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November, 14-16, 2018
Monterrey - Mexico

ENERGY SAVING SOLUTIONS AND LATEST DEVELOPMENT IN COATINGS TECHNOLOGY

ELECTRODE TECHNOLOGIES & WATER TECHNOLOGIES

Decio Barros \ Sales and Technical Assistance Director

Luiz Gonzaga \ Sales and Technical Assistance Engineer

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- De Nora: a unique blend of different expertise
- De Nora do Brasil
- Zero Gap Retrofit
  - MGC 30
  - INEOS Bichlor
- NRG® cathode coatings
- Anode coatings
- Conclusions

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DE NORA IDENTITY

Our daily activities are driven by our values

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DE NORA AT A GLANCE

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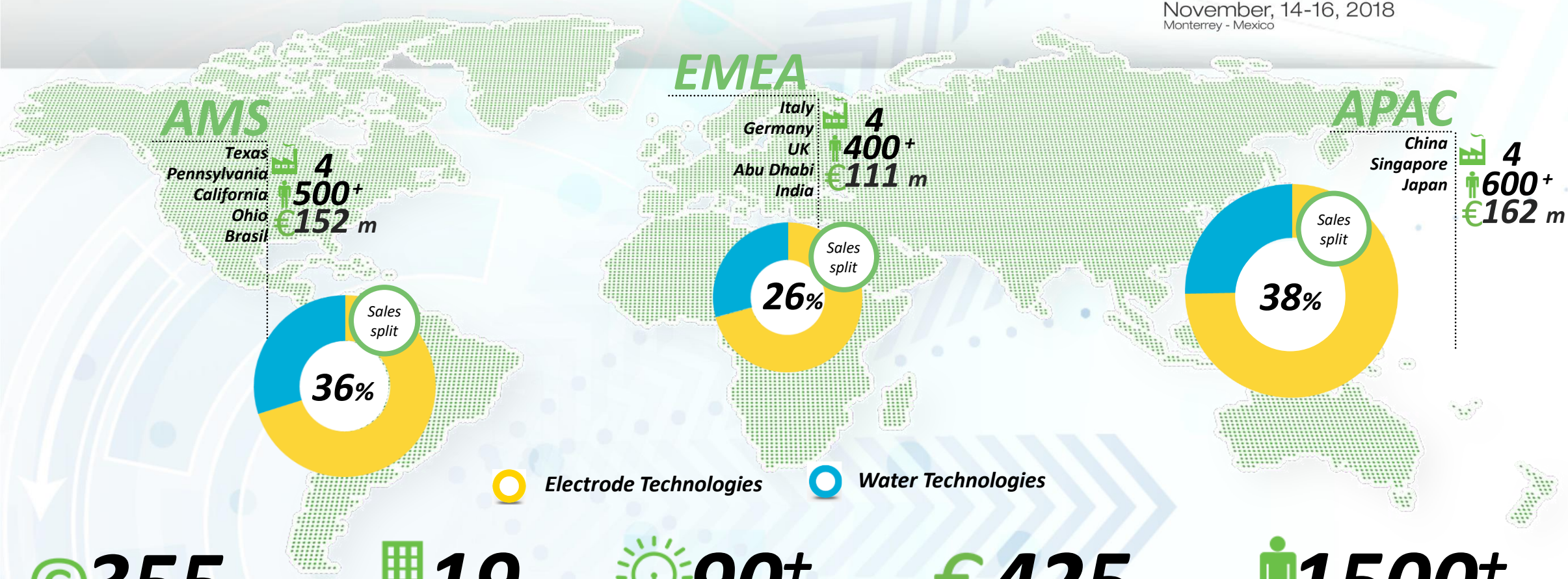

©355 Patent families

19 Locations

90+ Years of Innovation

€425m 2017 Revenues

1500+ People

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OUR COMMITMENT

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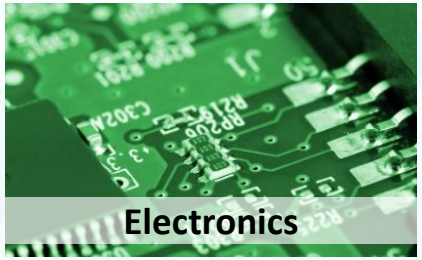
Delivering innovative products and solutions to diversified industries to address customers' needs

ELECTRODE TECHNOLOGIES
electrochemistry at your service


Chlorine & Caustic Soda


Electronics


Mining


Cathodic protection


Renewable energy storage


Pools


Surface finishing


Pulp & Paper

WATER TECHNOLOGIES
water made easy


Municipal


Energy


Oil & Gas


Marine


Food Processing & Sanitising


Industrial water treatment

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FUTURE CHALLANGES

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- Climate change
- Population growth
- Carbon footprint
- Resource scarcity

Strategic arenas

Energy storage

Mining

Water treatment

Energy savings and resource recovery

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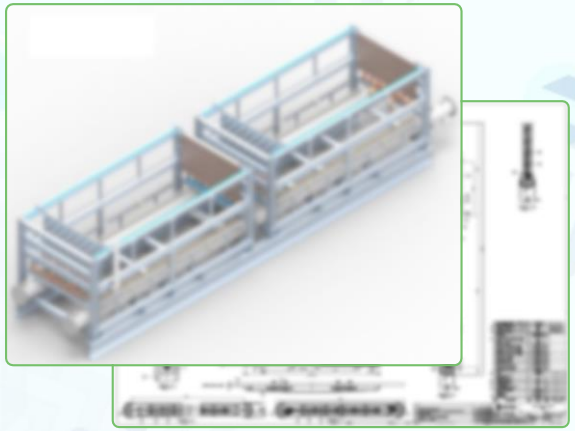
Coating domain, cell design engineering, cell mechanical manufacturing

R&D labs: coating development

- 3 R&D facilities (Italy, US, Japan)
- +100 researcher involved
- 30 lab-scale membrane C/A cells
- several testing protocols

Cell design engineering



- Engineering services for tkUCE
- R&D projects
- Prototyping and field testing

Electrodes & Cell manufacturing

- Production, commercialization, technical assistance and services for dimensional stable electrodes with precious metal coatings
- New assembly, repair and re-activation of Chlor-Alkali Membrane cells
- Laser welding
- Robot TIG welding
- …
- …

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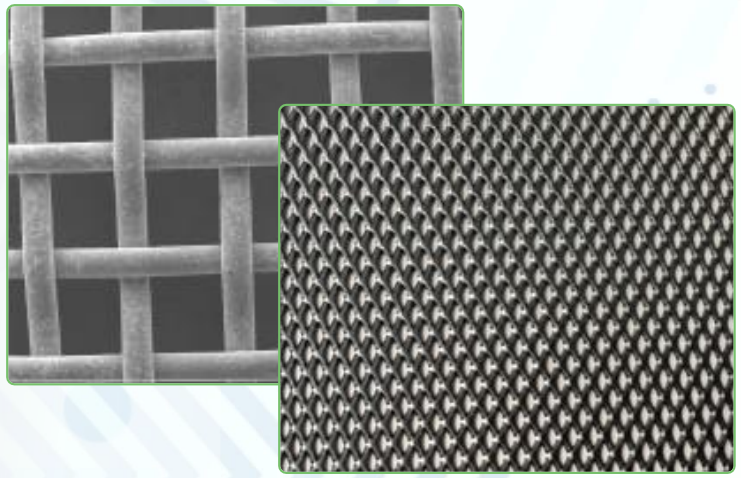
ENERGY SAVING SOLUTION

Concerns both cells and electrodes!

Cell modification: Zero Gap retrofit

Activated electrodes: cathodes and anode



- NRG®, the ultimate cathode coatings family
- New generation of anode coatings

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De Nora do Brasil is prepared to apply anodic and cathodic coating up to 35,000 m²/year of activated surface.

Part of the building	Area (m²)
Mechanical Activities	1800
Coating Activities	1700
Administration	900
Warehouse	300
Others	100
Total Area	45000

ACTIVATION TYPES:

- ❑ Anodic
- ❑ Cathodic
- ❑ Platinization

EXPANSION PROJECT:

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Not yet customers
Long term customers
New customers

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ZERO GAP RETROFIT

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ZERO GAP RETROFIT

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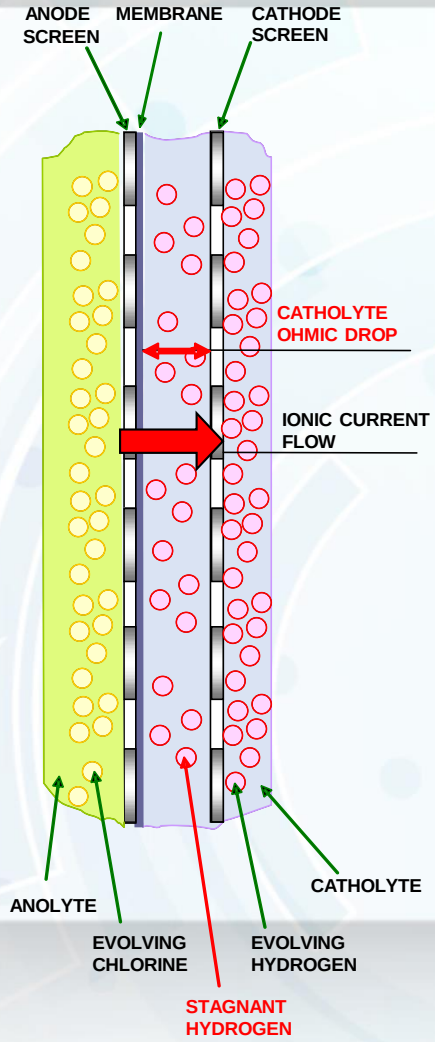
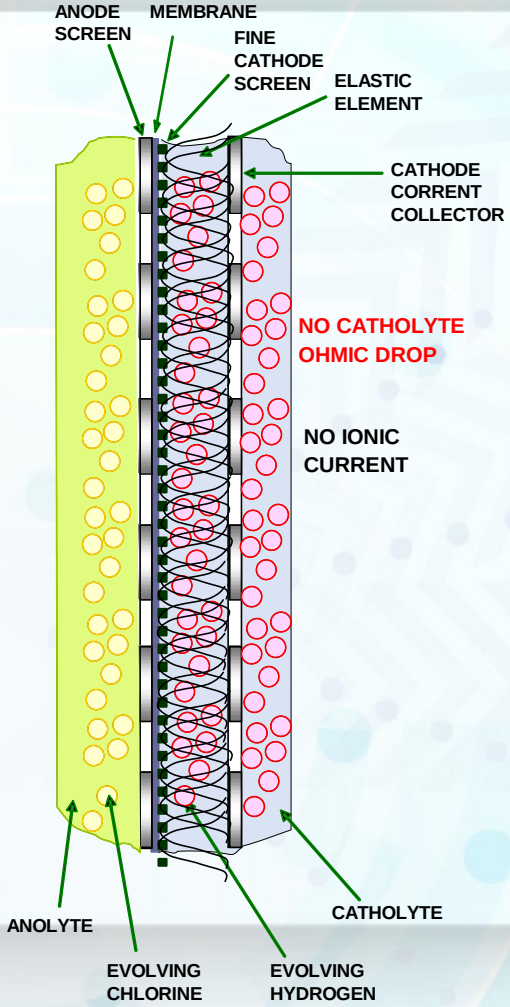
FINITE/NARROW GAP



ZERO GAP



- Zero Gap totally removes the ionic ohmic drop related to the catholyte gap: a significant cell voltage reduction is obtained!

- Zero Gap retrofit is obtained by installation of a package:
  - The old cathode screen is used as **current collector**
  - A **fine activated cathode screen** shifts up to gently touch the membrane
  - In between them a durable **elastic element** is inserted
  - Every component is designed to meet electrical, mechanical, fluid dynamic specifications

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ZERO GAP RETROFIT

- **New installations** – Zero Gap embedded in the most recent C/A cell technologies:
  - TKUCE (formerly UHDE/UHDENORA and CEC)
  - AKC / BLUESTAR

- **Existing installations** (finite gap, narrow-gap or out-of-date zero-gap) - Zero Gap achievable by retrofit
  - ELTECH MGC
  - AK FC, NCS, NCH
  - AGC Azec / CEC CME (monopolar) and BiTAC (bipolar) / UHDE-UHDENORA BM2.7 *
  - INEOS BiChlor

- Not all cells are equal → there is not an optimal Zero Gap retrofit solution equal for all cells → De Nora offers the Zero Gap solution tailored for each cell

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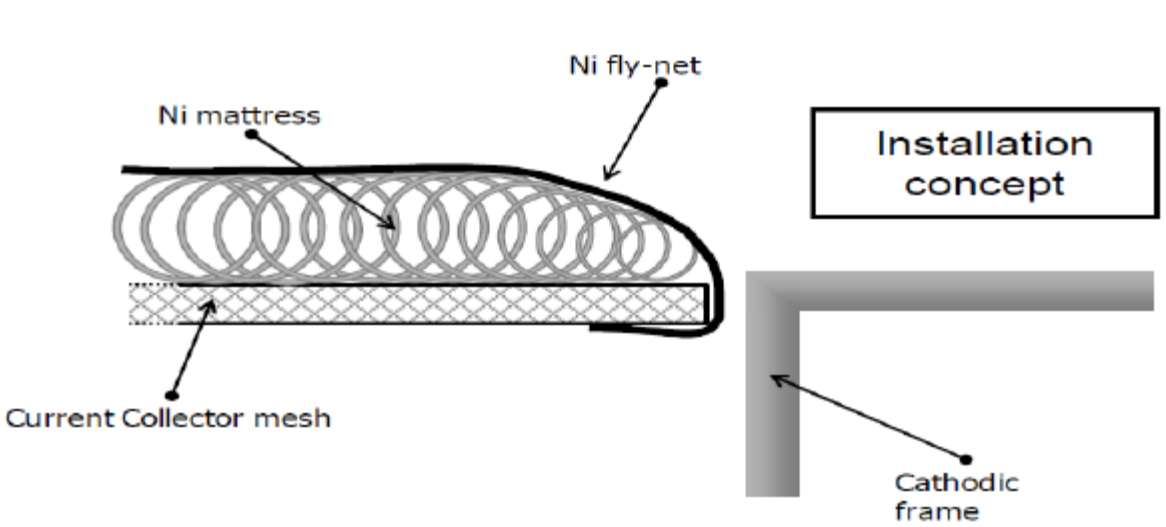
RETROFIT EXAMPLE: MGC 30

- Easy Installation Concept



- No change on the element structure

RETROFIT EXAMPLE: MGC 30

- Anode remeshing is like normal recoating procedure
- Original cathode mesh is maintained and used as current distribution. No need of coating.
- Mattress is fixed on current distributor by resistant welding.
- Possible to retrofit cathode package on site.
- Flynet is installed on mattress. Welding is not used for Flynet.

RETROFIT EXAMPLE: MGC 30

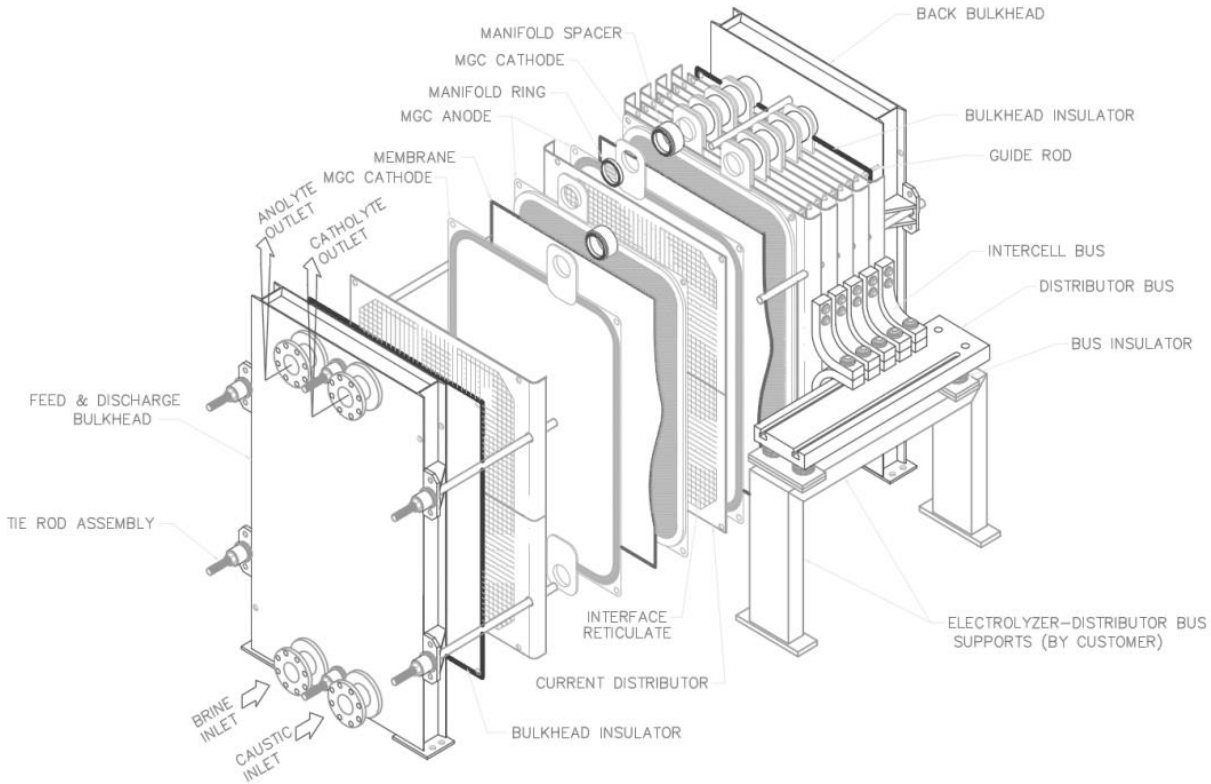
- Compensates for Fatigue of Cathode Springs
- Flat Cathode Profile – No “Pinch” Points
- Improved IR Drop (Anode-Cu Voltage)
- Cathode “Recoating” done by replacing Flynet at Site
- Coatings for Polarized and Non-Polarized Cell Rooms

RETROFIT EXAMPLE: MGC 30

- Manufacturing Process of MGC 30 Element

RETROFIT EXAMPLE: MGC 30

- MGC 30 Membrane Electrolyzer



RETROFIT EXAMPLE: MGC 30

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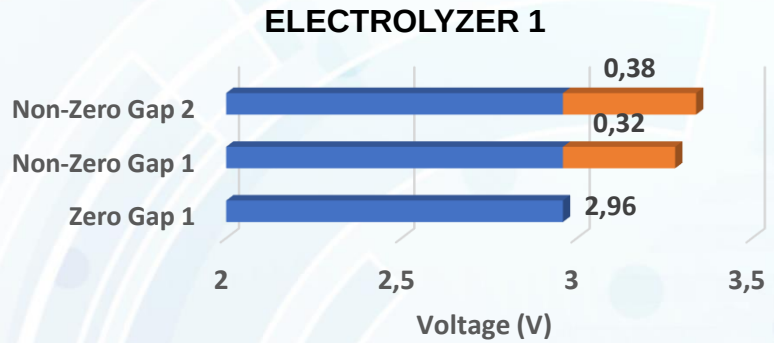
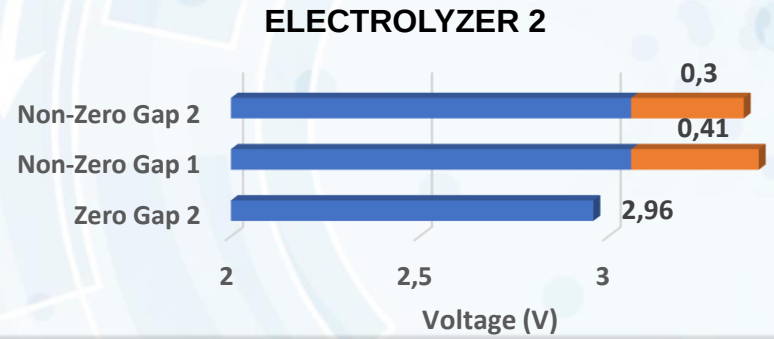
Customer 1

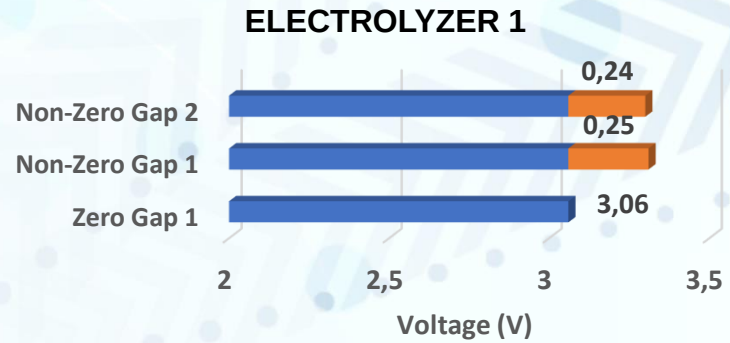
- 6.0 kA;
- 4.11 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 300 mV saving.

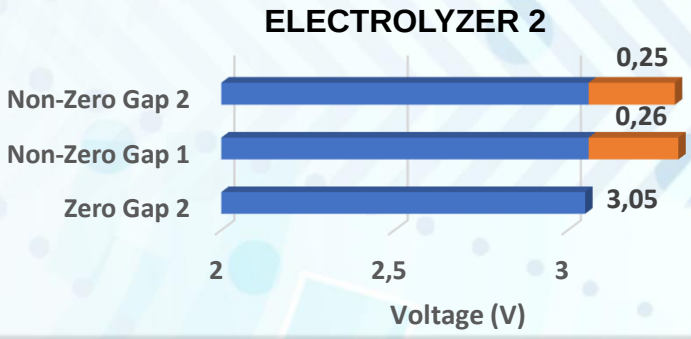




Customer 2

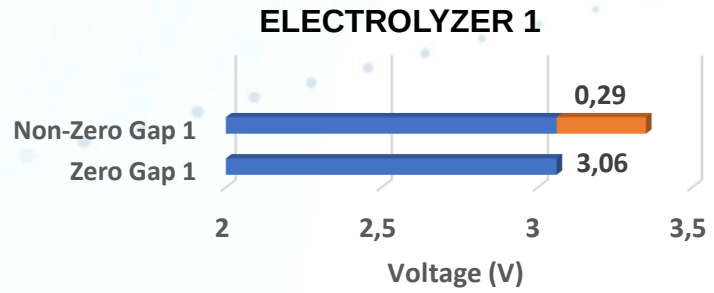
- 6.0 kA;
- 4.11 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 250 mV saving.

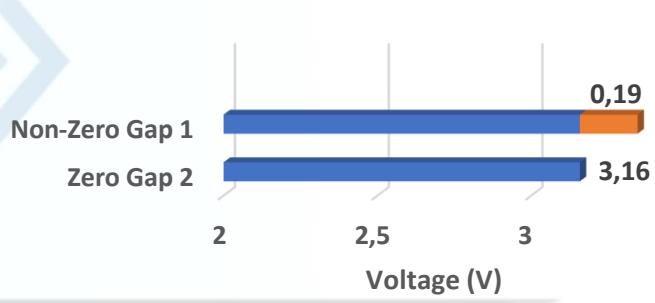




Customer 3

- 6.8 kA;
- 4.25 kA/m²;
- 2 (two) Electrolyzers with Zero Gap Technology;
- Around 200 mV saving.





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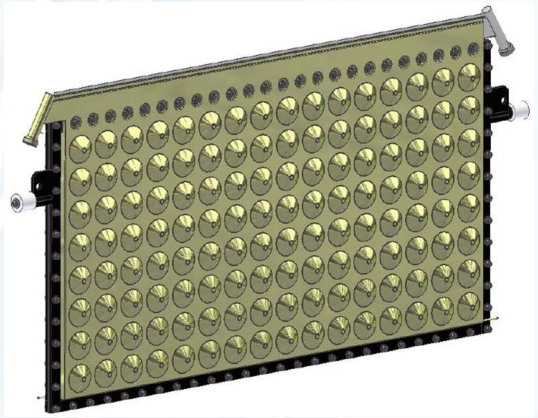
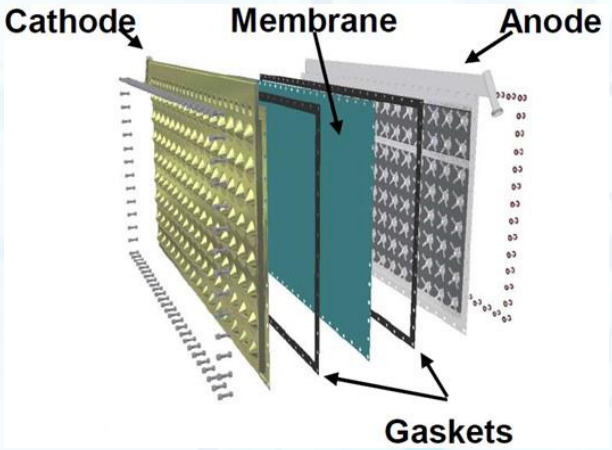
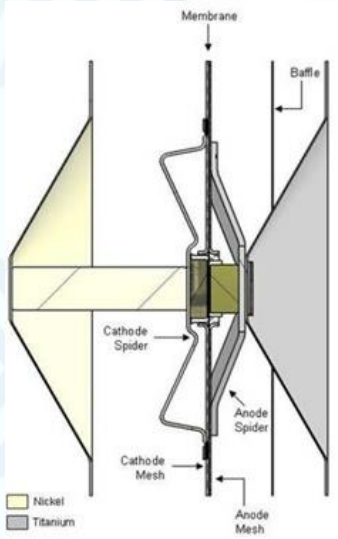
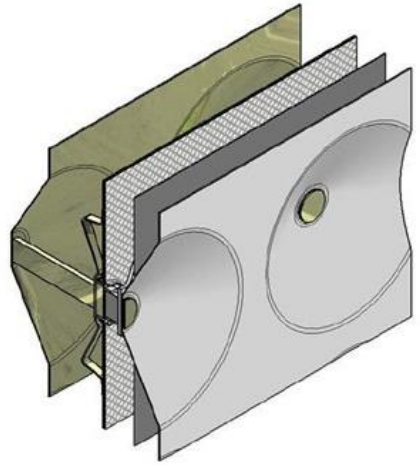
RETROFIT EXAMPLE: INEOS BICHLOR™

- Bipolar Ion-Exchange Membrane Chlor-alkali electrolyzer
- Cell module (or single element) *vs filter press*:
  - Separated anode pan and cathode pan
  - pans have dimples to improve the cell-to-cell electrical contact and to minimize the current path through titanium









Images taken from "www.ineos.com/globalassets/ineos-group/businesses/ineos-technologies/presentations/bichlor-electrolysers.pdf"

RETROFIT EXAMPLE: INEOS BICHLOR™

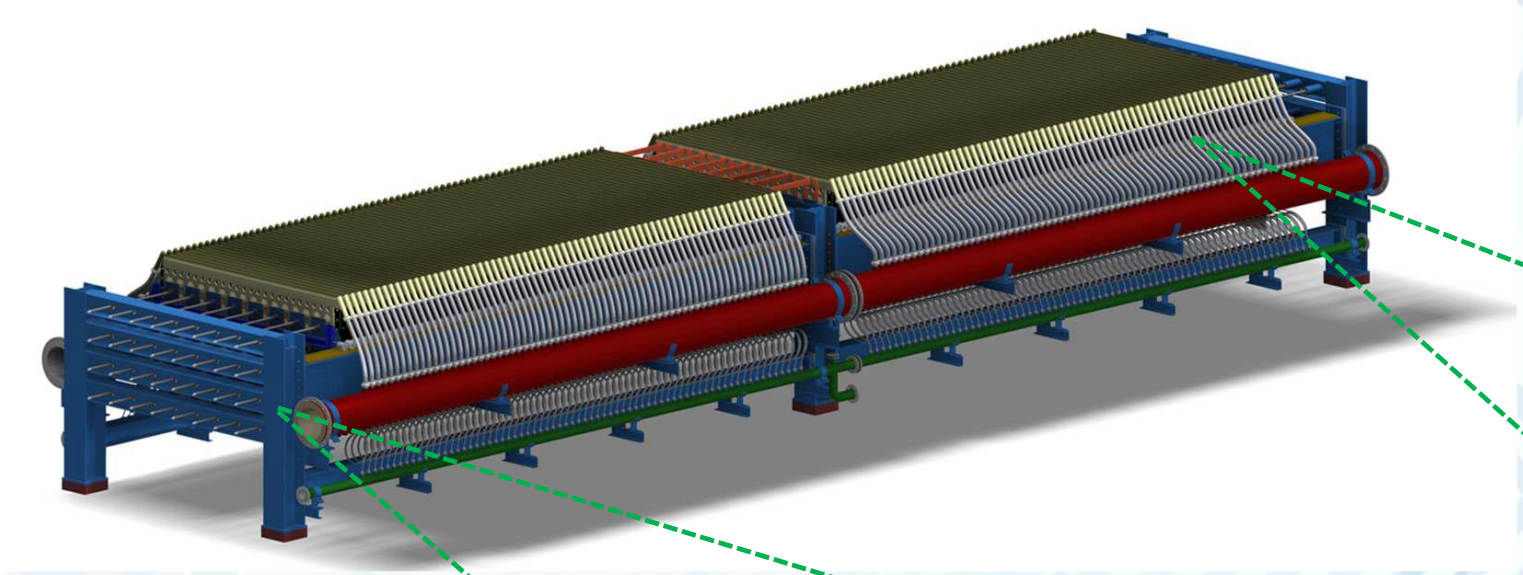
- In theory, very narrow gap (cathode «spiders»)..
- In practice, **exhausted** cells have space for:
  - superimposed activated anodic mesh (optional – on site revamping vs factory recoating)
  - thin elastic elements and activated cathodic fine mesh (on site cold installation)

- Once anodes and cathodes are upgraded, the standard assembly procedure of Cell Module is maintained:
  - Cathode pan on the assembly table
  - Gasket positioning
  - Membrane positioning
  - Gasket positioning
  - Anode pan on the cathode

RETROFIT EXAMPLE: INEOS BICHLOR™

Peculiarity of retrofit of Cell Modules vs Filter Press technology:

- elastic element compression is directly linked to electrolyzer tightening force



cell module wheels (cell modules can slides on the rack with low friction)

rack tightening system (32 bolts)

Image taken from "www.ineos.com/globalassets/ineos-group/businesses/ineos-technologies/presentations/bichlor-electrolysers.pdf"

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RETROFIT EXAMPLE: INEOS BICHLOR™

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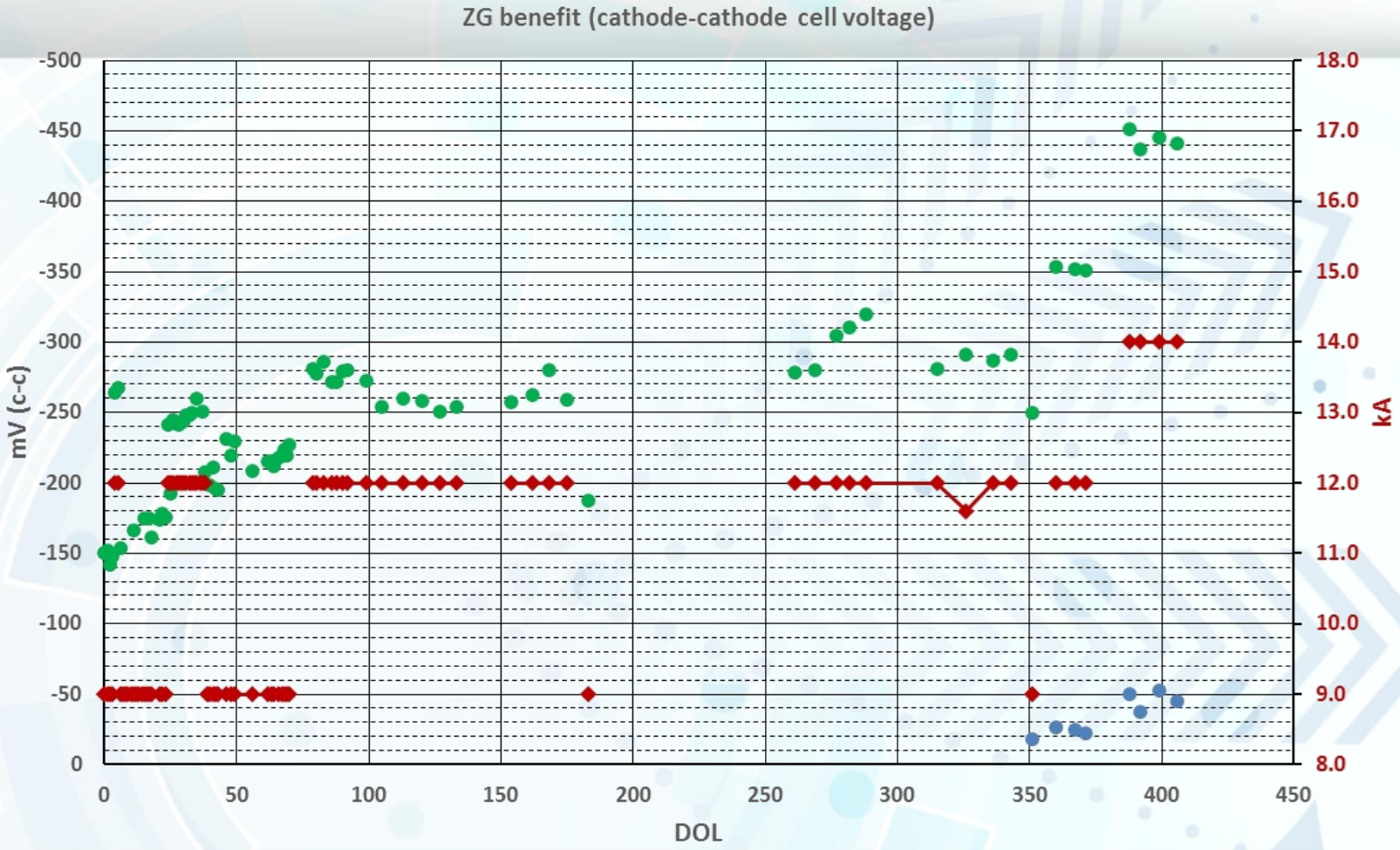

CV reduction of ZG retrofit cells (incl. new anode electrode, new membrane, cathodic ZG):
vs **exhausted** elements
- up to 200-250 mV @ 3 kA/m^2
- up to 250-300 mV @ 4 kA/m^2

vs **reconditioned** elements
- up to 25-50 mV @ 3-4 kA/m^2

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RETROFIT EXAMPLE: INEOS BICHLOR™

- Cathodes:
  - Full Zero Gap compensating for fatigue of exhausted Cathode Spiders
  - Adoption of NRG® cathodic coating family
  - Cathodic package On-Site Installation Option (cathodes never leave C/A plant)
  - On-site training for elastic element and activated fine mesh installation
  - Cathode “recoating” done by replacing activated fine mesh at Site
- Anodes:
  - recoating On-Site Installation Option (superimposed activated mesh)
- Diagnostics and follow-up

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NRG® CATHODE COATINGS

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NRG®, THE ULTIMATE CATHODE COATINGS

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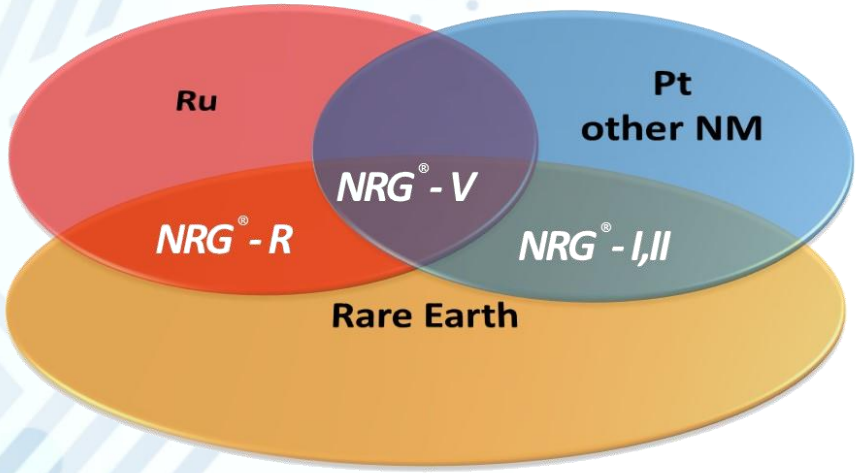
- NRG®, the ultimate De Nora cathode coating generation, is characterized by a series of “must have” that differentiate it from any other cathode coating available in the market:
  - The lowest overpotential for hydrogen discharge (HOV)
  - The longest stability of HOV during time
  - The highest robustness against operational upsets
  - Insensitiveness against catholyte pollutants
  - Smooth surface to prevent abrasion effect on membrane
  - Suitable for the application on all geometries



- All coatings are proven on industrial basis:
  - Noble Metals based
  - Designed to be offsets resistant
  - Long durability of performance
  - High quality and industrial reproducibility / Multiple sites manufacturing

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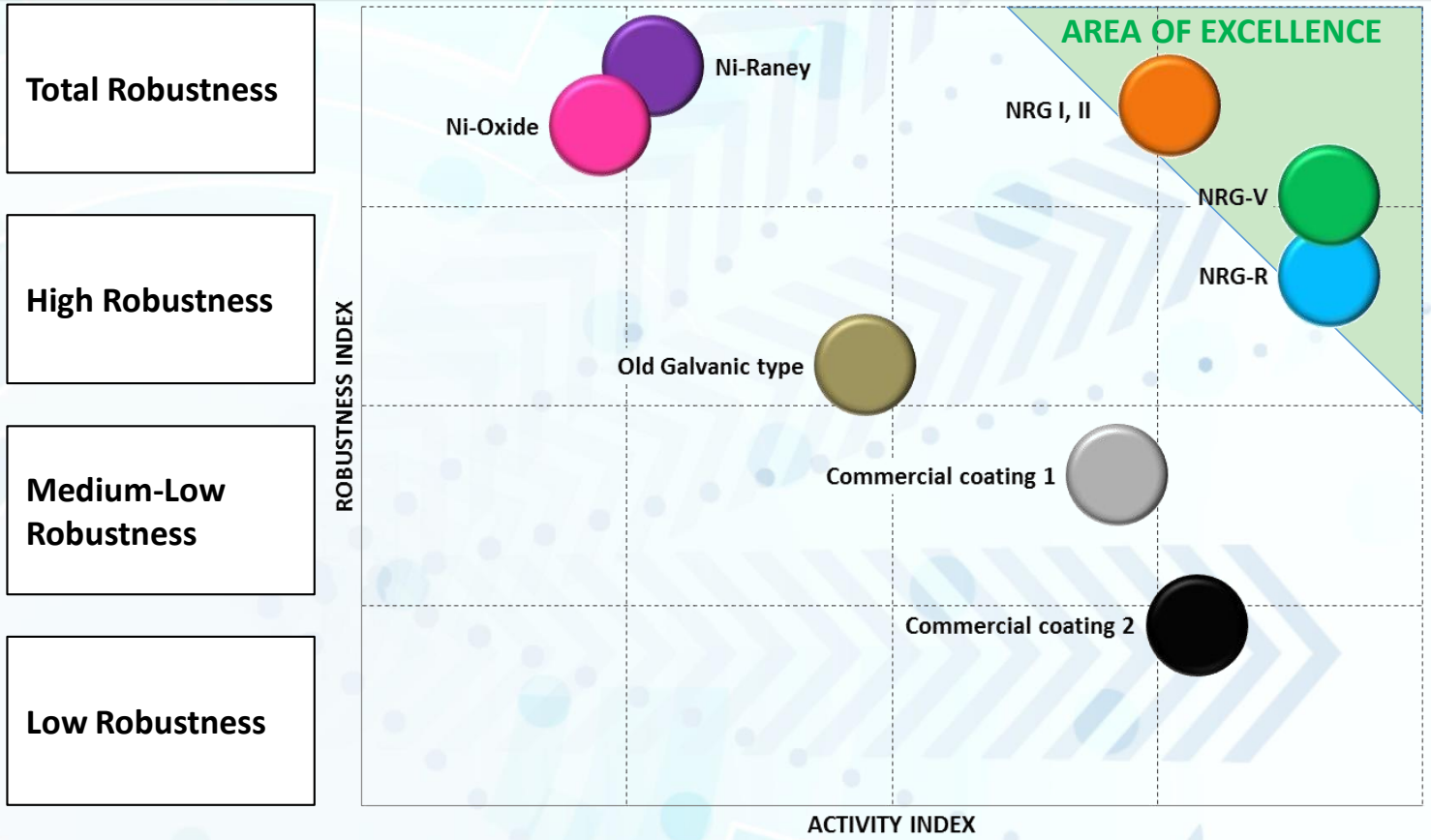
NRG®, THE ULTIMATE CATHODE COATINGS



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ANODE COATINGS

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WHAT IS A GOOD PERFORMING ANODE?

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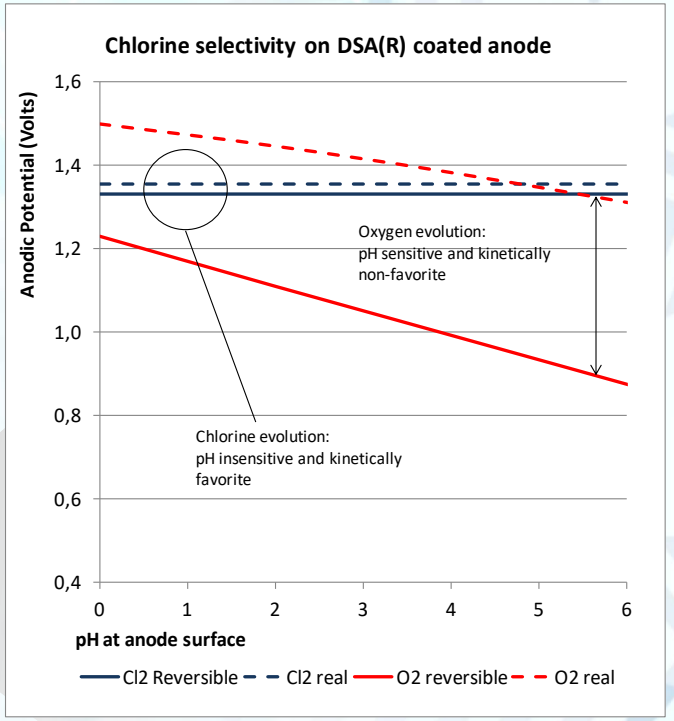
- What is the criterion to define a "good performing" Anode?

  It must satisfy the customer production needs

- For Chlor-alkali anode coating, this basically means:
  - ✓ High activity
  - ✓ Good selectivity
  - ✓ Long and predictable life
  - ✓ Promptness



- By thermodynamics, O_2 is favorite against Cl_2
- The nature of DSA® anode plays a key role to promote Cl_2 evolution
- Anode selectivity depends on different parameters: coating composition, morphology, architecture and manufacturing

The setup of parameters is always a trade-off among activity, selectivity, promptness, life and cost!

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HISTORICAL COATINGS
DE NORA KNOW HOW

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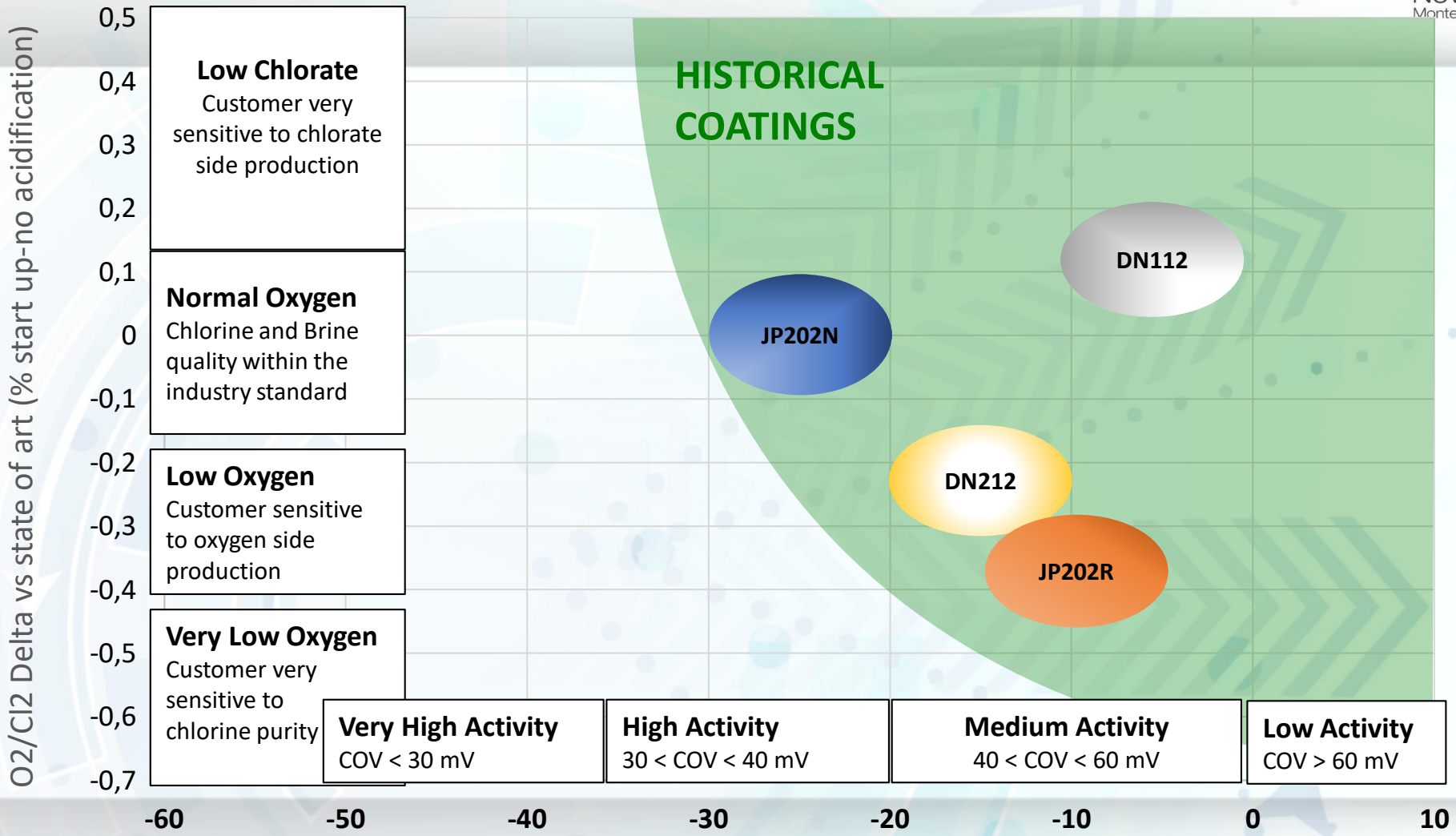

Values refer to current density from 4 kA/m² to 7 kA/m²

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HISTORICAL COATINGS FEATURES

- Production lines in the different production sites of DN group: Japan, Germany, USA, China, India, Brazil

- Years of proven performance in the field
- Widely used on all type of technologies and different substrates:
  - BM, BiTAC, AK, AGC, MGC…
  - expanded mesh, perforated plate…

- Low Chlorate family: JP202N, DN112
  - Low sub-production of chlorate

- Low Oxygen family: JP202R, DN212
  - Especially suitable for plants that require low oxygen level <1.00% at high efficiency without acidified brine

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LATEST COATING
DE NORA FORERUNNER

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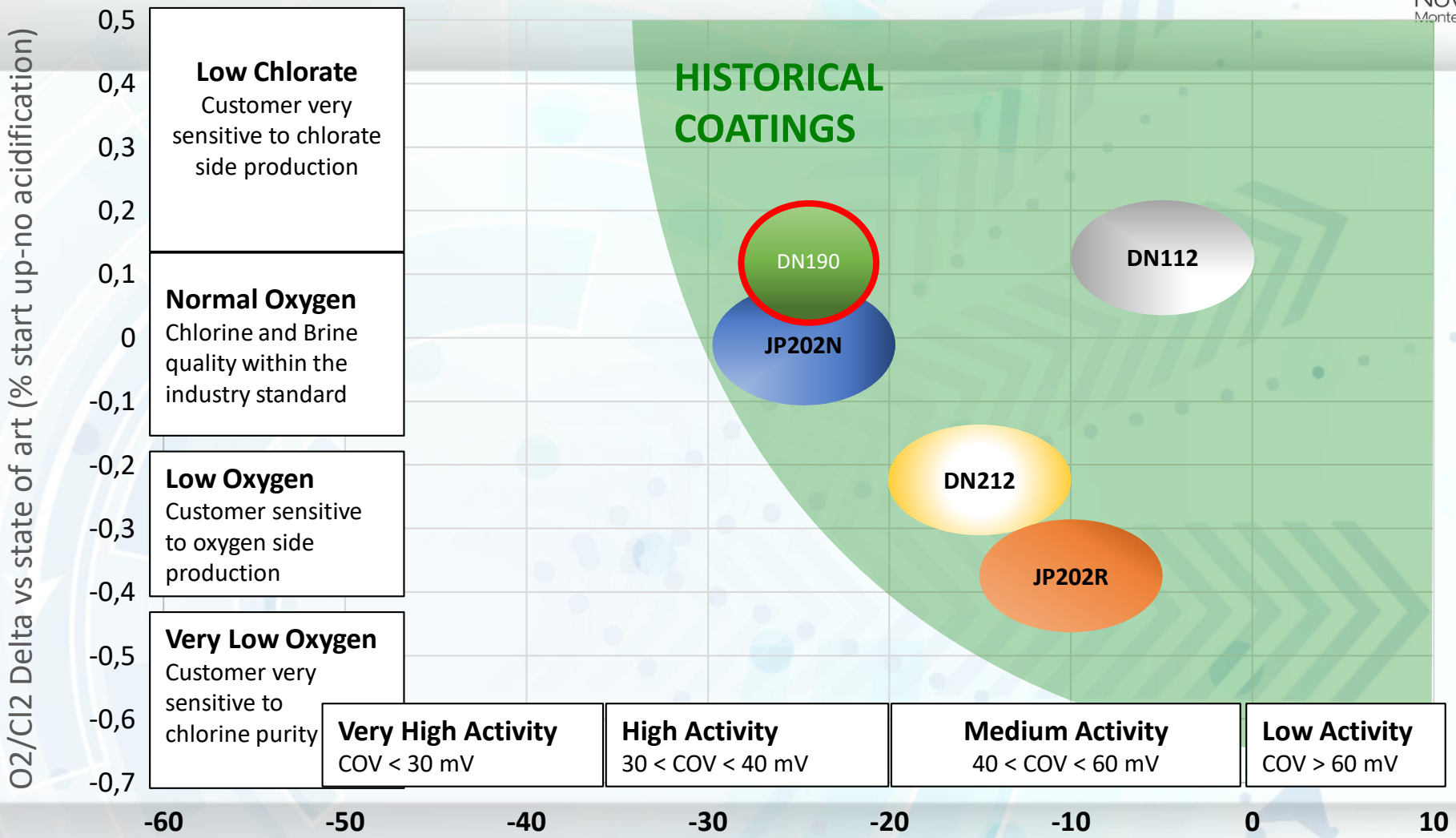

Values refer to current density from 4 kA/m² to 7 kA/m²

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LATEST COATING

Features

- Last added to DN portfolio:
  - Commercially available since few years with thousand of sqm already in operation after an intense qualification (lab scale to industrial size pilot).

- Latest coating feature:
  - Development work on new precursors: exploitation of chemical species different from the ones traditionally used within DN to achieve new morphology;
  - Good cell voltage in line with the best traditional De Nora coatings;
  - Normal oxygen in line with the traditional De Nora coatings in the whole range of efficiency range;
  - Fast break-in: promptness higher than traditional De Nora coatings.

NEXT COATINGS

Features

- Development of latest coating has opened the way for a new generation of anode coating to achieve further improvement
- Driver: maximize the value given to the customer achieving even more demanding features and creates a new coating family with modular performance depending on the single customer needs;
- Promptness is the new key value that besides activity and selectivity characterizes the new generation

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NEXT COATING

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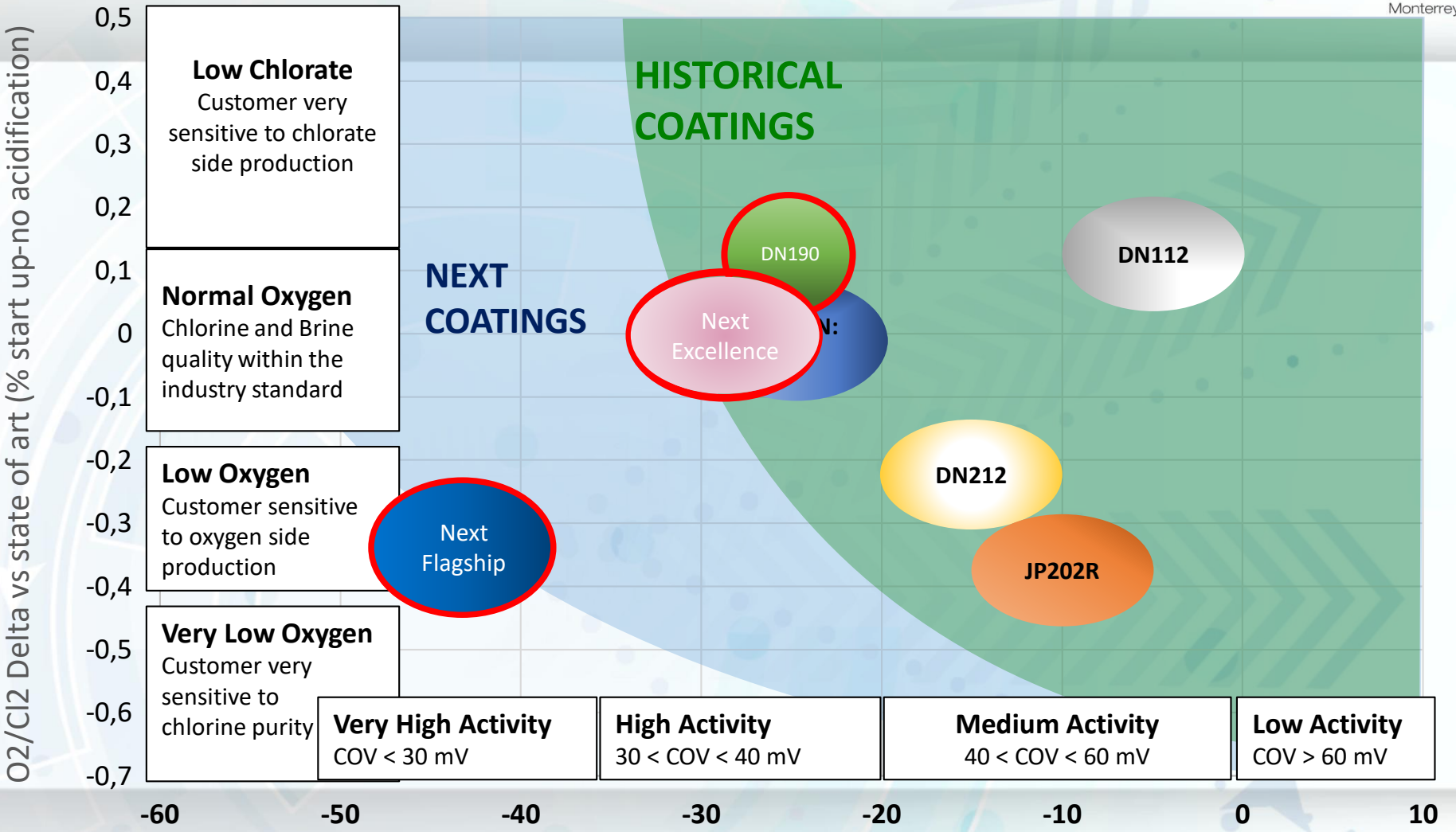
Features



Values refer to current density from 4 kA/m² to 7 kA/m²

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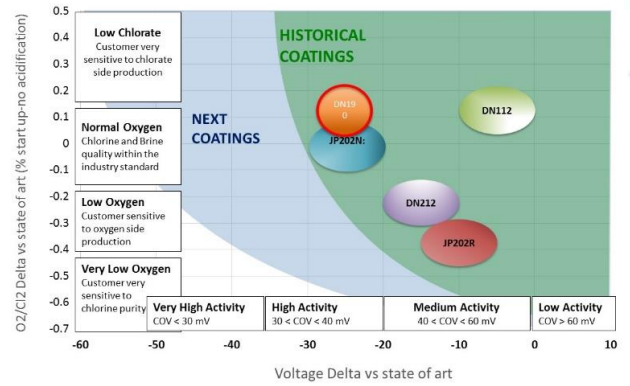
NEXT COATINGS

Features

- Next Excellent coating
  - Development made to achieve the excellence in performance in the low chlorate field.
  - Selectivity feature improved
  - Improved cell voltage respect to the best traditional De Nora coatings
  - Fast break-in: promptness higher than traditional De Nora coatings



- Next high edge coating: Flagship
  - Superior coating, combining high voltage saving
  - With excellent chlorine purity.
  - Ideal for high current density operation
  - Selectivity favored at high current density in the whole efficiency range
  - To maintain the high level of performance the same polarization used for the cathode is necessary during the shutdown events
  - Fast break-in

- Both are available for industrial test

CONCLUSIONS

CONCLUSIONS

- De Nora is unique:
  - **world-wide presence** with coating factories and mechanical workshops
  - De Nora **expertise** is a peculiar blend of coating domain, cell design engineering, cell mechanical manufacturing
- De Nora energy saving solution deals with both cells and electrodes!
- De Nora **Zero Gap retrofit**:
  - Great opportunity for Power Saving
  - Based on top-quality design, top-quality components, top-quality installation
- De Nora **NRG® cathode coatings** are capable to secure reliable and durable power saving even at extreme operating conditions
- A new generation of De Nora **anode coatings** is approaching, able to achieve even more demanding features with modular performances depending on the single customer needs

Thank you for your attention

Questions?