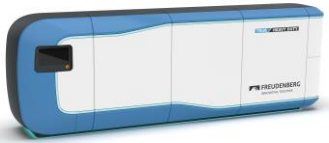
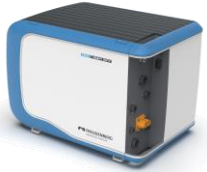
FREUDENBERG
Fuel Cell e-Power Systems





Technical Expertise meets Power to Industrialize

FREUDENBERG
INNOVATING TOGETHER

Technical Expertise meets Power to Industrialize

LONG-TERM EXPERIENCE
>170 years History

HOLISTIC UNDERSTANDING
Material & Design Know-How

POWERFUL GLOBAL COMPANY
>10 bn € Turnover

STRATEGIC FC COMMITMENT
Significant Budget

DEDICATED TO INNOVATION
~3.3 bn € Turnover
With products < 4 years

FAMILY OWNED
Sustainable Business

Freudenberg establishes business group e-Power Systems:
A strong commitment to e-mobility

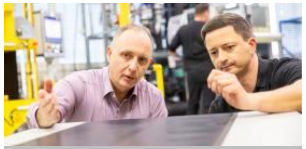
New Business Group (04/2022)
e-Power Systems
(focusing on
Battery & Fuel Cell Systems)

e-Power Systems

Sealing Technologies
2.2 bn. €

Vibracoustic
2.0 bn. €

EagleBurgmann
0.8 bn. €



Performance Materials
1.3 bn. €

Medical
0.3 bn €

Home & Cleaning Solutions
1.1 bn. €

Chemical Specialties
1.3 bn. €

Oil & Gas Technologies
0.1 bn €

Filtration Technologies
0.6 bn. €

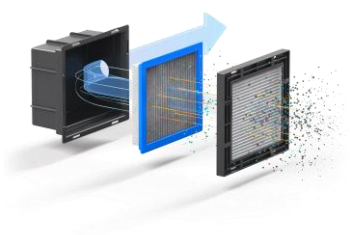
Japan Vilene Company
0.5 bn €

Freudenberg & Fuel Cell:
A success story of product innovation since 1995

The company committed itself to Fuel Cells as sustainable and forward-looking technology at an early stage

Freudenberg Filtration Technologies

Fuel Cell Filter



Fuel Cell Humidifiers

Freudenberg Sealing Technologies

Fuel Cell Stack Seals

Freudenberg Performance Materials

Gas Diffusion Layers

No major FC sold in market today without significant Freudenberg content.
Complete transfer of this long-term expertise to our heavy-duty FC systems

Freudenberg Combined Long-Term Component Expertise
Complemented by targeted acquisitions to enter FC system market

Business Group e-Power Systems

Freudenberg Fuel Cell e-Power Systems

Freudenberg Battery Power Systems

TRUCK & BUS

RAIL & CONSTRUCTION

MARITIME

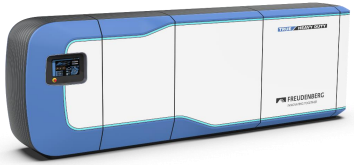
Fuel Cells designed for use **in heavy-duty systems** with the highest **lifetime, quality and durability requirements**

Lifetime heavy-duty system **(>35,000 h)** vs. passenger car (5 - 8,000 h)

FREUDENBERG
INNOVATING TOGETHER

Maximize Economies of Scale in Heavy-Duty Markets

MARITIME



METHANOL LNG HYDROGEN

TRUCK & BUS

HYDROGEN

Cruise
~60 MW

Yacht
~10 MW

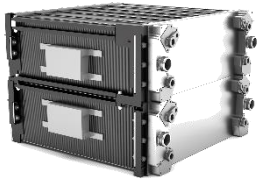
Truck
>100 kW

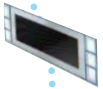
City Bus
>60 kW

BoP + **Reformer** + Battery

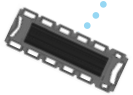
Balance of Plant (BoP) + Battery

MODULAR SCALABLE STACK
True Heavy-Duty





Integrated MEA



BPP

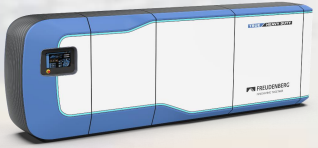
Heavy-Duty focused **strategy of identical parts** combined with **deep vertical integration** for key components to achieve **maximum economies of scale**

UNIQUE VERTICAL INTEGRATION

FREUDENBERG
INNOVATING TOGETHER

Strategic Partnership with leading Shipyard in Cruise Market

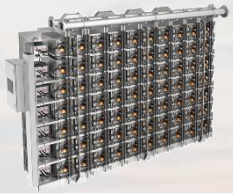
EXAMPLE: CRUISE



MEYER WERFT
PAPENBURG 1795

4 MW Freudenberg Fuel Cell - **LNG 500 Systems**

1.6 MWh Freudenberg **Battery Systems**



Royal Caribbean Group

2027+

CO_2 neutral Vessels

Powered by Fuel Cell and Batteries only

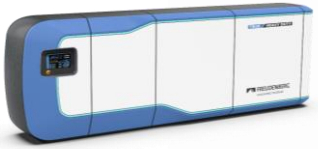
SILVER NOVA - First Vessel with possibility to cover Hotel Load in Hybrid Mode – Battery and Fuel Cell only

2023 | 2024 | 2025 | 2026 | 2027 | …

FREUDENBERG
INNOVATING TOGETHER

Strategic Partnership with leading Shipyard in the Yacht Market

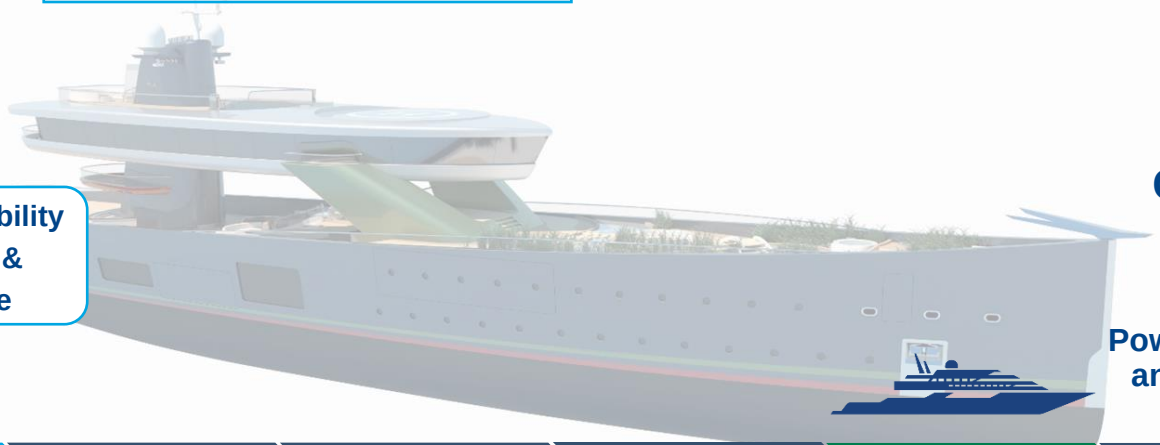
EXAMPLE: YACHT



LÜRSSEN

1 MW Freudenberg Fuel Cell
MeOH 500 Systems

Strategic Partnership: Common long-term Business Plan / Continuous increase of power installations @ yachts



2027+

CO_2 neutral Yachts

Powered by Fuel Cell and Batteries only

First Vessel with possibility to cover Hotel Load & Slow Cruising Mode

2023 | 2024 | 2025 | 2026 | 2027 | …

FREUDENBERG
INNOVATING TOGETHER

HyFleet – A consortium of market leading companies with the power to industrialize on large scale

HYFLEET
TRUE HEAVY-DUTY FUEL CELLS

Phase 01
<2024

HyPerform
Technology development
“True heavy-duty”

LIFETIME & EFFICIENCY FOR BEST TCO

Phase 02
2024 - 2025

HyCoach
Large scale technology demonstration

FLEET DEMONSTRATION >50 COACHES

Phase 03
2026 - 2030

HyScale
International scale up

COMPLETE FLEET TRANSITION

Truck: Similar long-term oriented project in pipeline

FLIXBUS ZF FREUDENBERG INNOVATING TOGETHER

Strong Strategic Partnerships to Realize Fuel Cell Industrialization for heavy-duty applications on Large Scale

EXAMPLE: TRUCK & BUS

2021
Project start HyFleet
1st Common customer project

2021
Development of best in class **Fuel cell products** by ZF

2022
1st Joint Technology Demonstration

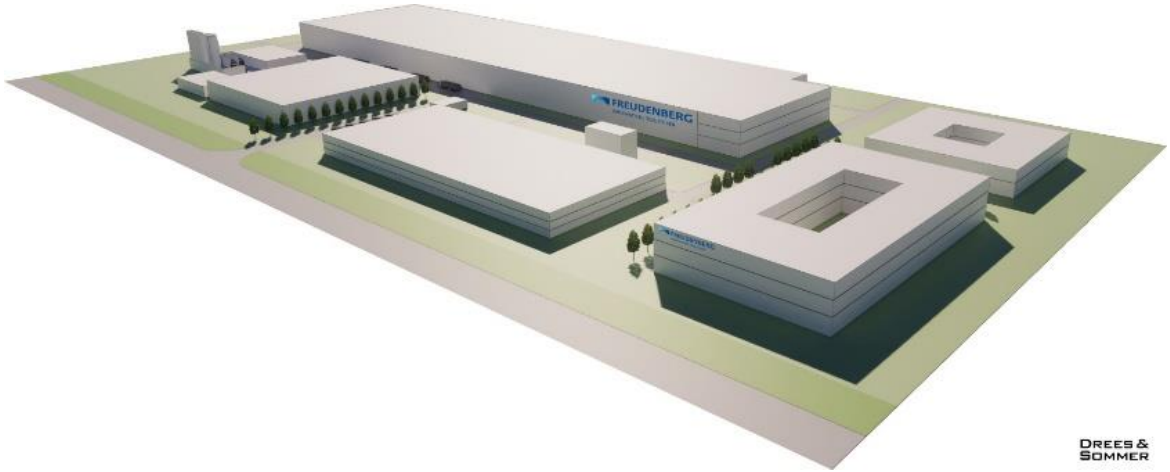
2023
Common **On-Road Demonstration**/Truck

2024
Freudenberg SOP
New Generation true heavy-duty Fuel Cell Module Truck & Bus

2024/2025
SOP 1st Joint e-Drive Solution
e.g., HyFleet/Phase 2

2027
SOP Highly-integrated e-Drive/Large Volume Series Truck & Bus ZF incl. FC-BoP components & Freudenberg

Industrialization is a Key Focus Area
European Manufacturing Site needed starting 2025

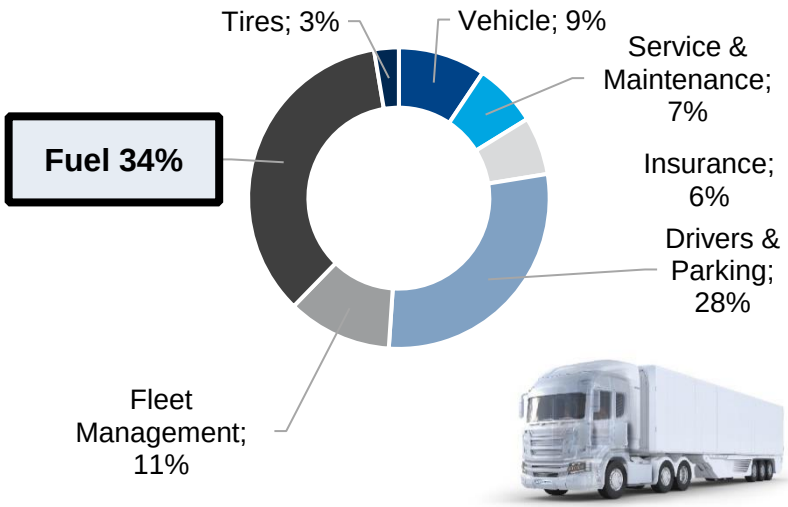


- Working with external partner for final site selection
- First draft of max. aggregate footprint (125,000 m^2) and scope finalized
- Modular concept allows for phased ramp-up and risk mitigation
- **Decision on location in 2023**
- Annual **capacity up to 6 GW**

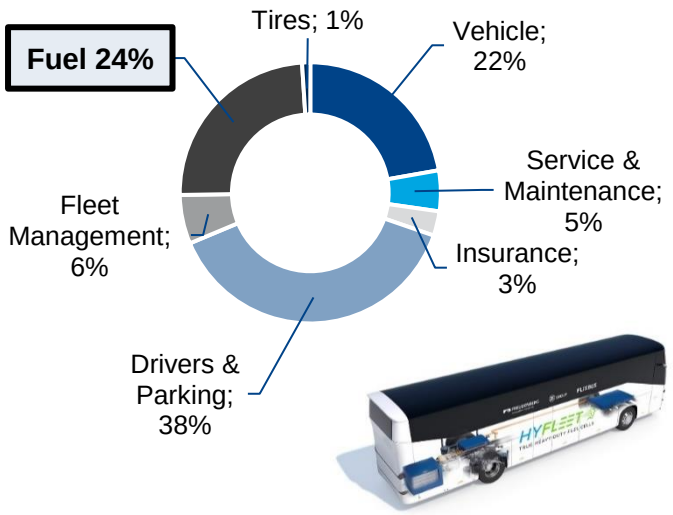
Long-term experience in large-scale industrialization of electrochemistry

Total Cost of Ownership is the Key Criteria in Heavy-Duty

TCO Structure TRUCK



TCO Structure COACH



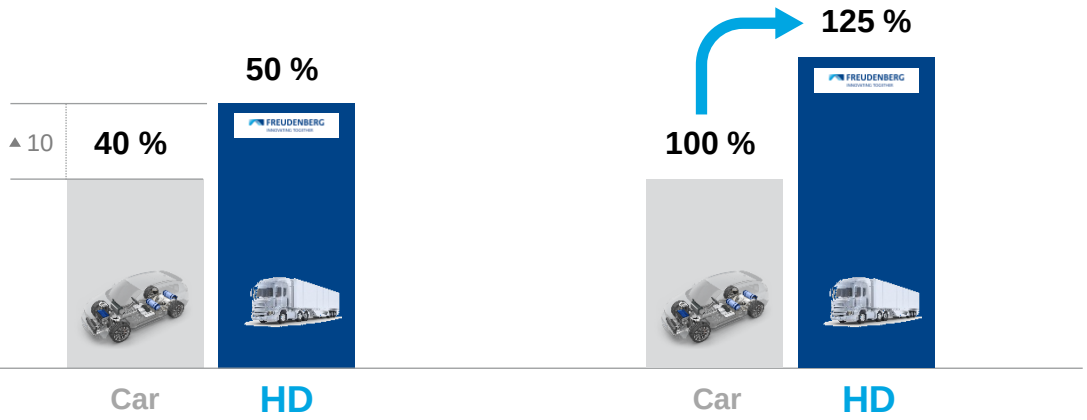
Efficiency => Fuel consumption, strongest leverage for Customer Value Add

Fuel Cell System Efficiency
as a significant cost leverage for fleet operators

+ 10 %
Absolute Efficiency Improvement[1]

=

+ 25 %
Relative Efficiency Improvement



Most FC Systems have their origin **in the passenger car segment**

High Fuel Consumption
up to +25% vs. true heavy-duty FC

Lower Lifetime Requirements
8,000 hours vs. 35,000 hours

1 Consideration of complete FC-BoP including DCDC, Compressor, LT and HT cooling pumps

SYSTEM EFFICIENCY IMPROVEMENT leads to significantly higher fuel efficiency.
Needs to be combined with lifetime performance / expectations for heavy-duty applications.

FREUDENBERG
INNOVATING TOGETHER

Freudenberg offers true Heavy-Duty Designs for best Total Cost of Ownership

Example: TRUCK & BUS

Tailored to heavy-duty applications

Lifetime target > 35,000 hours / Full vehicle life

100 kW FC Module

Deep Vertical Integration

Best Technical Performance & Competitive Cost Level

Superior Efficiency for best OPEX

Efficiency target > 50 % @ nominal power on system level[1]

Stack designed for High Volume Production

Best in Class Quality & Competitive Cost Level

[1] Consideration of complete FC-BoP including DCDC, Compressor, LT and HT cooling pumps

FREUDENBERG
INNOVATING TOGETHER

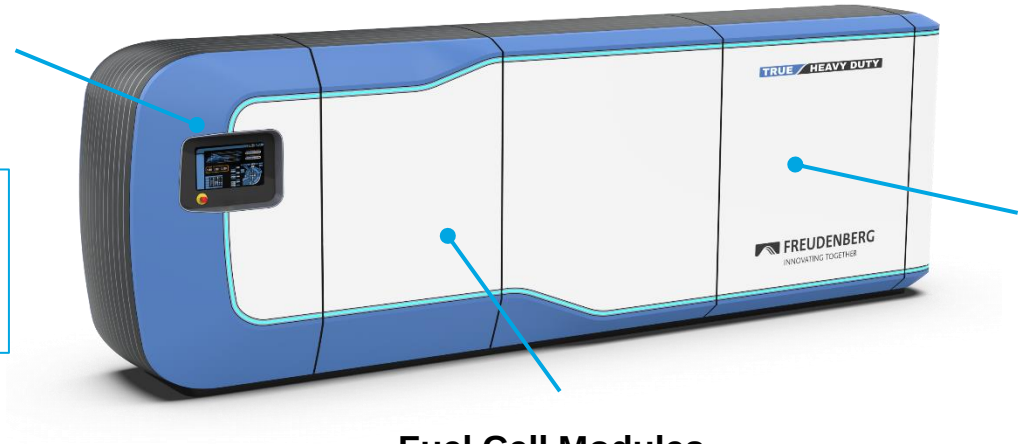
Maritime Technology Roadmap Deep-Sea: Modular and standardized fuel cell concept with integrated fuel reforming

MARITIME FC SYSTEM – POWER CLASS 500 KW

FIRST INSTALLATIONS @ Megawatt-Level in 2023

Electronic Module

Electrical Infrastructure + Control System



FUEL REFORMING

METHANOL or LNG

Hydrogen Supply Module

Fuel Reformer + Media Interfaces

Fuel Cell Modules

Stack + Balance of Plant Components

illustrative image

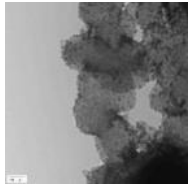
FREUDENBERG INNOVATING TOGETHER

Key Success Factors for True Heavy-duty Fuel Cells
Freudenberg USPs

PROPRIETARY CATALYST PRODUCTION

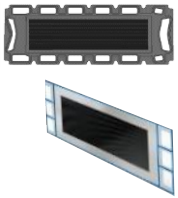
Significantly better degradation results than leading market players

35.000 - 50.000 h lifetime expected



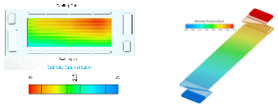
INTEGRATED MEA AND HEAVY-DUTY BPP

Durable and low-cost cell design successfully validated - testing of new “SMARTR” generation already started



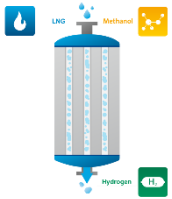
UNIFORM CELL PARAMETERS FOR ADVANCED LIFETIME

Temperature range <6K and extremely low pressure drop to achieve true heavy-duty lifetimes and meet highest efficiency targets



UNIQUE GAS PROCESSING

Highly efficient gas process proven consistently meeting CO values <10 ppm



MARITIME RULES & CERTIFICATION

Safety Concept fully in line with current IGF codes

PROVEN INDUSTRIALIZATION COMPETENCE IN ELECTROCHEMISTRY

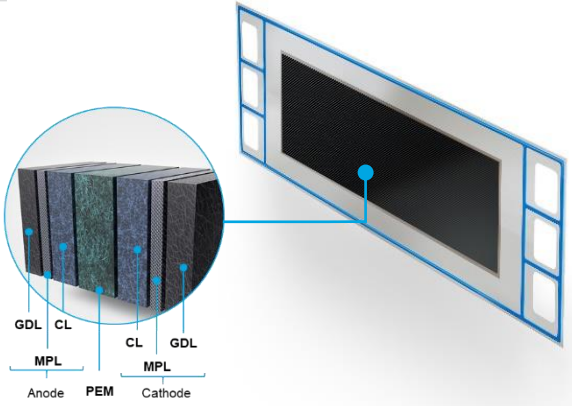
Roll-to-roll processes for complete MEA to achieve quality and cost targets

FREUDENBERG
INNOVATING TOGETHER

Membrane Electrode Assembly (MEA 7) – Proprietary Catalyst Production combined with Multi-Component approach

Unique vertical integration on cell level
To drive cost, quality and performance

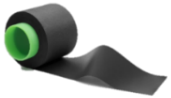
Proprietary catalyst production
Combining low-cost production with superior efficiency already on cell level



Heavy-Duty cell configuration
Uniform Cell Parameters for extremely prolongated degradation

Complete MEA7 – multi-component part
Reliable protection and integration of all MEA layers; no sophisticated assembly necessary

Roll-to-roll processes – Complete MEA
Low production cost and easy scalability



GDL: Gas Diffusion Layer, **MPL:** Micro Porous Layer,
CL: Catalyst Layer, **PEM:** Proton Exchange Membrane

Designed for Large Scale Industrialization and Superior Technical Performance in heavy-duty

True heavy-duty Fuel Cells & Methanol

The maritime sustainability alliance of the future

World’s first methanol driven and type approved fuel cell system

FREUDENBERG
INNOVATING TOGETHER

MEYER WERFT
PAPENBURG 1795

LÜRSSEN

CARNIVAL
MARITIME

RINA

Thank you!

FREUDENBERG
INNOVATING TOGETHER