bioeconomy** including through the Circular Biobased Europe (CBE) partnership

# Thank you



Links to EU Bioeconomy:

[EU Bioeconomy Progress Report. European Bioeconomy Policy: Stocktaking and future developments](#)

**Bioeconomy Council Conclusions April 2023:**

[https://www.linkedin.com/posts/peter-wehrheim-9b87b334\\_bioeconomy-bioeast-activity-7057293414286913536-1Lec?utm\\_source=share&utm\\_medium=member\\_desktop](https://www.linkedin.com/posts/peter-wehrheim-9b87b334_bioeconomy-bioeast-activity-7057293414286913536-1Lec?utm_source=share&utm_medium=member_desktop)

[13<sup>th</sup> October Bioeconomy Conference at Agricultural University of Plovdiv](#) → [https://lnkd.in/e2f\\_XVPS](https://lnkd.in/e2f_XVPS)

Fraunhofer Roadmap Circular Bioeconomy

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# Workshop A: The sustainability transition in the food sector

**Stefan Schillberg**  
Fraunhofer IME

**Mark Bücking**  
Fraunhofer IME



**Fraunhofer**  
FOOD

LEAD MARKET  
Agriculture and Food Industry

# Lead Market Agriculture and Food Industry

## Potentials of the Alliance

By bundling Fraunhofer competencies and technologies, the lead market Agriculture and Food Industry will:

- Tap novel raw materials and food to **secure supply** for a growing world population.
- Contribute to the improvement of **sustainability** with simultaneous **economic viability** as well as to the **development of new business models** in food production.
- Ensure food **safety** as well as **resilience** of the food supply, also in the face of the increasing trend toward individualized nutrition.

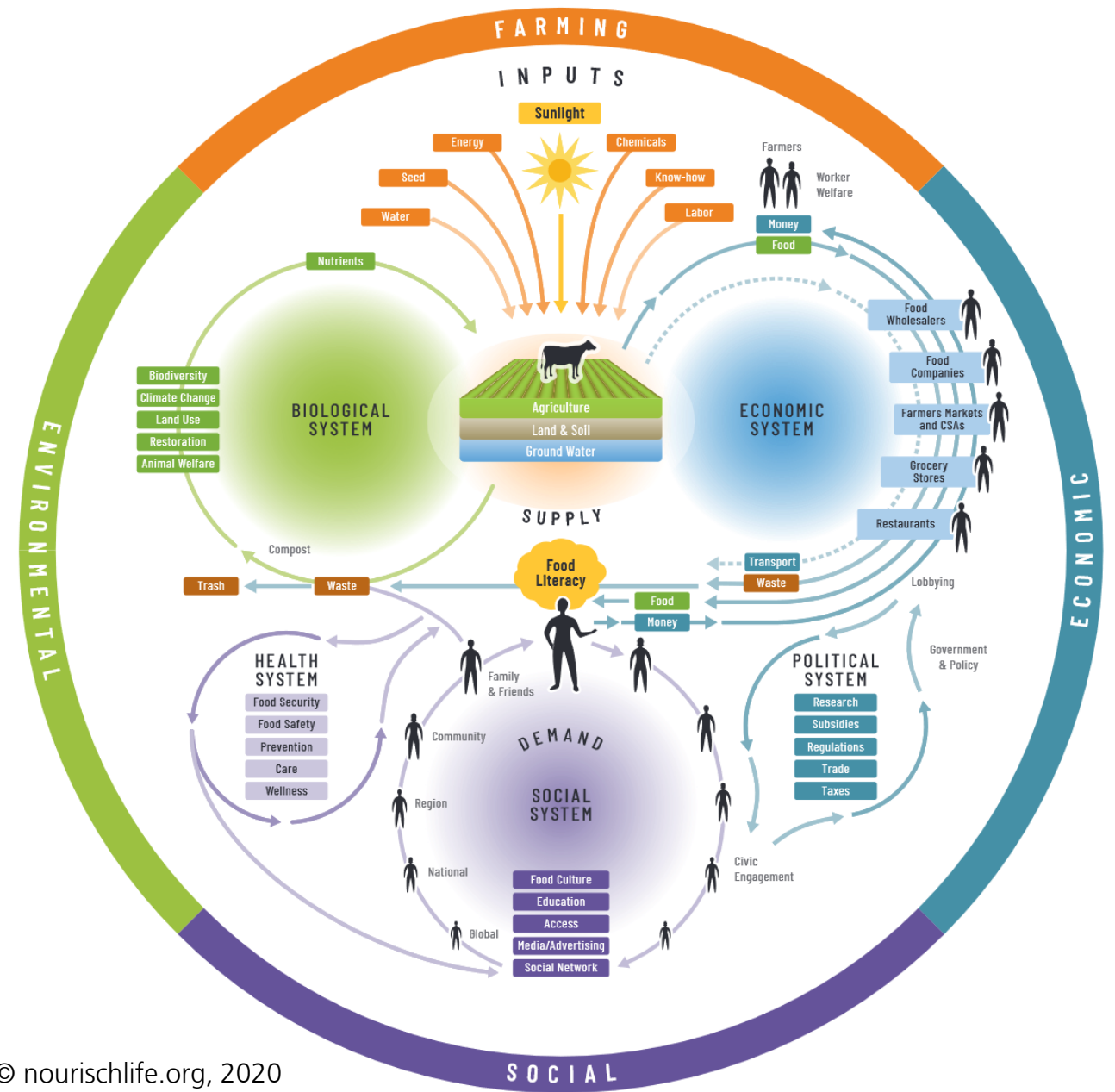




# The sustainability transition

Understanding the Connections

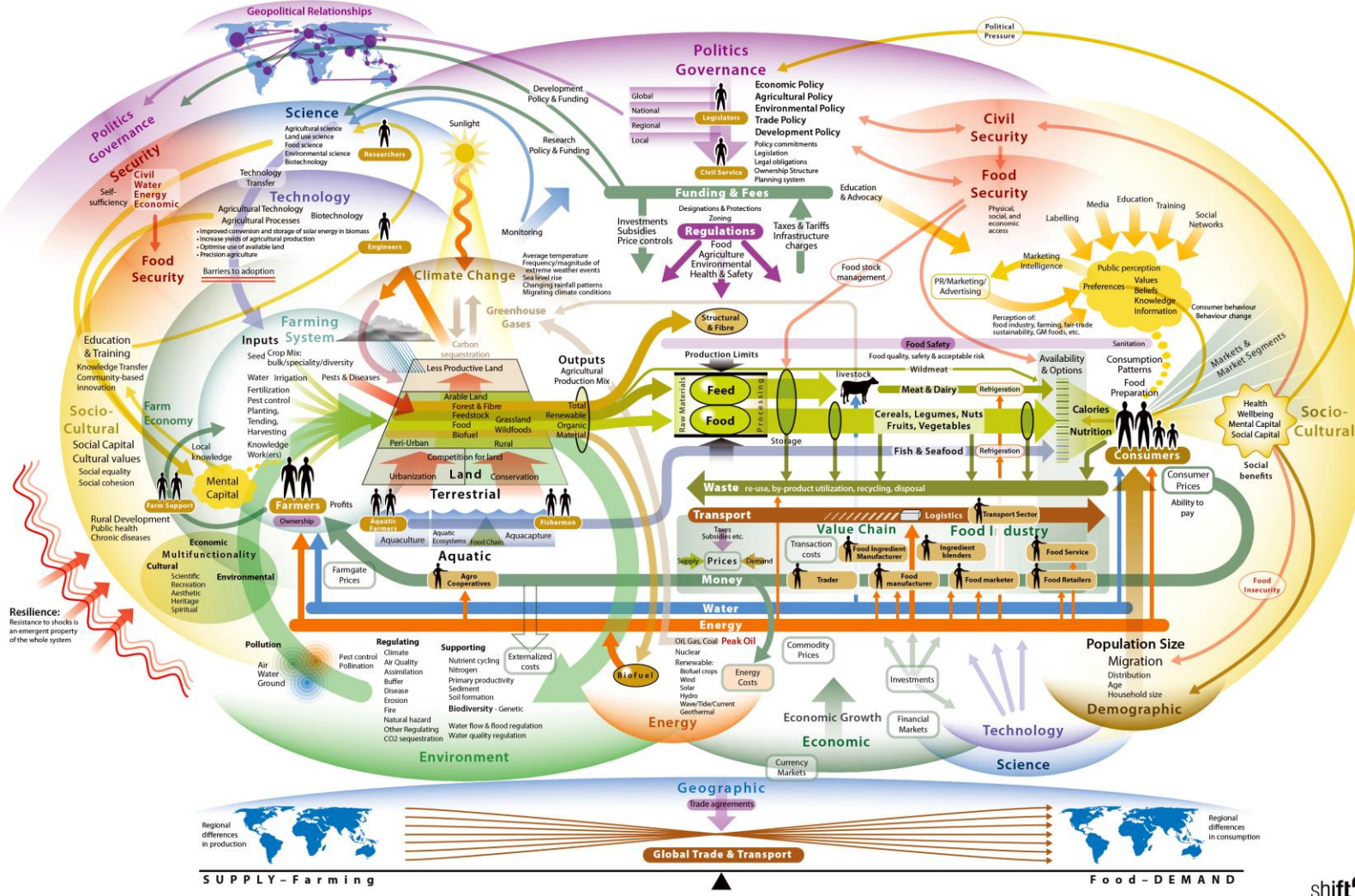
## Together & Sustainable



© nourischlife.org, 2020

# The sustainability transition in the food sector

Global Food System Map



# Key Questions

## Roadmap for the Future Development of the Circular Bioeconomy



- What are the scientific and technological potentials and challenges of the bioeconomy till 2035?
- Where will applied research promote a market ramp-up of the bioeconomy meeting ecological and socioeconomic needs?
- Which kind of political framework conditions are needed to achieve this

# Circular Bioeconomy for Germany

## FOOD

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- the price of rice has grown more than 2.5-fold from 2003 to 2023<sup>1</sup>
- FAO: around 800 million people worldwide could not satisfy their daily calorie requirements
- “hidden hunger”, a phenomenon that occurs in large areas of the world. Every year, it is the cause of death for around 700,000 children under the age of five
- current agricultural production levels can provide sufficient plant-based food for 9.5 billion people in 2050<sup>2</sup>
- DGE<sup>3</sup> malnutrition in Germany is partially responsible for the rise in obesity, cardiovascular disease, diabetes mellitus and many forms of cancer. One in five deaths in Germany and 30 percent of the healthcare system costs are associated with poor dietary habits and could be avoided in the majority of cases [35].

<sup>1</sup><https://tradingeconomics.com/commodity/rice>

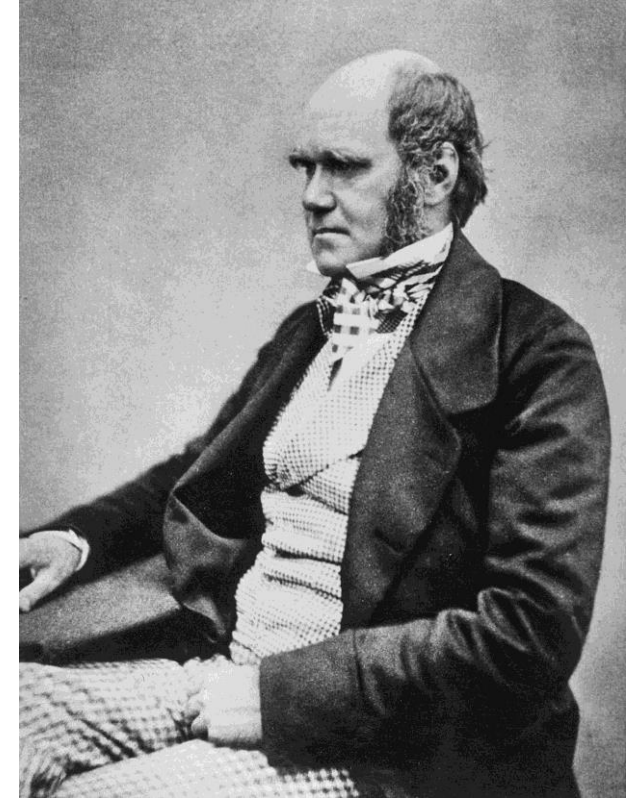
<sup>2</sup>Innovative Food Products in Biological Transformation

<sup>3</sup>German Nutrition Society

# Statements

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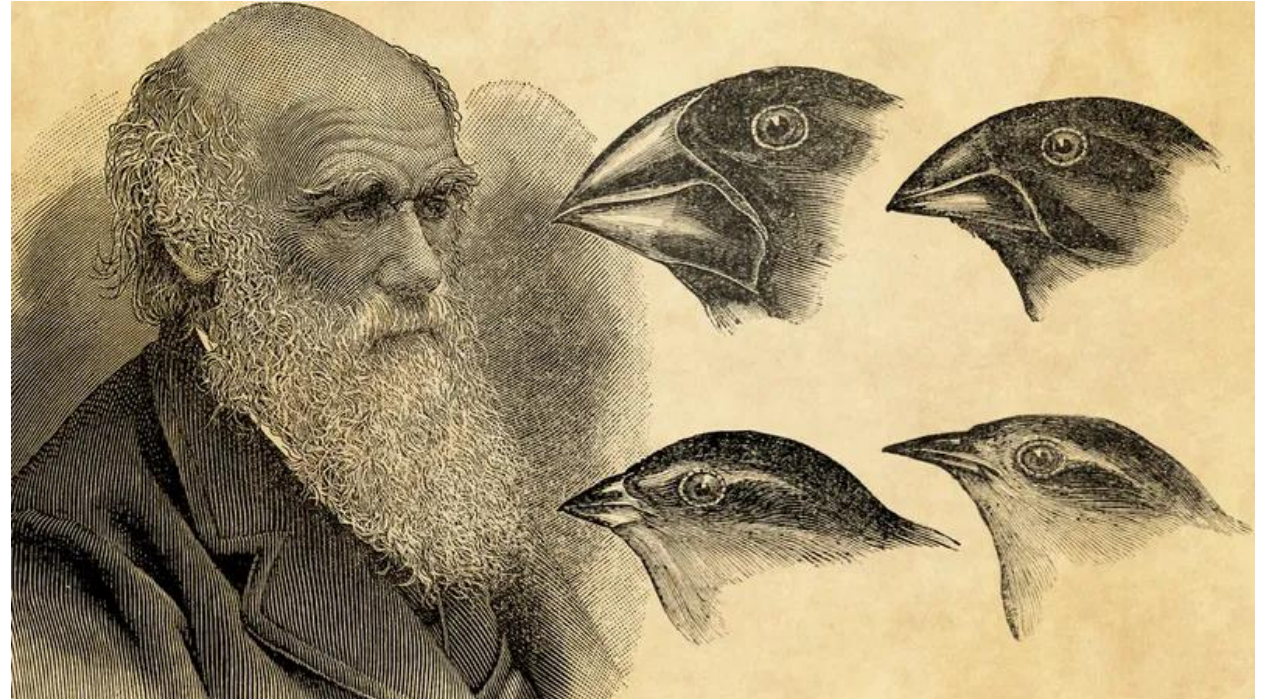
**There is a constant tendency of all animate life to multiply to the point where the available food is insufficient**



# Statements

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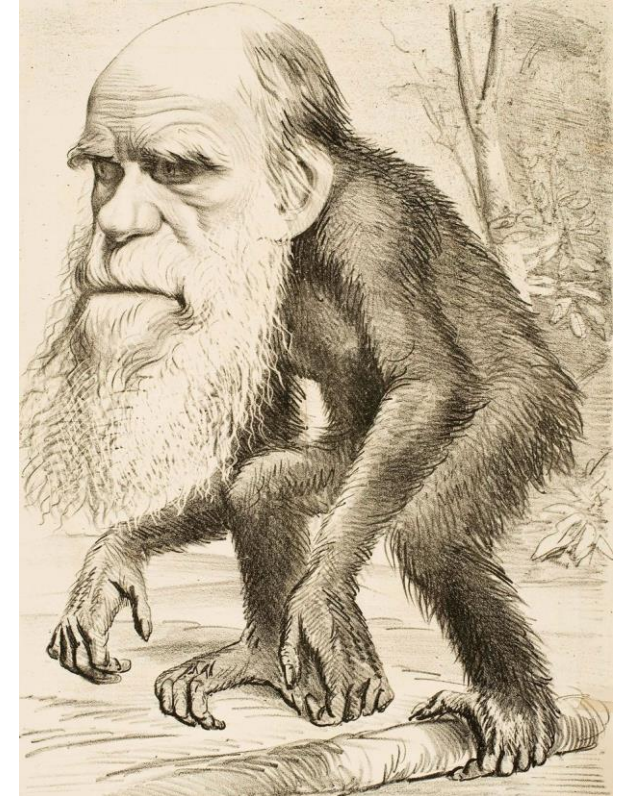
**The normal food of man is vegetable**



## Statements

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**The 'chicken society' does not even realize that its eggs are taken from behind while pecking a handful of food thrown in front of it**



# Resilience of food value chains

## Increasing the resilience of supply chains

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Resilience can be increased by planning strategies and countermeasures that enable the system as a whole to rapidly return to its original or target state. As such, “resilience” refers to the ability to maintain stability despite internal and external influences and disruptions.

Digitalization of processes

Defining countermeasures

Regional processing





# Global food security

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Alternative cultivation systems

Alternative protein sources & their consumer acceptance

Simplifying approval processes for novel foods

Are these the TOP 3?

What else?



# Sustainable and healthy nutrition

---

Food producers and manufacturers are seen as key actors in making the food system sustainable, above public authorities, but not all Europeans recognize their own role as consumers.

Around two thirds of those surveyed say that producers (farmers, fishers, aquaculture producers) (65%) have a role to play in making our food systems sustainable - these are the most-mentioned actors in 20 of the EU Member States. Nearly six in ten also cite food manufacturers (58%). National governments (47%) are the third most-mentioned actor.

Interaction Stakeholder

Yes / No

Why

How (to measure)



Special Eurobarometer 505 - Making our food fit for the future – Citizens' expectations, Report 2020

# Handling avoidable and unavoidable food waste

“Food waste can be found throughout the value chain, with the largest amount of avoidable waste occurring at the retail and consumer level” (in Europe)

- Male
- Born in 1948
- Grown up in UK
- Married, successful, rich
- Spends free time in the Alps
- Likes dogs
- Is in the public eye



Where (local, national, EU, global)

What

Fraunhofer Roadmap Circular Bioeconomy

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# Workshop B: Circular (Bio)economy – How can bio-based plastics contribute?

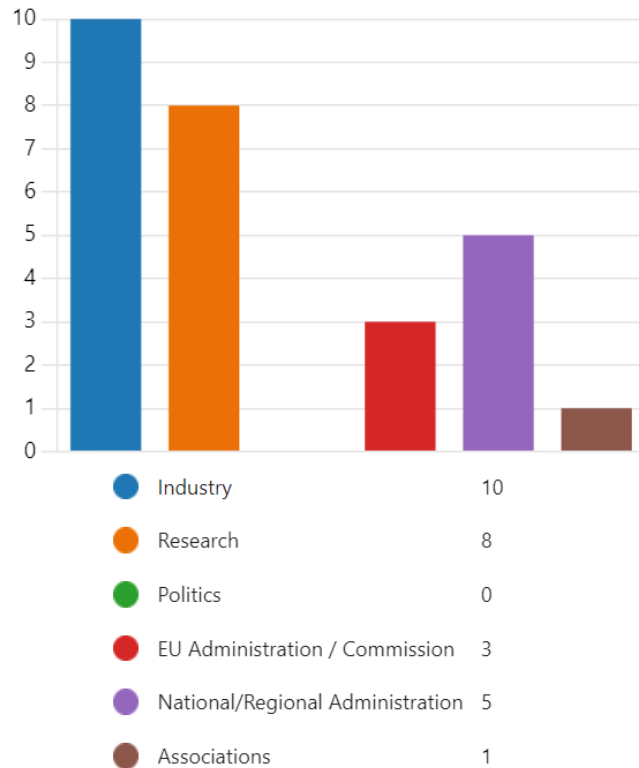
**Esther Stahl**  
Fraunhofer UMSICHT

**Bert Volkert**  
Fraunhofer IAP

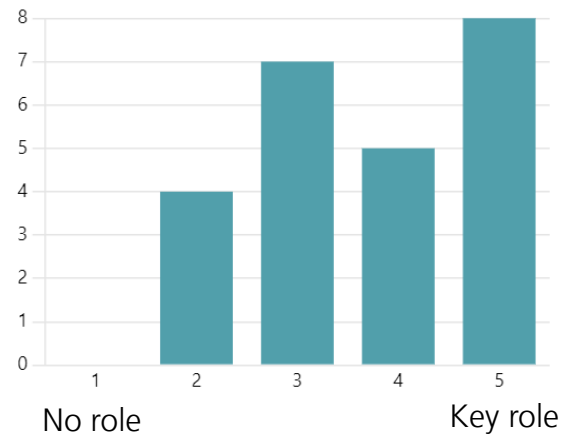
# Circular (Bio)economy

## Online survey - results

### What is your professional background?

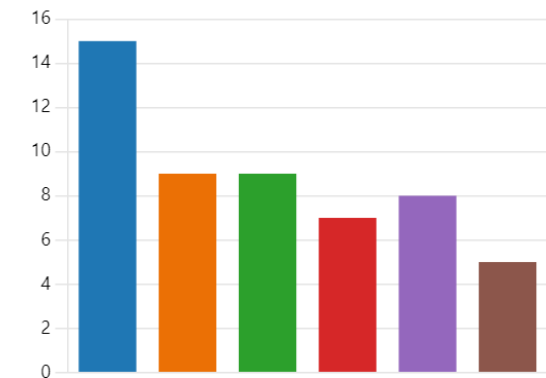


### What role will bio-based plastics play in achieving climate neutrality in the plastic industry by 2045?



3.71  
On average

### In your opinion, what are the key success factors for an effective contribution of bio-based plastics to climate neutrality?



- (Competitive) product qualities of bio-based plastics - 15
- Regulations (restrictions for fossil-based plastics, decreased carbon footprint) - 9
- Availability - 9
- Enhanced research and development incl. demonstration plants - 7
- Preferential use in public procurement - 8
- Others: costs, mixed materials, competitive price finding, recycling - 5

Fraunhofer Roadmap | September 20, 2023 | Brussels

# Circular (Bio)economy – How Can Bio-based Plastics Contribute?

Dr. Daniel Zehm, Fraunhofer Institute for Applied Polymer Research IAP

# Aiming for the Ideal Economy

We Need Something New

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**Economy = Organization of our social metabolism (= how materials are converted)**

## Key topics

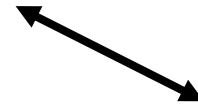
- **Limits** of our world system
- Moral responsibility that **future generations** can live on a planet that sustains them
- **Rethinking** economics
  - Reduce ecological footprint
  - ...
- Enable **decent living** for mankind (Zukunftsfähigkeit; Hans-Peter Dürr)



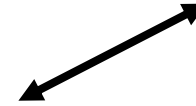
**We need a Circular Economy!**

# Interactions

## Extraction of natural resources



Social  
Metabolism



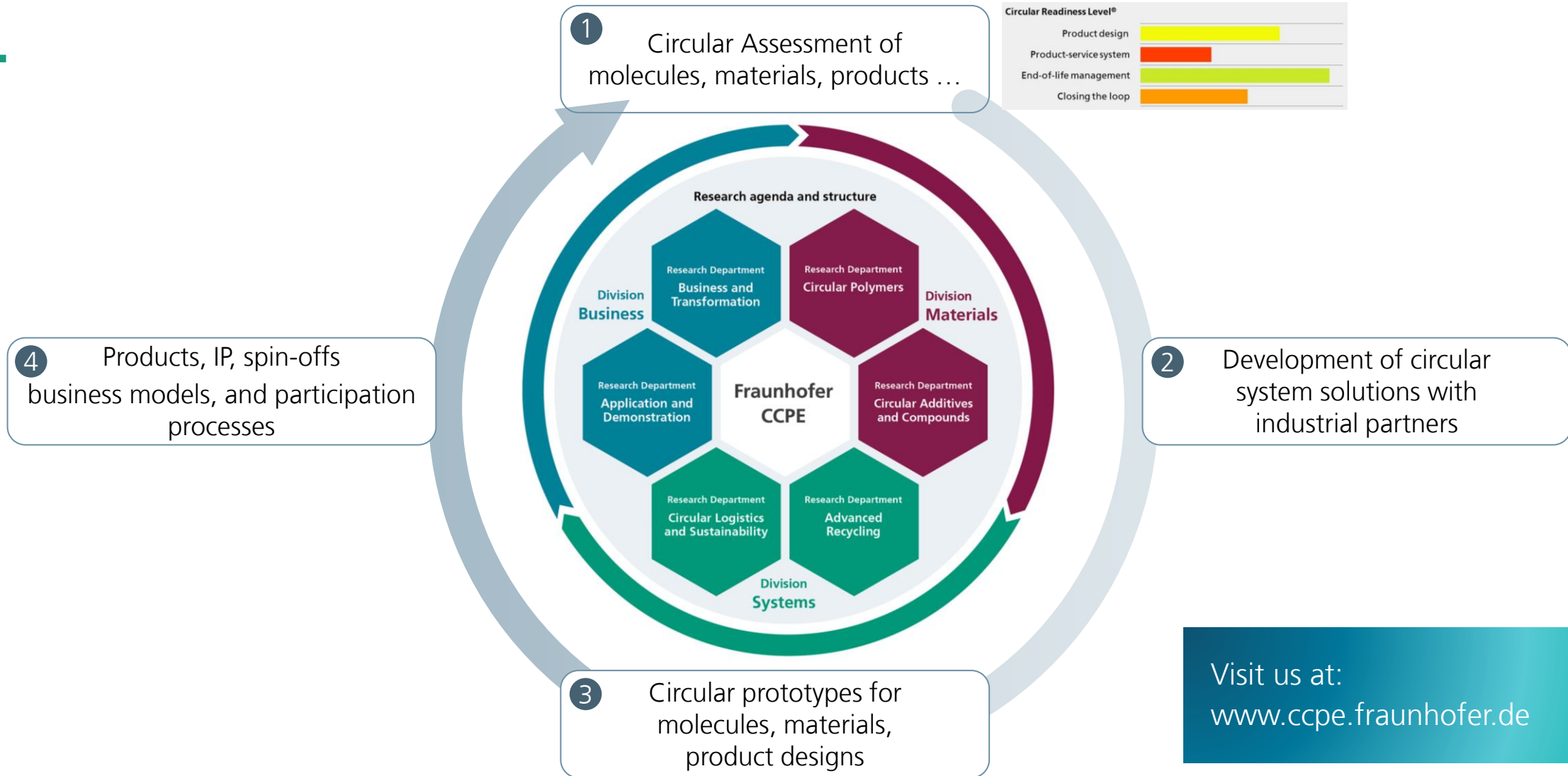
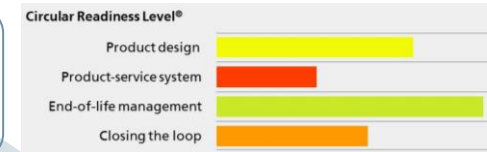
## Reuse of materials in Germany (2021)

- Water (96%), paper (77%), glass (84%), scrap metal (steel: 90%, Al: 69%, Cu: 60% ...), plastic (13%) → **reuse of plastic is poorly established**

Source: Umweltbundesamt; <https://www.umweltbundesamt.de/daten/ressourcen-abfall>



# System services for a circular plastics economy



Visit us at:  
[www.ccpe.fraunhofer.de](http://www.ccpe.fraunhofer.de)

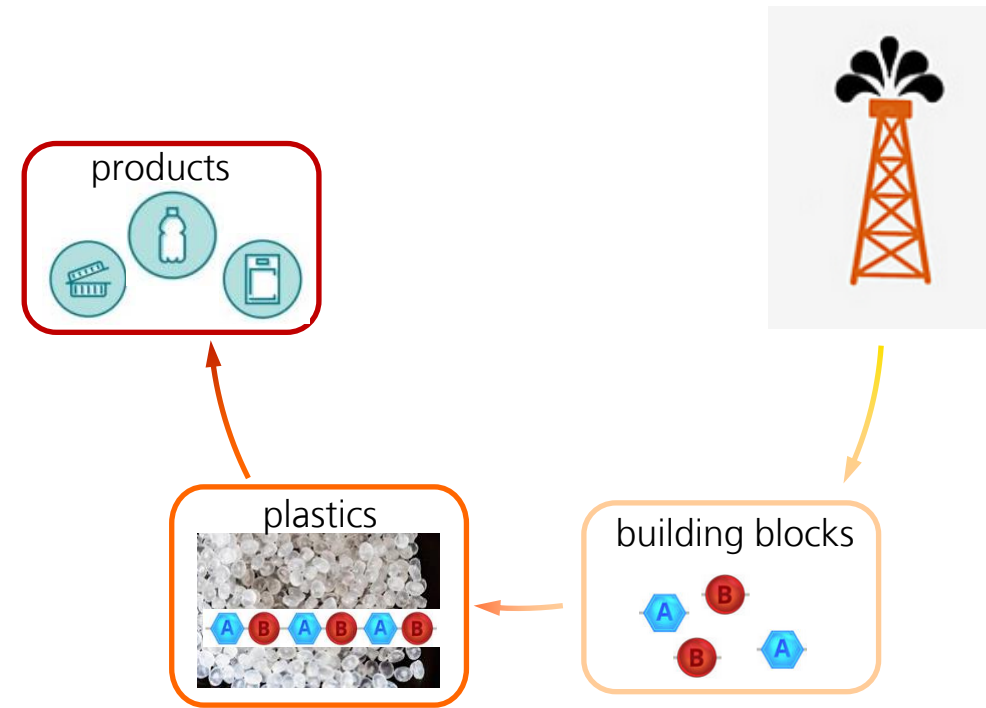
# The Plastic Value Chain

## Status Quo

**Economy = Organization of our social metabolism (= how materials are converted)**

### Key topics

- Metabolism is mainly based on fossil resources



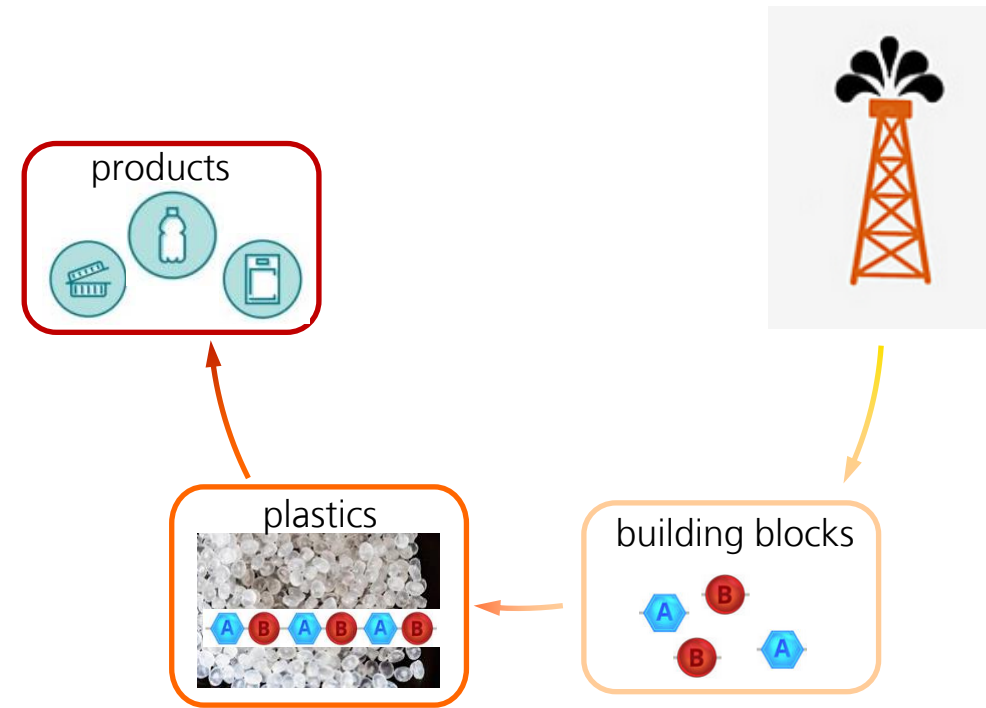
# The Plastic Value Chain

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**Economy = Organization of our social metabolism (= how materials are converted)**

### Key topics

- Metabolism is mainly based on fossil resources
- Metabolism is mainly based on linear value chains  
exceptions: PET-bottles (reuse & recycling), PES-membranes (reuse),  
containers for municipal solid waste, bottle crates ...



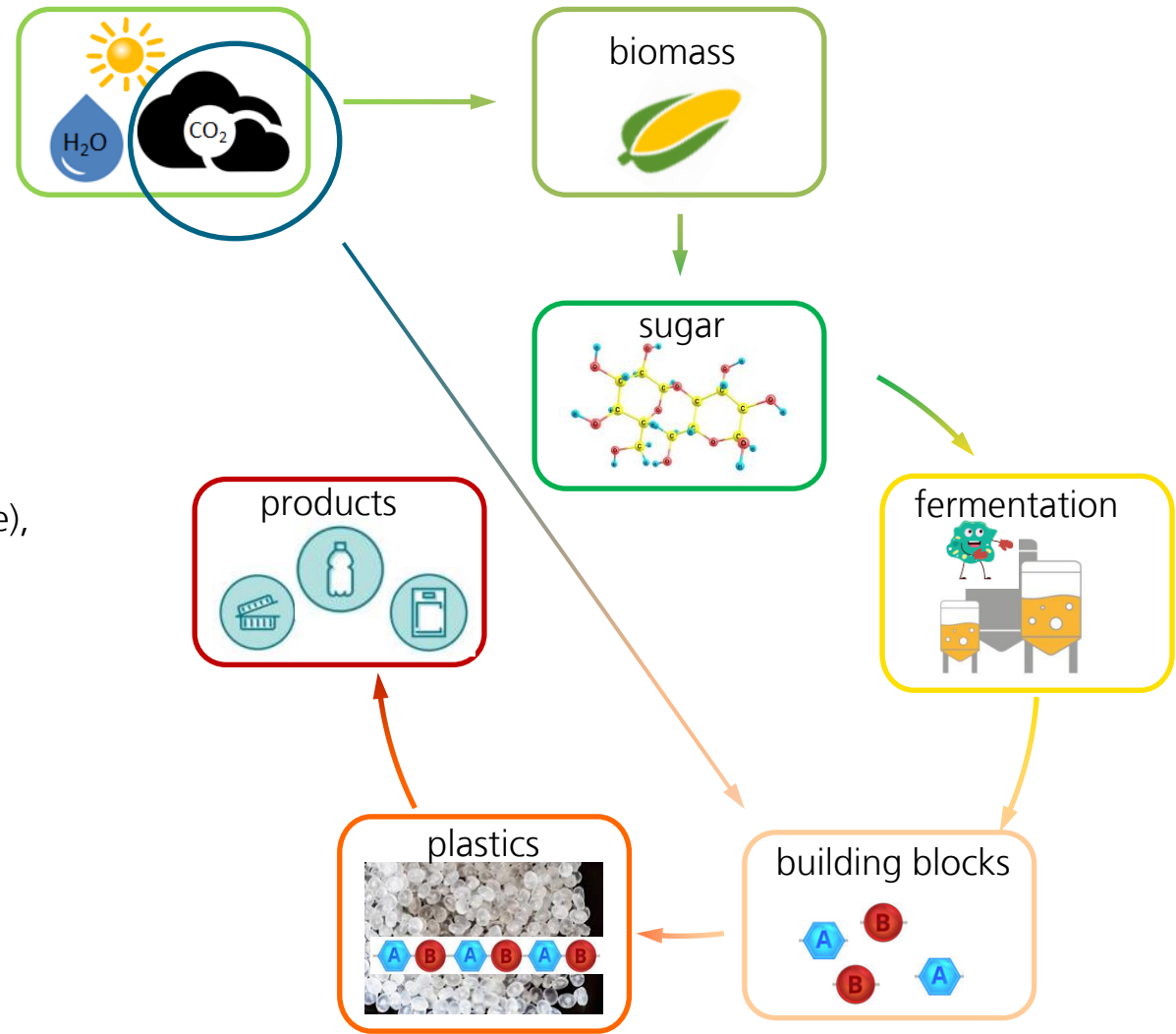
# The Plastic Value Chain in a (Bio)economy

Aiming for the Ideal Economy

**Economy = Organization of our social metabolism**

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- Metabolism is mainly based on fossil resources
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- Use of CO<sub>2</sub> (Carbon Capture and Utilization)



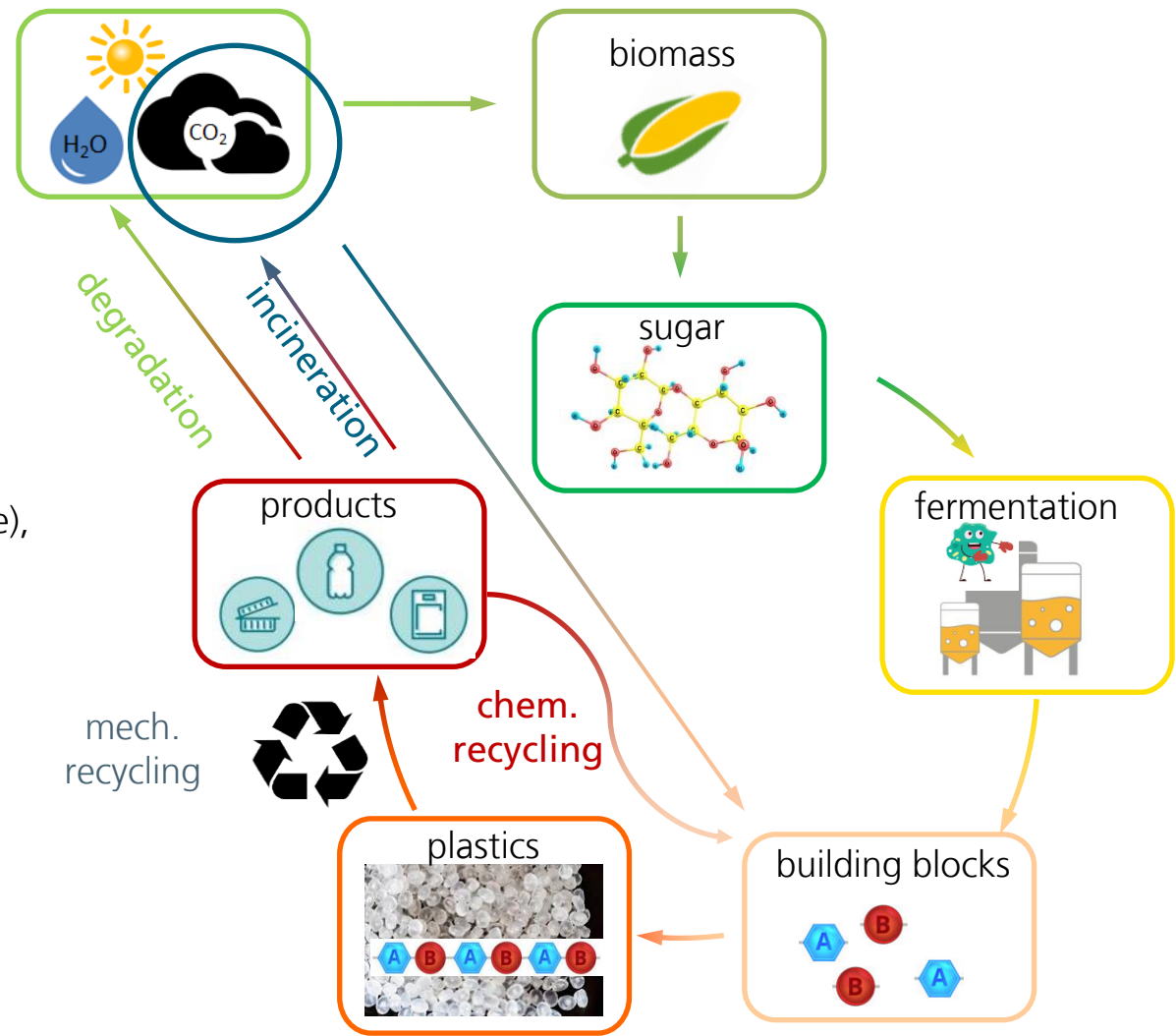
# The Plastic Value Chain in a Circular (Bio)economy

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- Integration of biomass (supported by biotech where useful)
- Use of CO<sub>2</sub> (Carbon Capture and Utilization)
- Implementation of recycling concepts
- Waste prevention



# An Example

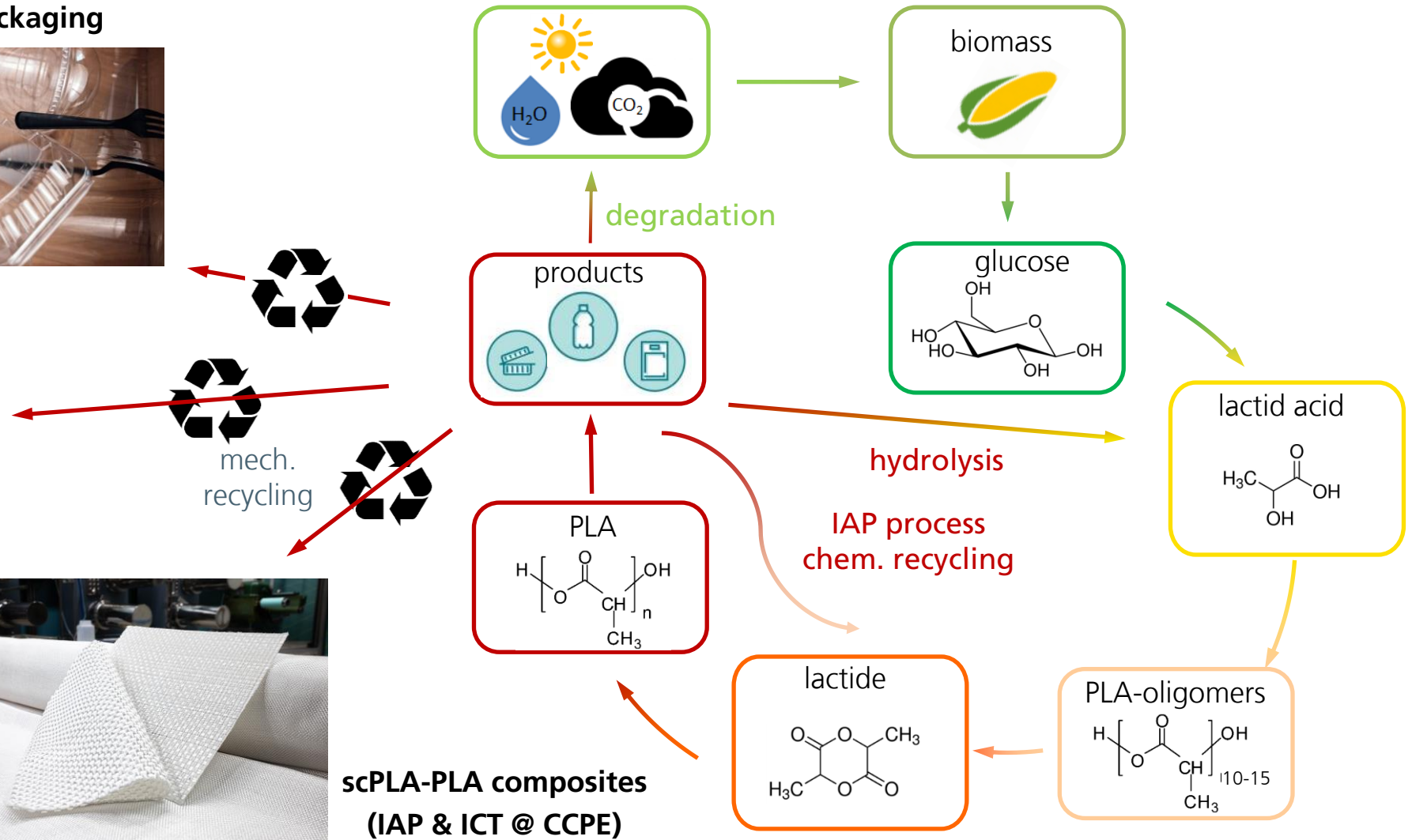
Rigid PLA packaging



Flexible PLA films (R&D @ IAP)



scPLA-PLA composites  
(IAP & ICT @ CCPE)



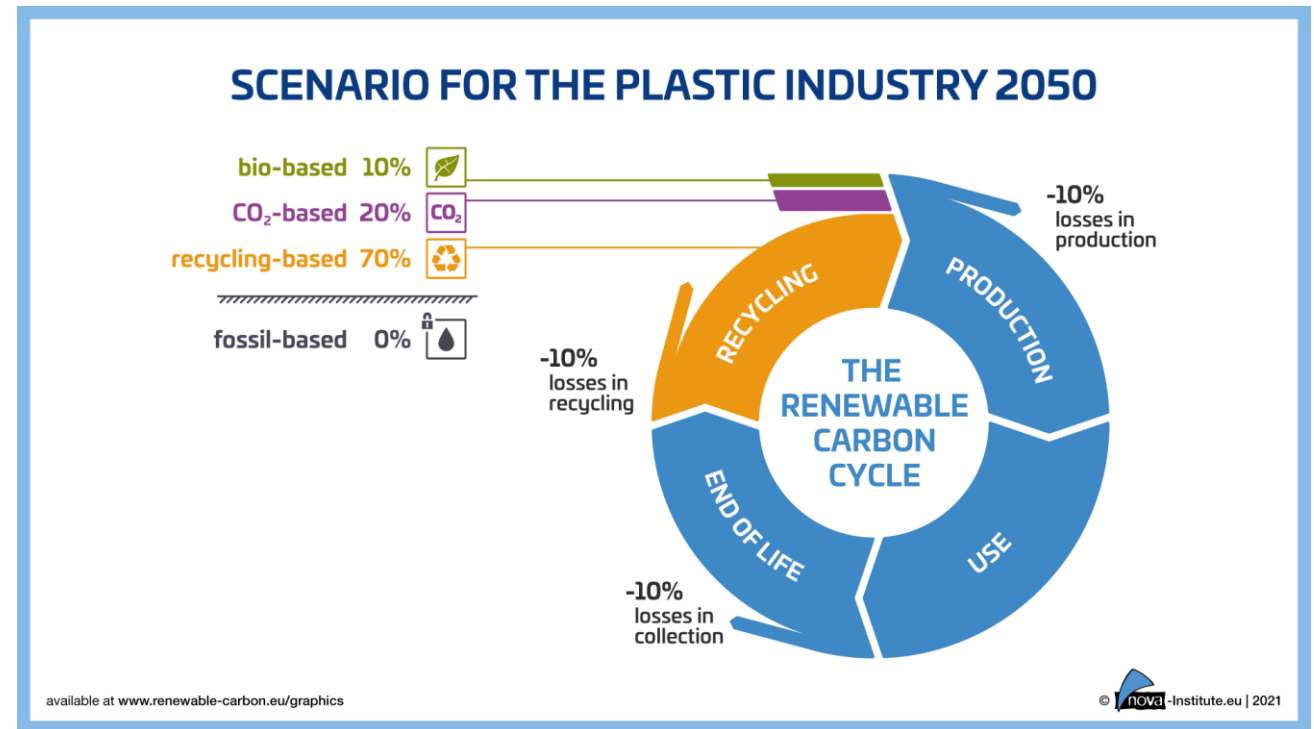
# A Circular (Bio)economy Won't be Perfect

## Aiming for the Ideal Economy

**Circular Economy = Mismatch between demand and supply (due to losses, quality, lifetime)**

### Compensation through

- Limitation of valuable fossil resources for special purposes, where small cycles are made possible (b2b)
- Substitution by biomass where feasible
  - Current scenario (2023): 55% recycling, 20% bio, 25% CO<sub>2</sub> → renewable carbon
- PLA, PBS, PA, PE, PP, bio-attributed (mass balance approach) ...





# Contact

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**[www.linkedin.de/company/fraunhofer-ccpe](https://www.linkedin.de/company/fraunhofer-ccpe)**





CO<sub>2</sub>

Fraunhofer Roadmap Circular Bioeconomy

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# Workshop C: CO<sub>2</sub> - a sustainable raw material for the bioeconomy?

**Grzegorz Kubik**  
Fraunhofer IGB

**Michael Hofer**  
Fraunhofer IGB

**Dr. Grzegorz Kubik**

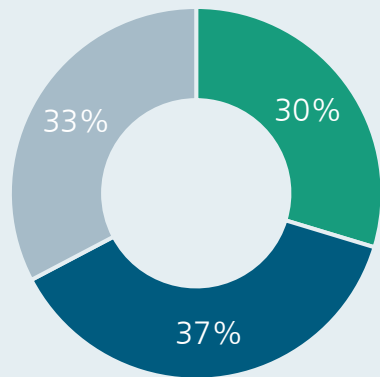
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# Microalgae – an effective CO<sub>2</sub> conversion platform

# Current global demand of fossil fuels

## Demand of fossil fuel worldwide

**11,700 Mtoe**

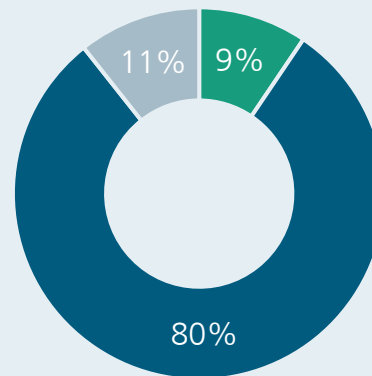


■ Gas ■ Oil ■ Coal

Source: <https://ourworldindata.org/fossil-fuels>

## Global demand of fossil fuel by the petrochemical industry

**750 Mt**



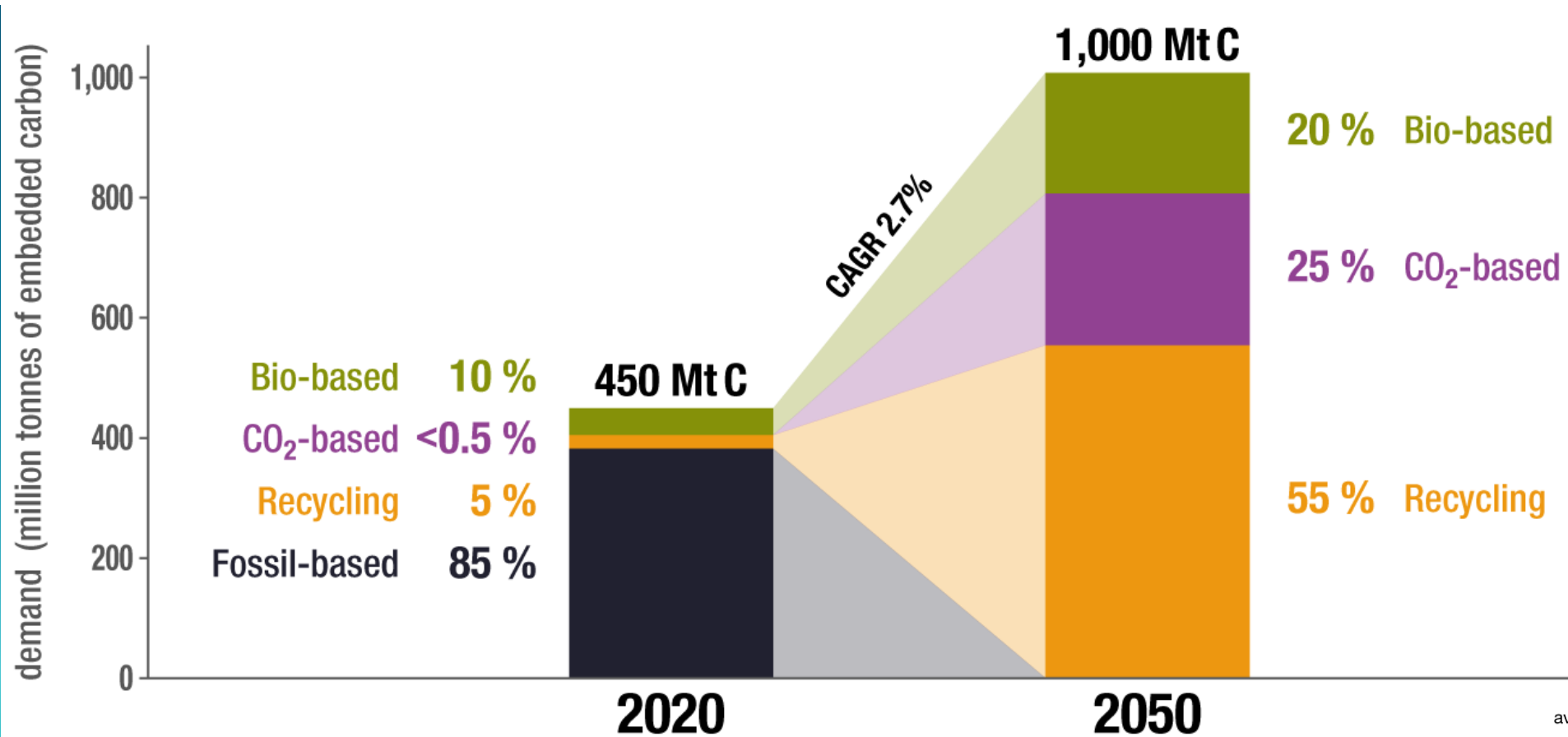
■ Gas ■ Oil ■ Coal

Source: IEA, 2018

To defossilize the chemical industry, we need to sustainably satisfy the energy and embedded carbon demand of chemical industry.

# Global carbon demand for chemicals and derived materials

In 2020 and scenario for 2050 (in million tonnes of embedded carbon)



Source: nova-Institut  
© nova-Institute.eu | 2021

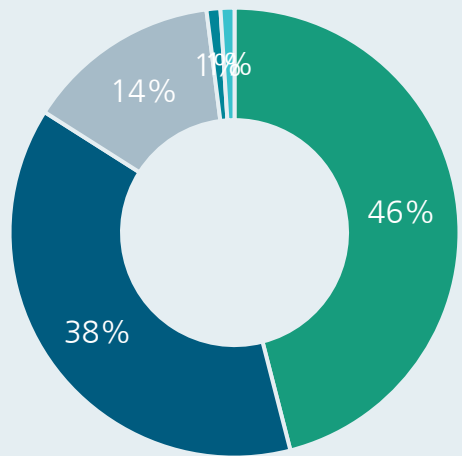
available at [www.renewable-carbon.eu/graphics](http://www.renewable-carbon.eu/graphics)



# Making products from biomass

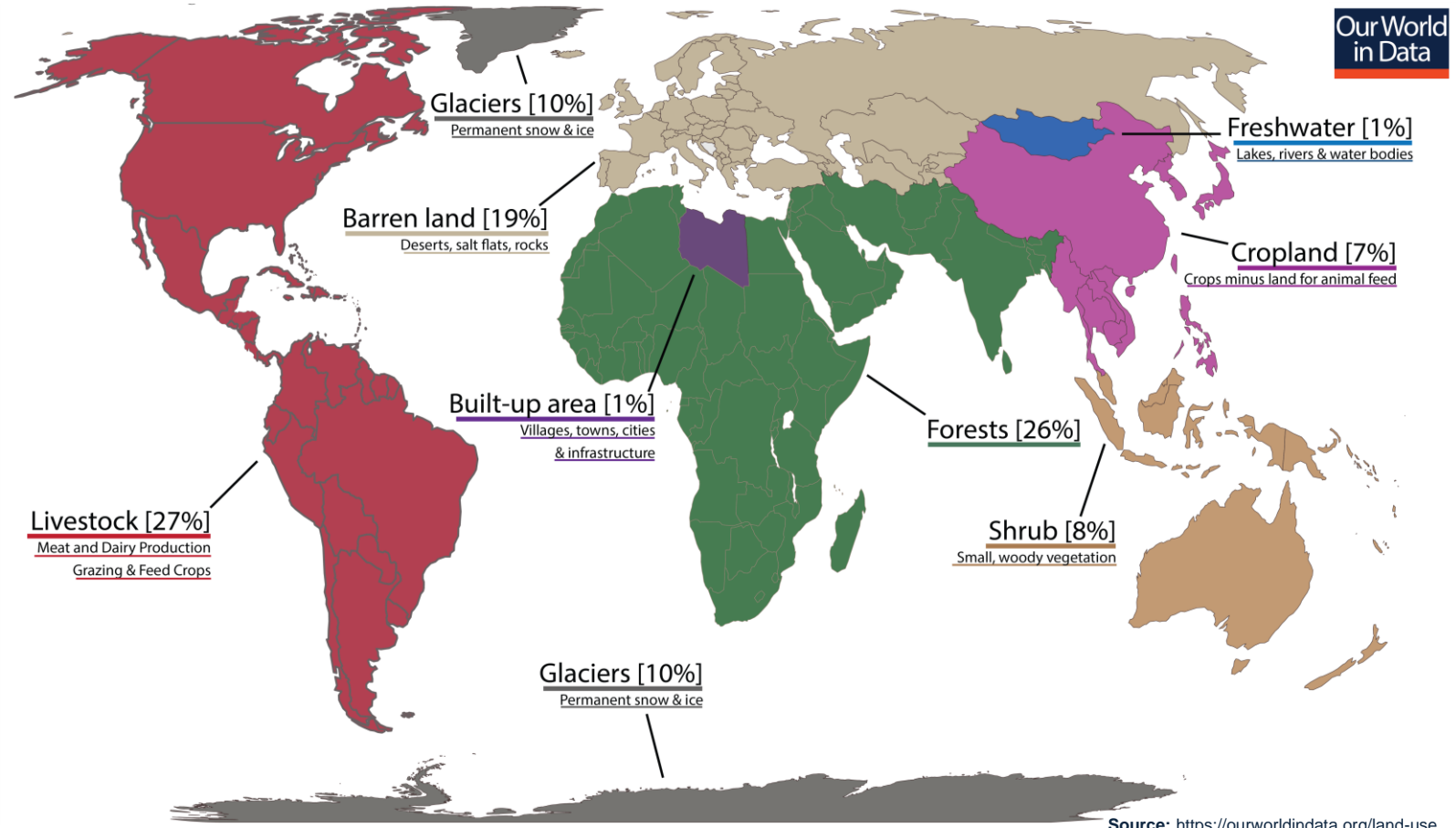
# Current distribution of land utilization

Utilization of habitable land in 2019



■ Agriculture    ■ Forests    ■ Shrub  
■ Built-up land    ■ Freshwater

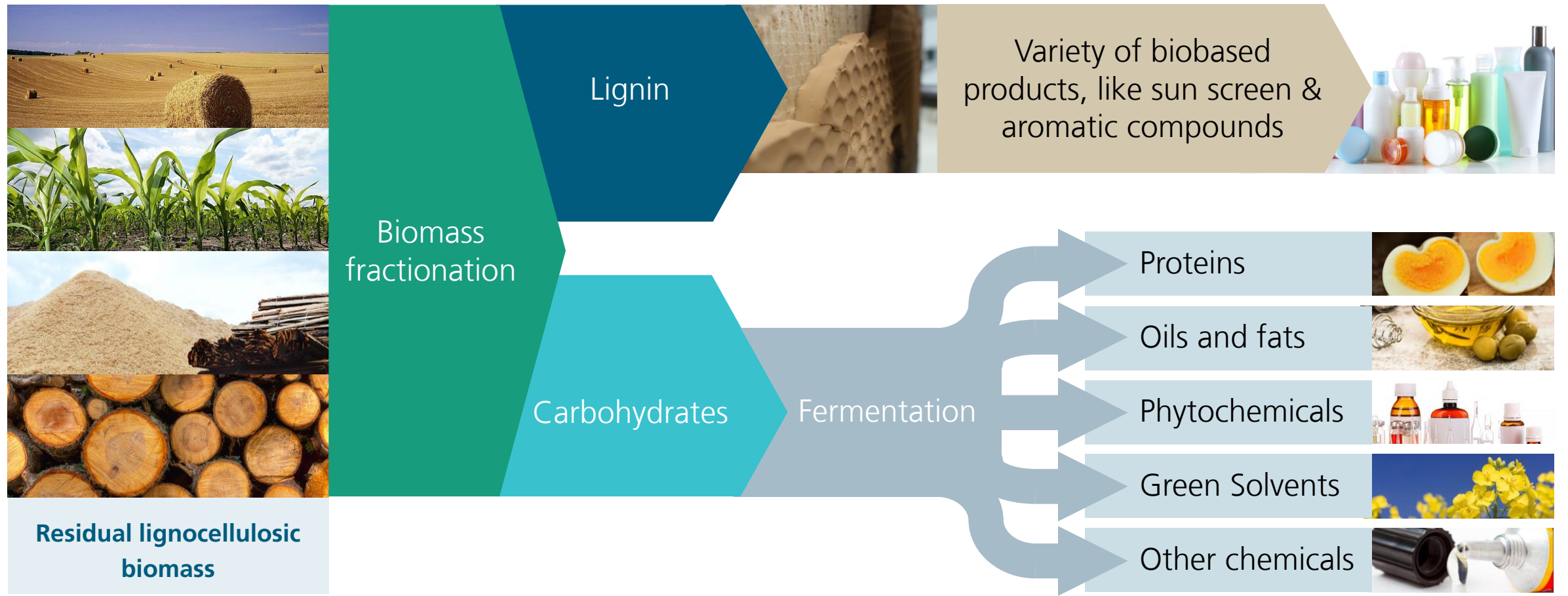
Source: UN Food and Agriculture Organization (FAO)



OurWorld  
in Data

Source: <https://ourworldindata.org/land-use>

# Efficient use of embedded carbon in biomass from agriculture & forestry



# Agricultural residues will not be sufficient cover the global carbon demand

Case study: Green ethylene via green ethanol

Global production capacity of Ethylene

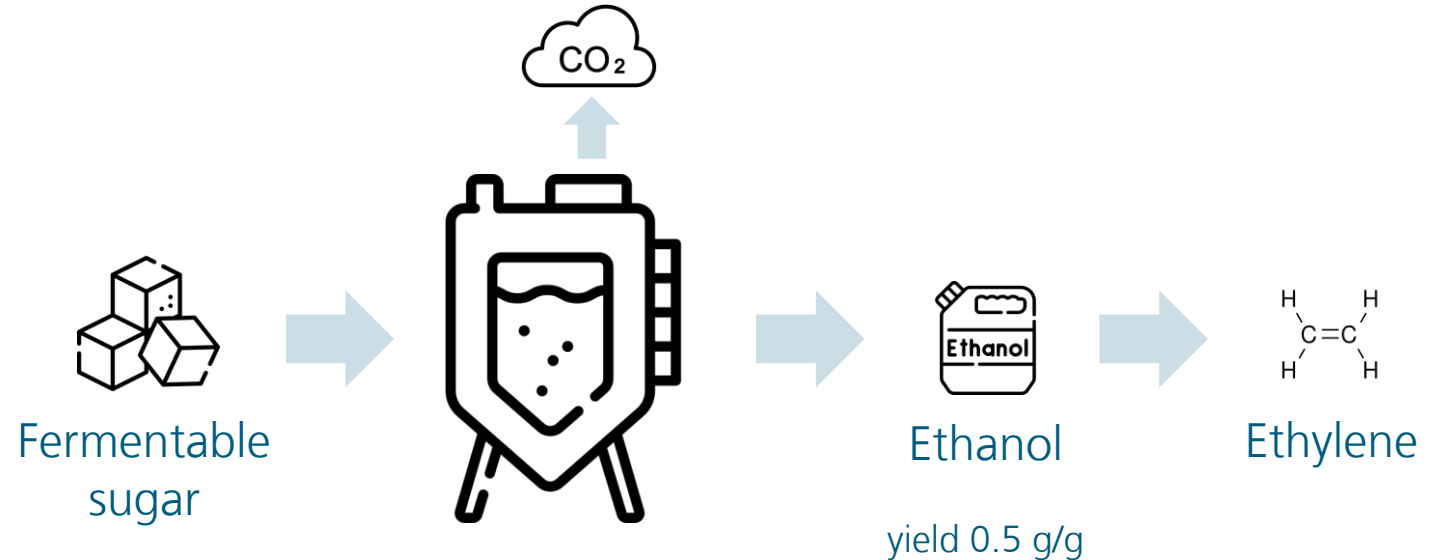
**215 MTY**

Source: GlobalData. (March 29, 2022).

Fermentable sugar potential from agricultural residues

**661 MTY**

Source: Wageningen UR Food & Biobased Research. Report 1391 (February, 2013).



Fermentable sugar demand for covering global ethylene production via ethanol

**706 MTY**

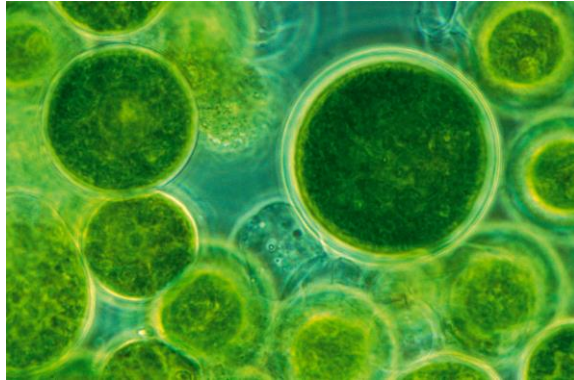
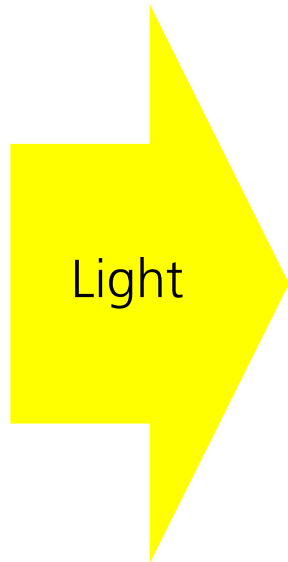


CO<sub>2</sub>

## Making products from carbon dioxide

# Microalgae cultivation

Fast growing biomass source



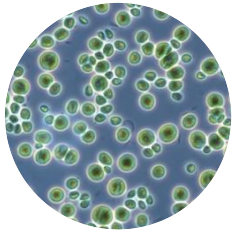
## Microalgae

- *Can directly utilize carbon dioxide as carbon source*
- *1 kg Biomass binds about 1.8 kg carbon dioxide*
- *Do not require fertile land*

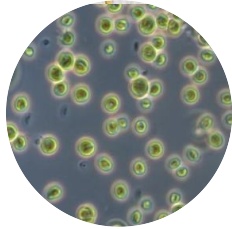


# Exploring the wide range of microalgal species

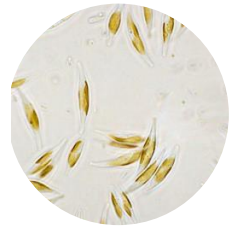
Strains used at Fraunhofer IGB



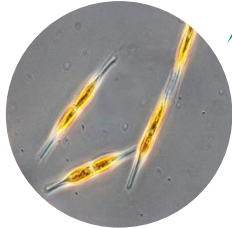
*C. vulgaris*



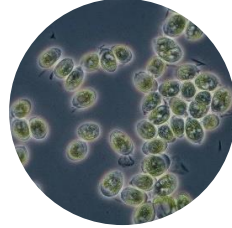
*N. oceanica*



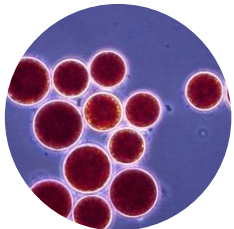
*P. tricornutum*



*C. fusiformis*



*T. suecica*



*H. pluvialis*

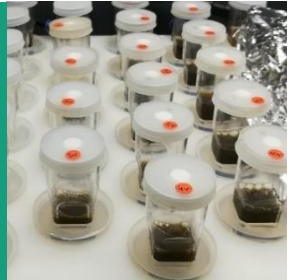


*Anabaena sp.*

- *Chlamydomonas*
- *Isochrysis*
- *Monodopsis*
- *Euglena*
- [...]

## 1) Strain and product screening

- Optimization of culture media
- Test of carbon sources (phototrophic, mixotrophic or heterotrophic)
- Influence of N- and P- source on product yield



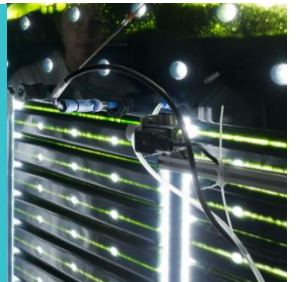
## 2) Preculture for FPA

- Inoculum production for FPA photobioreactor (3-5 L) in flasks or CellDEG system (0,5 L)



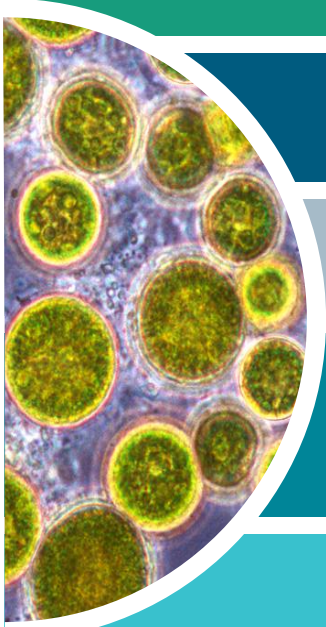
## 3) Process development in FPA






- Final evaluation of cultivation parameters (e.g. relative light availability) for 6 and 30 L FPA photobioreactors
- Process automation



# Microalgae ingredients

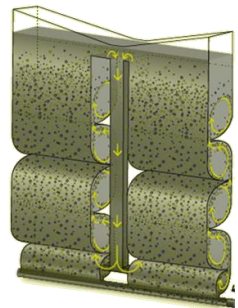
## and their potential applications



<b>Carbohydrates</b>	<ul style="list-style-type: none"><li>Up to 50 % (w/w) of dry weight accumulated as storage product</li></ul>	<ul style="list-style-type: none"><li>Plant biostimulants</li><li>Active ingredients for cosmetics &amp; animal feed</li><li>Feedstock for fermentation</li></ul>	
<b>Proteins</b>	<ul style="list-style-type: none"><li>Up to 50 % of biomass in growing algae cells</li></ul>	<ul style="list-style-type: none"><li>Vegan Food</li><li>Feed additive</li><li>Cosmetics</li></ul>	
<b>Triacylglyceride</b>	<ul style="list-style-type: none"><li>Up to 50 % (w/w) of dry weight accumulated as storage product</li></ul>	<ul style="list-style-type: none"><li>Replacement for palm oil</li><li>Biodiesel</li></ul>	
<b>Membrane lipids</b>	<ul style="list-style-type: none"><li>Glycolipids (10-12% of biomass) with 50% omega-3 fatty acids</li><li>Eicosapentaenoic acid (EPA) Up to 7% (w/w) of biomass</li></ul>	<ul style="list-style-type: none"><li>Food and feed</li><li>Glycolipids as natural biosurfactants</li><li>Antimicrobial effect</li><li>Cosmetics</li></ul>	
<b>Carotenoids, Phytosterols</b>	<ul style="list-style-type: none"><li>Carotenoids (xanthophylls): Fucoxanthin up to 2.5% of biomass</li><li>Phytosterols (C<sub>28</sub>, C<sub>29</sub>-sterols, β-sitosterol) 0.3 – 1.3 % of biomass</li></ul>	<ul style="list-style-type: none"><li>High-value nutraceuticals with functional properties</li><li>Anti-ageing effect by inhibition of enzymes like collagenase, hyaluronidase and elastase</li><li>Stimulate collagen production</li></ul>	

# Algaetex – Textiles from CO<sub>2</sub>

## Algae biotechnology



■ Product

■ CO<sub>2</sub>

■ H<sub>2</sub>O

■ N, P, Mineral salts

Photosynthesis

1.8 kg CO<sub>2</sub> → 1.0 kg Algae



ALGAE CULTIVATION  
& EXTRACTION



POLYMER  
DEVELOPMENT



YARN DEVELOPMENT



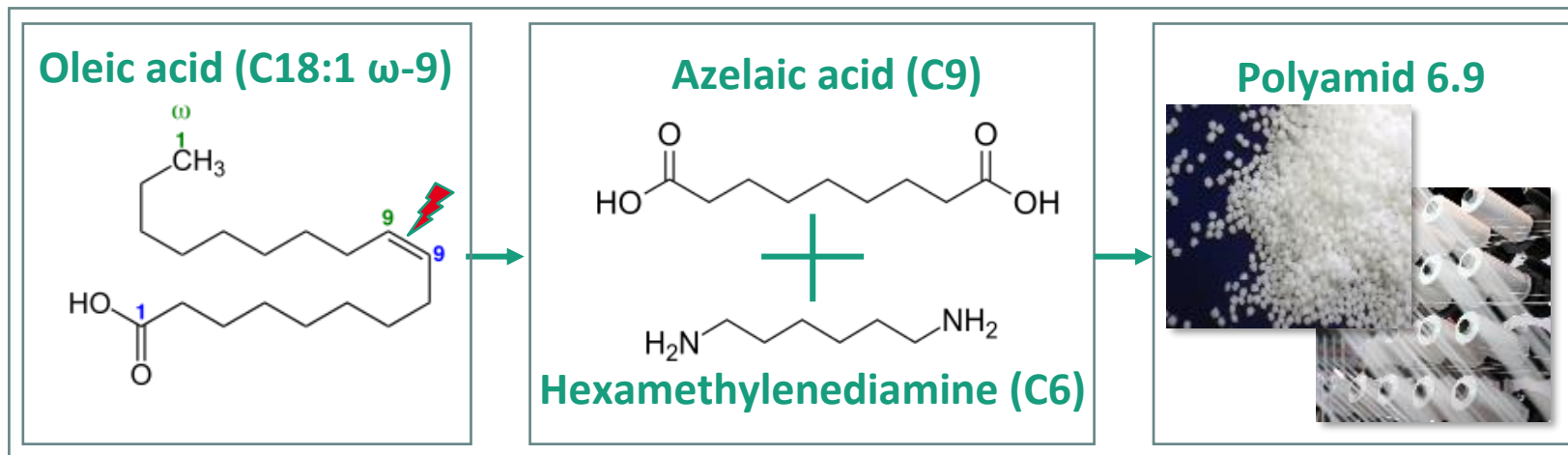
APPLICATION  
DEVELOPMENT



# Algaetex – Textiles from CO<sub>2</sub>

## Algae Based FAME to PA6.9

- Use of Fatty Acid Methyl Esters (FAME) derived from algae-oil
- Synthesis of polyamides and polyesters in fiber-spinning grade from monomers



# The benefits of microalgal oil



## 1 ha of rapeseed culture

- 1.4 t/a rapeseed oil
- 4.6 t/a CO<sub>2</sub> emission
- 125 m<sup>3</sup> H<sub>2</sub>O

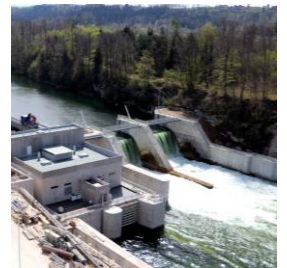


0.004 ha of microalgae can produce 1.4 t algae oil

No dependence on fertile land for the generation of renewable energy

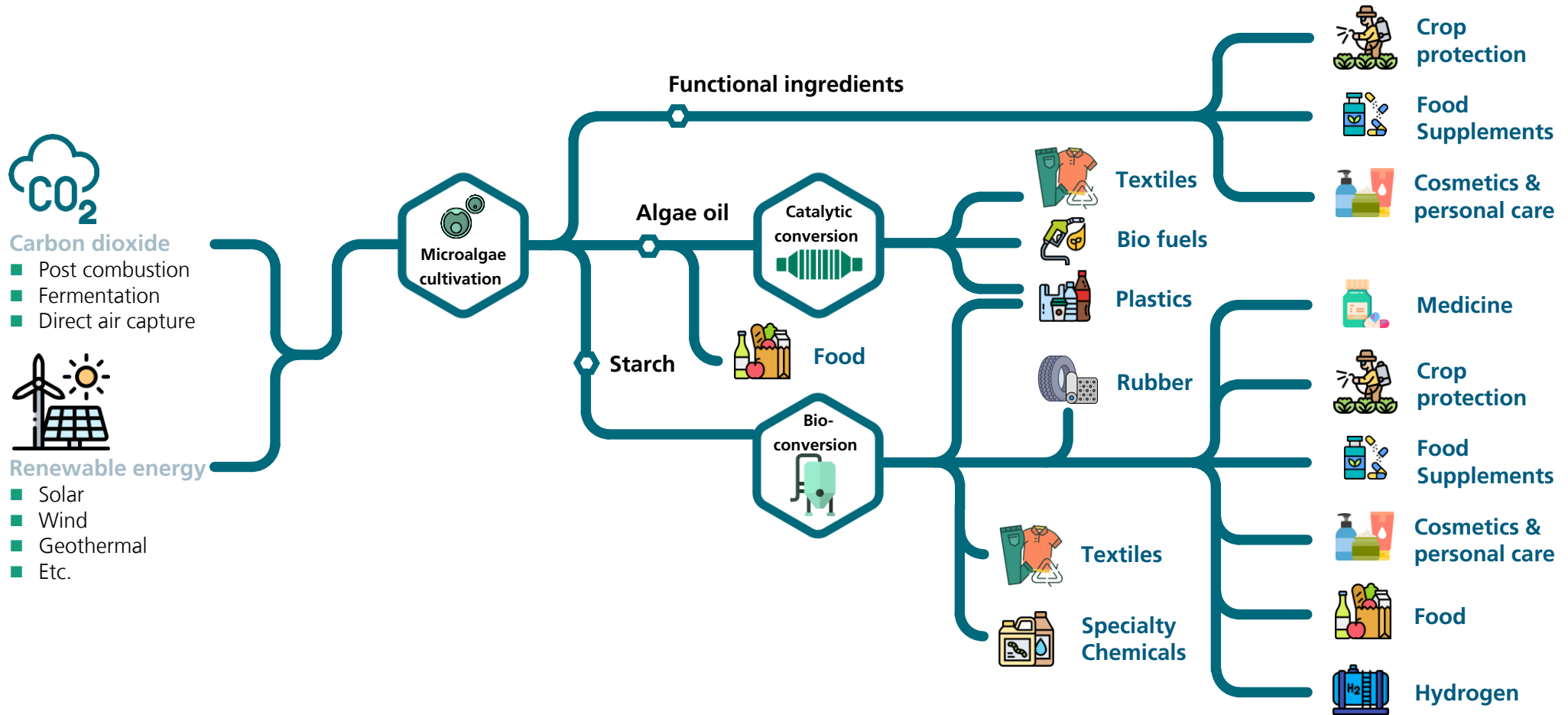
CO<sub>2</sub> neutral or even negative production is possible

Other environmental impacts need to be considered



# The carbon dioxide refinery approach

Combining biology and chemistry





# Contact

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 **Fraunhofer**  
IGB

Fraunhofer Institute for Interfacial  
Engineering and Biotechnology IGB

**Dr. Michael Hofer, September 20<sup>th</sup>, 2023**

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# Workshop C: CO<sub>2</sub> – a sustainable raw material for the bioeconomy?

# CO<sub>2</sub> as a driver of climate change

Graphic IEA

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[https://www.mcc-berlin.net/fileadmin/data/clock/carbon\\_clock.htm](https://www.mcc-berlin.net/fileadmin/data/clock/carbon_clock.htm)

# Carbon cycle for a sustainable future

## Circular Carbon Technologies

### CO<sub>2</sub> – the carbon source of the future

We have to reduce CO<sub>2</sub> emission as well as to remove CO<sub>2</sub> from the atmosphere to keep our climate in balance.

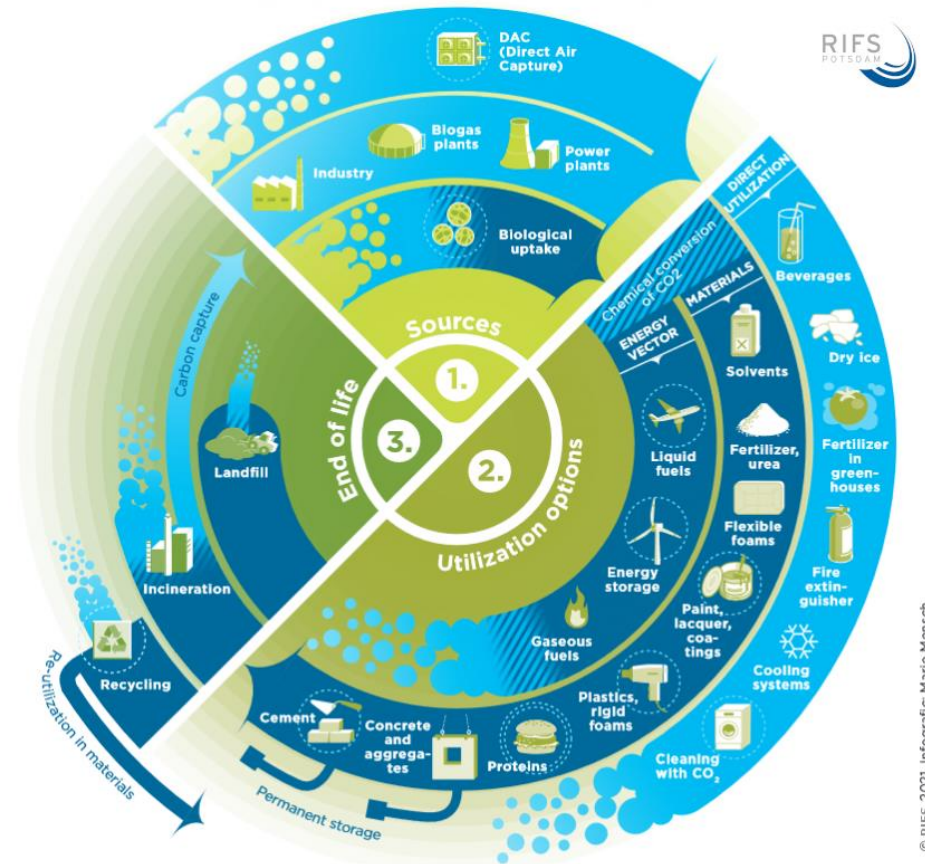
#### CCUS

- Carbon capture - **CC**
- Carbon utilization - **U**
- Carbon storage - **S**

## CO<sub>2</sub> AS FEEDSTOCK

Carbon dioxide from flue gas or other sources can be used for various purposes, either directly or after chemical conversion in carbon compounds. These purposes can cover various materials or energy vectors. These technologies are summarized by the term Carbon Capture and Utilization (CCU).

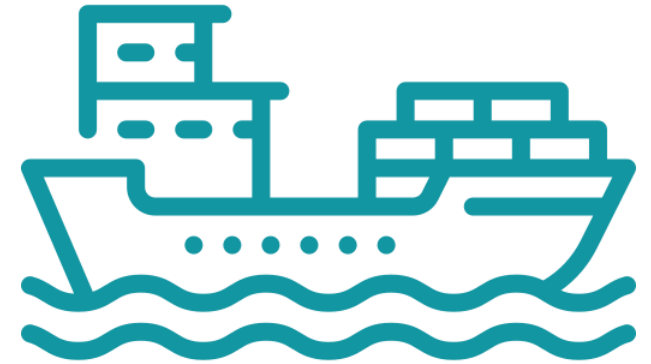
- ➔ Carbon dioxide
- ➔ Carbon compound
- ➔ Conversion
- ➔ Release to the atmosphere
- ➔ Removal from the atmosphere
- Near future
- Distant future



<https://www.rifs-potsdam.de/en/output/dossiers/co2-waste-feedstock>

# Why do we need sustainable CO<sub>2</sub>-based fuels?

→ Energy transition in areas that are difficult to electrify directly



## Advantages

- No change in motor technologies necessary
- Usage of existing infrastructure

# Circular carbon technologies – Power-to-X-to-Y

## Sustainable CO<sub>2</sub>-based fuels

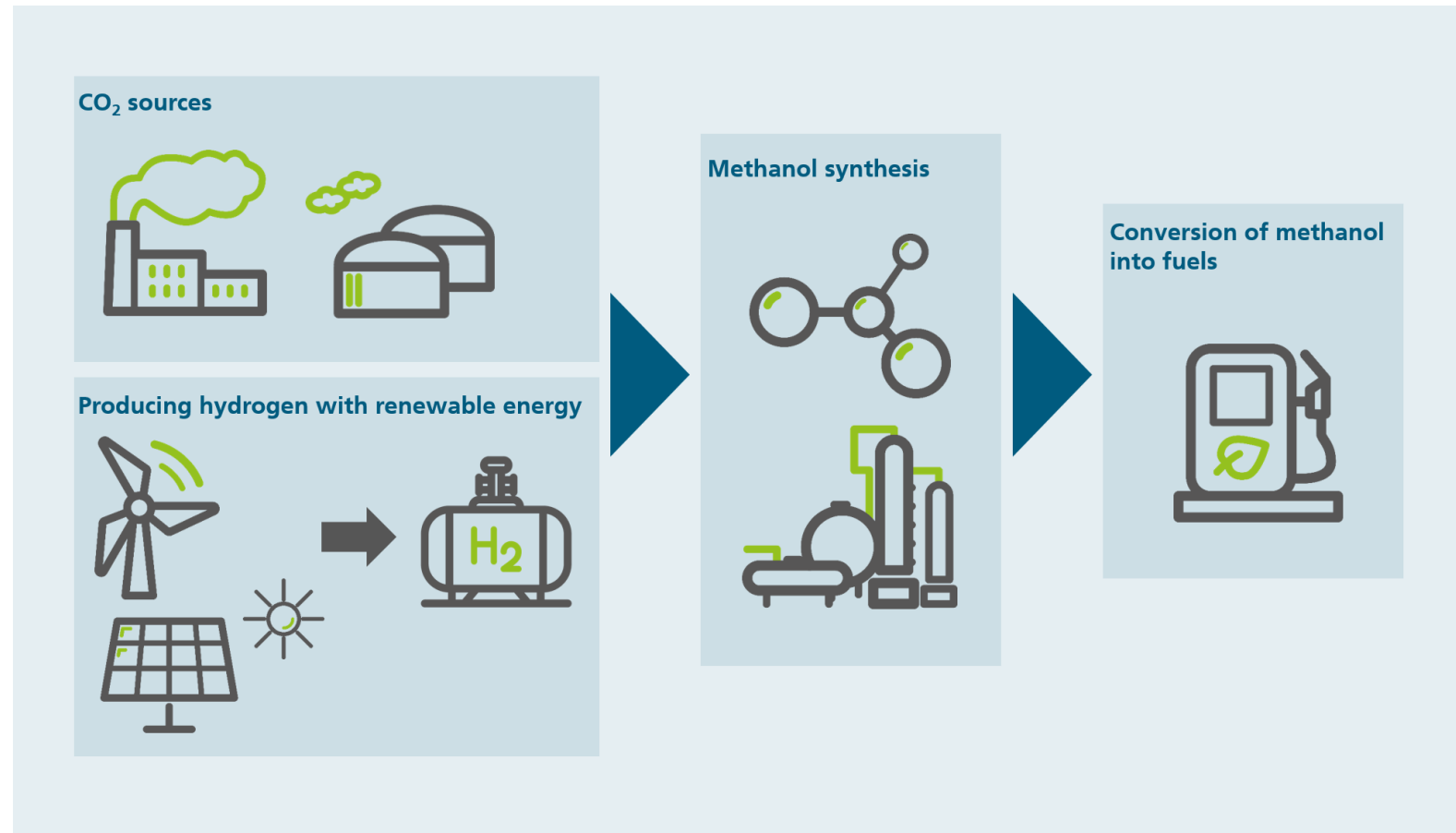
### Carbon utilization through chemical conversion

In a chemical reaction carbon dioxide and green hydrogen are transformed to methanol under high pressure and elevated temperatures. Methanol is then further converted through oligomerization into fuels.



#### Methanol to Olefins

- Synthetic aviation fuels (SAF)
- Synthetic ship fuels
- Fuels for heavy machinery



# State of the art

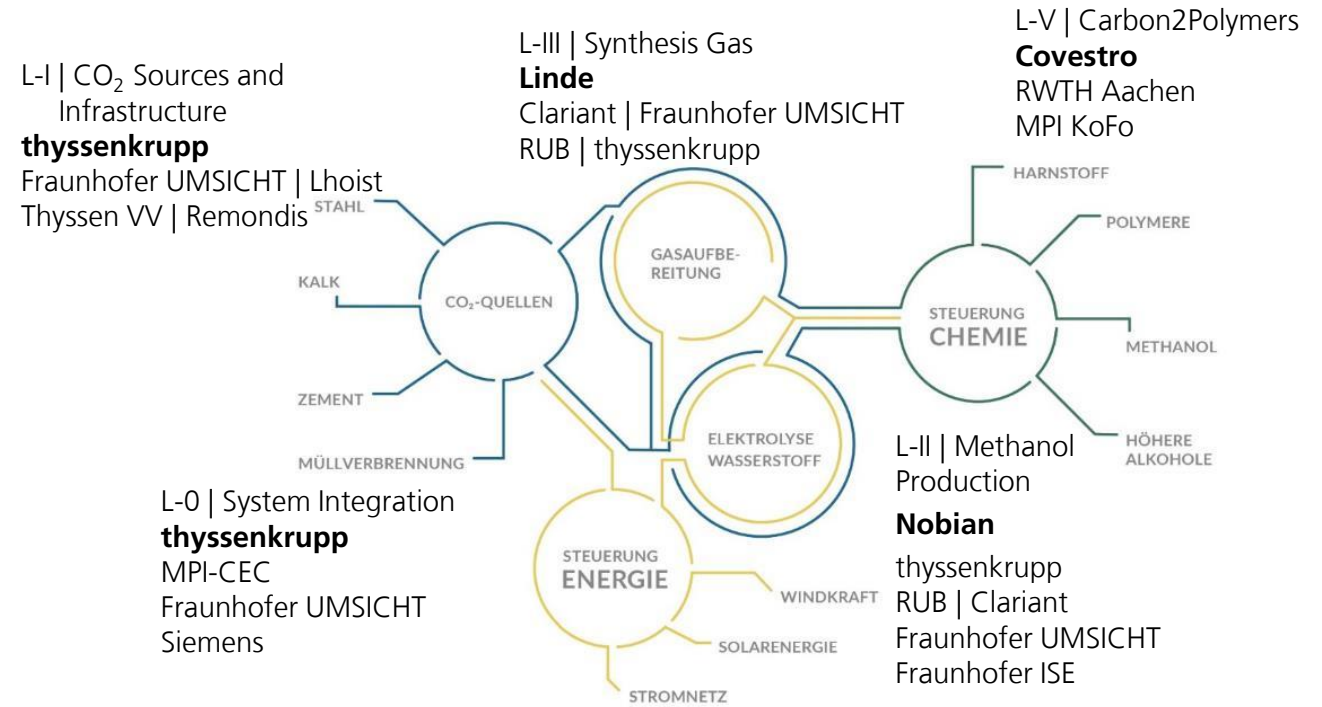
## From CO<sub>2</sub> to methanol

### Carbon2Chem® project

The purpose of the joint project Carbon2Chem® is to turn industry process gases such as smelting gases from steel production into a valuable source of carbon for the chemical industry.

#### Main achievements

- Successful continuous gas cleaning and CO<sub>2</sub> removal from steel mill gases
- Identification of catalyst poison and reaction mechanism
- Successful long term operation with steel mill gases in lab and demo scale
- Complete process model and simulation for single synthesis steps (methanol)
- Overall simulation and model for overall process optimization, which means steel production, gas cleaning, electrolysis, methanol synthesis



# R&D needs

## Power-to-X-to-Y – Chemistry



### Utilization of CO<sub>2</sub> point sources

For carbon utilization e.g. production of synthetic fuels, concentrated CO<sub>2</sub> streams are needed. Industrial point sources of CO<sub>2</sub> may contain contaminants

→ Adaption of catalysts and processes to different CO<sub>2</sub> streams

### Adaptation of catalytic processes

Transformation of chemical processes from crude oil to CO<sub>2</sub> small carbonaceous molecules.

- Establishing refinery operations for green production routes to modern synthetic fuels
- Establishing predictive computer models



# Circular carbon technologies – Power-to-X-to-Y

## Sustainable MeOH based fermentation platform

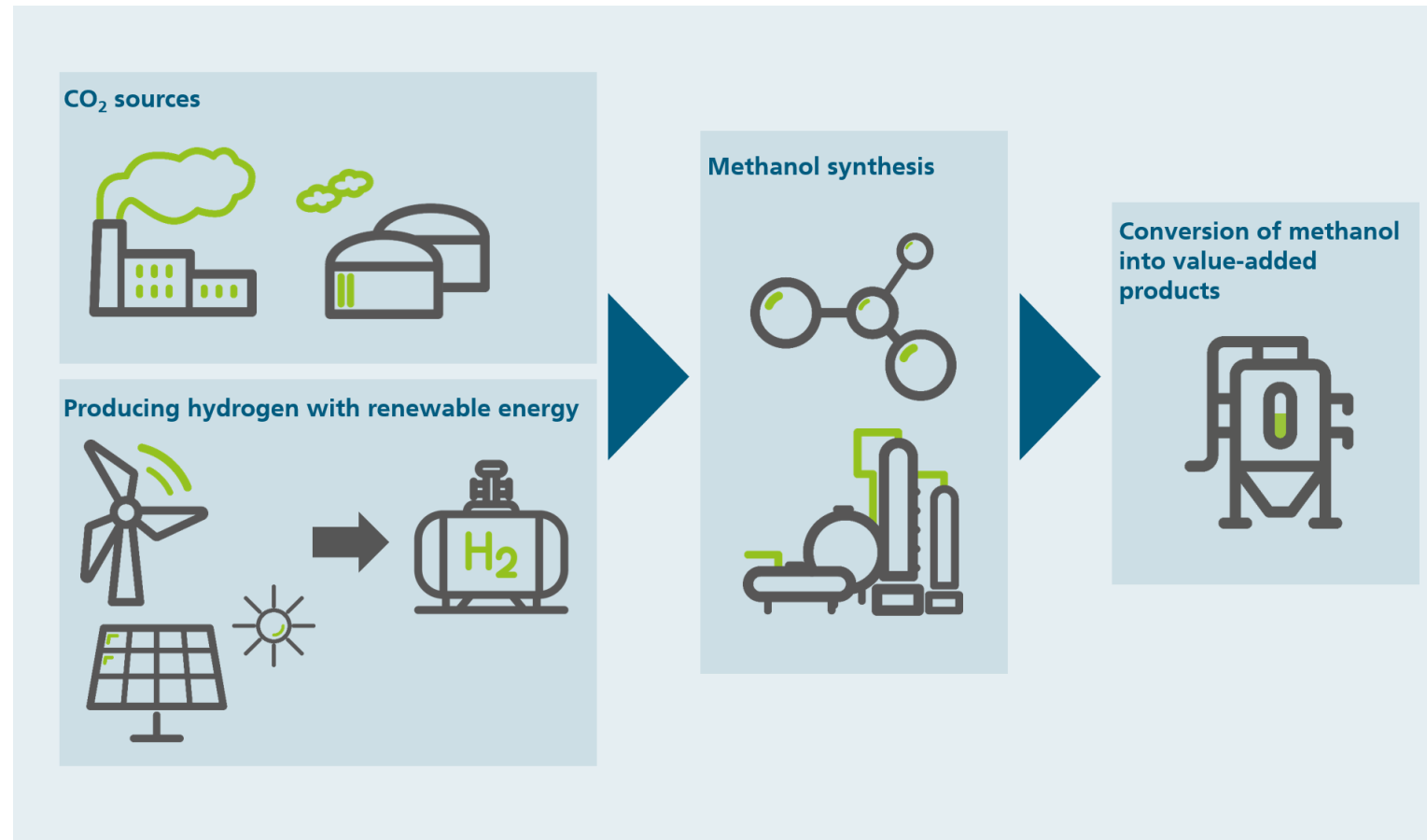
### Carbon utilization through chemical conversion and fermentation

In a chemical reaction carbon dioxide and green hydrogen are transformed to methanol under high pressure and elevated temperatures. Methanol is further converted through fermentation to the desired end product.



#### MeOH based fermentation

- Sustainable carbon source without competitive use
- Much easier to handle than any gas for fermentation ( $\text{CO}_2$ ,  $\text{CO}$ ,  $\text{H}_2$ )
- Many end products possible using microbial strain development tools



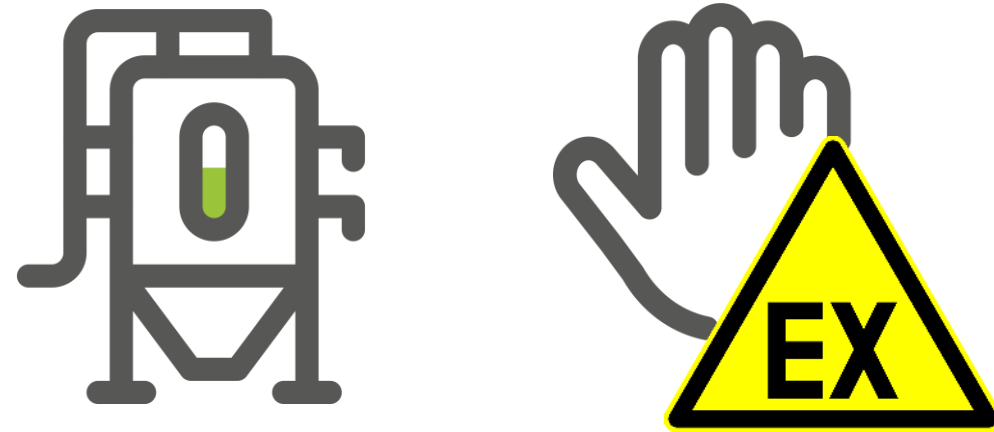
# R&D needs

## Power-to-X-to-Y – Biotechnology



### Strain and process development

Catch-up scientific advantage of glycolytic strains (60–80 years advance in comparison to methylotrophic strain development). Identification of suitable strains, understanding of physiology, regulatory tools for strain development and tools for genetic engineering.

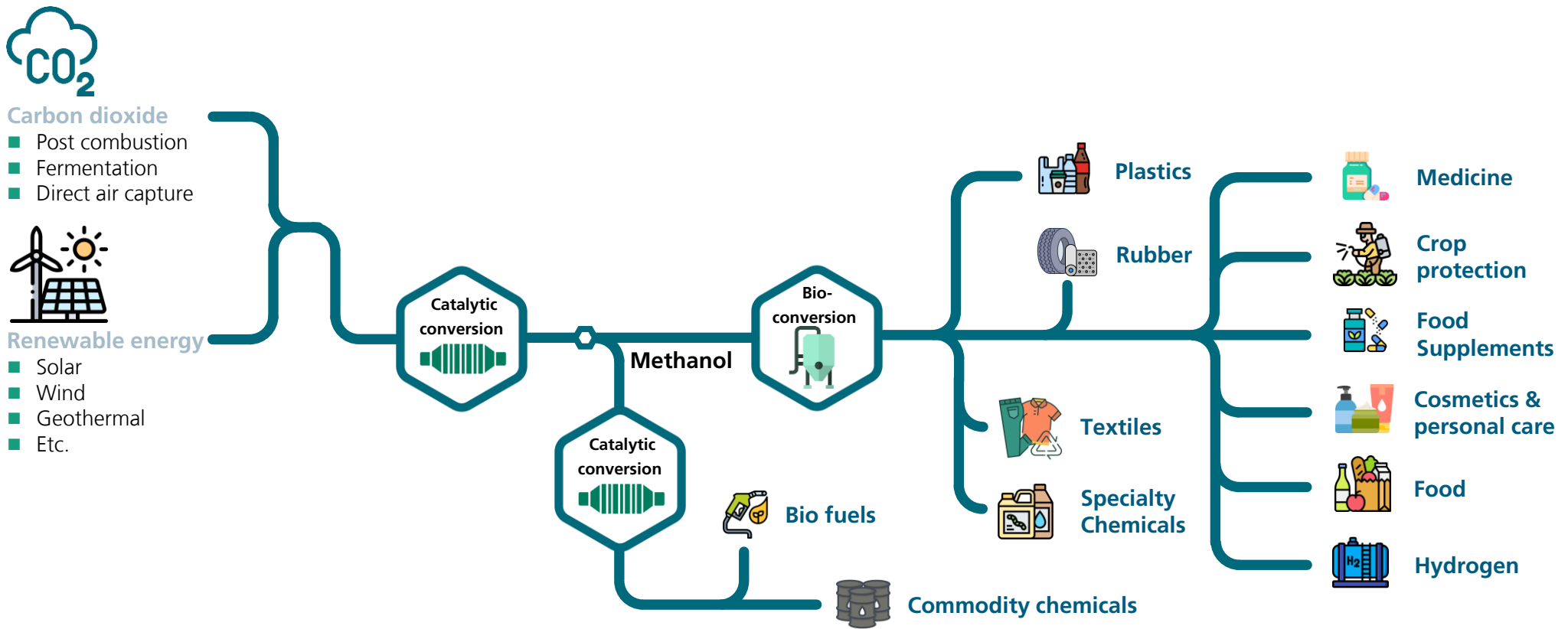


### Adaptation of equipment

Management of ATEX and heat exchange during methanol fermentation.

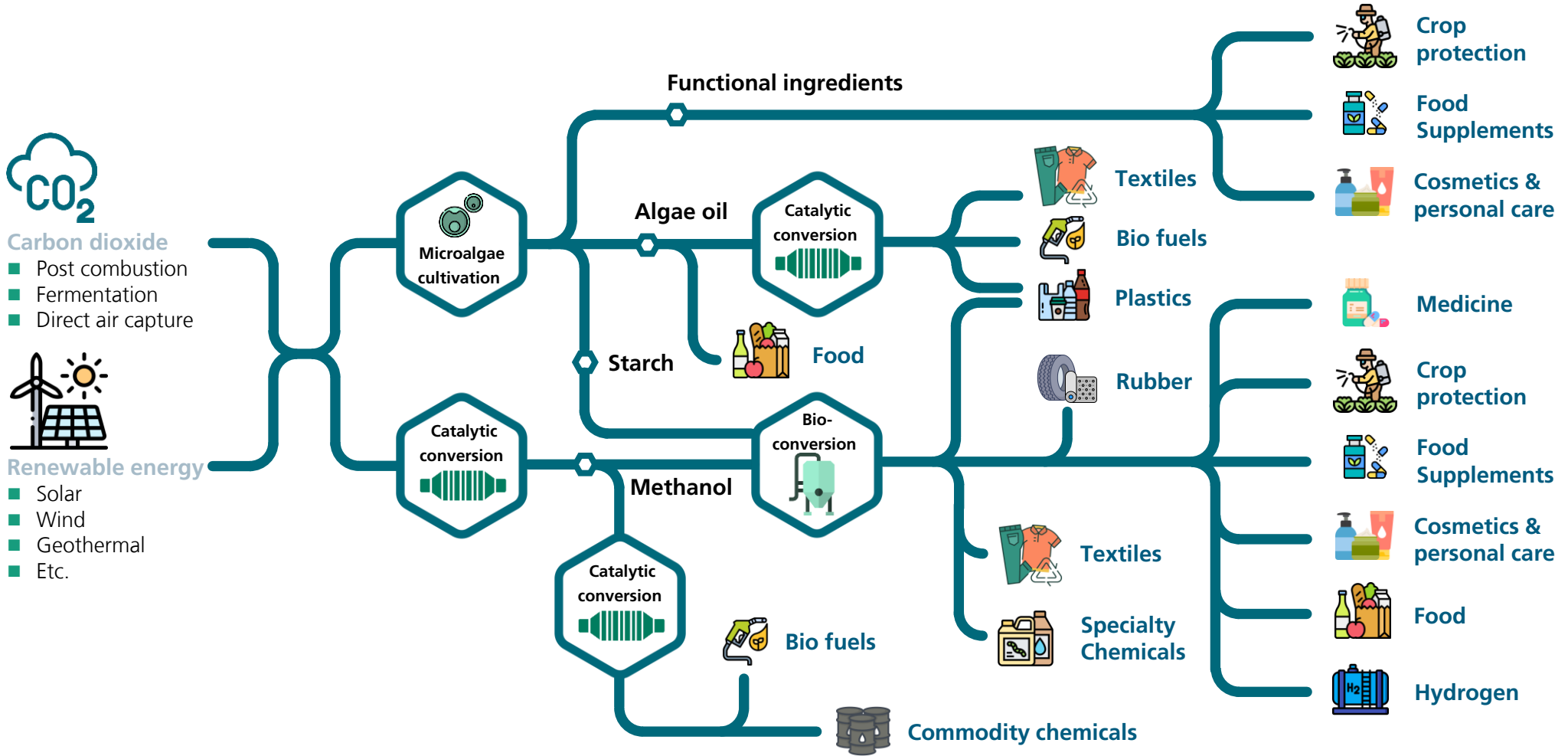
# The carbon dioxide refinery approach

Combining biology and chemistry



# The carbon dioxide refinery approach

Combining biology and chemistry



# Contact

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 **Fraunhofer**  
IGB

Fraunhofer-Institut für Grenzflächen-  
und Bioverfahrenstechnik IGB

Fraunhofer Roadmap Circular Bioeconomy

Workshop D:  
Governance of bioeconomy: a socio-  
economic transition

**Sven Wydra**  
Fraunhofer ISI

**Gabriel Däßler**  
Fraunhofer ISI

# Governance of the Bioeconomy — A socio-economic transition

Sven Wydra/ Gabriel Däßler

Fraunhofer Roadmap Circular Bioeconomy

»Sustainable and Competitive: the bioeconomic Future of the EU«

# Bioeconomy and Life Sciences

CC Emerging Technologies, Fraunhofer ISI

## Bioeconomy and Life Sciences



### Topics

- Identifying current innovative developments and assessing their economic and societal impact
- Analyzing the system transformation to the bioeconomy
- Analyzing and proposing policy instruments

### Coordinator

Dr. Sven Wydra  
[sven.wydra@isi.fraunhofer.de](mailto:sven.wydra@isi.fraunhofer.de)



### Methods

- Scenario analysis
- Surveys
- Indicators and economic modeling
- Expert interviews
- Workshops

### Projects

- Shaping the future bioeconomy across sectoral, governmental and geographical levels (ShapingBio)
- Monitoring of the German Bioeconomy
- Life and biological sciences and technologies as engines for bio-based innovation

### Team

- Dr. Piret Fischer
- Dr. Bärbel Hüsing
- Dr. Liliya Pullmann
- Dr. Annamarija Raic
- Naser Reyhani
- Gabriel Däßler





**ShapingBio** aims to provide evidence-based and concrete **information and recommendations** for better **policy alignment and stakeholder actions** to realize the **cross-sectoral potential of the bioeconomy** and to **reduce the fragmentation across bio-based sectors and food system** and policies across regions, domains and governance levels

# Objectives of our Workshop

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## Roadmap Introduction (p.4):

“The bioeconomy must be developed in such a way as to respect planetary boundaries and give equal weight to each of the three pillars of sustainability - the environmental, economic and social perspectives”



## Main discussion points for today

What are important socio-economic aspects (for whom) to be addressed by future bioeconomy development?

How do we deal with complex socio-economic challenges of the bioeconomy in the future?

How can we improve policy coherence and alignment?

# Outline

## Governance of the Bioeconomy – A socio-economic transition

### 1. Socio-economic aspects of the bioeconomy

- Visions of the bioeconomy
- Socio-economic aspects

### 2. Selected Recommendations of the roadmap

- Policy Dialogue
- Social and ecological aspects

### 3. Political Coordination across different levels

- Horizontal Coordination
- Vertical Coordination

### 4. Next Steps



# 1. Socio-economic Aspects of the Bioeconomy

# 1. Socio-economic aspects of the bioeconomy

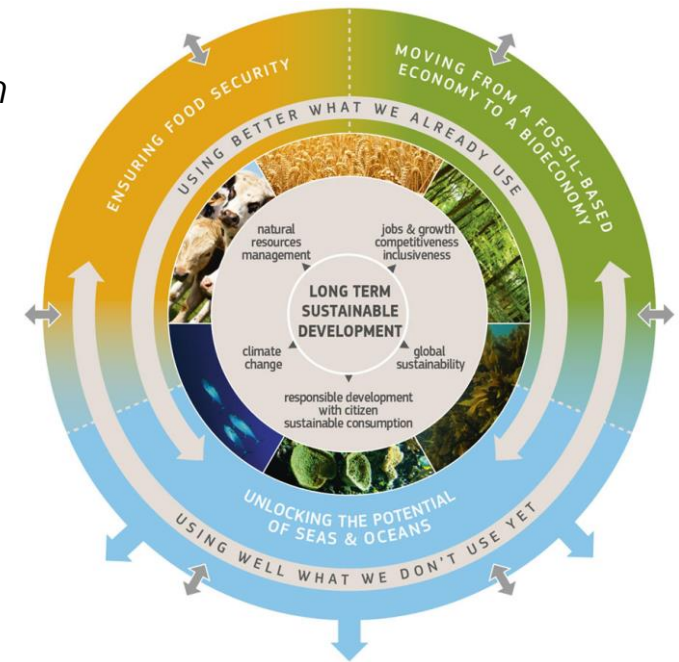
## European Bioeconomy Strategy

How is Bioeconomy defined by the European Commission? (Progress Report)

(...) *Bioeconomy encompasses **all sectors** and associated services and investments that produce, use, process, distribute or consume **biological resources**, including ecosystem services. As such it is a natural enabler and result of the **European Green Deal** transformation* (...) (European Commission 2022).

**Objectives** of the European Bioeconomy Strategy:

- Ensuring food and nutrition security
- Managing natural resources sustainably
- Reducing dependence on non-renewable, unsustainable resources whether sourced domestically or from abroad
- Mitigating and adapting to climate change
- Strengthening European competitiveness and creating jobs



# 1. Socio-economic aspects of the bioeconomy

## Three bioeconomy visions

Biotechnology Vision	Bioresource Vision	Bioecology Vision
Economic growth, Employment creation	Economic growth in a sustainable way	Conservation of biodiversity and ecosystem restoration
Biotechnology research	Research and development related to biological raw materials	Regionally concentrated circular processes
Biotechnological, industrial applications (e.g. genetics)	Biological raw materials and new biological-based supply chains	Ecological processes and sustainability
Innovations in Life Science (e.g. agriculture, biomanufacturing)	Biomass as significant source	Sustainability processes in rural regions

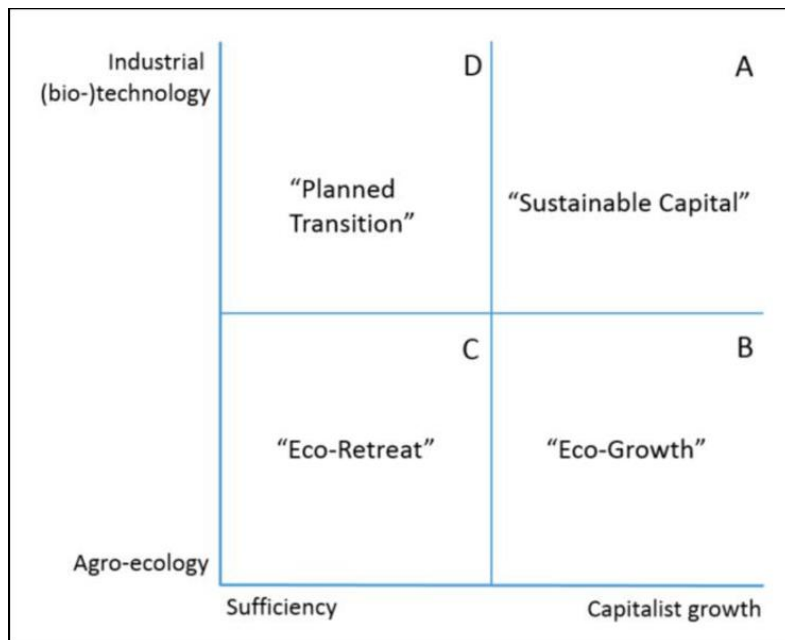
# 1. Socio-economic aspects of the bioeconomy

## Visions of the Bioeconomy

### Techno-political option space

locates different bioeconomy visions by two dimensions:

- continuum between visions of agroecology and industrial biotechnology
- continuum between visions of sufficiency and capitalist expansion



#### Planned Transition

- high biotech vision with sufficiency narrative
- state-centered visions
- reduction in material consumption

#### Eco-Retreat

- socio-economic sufficiency
- comprehensive socio-ecological transition
- global economic and environmental justice

#### Sustainable Capital

- eco-efficient use of renewable resources
- sustainable capital/sustainable capitalism

#### Eco-Growth

- Agro-ecology innovation
- growth-based capitalist economy
- regional focus

# 1. Socio-economic aspects of the bioeconomy

## Socio-economic aspects of the bioeconomy

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### Current socio-economic topics in the bioeconomy:

- The use of breeding technologies and how much they should be regulated (genetic engineering)
- Achieving a fair and just transition process towards a post-fossil economy (just transition)
- Competition of land use between the energy and food system (food-energy nexus)
- Consumer acceptance of bio-based products and the overall societal implementation of the bioeconomy.
- Equal consideration of all actors in the bioeconomy and the food system.

### Questions of discussion:

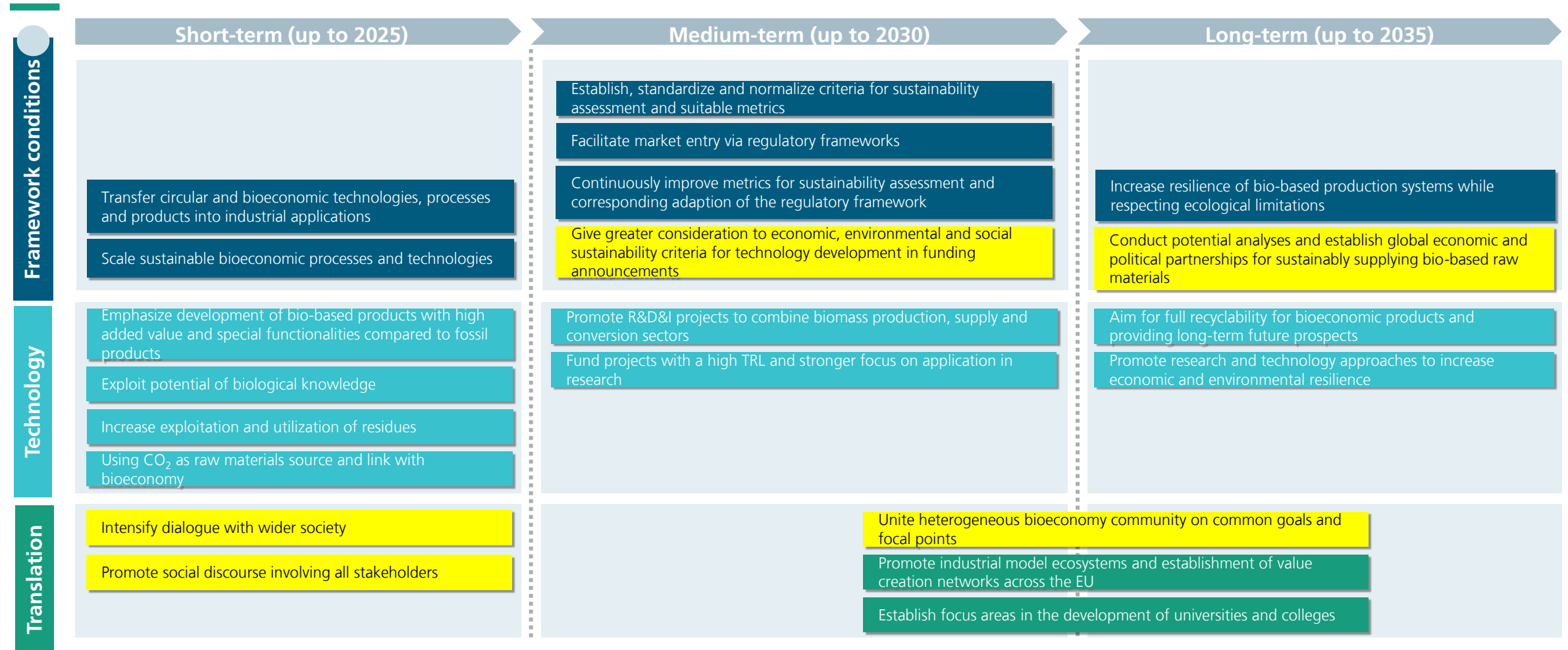
- Which aspects do you consider most important ?
- Which other socio-economic aspects should be considered in policy-making?
- How can we approach potential solutions for these socio-economic challenges?





## 2. Selected Recommendations of the Roadmap

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## 2. Selected Recommendations of the Roadmap

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### Policy and societal dialogue

- Intensify dialogue with wider society (including all relevant actors and create **shared visions**)
- Informing citizens about bioeconomy development and targets to reach a better understanding
- Establish **international economic partnerships** to ensure a long-term supply of bio-based raw materials (supplier countries must be included in these partnerships)
- Focus of all stakeholders in decision-making processes towards **common goals and focal points**.
- Formulating coordinated and **coherent bioeconomy policies** (cross-departmental and cross-level political decision-making)

### Integration of social and ecological Aspects in policy actions

- **appropriate metrics for assessing sustainability** must be continuously improved and the regulatory framework must be adjusted accordingly
- **sustainability assessment criteria** should be given greater weight in calls for funding applications
- Creating and strengthening **resilient value chains** based on foresight and scenario analyses.
- Using „**waste**“ as raw material that can potentially be used in a circular economy

## 2. Selected Recommendations of the Roadmap

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### **Discussion Questions:**

What are from your perspective important policy actions or policy instruments?

Are there any further approaches you would recommend?

What do we need to consider in shaping policy for the future' bioeconomy?

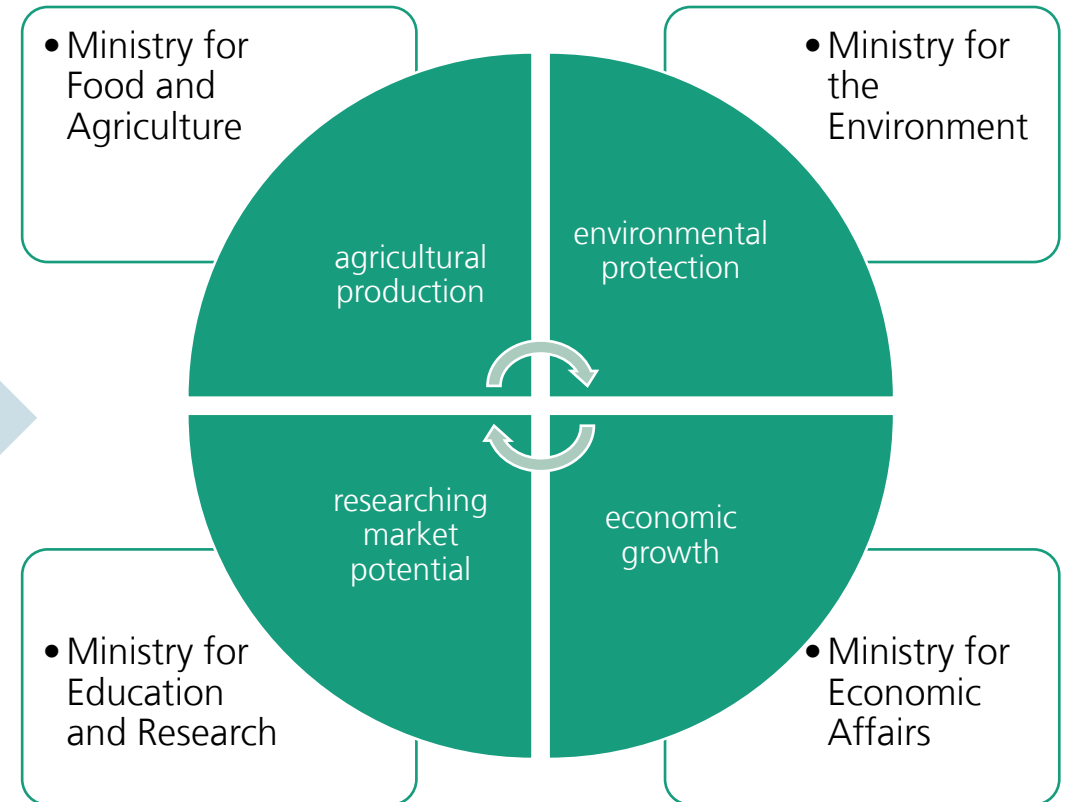
### 3. Political Coordination across different levels

### 3. Policy coordination across different levels

Horizontal policy coordination in respect to (partly) diverging interests among different societal actors



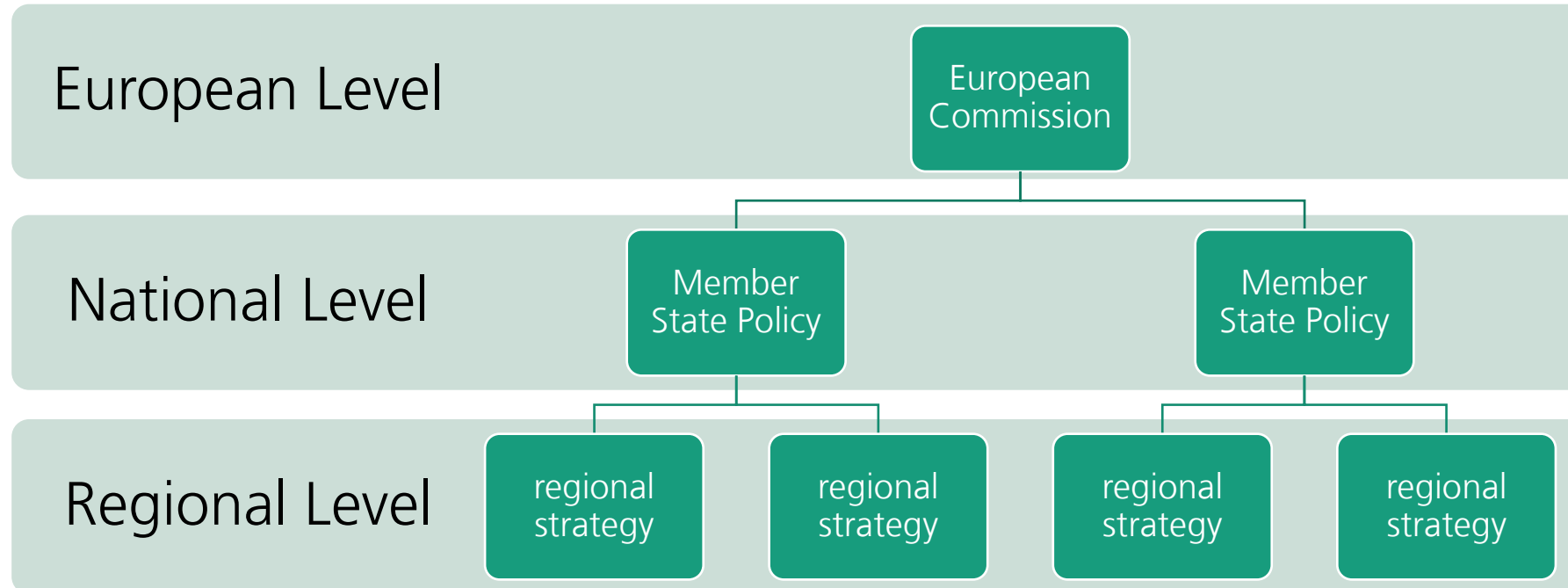
Multi-Level-Governance of the main societal actor groups



Policy Coordination between different federal ministries

### 3. Policy coordination across different levels

Vertical policy coordination in respect to different territorial levels



### 3. Policy coordination across different levels

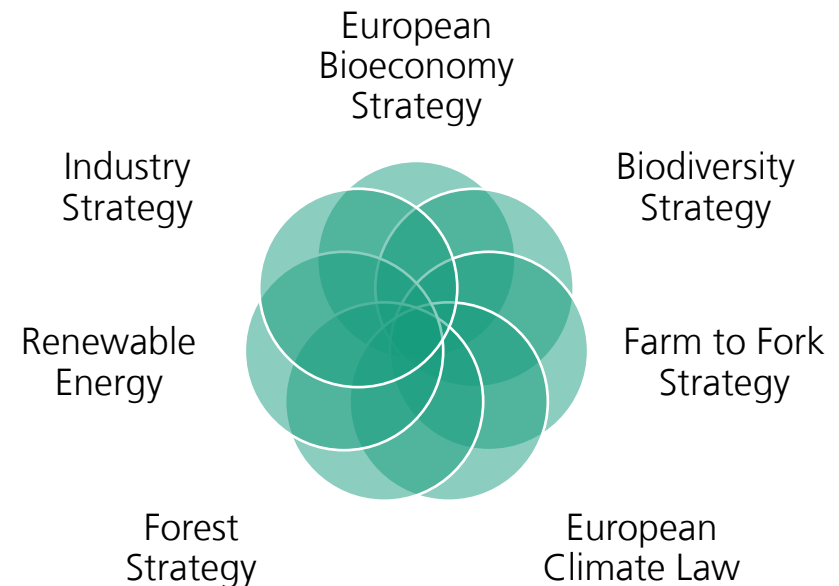
#### Discussion Question

Do we need more policy integration to develop a common ground of a bioeconomy vision?

Should the bioeconomy be more mainstreamed into other policy fields? (e.g. Energy, Agriculture, Environment)

How coherent are the policies of different territorial levels and how can they be better aligned?

How to achieve more policy coherence between different strategic priorities?

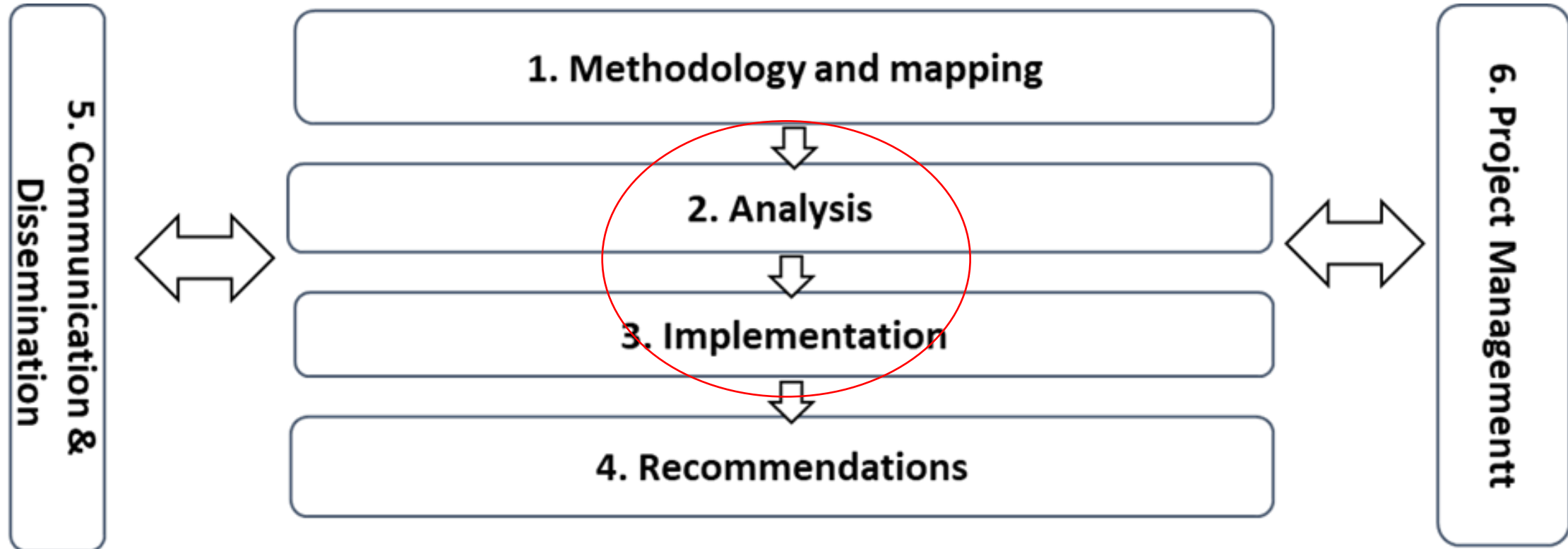




## 4. Next steps

# Next Steps

ShapingBIO Project



# Outlook

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We will take up your ideas from today in our project activities

Should you have any further ideas/recommendations/points, do not hesitate to get in touch with us!

Within our project we plan to conduct different participatory formats/workshops and we would be happy to have you engaged there.

Should you be further interested in our project, let us know, so that we can share information with you.

# Thank you for your attention!

## Contact

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Download roadmap  
and brochure

