

Technology Developments in the Chlor-Alkali Industry

12th November 2024 | Ranga Rao N



thyssenkrupp
NUCERA

Agenda



Introduction of thyssenkrupp nucera

nucera Chlor-Alkali Technology - Electrolyser Developments

Brine Treatment Developments

Product Quality Improvements

Agenda



Introduction of thyssenkrupp nucera

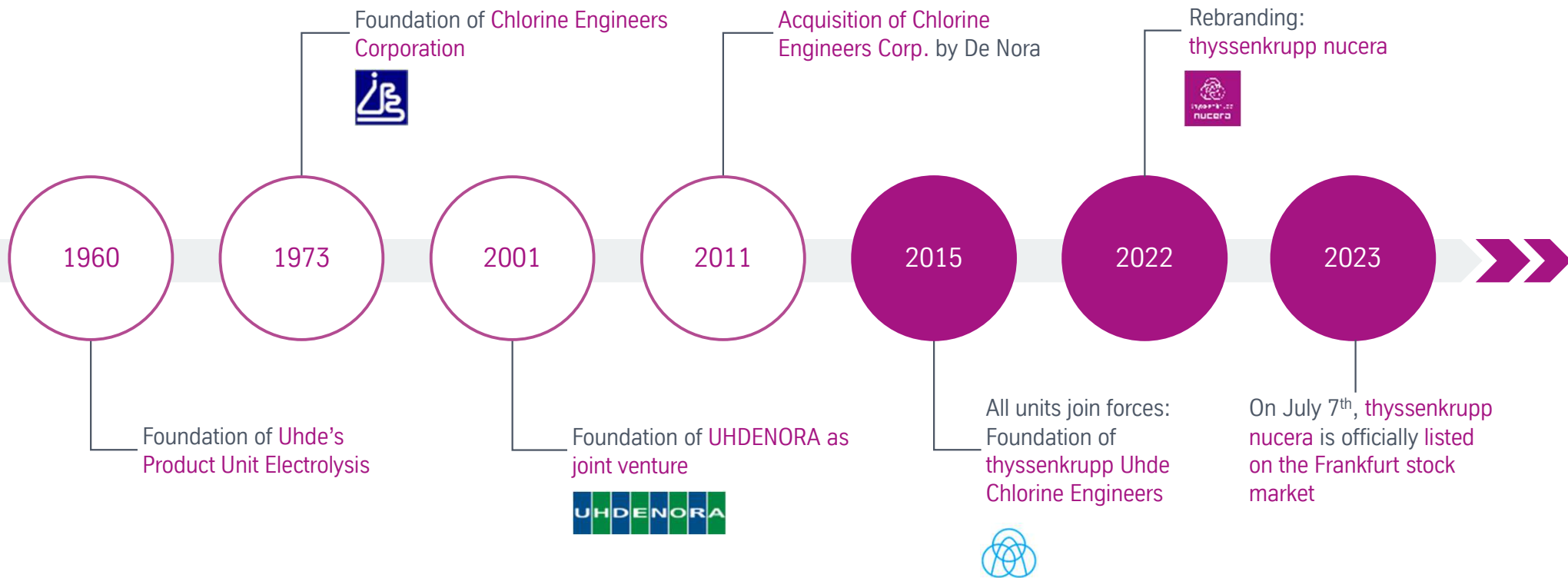
nucera Chlor-Alkali Technology - Electrolyser Developments

Brine Treatment Developments

Product Quality Improvements



The collective expertise of three renowned global electrolysis leaders is part of thyssenkrupp nucera



thyssenkrupp nucera is a global organization with a successful track record



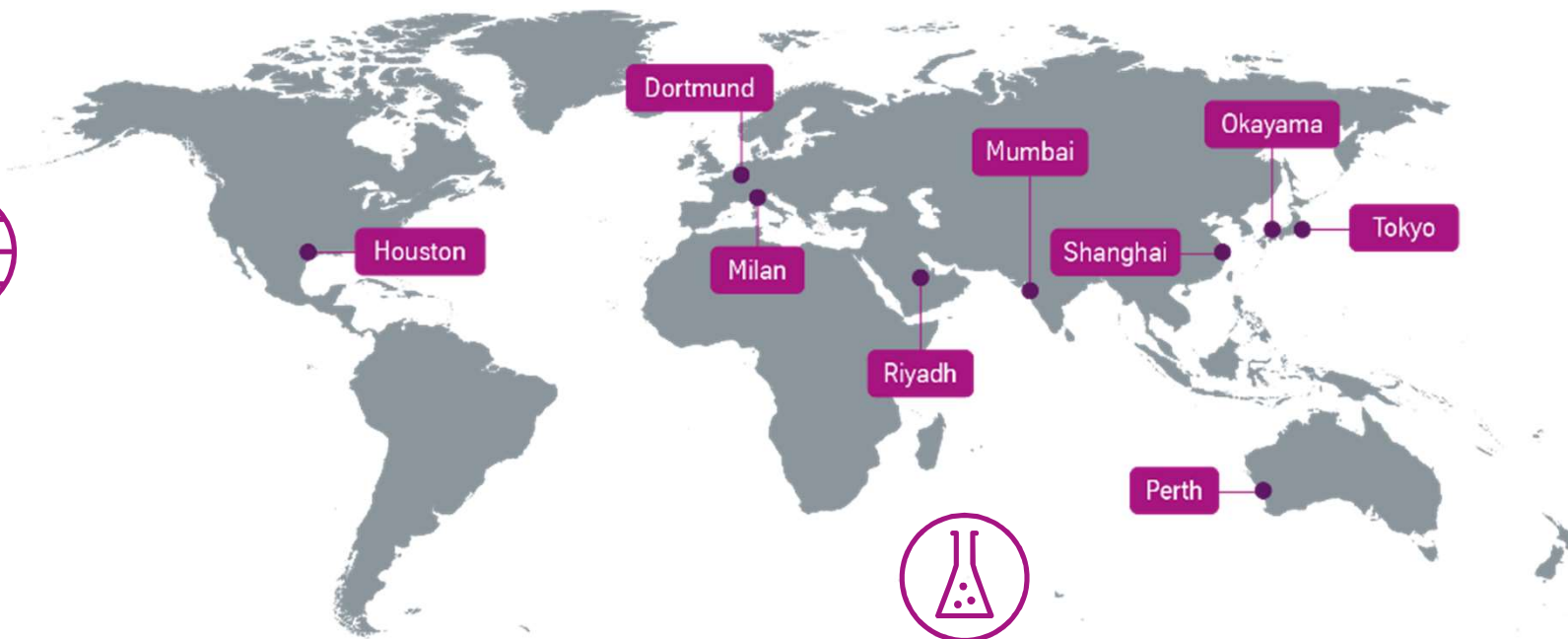
8

regions



750+

employees worldwide



600+

successful electrochemical projects worldwide

1. Based on 3GW+ contracted green hydrogen capacity.

Purpose:
We shape the new era.

Vision:
#1 provider for hydrogen and
chlorine technologies.

Mission:
With passion for innovation, we enable our
customers to make superior electrolysis
products and minimize the CO₂ footprint.



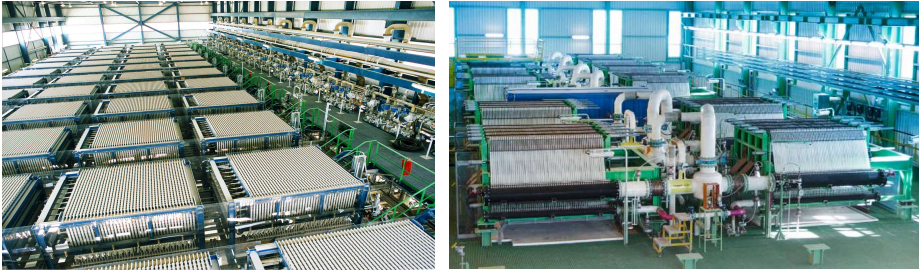
thyssenkrupp
nucera

thyssenkrupp nucera's Electrolysis Technologies – Chlorine Technology



Chlor-Alkali Electrolysis

Uhde Single Element / BM2.7
Chlorine Engineers BiTAC
NaCl ODC¹



Developed in earlies of year 1960

Hydrochloric Acid Electrolysis

HCl Diaphragm
HCl ODC¹



Developed in Year 1986



> 10 GW

executed Chlorine Technology

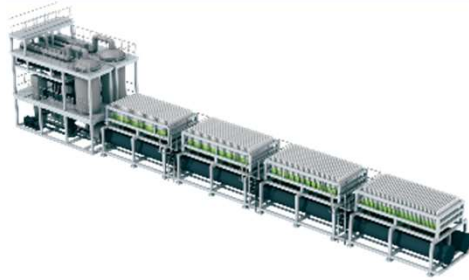
¹ ODC: Oxygen Depolarized Cathodes

thyssenkrupp nucera's Electrolysis Technologies – green Hydrogen Technology



Alkaline Water Electrolysis (AWE)

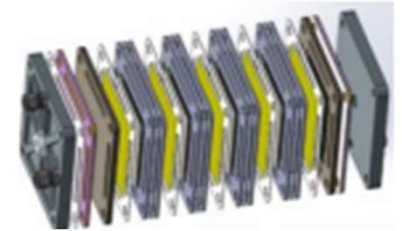
scalum®



Developed in Year 2018

Solid Oxide Electrolysis Cell (SOEC) – Pilot Plant

Strategic Partnership with Fraunhofer IKTS, Germany



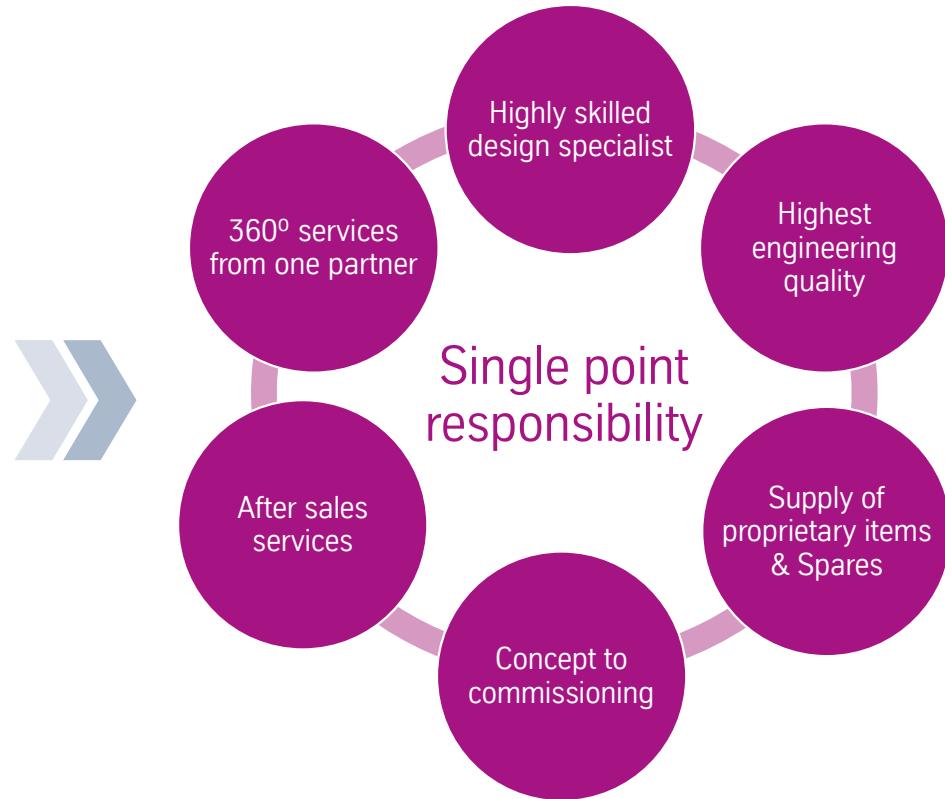
First quarter of Year 2025



>3 GW

contracted green Hydrogen Technology

... and a single point responsibility towards our customers



Agenda



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nucera Chlor-Alkali Technology - Electrolyser Developments

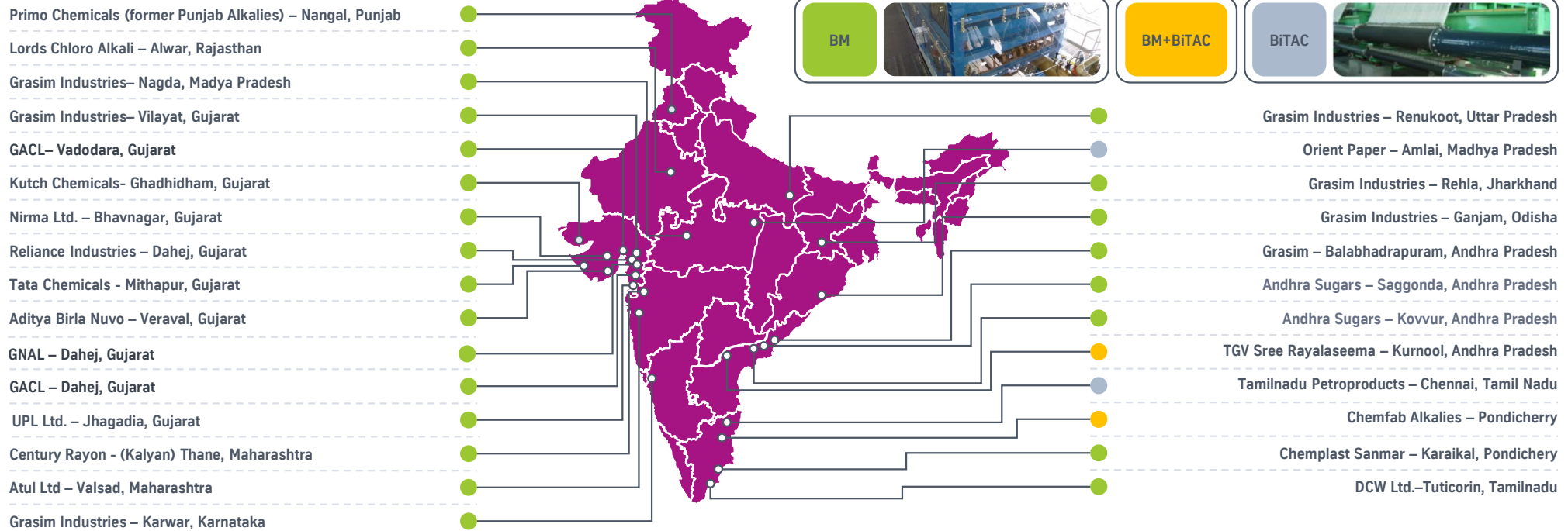
Brine Treatment Developments

Product Quality Improvements

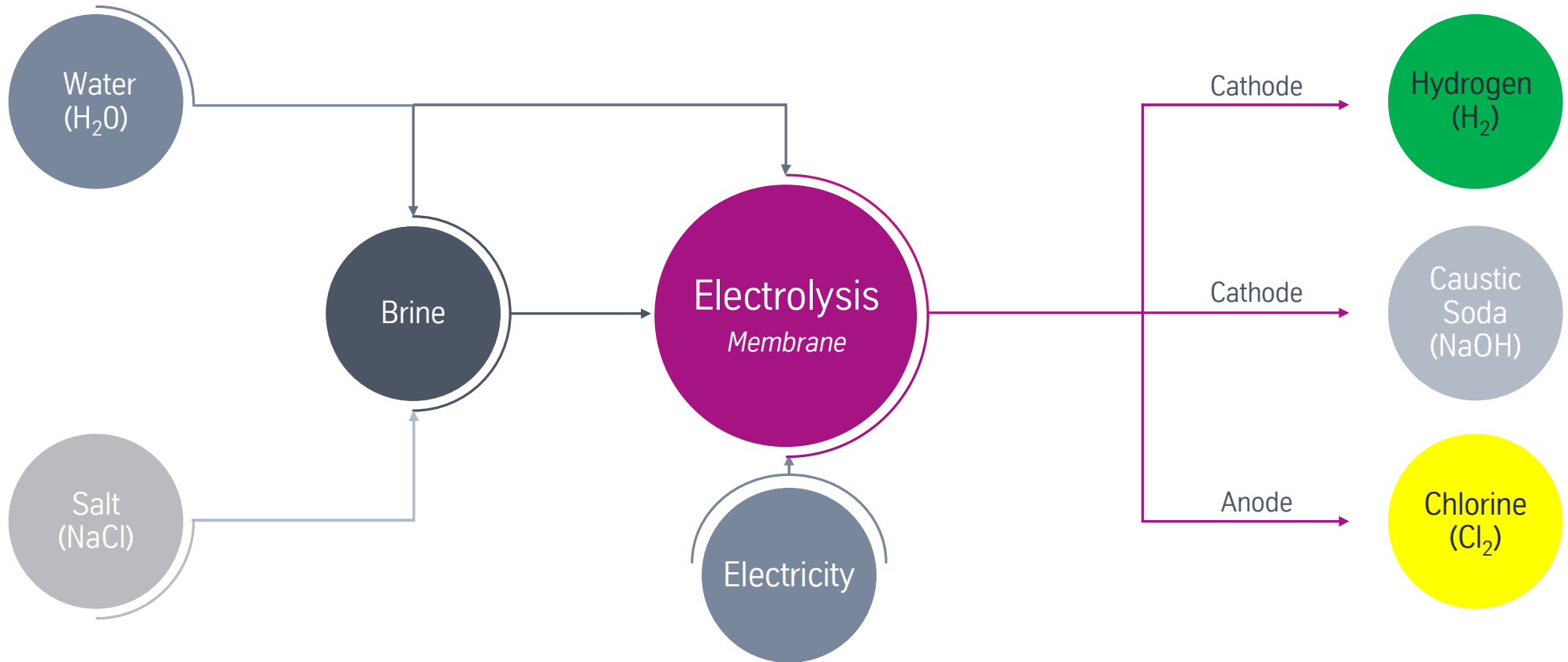
nucera Chlor-Alkali Technology - Electrolyser Developments



thyssenkrupp nucera Chlor-Alkali Plants – India Footprint



Chlor-Alkali chemical process in a nutshell



Innovative Chlor-Alkali and HCl solutions for industrial progress



Global leader
in electrolysis

>10 GW
electrolyzer capacity
installed¹

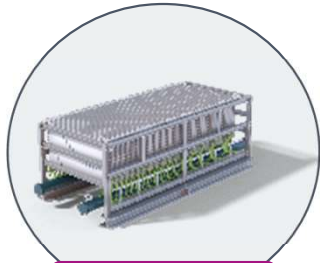
Over 600
electrochemical
projects realized

Over 240.000
electrolytic cell
elements produced

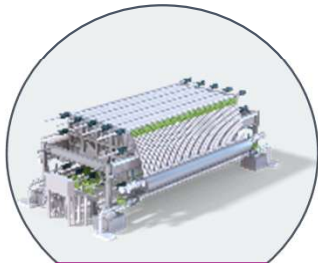
Product Portfolio

Chlor-Alkali Electrolysis:

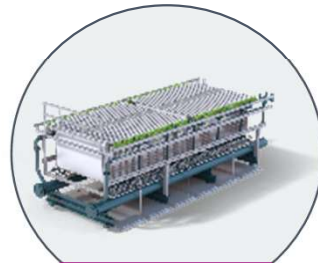
Local production of Chlorine (Cl_2), Caustic Soda (NaOH) and Hydrogen (H_2)



BM²



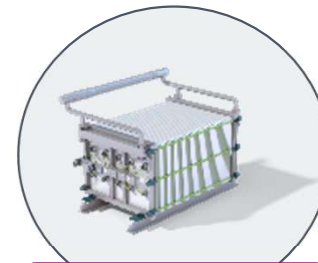
BiTAC³



NaCl ODC⁴

Hydrochloric Acid (HCl) Electrolysis:

Recycling of HCl into Chlorine (Cl_2) and Hydrogen (H_2)



HCl Diaphragm

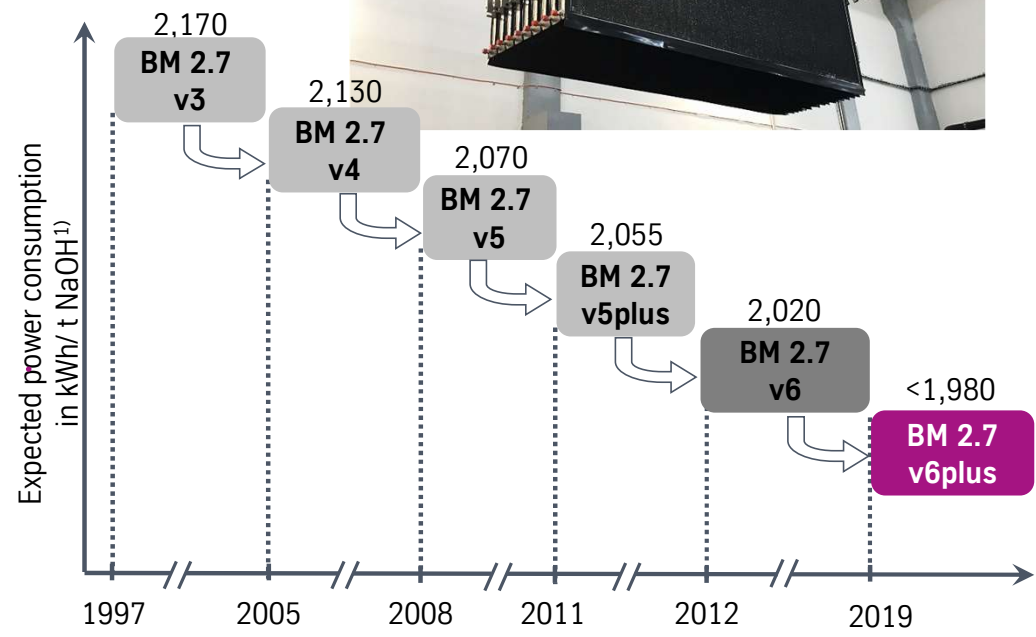
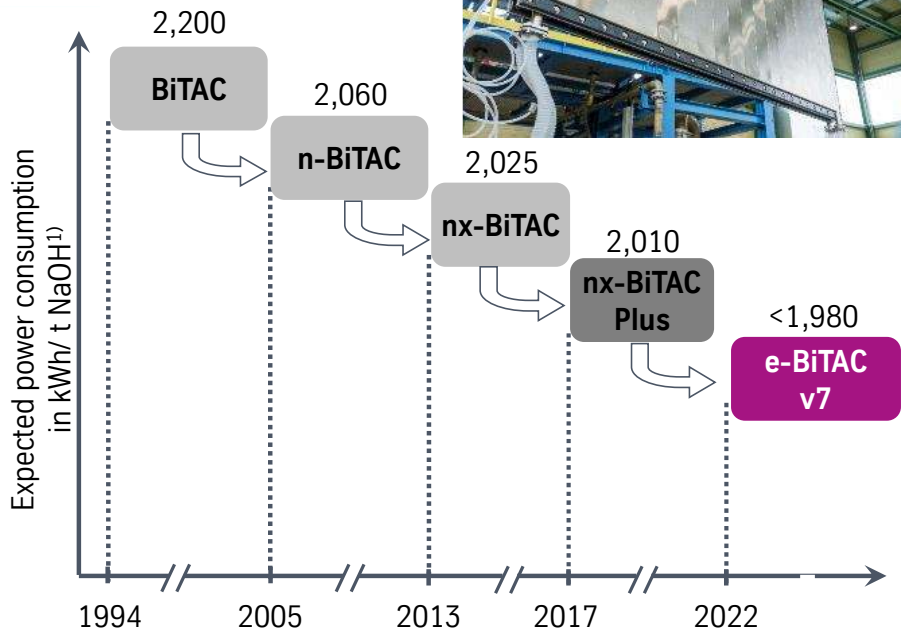


HCl ODC⁴

1. To produce chlorine and hydrogen 2. Bipolar membrane electrolyzer 3. BiTAC: Bipolar Tosoh and Chlorine Engineers 4. ODC: Oxygen Depolarized Cathode



History of power consumptions for BM/BiTAC series

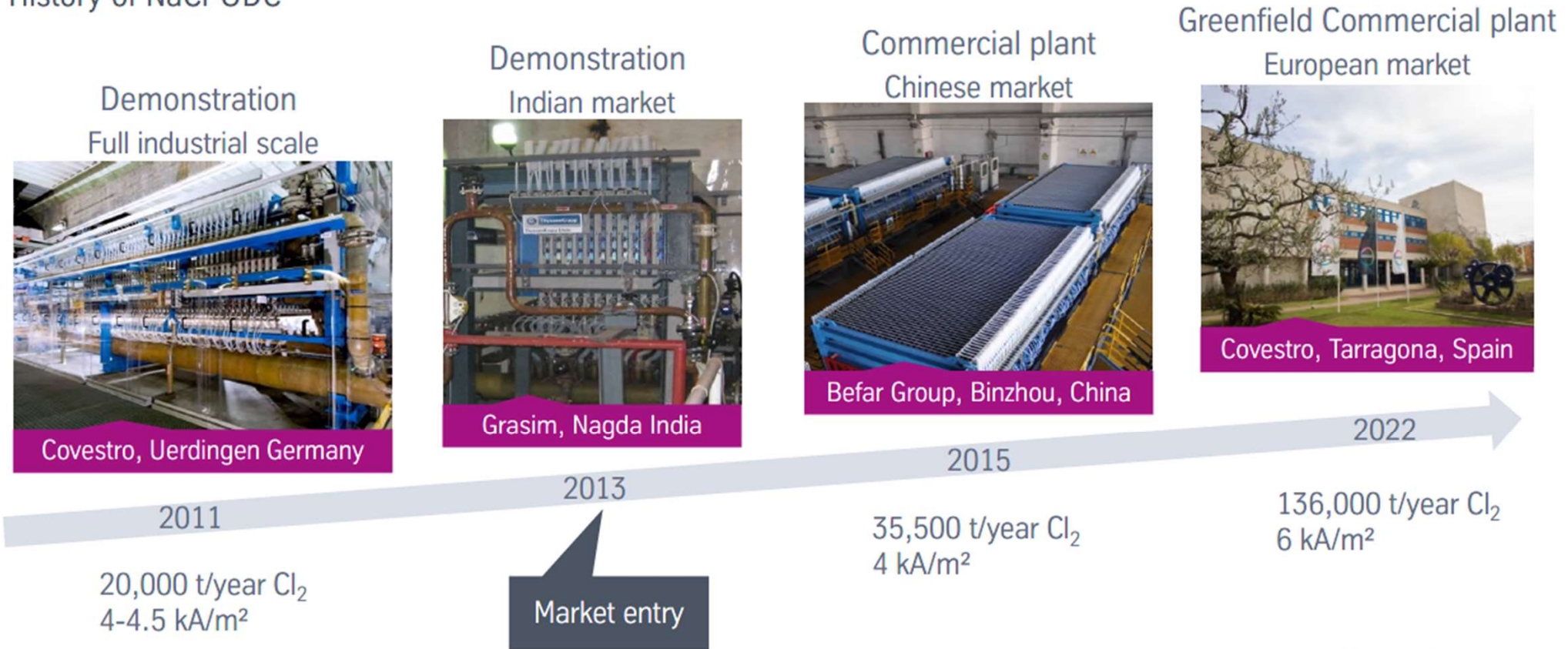


Power consumption reduced substantially over the last decades by our Technology improvements

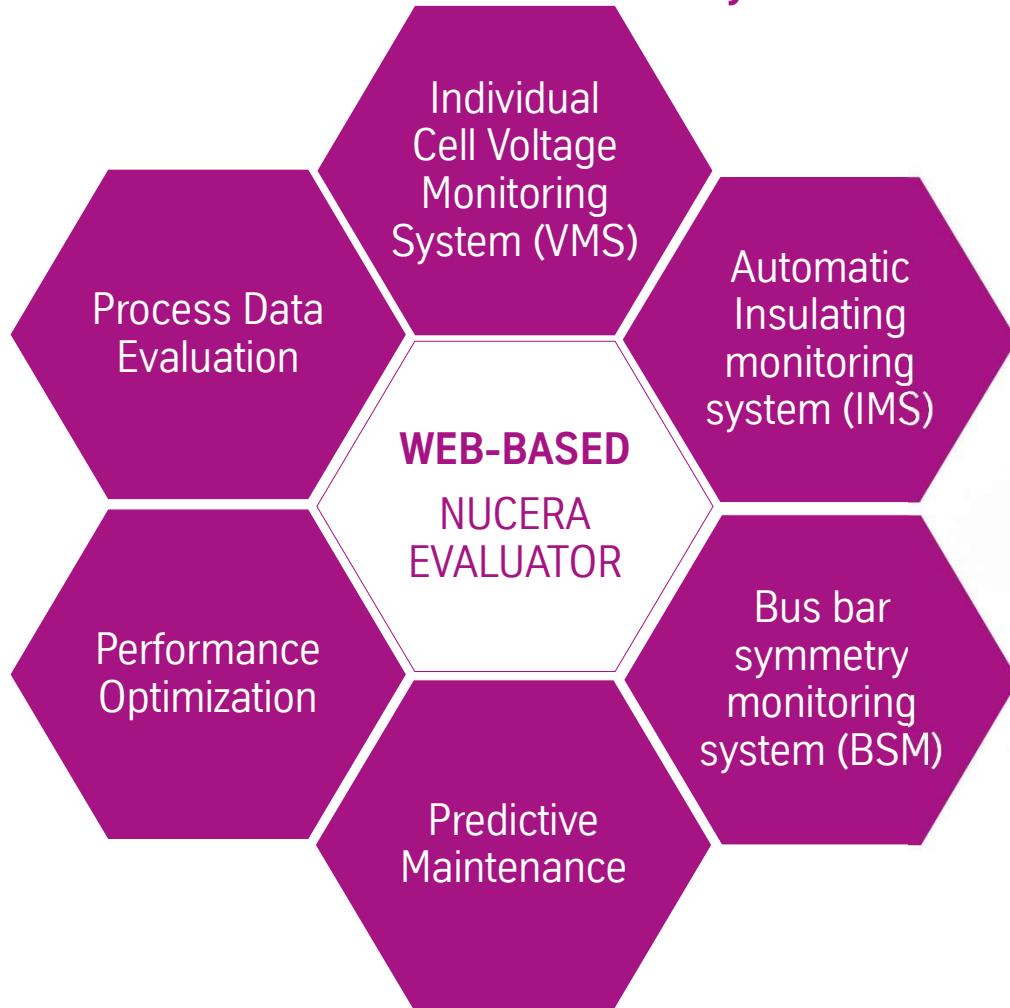


Successful market entry of NaCl-ODC technology

History of NaCl-ODC



nucera evaluator Electrolyser & individual cell element safeguards



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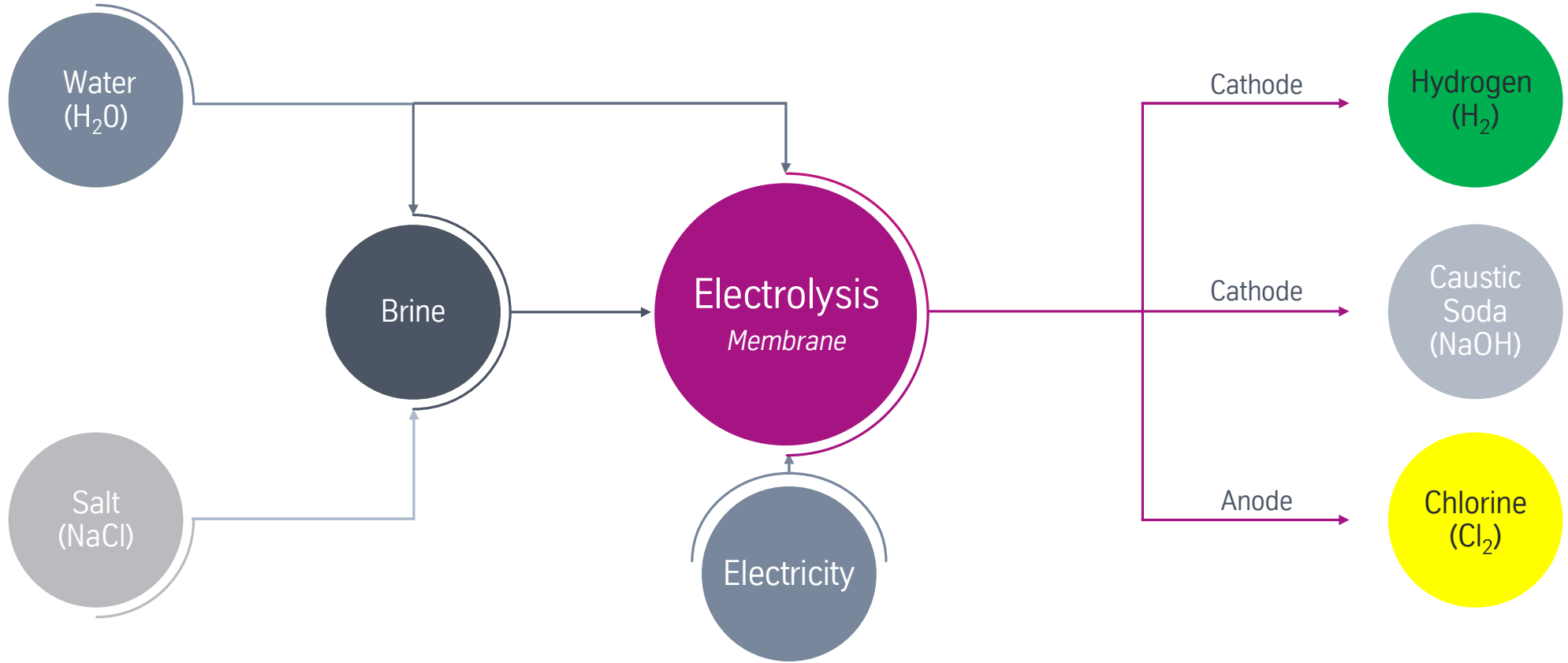
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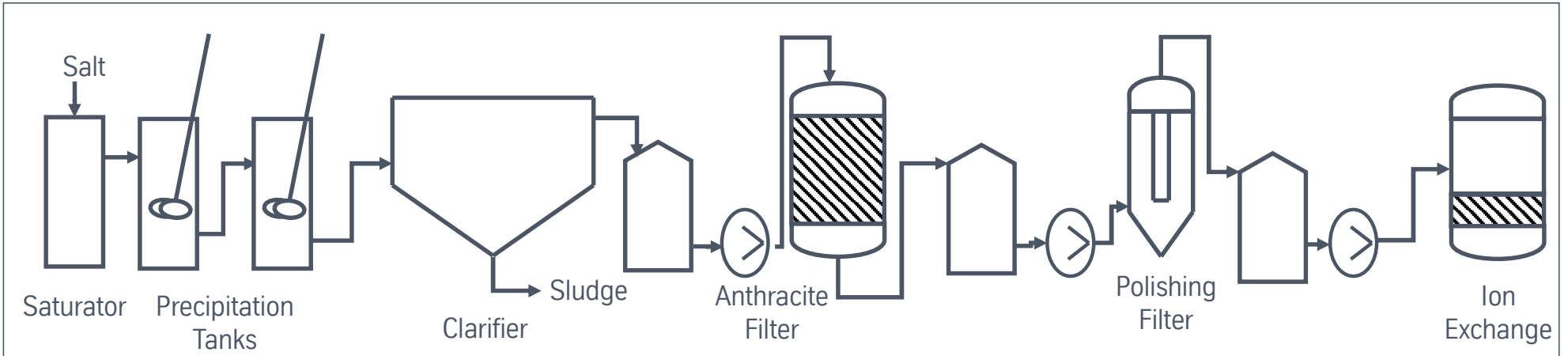
Chlor-Alkali chemical process in a nutshell





Developments/Improvements in Brine System

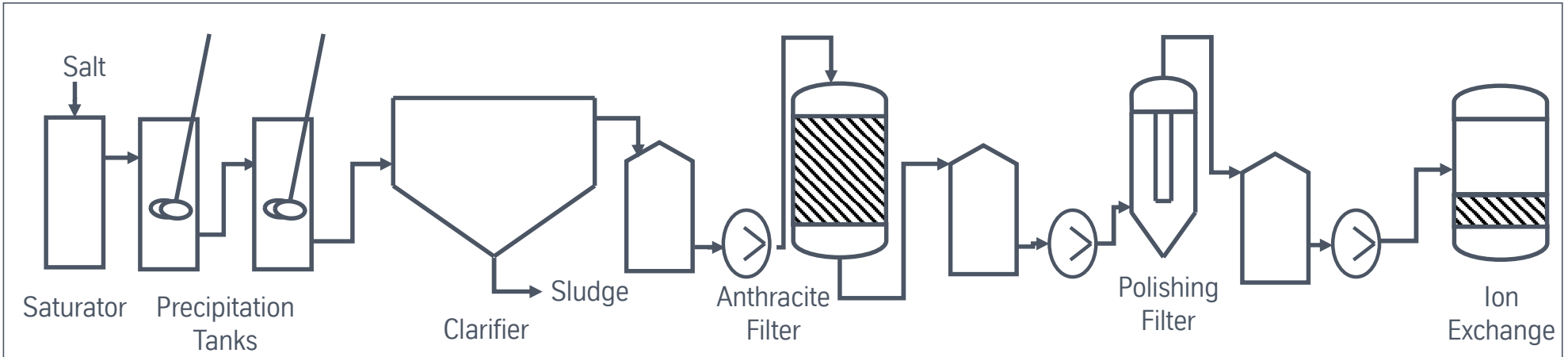
Conventional Brine Treatment System





Developments/Improvements in Brine System

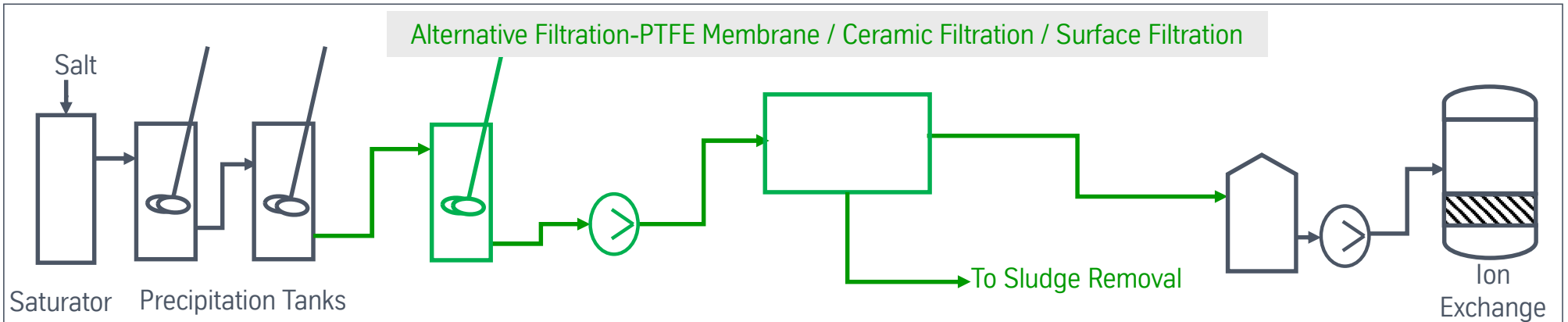
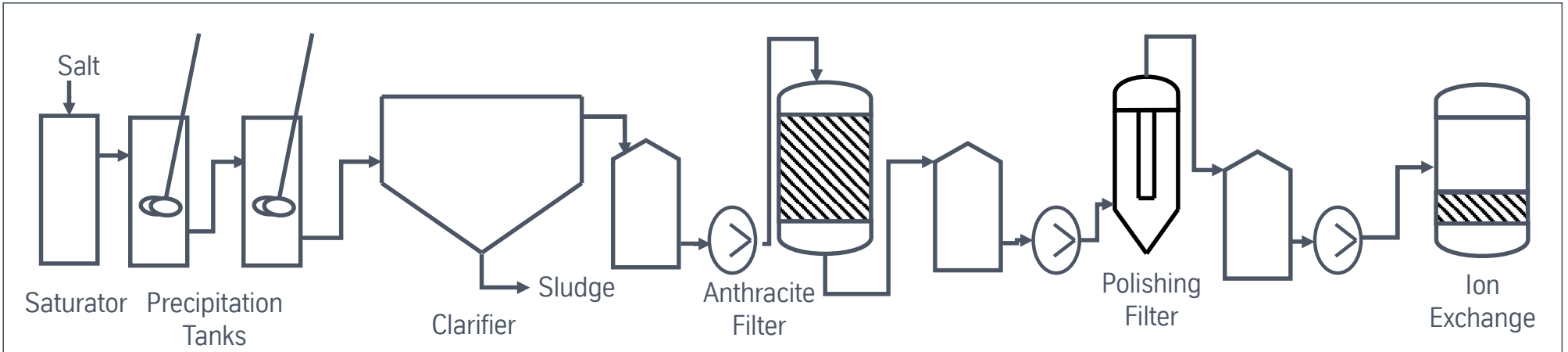
Conventional Brine Treatment System





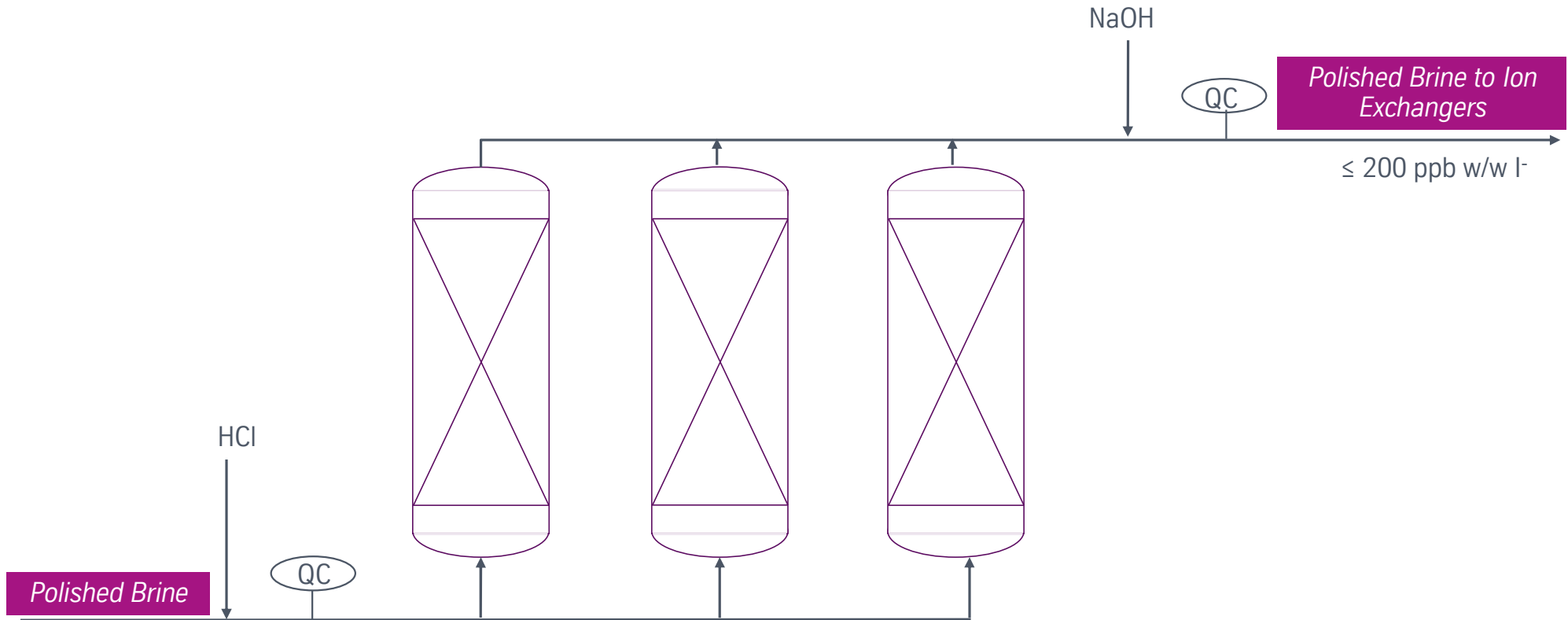
Developments/Improvements in Brine System

Single step filtration system



Developments/Improvements in Brine System

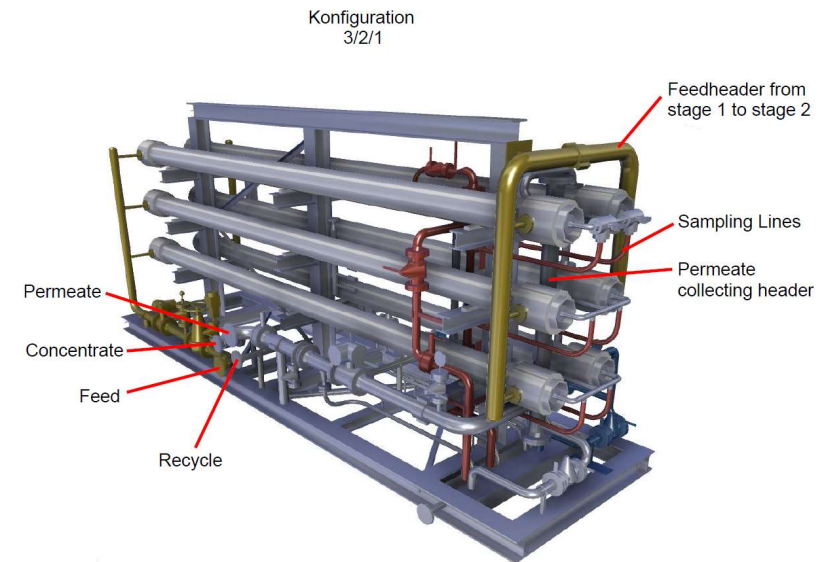
Membrane life improvement - Removal of Iodine in Brine



Developments/Improvements in Brine System



Removal of Sulphate – nucera SRU Unit



Anolyte Dechlorination – Alternative chemical Dechlorination using H_2O_2 and Removal of H_2O_2

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Product Quality Improvement



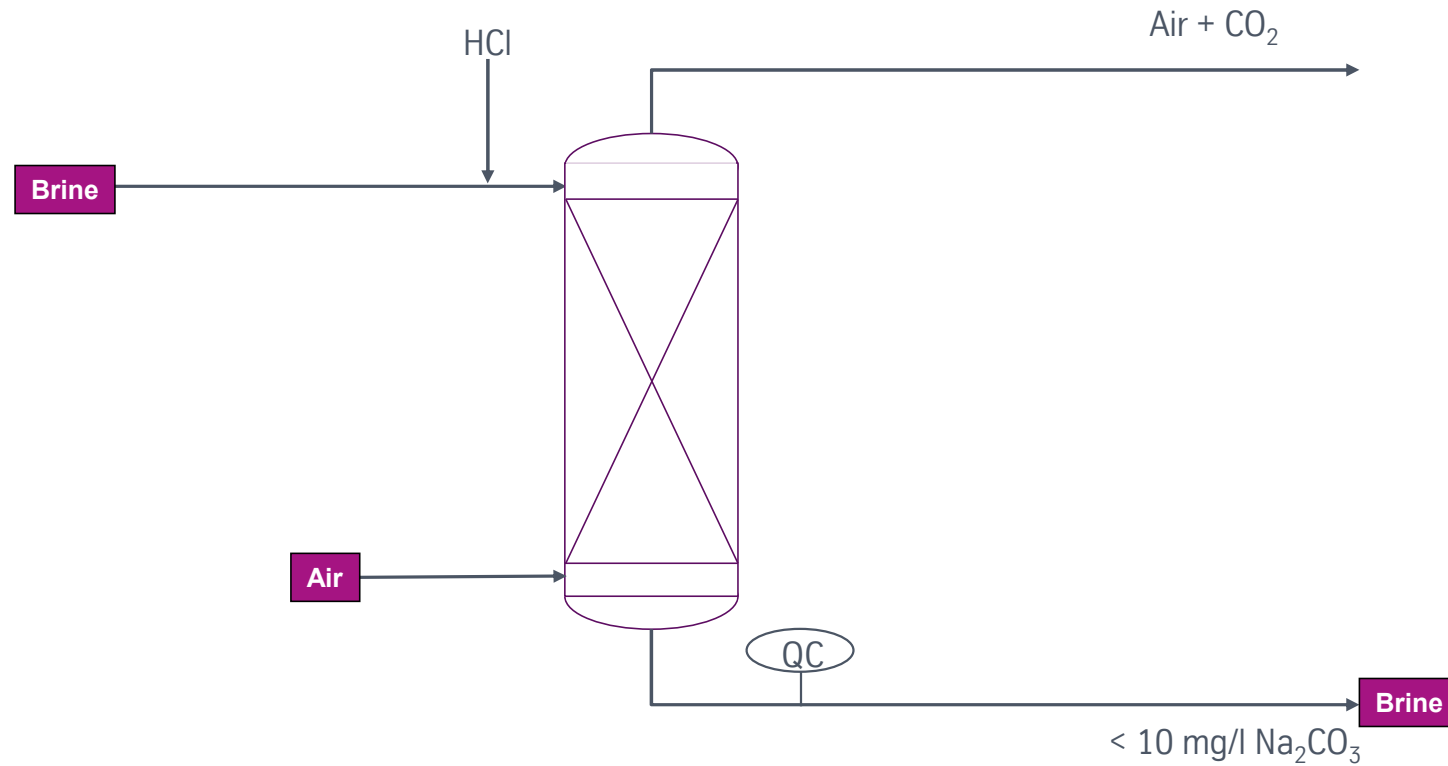
Caustic : ClO_3^- , SO_4^{2-}

Chlorine : CO_3^{2-} , Br^- , O_2

Hydrogen : O_2 , H_2O

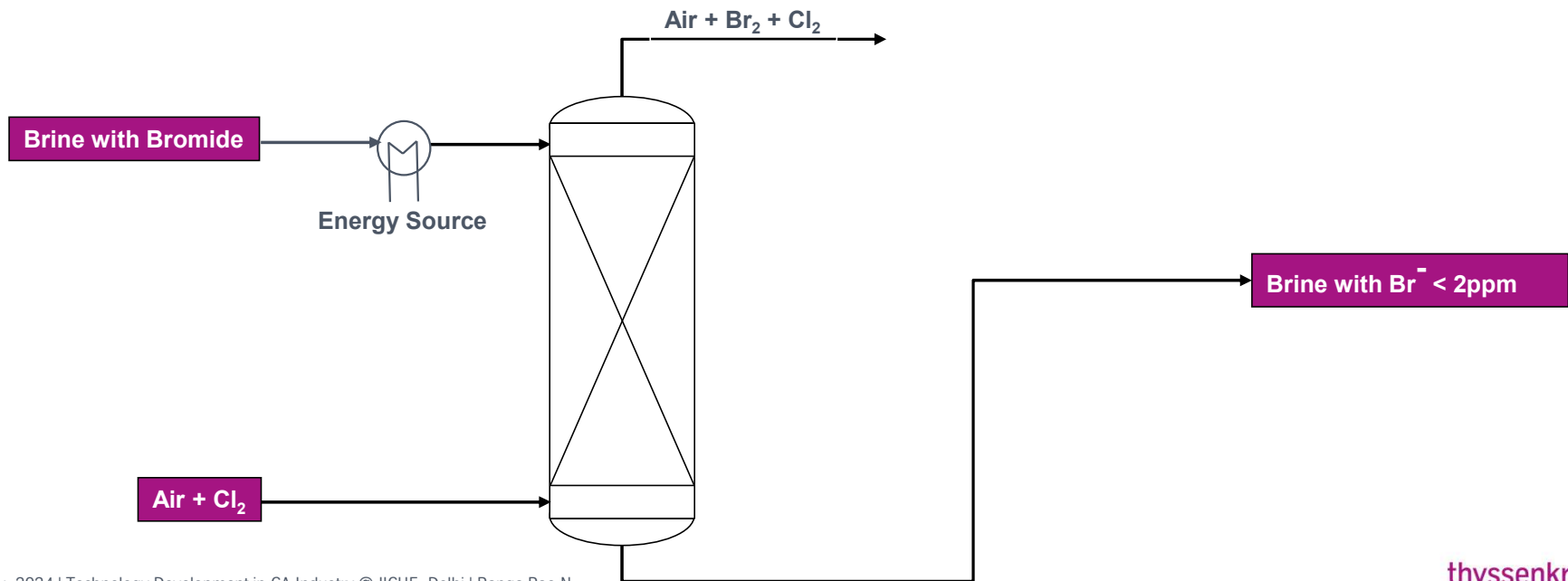
Gas Product(s) Quality Improvement

Product Chlorine Gas – Decarbonisation of Brine



Developments/Improvements in Brine System

Product Chlorine quality improvement - Removal of Bromine in Brine



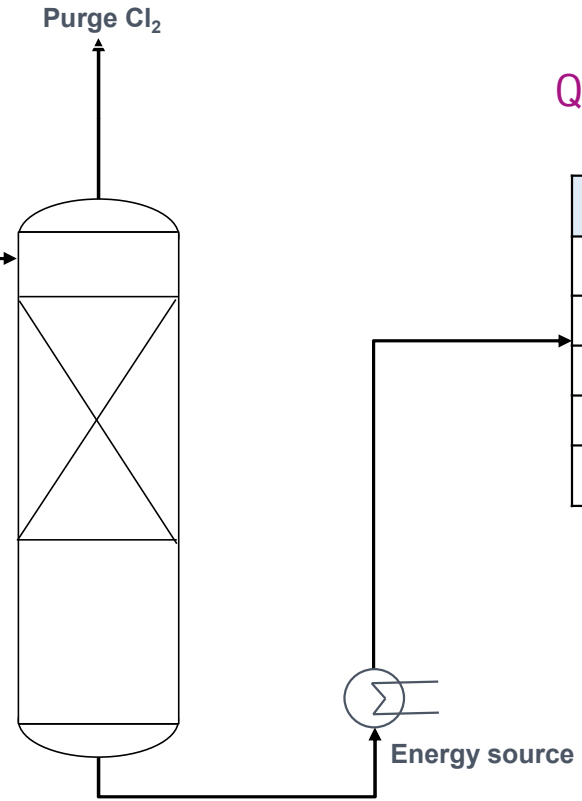


Gas Product(s) Quality Improvement

Product Chlorine Gas – Oxygen removal

Quality of Chlorine from Membrane cell plant

| Parameters | Unit | Specification |
|-------------------|---------|---------------|
| Chlorine | % v/v | ≥ 98.0 |
| Oxygen | % v/v | 0.6 to 1.0 |
| Nitrogen & Inerts | % v/v | ≤ 0.5 |
| Hydrogen | %v/v | 0.01 – 0.05 |
| Moisture | ppm w/w | Saturated |



Quality of Chlorine required for utilization

| Parameters | Unit | Specification |
|------------|---------|---------------|
| Chlorine | % v/v | ≥ 99.0 |
| Oxygen | ppm v/v | < 50 |
| | | |
| | | |

Gas Product(s) Quality Improvement

Product Hydrogen Gas – Hydrogen Purification - Deoxo and Drying Unit



Quality of Hydrogen from Membrane cell plant

| Parameters | Unit | Specification |
|-----------------|---------|---------------|
| Hydrogen | % v/v | ≥ 99.9 |
| Oxygen | % v/v | ≤ 0.1 |
| Nitrogen | % v/v | ≤ 0.5 |
| CO ₂ | ppm v/v | ≤ 15 |
| CO | ppm v/v | ≤ 2 |
| Moisture | % v/v | Saturated |

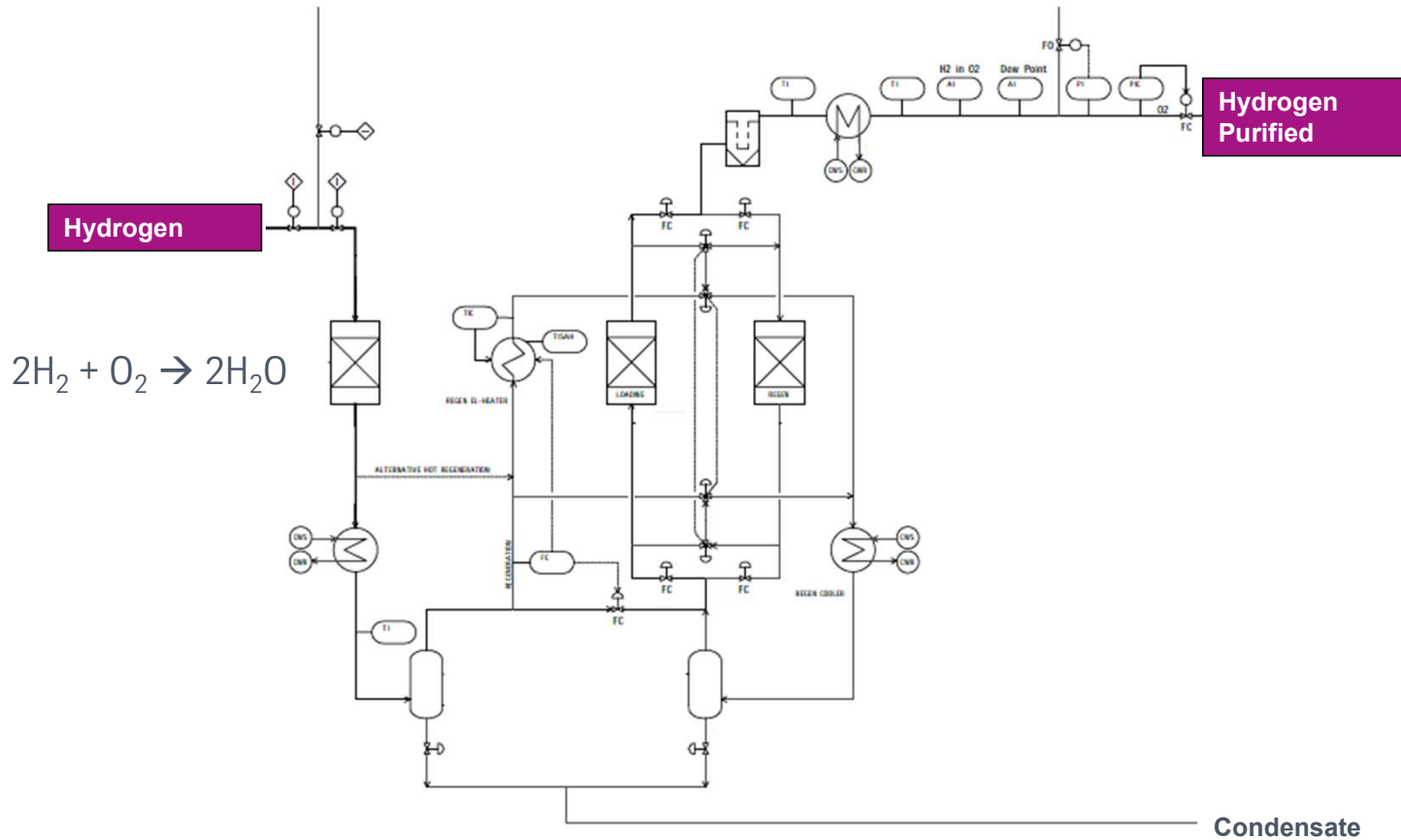
Quality of fuel Cell grade Hydrogen as per ISO 14687

| Impurity | Amount fraction limit (ppm) |
|-----------------------------|-----------------------------|
| Water | 5 |
| Total hydrocarbons | 2 |
| Oxygen | 5 |
| Helium | 300 |
| Nitrogen | 100 |
| Argon | 100 |
| Carbon dioxide | 2 |
| Carbon monoxide | 0.2 |
| Total sulphur compounds | 0.004 |
| Formaldehyde | 0.01 |
| Formic acid | 0.2 |
| Ammonia | 0.1 |
| Total halogenated compounds | 0.05 |

ISO 14687-2 specifications for maximum allowable impurity content of hydrogen

Gas Product(s) Quality Improvement

Product Hydrogen Gas – Hydrogen Purification - Deoxo and Drying Unit



Thank you very much for your attention!



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