Innovative Electrochemical CO_2 Conversion to Versatile Feedstock

Frank Kensy (b.fab GmbH)
WaterProof Workshop
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ICO_2NIC project

12 Partners

8 Countries

14 Million €

4 Years (Jan 2025 – Dec 2028)



ICO_2NIC's objectives

Ambition

Enable Net Zero in hard-to-abate process industries by demonstrating an integrated, industrial-scale Carbon Capture and Utilisation (CCU) solution that captures waste CO_2 and converts it into valuable products, making carbon recycling an economically viable route for global emitters.

What ICO_2NIC Delivers

Develop	High-efficiency CO_2 capture and electrochemical conversion to formic acid
Demonstrate	Integrated CCU operation at a cement production facility with real-world product validation
Scale	Techno-economic & life-cycle assessment enabling industrial deployment to 27.6 kt/year formic acid by 2035

ICO_2NIC concept



MEMBRANE-BASED CO_2 CAPTURE

- 95% CO_2 purity from cement production plant
- Low-energy capture (<520 kWh/tCO_2)
- Scalable membrane technology
- Up to 5 ktpa CO_2 captured and purified

ELECTROCHEMICAL CO_2 CONVERSION

- 90% electrical current efficiency
- Integrated electrochemical cell
- CO_2 converted into formic acid (FA)
- 50 tpa FA production

BIOLOGICAL PROCESSING

- Formic acid as a microbial feedstock
- Scaled biological processing (TRL7)
- 1,500–10,000 L bioreactor operation
- Protein-rich microbes and microbial oils

VERSATILE FEEDSTOCK OUTPUT

- Direct FA use in homecare cleaning products
- Protein-rich microbes for sustainable aquafeeds
- Microbial oils as flexible intermediate feedstocks

SUSTAINABLE APPLICATIONS

- Fishmeal replacement in aquaculture
- Drop-in oils for beauty and personal care
- Sustainable aviation fuel (SAF) feedstock
- Fatty acids & surfactants for fabric and beauty care

ICO_2NIC innovation



MEMBRANE-BASED CO_2 CAPTURE

A low-cost PolyActive™-based membrane system with a redesigned block copolymer structure that breaks the traditional permeability–selectivity trade-off, combined with a novel process cycle that prevents free water accumulation to reduce fouling and corrosion.



ELECTROCHEMICAL CO_2 CONVERSION

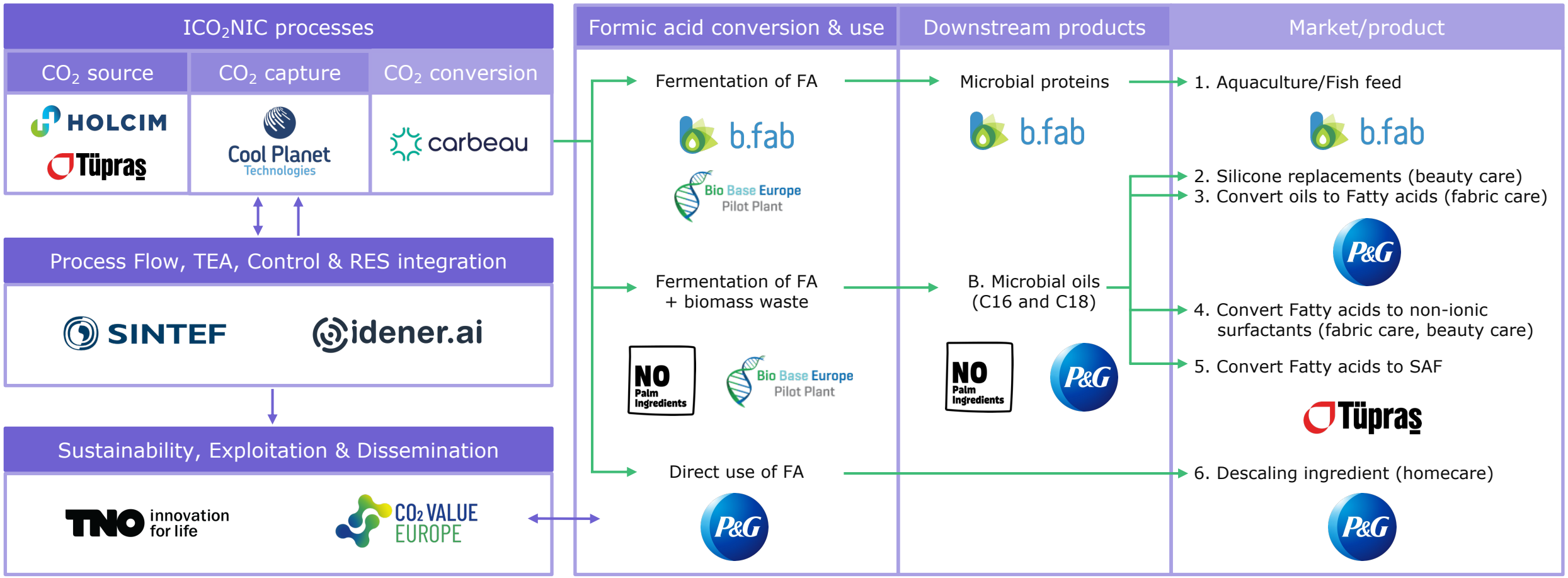
An indium-based GDE technology will be scaled to a 10 × 1 m² active-area cell stack using proprietary designs to overcome scale-up challenges, enabling industrial deployment through parallel stacks, first integration with carbon capture at an industrial site, and generation of data to support robust techno-economic analysis and renewable energy integration.



BIOLOGICAL PROCESSING

Formic acid from industrial CCU will be validated as a fermentation feedstock, enabling scale-up of single cell protein and microbial oil production to ≥1,500 L reactors and supporting end-user validation, commercial feasibility assessment, and investment decisions for industrialisation of integrated value chains.

ICO_2NIC consortium



ICO_2NIC timeline

Phase 1

Industrial requirements & specifications		
Focus on modifying process specifications, product targets and site requirements		Q1 2025 – Q1 2026

Phase 2

Technology development		
a.	**CO_2 capture and purification** Design and delivery of a CO_2 capture and purification plant at Holcim´s Höver Cement plant	Q1 2025 – Q1 2027
b.	**Electrochemical conversion of CO_2 to formic acid** Upgrading and repurposing equipment to integrate CO_2 conversion with the capture plant	Q1 2025 – Q1 2027
c.	**Formic acid conversion** Scale-up of fermentative conversion of formic acid into microbial proteins and oils for downstream applications	Q1 2025 – Q1 2029

Phase 3

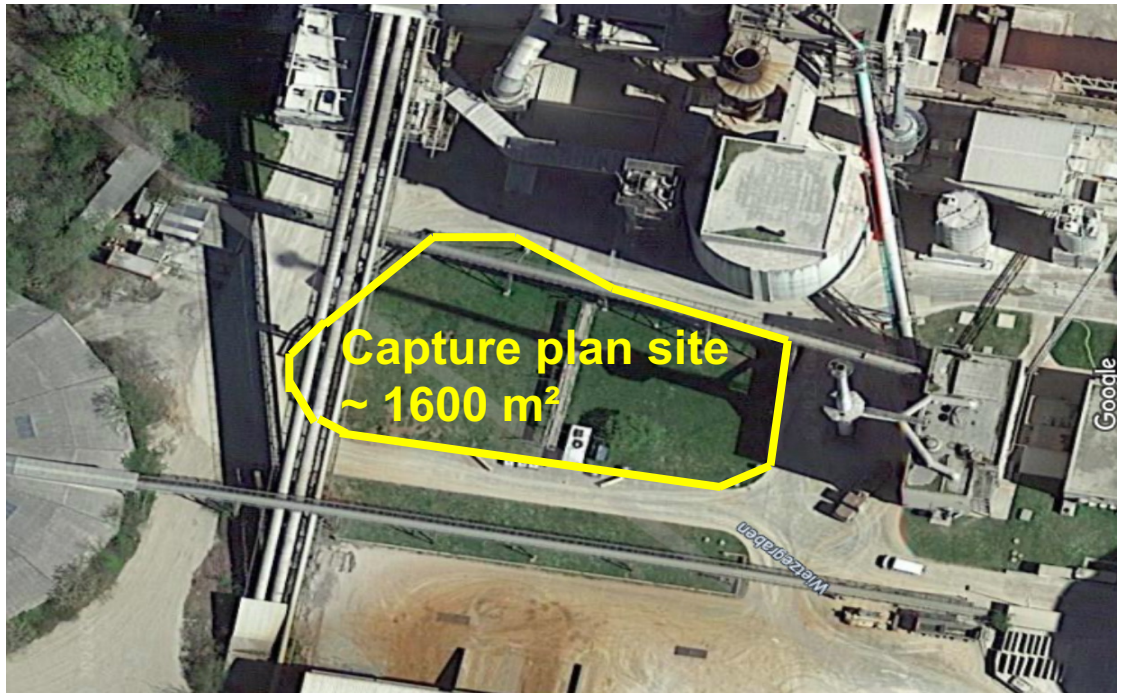
Technology development		
a.	**Downstream product conversion and use** Integration, demonstration, and 12-month monitoring of CO_2 capture and conversion	Q1 2026 – Q1 2029
b.	**Integration and demonstration** Demonstration of downstream products in consumer and feed applications	Q2 2027 – Q1 2029
c.	**Process design, modelling and control** Techno-economic modelling and digital control for optimised ICO_2NIC processes	Q1 2025 – Q1 2029

Status Carbon Capture (WP2)

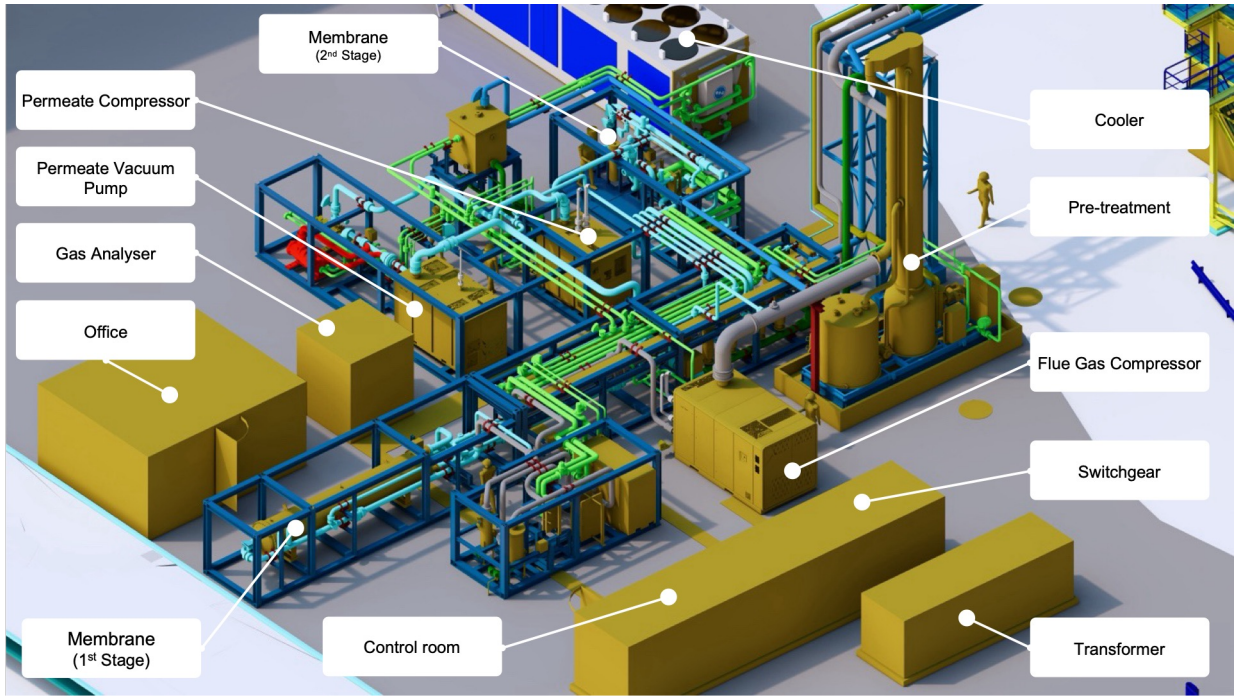
Task 2.2 - Detailed engineering (M18)

Cool Planet Technologies

Location Plan



Plant Layout



(Liquefaction plant not yet included)

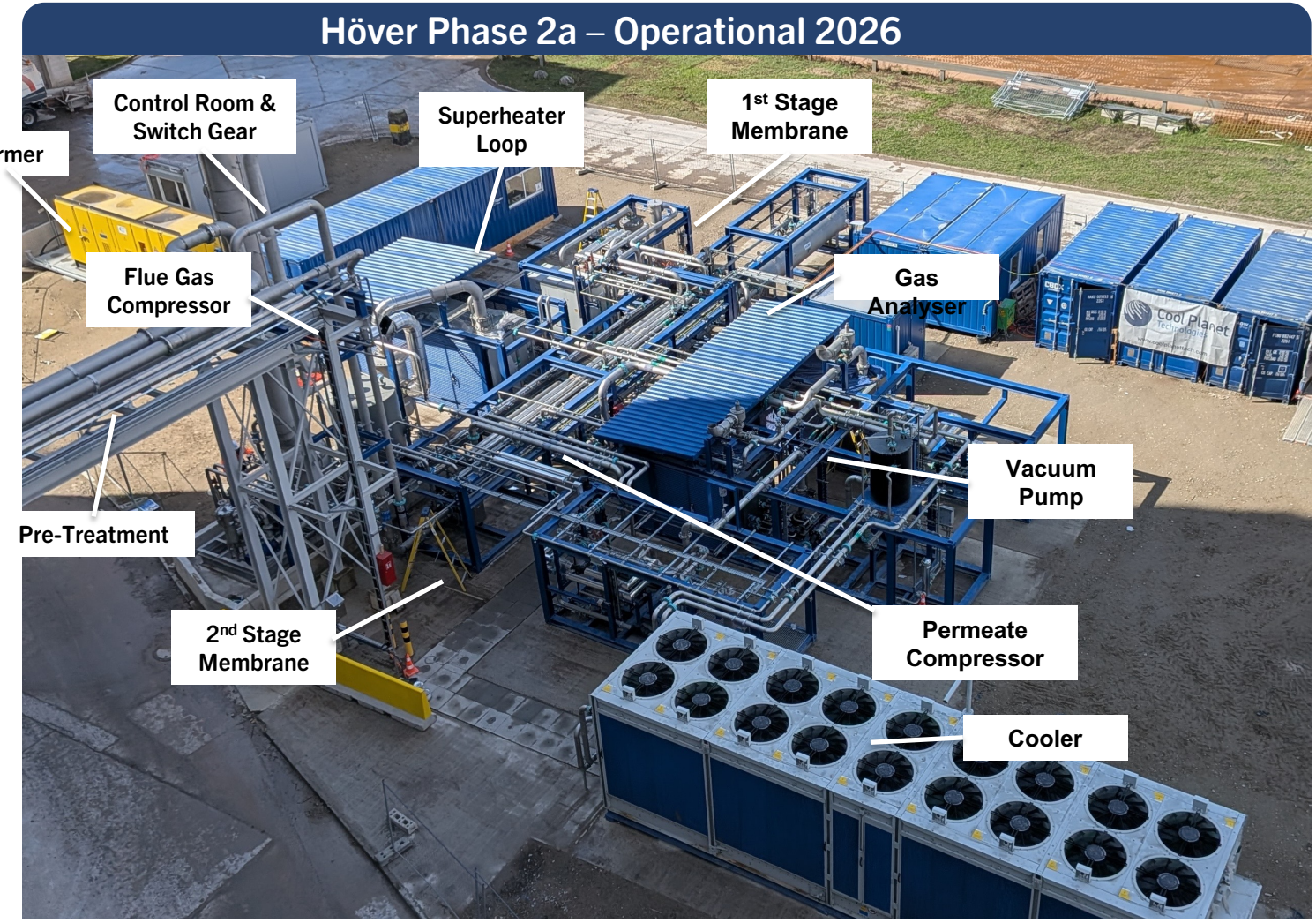
Status Carbon Capture (WP2)

Task 2.2 – Installation and commissioning completed

Objectives

1. Design and build a module housing two cartridges, each containing 491m² of CO_2-selective PolyActive™ membrane (providing ~1,000 m² in total); capable of capturing and purifying up to 5 ktpa* of CO_2 at a 95% purity from cement plant flue gas, containing an average of 13.6% CO_2 by M24 (27).

2. To design, construct, transport and install the CO_2 capture plant at Holcim's Höver cement plant (nr. Hannover, Germany) where it will be connected to the flue gas stream. The capture plant will initially be operated and optimized during M25–30 (28-33) and will then be integrated with the CO_2 conversion process (developed in WP3) in WP6, becoming operational from M30 (33) onwards.



*total capture capacity of up to 5,000 t/year, where approx. 1,800 t/year of CO2 will be directed to liquefaction.

Status Carbon Capture (WP2)

Task 2.3 Procurement of long lead items

CPT will procure the necessary equipment, materials and components for the capture plant, including capture units, compression systems, pipeline and any storage facilities that will be required. Long-lead items will be prioritised and these will be sourced from reputable suppliers and vendors.

- **Liquefaction plant is ordered and will be delivered in 2026**

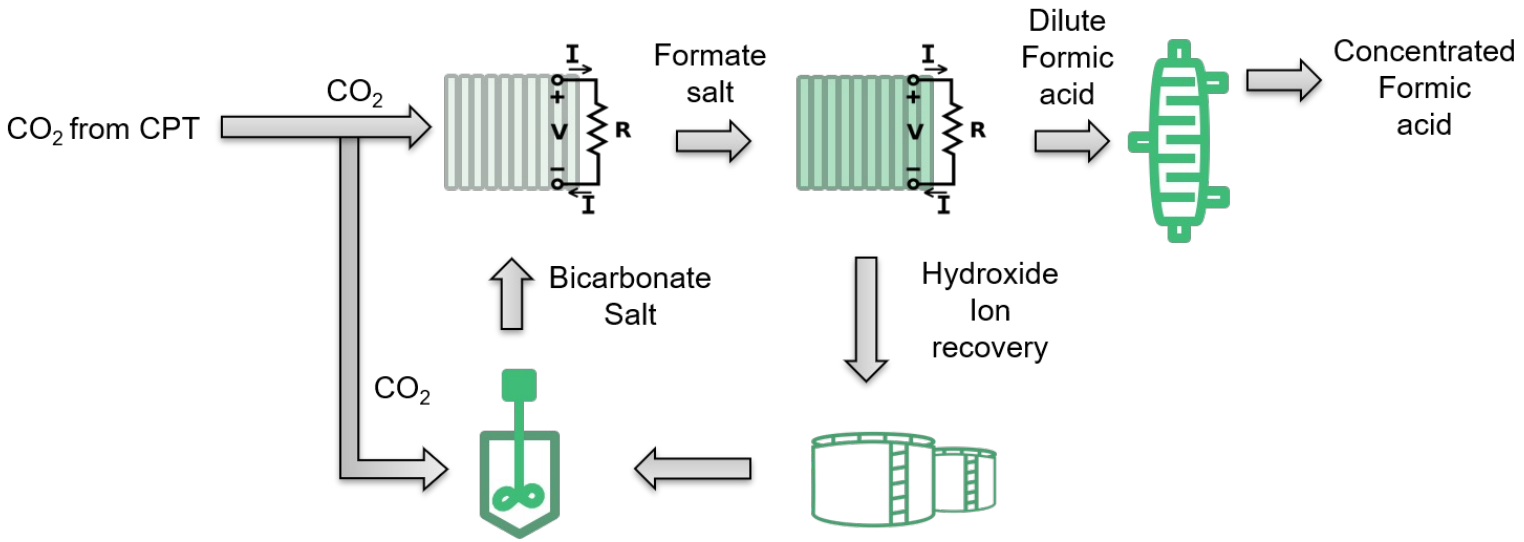
- **GEN4 module design completed, manufacturing site location agreed and work commenced on facility design.**

Status CO2 Conversion (WP3)

Objectives

1. To optimise and test the design of a 60-100 cm x 100 cm gas diffusion electrochemical cell and build a scalable stack of cells (up to 10 GDE cells) with close to industrial scale productivity (≥ 1 kA/m2 and 50tpa FA) for the conversion of captured CO2 to potassium formate and formic acid (30 and 15wt% aq) with current efficiency of at least 90% by Month 24.

Process Overview

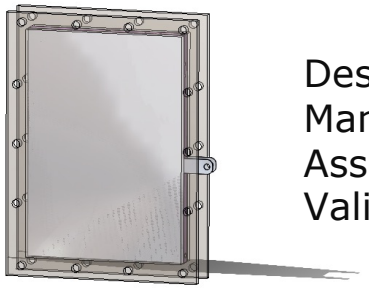


Status CO2 Conversion (WP3)

T3.1.1 Design and testing of the cell in lab

New cell design made which can be used for both reactors (CO_2 conversion and acidification)

Lab size → **Waterproof size** → **ICO2NIC size**



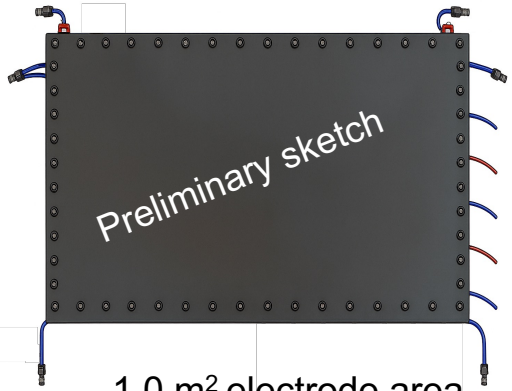
Design √
Manufactured √
Assembled √
Validated √

0.05 m^2 electrode area
0.3 ton/y formic acid



Design √
Manufactured √
Assembled √
Validated √

0.2 m^2 electrode area
1.2 ton/y formic acid



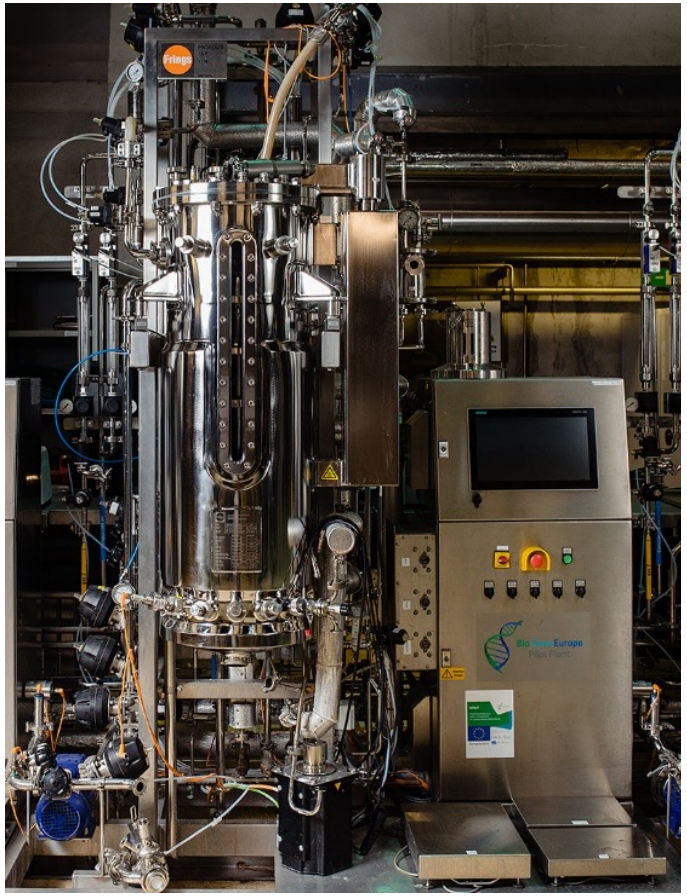
Design √
Manufactured
Assembled
Validated

1.0 m^2 electrode area
6.2 ton/y formic acid

Status Formic Acid Conversion (WP4)

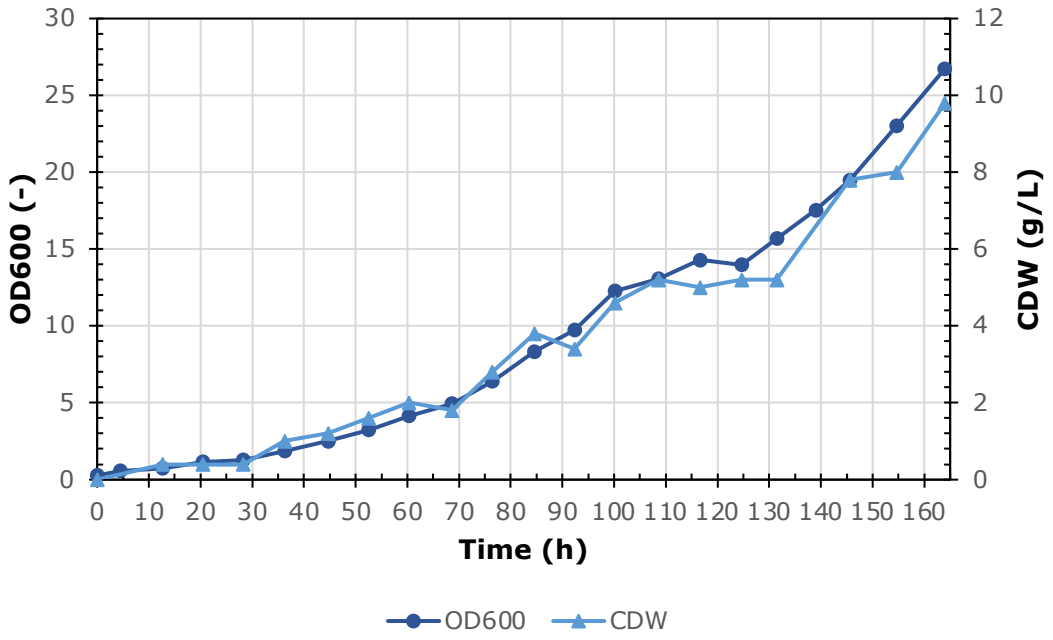
Task T4.4 Scale up of Microbial proteins

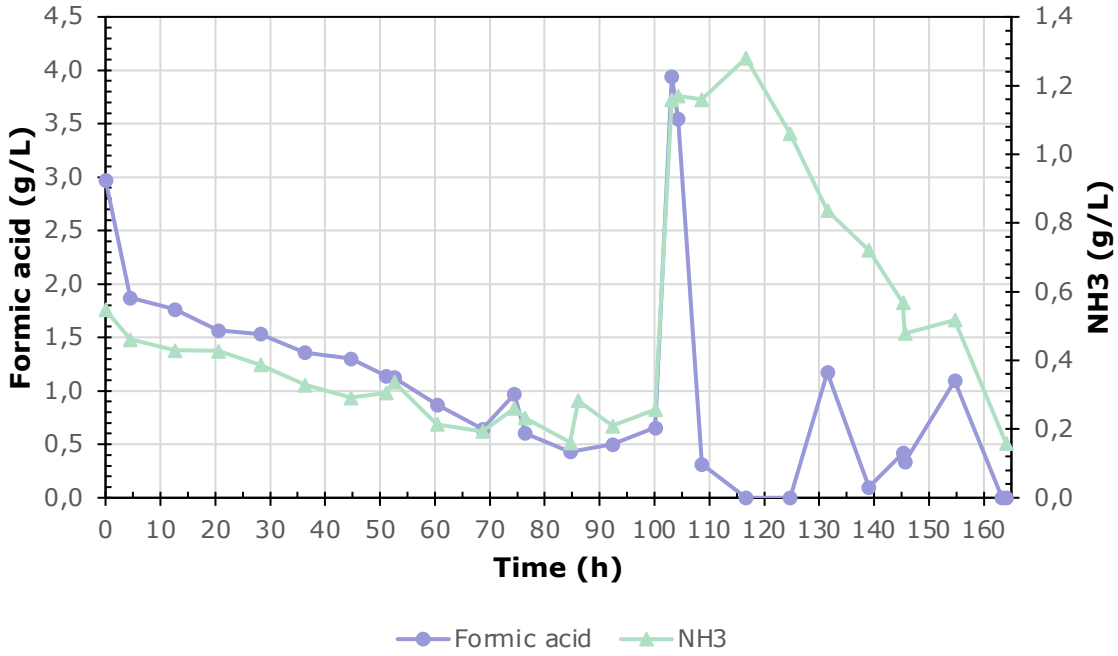
- TT run at 150L scale
  - Protocol received from b.fab
- Challenges identified
  - Formic acid as carbon source
    - Safety (flash point 42°C)
      - Compatibility equipment
    - Addition/ consumption directly impacts pH
      - Impact of CO_2 and NH_3
  - High seed percentage



Status Formic Acid Conversion (WP4)

Task T4.4 Scale up of Microbial proteins

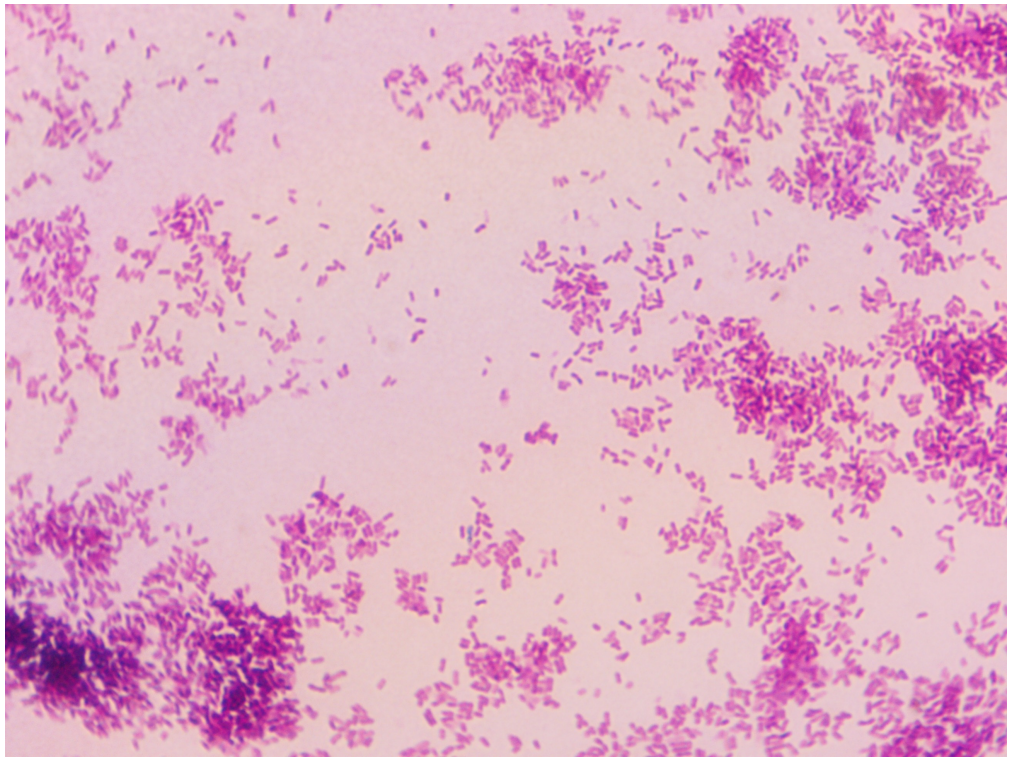




Status Formic Acid Conversion (WP4)

Task T4.4 Scale up of Microbial proteins

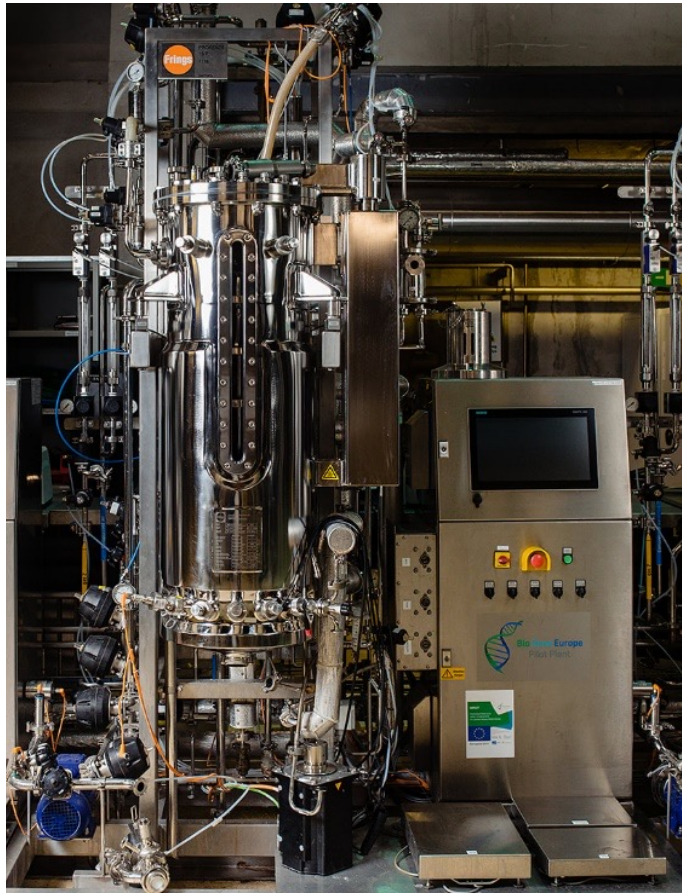
- Successful TT at 150L scale
  - 57,2kg broth (CDW = 9,8g/L)
  - Important learnings
    - Adoption of the FA feeding by BBEPP
    - Higher tolerance to NH_3 observed
- Scope for next run (TBD)
  - Adapted seed train
  - Adapted intervention strategy
  - Longer fermentation duration



Status Formic Acid Conversion (WP4)

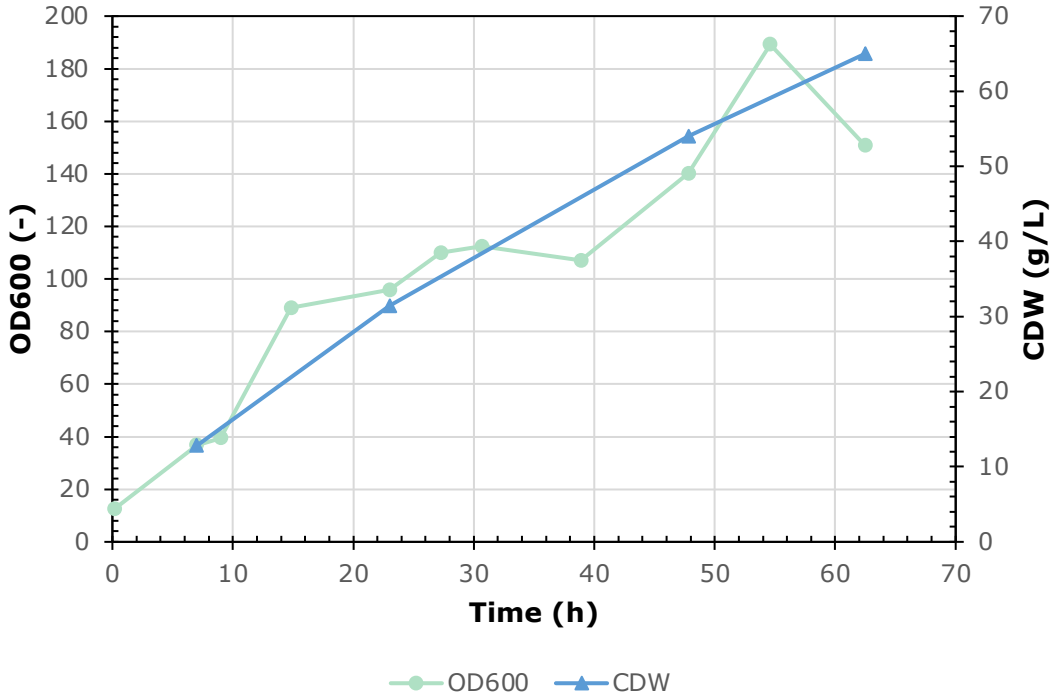
Task T4.5 Scale up of Microbial oils production

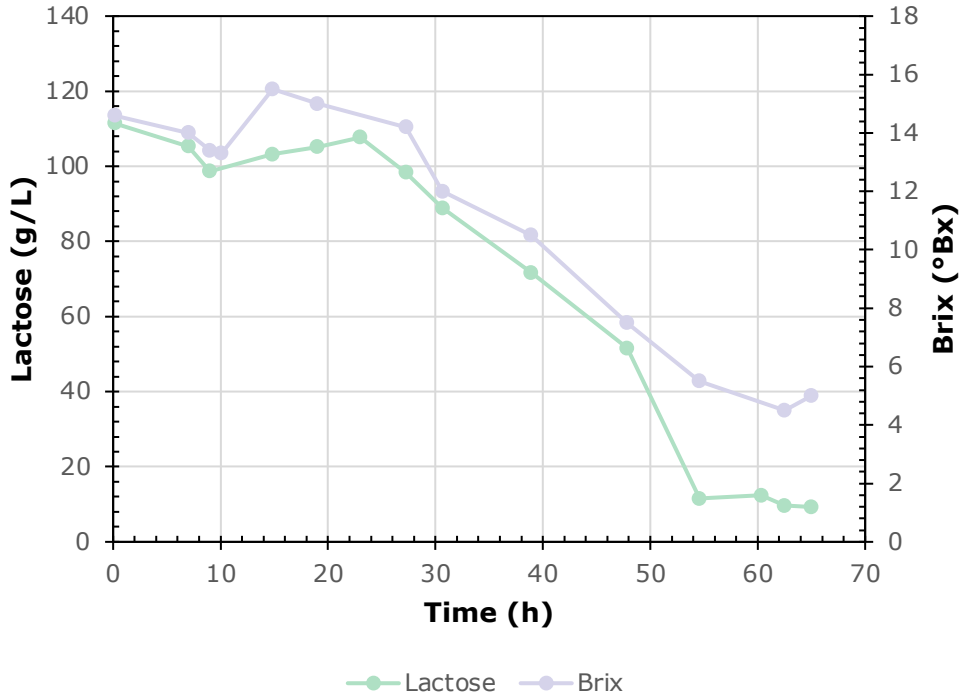
- TT run at 150L scale
  - Protocol received from No Palm Ingredients
- Challenges identified
  - Feed sterilization
    - Whey permeate not filter sterilizable
      - Need for heat sterilization
  - High inoculum %



Status Formic Acid Conversion (WP4)

Task T4.5 Scale up of Microbial oils production

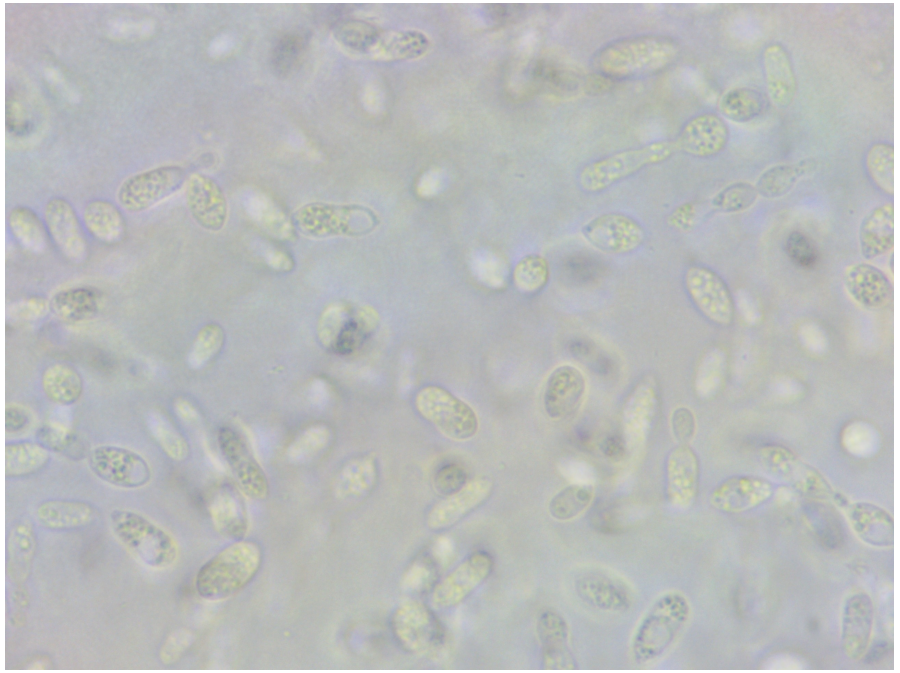




Status Formic Acid Conversion (WP4)

Task T4.5 Scale up of Microbial oils production

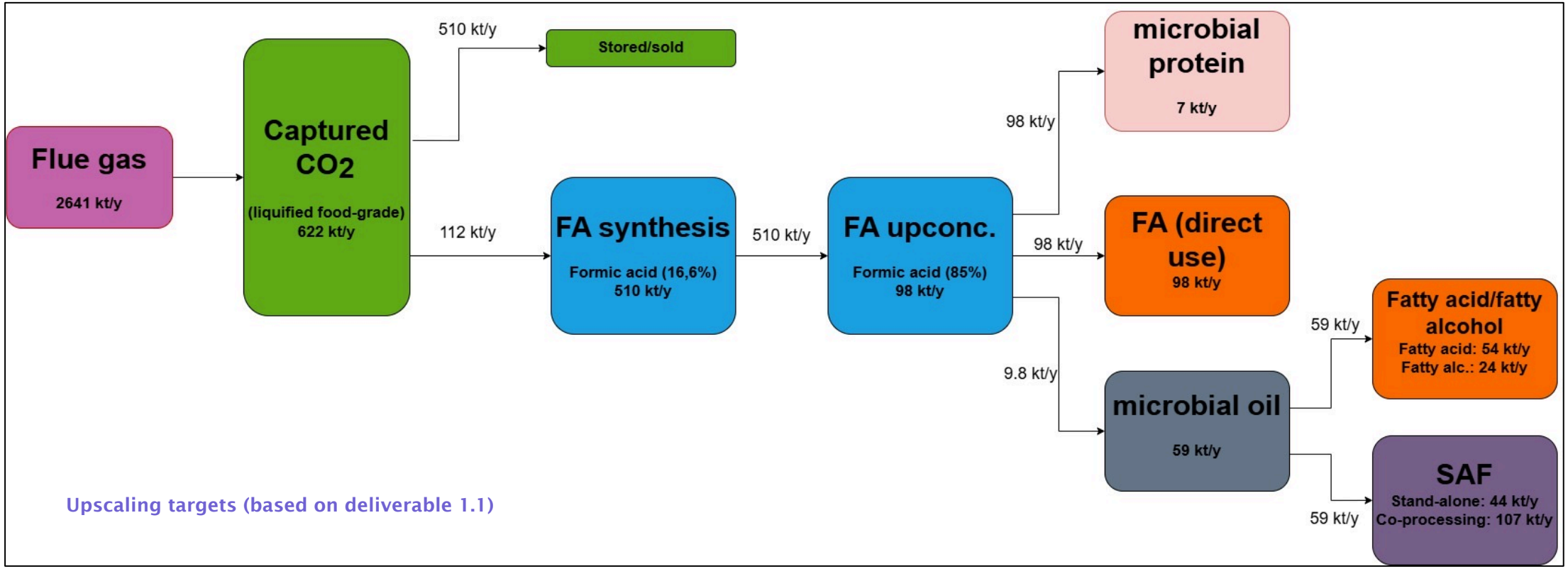
- Successful TT run at 150L
  - 95kg (CDW = 51.6 g/L)
  - Stable process
  - Alignment on analytics
- Scope for next run
  - Scale up to 1.5m³
  - Introduction of formic acid into the feed



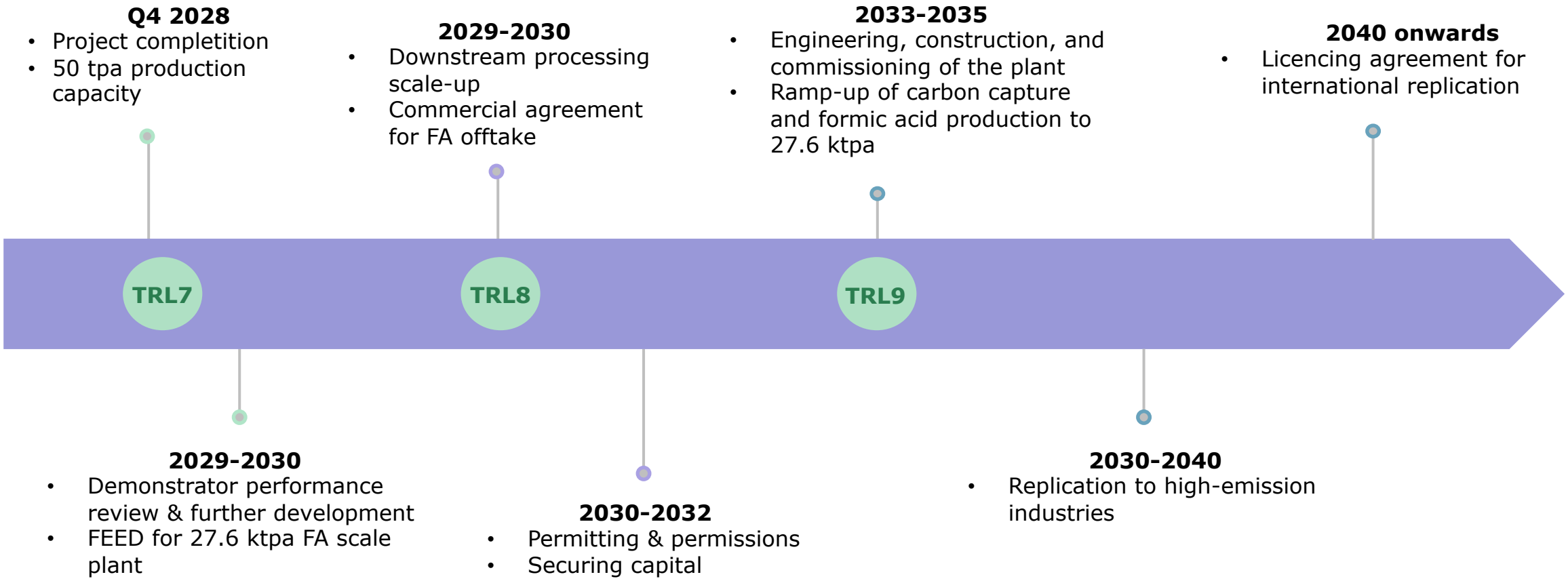
Status Value Chain Analysis (WP8)

Challenges until now:

- Aligning on production scales and TRL level of the ICO2NIC whole value chain (see diagram) for assessments. Differences in scale size/TRL level will affect results from TEA/LCA
- Is the upconcentration of formic acid to 85% necessary for all ICO2NIC products? What number to use in assessments?



ICO_2NIC route to commercialisation



Thank you!

Learn more at www.ico2nic.eu
and follow us on LinkedIn

Frank Kensy
kensy@bfab.bio

Coordinator:
Bernd Wittgens
Bernd.Wittgens@sintef.no



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PROCESSES4PLANET

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