Envisioning the future of aviation product liability in the European Union through the lens of circular economy

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LL.M. Air and Space Law

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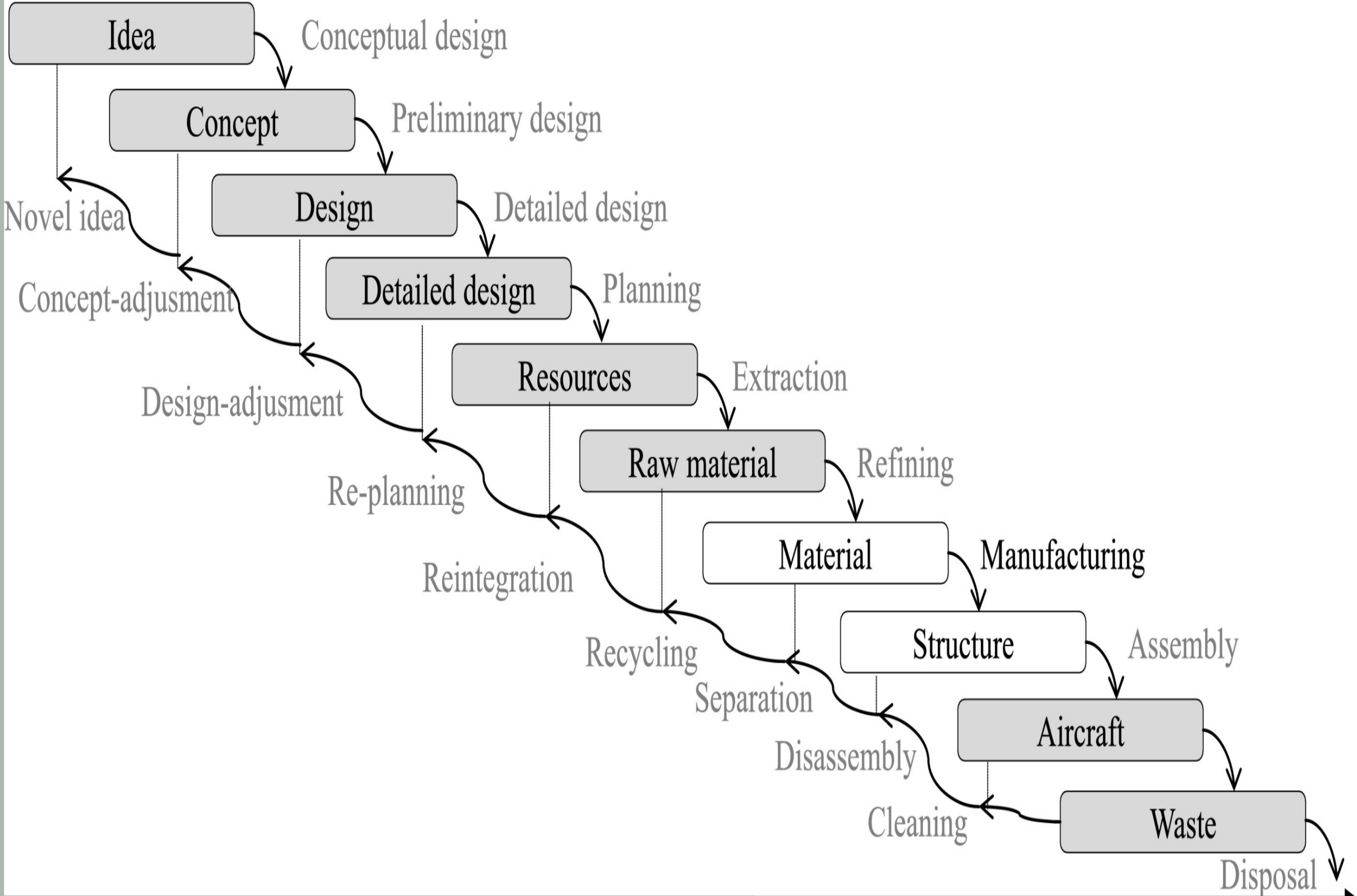
Committee Dr Benjamyn I. Scott

Prof. dr. Steven Truxal

Introduction

- Paris Agreement, 2015
- UN Sustainable Development Goals
- Creation-consumption-disposal = large amount of waste
- Closing the loop
- Aviation – contributor to GHG emissions
- Increase in air traffic = higher emissions, higher waste
- Where do we begin to address the problem?

Circularity



European Union

Green Deal 2019

Circular Economy Action Plan 2015

Circular Economy Action Plan 2020

Flightpath 2050

Horizon 2020

Research questions

Primary question:

Should the European Union product liability regime be amended to foster a circular economy while addressing the safety implications of developing, manufacturing and testing of products tailored to circularity?

Research questions

Secondary questions:

1) What does circular economy encapsulate in the context of the aviation sector?

2) What is the product liability regime in the European Union for parts, products, and components in the market?

3) Is the European Union product liability regime adequate for a system based on circularity?

4) Is there a need for changes in certification standards for products tailored to circularity?

Product Liability

European Convention on Products Liability in regard to Personal Injury and Death, 1977

Directive 85/374/EEC on the approximation of the laws, regulations and administrative provisions concerning liability for defective products

Directive 2001/95/EC on general product safety

Proposal for a new Product Liability Directive, 2022 v. Montreal Convention

Safety & Airworthiness

Regulation 748/2012 - implementing rules for the airworthiness and environmental certification of aircraft

Regulation 2018/1139 on common rules in the field of civil aviation

Regulation 1321/2014 on the continuing airworthiness of aircraft and aeronautical products

Aircraft maintenance and airworthiness

Findings

- Focus = emission reduction and not elimination at source
- Phase out aircraft or use retrofitting
- Identify linear lock-ins and systemic leakages
- Material complexity and proliferation
- Legislation – aircraft end-of-life

Findings

- New Product Liability law - acknowledge the complexity of the aviation sector and provide for manufacturer liability
- Improper to attribute liability to part/component manufacturers

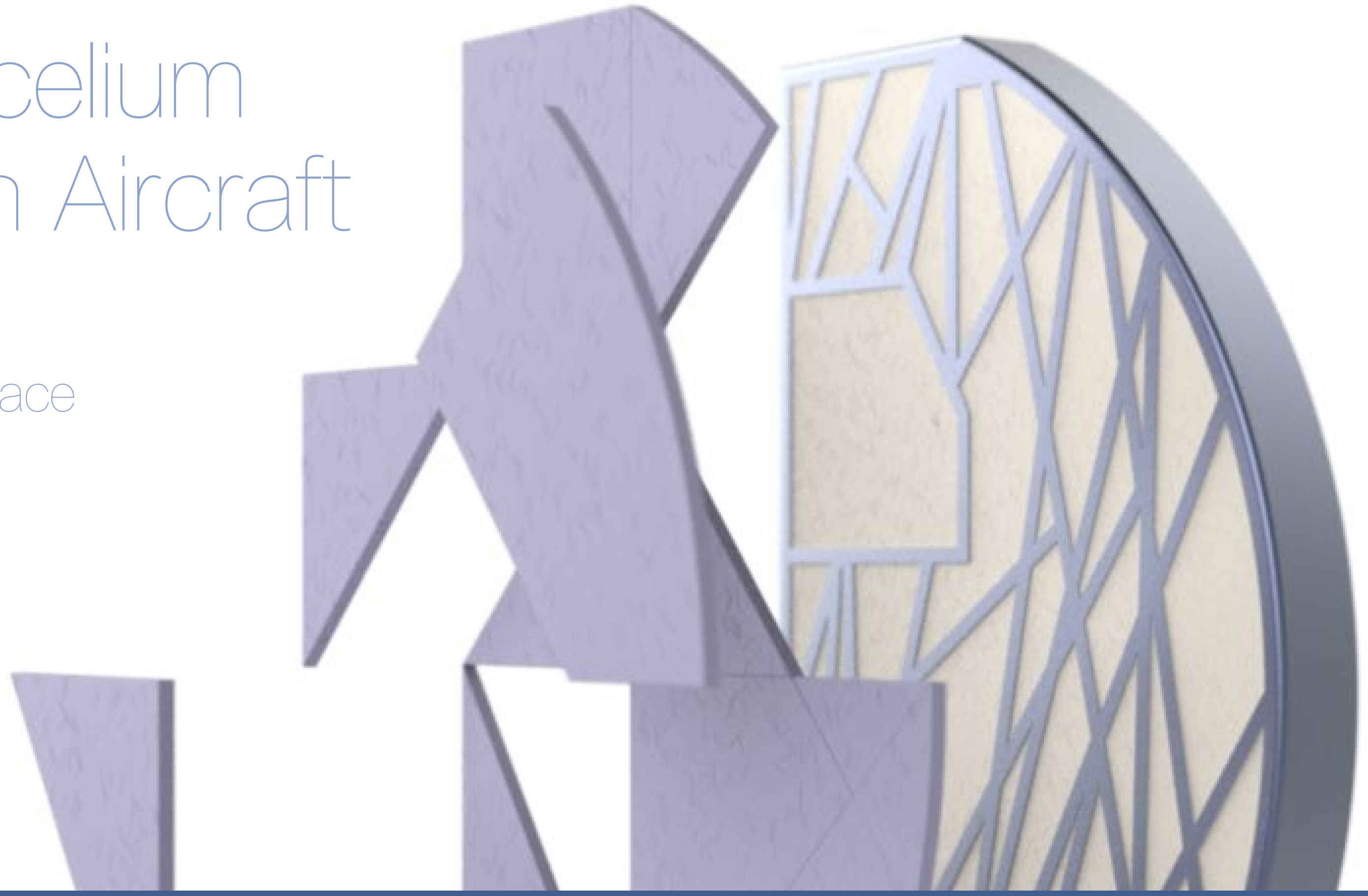
Findings

- How much change is permitted?
- What about safety critical systems?
- Traceability and life-cycle assessments
- Material passports
- Energy labels – emission labels
- Availability of spare parts

Application of Mycelium based Materials in Aircraft Cabins

Ref. Case: Biotechnology in Aerospace

hyfen



Mrinal Chaudhury

MSc Integrated Product Design

Delft University of Technology

Airbus Dr. Camille Carre
(Polymer Scientist at Airbus CRT)

Dr. Christian Weimer
(Head of Materials at Airbus CRT)

Committee Prof. dr. Balkenende, A.R.

Prof. dr. Karana, E.

Context

Why is mycelium a material of interest to aircraft and aerospace related manufacturing industry?

Mycelium in Aircraft Cabins

Mycelium is of interest in aerospace for it’s following known qualities

- Biological sourcing
- Renewable raw materials

- Lightweight
- Versatile

- Biodegradability
- Low carbon production

Project Name: Floriade Expo 2022, NL, (SIGN project)

Project Name: C Suite Business Class (Marie Sanou , Airbus)

Problem

Why are mycelium based materials not yet in commercial aircraft cabin products?

Key Challenges

Challenges in adoption of mycelium being addressed in this thesis assignment are as follows:

Architecture & Interior

Fashion & Consumer

Insulation & Protection

Aerospace & Aviation?

Image Sources: Published pages on mycelium products on Dezeen, Ecovative, Mogu & Airbus

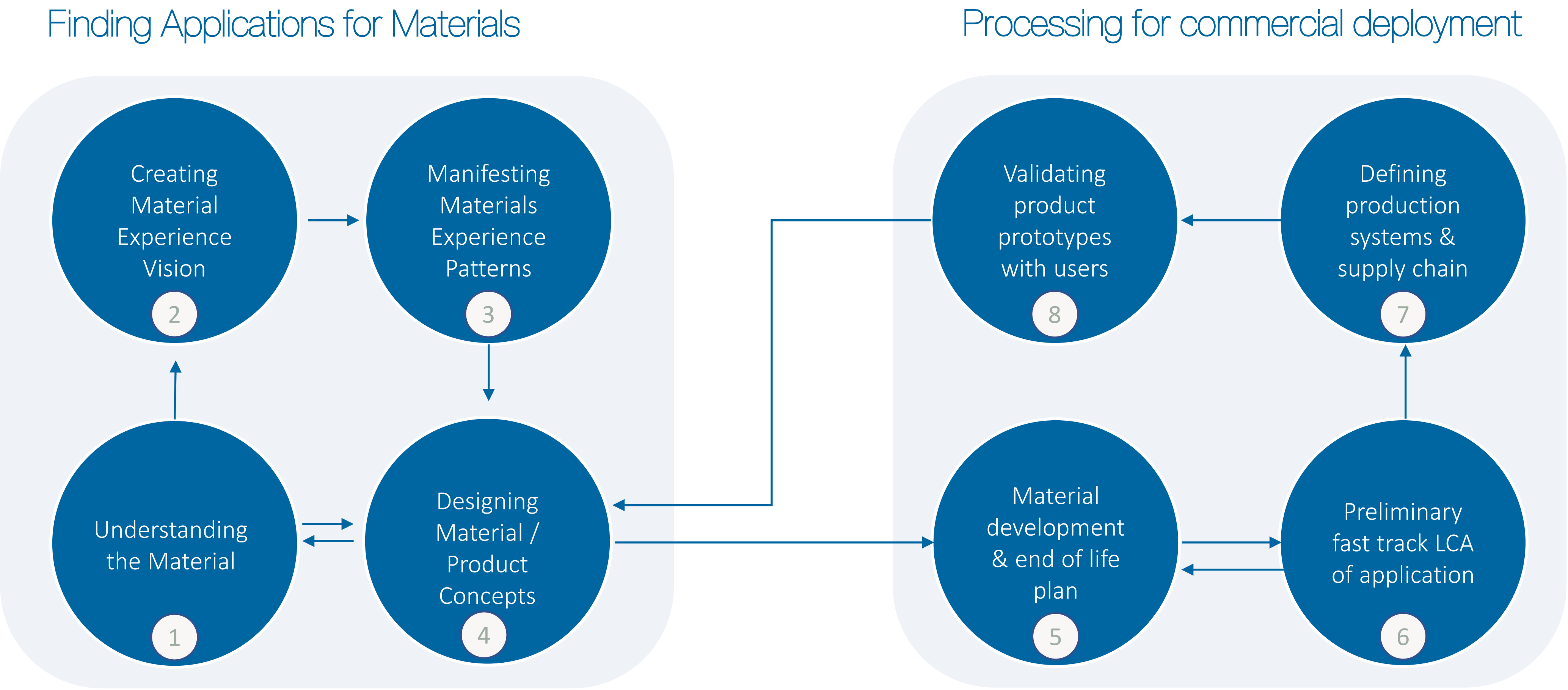
- Lack of ***demonstrated applications*** specific to Aircraft Cabins
- Incomplete knowledge of mycelium based material properties for aircraft cabin applications (e.g. FST properties)
- ***Inadequate natural mechanical properties*** for structural applications
- Requirement of new ***supply chains***, ***production process*** and ***life cycle management*** of the products is crucial before investments are made.

Method

How did this thesis assignment approach the challenge of finding suitable applications as well as material development of mycelium based materials for Aircraft Cabins?

Methodologies

The methodology used to design applications for the thesis assignment was adapted from 'Material Driven Design' methodology developed in TU Delft. In line with principles for circular design, a methodology for defining recommendations for processing for commercial deployment.



Design

How can mycelium based materials be applied to applications in aircraft cabins?

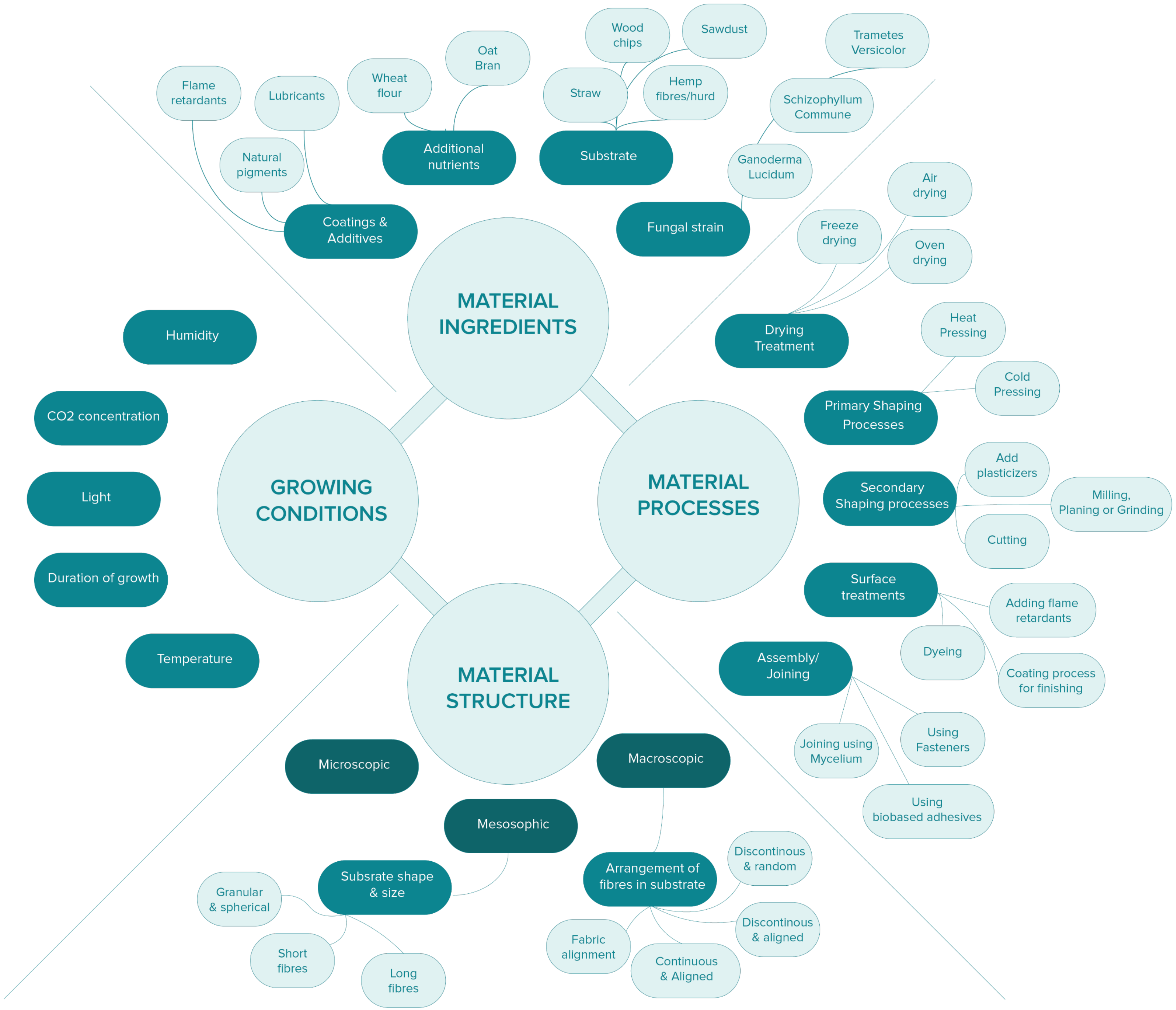
Understanding the Material

1

Material Taxonomy

Mycelium based materials can have a large number of material profiles based on several determining factors as shown in this Taxonomy.

NOTE: A combination of *material taxonomy, experimentation, data mining and Ontology* can aide the digital development of complex fungal materials for customized applications.



Suitable Range of Applications

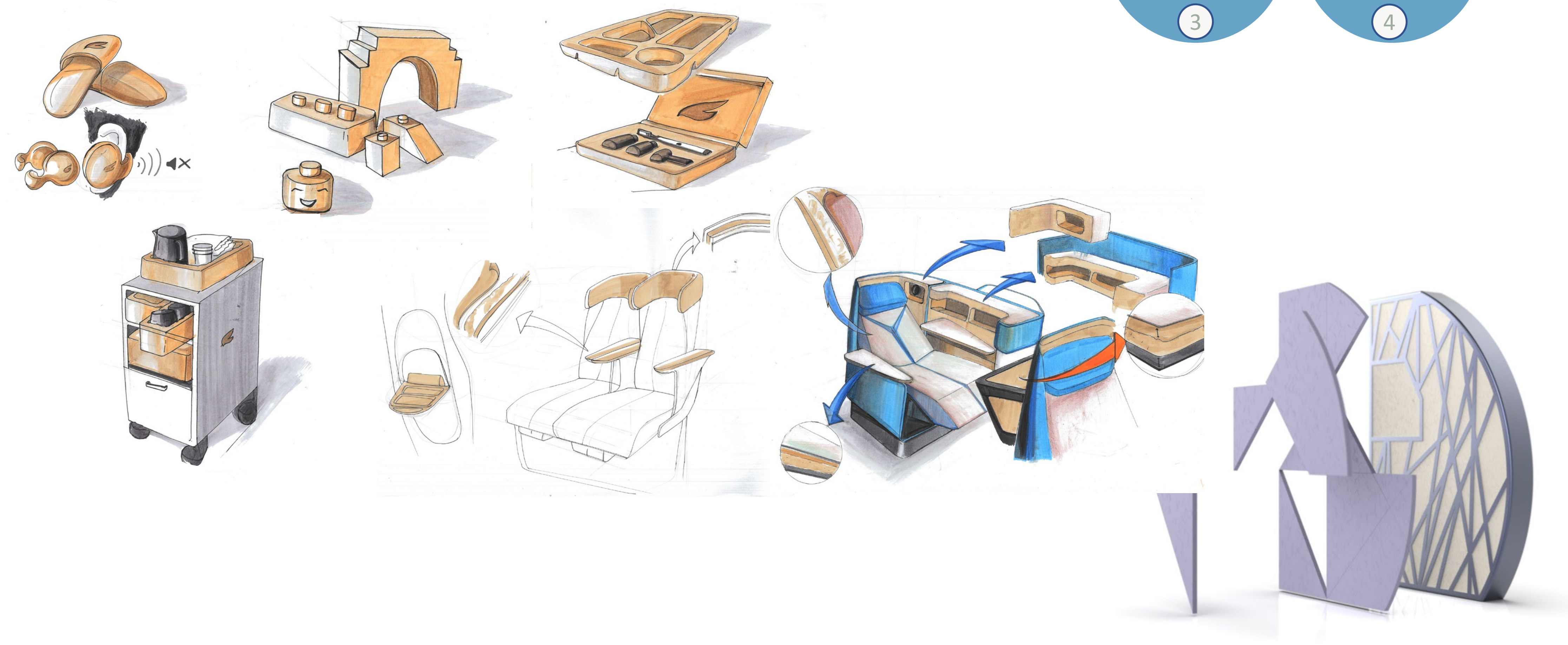
Manifesting Materials Experience Patterns
3

Designing Material / Product Concepts
4

Procured or Produced by Airlines

Produced by Cabin Interior Partners

Produced by Aircraft Manufacturers



1 day/flight

1 – 3 Weeks

4-5 years

10-15 years

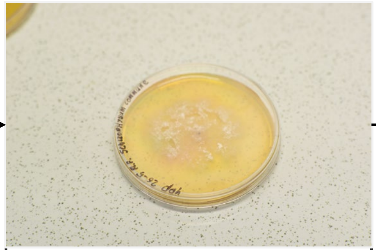
Increasing lifespan of the product in application

PoC

What is the proof of concept to use Mycelium based materials for intended applications? How is it developed and what is the road to commercialization?

Material Development Schematic

- Procure Strains
- Procure Substrate



- Grow pure mycelium on agar plates

- Determine size, additives, nutrients & colour
- Sterilize substrate

- Inoculate substrate grow bags & let it grow for 5-7 days

- Mix contents for homogeneity and transfer to growth forms (moulds). Grow for 5-7 days

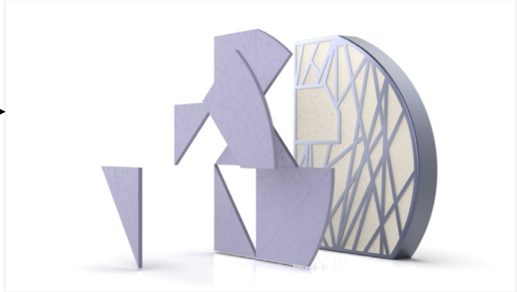
- Let the fungal skin growth occur (2 -4 days) if desired.
- Demould

Deactivate Growth (options)
- Freeze drying
- Oven drying

(60-70 degree Celsius)

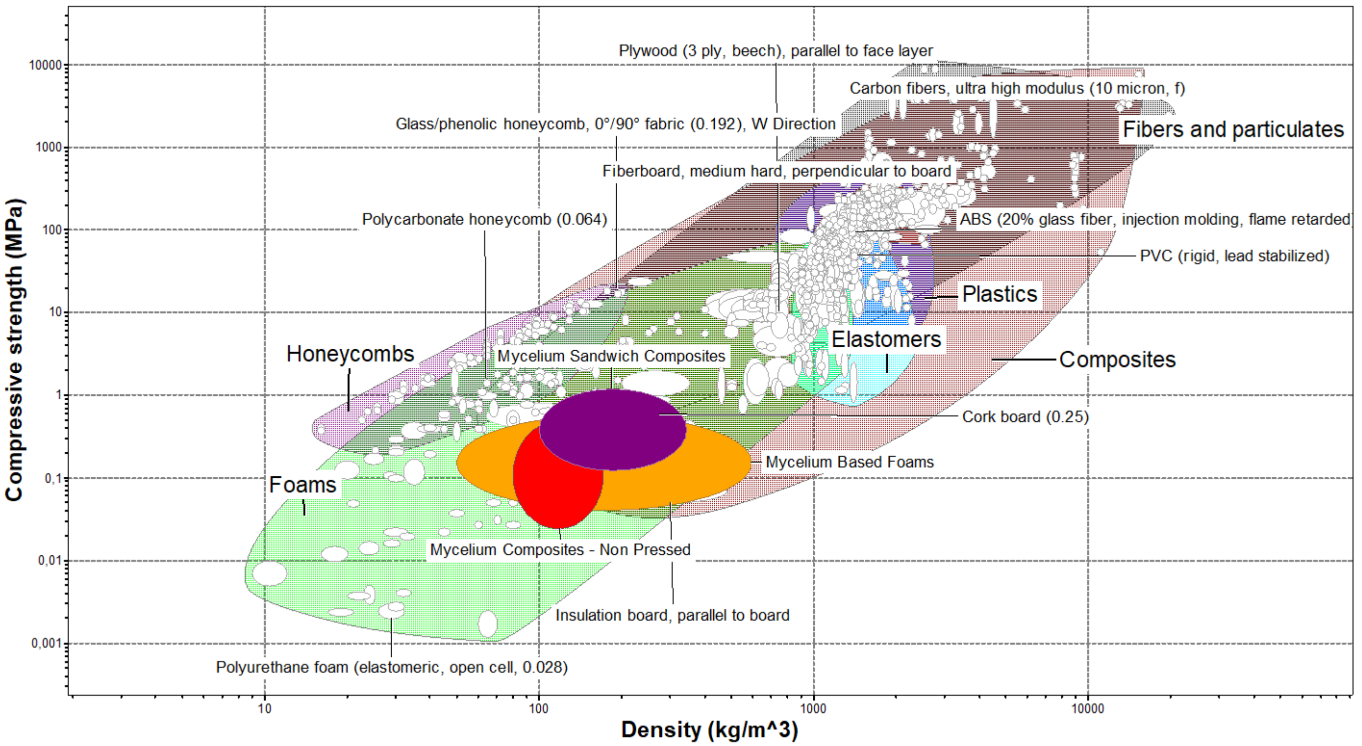
Processing
- Pressing (cold & hot pressing
- Coatings

Product forms
- Shaping
- Assembly & joining

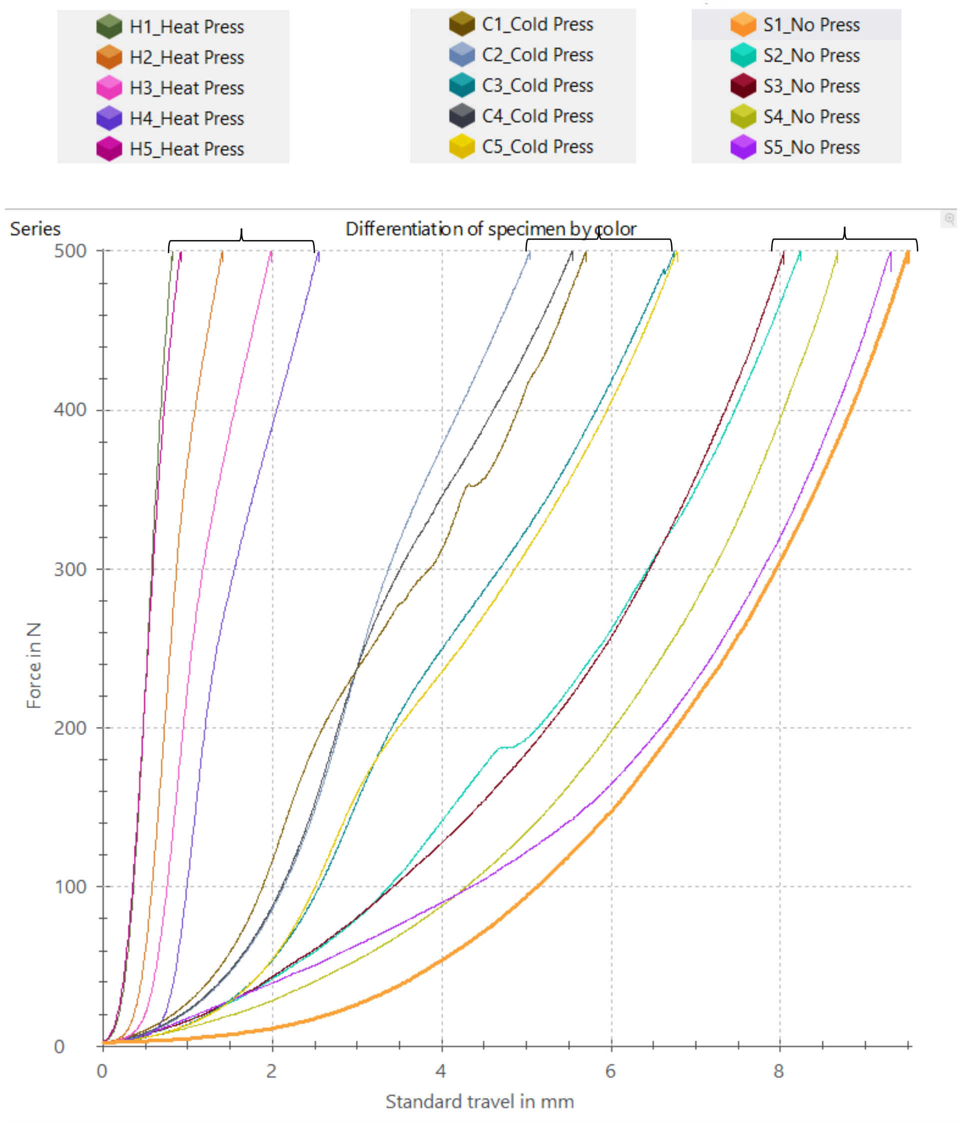


- Finishing
- Product Installation
- End of life plan

Technical Performance



Compressive strength of mycelium materials tested in literature plotted against aerospace materials In Granta Edupack 2021



Fabricated & processed Hemp myco-composite behaviour under compressive load

Environmental Performance

LCAs in literature of Mycelium materials (composite & leather) show following environmental hotspots in the production stage in order are

Electricity for Sterilization

Electricity for drying & heat pressing

Polypropylene grow bags & moulds

Hemp agricultural production (land use)

Passenger Experience

The material is experienced by users in the following way when tested using material experience toolkit of the MDD method

Sensorial: Lightweight, Matte texture, soft & velvety

Affective: Elicits curiosity & fascination

Interpretive: Crafted, calm & sustainable looking

Performative: Invites to caress & hold

Next Steps

In the completion of this thesis

1. ***Cradle to Cradle Fast track life cycle assessment*** of selected applications with focus on
   - Identification of environmental hotspots
   - Comparative analysis with existing products for the same function

2. ***Detailed design*** of selected applications with the following details
   - Form & achievable aesthetics
   - Assembly and installation opportunities
   - Controlled end of life activities

3. ***Preliminary supply chain and production process advice*** focusing on
   - Requirements to set up a fungal biotechnology research & production unit in Airbus production facility

Questions

Thank you for listening.

If you have feedback, questions, suggestions or interesting collaboration ideas, please email me

M.CHAUDHURY@STUDENT.TUDELFT.NL

Silvoarable Systems as Feedstock Provisioners for Sustainable Composite Manufacturing

Iñigo Irache Cabello
MSc Industrial Ecology
4th July 2023

Carbon fibre composites

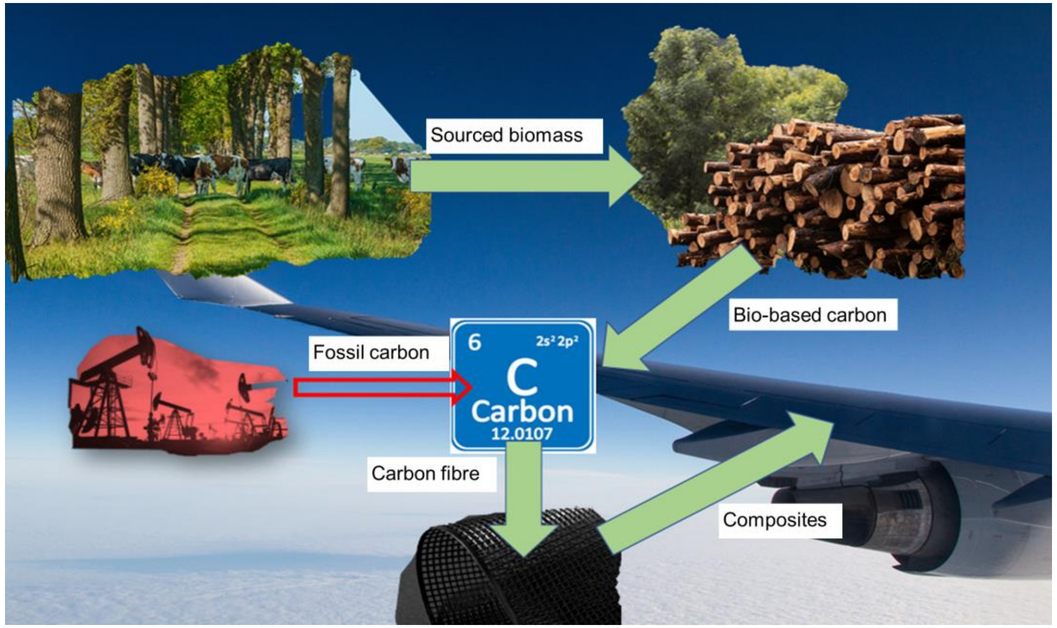
Great properties: weight-strength ratio

Sustainable issues: Made from fossil fuels, low recyclability, CFs most of the impact

¿Get rid of them? No! Flying emissions

Substitute with biofibres? → Lower properties

“Imitate” CFs with bio-based precursors → same performance lower impact

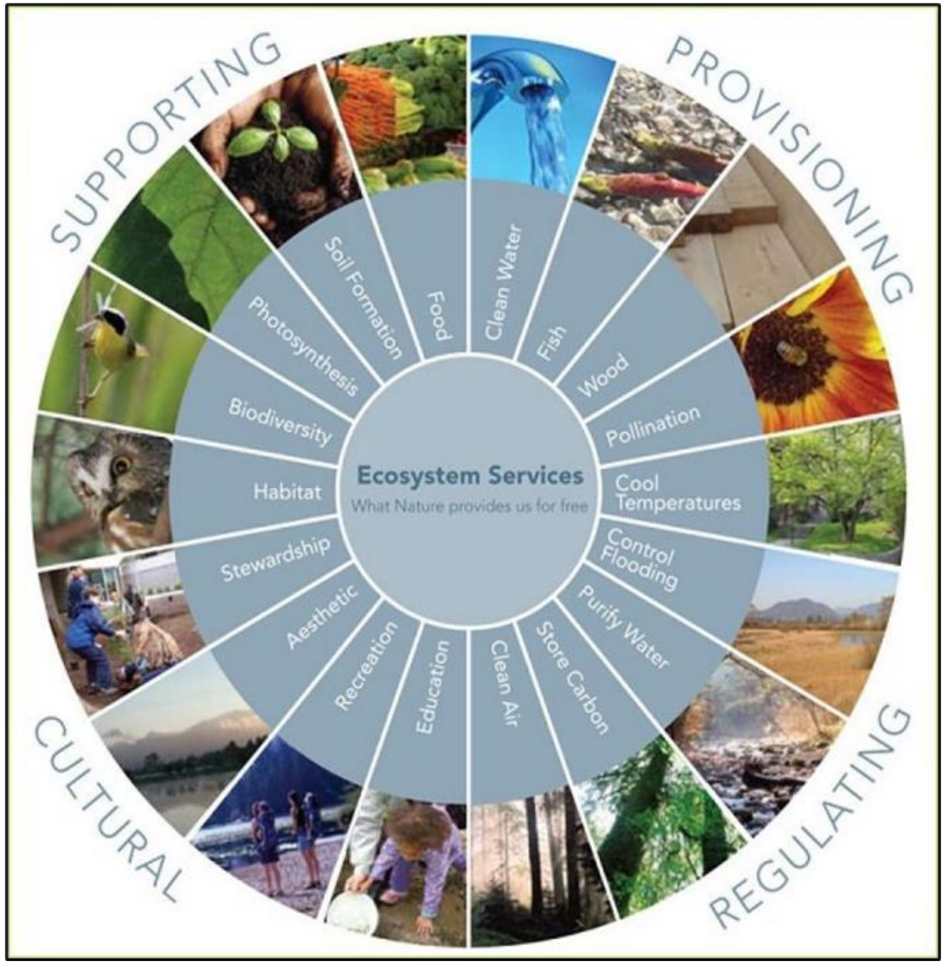


New Bioeconomy models

Biomass use is not always sustainable: soil depletion, biodiversity loss, food competition…

Move from resource extraction to nature restoration

Bioeconomy supply chains based on Ecosystem service provisioning: Climate adaptation, water purification, habitat creation…



Short rotation silvoarable systems

SRC as biomass producers and ESs provisioners: wind reduction, water regulation, soil health…

- Increase resilience and sustainability of farms
- Trees are more productive
- Extra income farmers and rural development
- Sustainable end-to-end biomass

LCA study

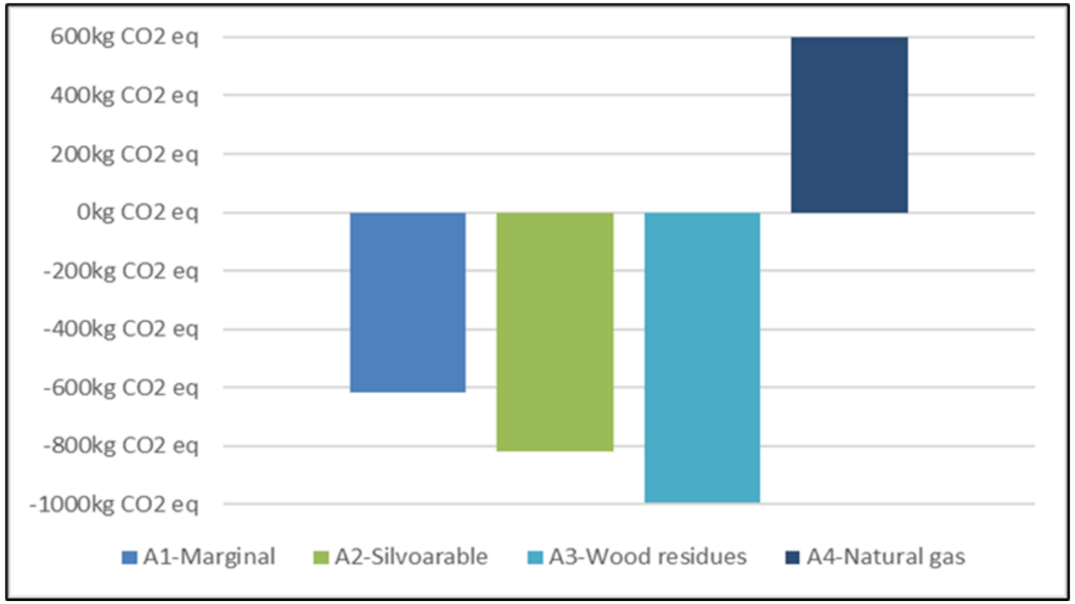
Functional unit: 1-ton Methanol for CF production (3bio and 1 fossil alternatives)

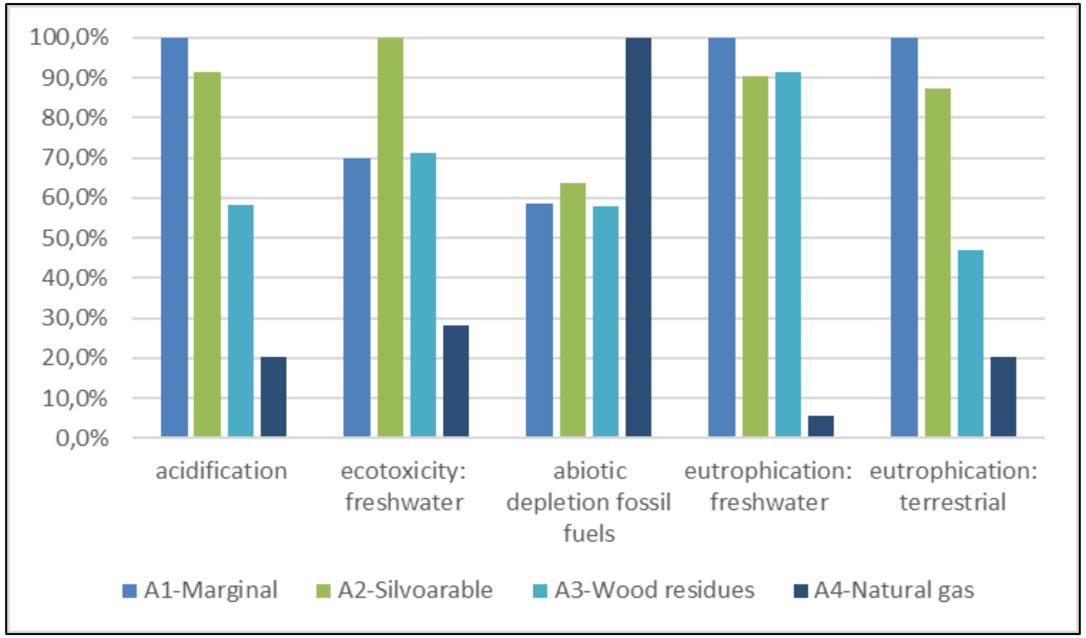
Bio vs fossil

- As two times better carbon performance
- Other impact categories are not benefitted: high electricity use German mix

Silvoarable vs bio alternatives

- Better than marginal →productivity
- Worse than wood residues

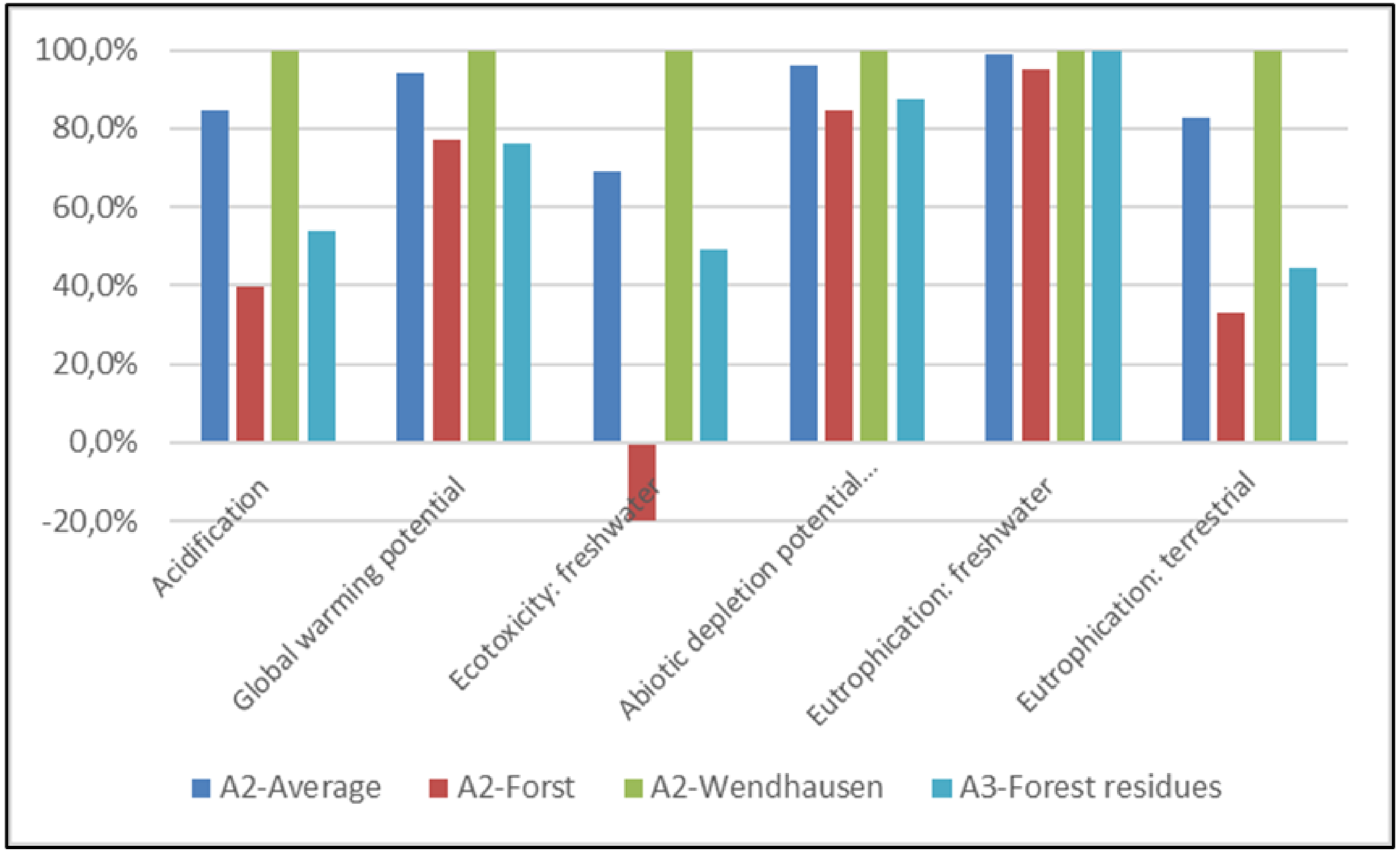




LCA study-sensitivity plantations

What is the influence of crop yields in wood impact?

When silvoarable plantations are able to increase crop yield→ outperform forest residues

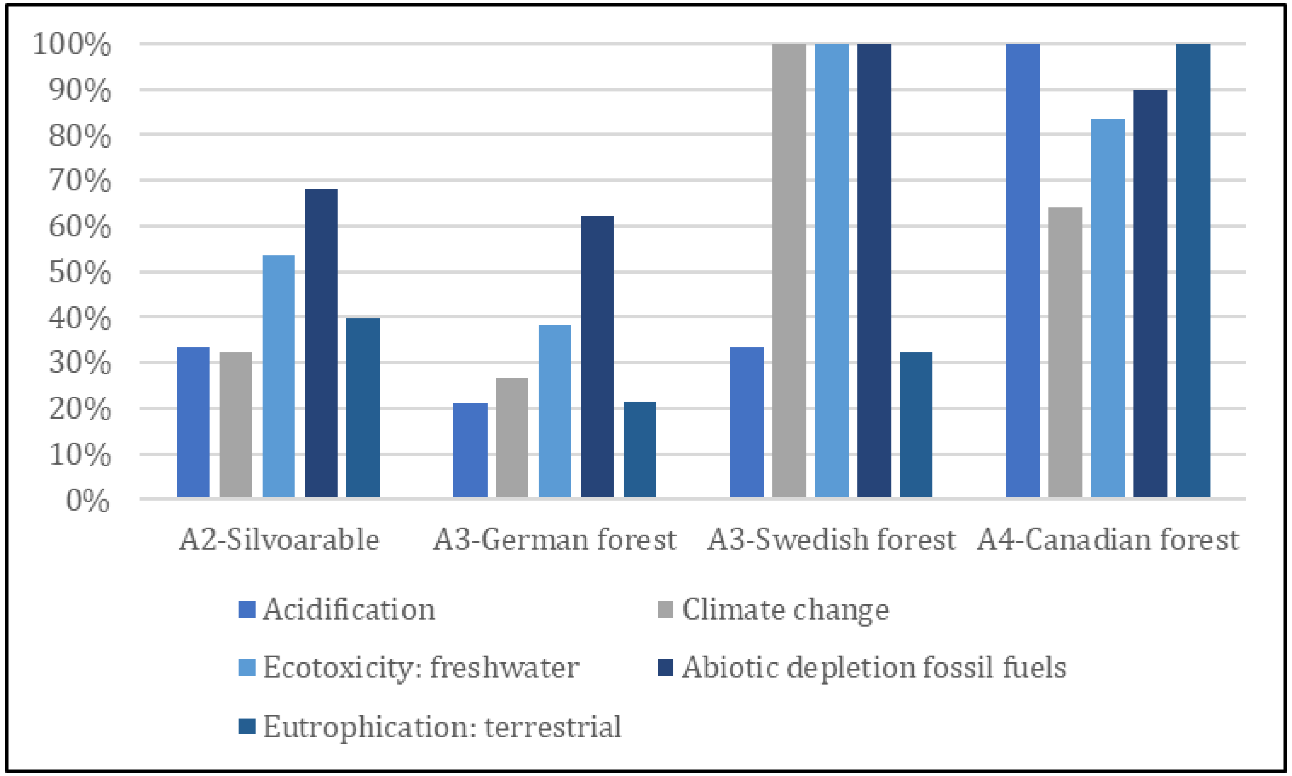


LCA study-import of wood

Locally sourced biomass is highly relevant

Availability of forest residues will be limited

When forest residues need to be imported silvoarable systems are a better option



LCA study-best future case

When renewable electricity and the most productive silvoarable systems→ outperforms fossil alternative

This shows the future potential of this systems

Category	Silvoarable (best case)	A4-Natural gas	%Difference
acidification	0,84	0,98	-14%
climate change	-1931,65	599,12	-422%
ecotoxicity: freshwater	-1656,81	1247,78	-233%
abiotic depletion fossil fuels	3155,86	29750,24	-89%
eutrophication: freshwater	0,09	0,09	9%
eutrophication: terrestrial	2,05	3,39	-40%

Conclusions

- Short-rotation silvoarable systems are a promising solution for sustainable biomass
- These systems need to be further researched to realize their full potential
- Farmers need incentives to start transitioning into more sustainable practices and this could be a great opportunity
- Today the cost might be higher, but Airbus can invest in a supply chain that will enhance sustainability in all its dimensions and be profitable in the long run

Direct Air Capture for Aviation

Amogh Ravishankara

MSc Complex Systems Engineering & Management
Faculty of Technology, Policy and Management, TU Delft

July 4th, 2023

Context

Why carbon removal is relevant for the aviation industry?

What role can it play in the aviation net zero pathway?

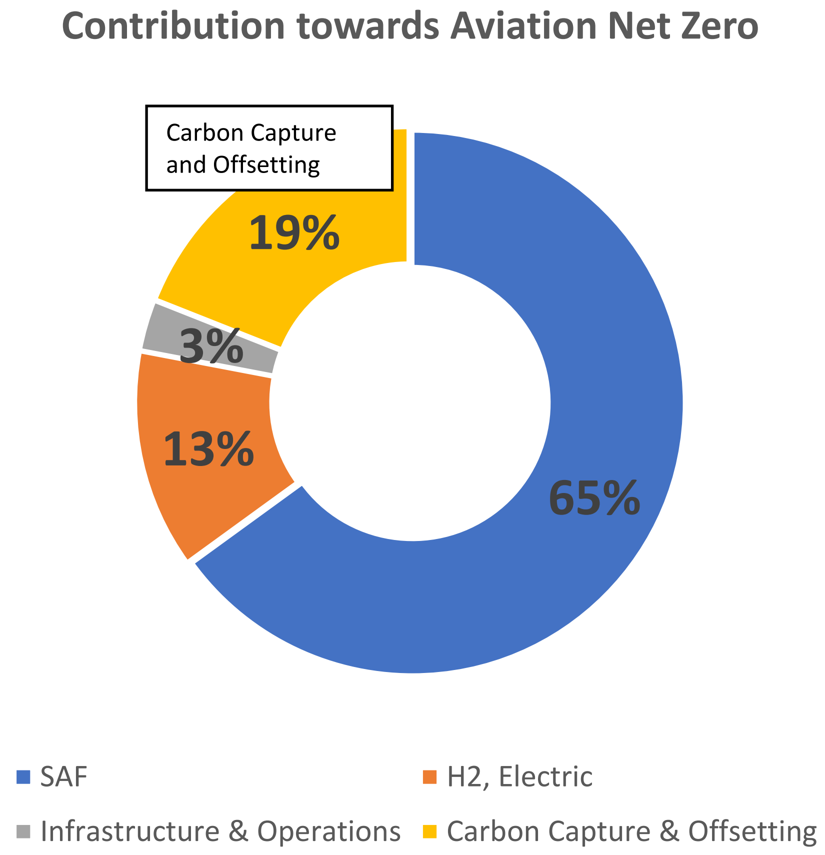
Need for Carbon Removal

- Airlines and industry stakeholders are increasingly committing to carbon neutrality and net-zero emissions targets.

- Complete decarbonization in aviation remains challenging. Carbon removal technologies provide a viable option to offset remaining emissions.

- Aircraft have long operational lifespans, making it difficult to transition quickly to new, low-carbon technologies. Carbon removal can help bridge the gap until cleaner aircraft technologies become widespread.

- Captured carbon dioxide can complement SAF production.



Source: IATA

Problem

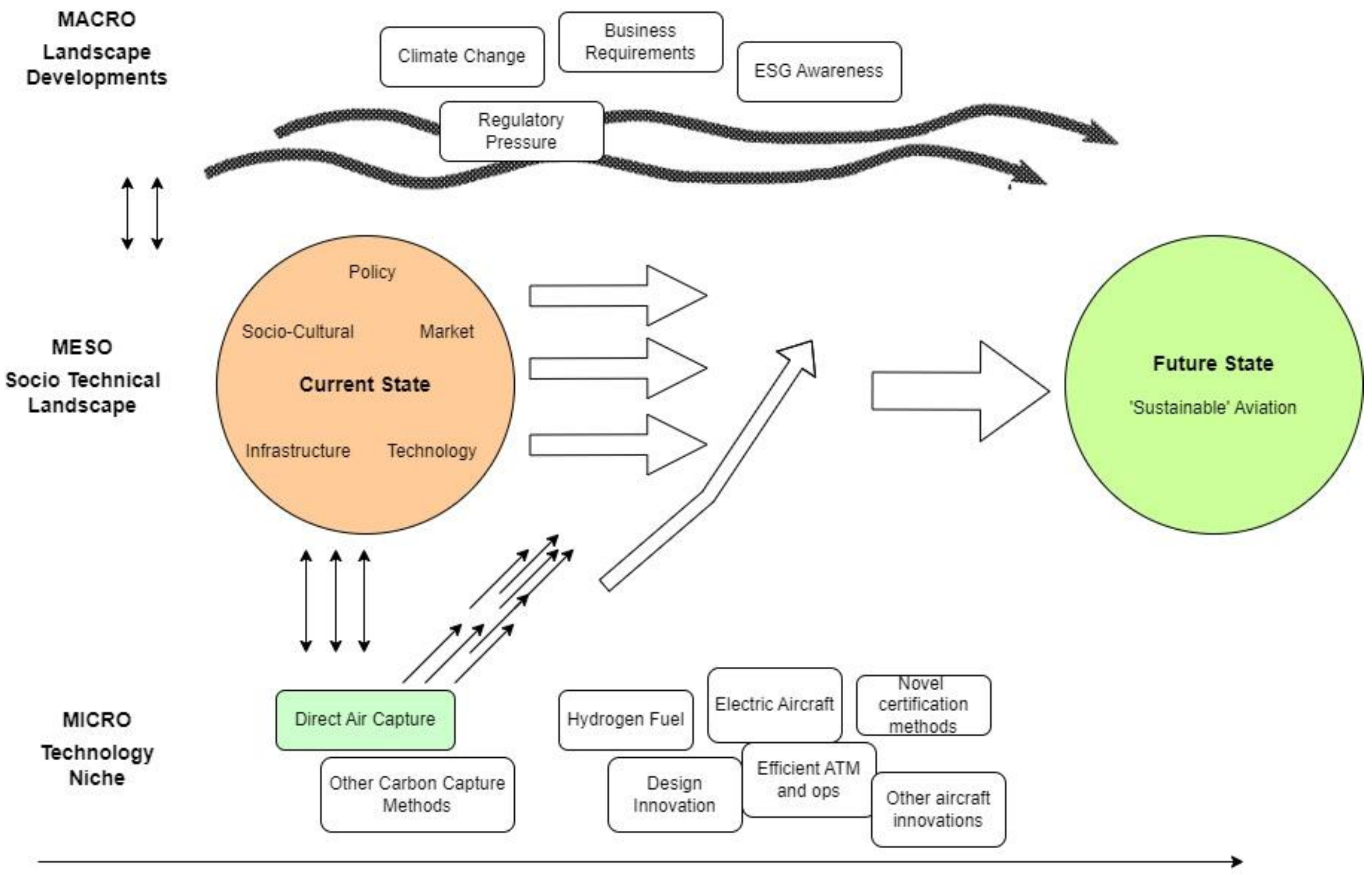
How can DAC be adopted into the aviation net zero pathway?

What are the enablers & barriers?

Method

- Qualitative Study
- Multi-Level Perspective on Sustainability Transitions
- Focus on institutional analysis of carbon removal policies

Multi-Level Perspective



Literature Study → Technology Overview → Actor Analysis → Policy Analysis → Enablers & Barriers → Roadmap

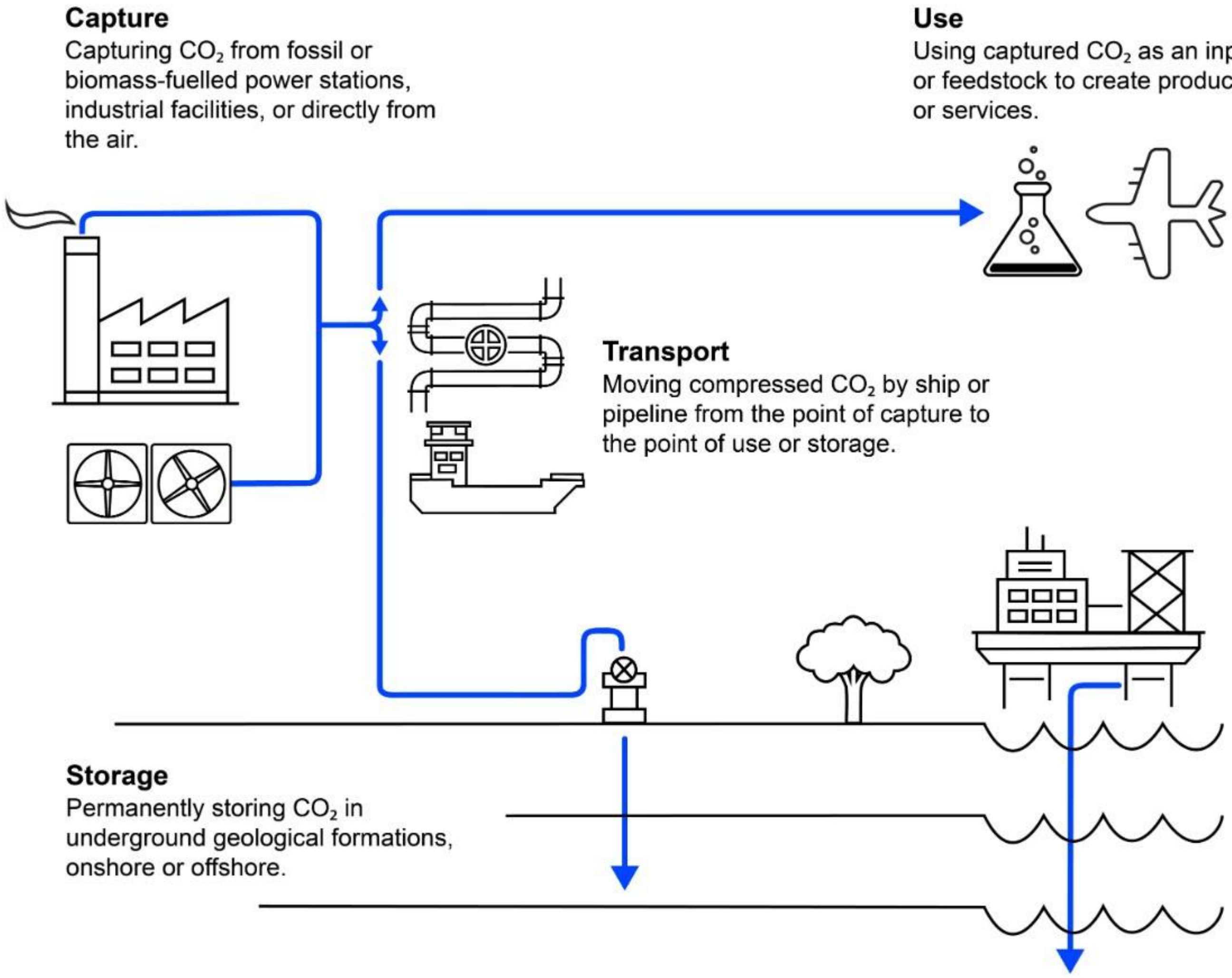
Direct Air Capture

Scale: SAF for all flights originating in Europe by 2050 would require 365 Mt CO_2 / Year to be captured

Energy: 3 EJ to capture ~365 Mt (~8% of annual EU energy consumption)

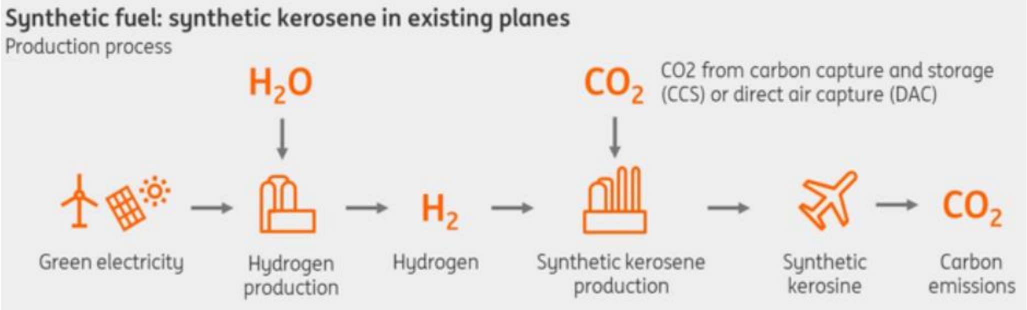
Cost: Existing €500/t CO_2 Expected : < €100/t CO_2

Land Requirement- Low compared to other CDR methods (flexible)

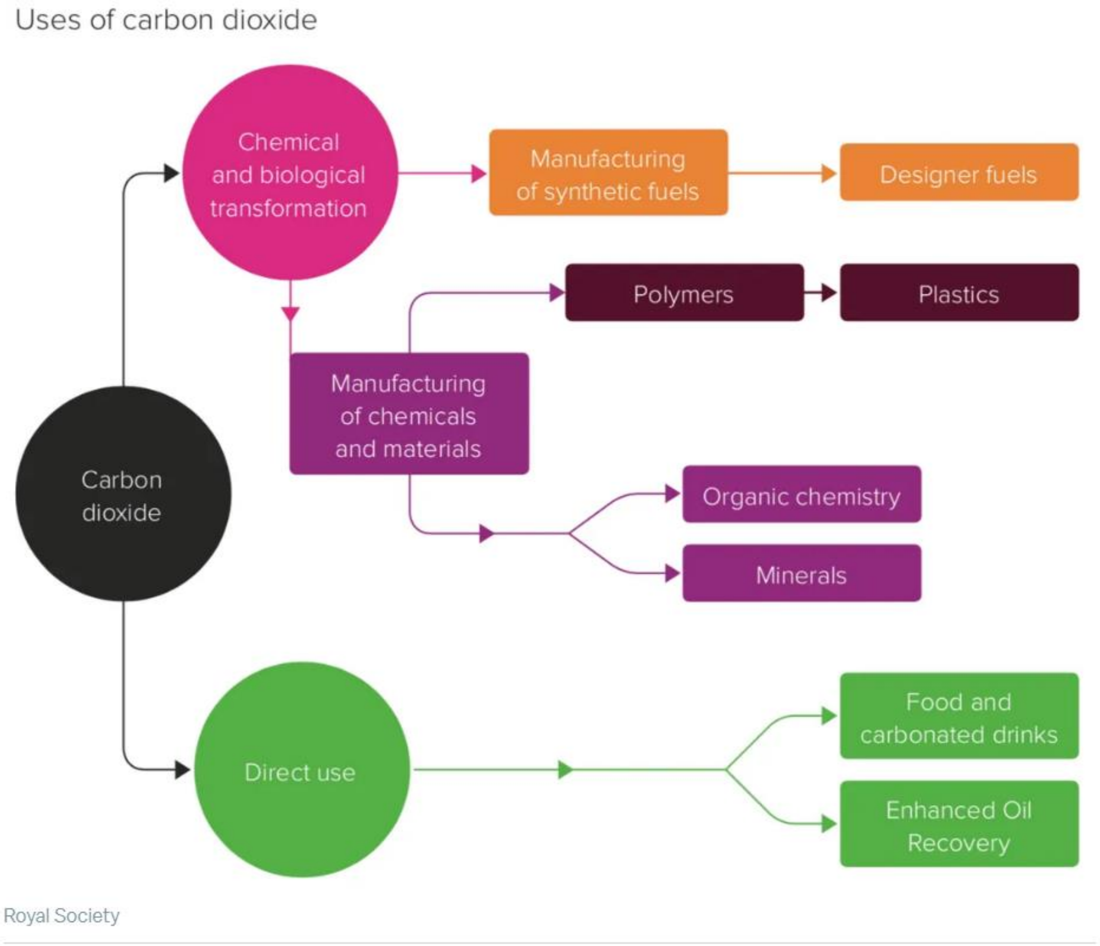


Use Cases

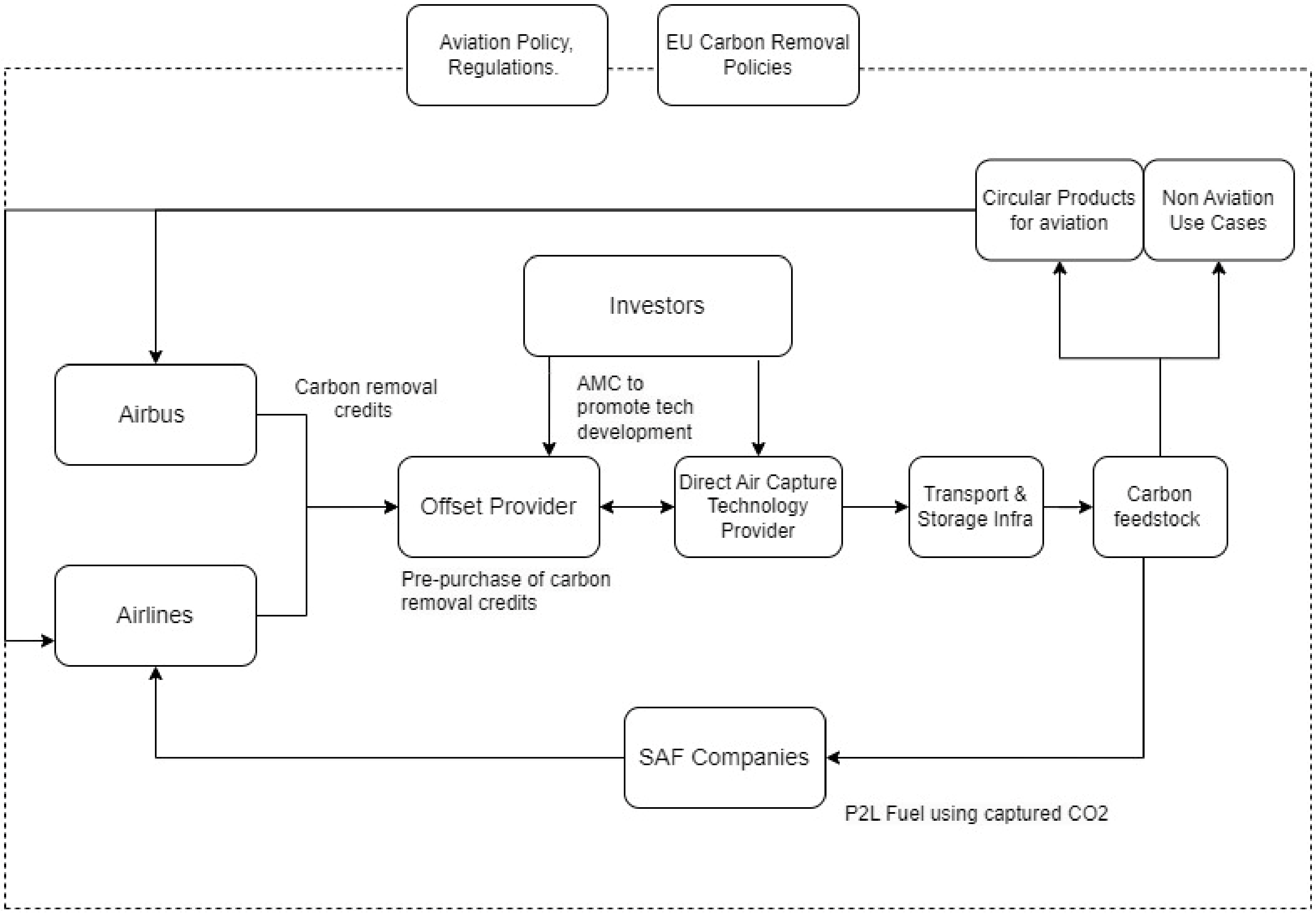
- Synthetic fuel
- Captured Carbon Dioxide and Green Hydrogen



DAC is expensive and does not necessarily offer better efficiency or product characteristics (like electric for example)
As of today, the primary reason to pursue it is for climate change only.



Actors



Aviation Policy, Regulations.
EU Carbon Removal Policies
Circular Products for aviation
Non Aviation Use Cases
Investors
Airbus
Carbon removal credits
AMC to promote tech development
Offset Provider
Direct Air Capture Technology Provider
Transport & Storage Infra
Carbon feedstock
Pre-purchase of carbon removal credits
Airlines
SAF Companies
P2L Fuel using captured CO2

Policy Landscape

EU Innovation Fund

Capital support financed by EU Allowances, includes carbon contracts fro difference (CCfD) (Commercialization problem)

EU Taxonomy for sustainable activities

Classifies CCUS as contribution to climate change mitigation. Companies with Taxonomy-aligned activities will benefit from investors

Directive 2009/31/EC- Geological storage

Net Zero Industry Act

EU objective to reach an annual 50Mt injection capacity in strategic CO2 storage sites in the EU by 2030,

Carbon Border Adjustment Mechanism (CBAM)

To prevent carbon leakage, DAC/ products may recieve lower carbon cost

Trans European Energy Networks Regulation

TEN-E

CO2 transport and infrastructure

European Green Deal- Fit for 55

Reducing net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels.

Proposed certification of carbon removals

Proposal for EU wide voluntary framework to reliably certify high-quality carbon removals. The proposal will boost innovative carbon removal technologies such as DAC (Accounting problem).

Communication on Sustainable Carbon Cycles

Recycling carbon, carbon farming as a green biz model. creating internal market for capture, use and storage of CO2.

RefuelEU Aviation

EU-wide harmonised rules for SAF. Specifically it contains an obligation on airlines to uplift SAF-blended aviation fuel when departing from EU airports. Introduces an obligation on fuel suppliers to include increasing shares of SAF into jet fuel from 2025 to 2050.

Renewable Energy Directive 2018/2001/EU

Overarching European renewable energy target of 32% Revised in 2023, for a binding target for 2030 of at least 42.5%, but aiming for 45%

Promotes SAF from green sources. Does not specifically mention DAC

Directive 2008/101/EC

EU ETS

Include aviation activities in the scheme for greenhouse gas emission allowance trading

Regulation (EU) 2017/2392

Continue limiitation of ETS aviation to EEA region.

ACI Airports Carbon Accredition

Directive 2008/50/EC

Abient Air Quality/ Cleaner Air

Voluntary framework for emission reduction

Preliminary Insights

- Setting a competitive carbon price so that carbon removal has a better market value
- Certification of carbon removals
- Internal system to channel offsets towards aviation sustainability innovation projects only

Next Steps

- Develop a roadmap for incorporating DAC in aviation
- Recommendations on collaboration, influencing regulatory frameworks, stakeholder engagement and circular material strategies

Thank you

System Dynamics Modelling of the SOFC Supply Chains

MSc. Project

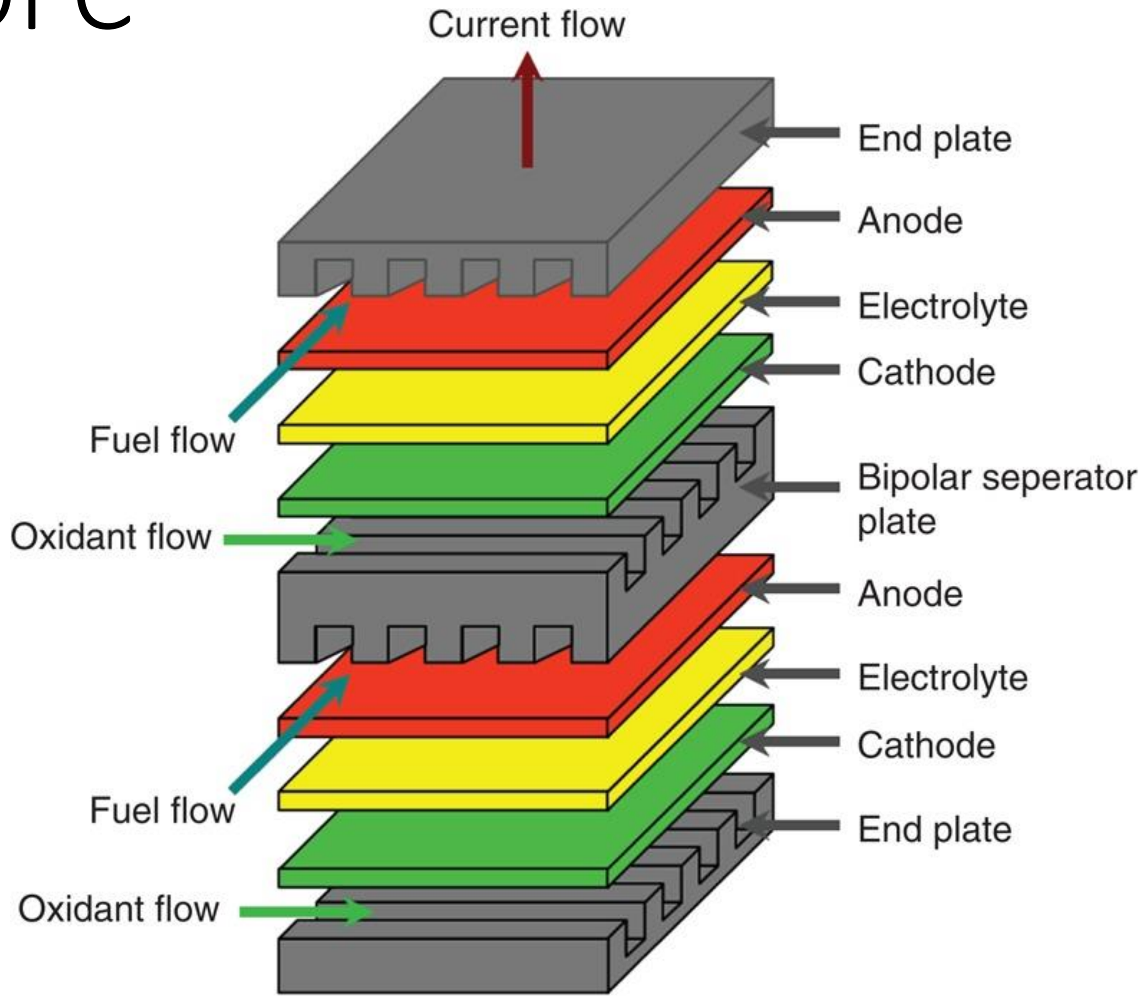
Critical Raw Materials for Future Propulsion Systems

Contents

Critical Raw Material in Solid Oxide Fuel Cells

Critical Raw Material in SOFC

- Critical Raw Material
  - High economic and strategic importance
  - High supply risk
- Solid Oxide Fuel Cells
  - Electrochemical conversion and storage technology
    - High Eficiency
    - High scalability
    - Lower costs
    - Lower emmissions
    - High fuel flexibility
- Critcal Raw Material in Solid Oxide Fuel Cells
  - Nichel (Ni) and YSZ from the anode composite
  - Lanthanum and Cobalt from the LSC cathode



Singhal (2013)

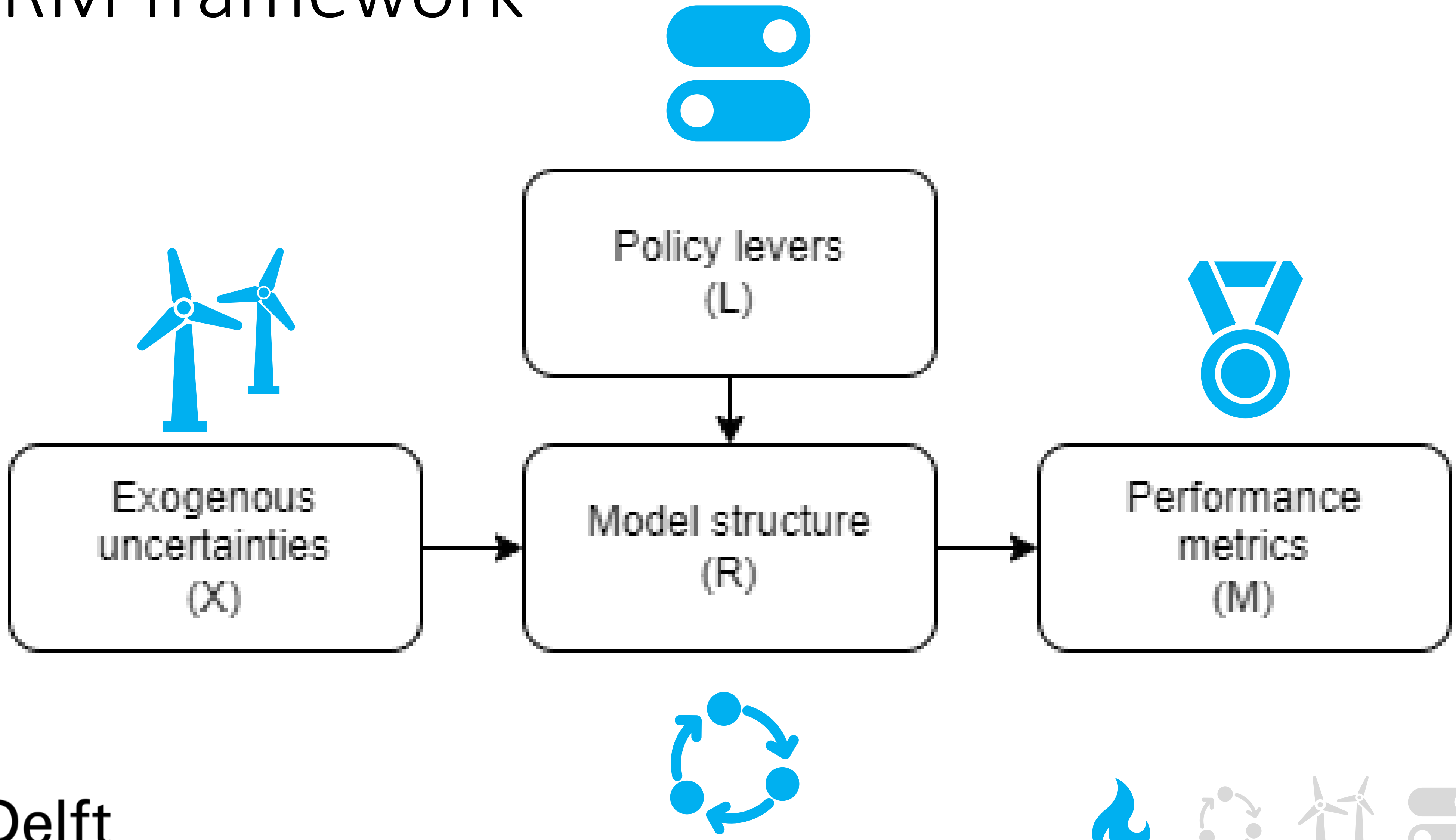
TUDelft

Model structure

SD metal models in Delft

Author	Year	Status	Metal	Methodological aspect
Willem	2011	MSc. Thesis + papers	Copper	Bottom-up vs top-down demand?
	2013	Conference paper	Tantalum	?
Erika	2020	MSc. Thesis, unpublished	Cobalt	Opportunity-cost vs fixed-stock
Jessie	2021	MSc. Thesis + conference paper + potential paper	Nickel	Disaggregation of supply (individual mines)
	2022	NWO project, unpublished	Tin	Disaggregation of supply & demand (trade), regional resilience
	?	EU project, potential paper	REE	
Lieke	2022	MSc. Thesis, unpublished	Lithium	Circularity extension
Jonas	2023	MSc. Thesis, in progress	REE	Focus on substitution
Arnoud?	2023	MSc. Thesis, exploration	Palladium?	?
Sebastiaan	2023	MSc. Thesis, exploration	Multiple	Multiple metals connected to a product?

XLRM framework



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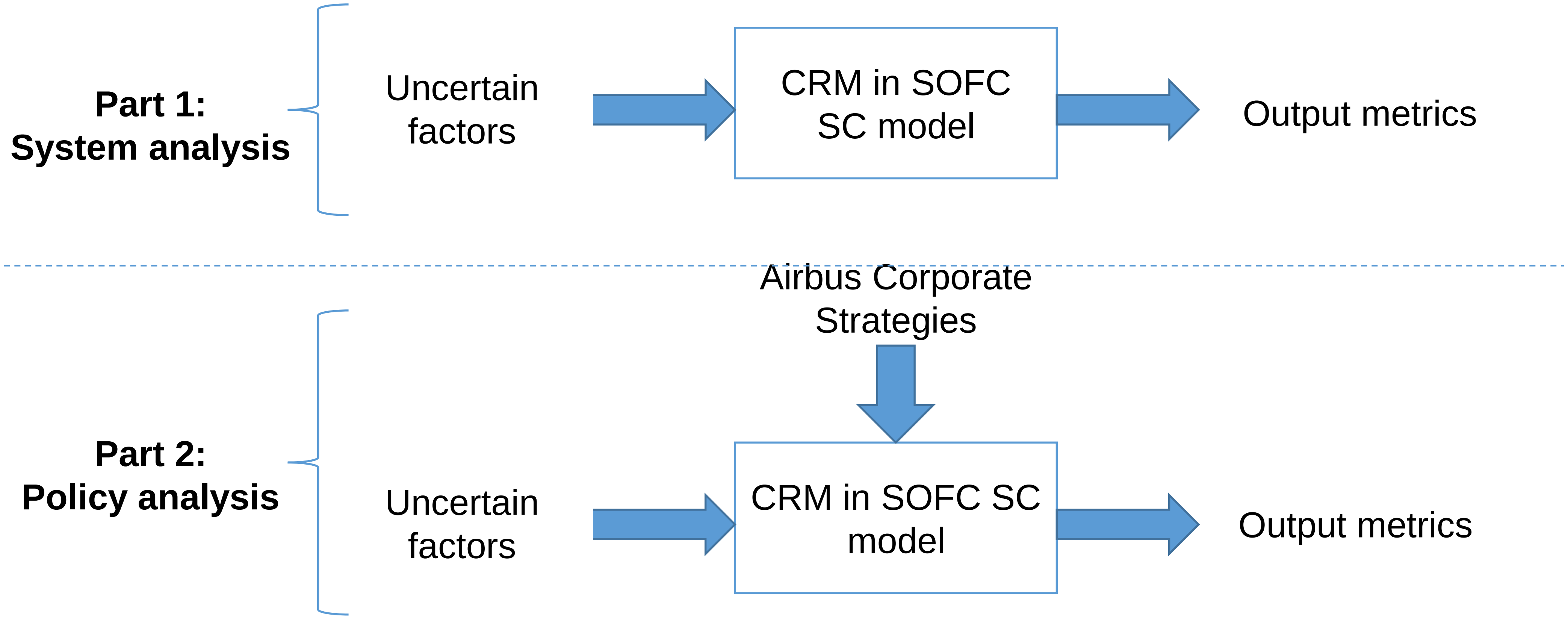
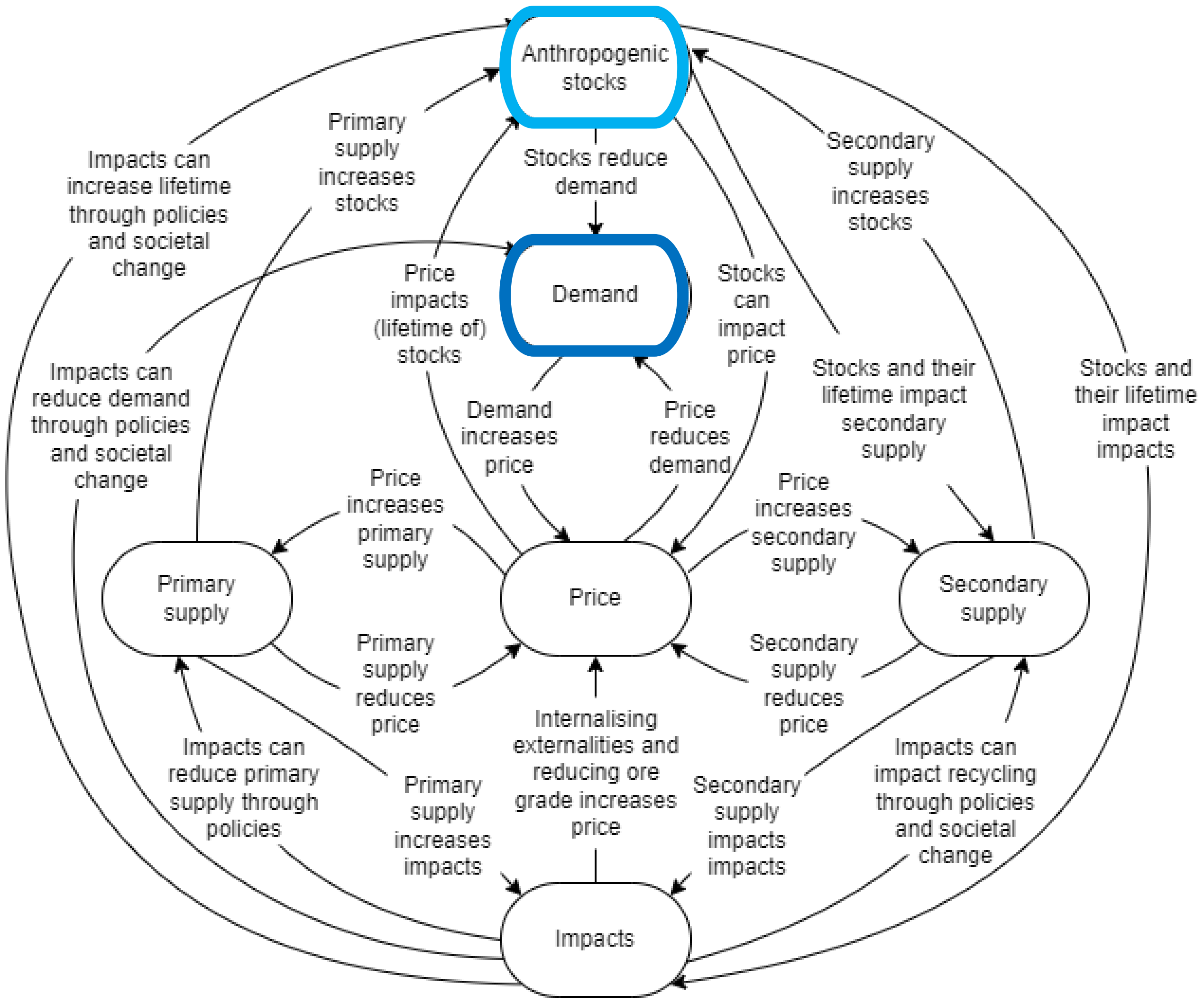
Experimental set-up



Van Essen (2022)

Submodels

- Demand submodel:
  - Mechanisms: intrinsic demand, (postponed demand), substitution, lifetime change effects
  - Other considerations : top down/bottom up, regional distinction, sectoral distinction
- Anthropogenic stocks submodel:
  - Mechanisms: hibernating stocks, lifetime change effects, **stockpiling**, (new scrap recycling), (trade)
  - Other considerations : regional distinction, sectoral distinction, source distinction



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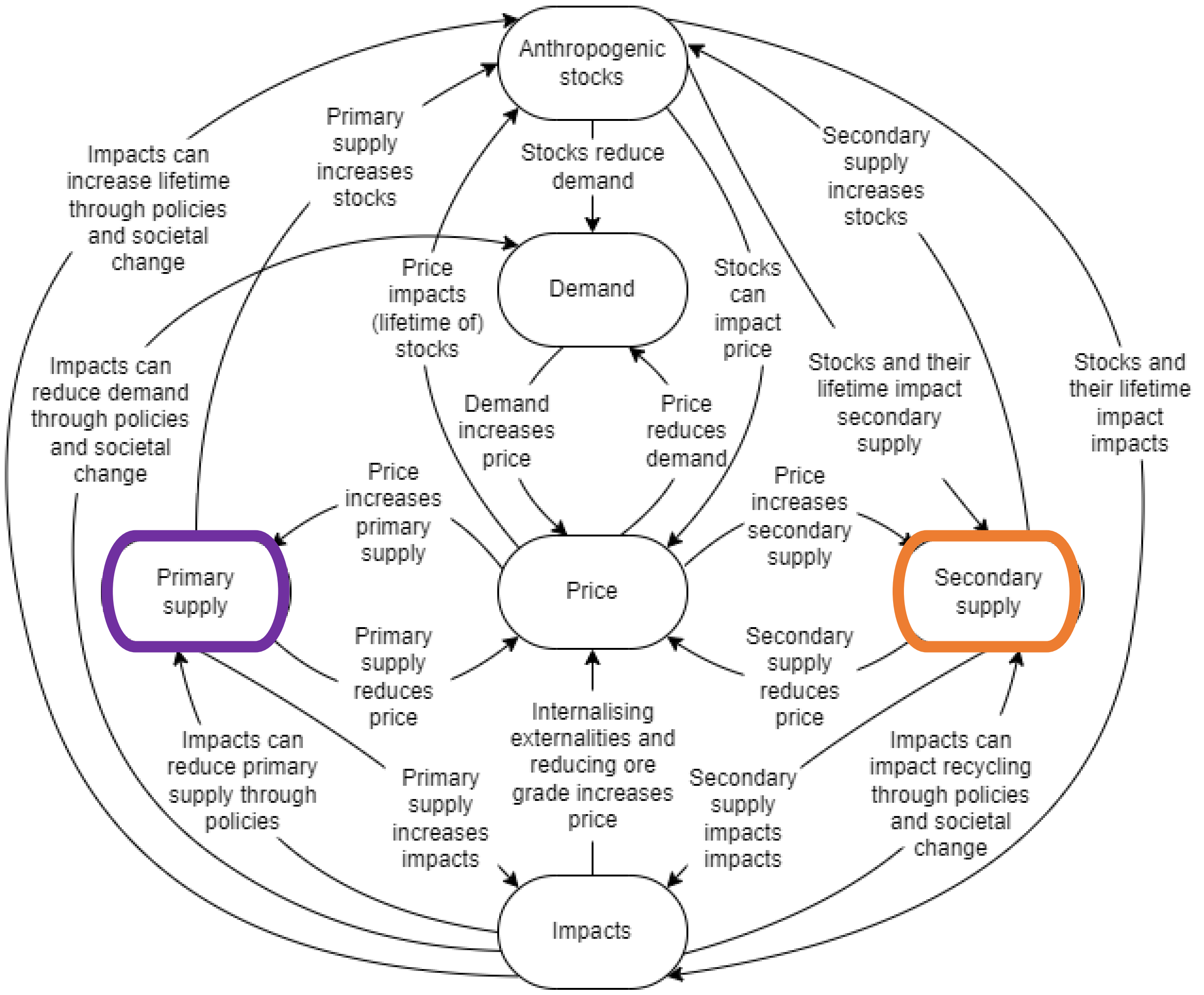
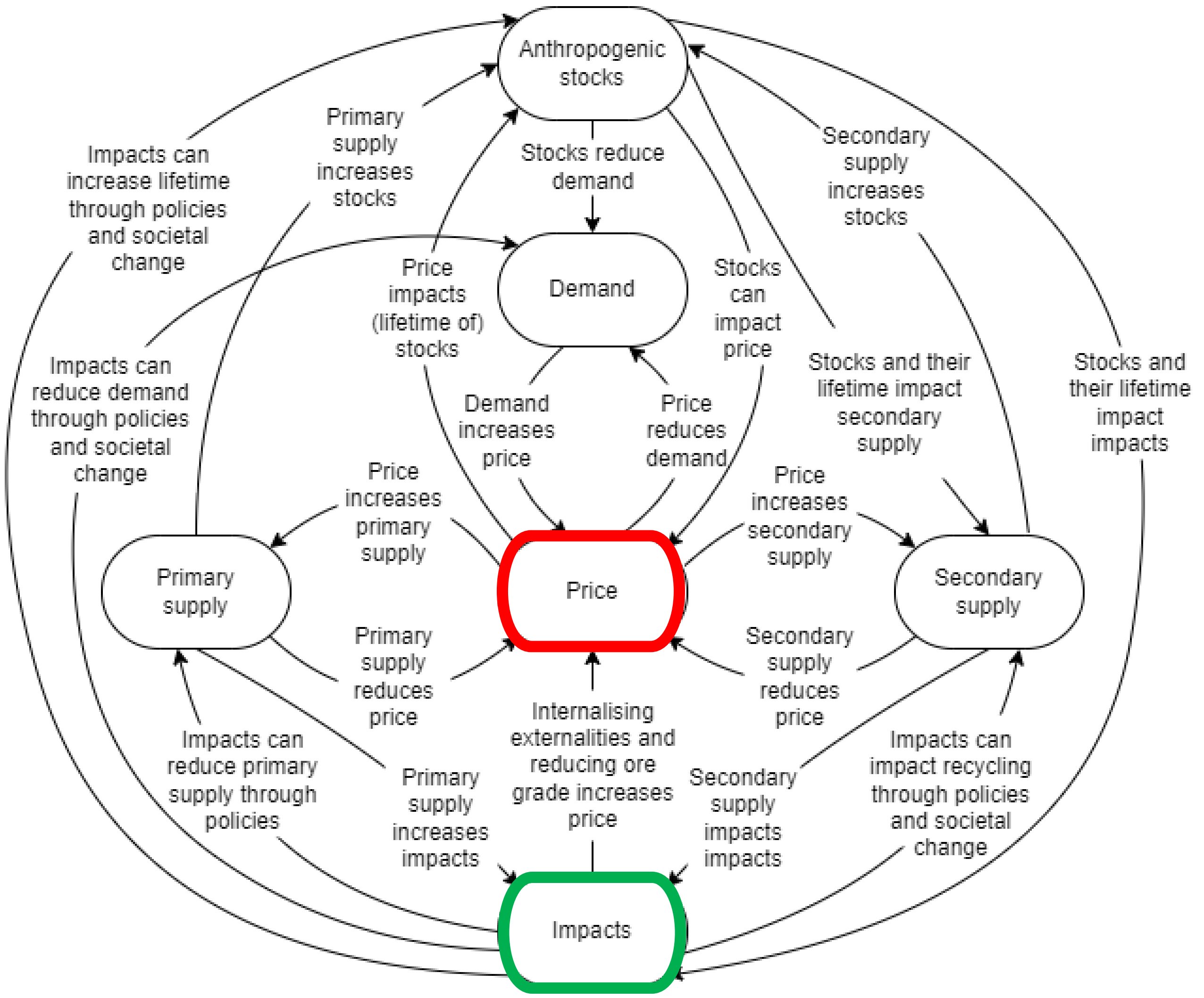
Submodels

- Primary supply submodel:
    - Mechanisms: mothballing, capacity increase, exploration, reserve declaration
    - Other considerations : opportunity cost/fixed stock, **host product/by-product(s),** composition, regional distinction, source distinction
- Secondary supply submodel:
    - Mechanisms: (new scrap recycling), EoL collection, EoL processing, capacity increase
    - Other considerations: alloyed/non alloyed, sectoral distinction, regional distinction



Submodels

- Price/economics submodel
  - Mechanisms: costs, price, profit, investment attractiveness, internalised externalities, by-products, (ore grade), energy price
  - Other considerations: by-product allocation, regional distinction, sectoral distinction, profit type
- Impacts submodel
  - Mechanisms: (ore grade), energy use, greenhouse gas emissions, other environmental impacts, social impacts
  - Other considerations: by-product allocation, regional distinction, sectoral distinction



SSD and focus

Willem, copper

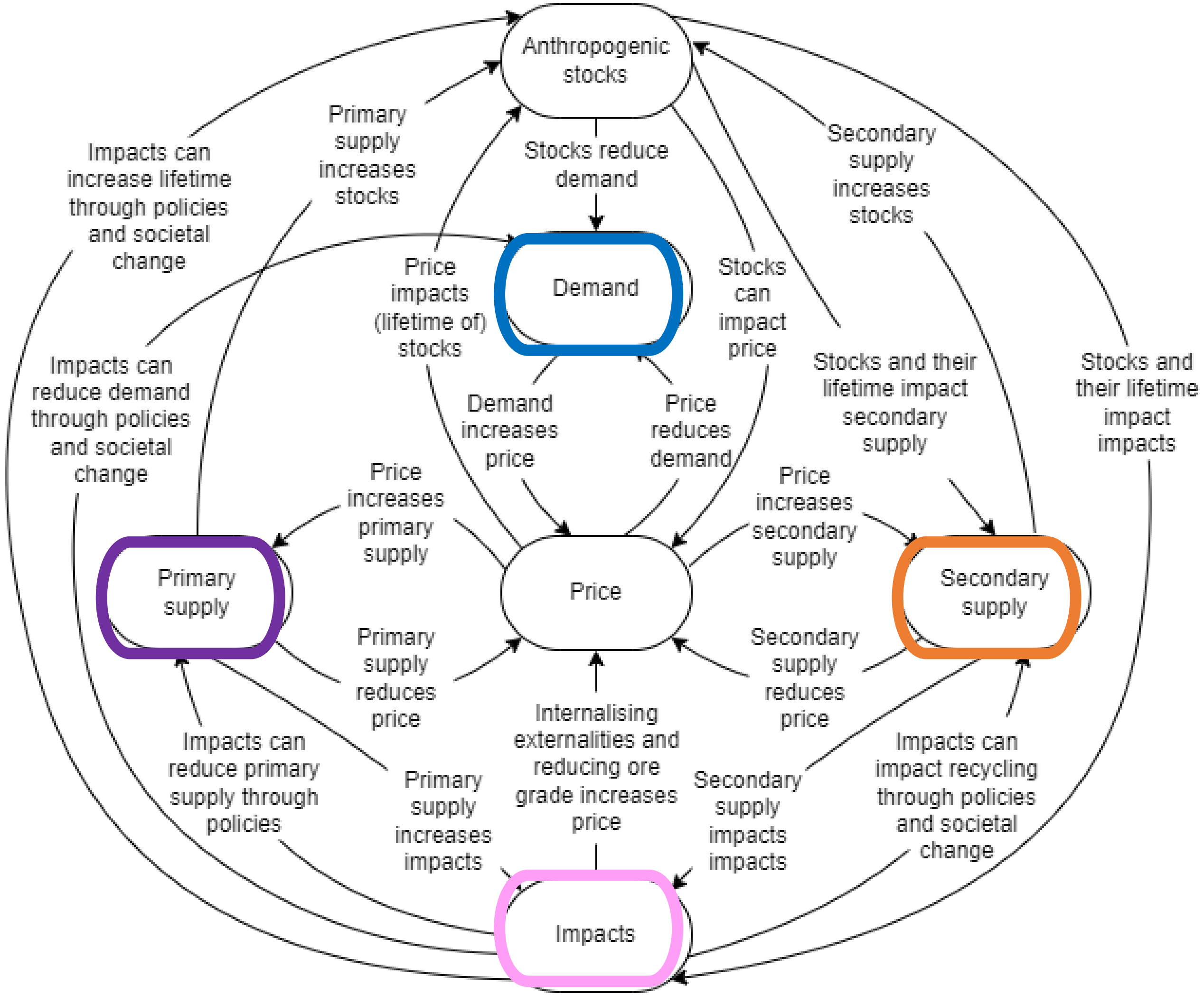
Erika, cobalt

Jonas, REE

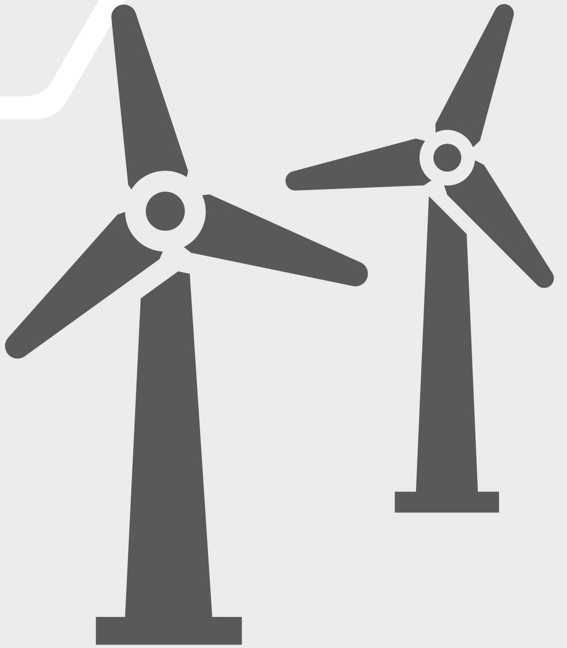
Jessie, Nickel

Bas, PS

Lieke, Lithium

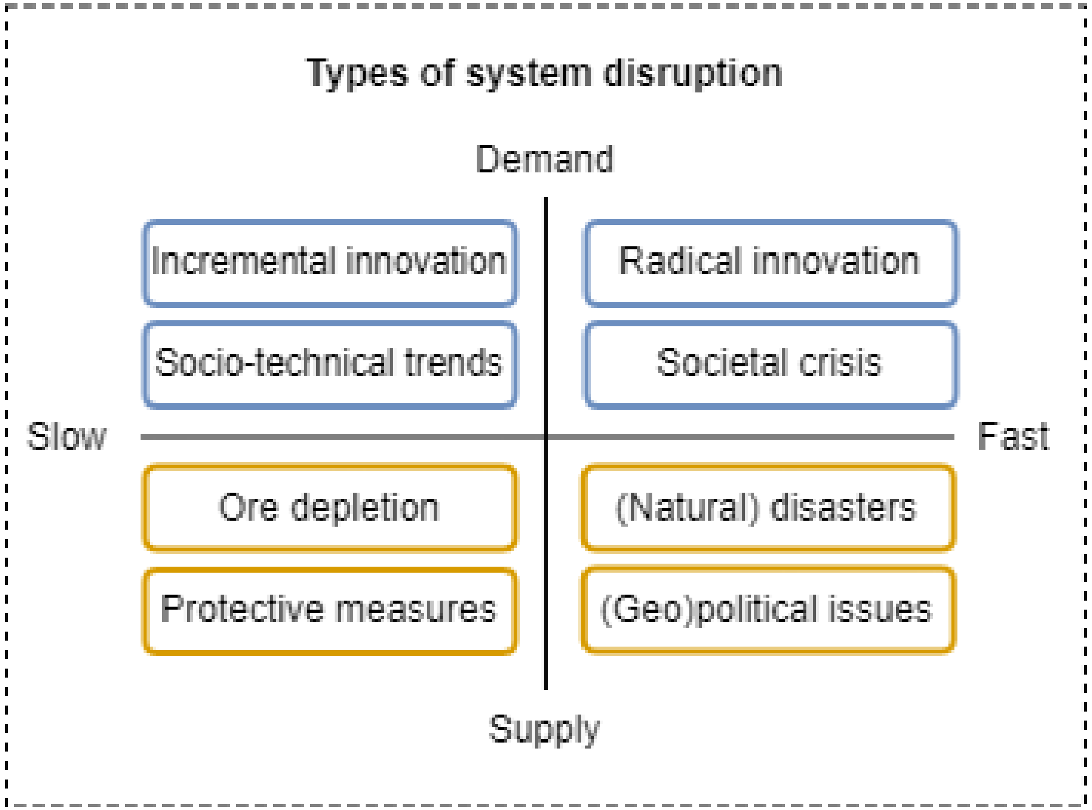


Exogenous uncertainties



Exogenous uncertainties

- The research questions allows us to think about:
  - Structural uncertainties
  - Parametric uncertainties
  - Potentiele (disruption) scenarios, eg:
    - SSPs or other energy transition scenarios
    - Other disruptions (figure)



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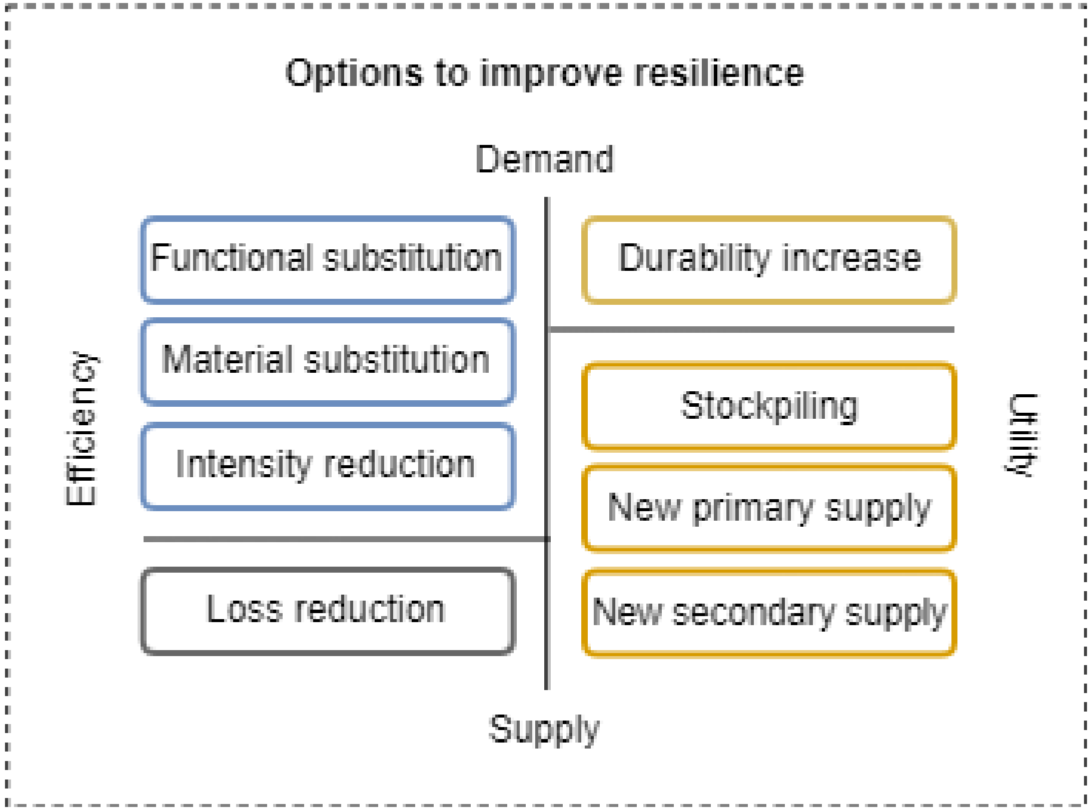
Policy levers

Policy levers

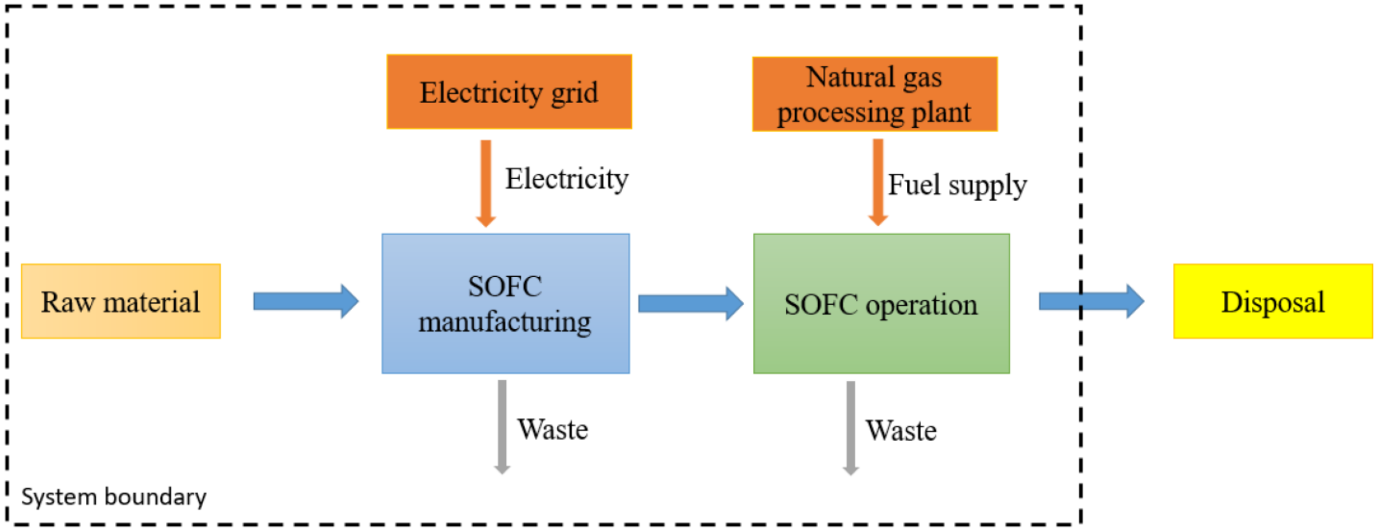
- The research questions allows us to think about :
  - Option that tackle a specific problem (like demand-side deficiencies)
  - Testing concrete policy actions



Performance metrics

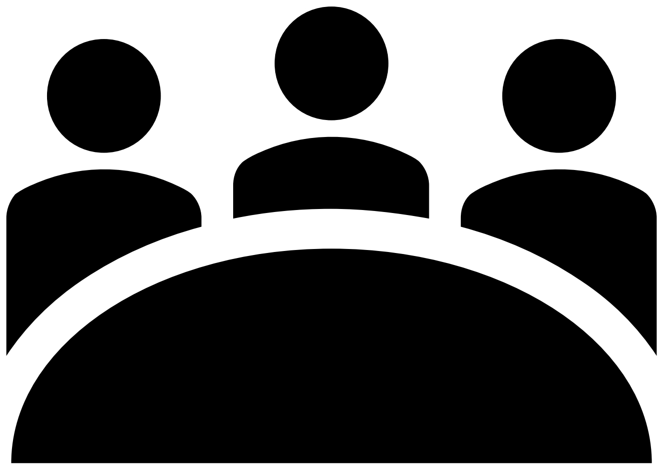
Performance metrics

- The research questions allows us to think about:
  - The performance of the policy we want to test
  - Specific metrics we want to use
    - Greenhouse gas emissions
    - Air Pollutant emissions
    - Water use
    - Extractive waste



Al-Khori et al. (2021)

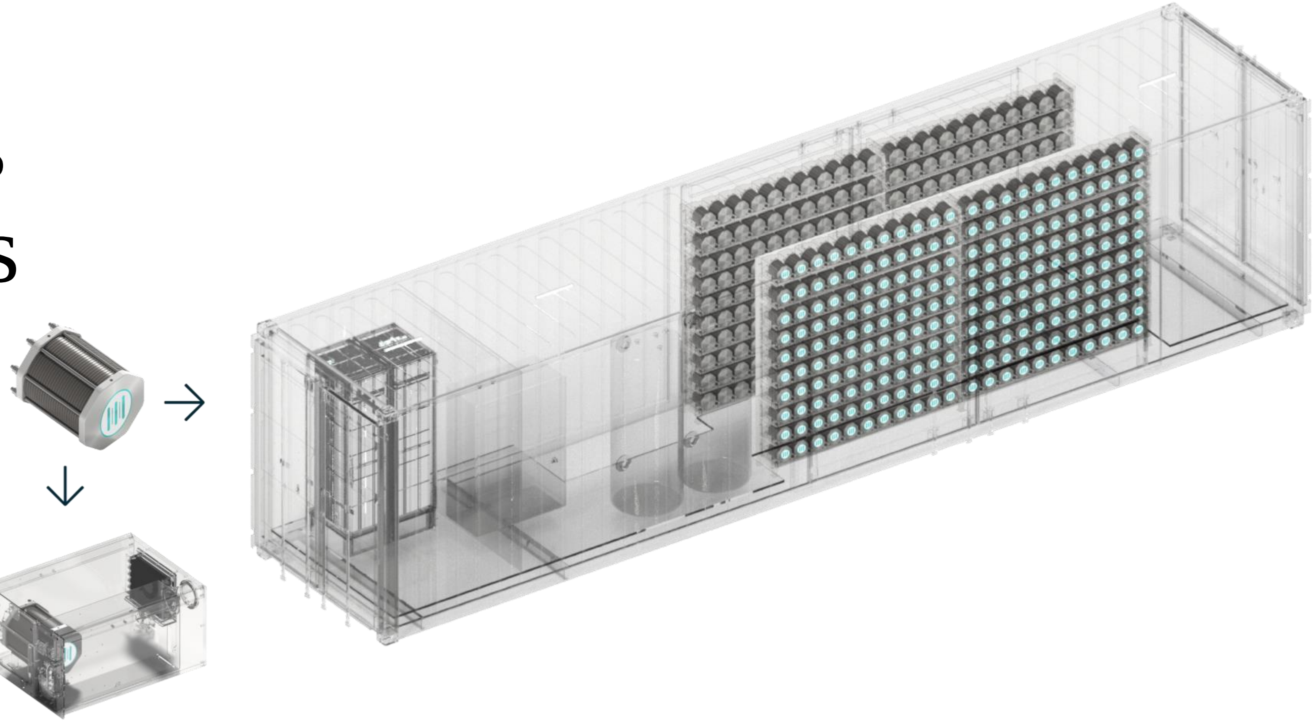
What now?



What now?

- Data Collecting
  - CRM make-up and polluting potentials
- Conceptual model buidling
  - Ethnographic mind map
  - Academic
  - Airbus

Evaluation and Performance Analysis of AEM Electrolysis and Improvement possibilities in terms of sustainability and efficiency



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Sustainable Energy Systems

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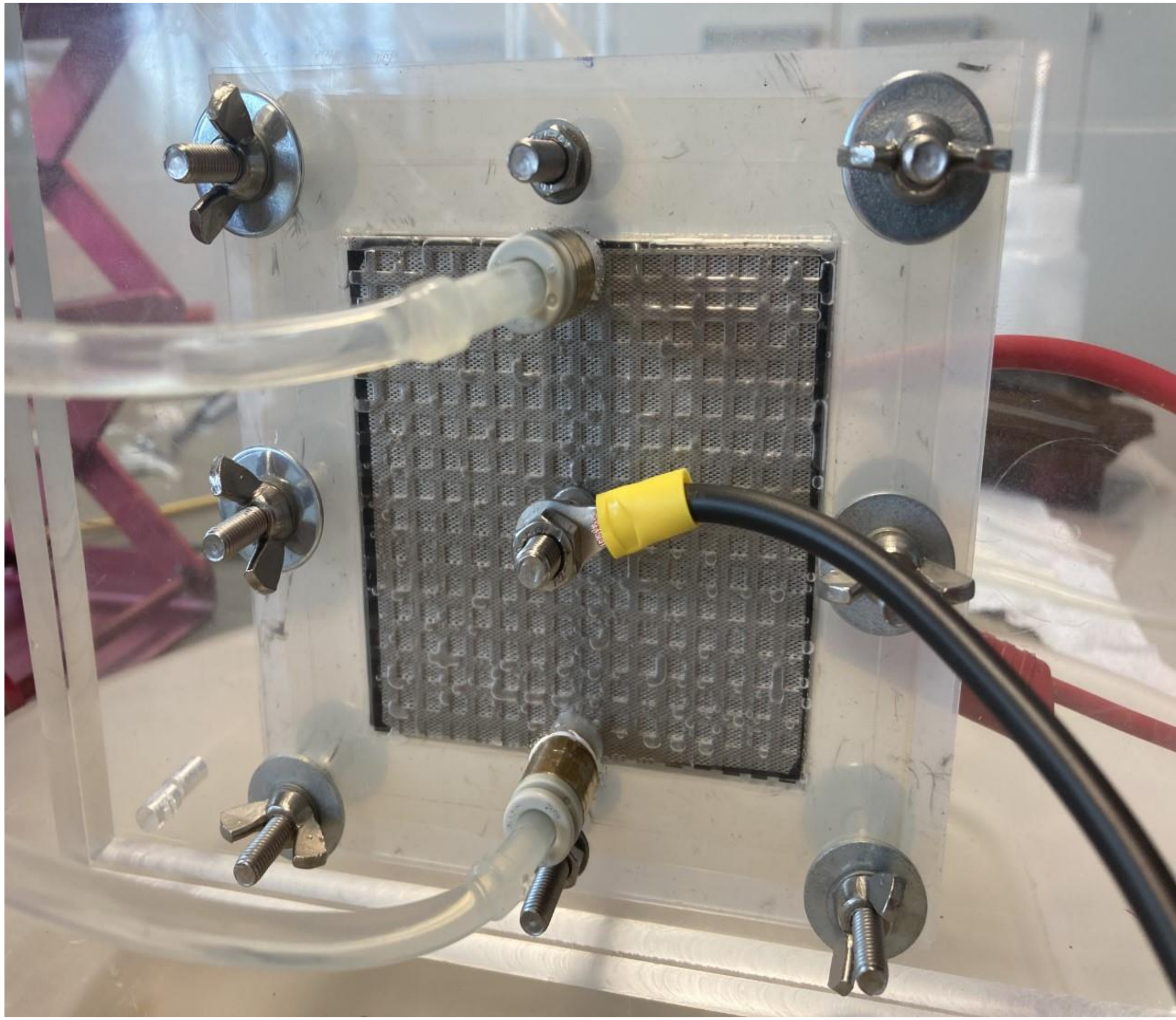


Context

Why is the aerospace industry looking into Hydrogen?

Catalysts for Transformations

By leveraging hydrogen as an alternative energy source, aviation can significantly reduce its carbon emissions and mitigate environmental impacts. This shift represents a crucial step towards a greener future for the aviation industry.

Problem

What is wrong with current method of production?

Steam Methane Reforming (SMR)

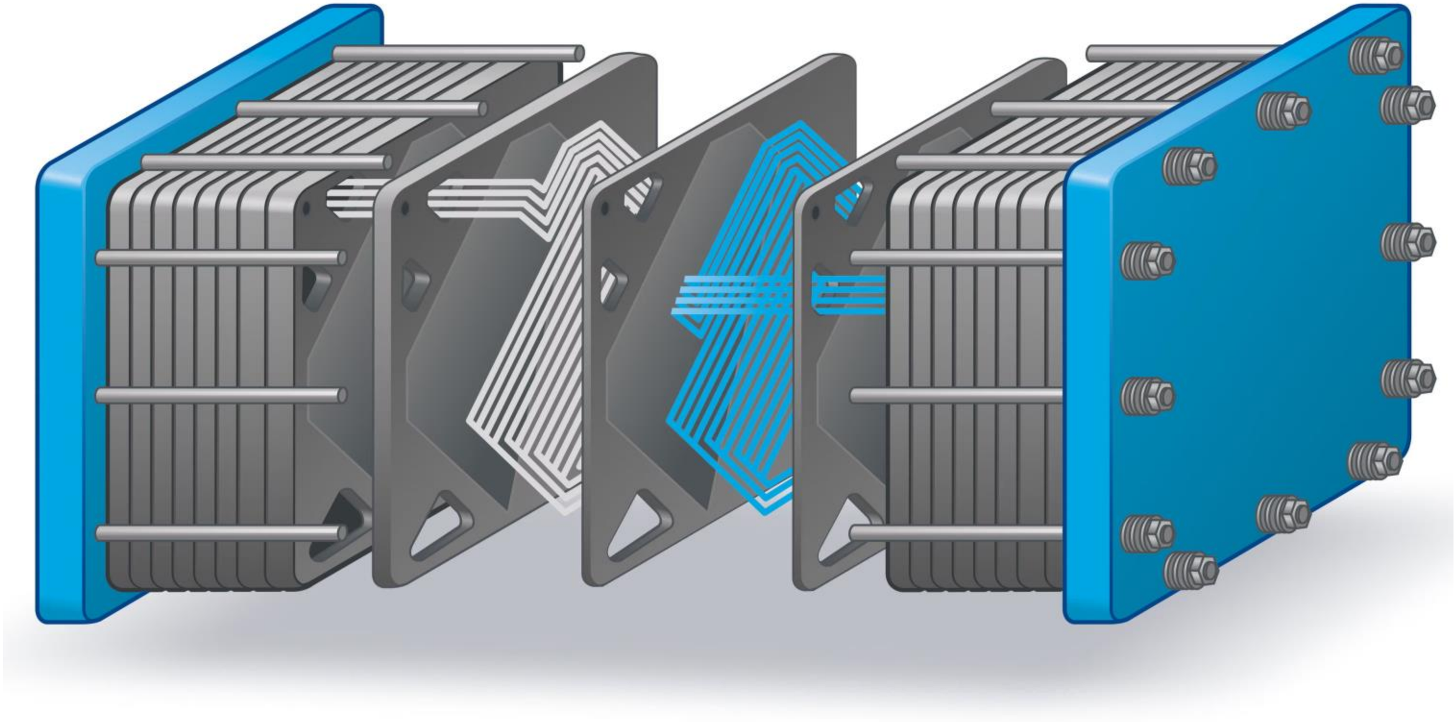
SMR relies heavily on fossil fuels, particularly natural gas, which contributes to greenhouse gas emissions and climate change. The process also produces significant amounts of carbon dioxide as a byproduct.

Problem

Why are we looking for alternatives of Critical Raw Materials in Hydrogen?

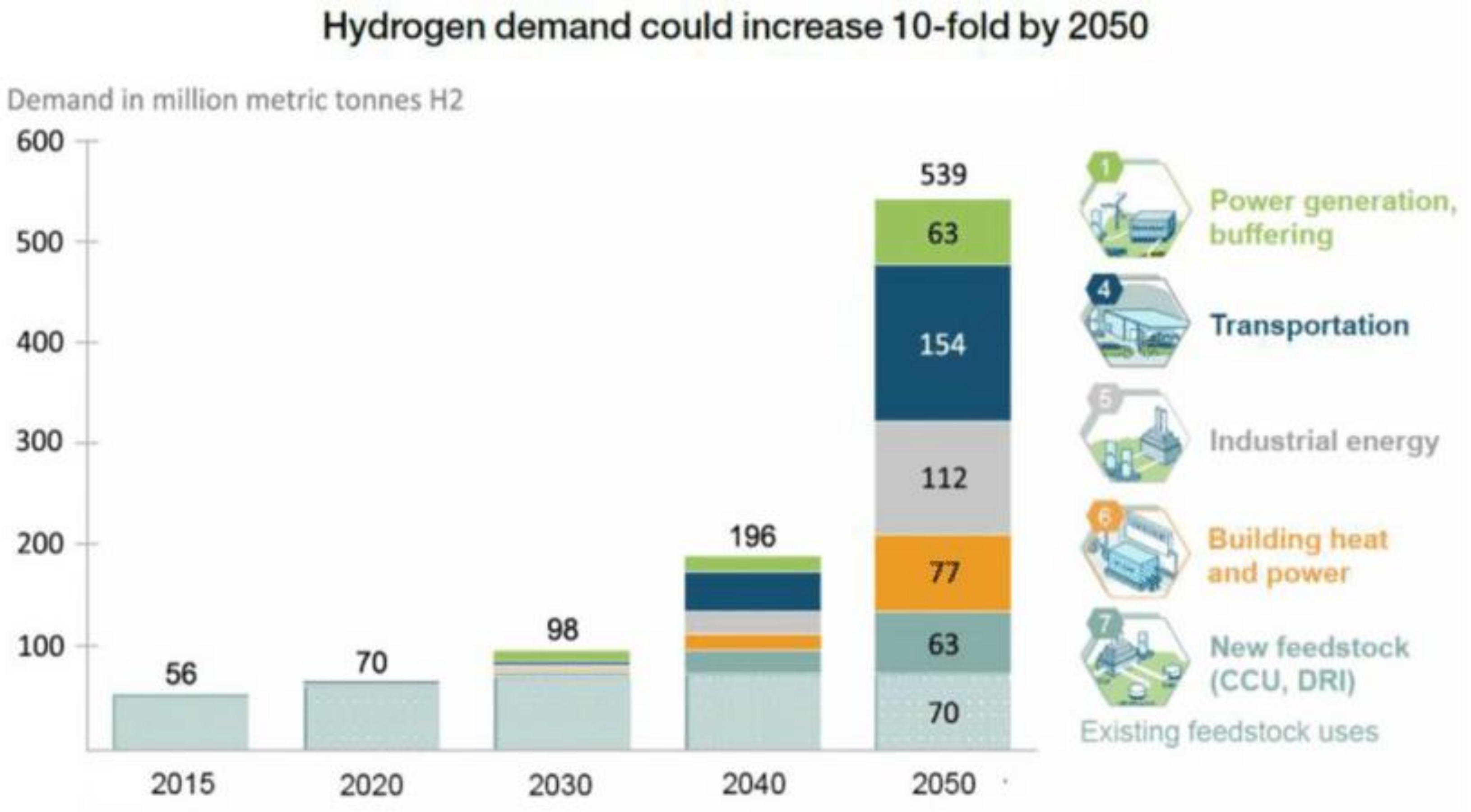
Electrolyzers

Electrolyzers generally use Platinum Group Elements. Which have less availability and needs to be imported from outside of the EU.



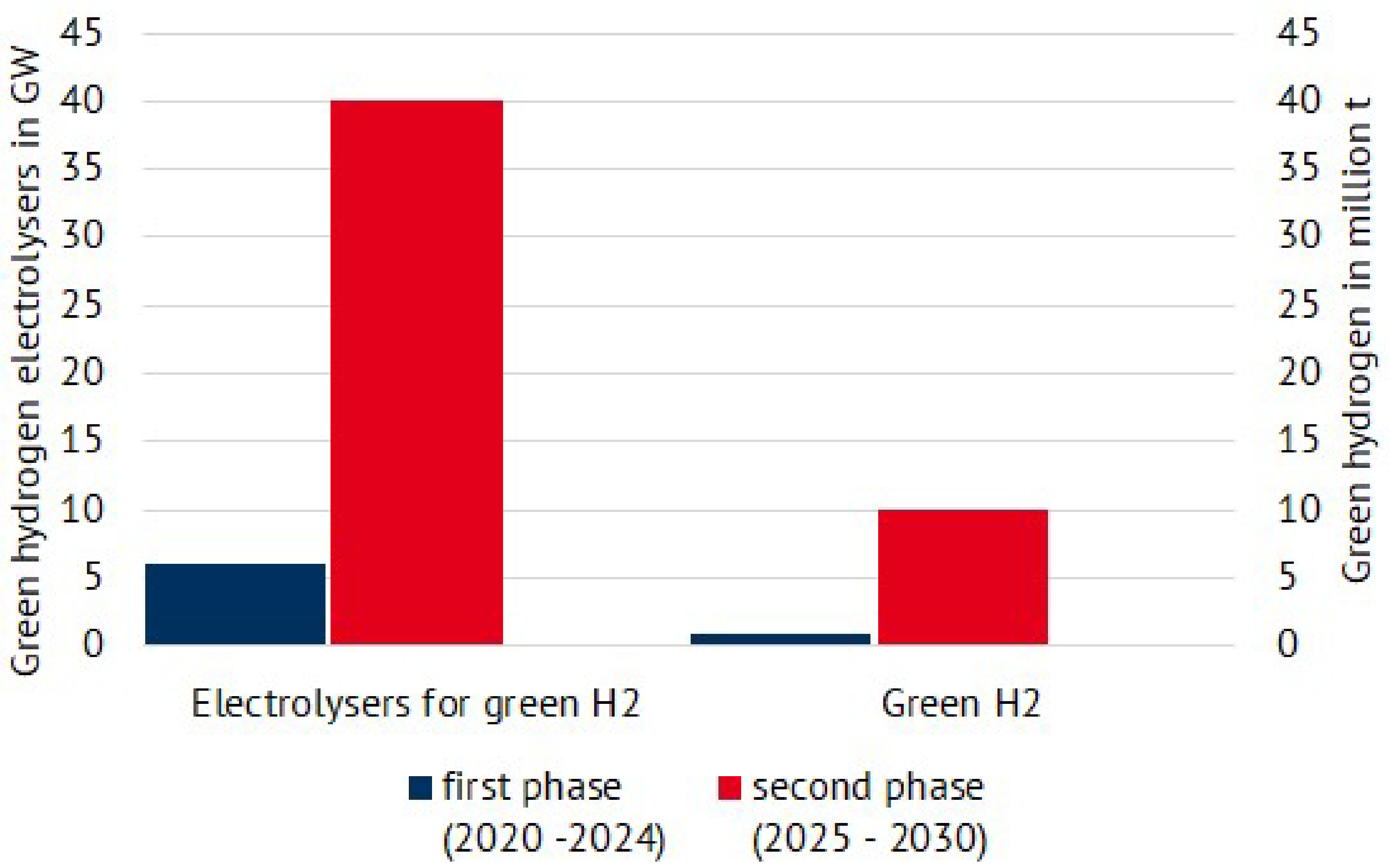
Demand for Hydrogen

The European Union foresees a significant surge in the demand for hydrogen as a pivotal component of its decarbonization strategy by the year 2050.



Demand for Electrolyzers

Europe anticipates a significant rise in electrolyzer demand, recognizing their crucial role in achieving a sustainable, decarbonized energy system by 2050.

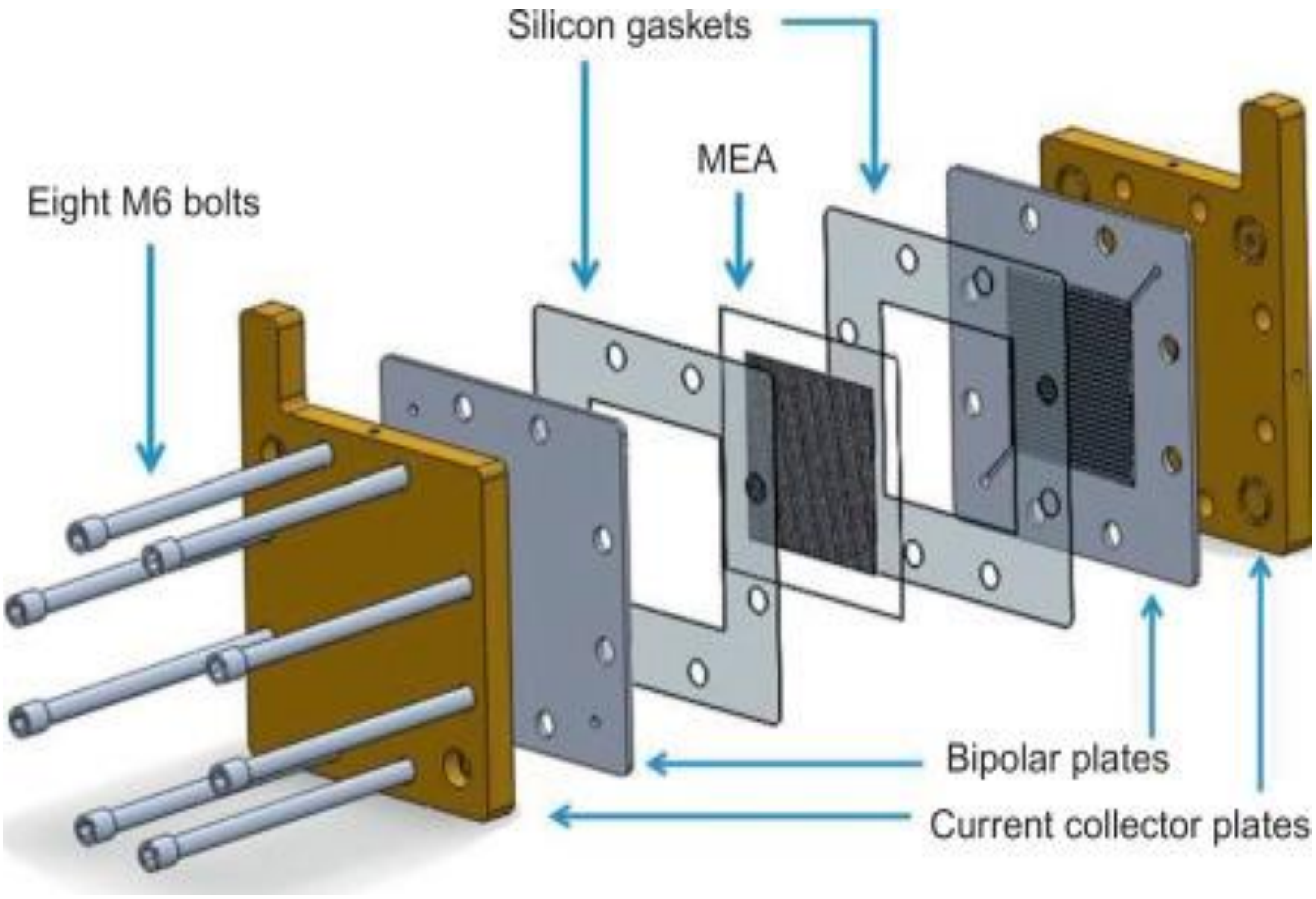


Problem

What can be change in the Electrolyzers?

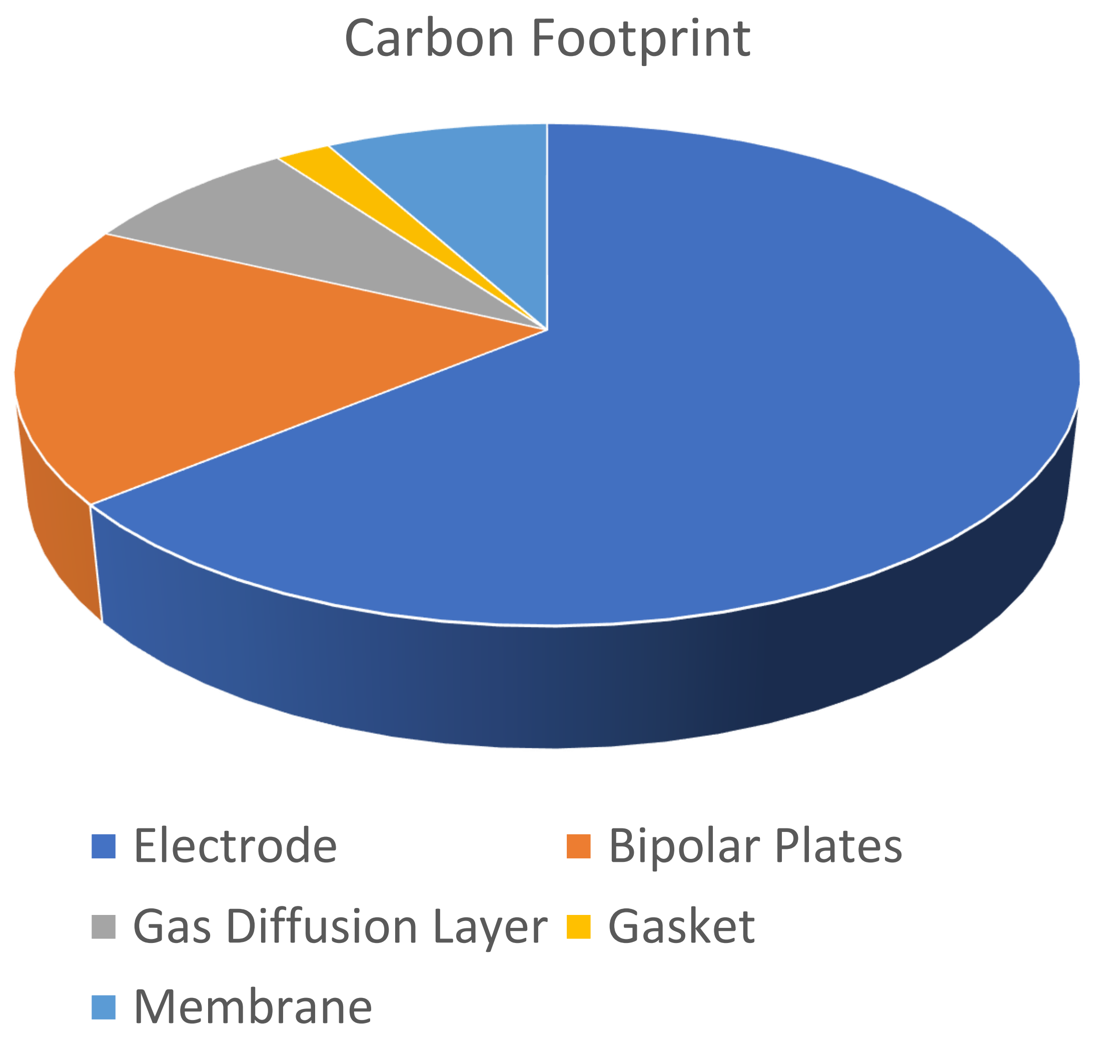
What to change?

- Membrane Electrode Assembly(MEA)
- Bipolar Plates



Why?

Electrode	**PGM, Ni, Ti etc.**
Bipolar Plate	**Ti**
Gas Diffusion Layer	**Stainless Steel**
Gasket	**Silicon**
Membrane	**Polyethylene, PFSA Polymer**

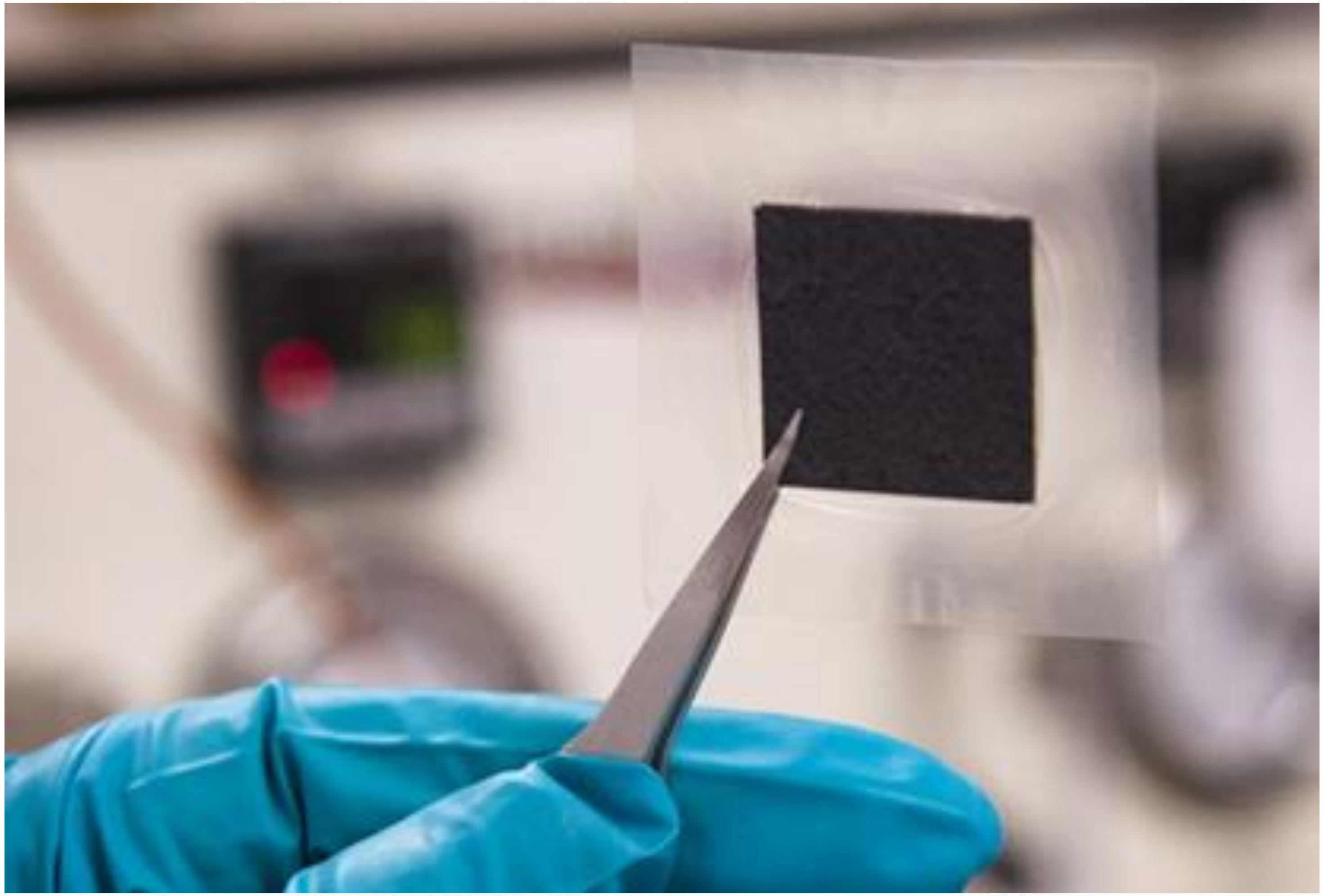


Problem

What can we change in Anion Exchange Electrolyzers?

Change in AEM

- Electrodes can be changed to Fe, Zn, CO with coating of Ni.

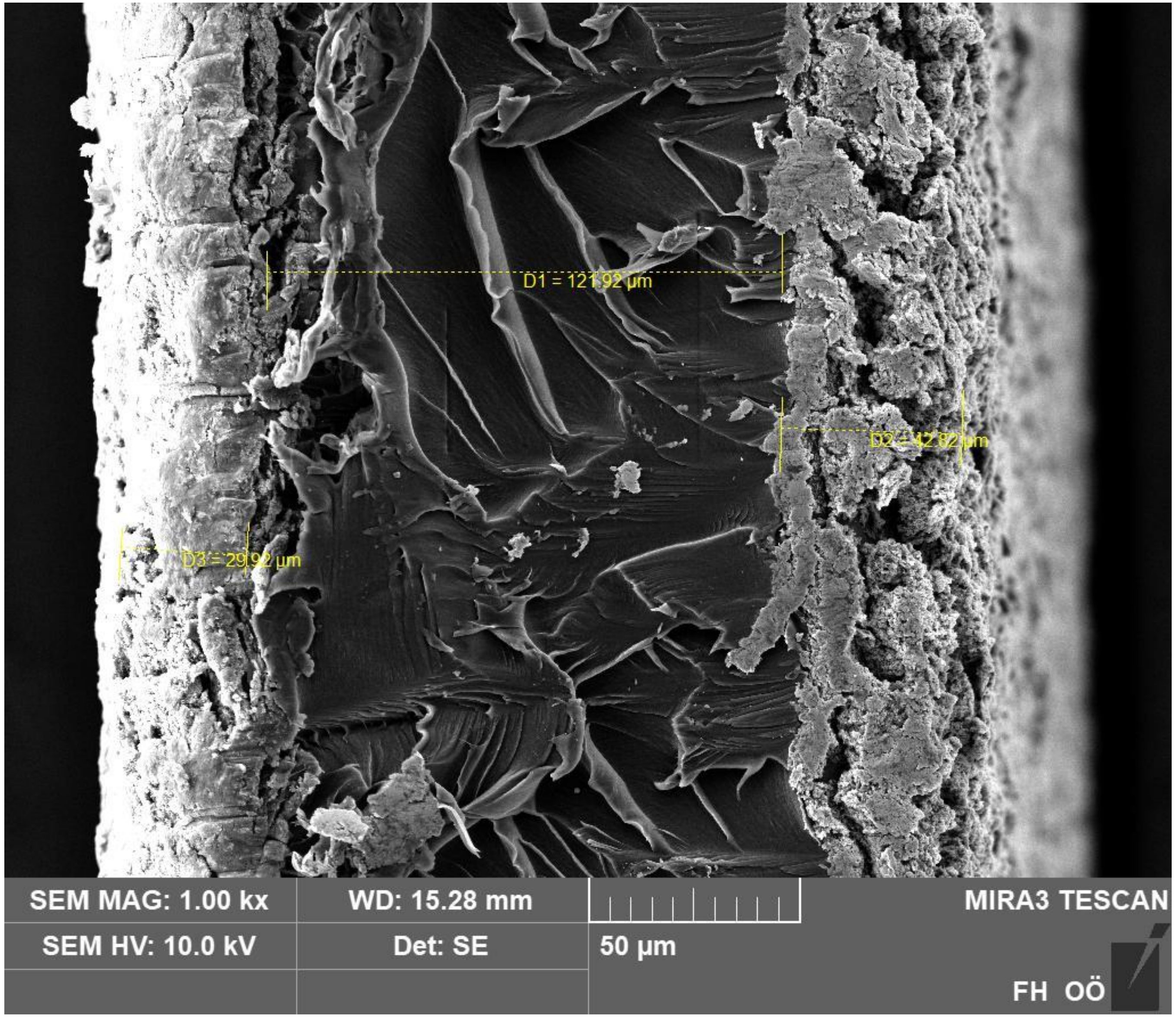


Problem

What are the problems associated with it?

Problems

- Keeping the porosity while coating.
- Not common coating methods.
- Sensitivity of Membrane with heat.

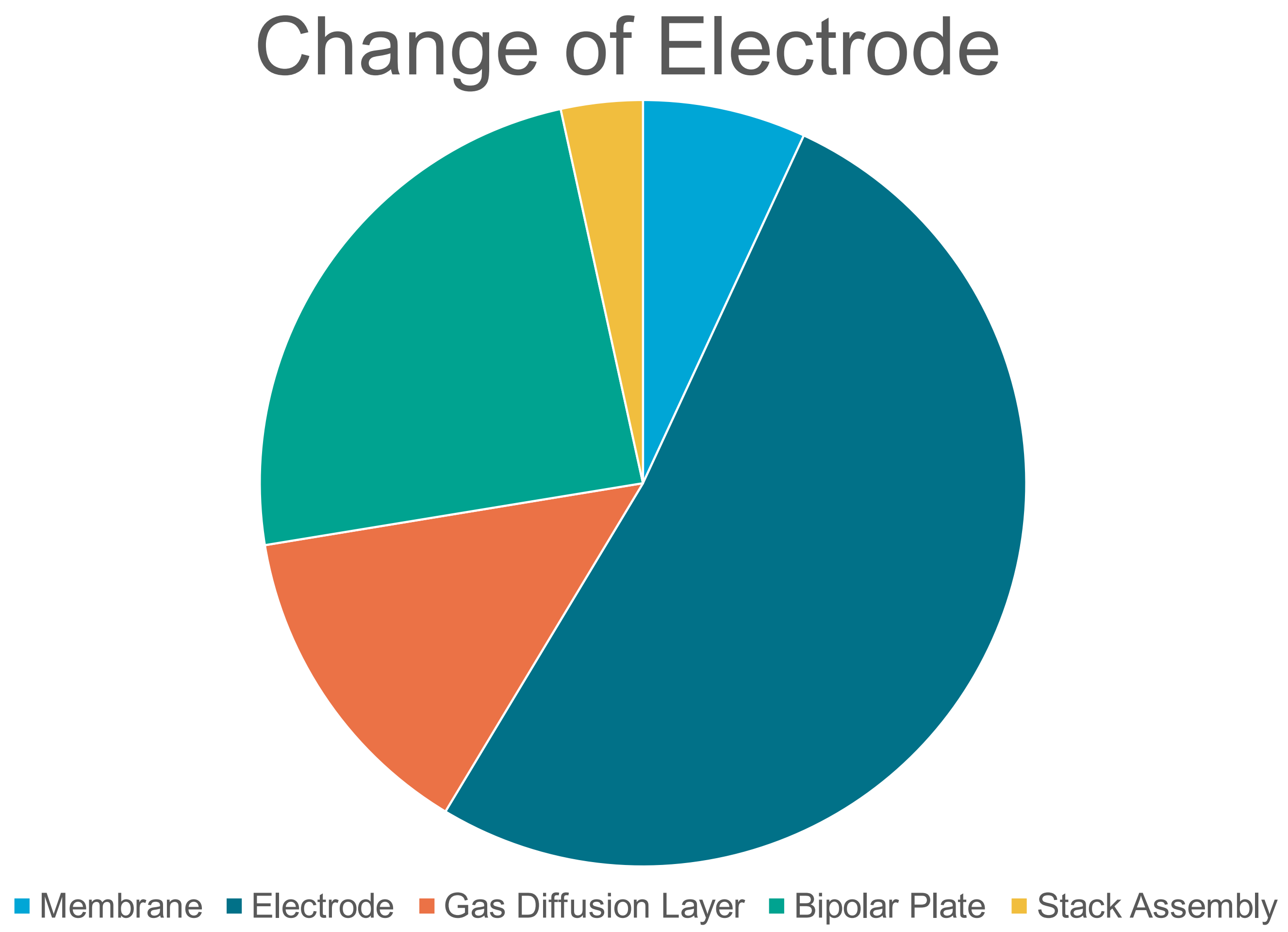


Problem

What will change once we do the change?

Impact after change.

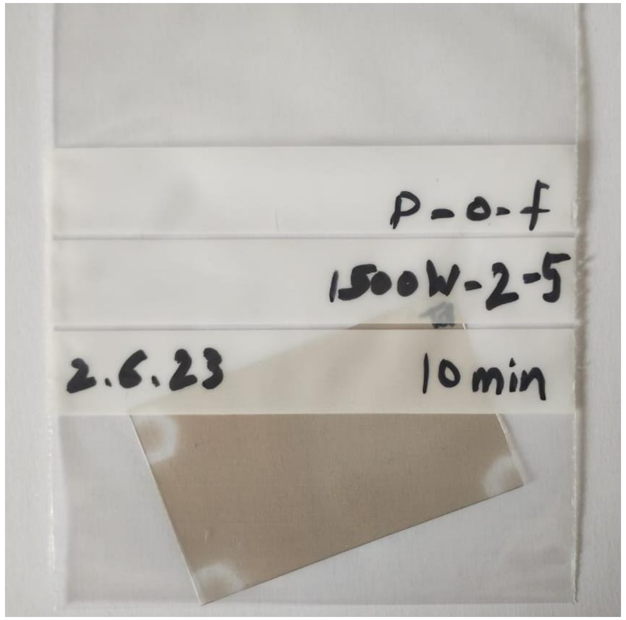
- The carbon footprint can be reduced by almost 15% from 8258 kgs to 6971 kgs.
- Cost of Electrolyzer can be reduced significantly.

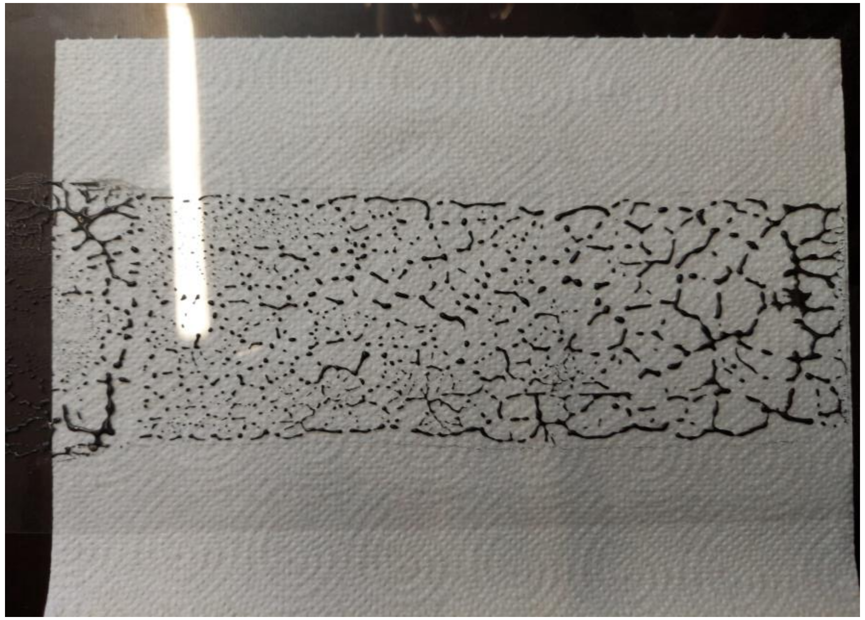


Next Steps

What are the upcoming milestones and expected outcomes in the journey towards completing this thesis assignment?

Upcoming Milestones





- Coating on the membrane is crucial for the Electrolysis.
- Efforts are currently underway to explore viable and effective coating methods.

Advice

What lies ahead for these explorations in the future?

What are the anticipated next steps for Airbus?

Advice

- The coating technology associated with electrolyzers is still in an evolving stage and requires further research and development.
- We recommend that Airbus expands its focus beyond hydrogen utilization and explores hydrogen production as well.
- A comprehensive approach that encompasses both production and utilization of green hydrogen would serve as an all-in-one solution, attracting more airlines towards its adoption.

Any Feedback/Questions?

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Thank You.

Interdisciplinary Results

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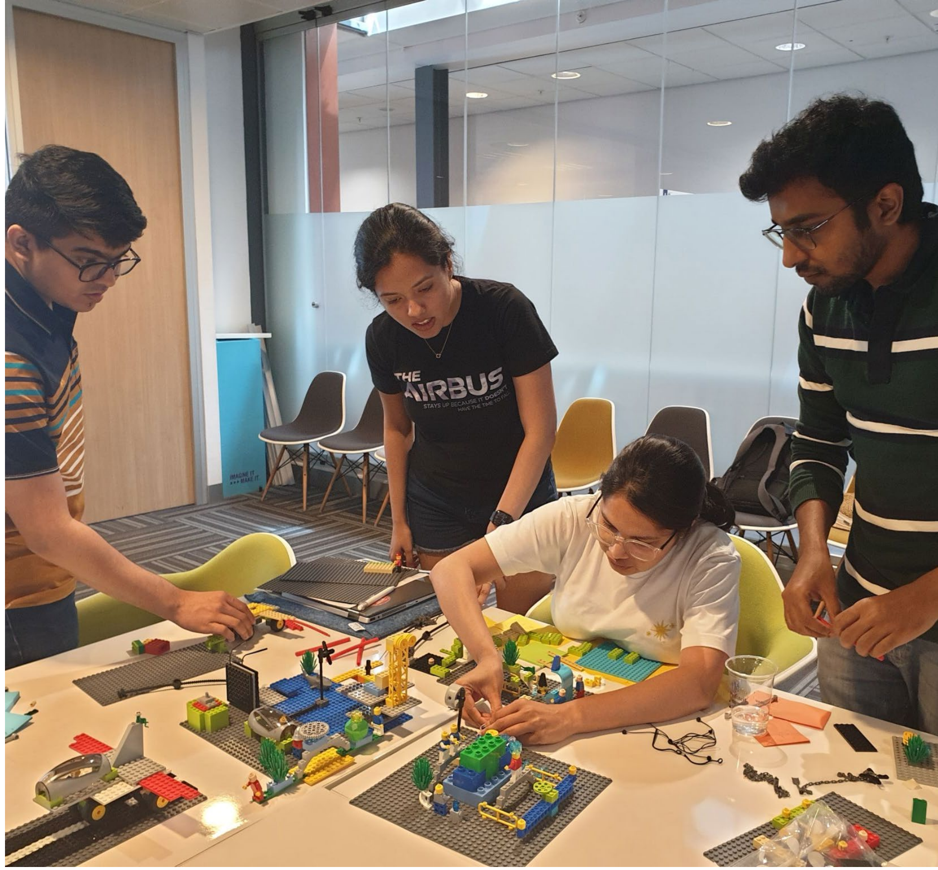
What made this lab attractive?

Why was this lab needed?

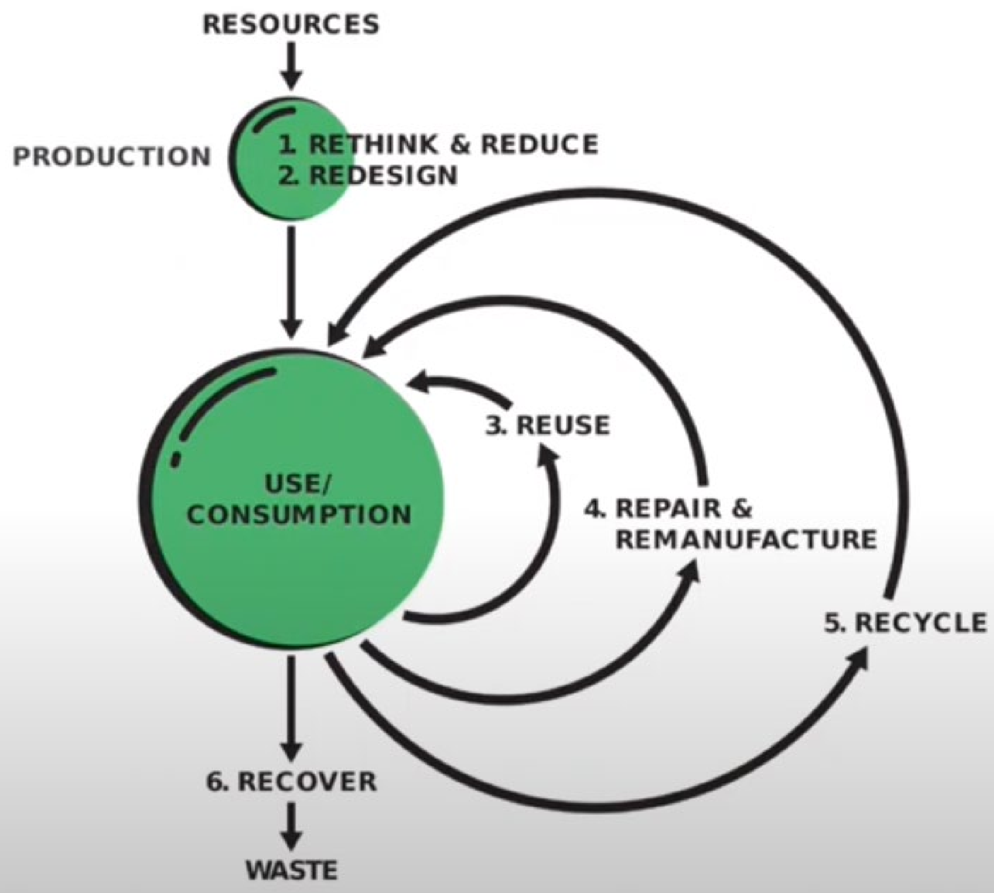
What did all stakeholders and the team of students wish to achieve with it?

- Interdisciplinary team and perspective
- Sense of community
- Application to industry
- Possibility to start or contribute to conversations



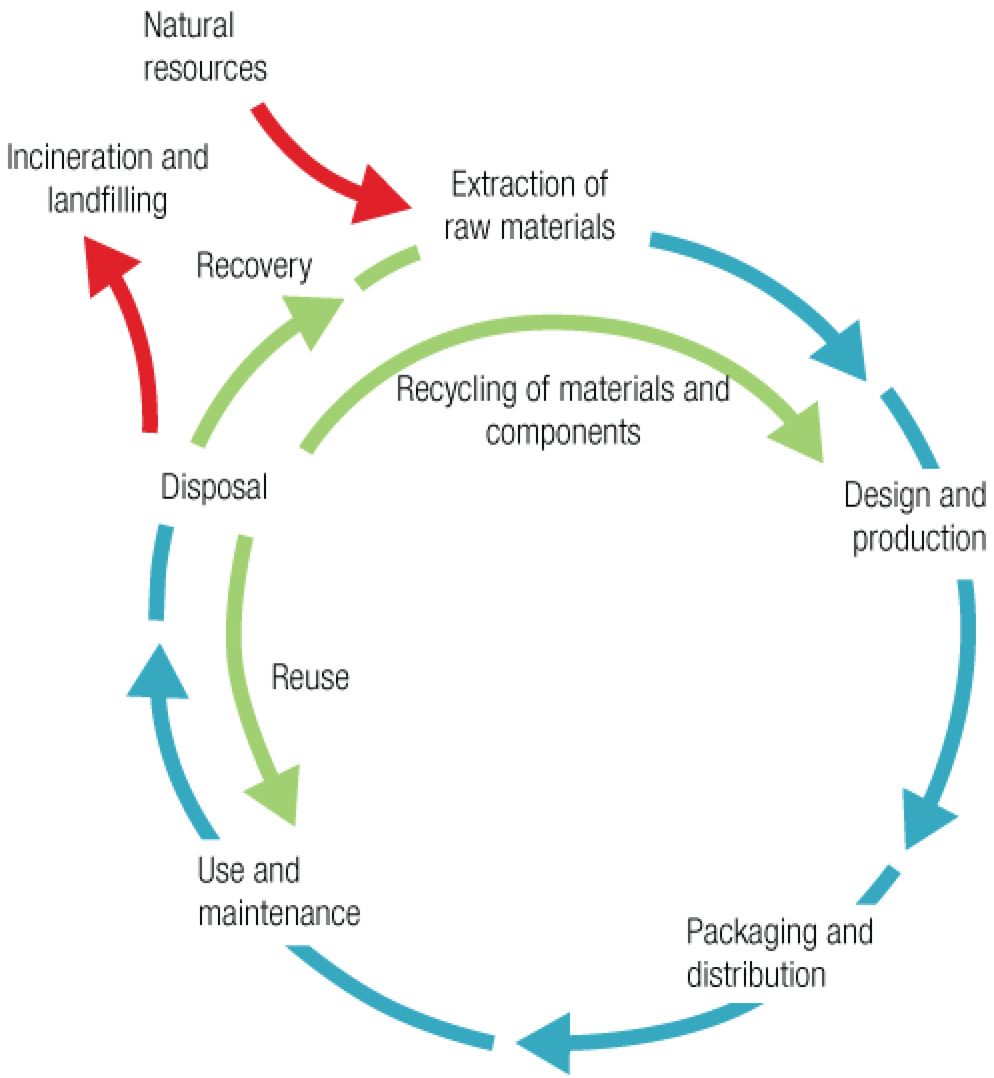
Our vision for the future

- **REFUSE**
- Airbus Forecasts
  - Passenger increase 3.6% over 20 years
  - 40,850 new passenger and freighter aircrafts
- **Aviation**
  - Connects
  - Essential Services
    - 35% of world trade value
- **REDESIGN**



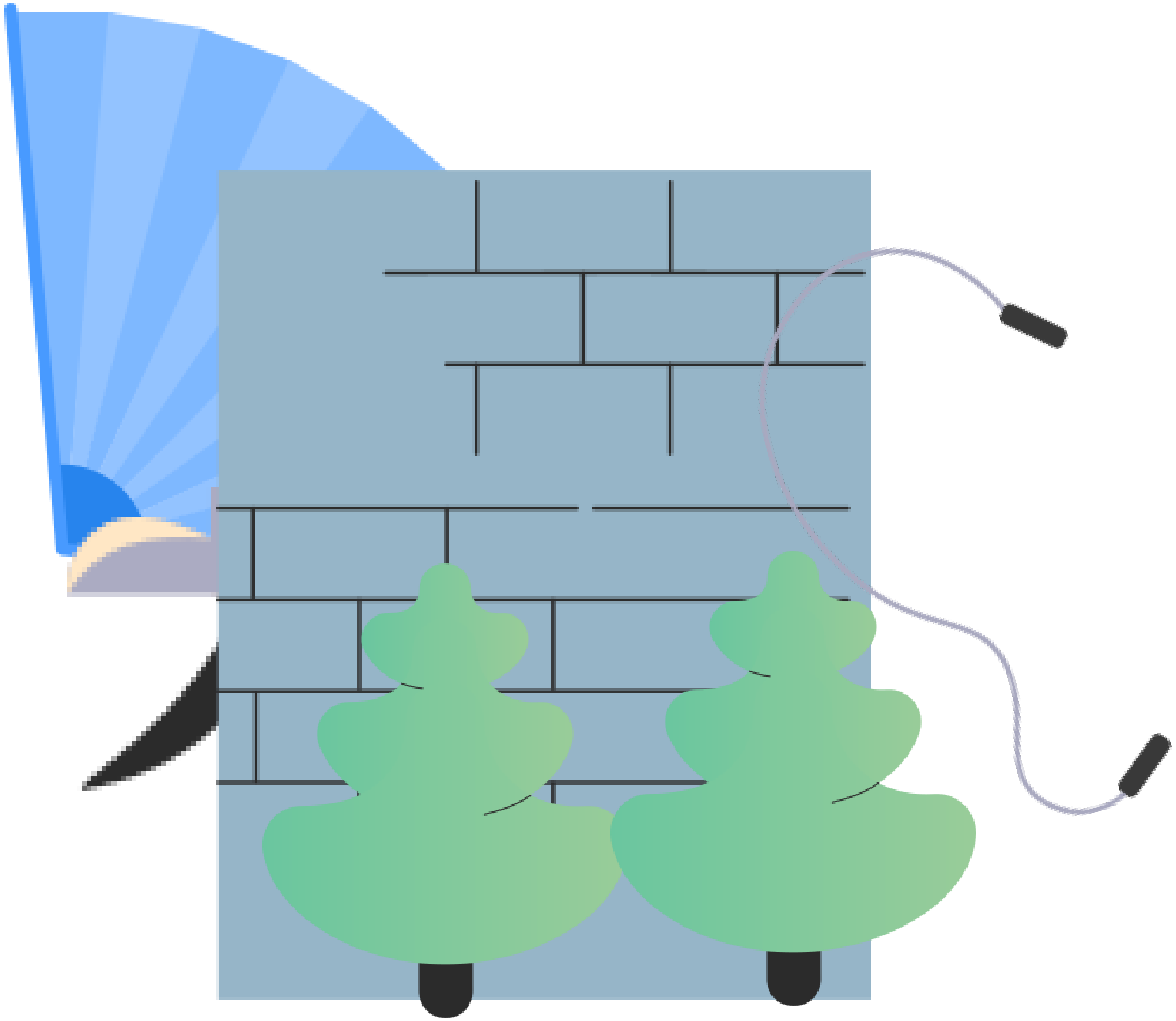
Emerging Technologies

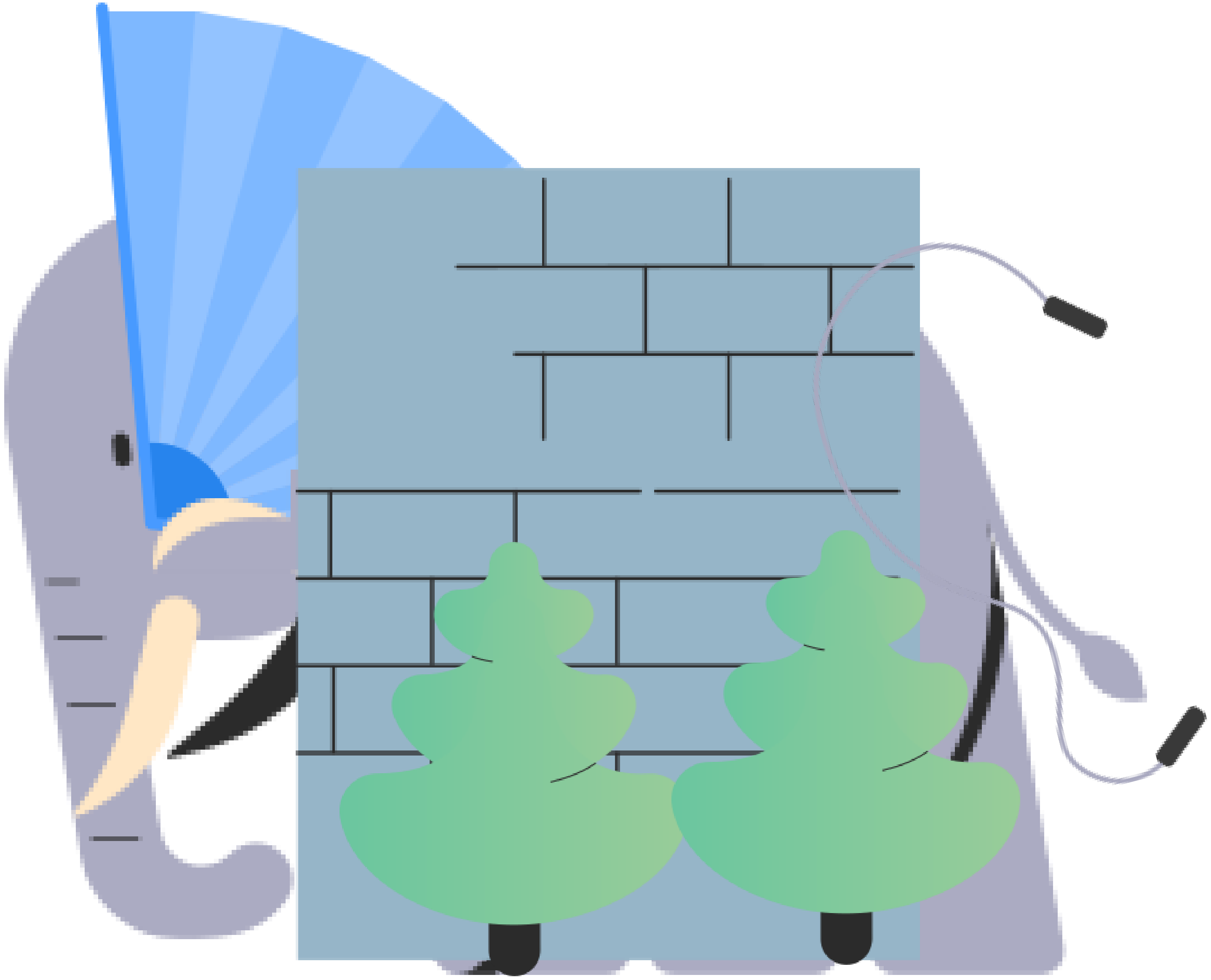
- Promise decarbonization pathways
- Possible shift of pollutions
- Still nascent
- Fixed supply chains and path dependencies
- New kind of fossilization

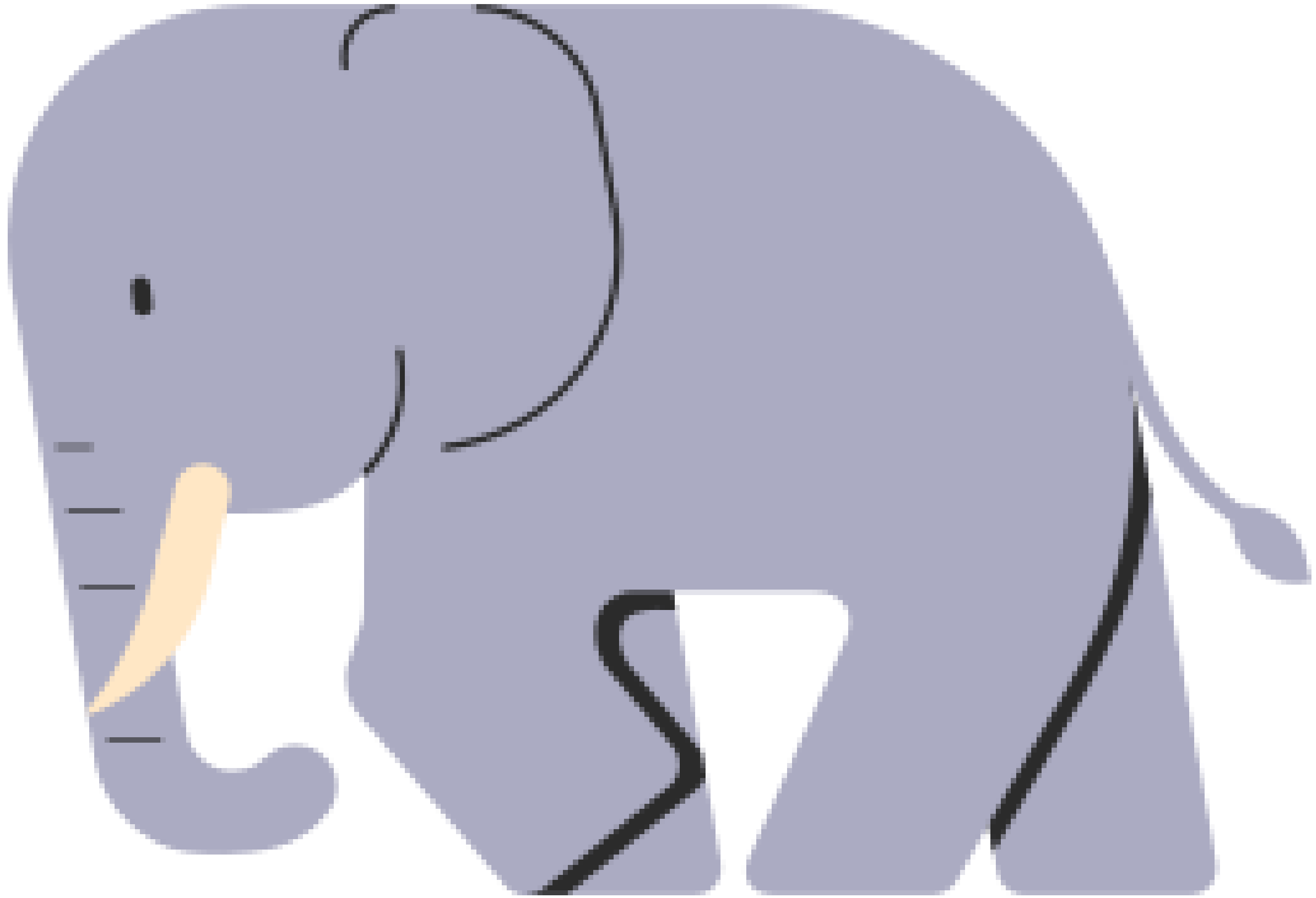


Message

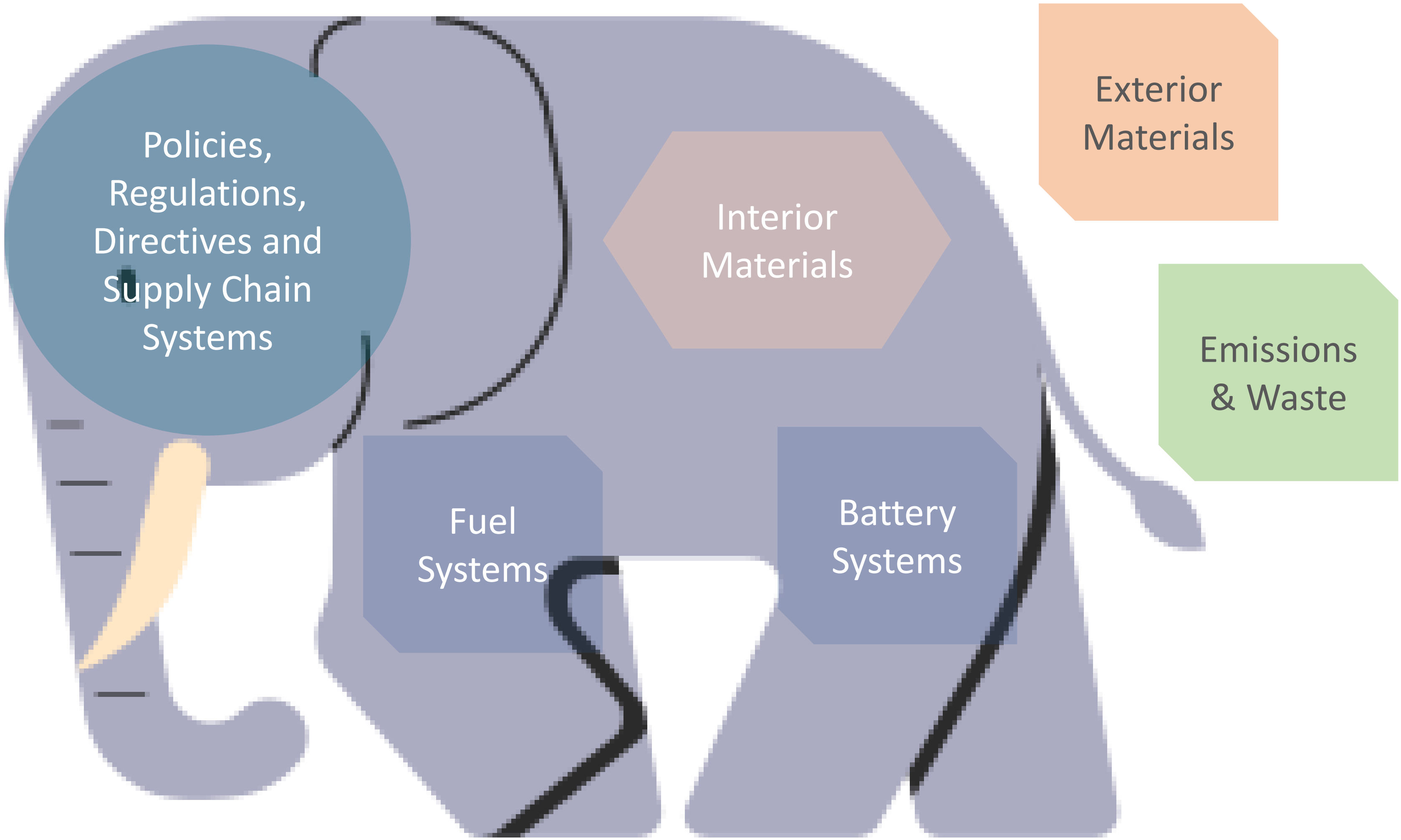
What is our message to Airbus and it's stakeholders through our collective understanding?







Any redesign to a sustainable future needs a systems thinking approach


Policies, Regulations, Directives and Supply Chain Systems
Interior Materials
Exterior Materials
Emissions & Waste
Fuel Systems
Battery Systems

Policies, Regulations, Directives and Supply Chain Systems

Materials

Fuel systems

Battery Systems

Waste & Emissions

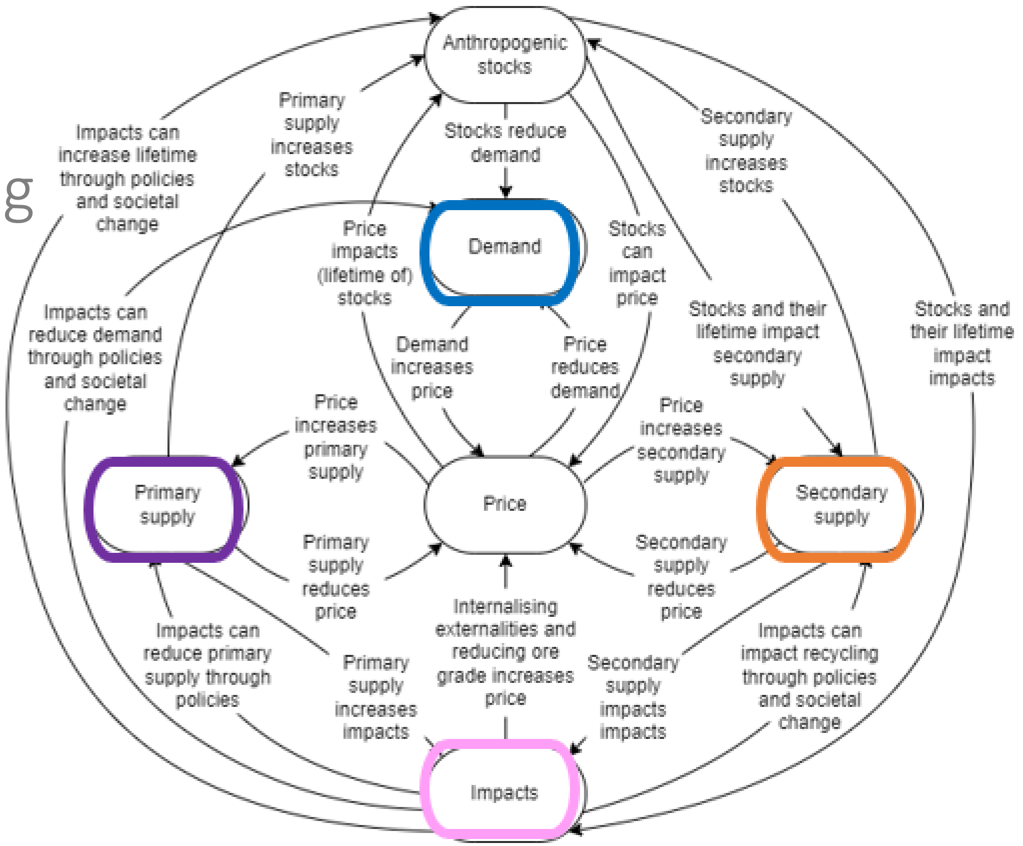
Make

Use

Return to the Cycle

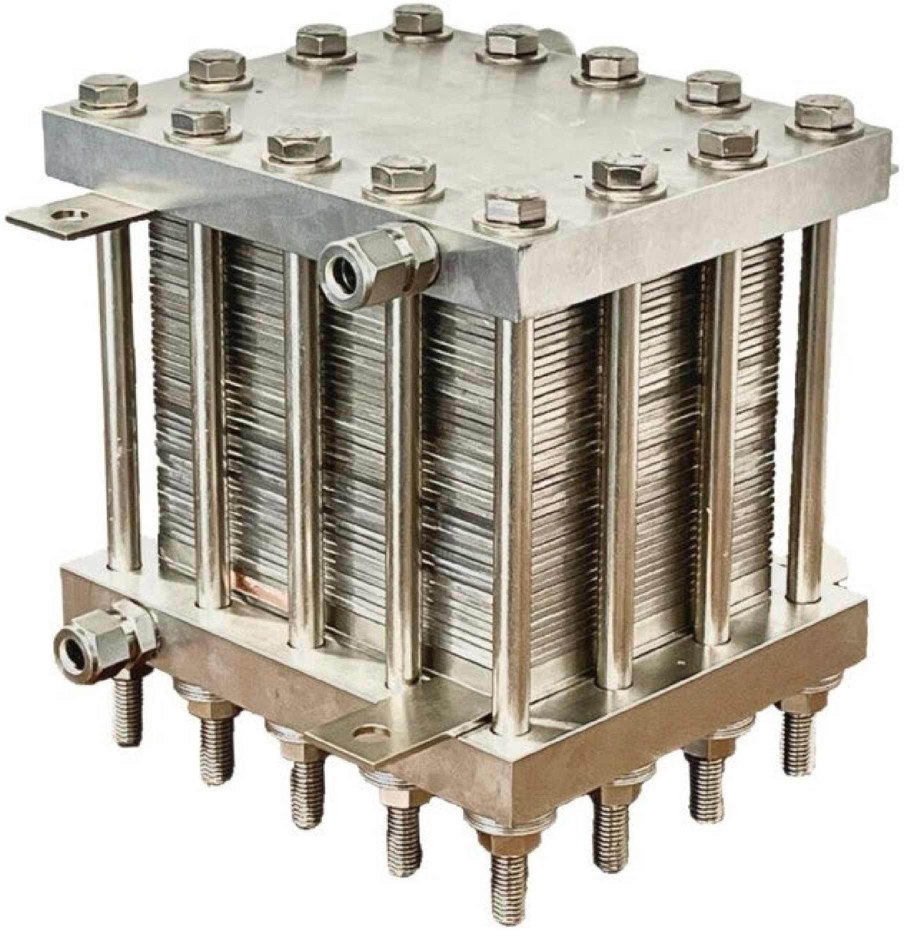
Individual Result FFs & Batteries

- One decarbonisation pathway enabled by SOFC
- Fuel Flexibility transition FF to Hydrogen
- Pollutant shift from operating to manufacturing and EoL
- Shift in new functionalities
- Shift in material



Individual Result Fuel Systems

- Replacement of CRM's is being a global priority looking at recent Global events.
- It is essential to explore opportunities for diversifying the supply chain.
- In addition to CRM, there is potential for the utilization of non-CRM solutions as well.
- There is a possibility to produce Low Cost Green Hydrogen that exhibits a significantly reduced Carbon Footprint.
- Further research is required to enhance familiarity with the intricate processes involved.

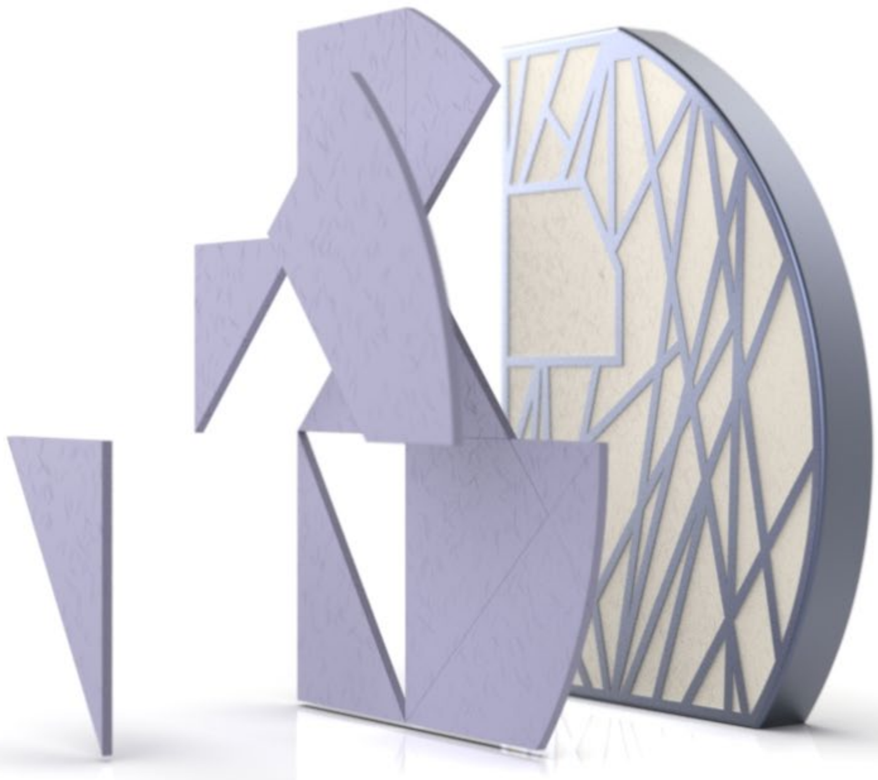


Individual Result Interior Materials

- Ecological composites and materials are lucrative future cabin interior materials.

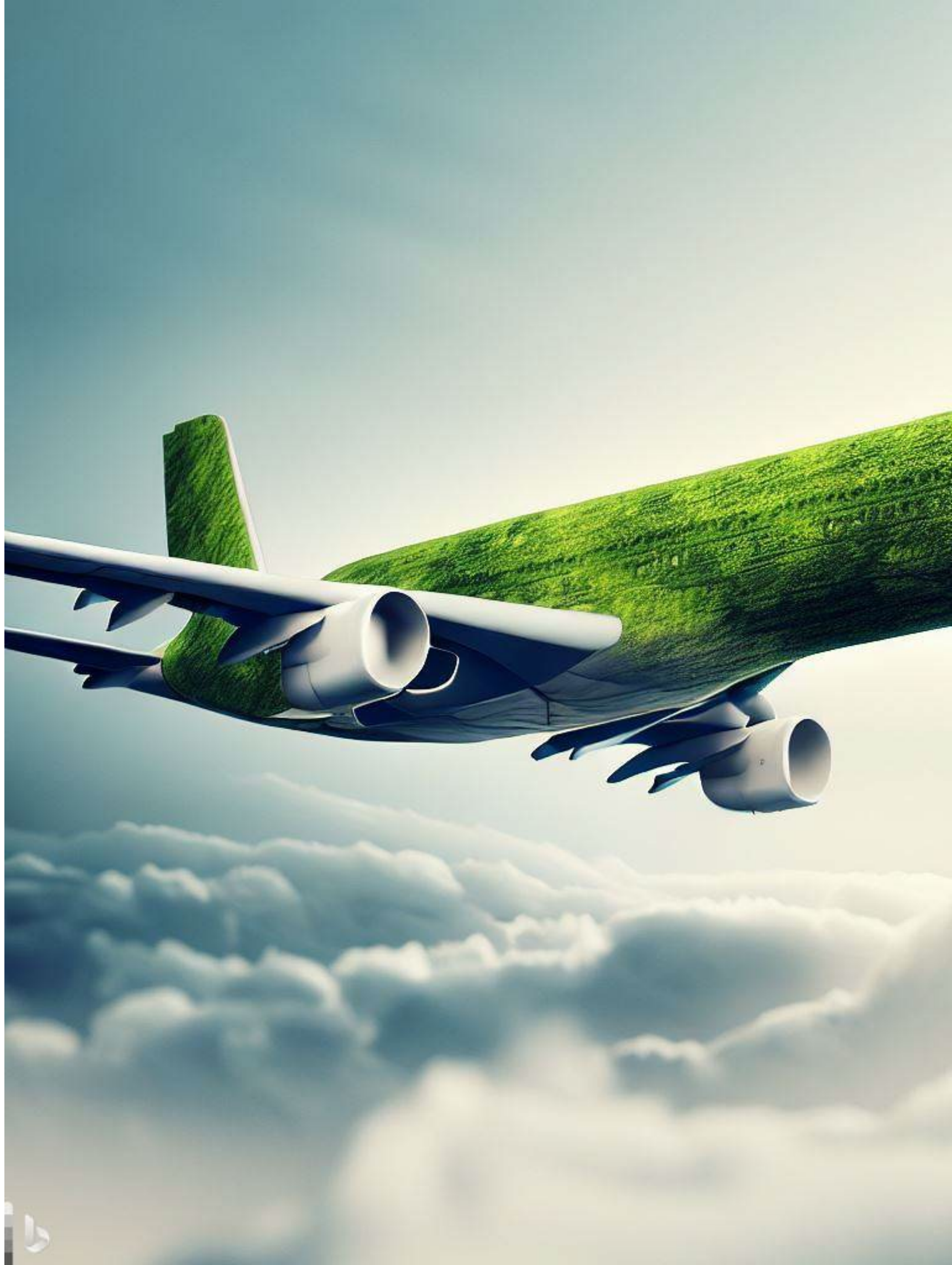
- For deployment in the initial stages, Airbus & partners should look at tertiary, non structural applications which do not affect the safety. Some single use materials can completely be eliminated through use of living composites.

- Ensuring *lower weight, controlled end of life processes* and cabin safety and passenger experience are crucial.



Individual Result : Materials Exterior

- Composites reduce fuel consumption and enable new lightweight designs
- Bio-based composites can save 1 million tons of CO_2 per year in plane manufacturing.
- Investing in biorefineries reduces costs for bio-composites and promote sustainable aviation fuel.
- Downcycling strategies in interior structures or other industries increase composite circularity and facilitate recycling.



Individual Result : Emissions & Offset

- Potential to use captured carbon for PtL fuels
- Can we create an internal aviation specific offsetting system to accelerate system innovation?
- There is a need to improve coordination and mobilize joint action among stakeholders
- Policy plays a key role in leading innovation

General Conclusions from the Lab

- Sustainability issues are complex
- A need for systemic understanding
  - Hydrogen is good if renewable
  - Composites are fossil fuel based but save fuels
  - Without policies in place no space for innovation
- Multidisciplinary approaches bring new insights
  - Biomaterials for planes
  - Technology is not the only barrier
- There is no perfect solution. This is however not an excuse
  - We need to move away from the minimum
  - Planet and people ahead of profits

Recommendations

Action Point 1:Develop technologies and supply chain parallely

E.g. Infrastructure for Hydrogen & Captured carbon
Biomass feedstock for SAF & Biobased CF

Benefits

- Resource optimization
- Supply chain reliability
- Cost efficiency

Action Point 2:
Invest in sustainable supply chains while technologies are nascent

- Become early adopters
- Avoid costly end-of pipe solutions
- Competitive advantage
- Build trust from society
- Avoid path dependency
- Engage stakeholders from the beginning
- Advocate for policy changes

Action Point 3:
Rethinking the role of aviation in a future sustainable society
We should promote circular aerospace but… Do we even need to fly?

- We should promote circular aerospace but… Do we even need to fly?
- Flying is an environmental luxury and therefore should be limited in a future sustainable society.
- For what is flying essential?
- Should we not be promoting local and regional connectivity? Trains, innovative ways of transport.
- Blaming is not the answer but if we fail to address these issues today the future will force us to change in a more dramatic way