INTERNATIONAL COOPERATION FOR SUSTAINABLE AVIATION BIOFUELS

Sustainability Certification of Novel SAF Pathways

Online Webinar

2 October 2025

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101122303.

Agenda

Time	Topic	Speaker
14.00 - 14.10 pm	Welcome & Introduction	Esther Hegel (RSB) - ICARUS
14.10 – 14.25 pm	Novel SAF Pathways in ICARUS	Berend Vreugdenhil (TNO)
14.25 – 14.45 pm	Understanding SAF Certification: EU RED, CORSIA and Voluntary Schemes	George Deslandes (RSB) - ICARUS
14.45 – 15.05 pm	From Innovation to Certification: Insights from the SusAlgaeFuel Project	Darren Carty & Agnes Thornton (SFS)
15.05 – 15.10 pm	The ICARUS SAF Certification Guidance	Esther Hegel (RSB) - ICARUS
15.10 – 15.25 pm	Open Discussion & Online Poll	
15.25 – 15.30 pm	Closing Remarks and Next Steps	Esther Hegel (RSB) - ICARUS

- This webinar is recorded for internal purposes.
- Recording & Slides will be shared on the ICARUS website after the webinar.

Welcome & Introduction

Esther Hegel, RSB

ICARUS Project Partner

ICARUS at a glance

- **Duration & Framework:**
  Runs from **October 1, 2023**, to **September 30, 2026**, under the EU's **Horizon Europe** RIA scheme (Grant Agreement No. 101122303).
- **Budget**
  Total cost approximately **€3.16 million**, fully funded by the EU.
- **Consortium**
  Featuring **20 partners** spanning Europe and Mission Innovation Countries (Canada, India, Brazil), with additional input via an External Executive Advisory Board from the USA.

Partners

ΚΑΠΕ CRES
LNEG
TNO innovation for life
NTNU
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Associated Partners

RSB
SENAI CIMATEC
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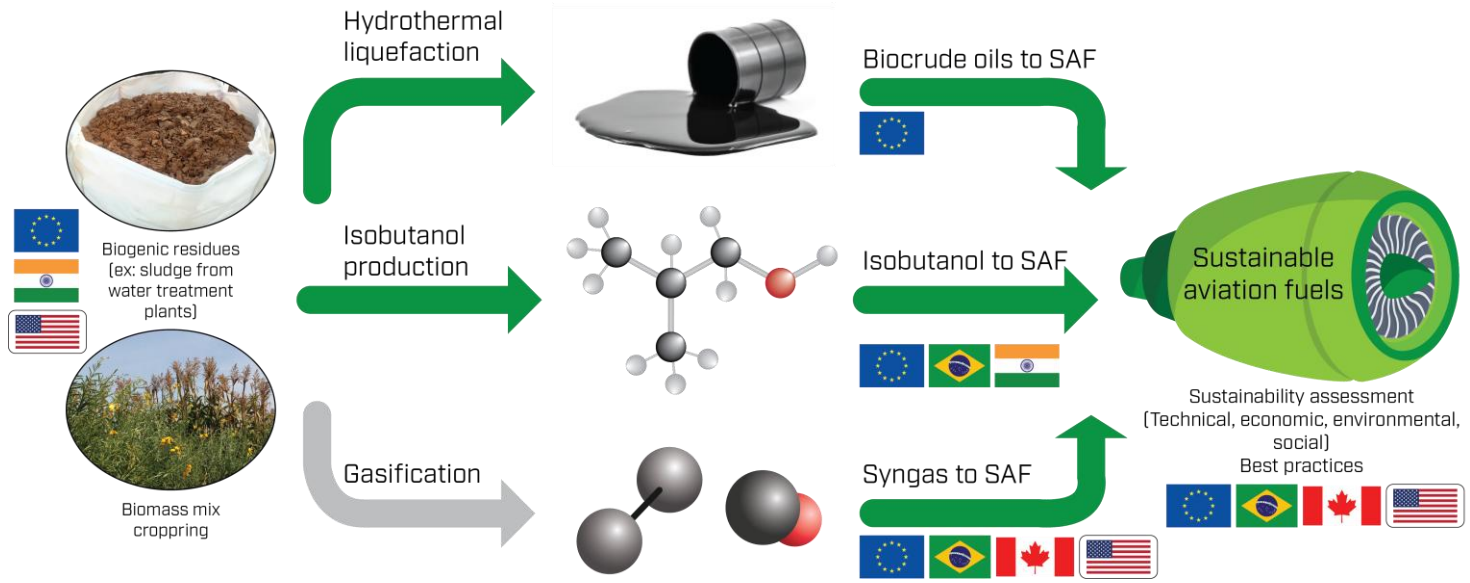
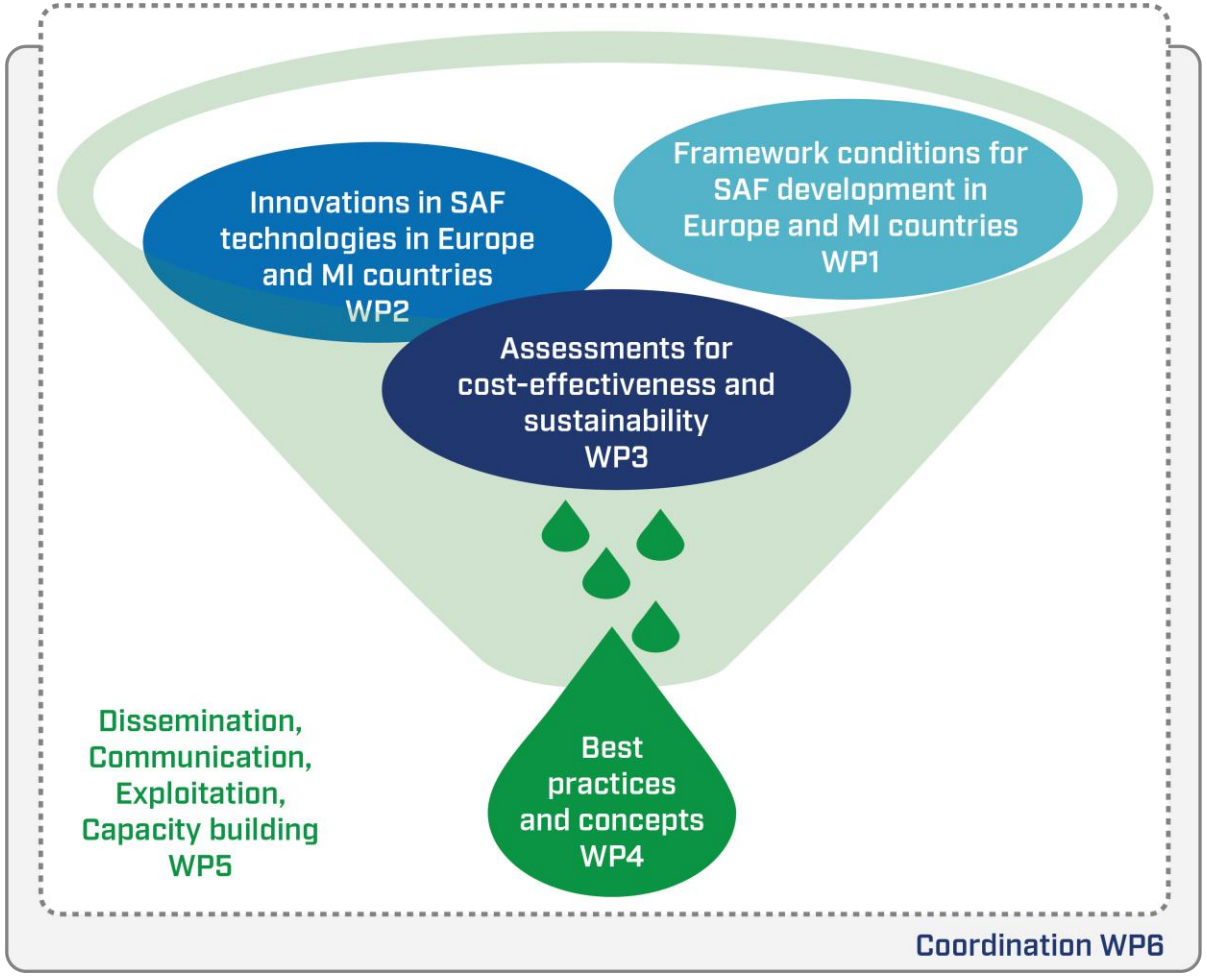
ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS
AVIONIC
BIOVOLATILES
INSTITUTO SENAI
DE INOVAÇÃO
ENERGIAS RENOVÁVEIS

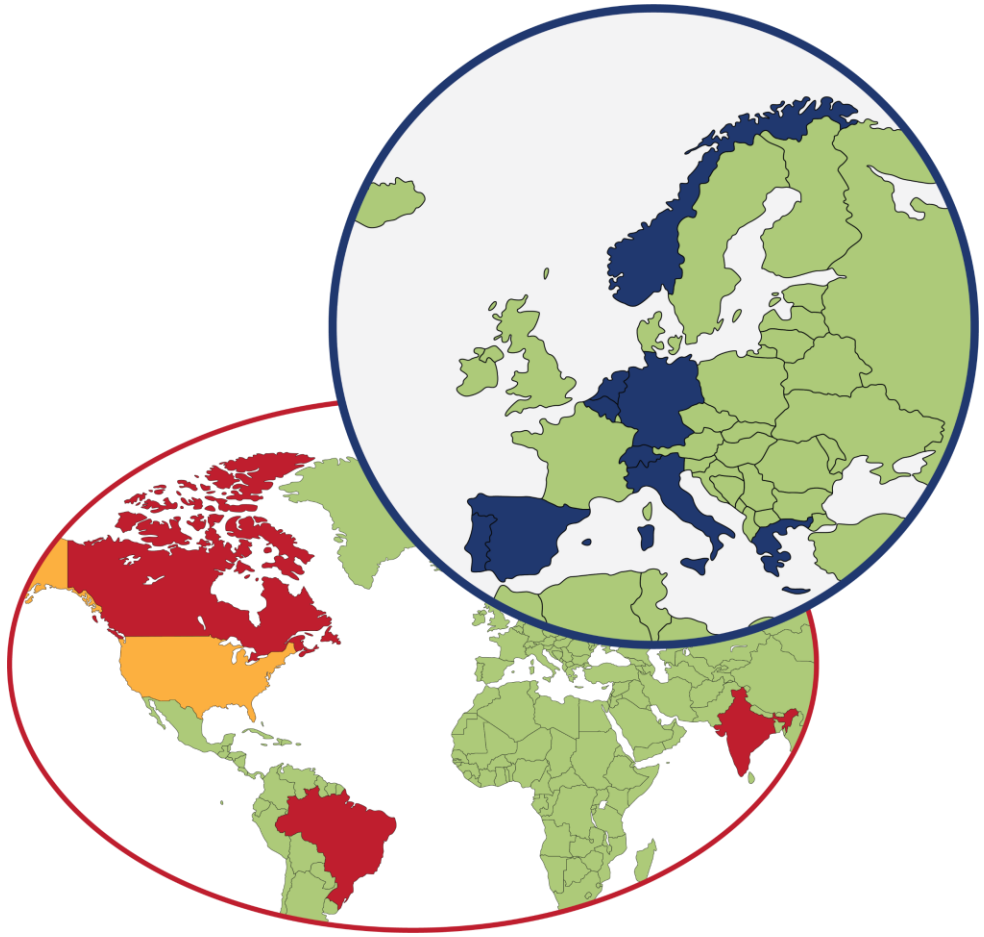
ICARUS at a glance

Aims to develop future best practices and concepts along the entire value chain for the three technological pathways selected in ICARUS for accelerating the scale-up of sustainable aviation biofuels production worldwide.



ICARUS at a glance





Spotlight: Novel SAF Pathways

The relevance of novel SAF pathways in mitigating aviation's climate impact

- SAF is recognised as a cornerstone for reducing aviation emissions and enabling carbon-neutral growth.
- To date, only eight SAF production pathways are ASTM-approved to be blended and used with kerosene.
- Scaling challenge: Current feedstocks and technologies alone cannot meet future demand cost-effectively.

→ **Novel pathways are critical**, as they have the potential to:

- Unlock novel feedstocks, including sustainable low-ILUC bio-feedstocks (e.g. lignocellulosic biomass, algae), wastes and residues, as well as captured CO_2 and renewable electricity.
- Enable new and more efficient production routes.
- Improve cost-competitiveness and scalability.
- Diversify feedstocks to strengthen supply security.
- Enhance sustainability across the full life cycle.

Why Sustainability Certification matters

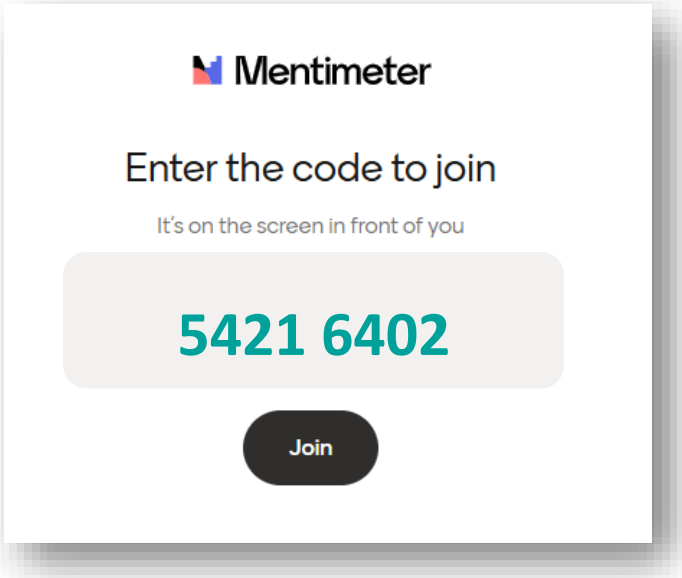
1. ASTM certification ensures technical performance, but sustainability certification is needed to guarantee environmental and social integrity.
2. Certification is key for market access, since only certified SAF can qualify under EU and global schemes, and only then deliver recognised climate benefits.
3. Different regions apply different schemes (e.g., EU RED / CORSIA), creating a complex and sometimes fragmented certification landscape.
4. Sustainability must be integrated early: Project developers and researchers should consider certification requirements already during R&D to ensure later compliance.

→ Today's Webinar: Shaping ICARUS outcomes

- **Navigating certification is challenging** – today's session explores the complexity of sustainability certification for novel SAF pathways.
- **ICARUS is developing guidance** – a 2026 public deliverable will support researchers and developers in applying certification. **Your feedback today will help shape it!**

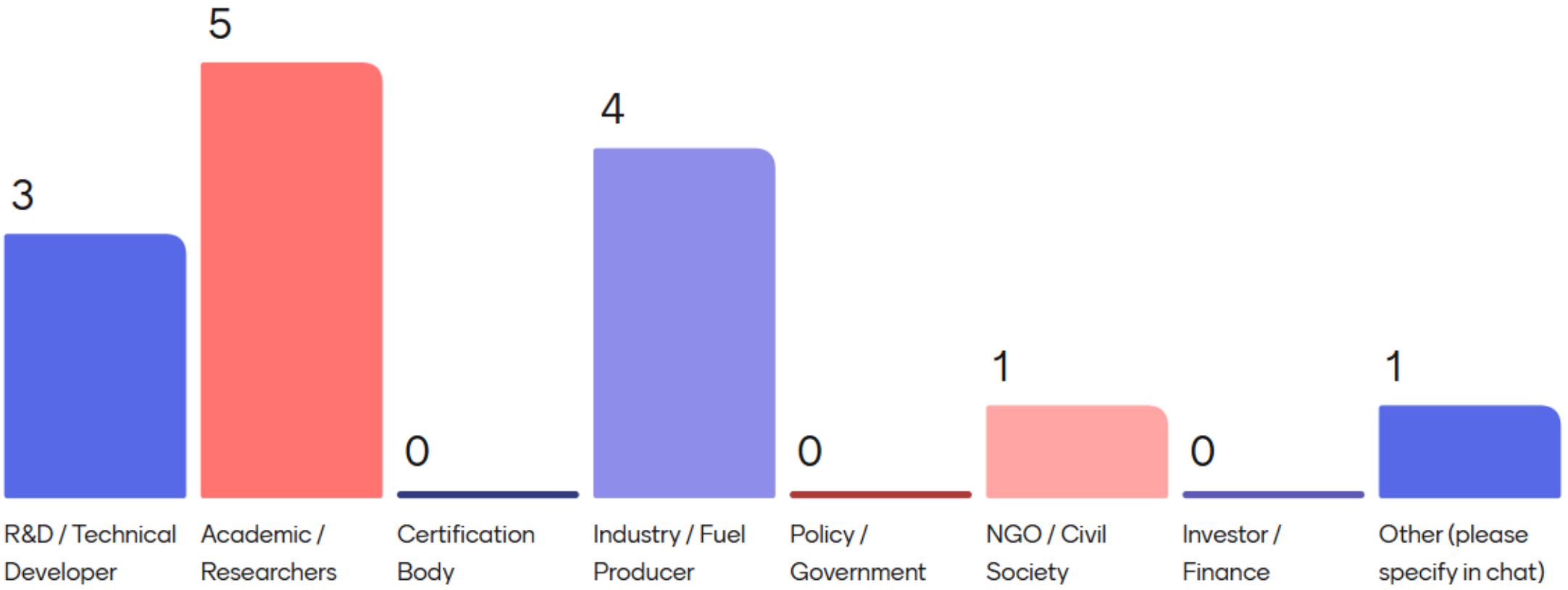
We want to hear from you!

1. Take your phone/computer
2. Scan the QR code OR go to www.menti.com & enter the code: 5421 6402



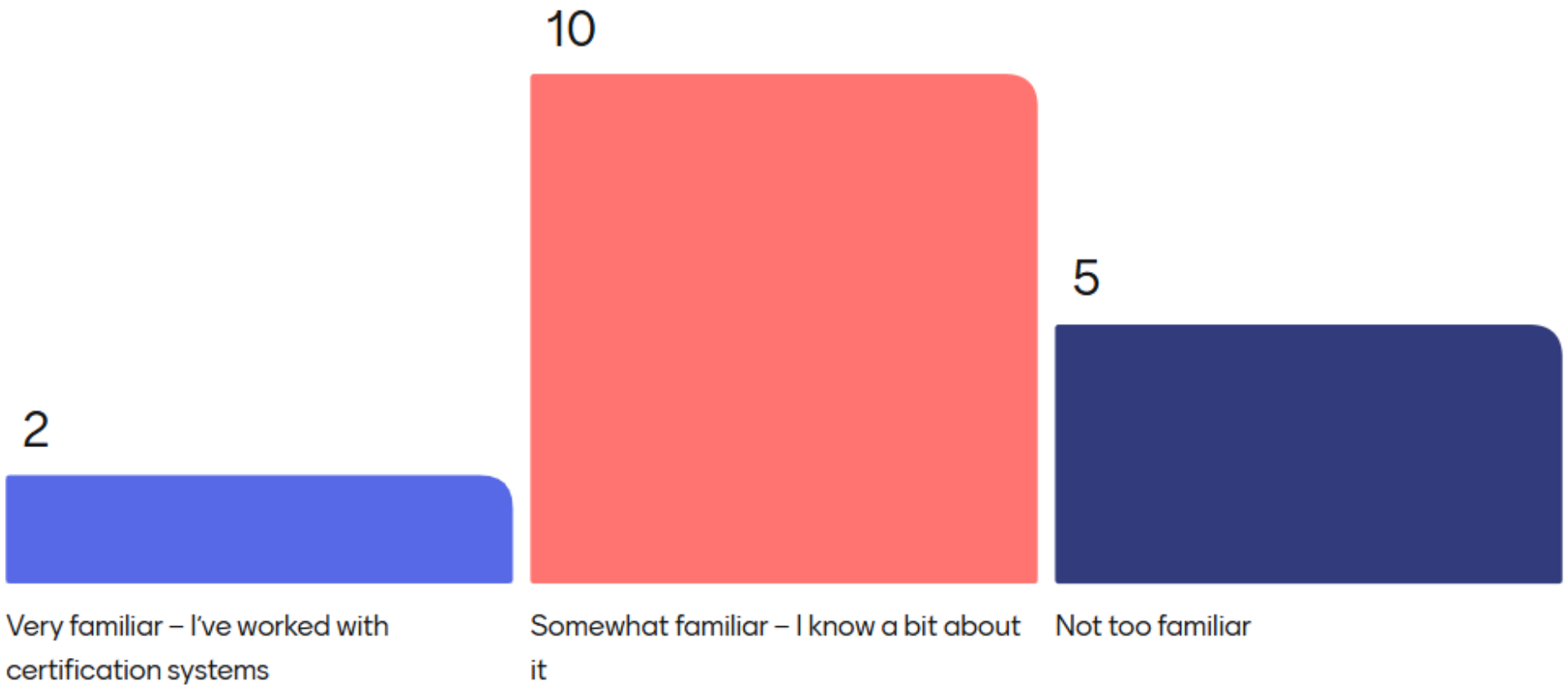
Multiple-choice question

What is your background or role in the SAF ecosystem?



Multiple-choice question

How familiar are you with SAF certification?



Novel SAF Pathways in ICARUS

Berend Vreugdenhil, TNO
Specialist gasification

INTERNATIONAL COOPERATION FOR SUSTAINABLE AVIATION BIOFUELS

Sustainability Certification of Novel SAF pathways

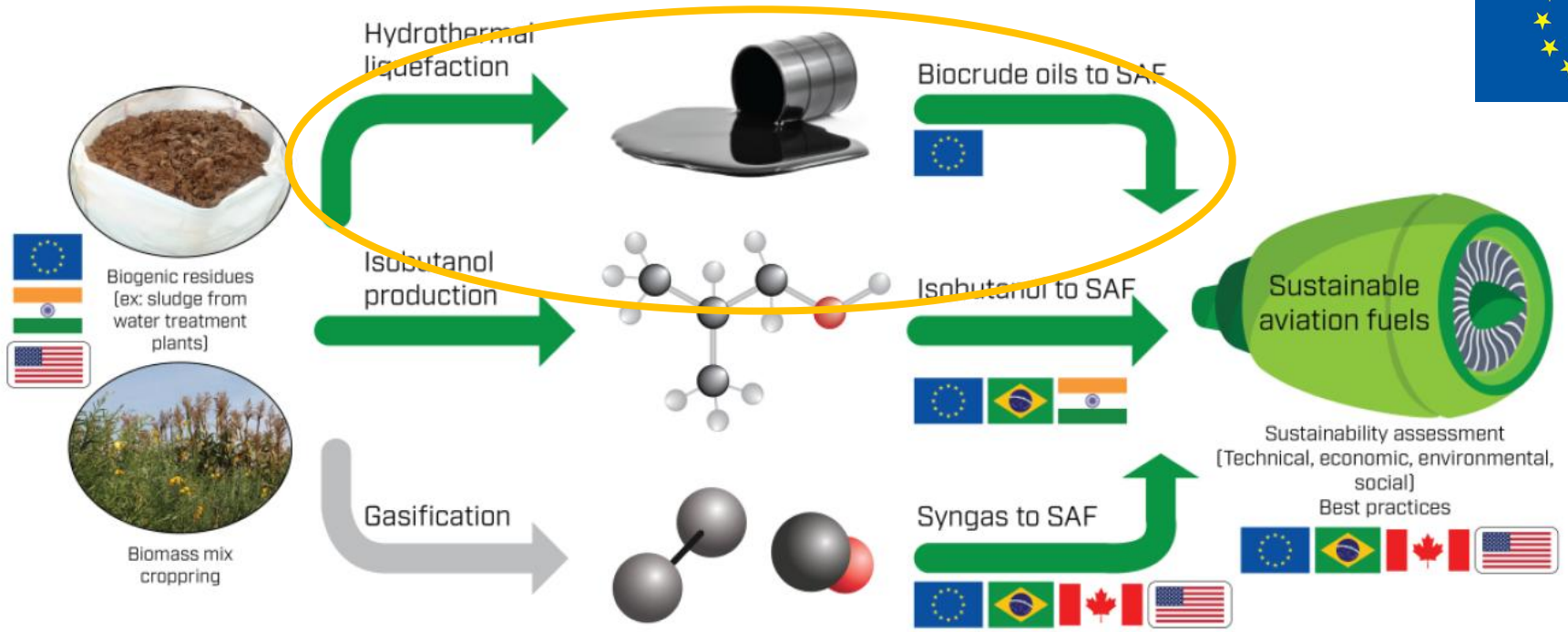
Webinar

Date: 2nd October 2025

Berend Vreugdenhil

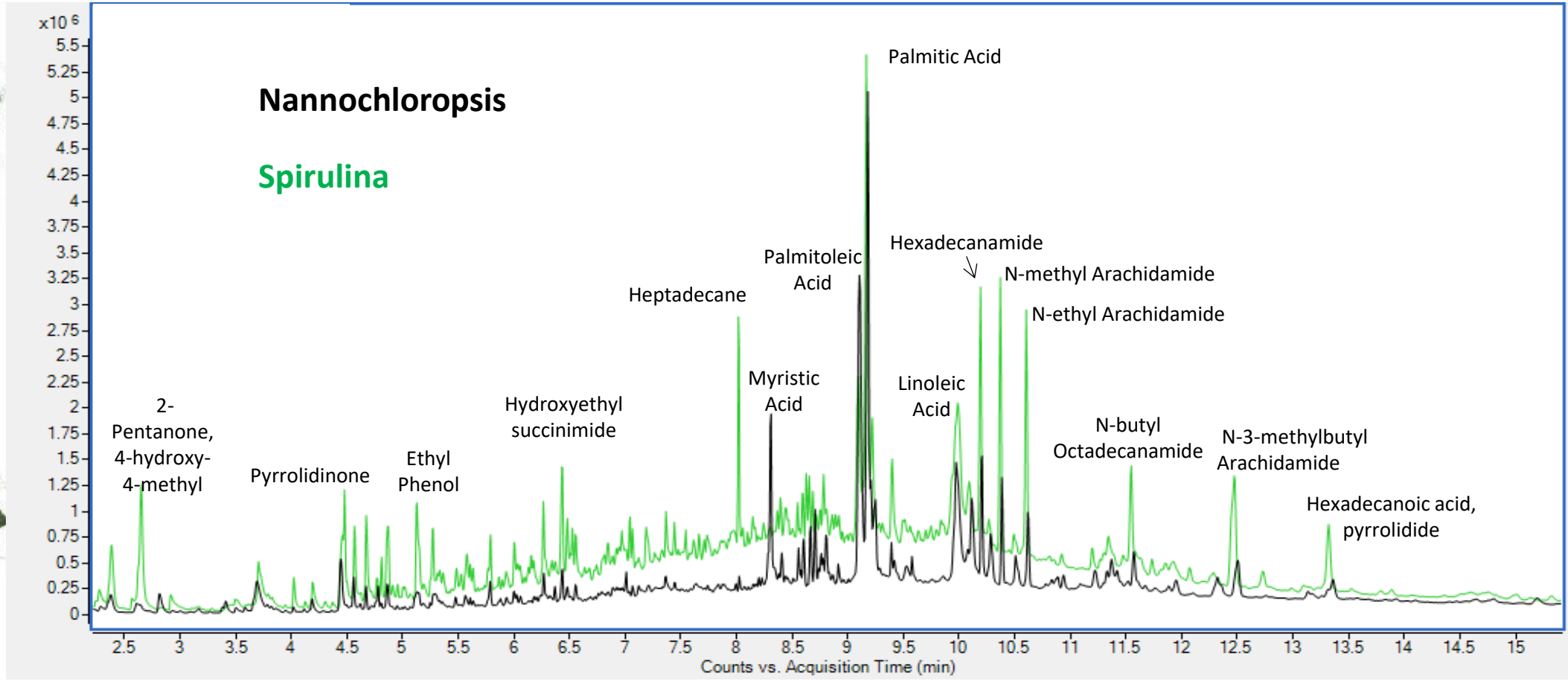
The ICARUS project

International cooperation for sustainable aviation biofuels.

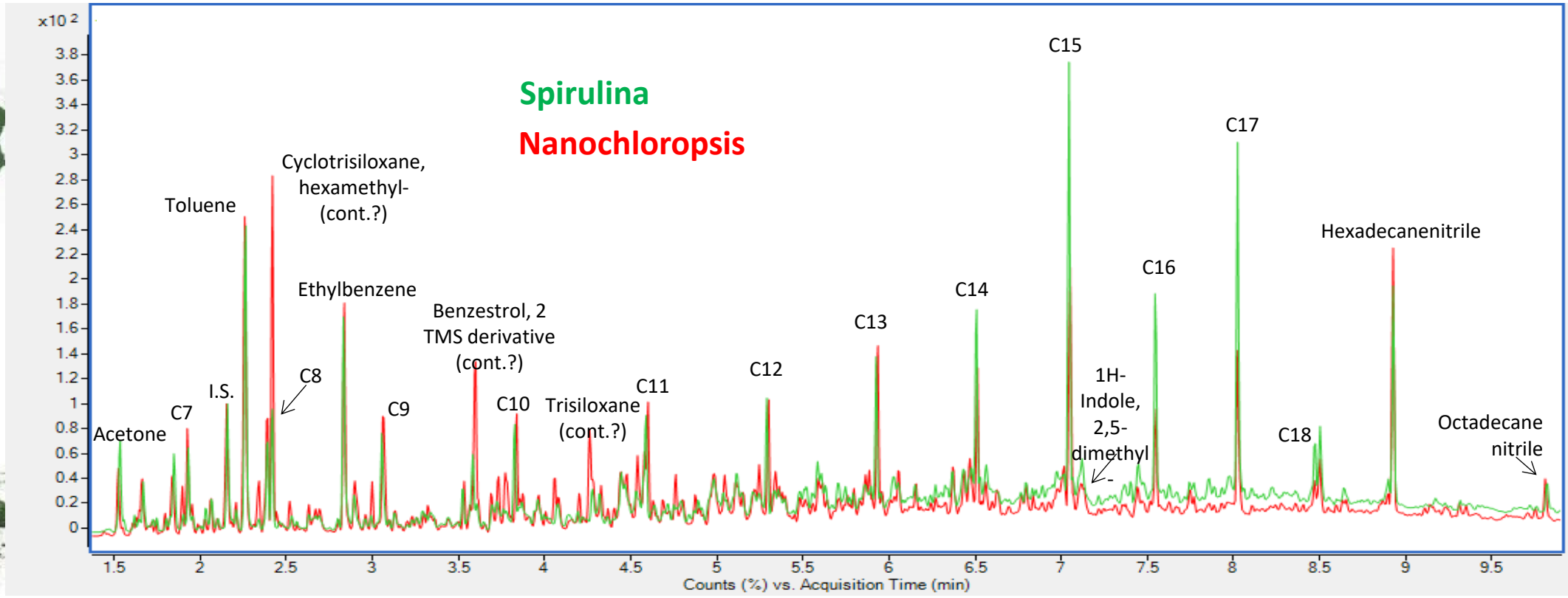


Aim: "Accelerate the deployment of three SAF production pathways by focusing on key technologies that currently limit their scalability."

Bio-oil to SAF pathways – N as an issue

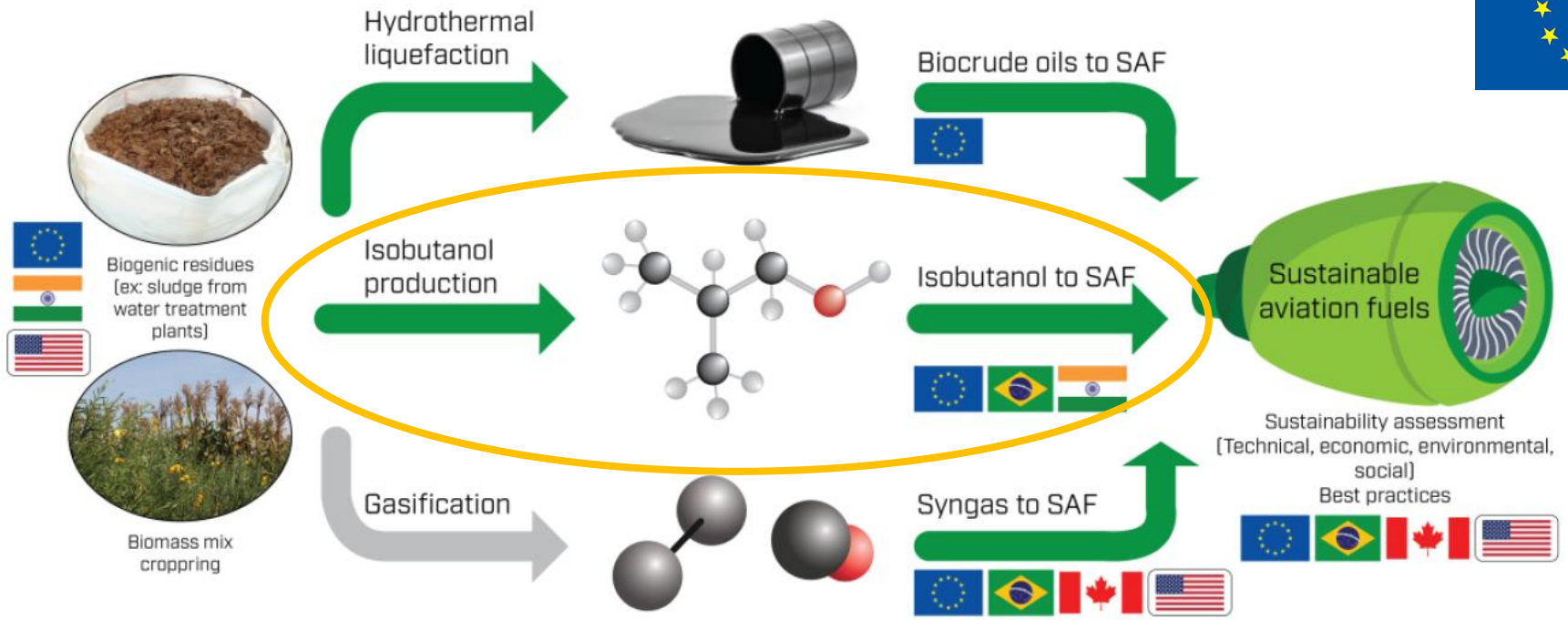


Bio-oil to SAF pathways – After HDO



The ICARUS project

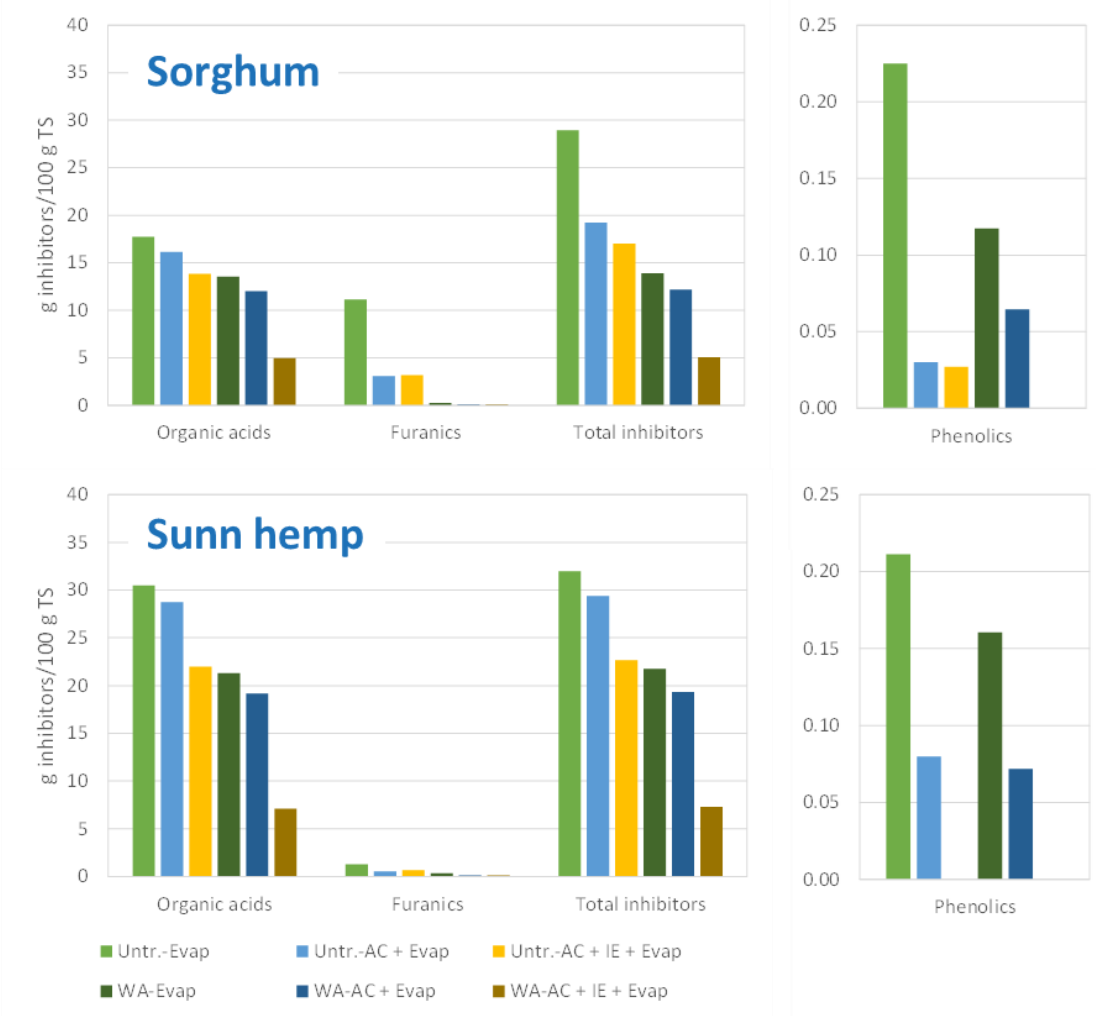
International cooperation for sustainable aviation biofuels.



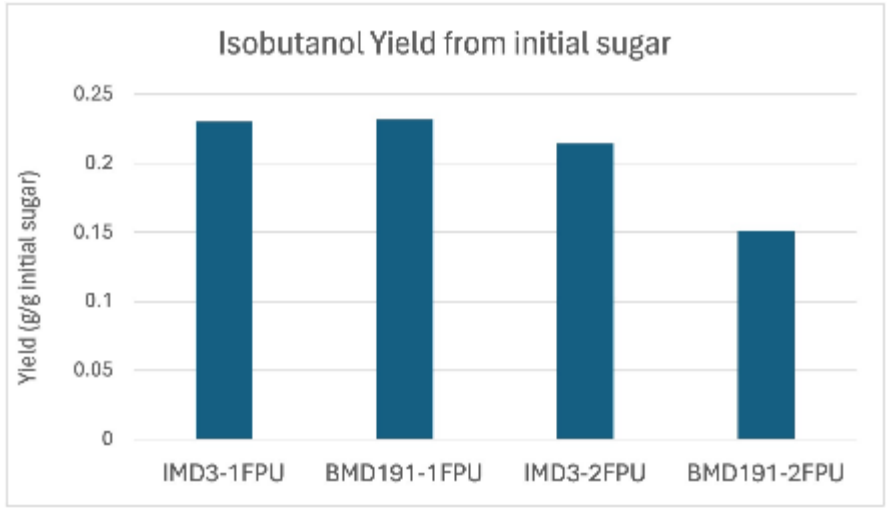
Aim: "Accelerate the deployment of three SAF production pathways by focusing on key technologies that currently limit their scalability."

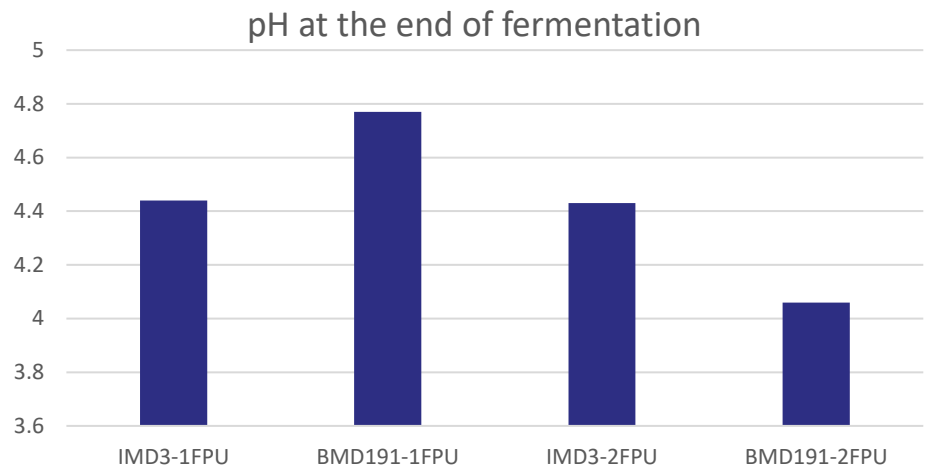
Isobutanol to SAF pathway – reducing enzymes

- Isobutanol is produced from sugars.
- ICARUS focusses on converting both C5 and C6 sugars simultaneously to iso-butanol
- Strain development is focussing on utilizing both as well insitu production of enzymes
- First step is providing real sugars from 2nd generation feedstocks



Isobutanol yield





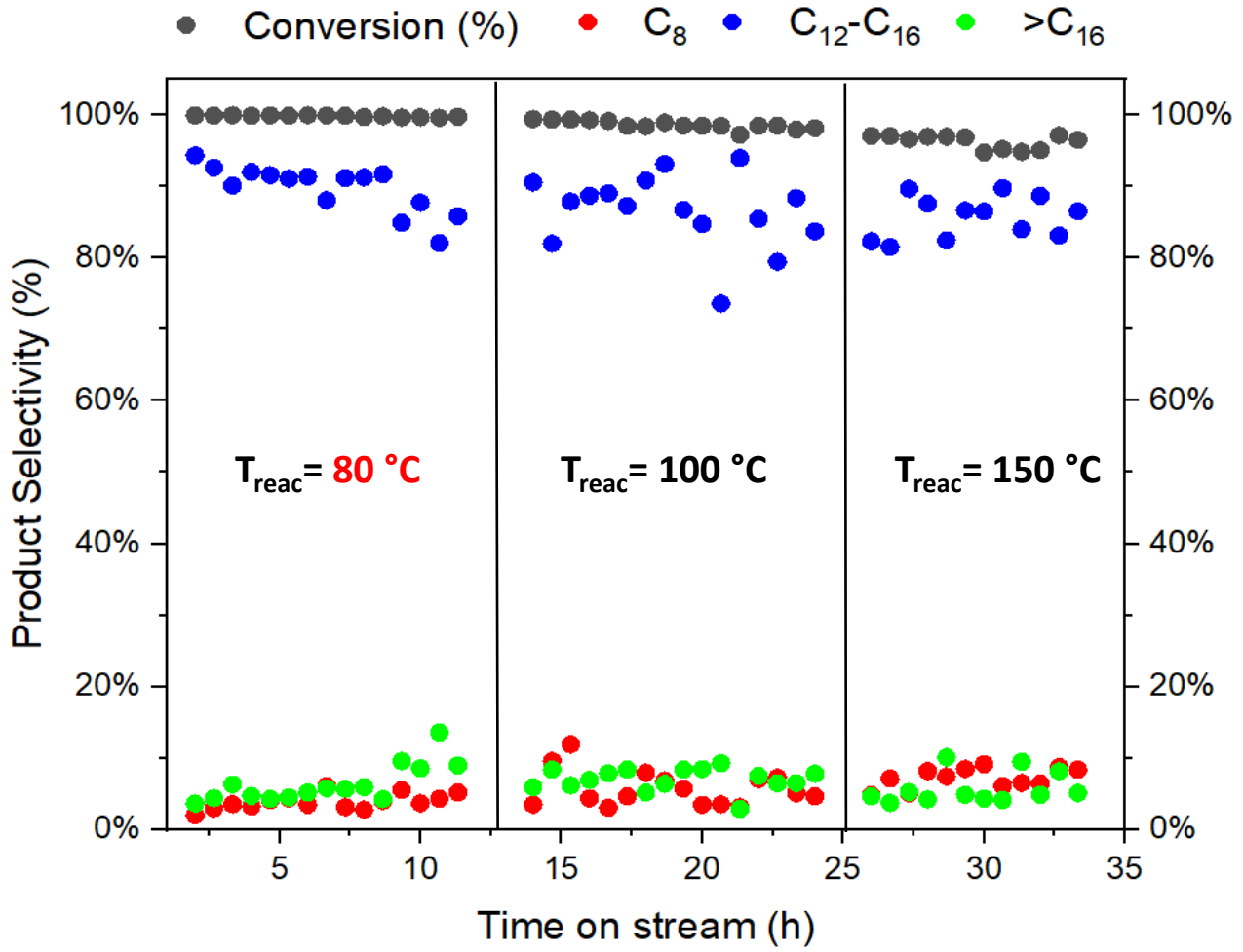
- Similar yield of isobutanol by IMD3 and BMD191 in 1FPU condition, despite a lower final pH in IMD3

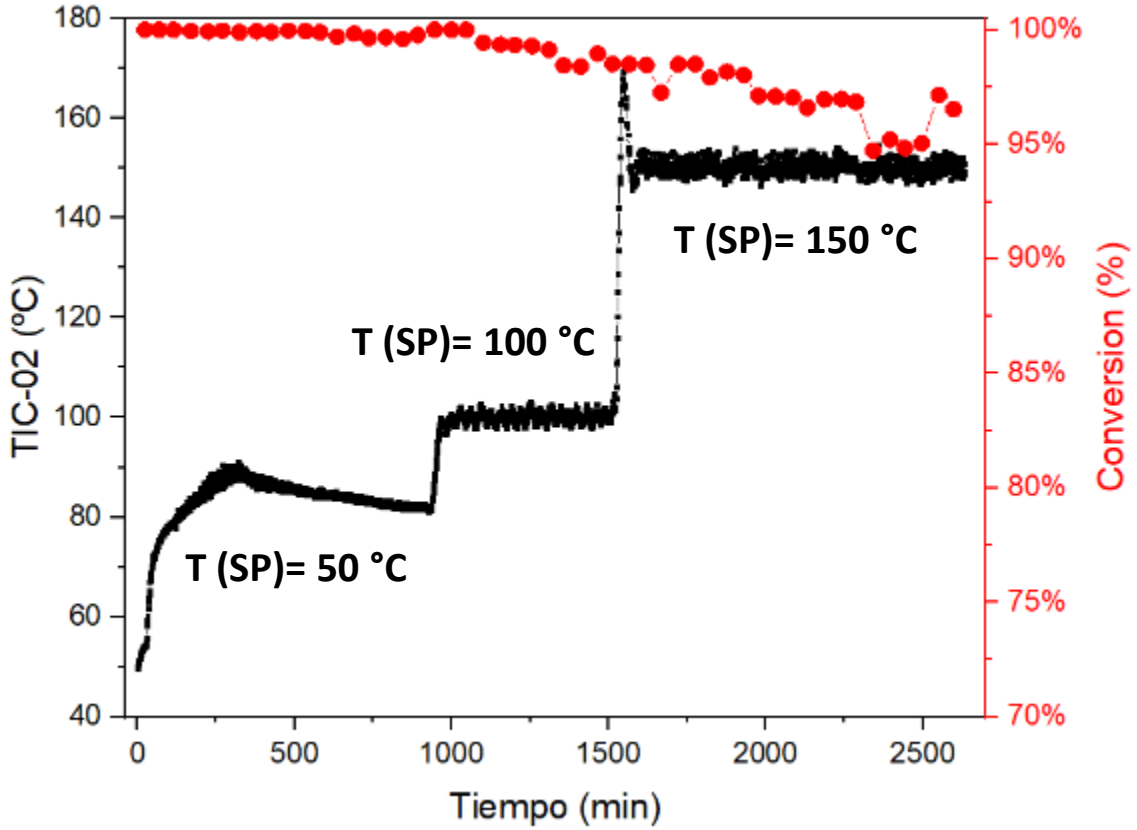
- Higher yield of isobutanol by IMD3 in 2FPU condition –
  - Possible positive effect of enzyme secretion by IMD3
  - Also associated to lower pH by BMD191 at the end of the fermentation

Catalytic tests:

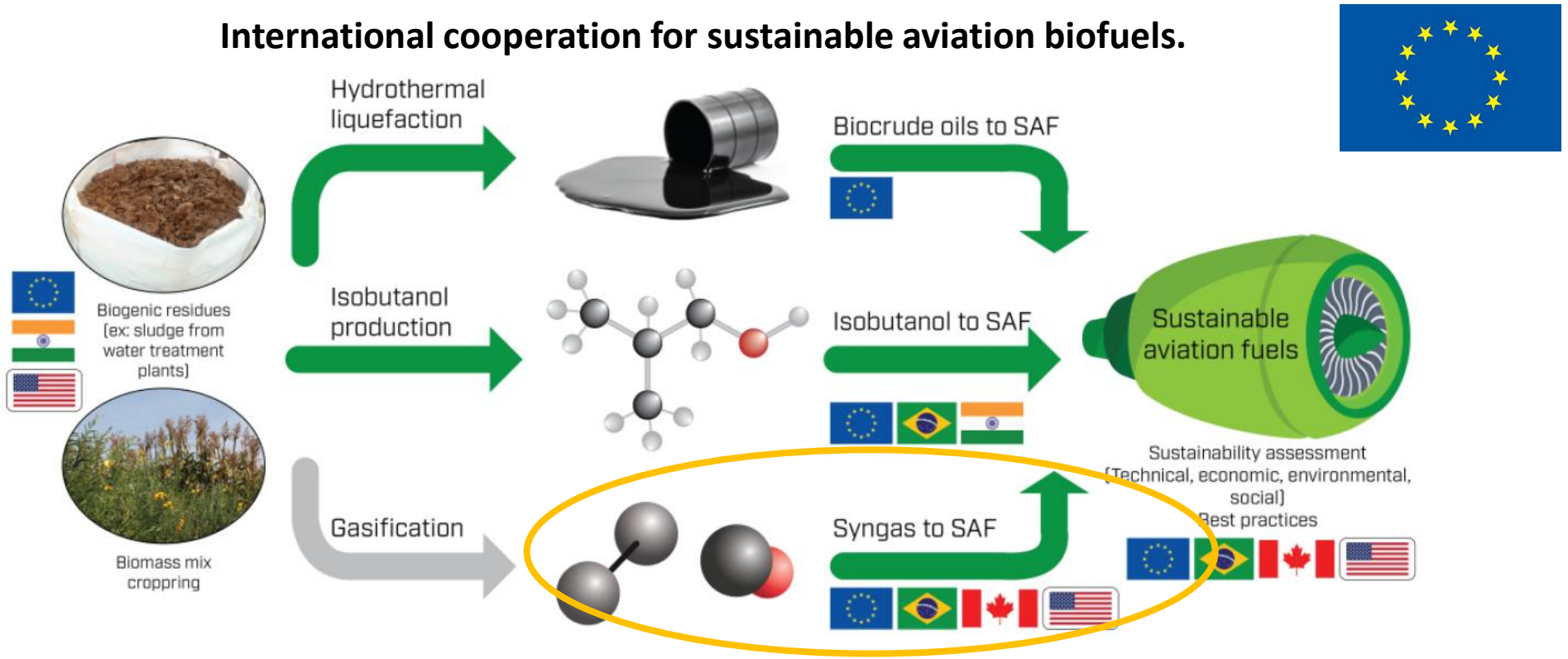
0,50 g of cat., WHSV= 7,0 $g_{isob} \cdot h^{-1} g_{cat}^{-1}$ P_{isob}= 5,7 bar
Pretreatment: 350 °C 1 h with N_2

Sample (from commercial NH_4^+-ZSM-5 (SiO_2/Al_2O_3= 23): Previously calcined at 550 °C, 5 °C/min, isotherm 4 h) → **H-ZSM-5_23** dissolved in silica





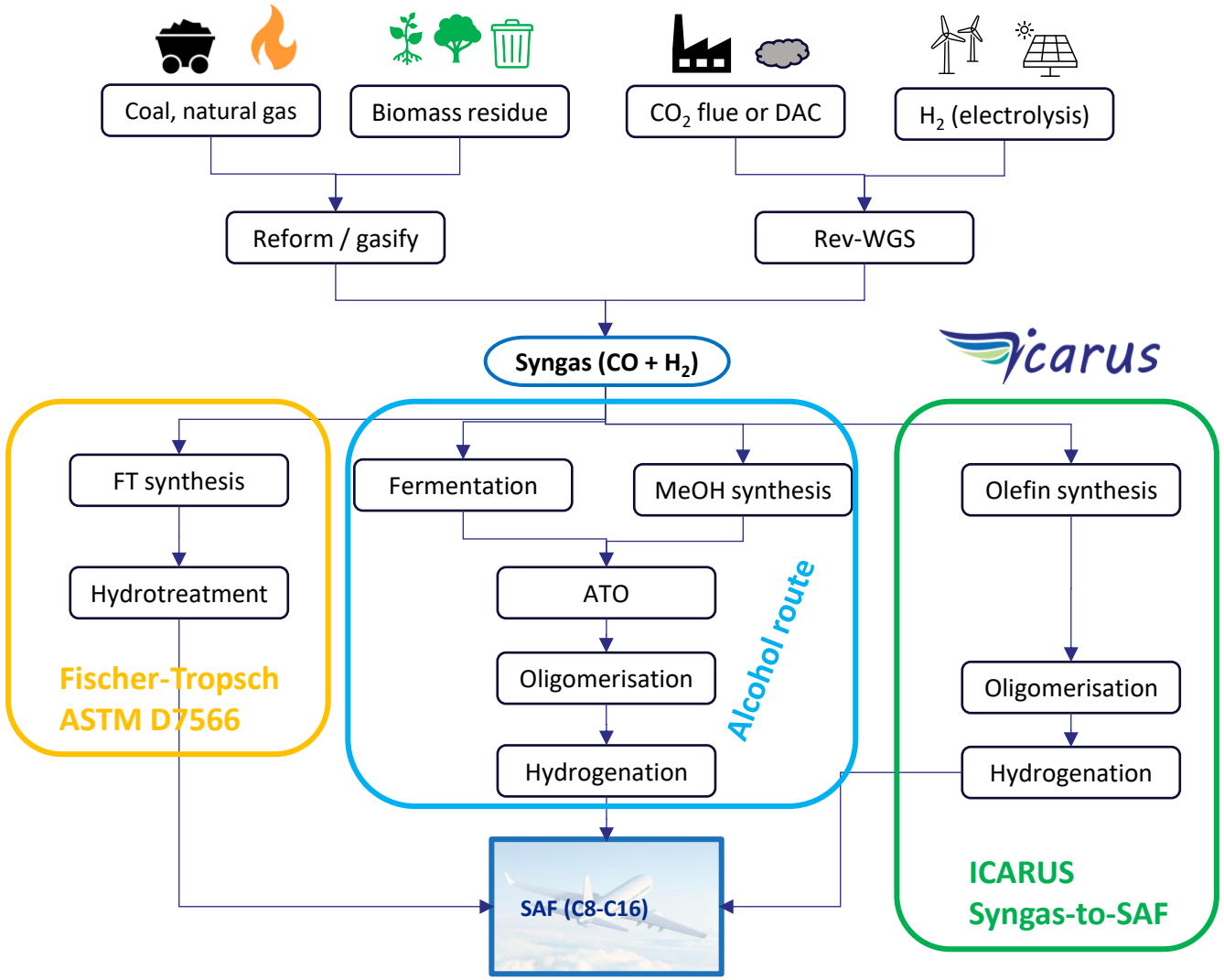
The ICARUS project



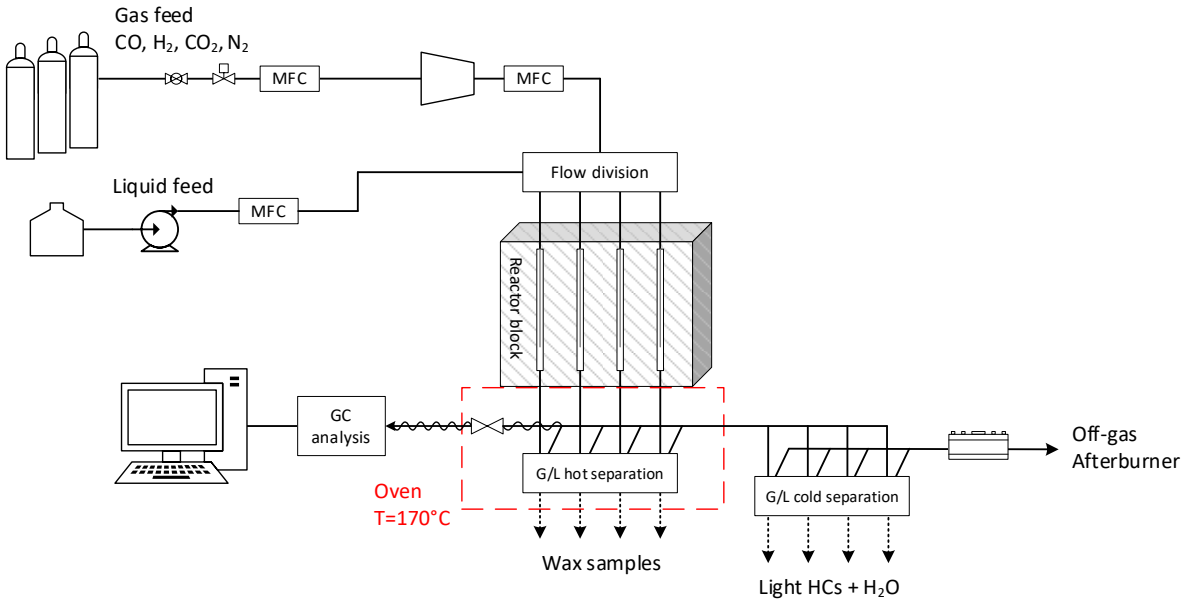
Aim: "Accelerate the deployment of three SAF production pathways by focusing on key technologies that currently limit their scalability."

Syngas-to-SAF overview

- Fischer-Tropsch ASTM D7566 approved
  - Large scale, still fossil based, SAF as co-product
- MeOH route MtJ under ASTM approval
  - Exxon/UOP/Topsoe in lead
  - MeOH and MeOH-to-olefins established processes
  - Oligomerisation of C_2-C_3 olefins challenging compared to higher olefins (still low TRL to SAF)
- Direct olefin synthesis intermediary system identified as promising
  - Direct olefins from syngas
  - Low C_2-C_3 olefins for more facile oligomerisation

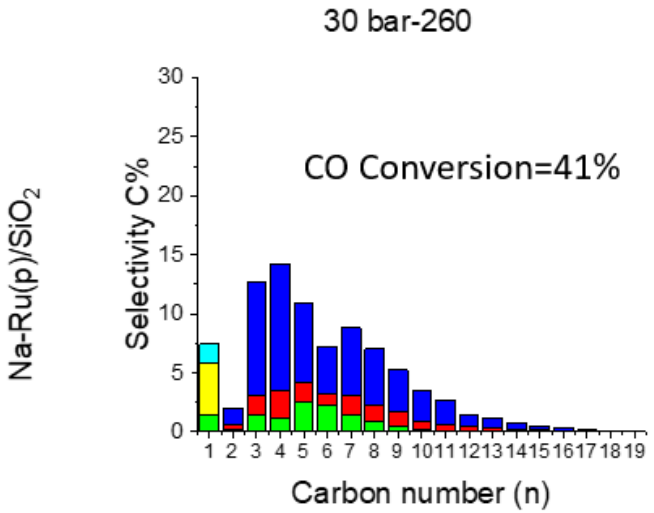


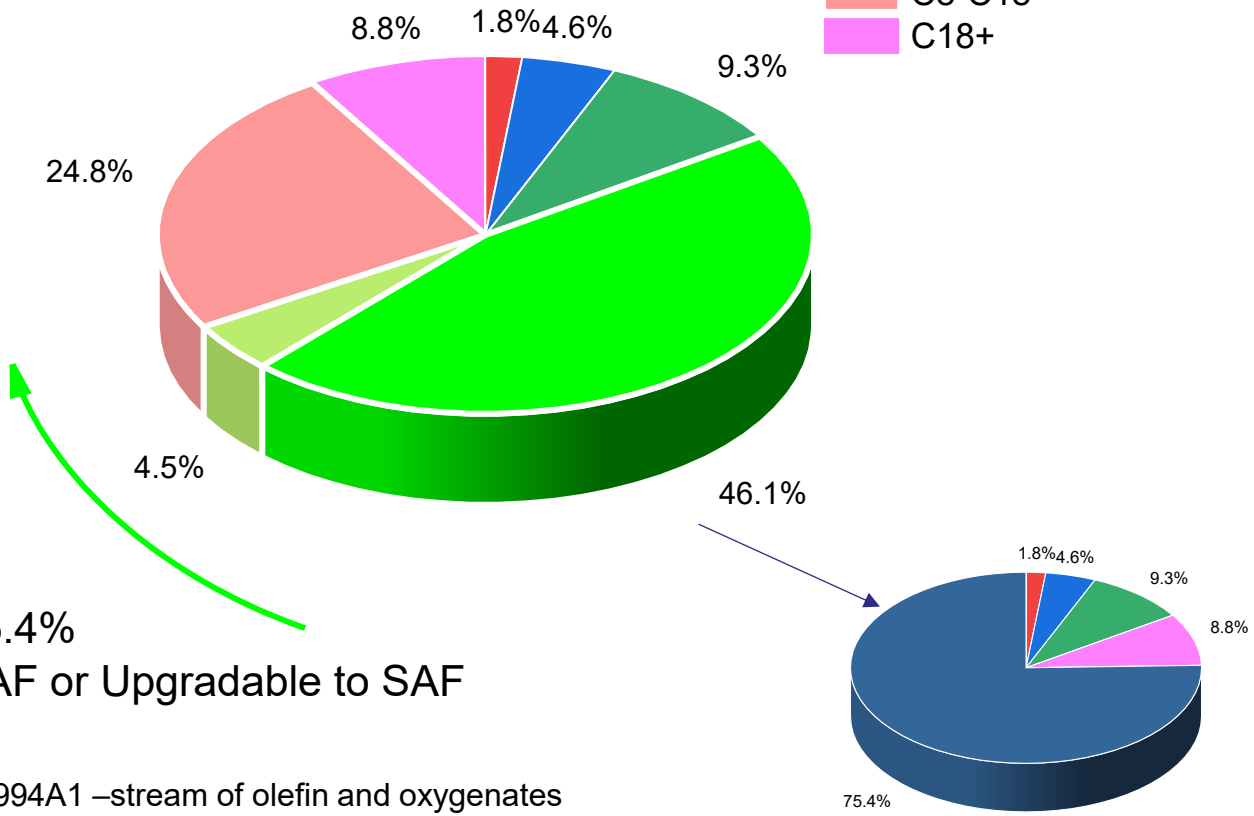
Reactor system



- 4 isothermal fixed bed (FT) reactors, ca. 1 g catalyst per reactor
- Up to 100 bar, 600 °C, 4-200 g/h gas feed, 10 g/h liquid feed (MeOH/water design)
- **Online GC hot gas analysis (syngas, C1-C6, incl. alcohols olefins)**
  - Collected liquid product offline GC-MS/FID, HPLC, other physicochemical

Product distribution

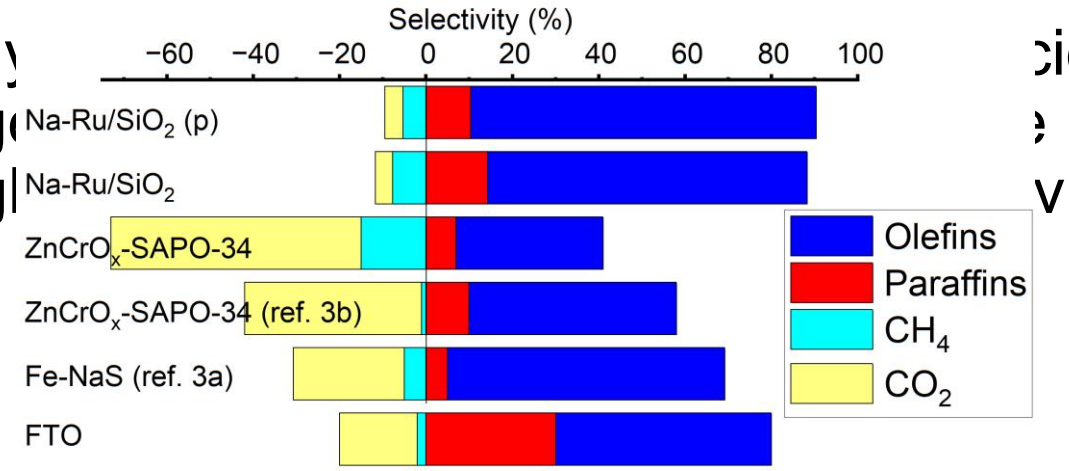




*Patent by Haldor Topsøe A/S-WO2022063994A1 –stream of olefin and oxygenates can be upgraded to jet fuel.

STO compared

- Selectivity comparison between the different syngas-to-olefin catalytic systems
- Na-Ru demonstrates high olefin selectivity at low WGS and C_1 formation
  - Additionall cid-catalysed oligom. to SAF (oxyg e minimal at low P though hig vity)

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RESEARCH ARTICLE | November 15, 2024

Optimization of Sustainable Aviation Fuel Production through Experiment-Driven Modeling of Acid-Catalyzed Oligomerization

Florent J. Dubray, Vladimir Paunovic, and Jeroen A. van Bokhoven*

"To maximize SAF-range products, a feed composed of C_4 and C_5 olefins is most desirable, while controlled C_3, C_6, and C_7 olefin cofeeding and C_4/C_5 olefin feed ratio are required to finely tune the SAF product composition. "

Reference for the graph: 3-a) Nat. Commun. 13, 5987 (2022) **b)** Science 351, 1065–1068 (2016)

Innovations drive change

- Novel pathways SAF are not automatically cleared to be called SAF.
- But Novel pathways are needed to achieve SAF mandates in the future
- Certification is therefore important already at an early stage

- Good to keep in mind other outlets for your products, which allow a business case development on the road to SAF

Thank you

Partners

Associated Partners

ICARUS has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement no. 101122303

Understanding SAF Certification: EU RED, CORSIA and Voluntary Schemes

George Deslandes, RSB

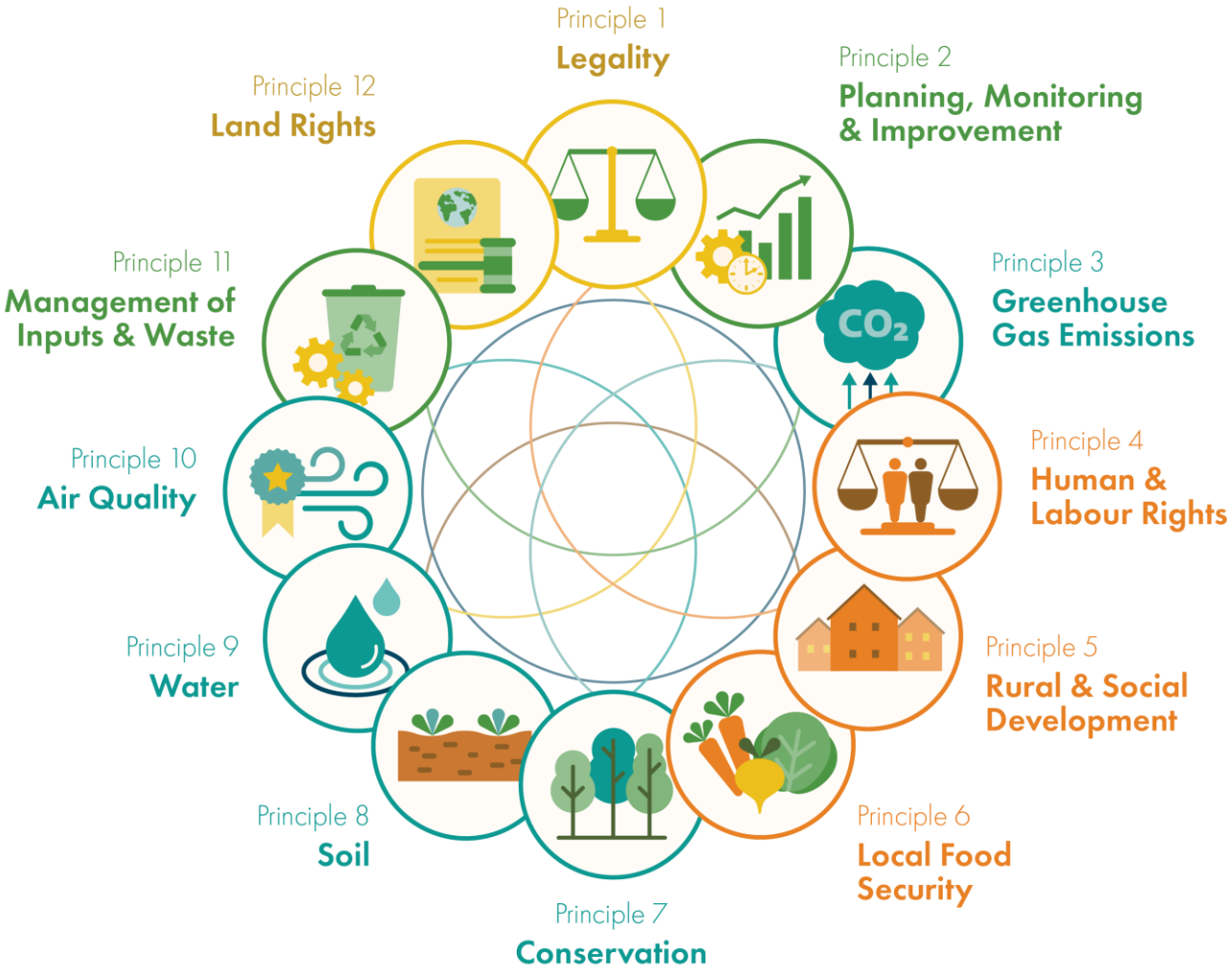
Certification lead

The world we are trying to create

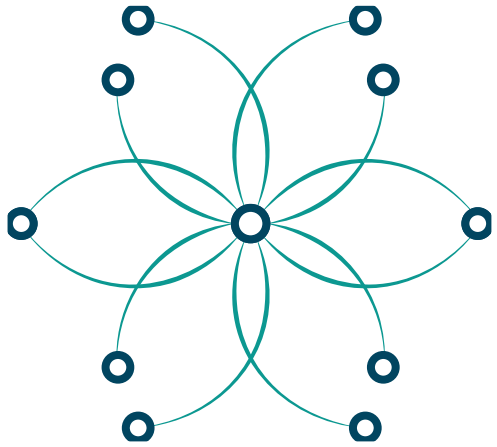
RSB is a collaborative network that works together to *ACCELERATE* the transformation to a sustainable circular and bio-based economy

where climate change has been mitigated, ecosystems have been restored and livelihoods have been enhanced

Holistic approach to support creating a positive impact



Our mission



To advance the just and sustainable transition to a net-positive world, in collaboration with global partners from industry, civil society, policymakers and academia.

Our activities

Certification

Providing clarity on what good looks like

Programmes

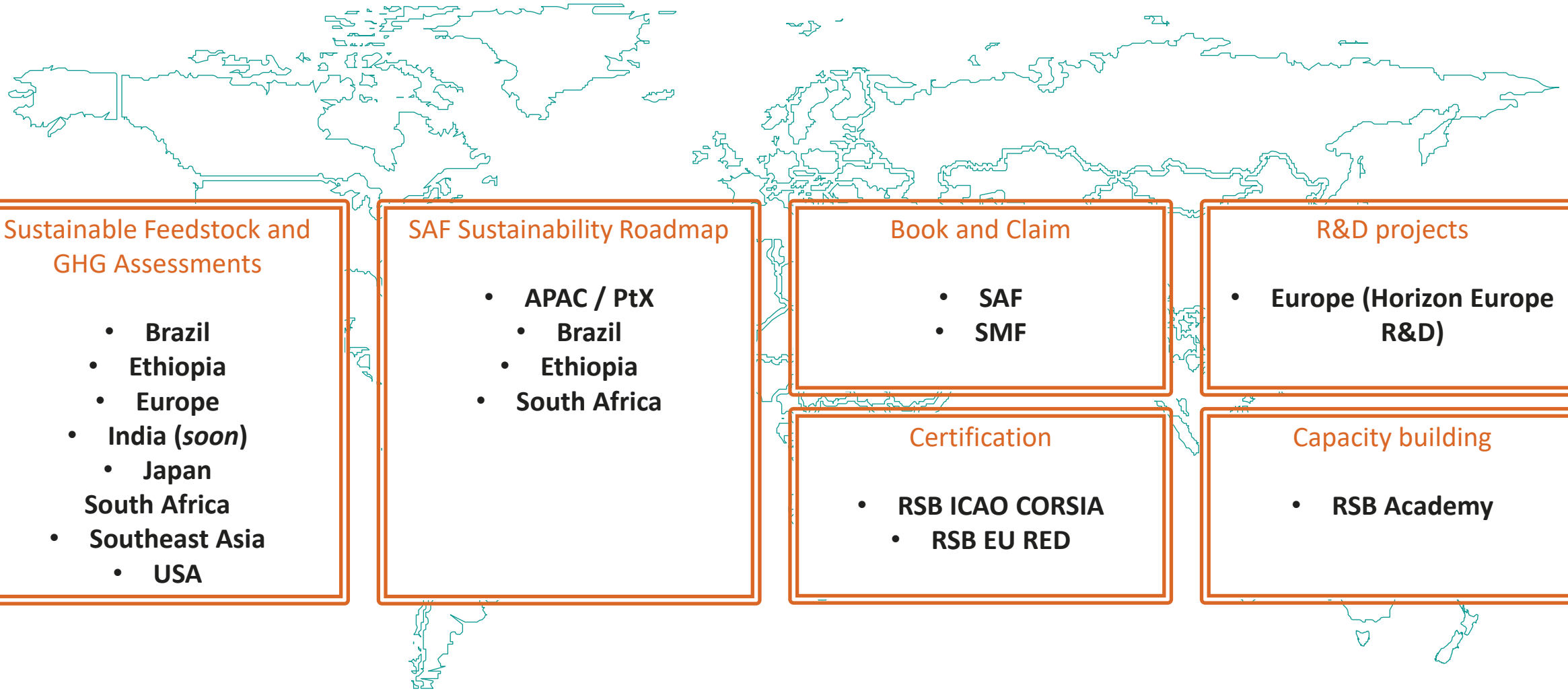
Building capability to make change happen

Community

Enabling collaboration for greater impact

Our global membership is highly diverse
A wide range of organisations across supply chains, regions and industries

RSB: Supporting the transition to sustainable industries



Sustainable Feedstock and GHG Assessments

- Brazil
- Ethiopia
- Europe
- India (*soon*)
- Japan

South Africa

- Southeast Asia
- USA

SAF Sustainability Roadmap

- APAC / PtX
- Brazil
- Ethiopia
- South Africa

Book and Claim

- SAF
- SMF

R&D projects

- Europe (Horizon Europe R&D)

Certification

- RSB ICAO CORSIA
- RSB EU RED

Capacity building

- RSB Academy

SAF Certification

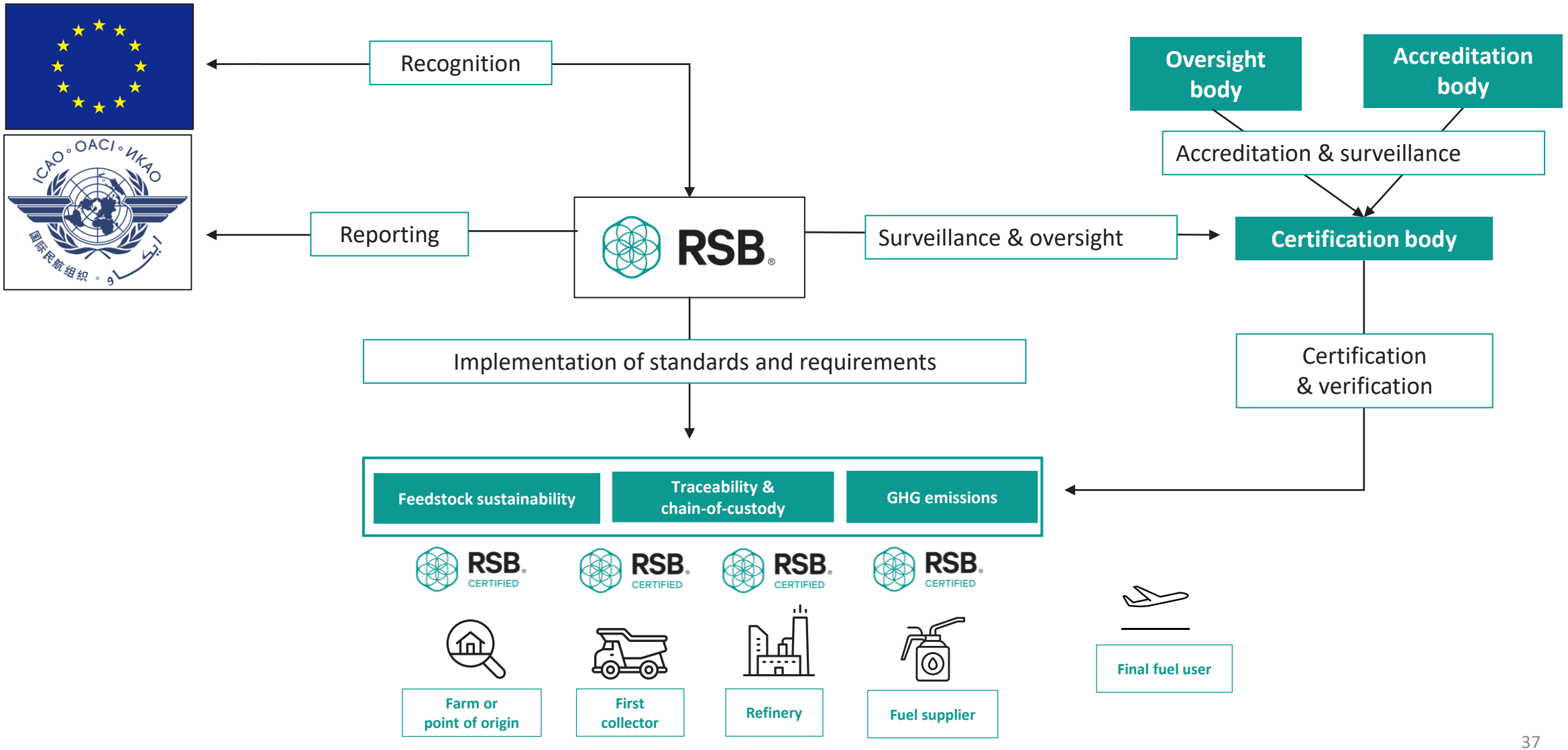
SAF Certification Schemes

	RSB Global Fuels & Advanced Products	RSB EU RED	RSB CORSIA
Sustainability requirements	RSB Principles and Criteria		
Type of claim	Voluntary	Regulatory; linked to EU RED targets	Regulatory; linked to ICAO CORSIA targets
Scope	Fuels and materials produced from biocircular feedstock	Renewable fuels and energy produced with bio-based feedstock and RCF/RFNBOs	SAF from bio-based feedstock and waste gases
Renewable input allocation	Across all outputs, based on energy or economic value. Flexible attribution options.	Across all outputs, based on energy value (LHV).	Across all outputs, based on energy value (LHV).
GHG reduction threshold	Fuel: 50% (60% after 2015) Products: 10%	60% (65% after 2021) RCF/RFNBO: 70%	50% core LCA (10% LCA+ILUC)
Fossil baseline	Fuel: 90g CO2e/MJ Products: fossil comparator	94g CO2e/MJ RCF/RFNBO:	89g CO2e/MJ
Book and claim allowed?	Yes	No	No

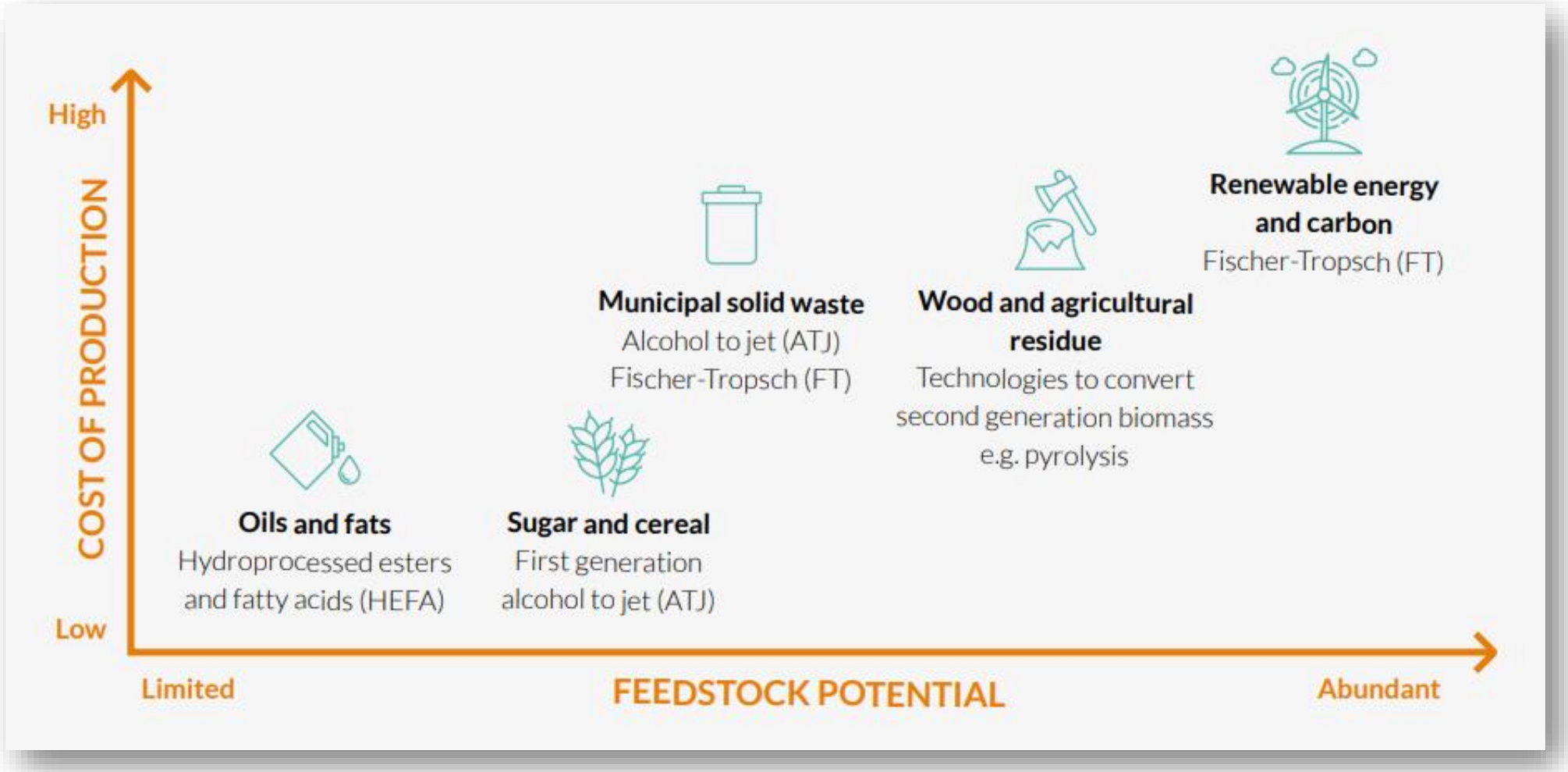
Pillars of sustainability certification

Management system	▪ **Clear responsibilities of staff pertaining to all relevant RSB requirements** (e.g. record keeping, GHG calculation, forwarding of sustainability documents) ▪ **Yearly internal audit** conducted and results kept for check by auditor ▪ **Written commitment by Management** to comply with relevant rules
Sustainability	▪ **Meet the RSB 12 Principles and Criteria – Industrial and Agricultural sites** ▪ Meet social, legal & rights-based, environmental and management practices for sustainable production in a bio-based supply chain
GHG emissions calculation	▪ **Availability, completeness and correctness of GHG calculation** ▪ Appropriate use of **emission factors** ▪ **Correct indication of GHG emission value on sustainability documents** (e.g., on Proof of Sustainability)
Traceability and chain of custody system	▪ **Record of documentation** (e.g. Proofs of Sustainability documents, delivery documents, contracts, weighbridge tickets, etc.) ▪ Fit-for-purpose **traceability and mass balance system**

SAF certification ecosystem



Main feedstock families



Source: BP (April 2023), "How all sustainable aviation fuel (SAF) feedstocks and production technologies can play a role in decarbonizing aviation"

What feedstock pathways are eligible under EU RED?

Annex IX Part A	Annex IX Part B
Feedstocks that can be processed into biofuels, or biogas for transport, with "advanced technologies"	Feedstocks that can be processed into biofuels, or biogas for transport, with "mature technologies"
E.g. algae, biomass fractions of MSW, and other waste-based feedstocks not fit for food or feed.	E.g. UCO and animal fats
No cap	1.7% cap (can be modified by Member States)

Category in Annex IX to Directive (EU) 2018/2001	Feedstock sub-category/examples
Annex IX Part A d)	Drink waste
Annex IX Part A d)	Fruit/vegetable residues and waste (Only tails, leaves, stalks and husks)
Annex IX Part A d)	Bean shells, silverskin, and dust: cocoa, coffee
Annex IX Part A p)	Shells/husks and derivatives:, soy hulls
Annex IX Part A d)	Residues and waste from production of hot beverages: spent coffee grounds, spent tea leaves
Annex IX Part A d)	Dairy waste scum
Annex IX Part A d)	Food waste oil: oil extracted from waste food from industry
Annex IX Part A d)	Non-edible cereal residues and waste from grain milling and processing: wheat, corn, barley, rice
Annex IX Part A d)	Olive oil extraction residues and waste: olive stones
Annex IX Part A p)	Agricultural harvesting residues
Annex IX Part A q)	Palm fronds, palm trunk
Annex IX Part A q)	Damaged trees
Annex IX Part A p)	Unused feed/fodder from ley
Annex IX Part B b)	Waste fish oil classified as categories 1 and 2 in accordance with Regulation (EC) No 1069/2009.
Annex IX Part A d)	Other slaughterhouse waste (Animal residues (non-fat) Cat 1)
Annex IX Part A d)	Industrial wastewater and derivatives
Annex IX Part A g)	Palm sludge oil (PSO)
Annex IX Part A d)	Industrial storage settlings
Annex IX Part A d)	Biogenic fraction of end-of-life tyres
Annex IX Part A q)	Recycled/waste wood
Annex IX Part A d)	Humins
Annex IX Part A d)	Spent bleaching earth

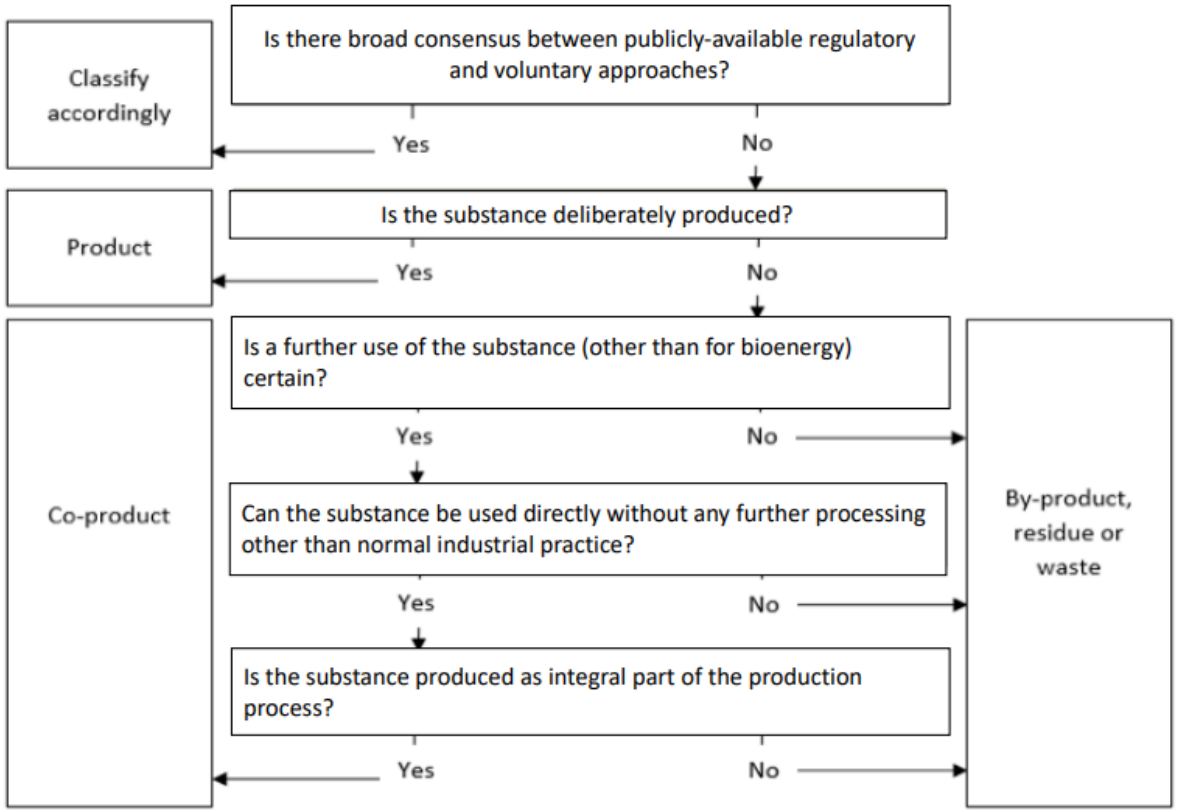
Source: RSB EU RED Standard for Advanced Fuels– RSB-STD-11-001-01-010 Version 2.0

What feedstock pathways are eligible under CORSIA?

List of CORSIA-eligible waste & residues

Residues	Wastes	By-products	Co-products
Agricultural residues:	Municipal solid waste (see details in Section 4.2.2)	Palm Fatty Acid Distillate	Molasses
Bagasse	Used cooking oil	Beef Tallow	
Cobs	Waste gases	Technical corn oil	
Stover		Non-standard coconuts (see details in Section 4.2.3)	
Husks		Poultry fat	
Manure		Lard fat	
Nut shells		Mixed Animals Fat	
Stalks			
Straw			
Forestry residues:			
Bark			
Branches			
Cutter shavings			
Leaves			
Needles			
Pre- commercial thinnings			
Slash			
Tree tops			
Processing residues:			
Crude glycerine			
Cobs			
Forestry processing residues			
Empty palm fruit bunches			
Palm oil mill effluent			
Sewage sludge			
Crude Tall Oil			
Tall oil pitch			
Wheat Starch Slurry (see details in Section 4.2.1)			

CORSIA product classification decision tree



Source: CORSIA Methodology For Calculating Actual Life Cycle Emissions Values, Oct 24

Feedstock Classification - CORSIA

Primary and co-products

Main products of a production process. These products have significant economic value and elastic supply.

Must comply with the CORSIA Sustainability Criteria.

By-products

Secondary products with inelastic supply and economic value (e.g. tallow, corn oil).

Residues

Secondary materials with inelastic supply and little economic value (e.g. agricultural residues, like sugarcane bagasse).*

Waste

Materials with inelastic supply and no economic value. A substance that will be discarded or required to be discarded (e.g. UCO).*

* Must be *genuine* waste/residues, included in the ICAO CORSIA positive list.

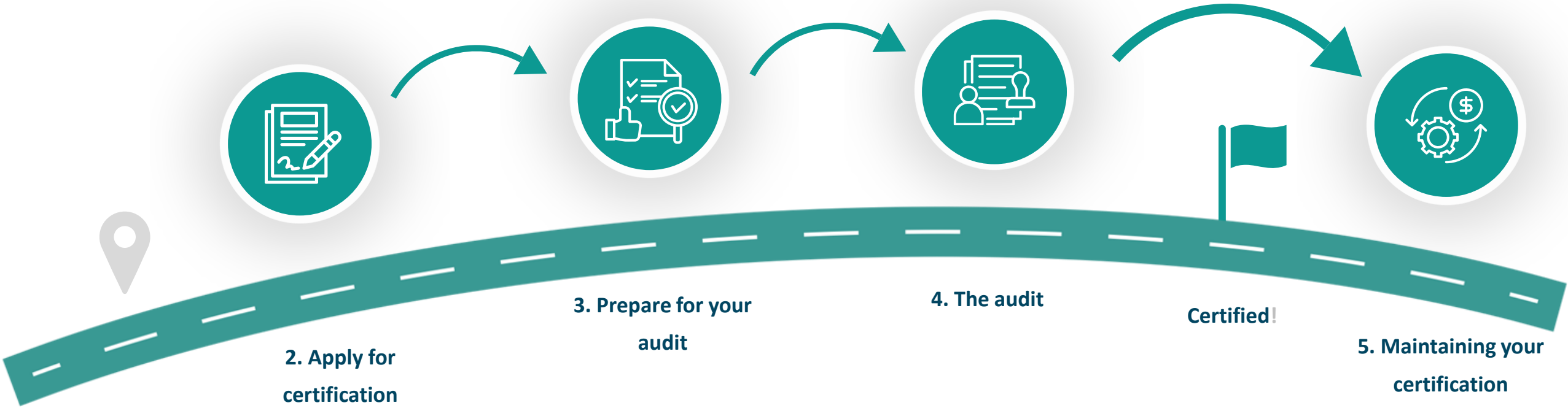
Sustainability Themes: CORSIA and EU RED

GHG	CORSIA SAF = 10% reduction EU RED = 65% reduction	**RSB Principle 3**
Carbon stock	CORSIA and EU RED SAF should not be made from biomass obtained from land with high carbon stock.	**RSB Principle 7**
Water	Production of CORSIA SAF should maintain or enhance water quality and availability	**RSB Principle 9**
Soil	Production of CORSIA SAFs should maintain or enhance soil health.	**RSB Principle 8**
Air	Production of CORSIA SAF should minimise negative effects on air quality	**RSB Principle 10**
Conservation	Production of CORSIA SAF should maintain biodiversity, conservation value & ecosystem services.	**RSB Principle 7**

CORSIA themes

Waste & chemicals	Production of CORSIA SAF should promote responsible management of waste and the use of chemicals.	**RSB Principle 11**
Human rights	Production of CORSIA SAF should respect human and labour rights.	**RSB Principle 4**
Land-use rights	Production of CORSIA SAF should respect land rights and land use rights including indigenous and/or customary rights.	**RSB Principle 12**
Water-use rights	Production of CORSIA SAF should respect prior formal or customary water use rights.	**RSB Principle 9**
Local development	Production of CORSIA SAF should contribute to social and economic development.	**RSB Principle 10**
Food security	Production of CORSIA SAF should promote food security in food insecure regions.	**RSB Principle 6**

Certification Journey



1. Define your RSB Certification scope
2. Apply for certification
3. Prepare for your audit
4. The audit
5. Certified!
6. Maintaining your certification

- Annual audits depending on your risk-class

From Innovation to Certification: Insights from the SusAlgaeFuel Project

Darren Carty, SFS Ireland

Agnes Thornton, SFS Ireland

SusAlgaeFuel

SFS Ireland

Piloting a Pathway to Net-Zero

ICARUS Webinar
Case Study Presentation

Darren Carty

Agnes Thornton

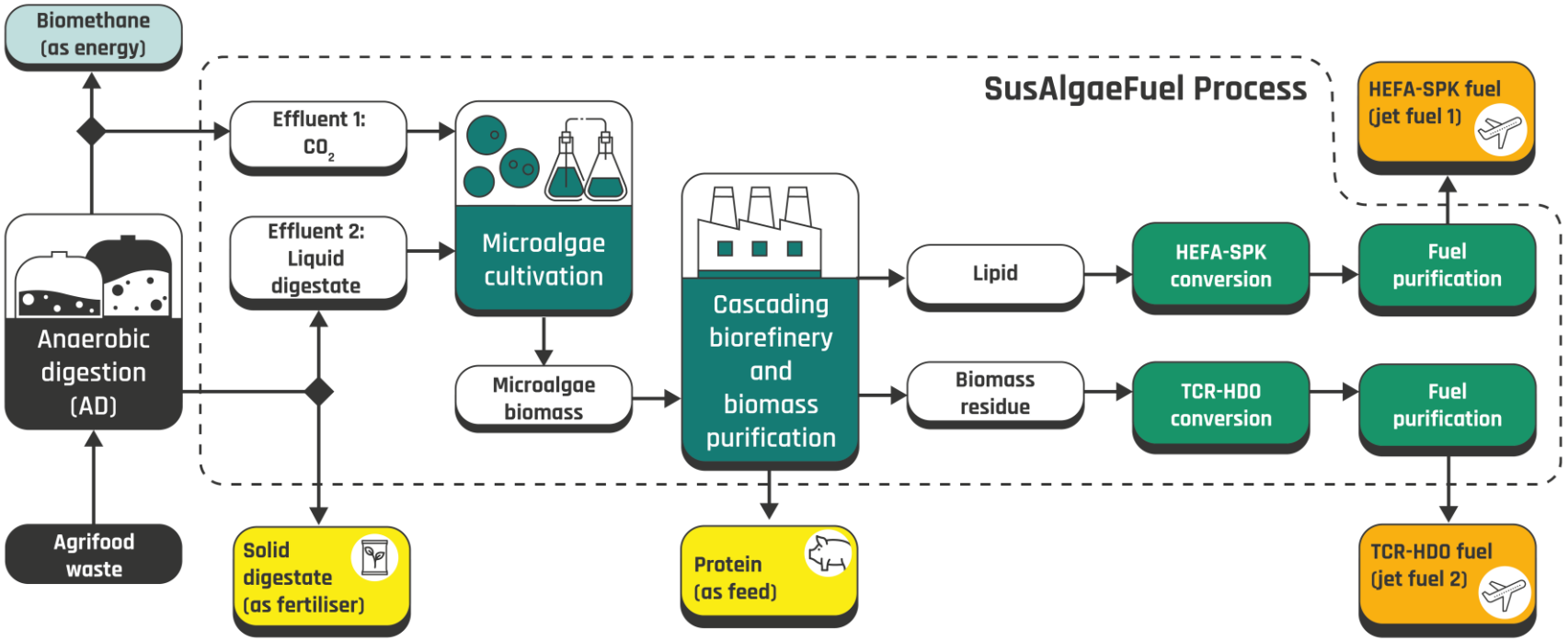
SFS Ireland

25.09.2025

SusAlgaeFuel Project Summary

Objectives:

Developing Innovative and sustainable processes for producing microalgae-based sustainable aviation fuels (SAFs).



✓ **Innovate across multiple stages of the microalgae value chain**

✓ **Cost-competitive and Sustainable SAF**

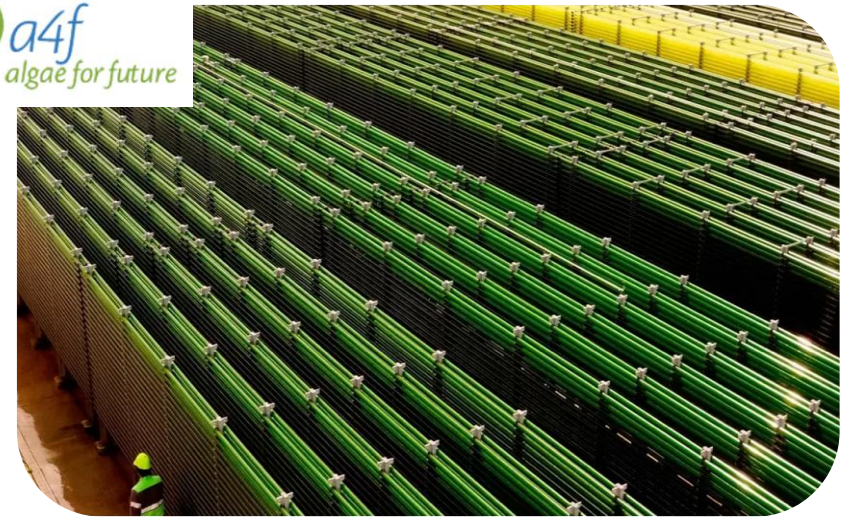
✓ **Create a synergistic relationship between anaerobic digestion by-products and microalgae cultivation**

Funded by the European Union under grant agreement number 101147601

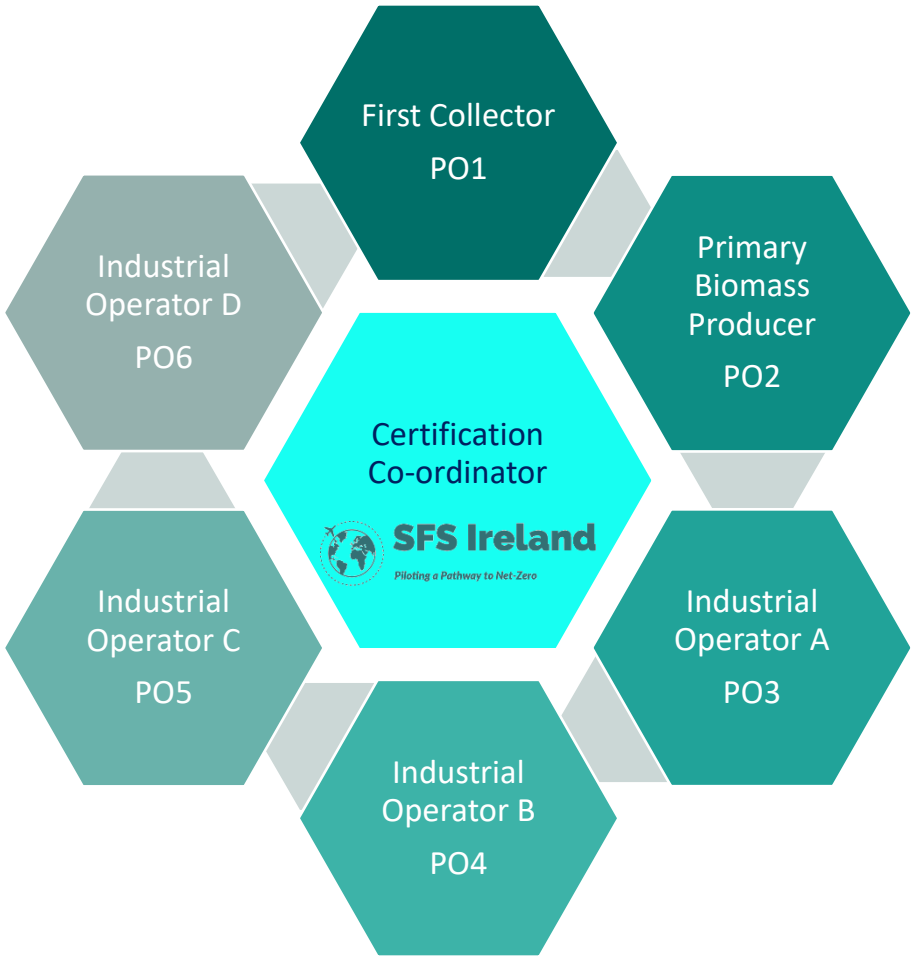
SusAlgaeFuel Project Summary

Objectives:

Developing Innovative and sustainable processes for producing microalgae-based sustainable aviation fuels (SAFs).



Our Role in the Project



- S-LCA & S-LCA Optimisation
- Fuel Certification Assessment
- Stakeholder Management
- COMs & Industry Engagement

Funded by the European Union under grant agreement number 101147601

RSB EU RED Roadmap for SusAlgaeFuel

Next Steps:

Stakeholder Engagement

Funded by the European Union under grant agreement number 101147601

Our project Toolset

SFS Ireland

Piloting a Pathway to Net-Zero

Social Assessment

(S-LCA)

United Nations - Guidelines for social life cycle assessment of products

S-LCA Database

PSILCA v4

SFS Team Expansion

Environmental Assessment

(S-LCA)

Open LCA

Custom full S-LCA modelling

Enviro Database

RSB Tools / US GREET / Canadas Fuel LCA …

SAF Certification Project Management

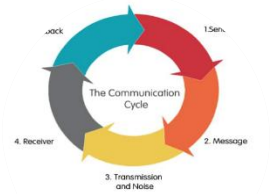
QMS – ISO 9001

Bespoke SAF-C QMS

RSB Procedures & Standards

Certification Bodies

Project Management- ClickUp



Stakeholder Management & Communication

Aviation Industry Network

Government Engagement

RLCF and ACT-SAF Member

SAF Feasibility study & Project Scaling/Funding

SFS Team

Finance & Leasing Industry

Previous Experience

Fund Applications

SAF Ireland Feasibility Study

Thank you

Darren (S-LCA) Darren@sustainableflightsolutions.com

Agnes (STKH Management) Agnes@sustainableflightsolutions.com

SFS Ireland

Piloting a Pathway to Net-Zero

SusAlgaeFuel

The ICARUS SAF Certification Guidance

Esther Hegel, RSB

ICARUS Project Partner

ICARUS DELIVERABLE

“Sustainability Certification Guidance for Novel SAF Pathways“

- Goal: Provide practical guidance to make sustainability certification transparent, usable, and integrated early in R&D for novel SAF pathways.
- Audience: Researchers, technology developers, and project partners working on new feedstocks and production routes.
- Scope: Explains certification basics, compares major schemes (CORSIA, EU RED, voluntary), and offers step-by-step guidance on criteria, LCA, chain-of-custody, and scheme-specific rules.

Scope of the guidance (tentative outline):

- **SAF certification basics:** ASTM vs. sustainability certification and why both are needed.
- **Certification schemes explained**: Overview of CORSIA, EU RED, and major voluntary schemes.
- **Practical guidance for R&D projects**: Feedstock eligibility, sustainability criteria, life-cycle assessment basics, chain-of-custody, and scheme selection.
- **Deep-dives into key schemes**: Specific requirements under CORSIA (feedstocks, GHG thresholds, auditing, use in offsetting) and under EU RED (Annex IX, land-use rules, GHG savings, access to incentives).

ICARUS Guidance Development Timeline

1. WEBINAR

September 2025

Main topics: Introduction to SAF certification, presentation of goal & scope of the ICARUS guidance, stakeholder feedback

2. WEBINAR

July 2026

Presentation & feedback of the final guidance document

GOAL & SCOPING

March – September 2025

Drafting of goal and scope of the guidance document including pathways, certifications and standards, the main target group and broader applicability of the guidance.

FROM DRAFT TO FINAL

September 2025 – July 2026

Guidance development:

- Refinement of goal & scope
- Exchange with external experts and related projects
- Certification case studies

FINAL GUIDANCE

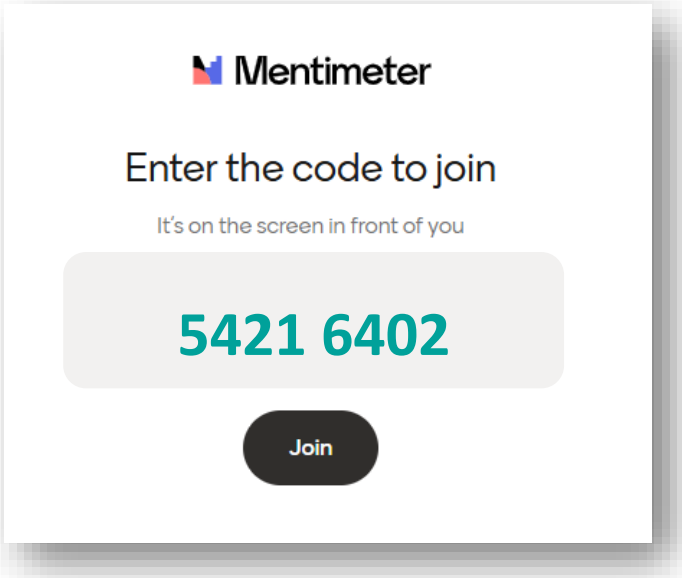
September 2026

The guidance for SAF certification will be finalised

Open Discussion & Online Poll

We want to hear from you!

1. Take your phone/computer
2. Scan the QR code OR go to www.menti.com & enter the code: 5421 6402



Open-ended question

What is your biggest challenge or question about SAF certification?

Can this certification proces be simplified?

Lack of understanding about certification requirements.

Scoping the work, costs, timelines. What resources are required specific to the project?

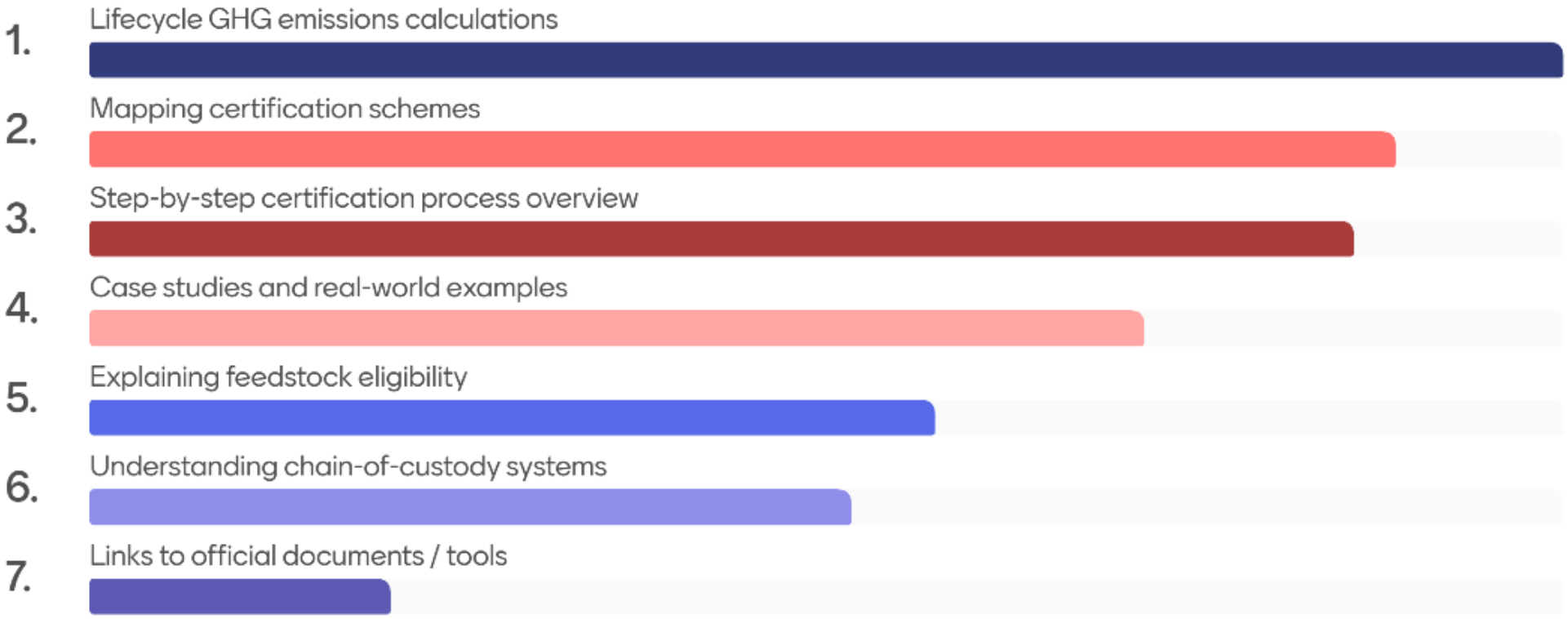
what type of verifiers or auditors is needed?

How transferreable is data from a pilot scale-up to a full commerical scale operation

Lack of detailed understanding around the fuel certification steps and how these link to other voluntary and compliance standards like CORSIA and EU RED

Raking question

What should be the top priority in a certification guidance for new SAF pathways?



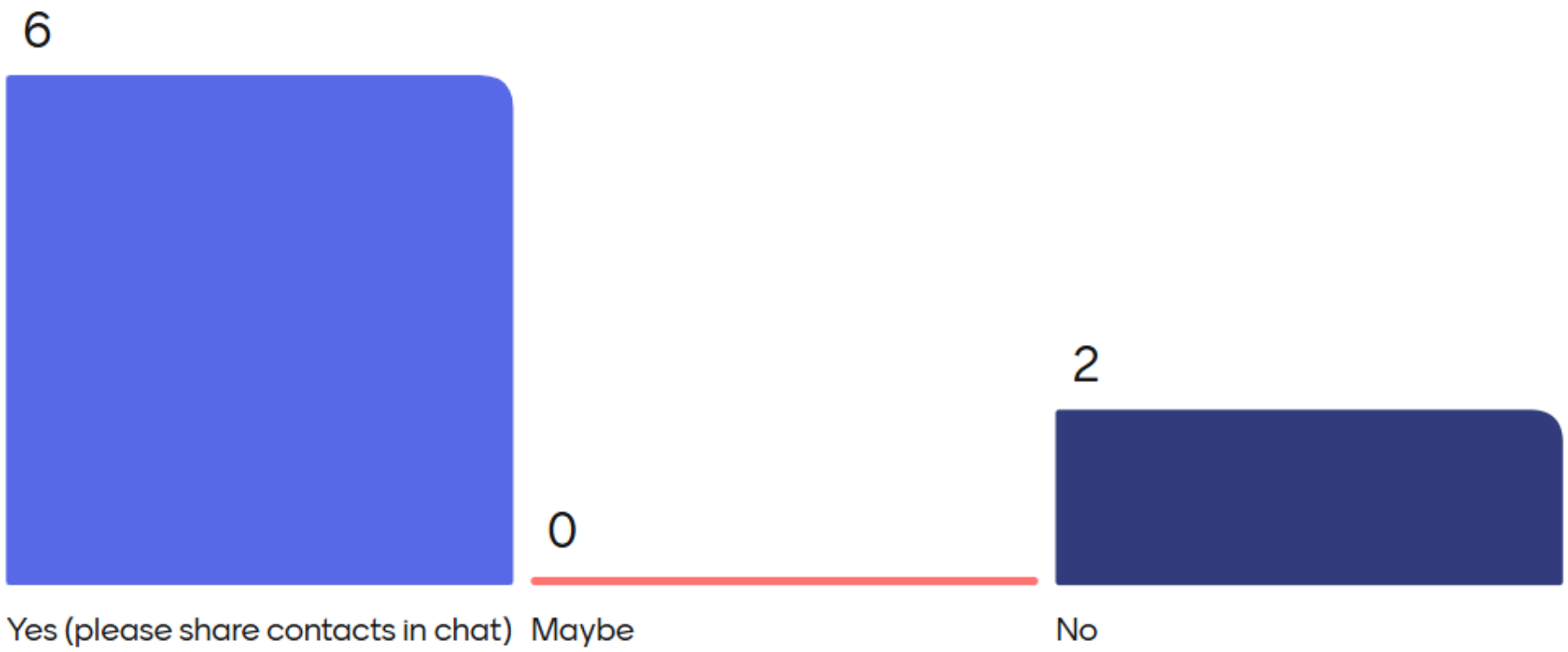
Open-ended question

Which specific novel feedstocks or pathways would you like us to include in the guidance?

- Green methanol to SAF
- BTG pyrolysis of saw dist with upgrading to SAF
- Methanol-to-Jet
- Pyrolysis of waste tyres
- Recycled Carbon Fuels
- Mixed-alcohol to jet
- direct alcohol to olefins pathways
- rfnbo:%20FT%20with%20CO2%20from%20waste%20incineration%20
- AtJ
- Microalgae
- Cassava

Multiple-choice question

Would you be interested in reviewing or contributing to the SAF certification guidance later in the project?



Closing Remarks and Next Steps

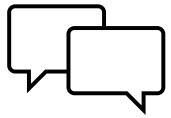
Esther Hegel, RSB

ICARUS Project Partner

Oulook & Closing

- You can access the slides & recordings via the ICARUS website soon!
  → https://www.icarus-biojet.eu/

- Development of **ICARUS Deliverable** on "Sustainability Certification Guidance for Novel SAF Pathways" in 2026 & **Webinar** on final study findings in Q3 2026



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