Technology of 100% Circular Economy for Chlor-Alkali

Creation by Recycling

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Cefic sector group

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12th International Chlor-Alkali Technology Conference & Exhibition

13-15 May 2025
Barcelona - Spain

AGENDA

- Technology Overview
- Chlor-Alkali Membrane Recycling
- Catalyst Coated Membrane Recycling
- Certification and Verification
- Appendix

Technology Overview

1) Background
2) Core technology for recycling
3) Feedstock for recycling

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Technology Overview

Background – I

- ❖ **Purpose:** Promote the adoption of environmentally treated materials by providing innovative and sustainable solutions.

- ✓ **AMB-Tech** is a specialized manufacturer that recycles high-performance ionomers used in the membranes of various electrochemical devices.

- ✓ By leveraging cutting-edge technology and a circular economy approach, **AMB-Tech** aims to provide sustainable solutions and play a key role in the eco-friendly product market.

- ✓ Through innovative recycling technology, **AMB-Tech** enhances the efficiency and sustainability of material production, contributing to the widespread adoption of environmental-friendly materials.

Technology Overview

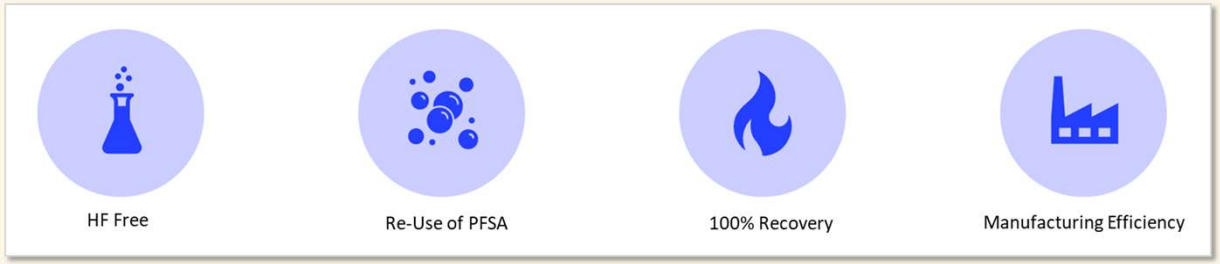
Background – II

❖ **Pain Points in the Market:**

- **Growth requirements** for manufacturing supply chains.
- **Environment issues :** PFSA ionomers have environmental concerns due to use fluoropolymers.
- **High raw material costs** limit scalability.

❖ **AMB-tech's Competitive Edge:**

- Proprietary **recycling technology** reuses end-of-life products.
- **Higher performance ionomers** than market competitors.
- **Cost-efficient solutions** via advanced recovery processes.



Technology Overview

Feedstock for recycling

*PEMWE, polymer electrolyte membrane water electrolysis
*PEMFC, polymer electrolyte membrane fuel cell

*PEM, polymer electrolyte membrane
*MEA, membrane electrode assembly
*CA, Chlor-Alkali membrane

Membrane electrode assembly(MEA)

From MEA manufacturing & *PEMWE/PEMFC stack

CCM(catalyst coated membrane)

Used, failed & scrapped

MEA(CCM) → Electrode + electrolyte membrane

Recovery materials : Catalyst & Ionomer

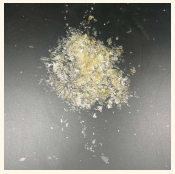
Polymer electrolyte membrane(PEM)

From PEM manufacturing & CA Electrolysis Cell

Membrane for Chlor-Alkali process, Water electrolysis(Green hydrogen production) & PEM Fuel cells etc.

Used, failed & scrapped

PEM → Electrolyte membrane only



Recovery materials : Ionomer

Chlor-Alkali Membrane Recycling

1) Chlor-Alkali membrane
2) Recycling process
3) Recycling product evaluation

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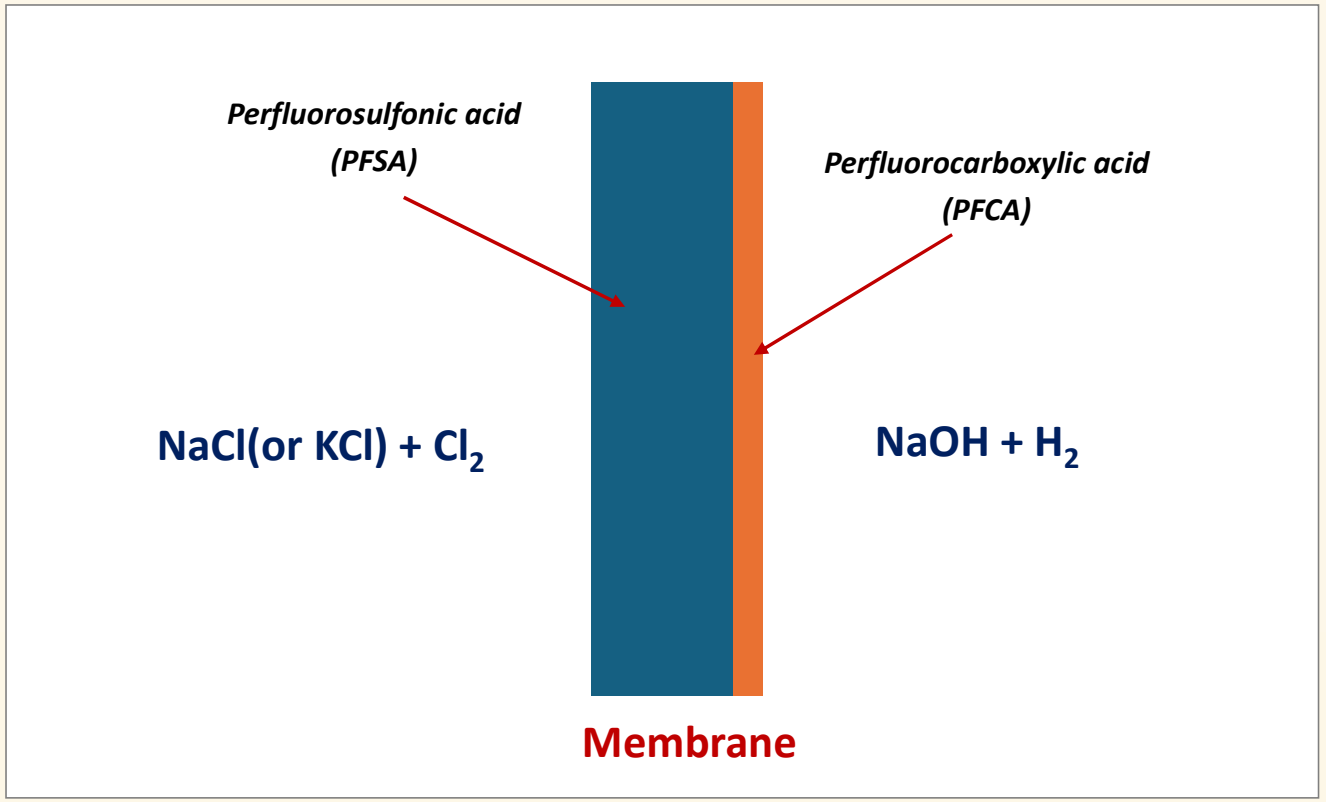
Chlor-Alkali Membrane Recycling

Composition & structure of Chlor-Alkali membrane

Adopted in the production process of chlorine, caustic soda and hydrogen.

Composed of:

- Perfluorinated sulfonic acid
- Perfluorinated carboxylic acid
- Polytetrafluoroethylene
- Inorganic additive



Chlor-Alkali Membrane Recycling

Composition & structure of Chlor-Alkali membrane

Perfluorinated sulfonic acid(PFSA)

Characteristics

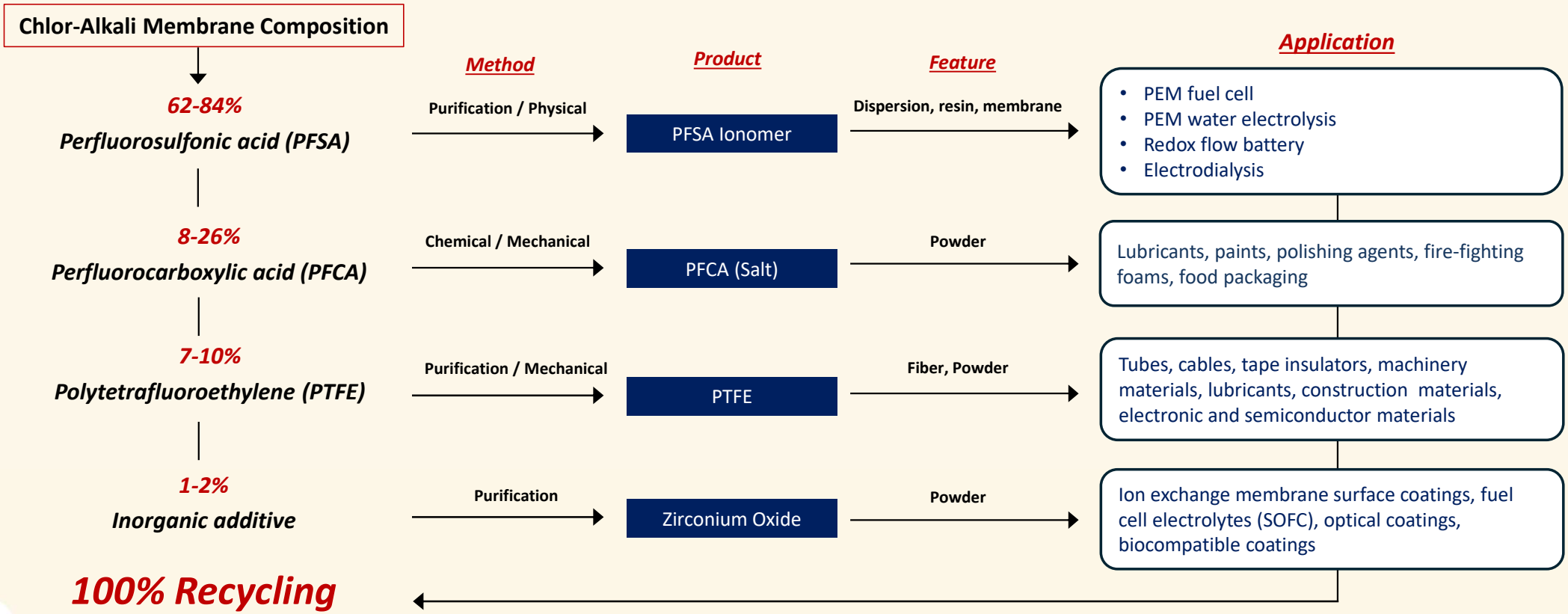
- PFSA is a proton conducting polymer.
- It has PTFE backbone that is responsible for mechanical strength due to its hydrophobicity.
- It possesses excellent chemical resistance under strongly acidic and high base conditions

Applications

PEMFC, PEMWE, Chlor-Alkali process, Electrodialysis, Flow Batteries, Chemical Sensors

Chlor-Alkali Membrane Recycling

Composition of Chlor-Alkali membrane, the recycled End Product and their Application



Chlor-Alkali Membrane Recycling

Recycling Process

❖ Core Technology

AMB-Tech proprietary **ionomer recycling technology** enhances membrane performance by enabling:

- **Superior ion conductivity** & **Lower hydrogen permeability**.
- **High recovery efficiency**, allowing reuse of valuable components.
- **Advanced dispersion techniques**, ensuring uniform coating for consistent performance.

❖ Recycling Technology

- **Non-thermal PFSA recovery:** AMB-Tech's process treats used membrane without high-energy thermal treatments.
- **Physical & Chemical treatment processes:** Ensuring high purity of recovered materials.
- **High-efficiency material separation:** Enabling extraction of PFSA ionomer from membranes.

Chlor-Alkali Membrane Recycling

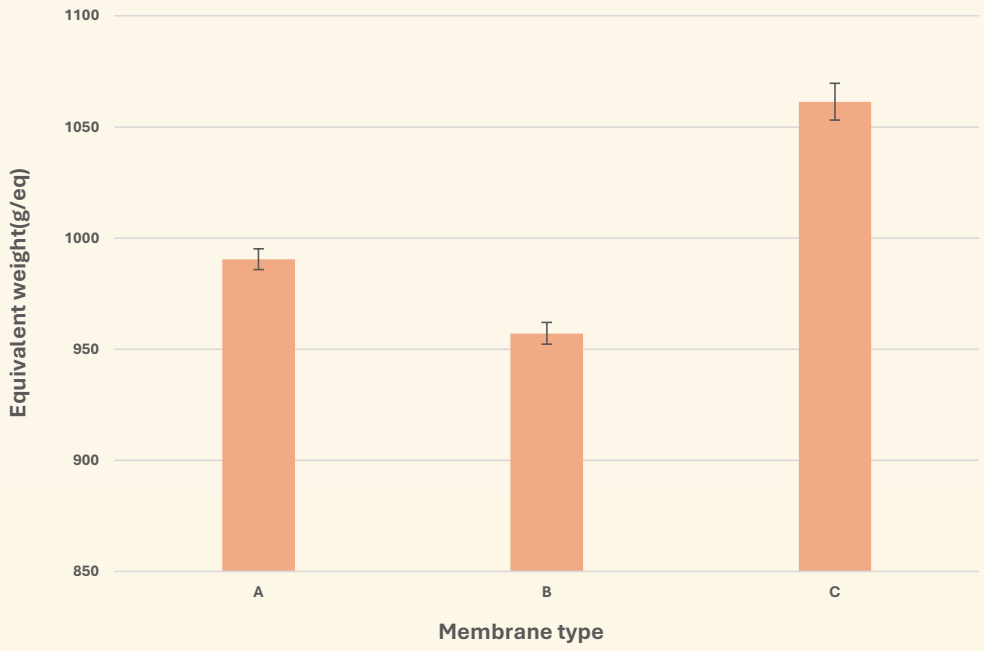
Recycling Process

ITEM	Impurity Removal	Ionomer Recycling	Ionomer Production
Process Flow	Feedstock → Physical Treatment → Chemical Treatment	Ionomer Extraction (Reaction) → Physical Separation	Solidification → Resin; Dispersion (Mixing) → Dispersion
	To remove impurity from used membrane → clean material	To separate Ionomer & others	Ionomer resin → Ionomer dispersed solution

Chlor-Alkali Membrane Recycling

Recycling product evaluation

※ EW(Equivalent weight) of AMB-tech's Recycled Ionomer



EW(Equivalent weight) was calculated from IEC(Ion exchange capacity) values obtained through acid-base titration

(Error bars represent 95% confidence intervals)

Chlor-Alkali Membrane Recycling

Recycling product evaluation

※ Impurities of Recycled Ionomer

Element	Unit	Inspection Method	Results	
			Data	Spec.(Max.)
Fe, Cr, Ni	ppm(μg/g)	DIN EN ISO 11885 (ICP-MS)	<1	20
Na, K			<10	100

Chlor-Alkali Membrane Recycling

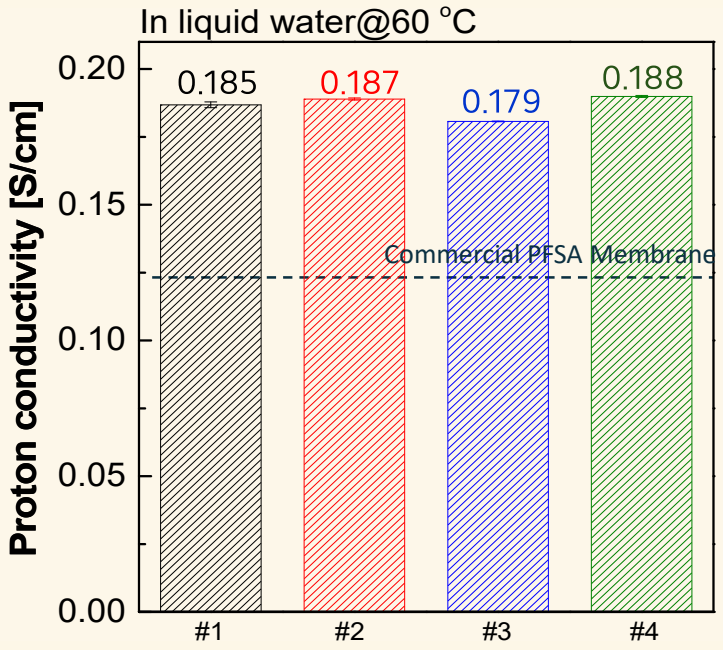
Recycling product evaluation

※ Ion conductivity measurement (4-probe, In-plan)

The bulk resistance of each membrane coupon (size: 1 cm×4 cm) was measured with an electrode system connected with Biologic VSP multi-channel potentiostat (Claix, France) using 4-probe alternating current (ac) impedance spectroscopy. The proton conductivity was obtained using the following equation :

$$\sigma = \frac{l}{R \times S}$$

where *ó* is the proton conductivity in Scm^{-1}, *R* is the ohmic resistance of the membrane, *l* is the distance between reference electrodes, and *S* is the cross-sectional area of the membrane. The impedance measurement was carried out in constant temperature chamber that was electrically shielded to ensure a stable measurement without any noise

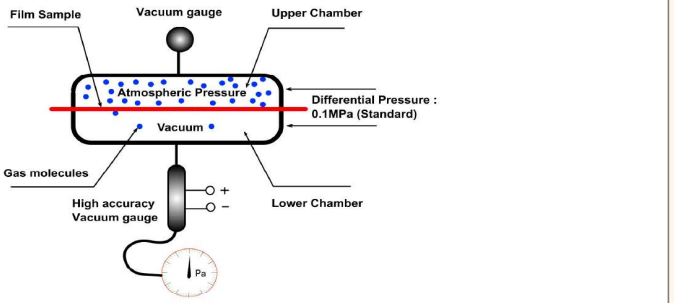


The ion conductivity of the polymer was shown to be up to 50.4 % higher than commercial PFSA membrane.

Chlor-Alkali Membrane Recycling

Recycling product evaluation

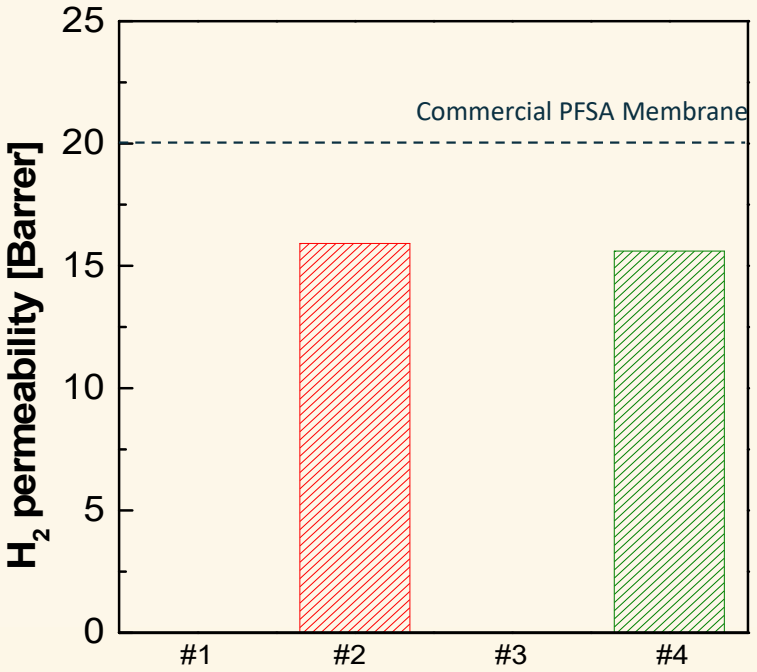
※ Gas permeability measurement (Time-lag method)



$$P = \frac{V_1(cm^3) \times l(\mu m)}{p_2(torr) \times A(cm^2) \times R(76/273.15 cm^3 \cdot cmHg/cm^3 \cdot K) \times T(K)} \left(\frac{dp_1(torr)}{dt(\sec)}\right) = D\left(\frac{l^2}{6\theta}\right) \times S\left(\frac{C}{p}\right)$$

$$1\ \text{“barrer”} = 1\left[\frac{g \cdot cm}{sec \cdot cm^2 \cdot bar}\right]$$

- V_1 = bottom chamber's volume
- l = thickness of membrane
- P_2 = upper chamber's pressure
- A = area of membrane
- R = gas constant
- T = temperature



Ionomer form a denser membrane structure during fabrication.
This reduces the free volume of the polymer, limiting the diffusion pathways for hydrogen molecules.
Consequently, the membrane exhibits approximately 20% lower hydrogen permeability compared to commercial PFSA membranes.

Catalyst Coated Membrane(CCM) Recycling

1) CCM recycling process

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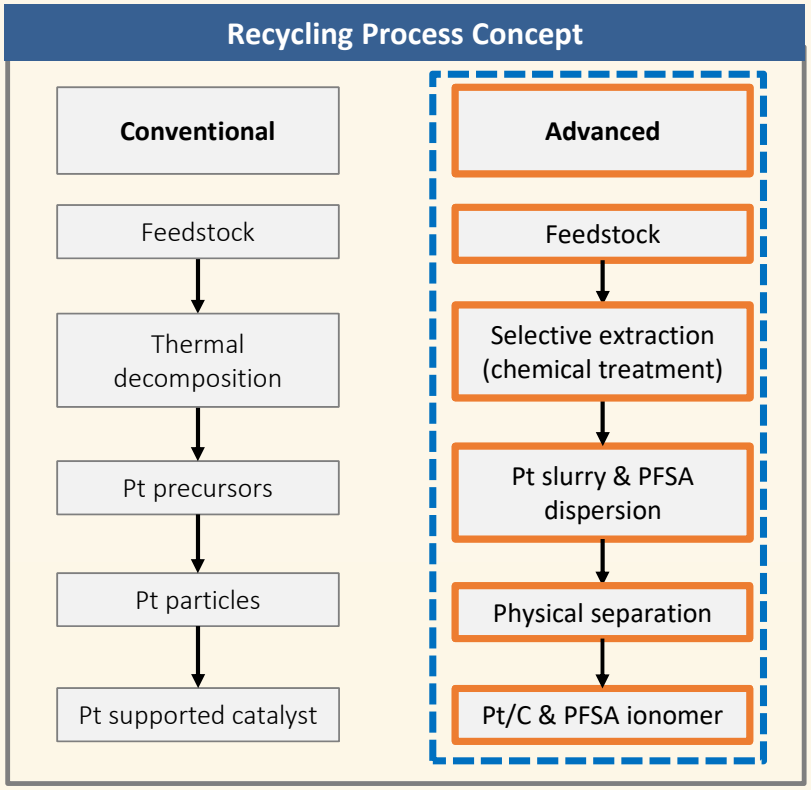
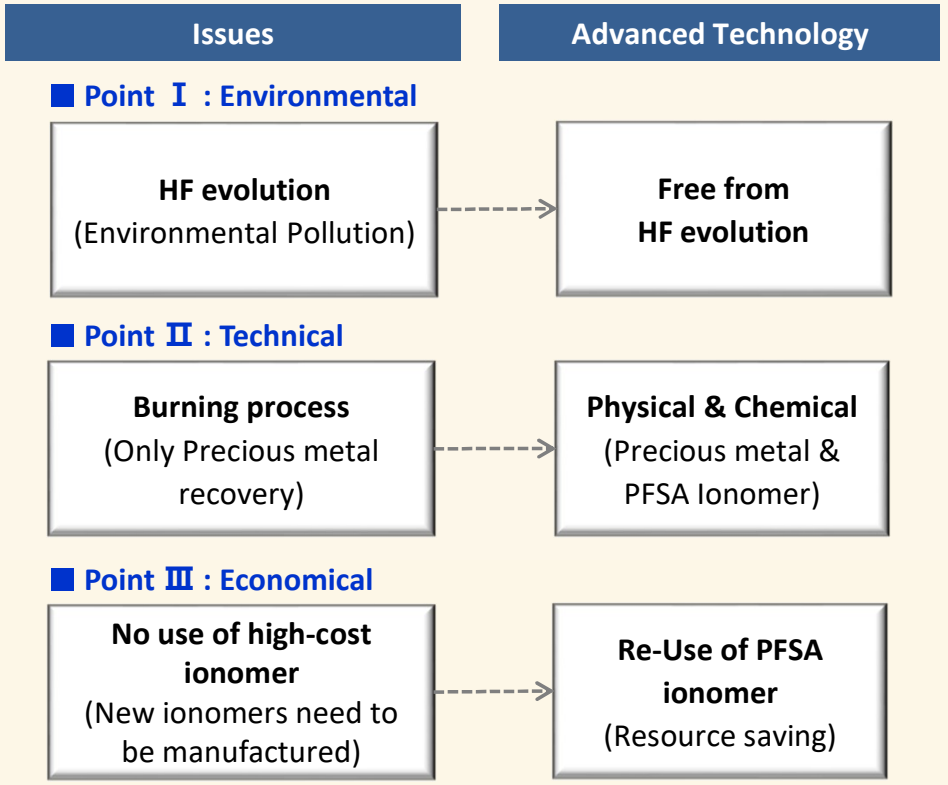
Catalyst Coated Membrane (CCM) Recycling

CCM recycling process

- **Challenge:** Thermal process currently used to recycle MEA(CCM)s produces HF(Hydrogen Fluoride) toxins, uses high levels of energy and burns away valuable components.





Certification & Verification

1) Overview
2) Summary : TUV verification

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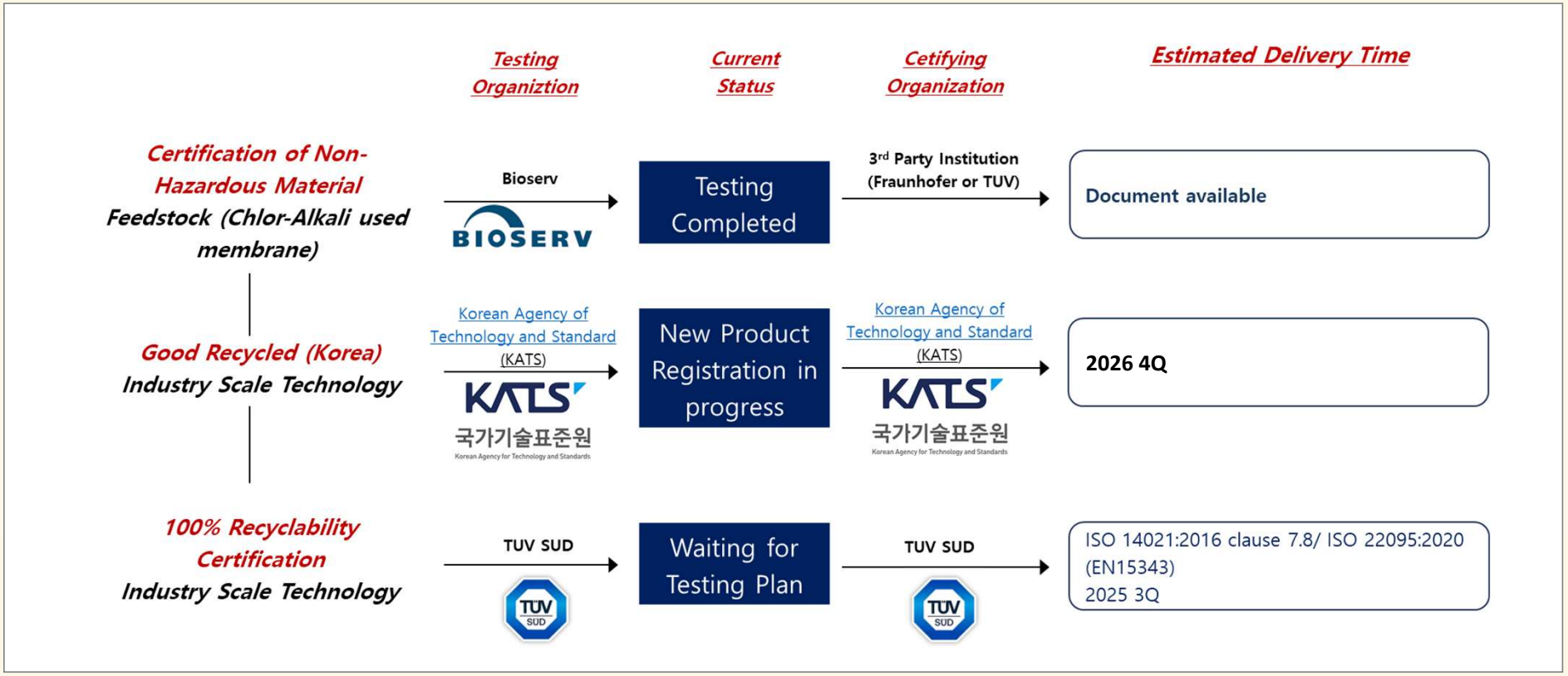
Certification & Verification

Overview



Certification & Verification

Summary : TUV Verification

EN 15343:2007-Recycled Plastics Traceability

- Purpose: Ensures traceability and recycled content verification for plastics.
- Scope: Plastics value chain(manufacturers, recyclers, processors).
- Key features:
  -. Documents raw material origin(collection, sorting, proceeding).
  -. Calculates pre/post-consumer recycled content(%).
  -. Verifies quality and process transparence via certification(e.g., c)

ISO 14021:2016-Self-Declared Environmental Claims(Type II)

- Purpose: Guarantees transparent, non-misleading environmental claims(e.g., recycled content).
- Scope: All industries (plastics, packaging, electronics).
- Key features(Clause 7.8-Recycled Content):
  -. Requires quantitative claims(e.g., “30% recycled plastic”) with traceability.
  -. Distinguishes pre/post-consumer content; uses Möbius loop with %
  -. Prevents greenwashing via documented evidence.

ISO 22095:2020-Chain of Custody

- Purpose: Provides a framework for supply chain traceability of materials/products.
- Scope: All materials(plastics, metals, textiles);excludes services.
- Key features:
  -. Standardizes terms(e.g., traceability, mass balance).
  -. Defines models(segregation, mass balance, identity preserved).
  -. Enhances claim credibility but requires additional data for verification.

Conclusions

1) Company’s aims

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Conclusions

Company's Aims

AMB-Tech

Let's build a cleaner future together

World's best commercialized ionomer recovery technology

Leading global player in the materials(membrane & MEA) recycling

100% PFSA ionomer recovery rate

Circular economy model

Better recycling efficiency

Innovative technology

Significantly lower costs

Cost-efficient production

Supply stability & Manufacturing scalability

Providing sustainable solutions to meet the growing global demand

THANK YOU

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The European Chemical Industry Council, AISBL – Rue Belliard, 40 - 1040 Brussels – Belgium
Transparency Register n°64879142323-90

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Chlor-alkali: achieving climate neutrality