

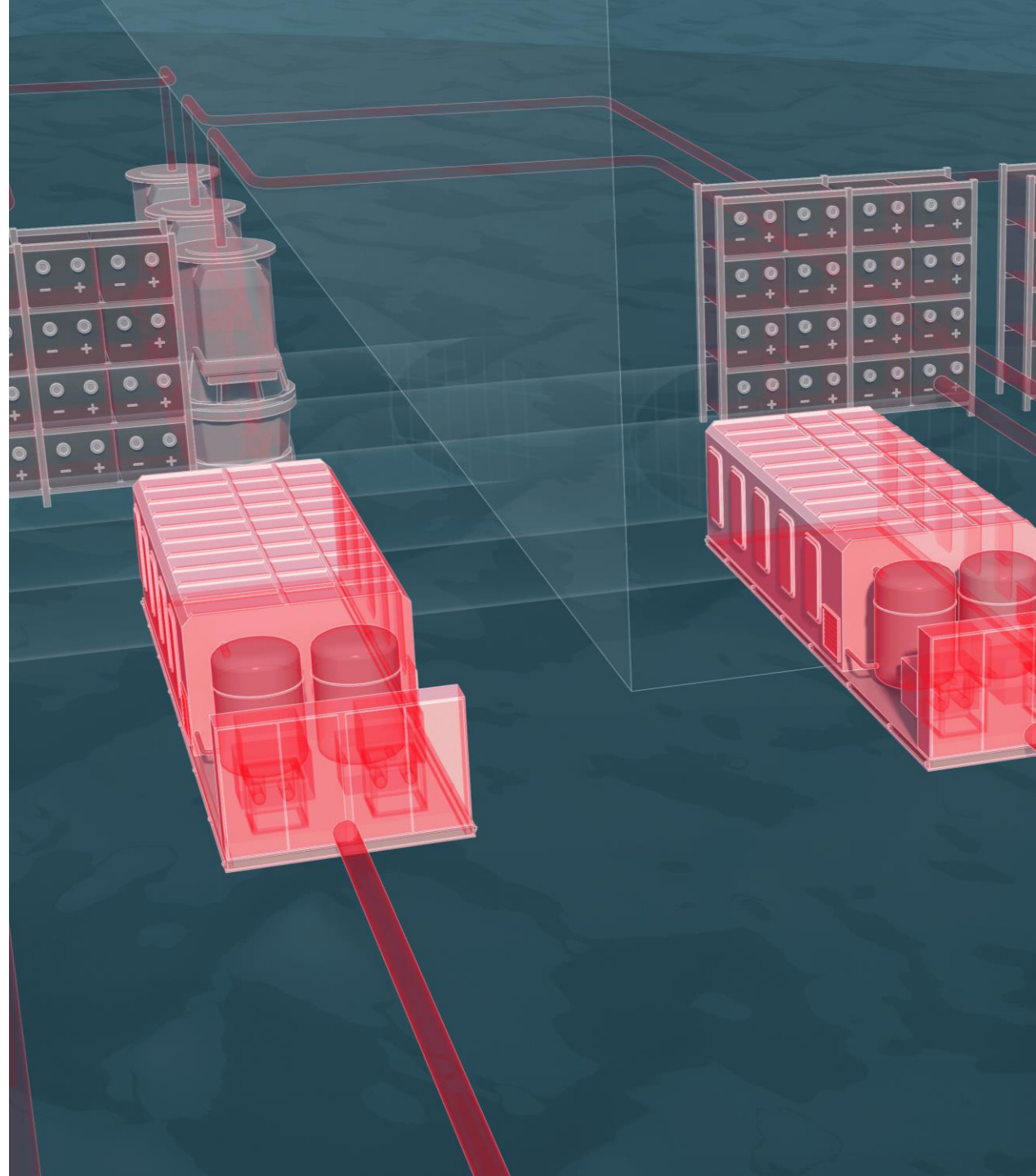
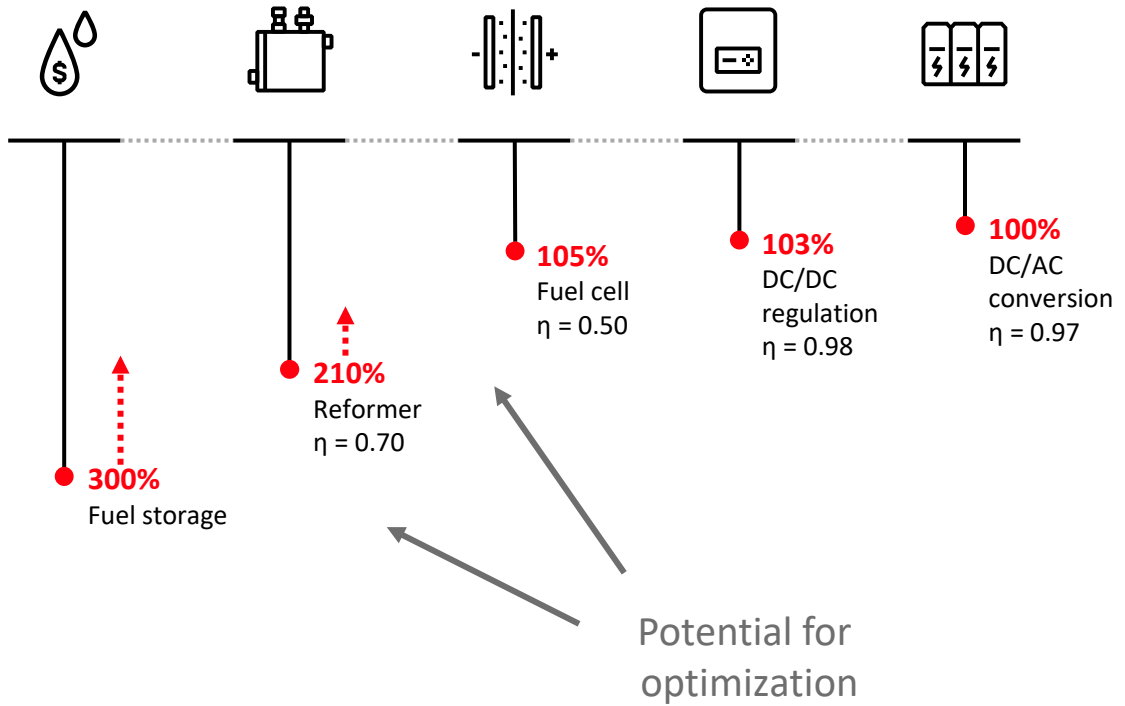
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Marine Fuel Cell Technology

Sami Kanerva, Global Product Manager

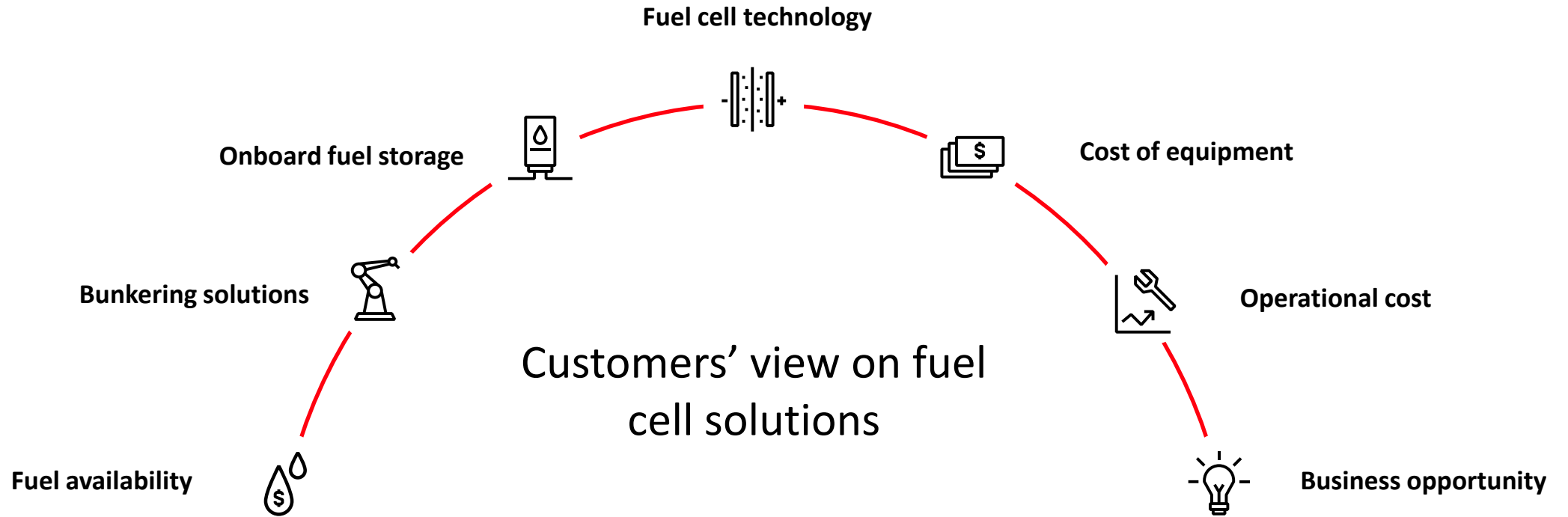
Fuel cell power train

Fuel to electricity

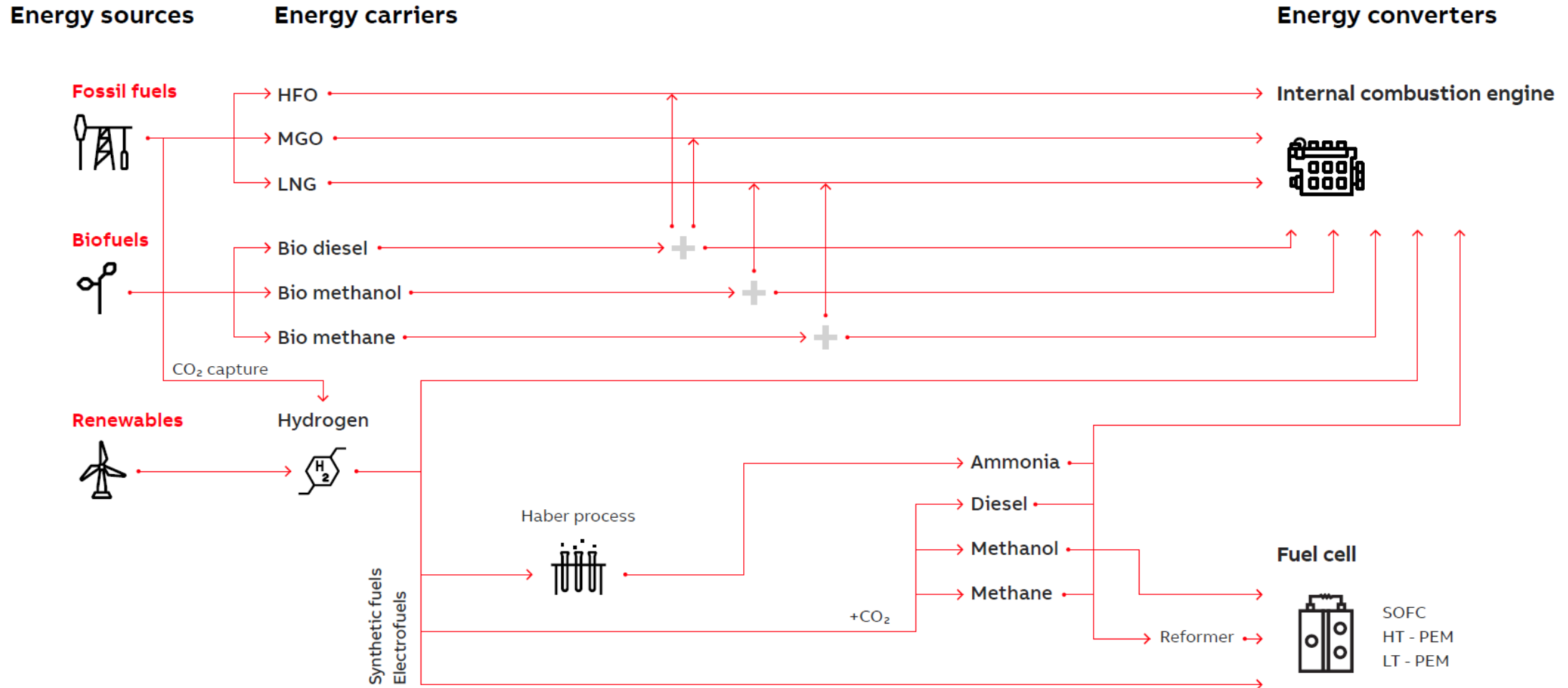


Enablers and barriers for fuel cell solutions

It's not only about fuel cells



Current and future compliant fuels



Alternative marine fuels driving decarbonization

Focus on cost and emissions

LNG

- Widely available but fossil origin
- Generally considered as transition fuel



METHANOL

- Benefits with onboard storage
- Requires carbon capture in long term



HYDROGEN

- Enables zero-emission operation
- Challenges with onboard storage



AMMONIA

- Efficient carbon-free energy carrier
- Highly toxic and challenging to operate



Fuel cell as onboard power source

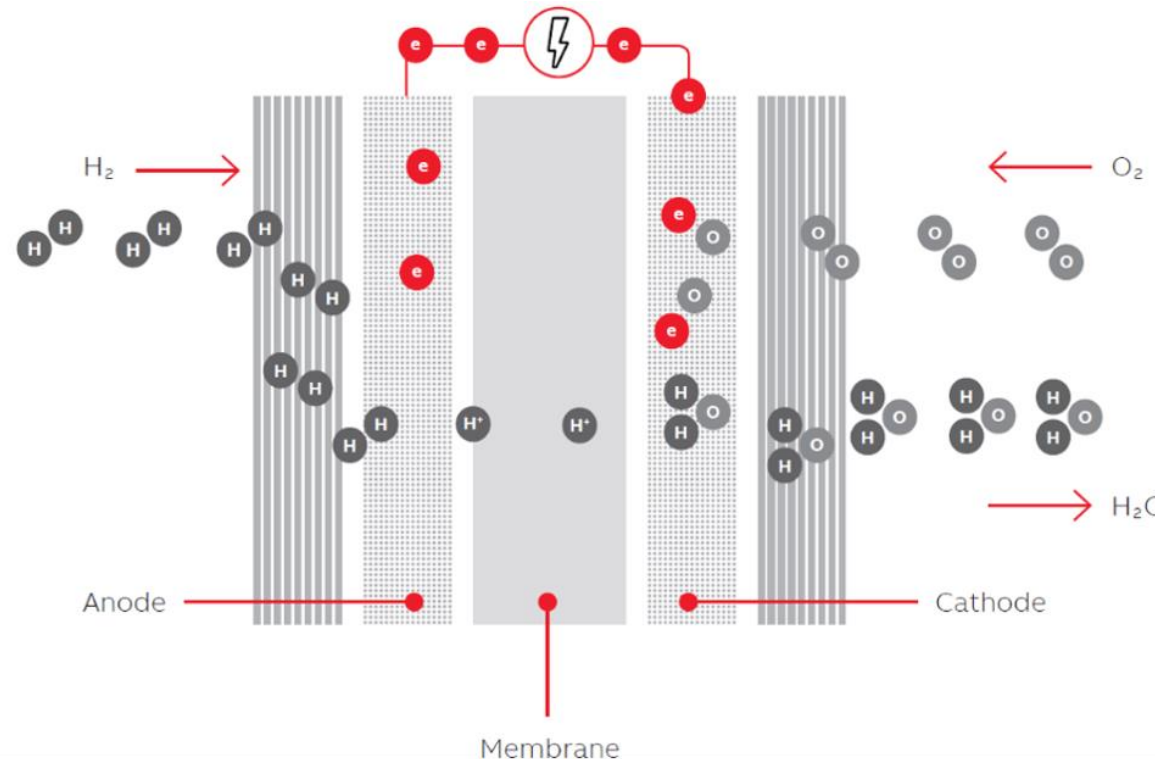
Enabling power generation with zero emissions

Hydrogen as primary fuel

- Direct emission from the fuel cell is pure water when supplied by hydrogen
- Reforming process required for other feedstock, such as methanol or LNG

Life cycle cost optimization

- High efficiency and low maintenance need
- Fuel cell systems designed for stack replacement or renewal after degradation



Process integration

- Balance of plant includes fuel regulation, process air supply, cooling, ventilation and internal safety systems
- Project-specific integration with external subsystems

Electrical & control systems

- Electric power regulation by converters and integrated power management system
- Safety system integration tailored for each application

Fuel cell technologies for marine applications

Certified products already available and continuously developing

PEM fuel cells provide high technology readiness level

- Dominant fuel cell type in automotive and heavy transport
- Reasonable production cost and straightforward production scale-up for increasing marine demand
- High power density and durability
- Refurbishment and recycling processes already in place



Efficient solutions by high-temperature fuel cells

- High operating temperature provides high efficiency and supports co-generation of power and heat
- Internal reforming capability enabling multiple alternative fuels
- Products for marine applications are yet under development and piloting



IMAGES: Ballard Power Systems, PowerCell Group, Bloom Energy

Power system integration

Flexible hybrid power systems

Integrated power converters

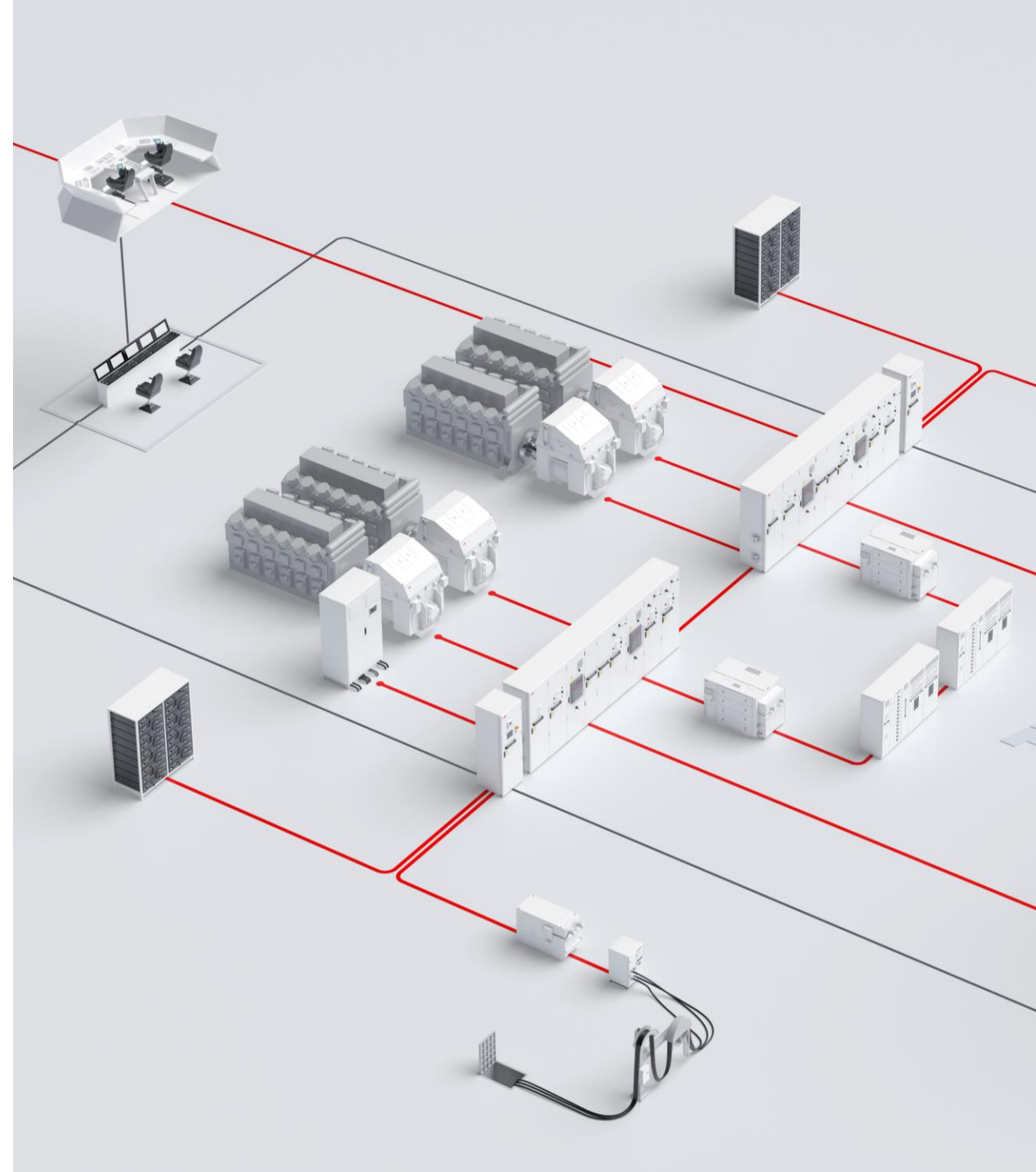
- DC/DC converters for fuel cells and battery systems
- Inverters or rectifiers for variable speed generators
- Grid converters for shore connection

Optimized dimensioning of fuel cells and batteries

- Full utilization of available shore power
- Optimized efficiency of fuel cells
- Batteries for peak shaving and backup reserve

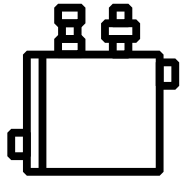
Operational modes of hybrid power system

- Zero-emission mode with fuel cells and batteries
- Hybrid mode with any combination of power sources



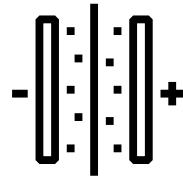
Dynamic performance of fuel cell systems

Ensure load response by battery systems



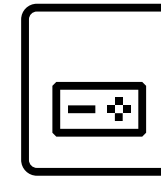
Reformers / HT fuel cells

- High-temperature processes are relatively slow by characteristics
- Reformers and high-temperature fuel cells are typically operated continuously to produce steady output flow or power
- Startup or shutdown may require several hours in some cases
- Alternative power sources are needed to support the dynamic capability



Low-temperature (LT) fuel cells

- Chemical process in low-temperature fuel cells is relatively fast to adjust
- Inlet pressure of hydrogen supply has significant impact on the dynamics
- Startup or shutdown takes typically less than hour, from standby only minutes
- LT fuel cells with compressed hydrogen may operate alone in some cases

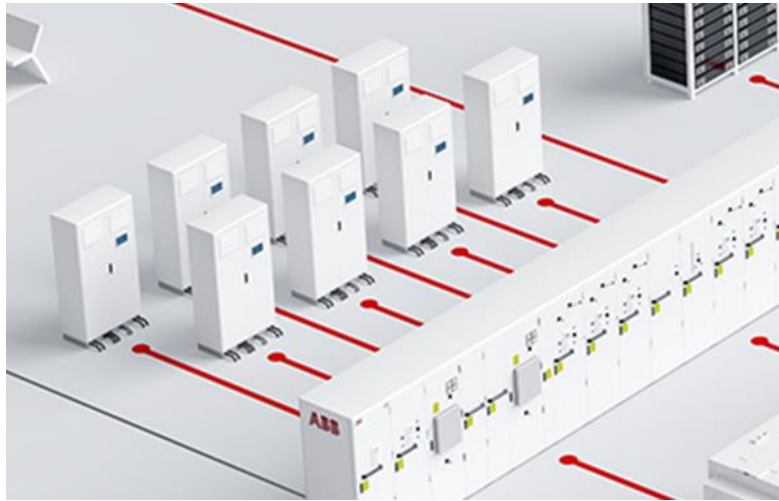


Batteries / Supercapacitors

- Batteries and supercapacitors can respond quickly to rapid changes
- Batteries can be optimized or balanced between high energy and high power
- Supercapacitors have low capacity but practically immediate load response
- Dynamics of fuel cell systems must be supported by batteries with adequate power and energy ratings

ABB roadmap of marine fuel cell solutions

System integration for MW-scale fuel cell installations



Integration of 3rd party fuel cells

- Scalable and flexible installation with marine certified fuel cell modules
- Integrated solutions available for sales



E-house installation of fuel cells

- Integration of fuel cell modules with total 1 MW per high-cube 40'' container
- Suitable for on-deck installation



High-power marine fuel cell concept

- Approval of principle by DNV for the concept design of 3 MW fuel cell unit
- Next generation technology

Fuel cell reference projects by ABB Marine & Ports

Gradual extension from demonstrators to integrated onboard power systems



System integration of 100 kW fuel cell system for two technology demonstrators

Fuel cell technology demonstrators



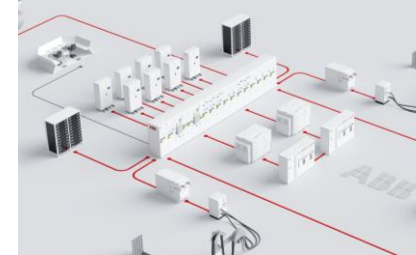
Research project to develop 165 kW fuel cell system for an arctic research vessel

MARANDA project arctic research vessel



Research project with 400 kW fuel cell system on hydrogen powered river container vessel

FLAGSHIPS project river container vessel



Marine newbuild project with Onboard DC Grid and MW-scale fuel cell system

Fuel cell integration with Onboard DC Grid



Electric propulsion and power plant with integrated methanol reformer and fuel cells

Methanol-hydrogen fuel cell towboat

ABB