Pathfinder Challenge

Waste-to-value devices: Circular production of renewable fuels, chemicals and materials

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Vision: Diverse pathways to support a renewable-driven, circular economy

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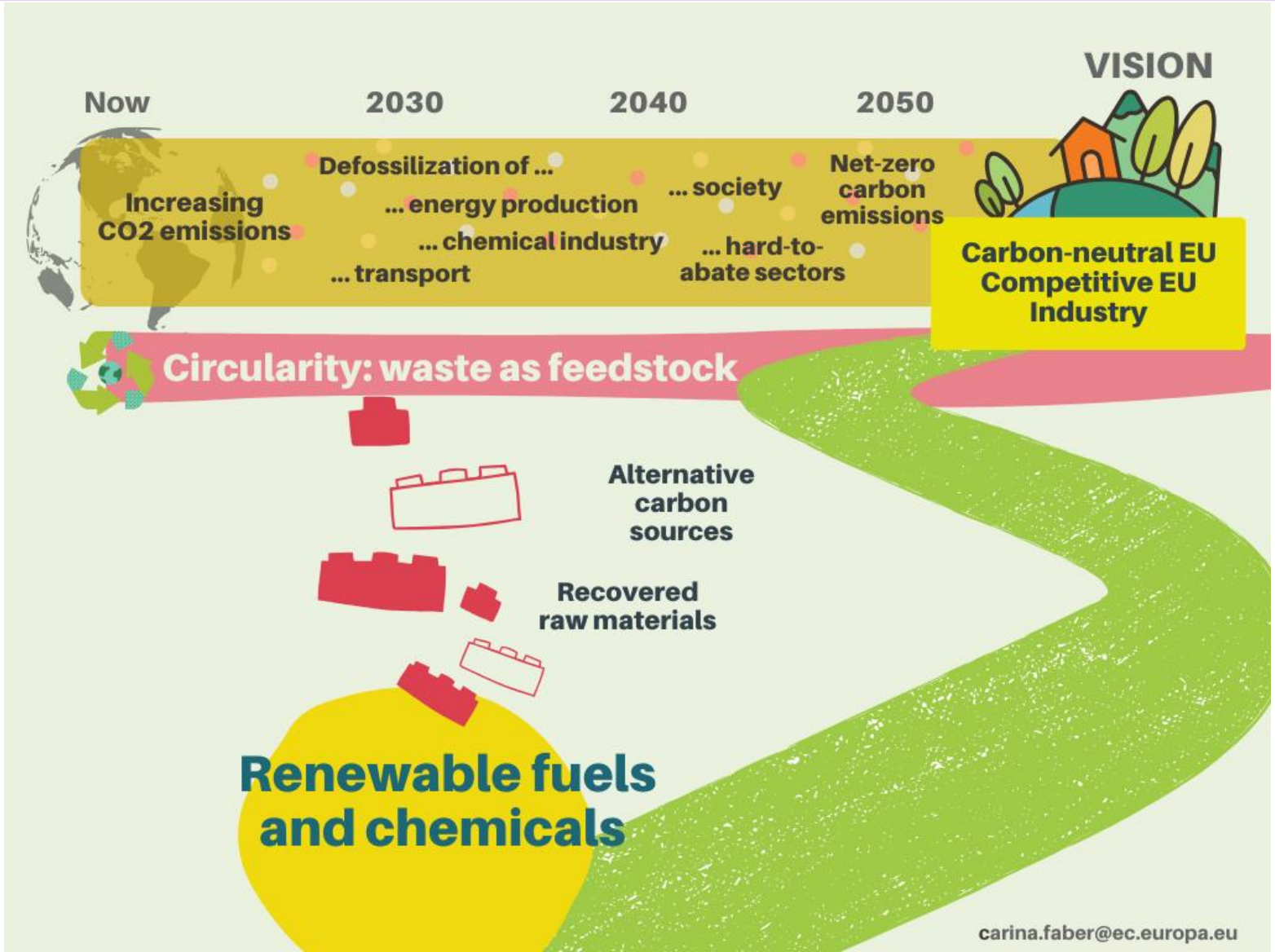

Adressed future markets are enormous..

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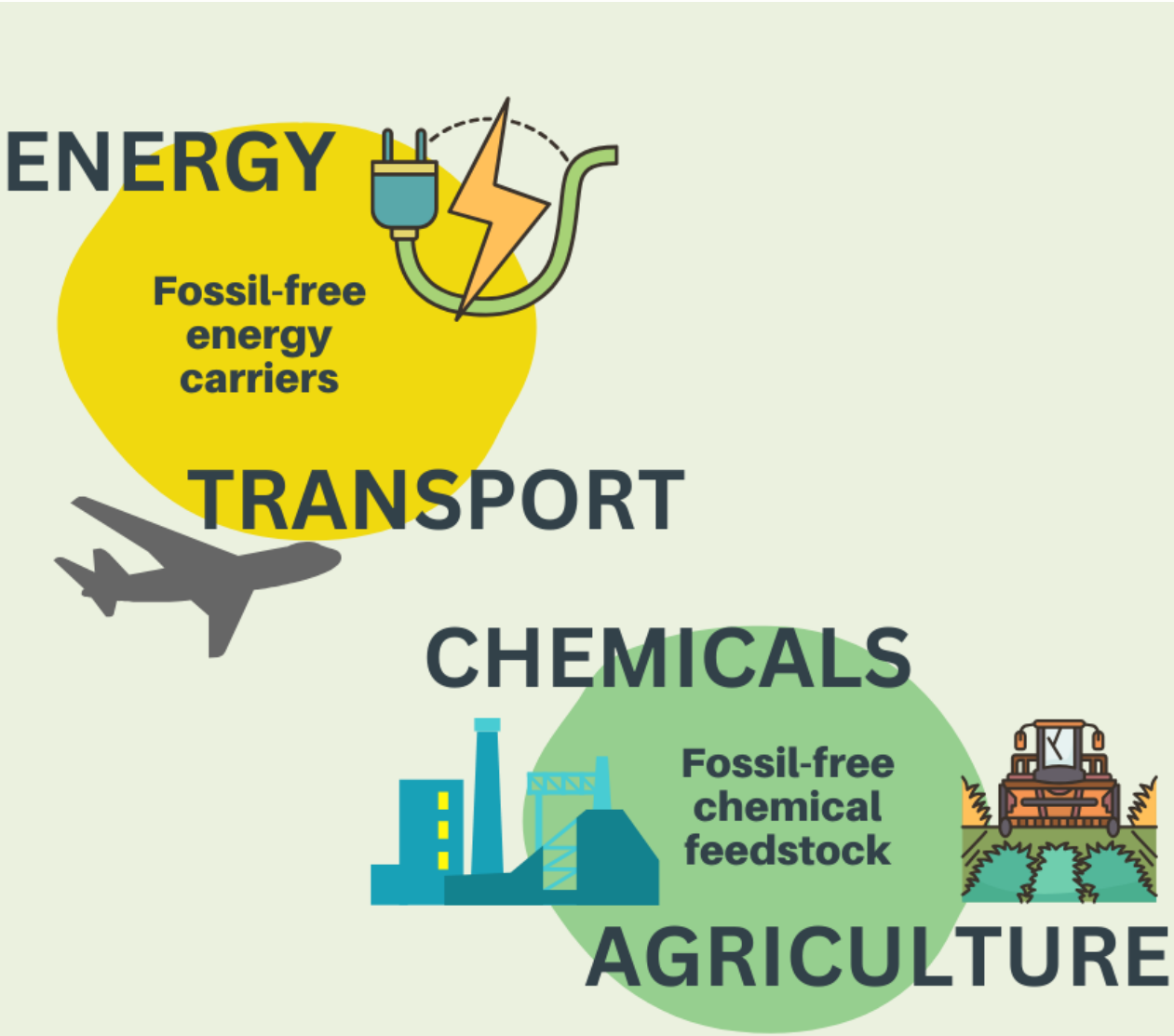

Renewable fuels and chemicals: what do we need for a large-scale deployment?

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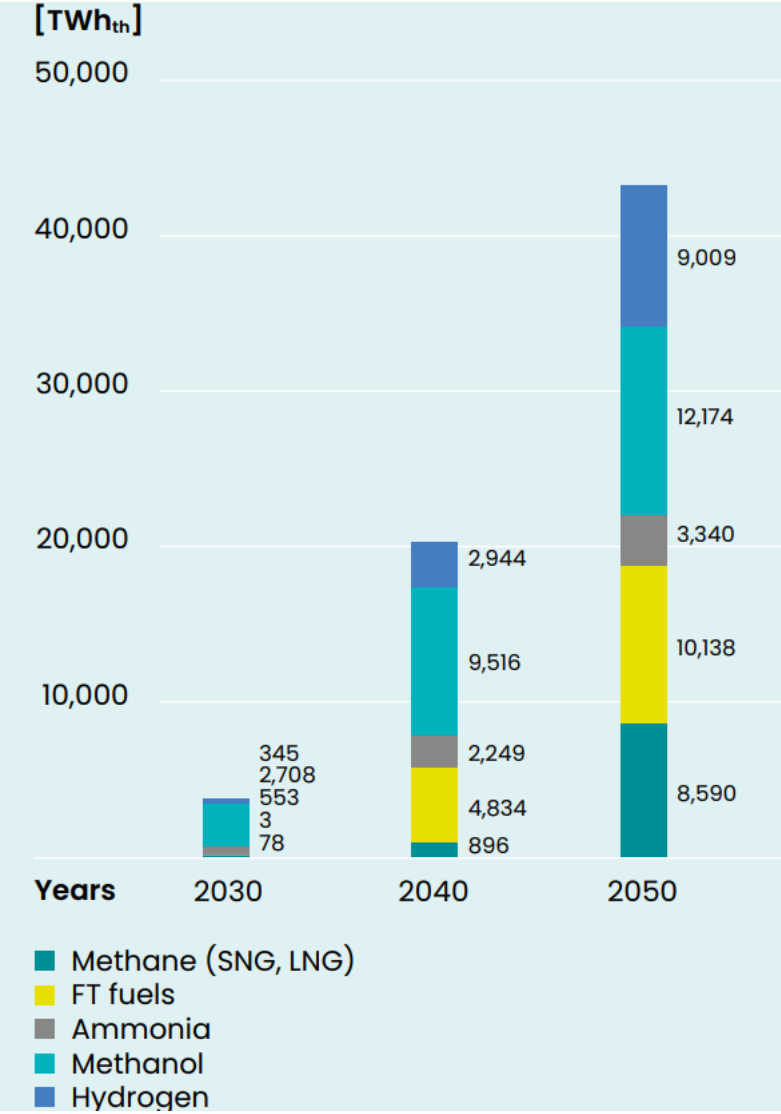

→ **Renewable energy sources:**
Cheap, at large-scale abundantly available

→ **Devices:**
Energy and materials efficient, robust

→ **Material sources:**
At large-scale abundantly available, fossil free

Fig.: Global powerfuels demand across the transition

Ram M., Galimova T., Bogdanov D., Fasihi M., Gulagi A., Breyer C., Micheli M., Crone K. (2020). Powerfuels in a Renewable Energy World - Global volumes, costs, and trading 2030 to 2050. LUT University and Deutsche Energie-Agentur GmbH (dena). Lappeenranta, Berlin.

Waste-to-Value devices:
Circular production of renewable fuels, chemicals & materials

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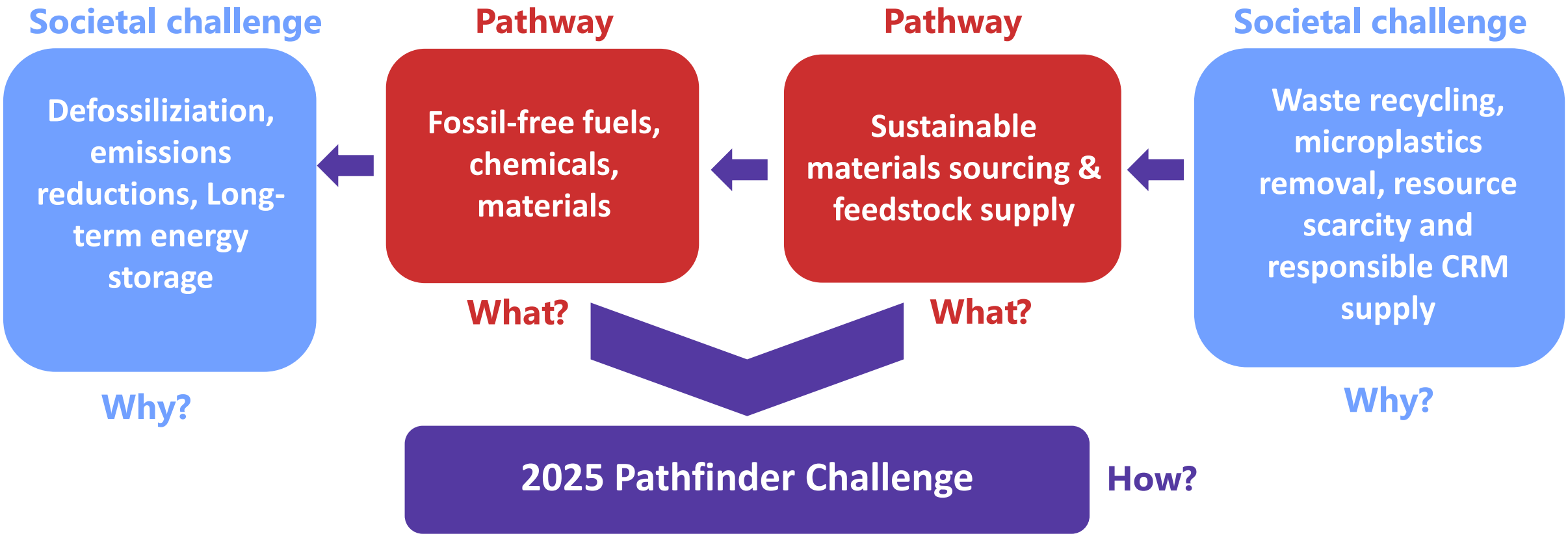
The ambition is the development of next generation technologies which enable a cost-efficient and fully sustainable provision of feedstock and raw materials to produce non-fossil-based fuels and chemicals – and their respective devices – at scale.



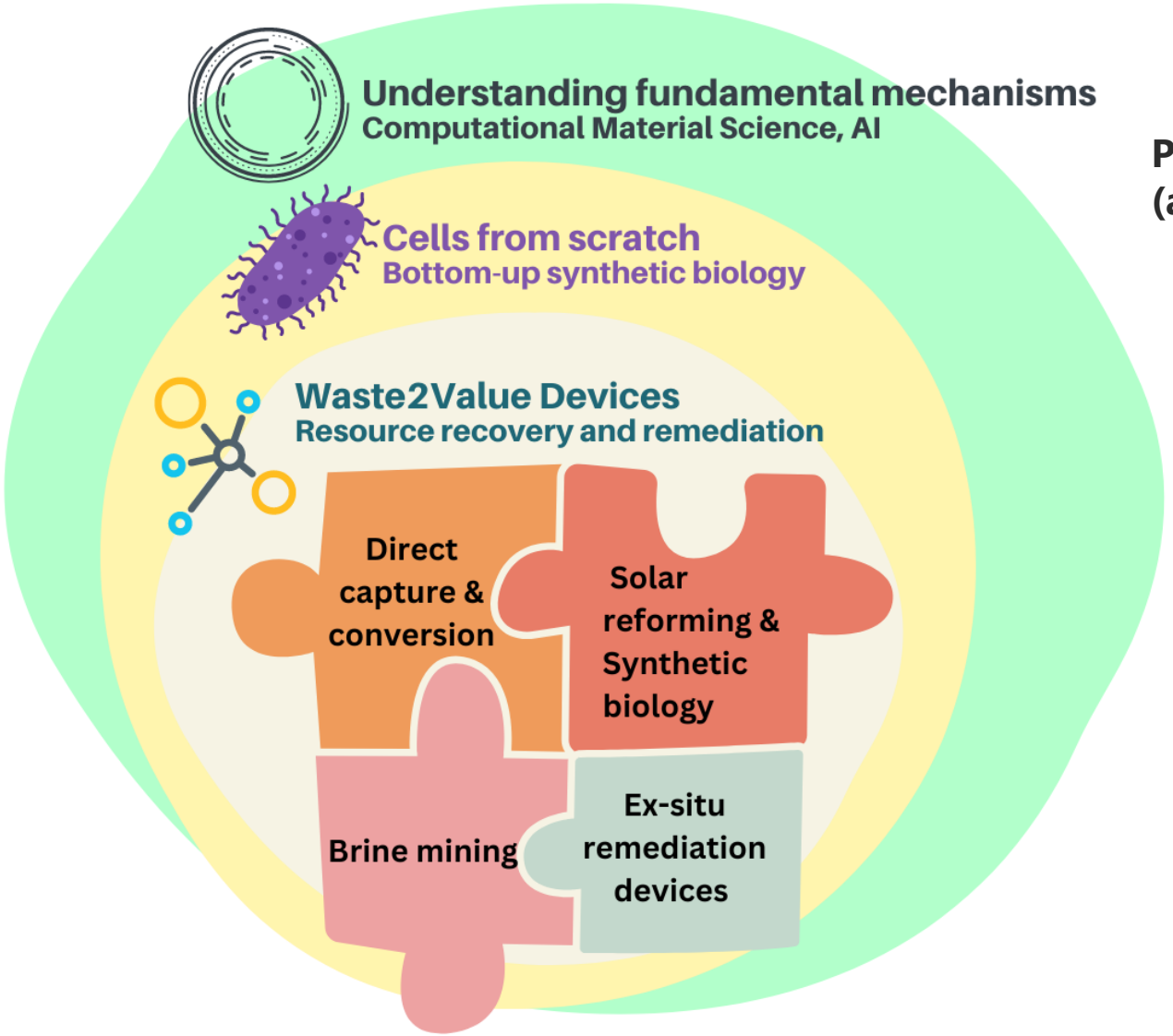
Scope: Types of waste

Real-life industrial and household waste: Non- or hard-to-recycle types of synthetic polymer materials (including among other mixtures of different types of plastics, polymeric composite materials, micro-/nanoplastics, untreated plastic waste, diapers, rubber, etc.), flue gases, wastewater and seawater desalination brines;

Out-of-scope: Food and biomass waste, traditional bulk metal waste, glass, paper, cardboard, mono-PET waste

Ref.: Stephen Buranyi, The Guardian, 'We are just getting started': the plastic-eating bacteria that could change the world

Scope: Three areas of projects



Project proposals should address one (and only one) of the following three areas:

- **Device development**: fully-integrated devices for resource recovery from waste and renewable energy, and devices for remediation: *Solar reforming*, *Microbial/enzymatic processes*, *Remediation*, *Brining*, *Direct capture and conversion*
- **Cells from scratch**: fully artificial microbial cells tailored for targeted degradation and valorisation processes – *Bottom-up synthetic biology*
- **Understanding underlying mechanisms**: enable next generation devices via *Computational material science and AI*

Specific objectives: Devices

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- **Fully integrated solar reforming or synthetic biology devices:**
  Treatment of synthetic polymer materials, fast and efficient decomposition, sustainable reaction conditions
- **Integrated capture and conversion technologies**:
  Capturing and converting feedstock from flue gases, or wastewater in a single step/ single device, increased energy- and materials efficiency as compared to not fully integrated process chains

- **Ex-situ remediation devices**, recovering elements and feedstock:
  - **Microbial/enzymatic and/or photocatalytic degradation**,
  - Purification of wastewater and seawater of noxious substances, metals, or nano- /microplastics
  - Production of added value remediation products.

- ***Membrane-based and electrochemical brine mining technologies***:
  Recovering raw materials, CO_2 and water from seawater desalinisation brines.

Out-of-scope: Thermochemical approaches (such as pyrolysis or gasification) and "dark" (not light-driven) chemical recycling

Specific objectives: Devices

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The targeted processes:

- are solely driven by renewable energy sources (**preferably directly by sunlight**)
- focus on the selective production of added value products, **beyond hydrogen as the sole end product**
- must not down-cycle the waste substrate, an **overall higher economic and environmental value** is achieved
- must be **energy and material-efficient** (minimising the associated energy, water, chemicals, and land footprint)
- must deploy **environmentally safe, stable materials**, with non-toxic degradation products

The developed devices have to reach **TRL 4 within a 3–4-year project runtime**.

The systems must also **be robust and easy-to-handle** to allow operations that are independent from large-scale infrastructures, with **extended lifetimes** and a **capability to treat real-life waste streams** which have undergone **minimal sorting and pre-treatment**.

Specific objectives: Computational material science and AI

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Objective: Advances and scientific breakthroughs in the fundamental understanding of the underlying physical, chemical and biological processes will enable fully-sustainable and scalable waste-to-value devices.

- Explore fundamental phenomena crucial to multiple waste-to-value device types, such as the development of efficient, stable and inexpensive catalysts, interface engineering and the effect of the surrounding medium.
- Drive forward the one-to-one comparison between theory at the atomistic level and experiment. Developing more accurate and less resource-demanding quantum mechanical methods is highly encouraged.
- Bridge the scales from describing properties at the atomic, mesoscopic up to the macroscopic device level within a multiscale approach and describe phenomena at different timescales.

Specific objectives: Fully artificial microbial cells

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Objective: Scientific breakthroughs in bottom-up synthetic biology will enable future biotechnology applications using tailored microbial cell factories for the degradation and valorization of waste and the production of fossil-free fuels, chemicals and materials.

- Develop synthetic, fully artificial cells for future large-scale biotechnology applications, tailored to desired functionalities such as carbon fixation or polymer decomposition.
- Engineer cell-like systems to produce compounds from abundantly available building blocks, such as water and carbon oxides.
- Engineer cell-like systems to decompose diverse types of waste, in particular plastic waste, into compounds valorizable as feedstock for an upstream production of fossil-free fuels, chemicals and materials.
- At this stage, systems do not have to be completely autonomous and self-replicating, but the integration of different modules should be explored.

Expected outcomes and impacts

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The resulting portfolio of projects will in time contribute to:

- **Local energy and resource supply**, allowing communities and remote areas to have access to reliable and sustainable waste recycling, supporting the local production of fuels, chemicals and materials.
- **Reduction/ eventual independence from the importation of critical raw materials** in the context of increasing demand for such materials for renewable energy and fuel technologies.
- **Increased share of recycled waste**, minimizing waste disposal in open dumps, landfills and incineration and the related negative impacts on our environment.
- **Micro-/nano plastic removal**, towards a **zero-brine discharge**.
- **Decentralised, circular production of fuels, chemicals and materials** where waste serves as an indispensable local resource enabling on-site production replacing fossil resources. Reduction in the demand for fossil fuels alongside associated CO2 and pollutant emissions reductions.

EIC Challenge Portfolio

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Overall objective

Develop fully integrated waste-to-value devices reaching at least the small-scale prototype level (TRL 4). Fundamental phenomena crucial to various waste-to-value device types will be explored, along with the pursuit of scientific breakthroughs in bottom-up synthetic biology.

- **EIC Challenge portfolio: close interaction guaranteed!**
- **Collaboration on:**
  - ✓ **Technology**
  - ✓ **Regulatory**
  - ✓ **Transition of technology to innovation**
  - ✓ **Communication and dissemination**

EIC Challenge Portfolio

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How is the Challenge portfolio built?

Tech topics in Area 1	(i) Fully integrated solar reforming or synthetic biology devices, (ii) Integrated capture and conversion technologies, (iii) Membrane-based and electrochemical brine mining technologies, (iv) Ex-situ remediation devices based on microbial/enzymatic and/or photocatalytic degradation.	
Secondary categories	Waste feedstock	- Non- or hard-to-recycle types of synthetic polymer materials (including among other mixtures of different types of plastics, polymeric composite materials, micro-/nano-plastics, untreated plastic waste, diapers, rubber, etc.) - Flue gases - Wastewater and seawater desalination brines

- **For details: EIC Challenge Guide**
- **Goal: maximize the overall impact of the Challenge portfolio**
- **How? Composition of a balanced and diverse portfolio of projects**
  - Covering the three aforementioned areas
  - Devices: as many projects as possible
  - Underlying mechanisms: 1 project
  - Synthetic biology: 1 project
- **Addressing as much complementarities as possible**

In a nutshell

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Waste-to-Value devices: circular production of renewable fuels, chemicals & materials

- Development of next generation technologies enabling **a cost-efficient and fully sustainable provision of feedstock and raw materials** to produce renewable fuels and chemicals of non-biologic origin – and the respective conversion devices – at scale.
- **Different waste sources** – such as plastics, polymer materials, wastewater, flue gases and desalinization brines – are valorized as a source for energy, feedstock molecules such as CO_2 and critical raw materials, while ensuring overall economic and sustainable processes. They are scalable, easily applicable and deliver products with high economic value from waste substrates.
- **Technologies included**:
  - Device and process development:
    - Solar reforming and synthetic biology for waste valorization,
    - Brining,
    - Microbial and photocatalytic remediation of wastewater,
    - Integrated capture and conversion technologies.
  - Breakthrough fundamental research:
    - Computational material science and AI to explore fundamental underlying phenomena,
    - Fully-artificial microbial cell factories development.

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Thank you!