Nedstack
PEM FUEL CELLS

PEM FUEL CELL TECHNOLOGY

Welcome KIVI @ Nedstack

22 January 2025 – Arnhem (NL)

KIVI
Engineering Society

Nedstack | Personal Introduction

Name	Jogchum Bruinsma
Position	Commercial Director
Since	2018
Location	Arnhem – The Netherlands

Role and Background

Role at Nedstack

- Responsible for Sales, Marketing and Service;
- Responsible for Customer Application Studies in the maritime domain.
- Responsible for Pursuing and Administering Class Approvals;

Other functions

- Chair of Zero Emission Shipping Technology Association
- Former Roadmap Leader for Waterborne at Hydrogen Europe;
- Former Member of STEERER Green Shipping Expert Group;
- Former Member of IEA-HIA Maritime task expert group

Background and Education

- 2 years at Huisman as Lead Engineer;
- 8 years at Boskalis as Senior Lead Engineer;
- First FC-Boat Application Project in 2010 at Alewijnse
- MEng in Control Systems Engineering – HAN University
- BEng in Industrial Automation Studies – HAN University

Nedstack | Table of contents

Nedstack
PEM FUEL CELLS

A

Company

Nedstack fuel cell technology

Nedstack | Company Profile

Name	**Carbon Technology Energies BV**
Location	Westervoortsedijk 73-VB, Arnhem, the Netherlands
Founded	1999 | 2024
Ownership	Privately

Website	www.nedstack.com
Industry	PEM Fuel Cells
Logo	Nedstack PEM FUEL CELLS

High lights

- Independent Company since 1999, re-started in 2024
- Leading Global Player in PEM-FC R&D;
- In-house Cell plate production and Stack Assembly;
- > 700 FC Systems installed-base as per 2017;
- > 23.000 Hours in-use Lifetime demonstrated;
- Highly competent Application Support team in-house;
- Strong footprint in EU and maritime

WE SUPPORT UN GLOBAL COMPACT

Specialized in Industrialized Power Plants

Nedstack main location

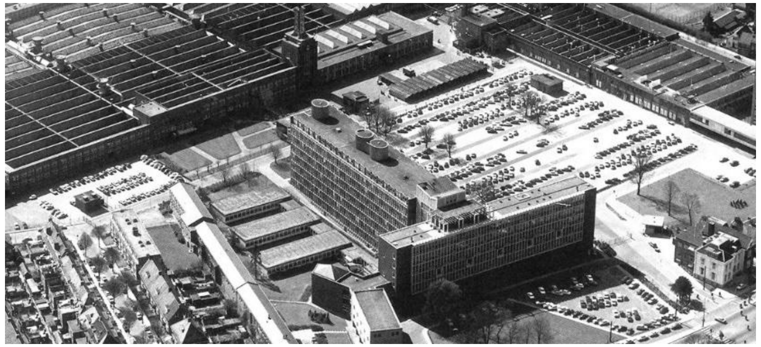
Nedstack Heritage

>25 years of PEM Fuel Cell Excellence

In 1999, AkzoNobel and ECN jointly established Nedstack, combining AkzoNobel applied chemistry products with the fundamental PEM Fuel Cell expertise that was vested in ECN. In doing so they created a global first PEM-FC player with a commitment to high-power / high-use type PEM-Fuel Cell Applications.

In 2024, Carbon Technologies Energies continued Nedstack Fuel Cell Technology, strengthen it with their Carbon & Graphite production technology expertise

IPKW (current Site) – former AkzoNobel



AkzoNobel - Velperweg Arnhem (first site of Nedstack)

Process & Systems Engineering

AkzoNobel Engineering

- Power Plant Process & Instrumentation Design
- HAZOP & Safety in industry
- Process Engineering Capacity

LT - PEM Fuel Cell Expertise & Technology

Energieonderzoek Centrum Nederland (ECN)

- PEM-FC Engineering & Test Expertise
- PEM-FC Testing laboratory
- Electro-Chemical Engineering Capacity
- Applied Membrane expertise

Material & Production Engineering

Carbon Technology Energies

- Carbon & Graphite Expertise
- Plate production technology
- Materials innovation centre
- Production innovation centre

■ **PEM Fuel Cell Building Blocks from AkzoNobel Group – Advanced Chemicals**

KETJEN	NOURY	ENKA GLANZSTOFF	AKZO ZOUT	SIKKENS
Carbon & Graphite Expertise	Catalyst Expertise	Polymers & lamination Expertise	Electrolyte Expertise	Coating Technology

FCGF Motivation

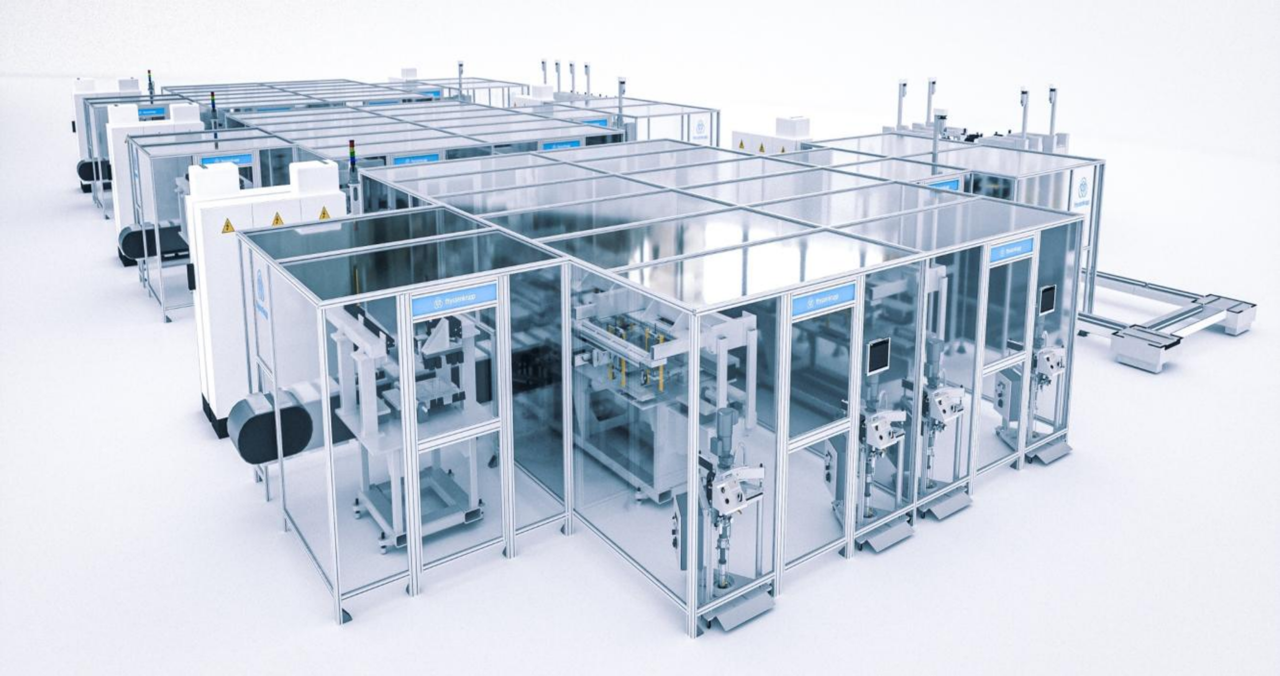
A FCGF is required to make the quantum leap

- **Cost down**
- Increase capacity
- Increase quality
- Global expansion
- Provide clean energy
- **Create a sustainable business**

Project NextStep – Towards 1 GWe per Annum Capacity

Industrialization Plan – Simultaneous Engineering

Nedstack PEM FUEL CELLS | FGF FUEL CELL GIGA FACTORY



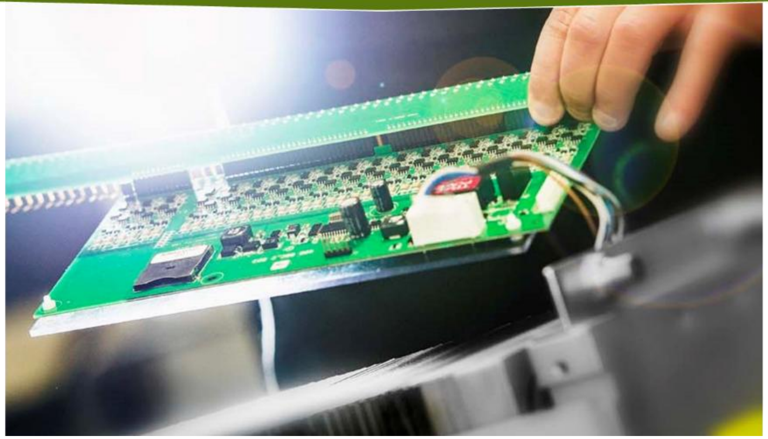
B

Capabilities

From Powder to Power

Nedstack | Fuel Cell Centre of Expertise

Fuel Cell Development



Fuel Cell Verification

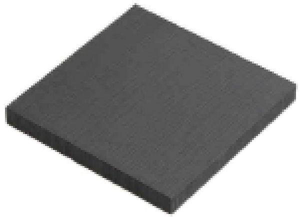
Fuel Cell Application

Fuel Cell Manufacturing

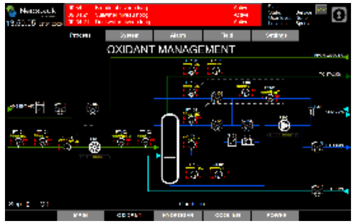
Nedstack | Services Portfolio

Signature PEM Fuel Cell Technology Portfolio

Fuel Cell Parts			Fuel Cell Solutions		
BMC's	BPP's	CVM	PEM Stacks	Power Plants	FC Control





Application Engineering & Project Management Services

Field Engineering Services (Commissioning / Inspection)

Maintenance & Support Services

■ By Co-Maker

Nedstack PEM FUEL CELLS

C

Technology

Low Temperature PEM Stacks & Systems

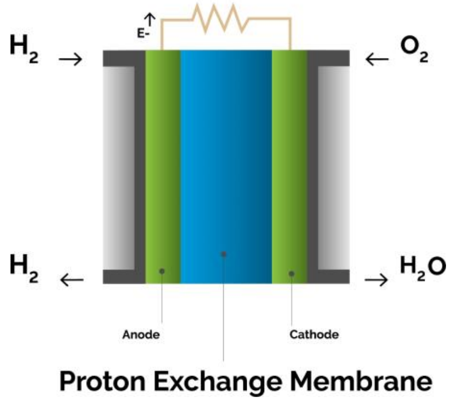
Nedstack | LT-PEM Fuel Cell Principle

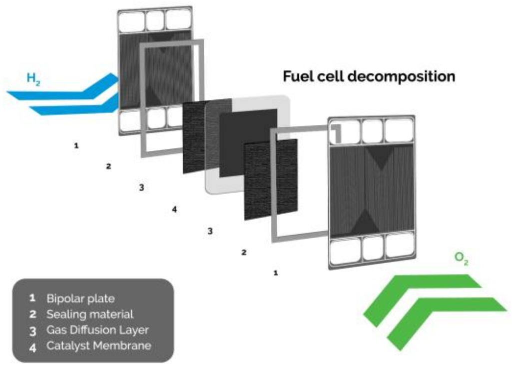
PEM FC's use Hydrogen as a Fuel and a PEM Membrane as Electrolyte

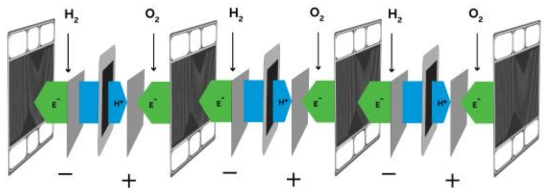
	Operating temp (°C)	Fuel	Electrolyte
PEMFC	40-90	H_2	Proton Exchange Membrane
AFC	40-200	H2	KOH
DMFC	60-130	Methanol	Proton Exchange Membrane
PAFC	200	H_2	Phosphoric Acid
MCFC	650	CH_4, H_2	Molten Carbonate
SOFC	600-950	CH_4, H_2	Solid Oxide

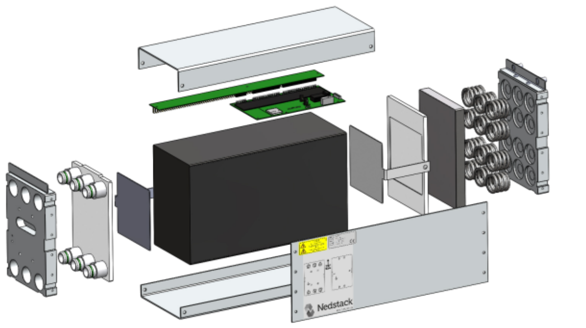
- Noble metals
- Noble metals/ non-noble metals
- Non-noble metals

Nedstack | LT-PEM Fuel Cell Stacks









PEM FC Principle

> **Emission free power generation**
> Gaseous Hydrogen (H2)
> Oxygen (O2) from air
> Produce electricity, heat and water

Fuel Cell Decomposition

> **Inhouse cell plate production**
> Flow fields distribute gases
> Membrane Electrode Assembly
> Cell plates are conductive

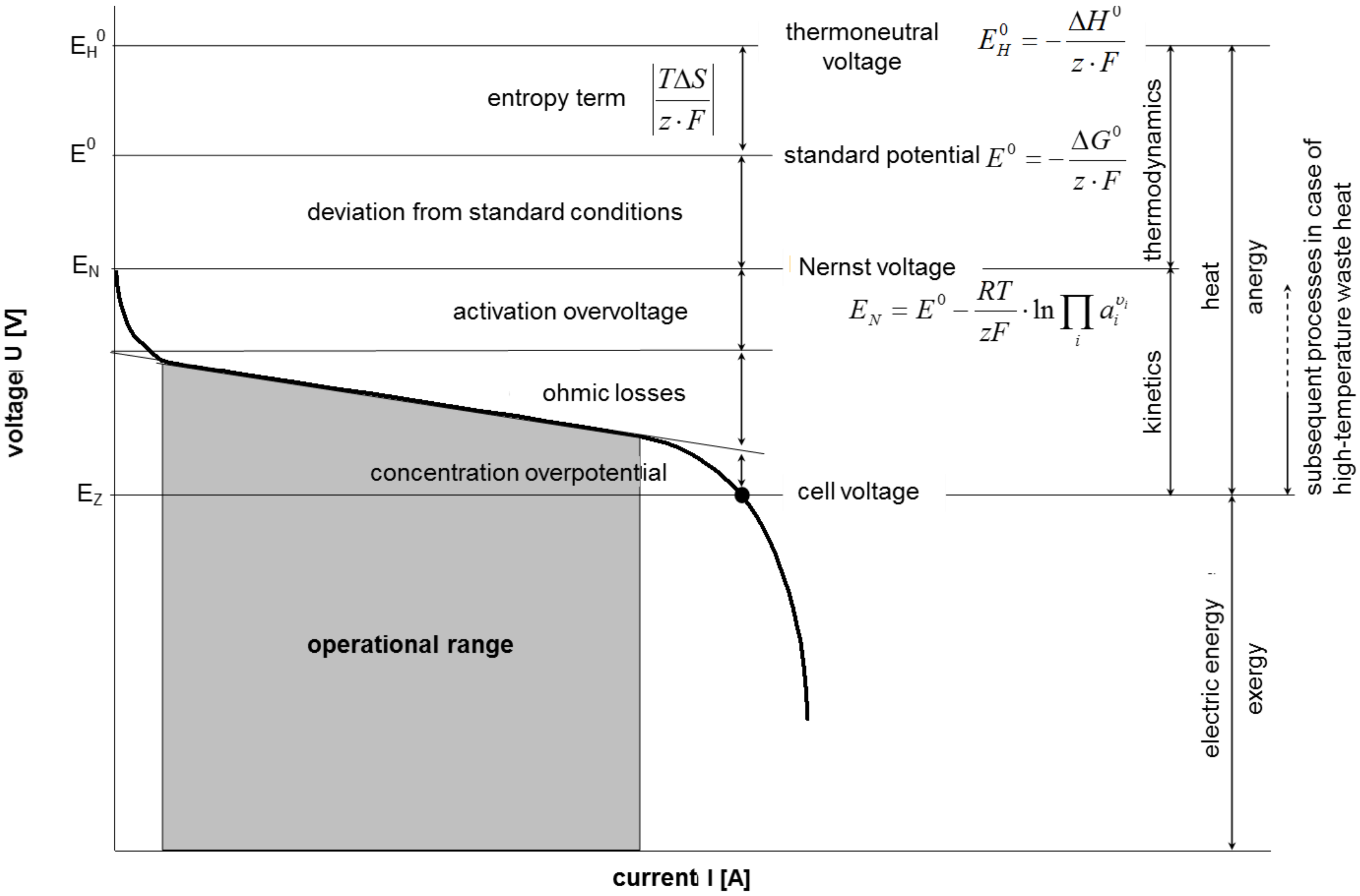
FC Stack Concept

> **Multiple cells are stacked**
> Cells are connected in series
> A single cell produce > 200A
> Individual cell voltage < 1VDC

FC Stack Exploded View

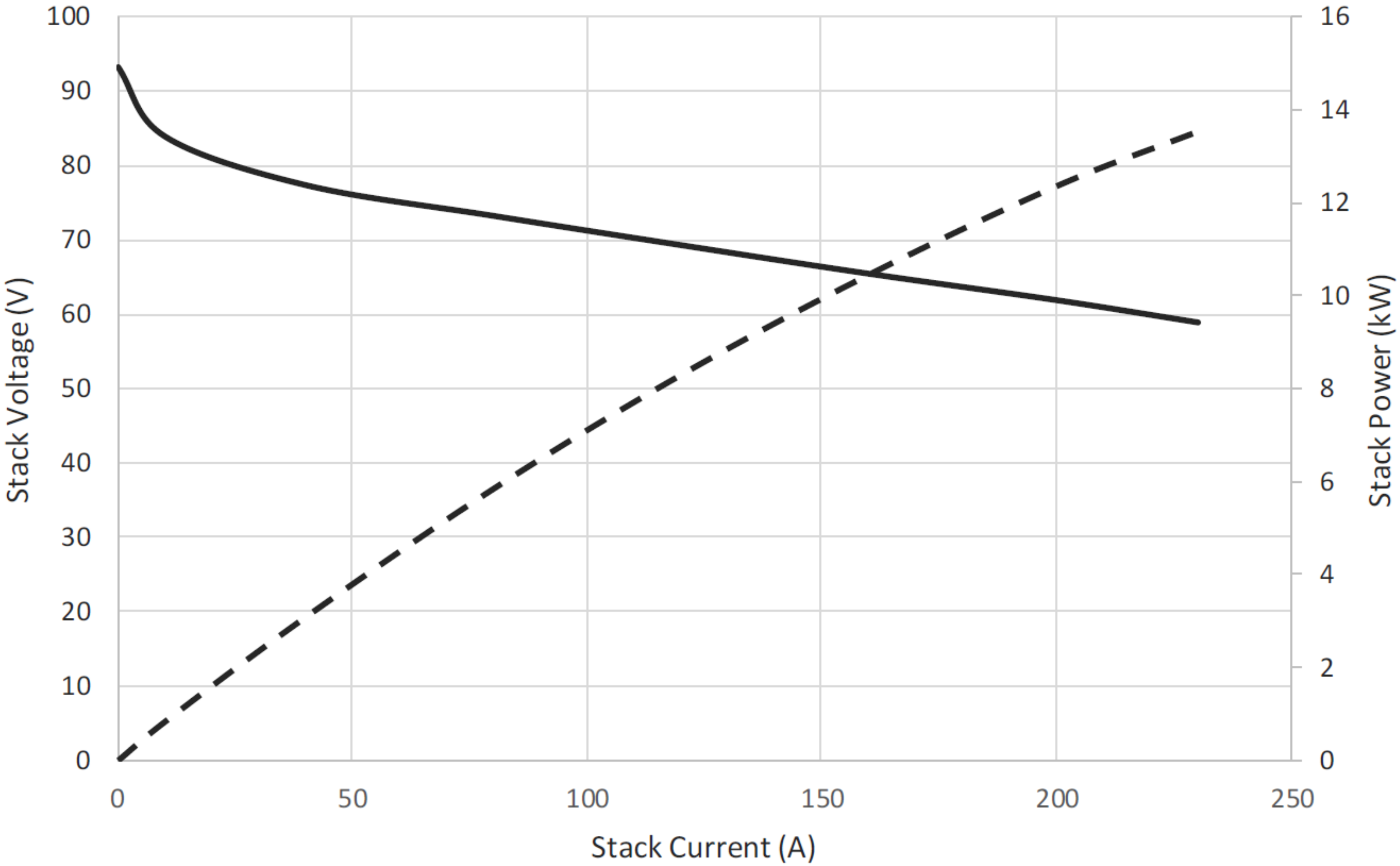
> **The stack of fuel cells is enclosed**
> Cell voltage monitoring is included
> Quick connections for ease of service
> Spring-loaded

Nedstack | Fuel Cell Co-Generation Principle

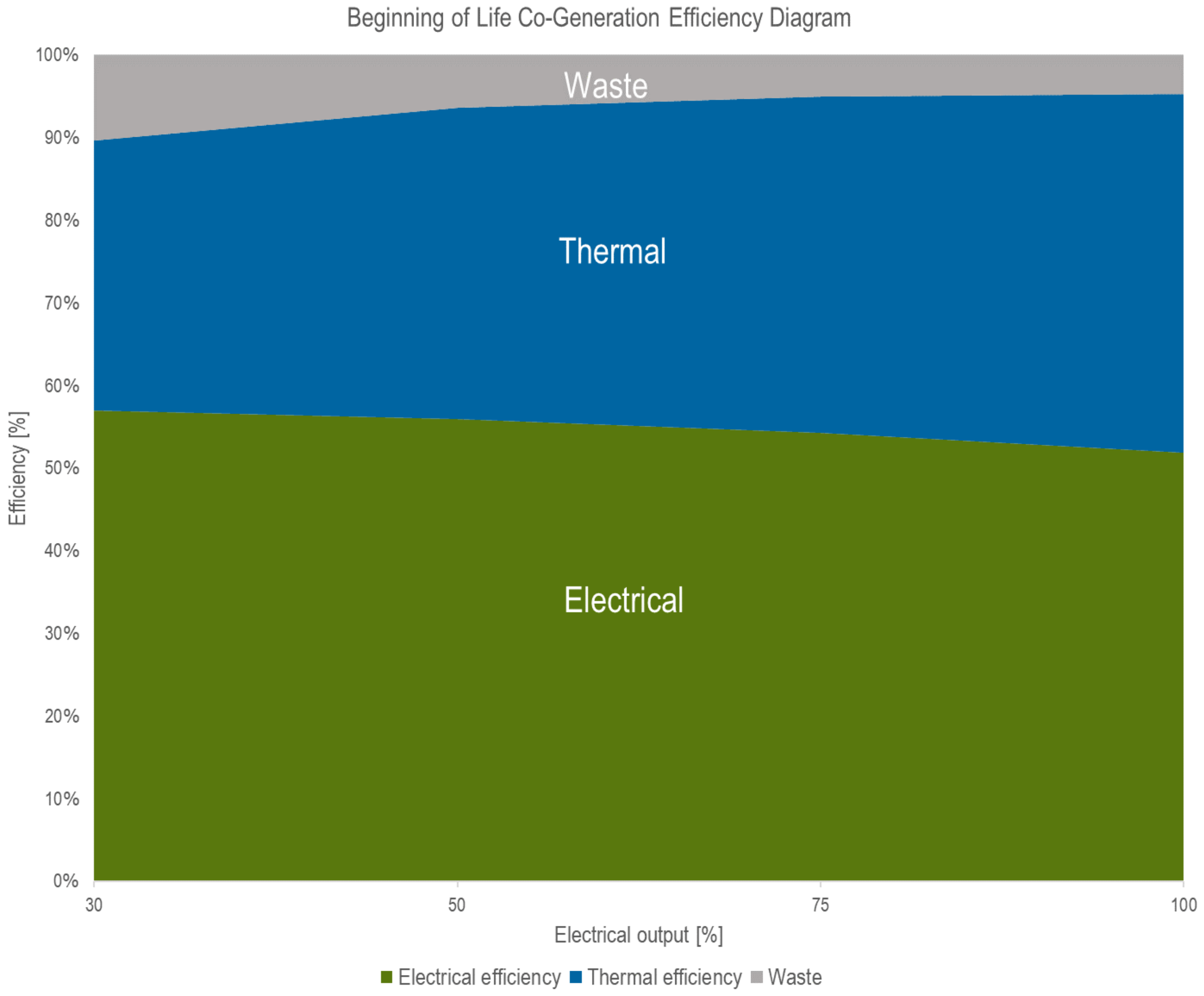


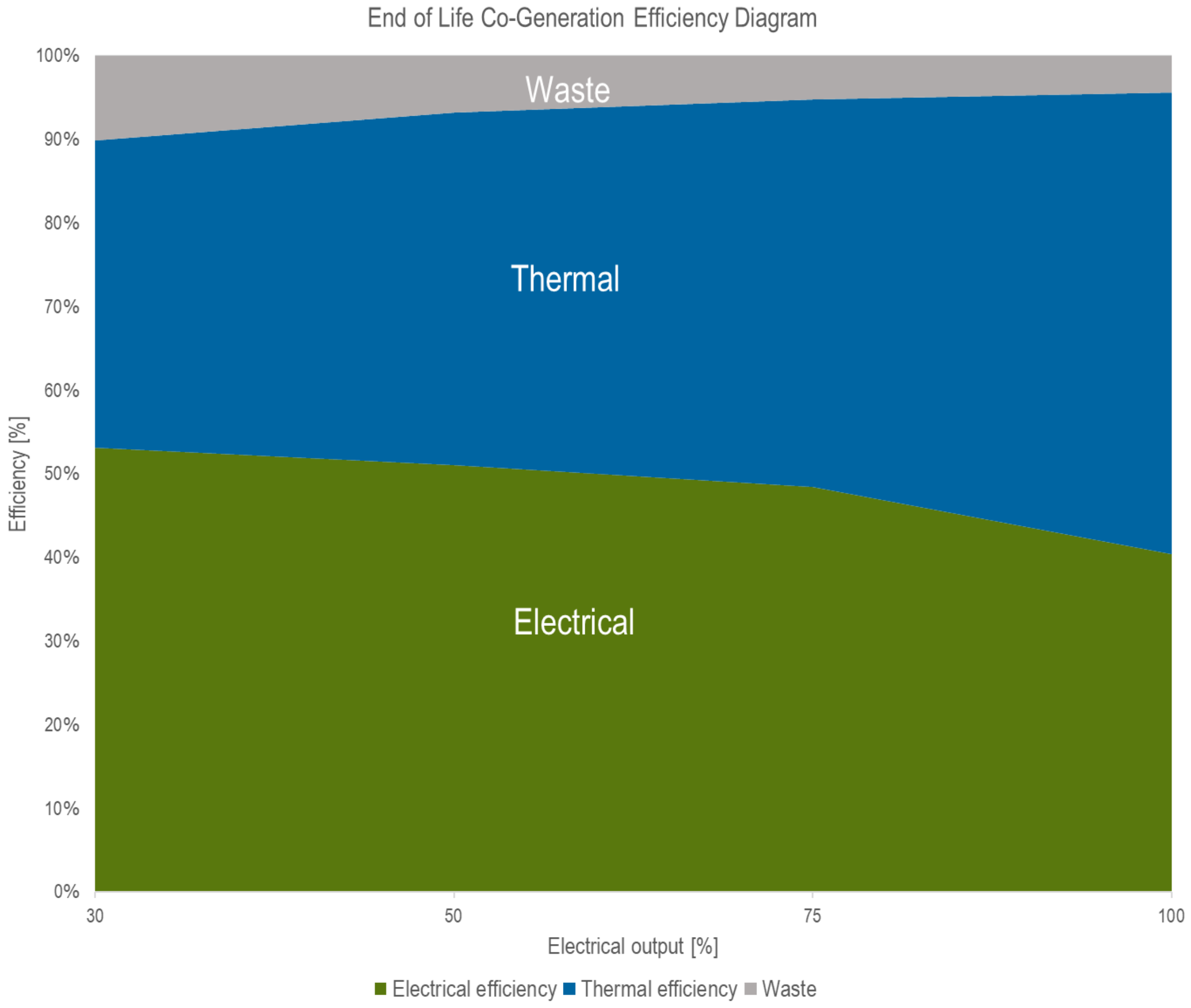
1) Nedstack Proprietary Model

Nedstack | Polarization curve



Nedstack | PEM Fuel Cell co-generation efficiency





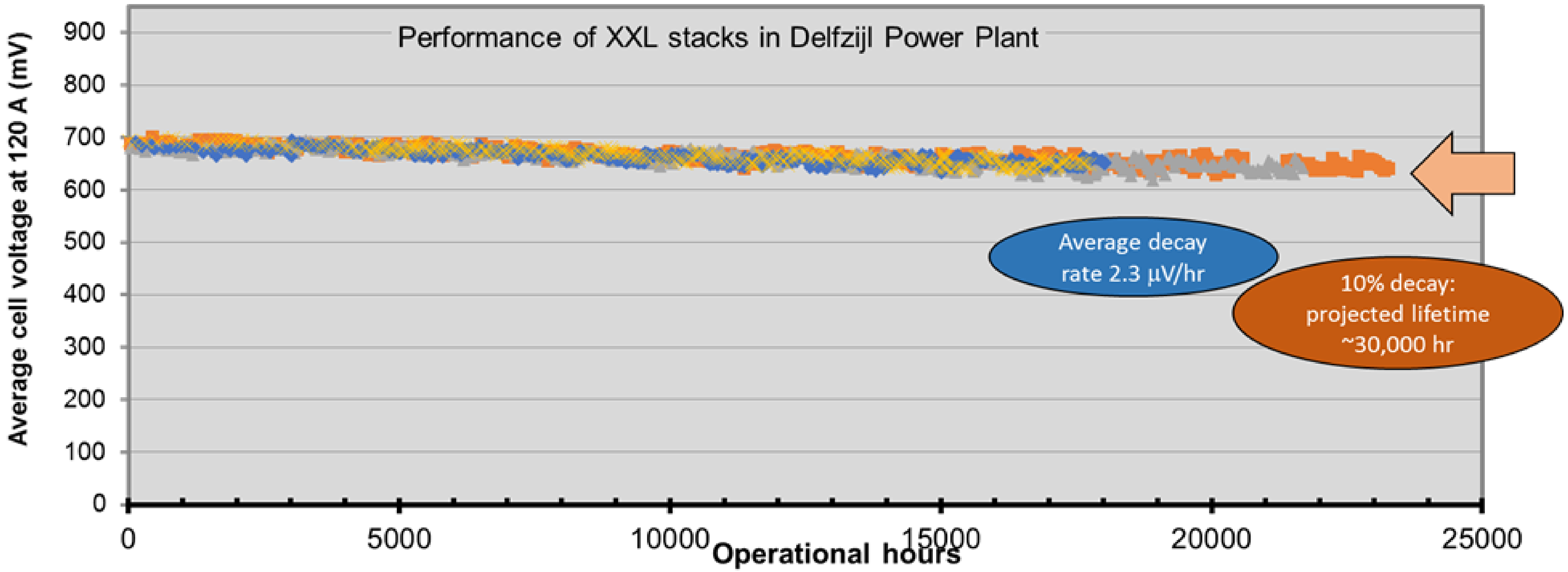
Nedstack | Lifetime Assessment

Plant Lifetime Indication

- Designed for 15 years

Stack Lifetime Indication

- 24.000 running hours till refurbishment



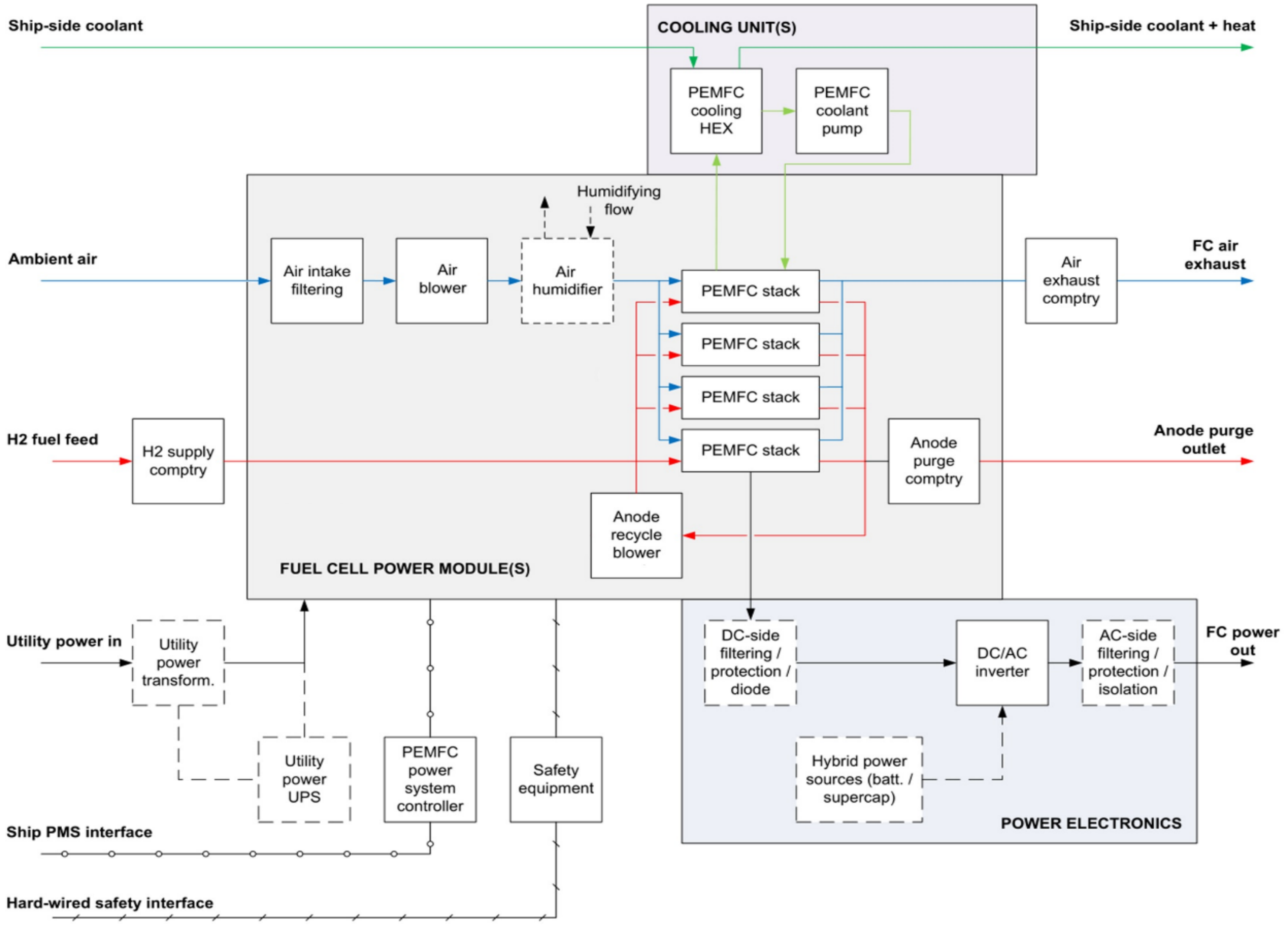
Nedstack | Fuel cell stack degradation

- Reversable decay
- Irreversible decay

- Material aging
- Hydrogen impurities
- Air contamination
- Cooling water contamination
- Catalyst oxidation

- Fuel starvation
- Cooling failure
- Membrane overpressure

Nedstack | Functional Definition



comptry = componentry, all relevant components

Nedstack | PemGen 120 FC power system

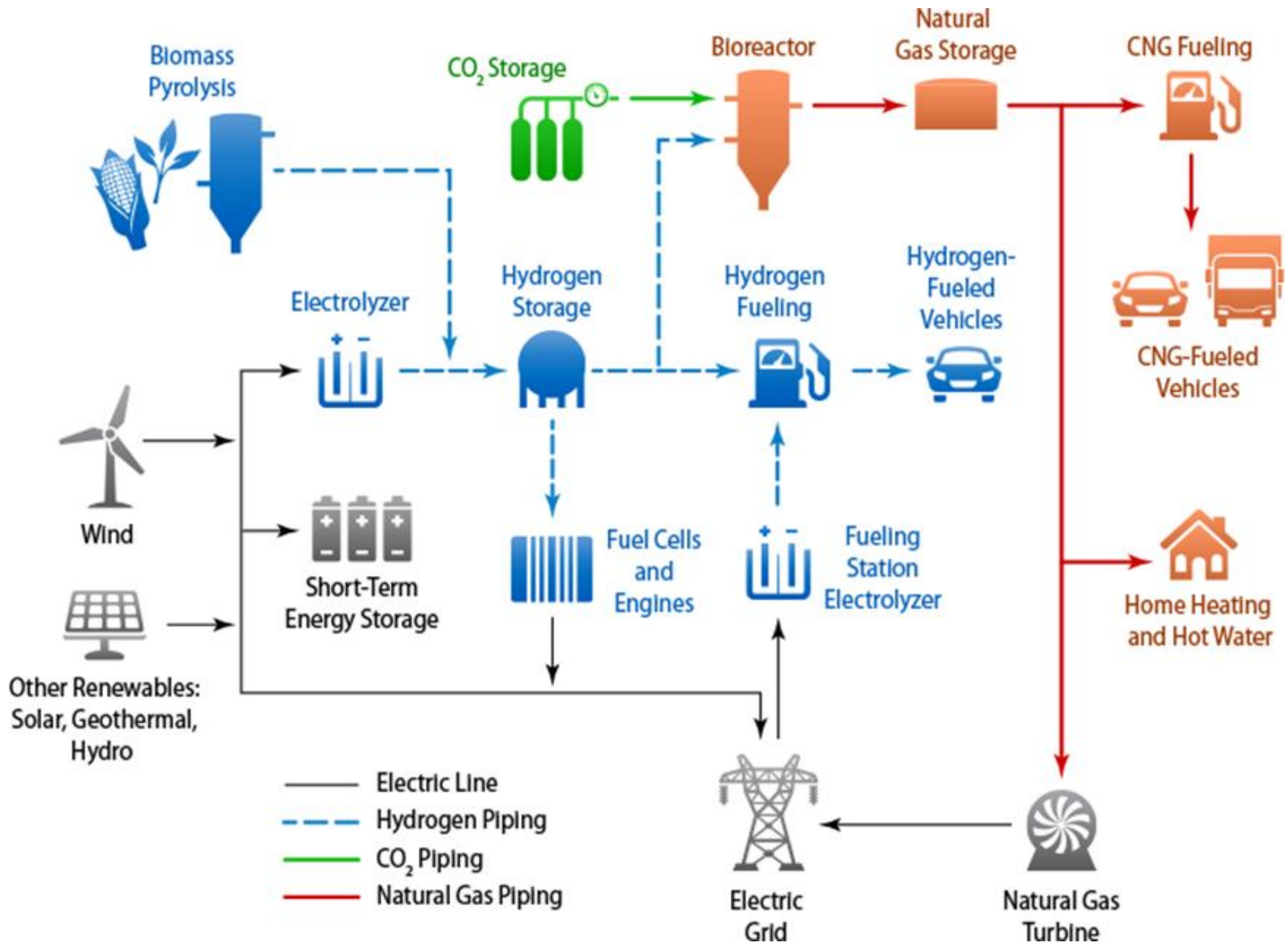
Nedstack | PemGen 600 FC power system

D

Markets & Solutions

Mission Critical High Power PEM solutions and applications

Nedstack | Hydrogen Economy

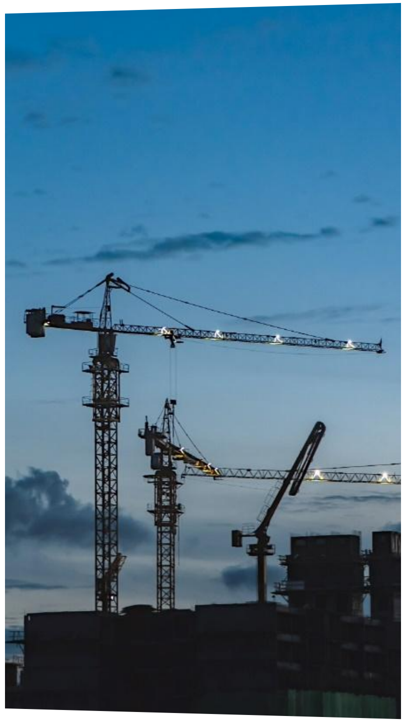


PemGen Focus Markets

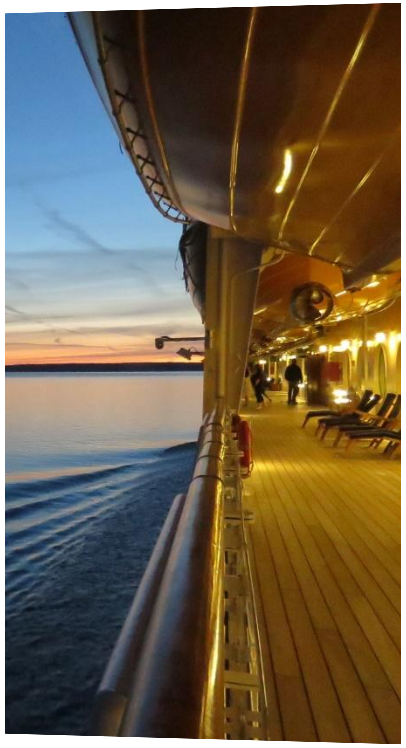
Servicing the High-Power / High-Use Domain

Industry

Utility Power to Power



Distributed Power / RAPS



Maritime & Ports

PemGen - Focus Markets

- PemGen focus markets are focused at delivering technology and cost (LCoE) leadership for high-power / high-use markets.
- PemGen® pursues leadership at the utility scale level with power plants intended for 20 years in the field, having advanced safety concepts.
- The PemGen portfolio is tuned for either land-based use (in compliance with EC directives and IEC standards) or maritime use (in compliance with IMO codes, maritime Class Rules and IEC standards).
- The PemGen® business model assumes configure-to-order type technology delivery models where customer value is maximised.

Project NextGen – The new standard in maritime fuel cell

Higher efficiency, power density, lifetime > lower costs

SH2IPDRIVE

Developing a next generation of maritime fuel cells

KIVI Engineering Society | Nedstack PEM FUEL CELLS

Innovative hydrogen technology

WP1 – BUNKER & STORAGE SYSTEMS
Leader: Shell
Partners: FPS, TUD, Bosch, Cryovat, H2Storage

WP2 – HYDROGEN CARRIERS
Leader: TU Delft
Partners: H2 CiF, H2FUEL, Royal Roos, SH, UvA, Voyex

WP3 – FUEL CELLS
Leader: Nedstack
Partners: FPS, TUD, UT, Koedood, TNO, Encontech, TU/e, Shell

Modelling, validating and evaluating integrated hydrogen systems

WP4 – DATA COLLECTION & SYSTEM VALIDATION
Leader: MARIN **Partners:** TUD, Rivermaas, DMO

WP5 – SYSTEM INTEGRATION
Leader: Koedood **Partners:** FPS, TUD, MARIN, Bosch, Voyex, Shell

Validating hydrogen systems in sea trials

WP6 – MODULAR TESTING
Leader: Van Dam **Partners:** TNO

Application of validated hydrogen systems in ship design

WP7 – SHIP DESIGN
Leader: Holland Shipyards **Partners:** FPS, IHC, Shell, Concordia Damen

WP8 – SAFETY
Leader: TNO **Partners:** FPS, TUD, MARIN

INLAND VESSEL (RETROFIT)	INLAND VESSEL (NEW)	SHORT SEA VESSEL	PASSENGER VESSEL	SPECIAL PURPOSE VESSEL

TU Delft | TU/e | TNO innovation for life | UNIVERSITY OF TWENTE.

Collaboration between FC design powerhouses

Nedstack PEM FUEL CELLS | ZBT | AVL

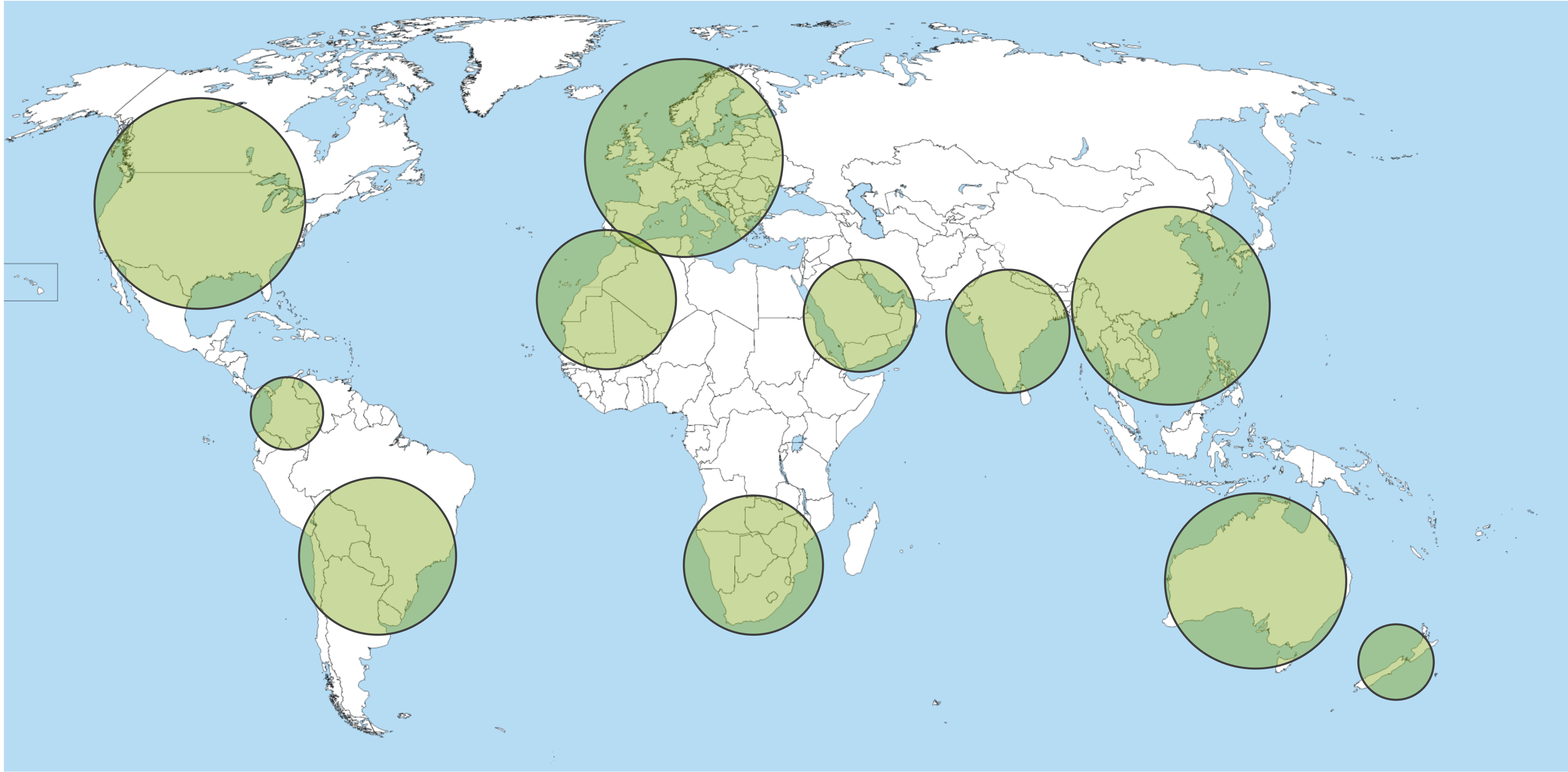
Project NextGen – The new standard in industrial fuel cell

Higher efficiency, power density, lifetime > lower costs

- Prime power: 900 kW @ 50% net efficiency
- Nominal power: 700 kW @ 52% net efficiency
- Modular FC and auxiliary systems
- Integrated DC/DC converter – 800 VDC output
- Anticipated dimensions
  - Footprint: 4 [m^2]
  - Height: 2,1 [m]
  - Weight: 4300 [kg]
- Integrated multi-MW control system
- Hydrogen inlet pressure: > 2 bar
- Market introduction: Q2 - 2025

International developments: H2 strategies

Market potential for H2 production and use is massive



1E. How is H2 Available Today?

Mostly in Compressed solutions

H2-Fuel Feed Strategy

Bundle
30 Mpa
~ 12 kg

Tube Trailer
30 Mpa
~ 300 kg

MPED Container
50 MPa 20' MPED
~550 kg

Cryogenic Trailer
Cryogenic
~ 3000 kg

PemGen MPU
Assuming η=50%

Power Endurance Per Fuel Unit

Endurance
200kWhe

Endurance
5 MWhe

Endurance
9 MWhe

Endurance
50 MWhe

1) 1 kgH2 = 33.33 kWh LHV

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PEM FUEL CELLS

F

Hydrogen Safety

Characteristics and Considerations

Nedstack | Hydrogen properties

• Density	0.08988 kg/m3	*14 times lighter than air*
• Boiling point	-252.87 °C	*Boiling point Nitrogen is -195,79 ºC*
• Auto ignition temperature	500 °C	*Auto ignition temperature of diesel is 210 ºC*
• Energy density	33.33 kWh/kg	*On average 16,5 kWh electrical energy*
• Lower explosion limit	4 %	*Wide range requires caution*
• Upper explosion level	75 %	*Diesel ranges from 0,6% – 7,5%*

Nedstack | Key safety considerations

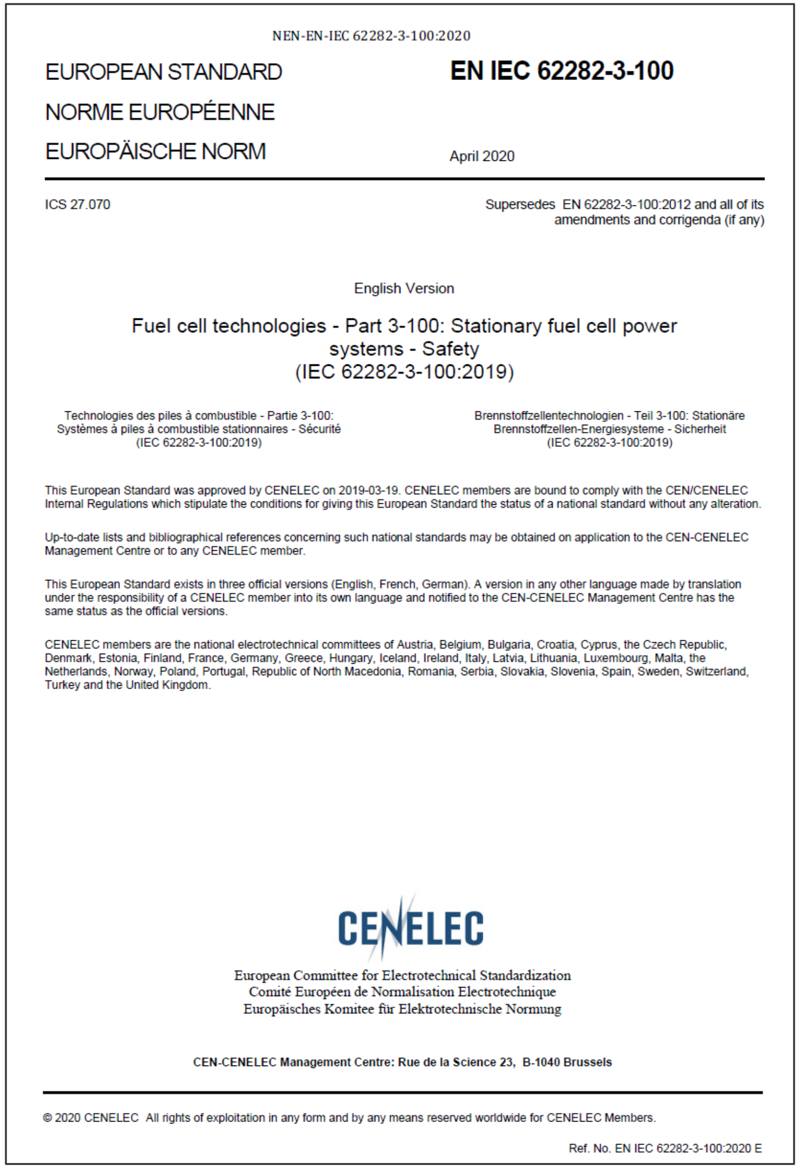
- Collision
- Fire
- Purging
- People
- …

518 kg - 500 bar

0,03 kg - 0,25 bar

Nedstack | Safety concepts

- Diluted concept with Emergency Shutdown (Ventilation)
- Explosion safe
- Inert



NEN-EN-IEC 62282-3-100:2020

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN IEC 62282-3-100

April 2020

ICS 27.070

Supersedes EN 62282-3-100:2012 and all of its amendments and corrigenda (if any)

English Version

Fuel cell technologies - Part 3-100: Stationary fuel cell power systems - Safety
(IEC 62282-3-100:2019)

Technologies des piles à combustible - Partie 3-100: Systèmes à piles à combustible stationnaires - Sécurité
(IEC 62282-3-100:2019)

Brennstoffzellentechnologien - Teil 3-100: Stationäre Brennstoffzellen-Energiesysteme - Sicherheit
(IEC 62282-3-100:2019)

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

Ref. No. EN IEC 62282-3-100:2020 E

Nedstack | Risk assessments

System number	Component	Description	Functionality	Operation mode	Potential failure mode	Potential Effect(s) of Failure	Severity	Potential Cause/ Mechanism(s) of Failure	Occurrence	Current Design / Process Controls	Detection	Likelihood	Risk level	Remarks / comments	New mitigation actions	Final risk assessment				
																Severity	Occurrence	Detection	Likelihood	Risk level
1	FUEL CELL MODULE																			
	Housing	Housing around the fuel cell system including the fuel cell module, balance of plant and electrical cabinets and compartments	Mechanical protection	Operation	Lack of mechanical protection	Physical damage to system components or stacks caused by objects entering fuel cell system	4	Mishandling during transport and installation	1	Inspection on delivery, installation and SAT; underpressure switch in fuel cell space will detect if housing is gas tight.	1	1	4							4
							4	Door/hatch opened	2	Underpressure switch in fuel cell space will detect if housing is gas tight	2	2	5							5
							4	Housing heavily corroded	1	Marine grade conservation, regular inspection; underpressure switch in fuel cell space will detect if housing is gas tight	1	1	4							4
			Thermal isolation	Operation	Decreased thermal insulation	If fire occurs in fuel cell space, it will sooner propagate to adjacent spaces	2	Mishandling during transport and installation	1	Inspection on delivery, installation and SAT	1	1	2							2
							2	Mishandling during maintenance	1	Regular inspection	1	1	2							2
			Gas confinement	All	Housing contains gas leaks	In case of a gas leak, hydrogen or depleted oxygen could enter adjacent spaces	3	Mechanical damage to housing	1	Underpressure switch in fuel cell space will detect if housing is gas tight	1	1	3							3
			Fixation of plant components	All	Components coming loose, whether or not partially	Damage to system components	2	Fixation bolts coming loose	1	Fixation bolts tightened at a specified torque; luck nuts applied where possible; regular inspection	2	1	2							2
							2	Broken fixation	1	Regular inspection	1	1	2							2
						Gas leakage	3	Moving or vibrating components	2	Regular inspection, gas detection	1	1	3							3
			Plant fixation	All	Fixation loose, whether or not partially	System exposed to excessive vibrations	2	Fixation bolts coming loose	1	Fixation bolts tightened at a specified torque; luck nuts applied where possible; regular inspection	2	1	2							2
							2	Broken fixation	1	Regular inspection	1	1	2							2
			Grounding	All	No grounding	In case an electrical connection between stacks and houding occurs, housing will be under high voltage	3	Corrosion	1	Ground fault protection system	1	1	3							3
							3	Mechanical damage caused by mishandling	1		1	1	3							3
	Interface connections			All	Mechanical damage	External damage to piping and cabling entering the fuel cell system	2	Items falling on piping, cables	1	Inspection before startup	1	1	2							2
1.1	FUEL CELL STACK																			
	MEA	Membrane	Conduct protons from anode to cathode		Loss of proton conductivity	Low cell voltage(s), thus low efficiency	2	MEA temperature too high / too low	1	The coolant temperature is monitored on the inlet manifold and the on the outlet manifold. Individual cell temperature deviations cannot be observed, however, these will probably show a low cell voltage reading for the corresponding cell	2	1	2							2
							2	Membrane dehydration	2	The CVM measures individual cell voltages. Low cell voltages can be observed, however, the root cause can not be determined	2	2	3							3
		Catalyst	Enable the chemical reactions to take place		Loss of catalysis		2	Oxydation of catalyst	1		2	1	2							2
							2	Physical damage to catalyst layer	1		2	1	2							2
		Catalyst support	Carrier of the catalyst		Loss of catalyst		2	Fuel starvation	1		2	1	2							2
		GDL	Distribute gasses across active area		Uneven gas distribution across active area	Local fuel starvation, potentially damaging the stack if this occurs at the anode side	2	GDL clogged by particles	1		2	1	2							2
							2	GDL flooded with water	1		2	1	2							2
		Membrane, border	Offer electrical insulation between anode and cathode		No electrical insulation between anode and cathode side	Leak current will flow from cathode to anode cell plate, possibly causing hot spots in the cell plate, possibly leading to melting plates or fire	3	Border damaged combined with contamination	1	A leak current from one to another cell will not be detected if this current is relatively low compared with the stack current	3	1	3							3
							2	Pinholes in membrane	1	Pinholes in membrane will cause additional hydrogen-crossover, thus lead to lower cell voltage, reduced OCV and increased voltage decay	2	1	2		Include regular individual cell OCV check					2
			Keep hydrogen (anode) and air (cathode) separated from each other				0		0		0	0	#REF!							#REF!
			Conduct electrons	Commissioning	low current and/or voltage	Lower power output, low efficiency	2	-poor reactant distribution due to blockage/particles in the flow field	5	cell voltage drop	2	3	3		Incorporate stack interface filters during commissioning & start up					3
			Conduct heat from MEA to coolant		H2 leakage (inside the stack)	fuel starvation, accelerated stack degradation	3	cell plate permeable (can be due to ruptures, cracks, creep)	3	excess stoich & monitoring thereof, cell voltage drop	2	2	4							4

Nedstack
PEM FUEL CELLS

G

Projects

Pilot projects and developments in inland navigation

Fuel cell power installations

With our co-makers, we deliver today

MPU-20

- Mobile power units
- 20 [kW] – End of Life

PEMGEN 120

- Maritime and stationary
- 120 [kW] – End of Life

PEMGEN 300

- Inland navigation
- 300 [kW] – End of life

PEMGEN 600

- Maritime and Stationary
- 600 [kW] – End of Life

aggreko FINCANTIERI ENGIE VIKING FutureProofShipping Boskalis

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