Integration of Fuel Cells & Batteries to Power the Future

Part 2

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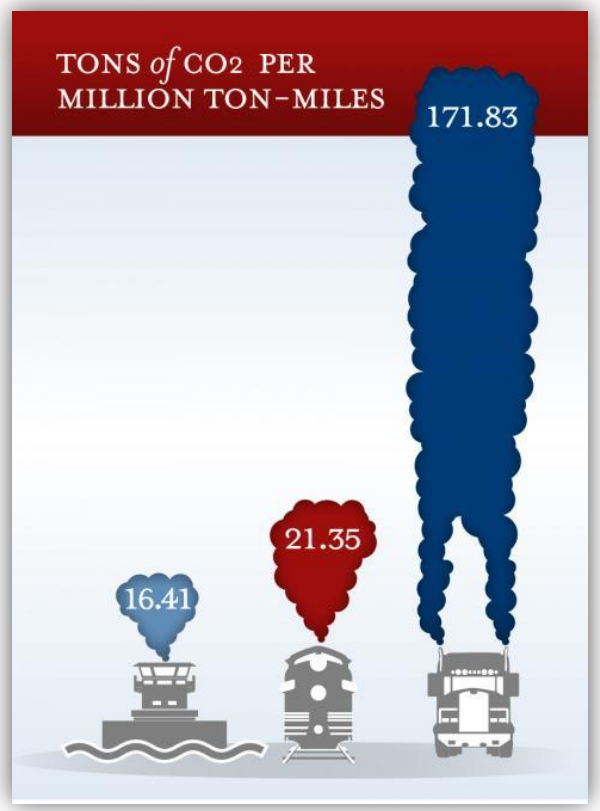
Corvus Energy

The American Waterways Operators

The Most Sustainable Mode of Transportation

- AWO is the tugboat, towboat, and barge industry's advocate, resource, and united voice for safe, sustainable, and efficient transportation on America's waterways, oceans, and coasts
- The largest segment of the U.S.-flag domestic fleet
  - 5,000 towing vessels
  - 33,000 barges
  - 665 million tons of cargo annually
  - 90% less CO_2 than trucking



The American Waterways Operators

Integration of Fuel Cells & Batteries to Power the Future

AWO Winter Sustainability Part #2

Environment Social & Government

Data & Fuel Monitors

Fuel Cells & Batteries *Pt.1*

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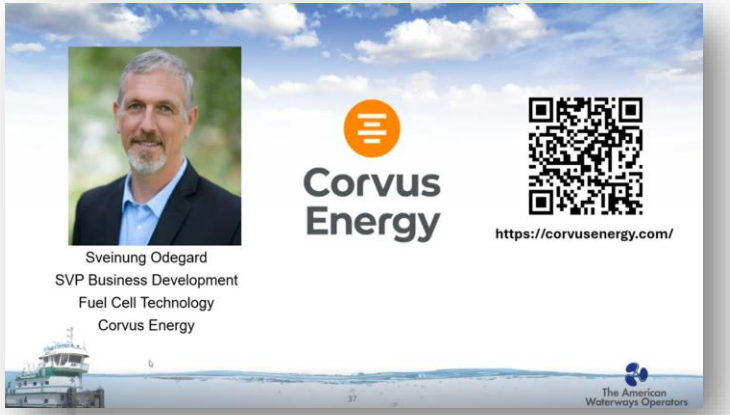
Integration of Fuel Cells & Batteries *Part 1*



- Hybrid/Electric Propulsion
- Zero-emission goals
- Regulatory Drivers
- Economic Incentives
- Technology Integration
- Energy Storage Systems (ESS)
- Safety & Training Considerations

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Today's Discussion The Integration of Fuel Cells & Batteries to Power the Future

Part 2

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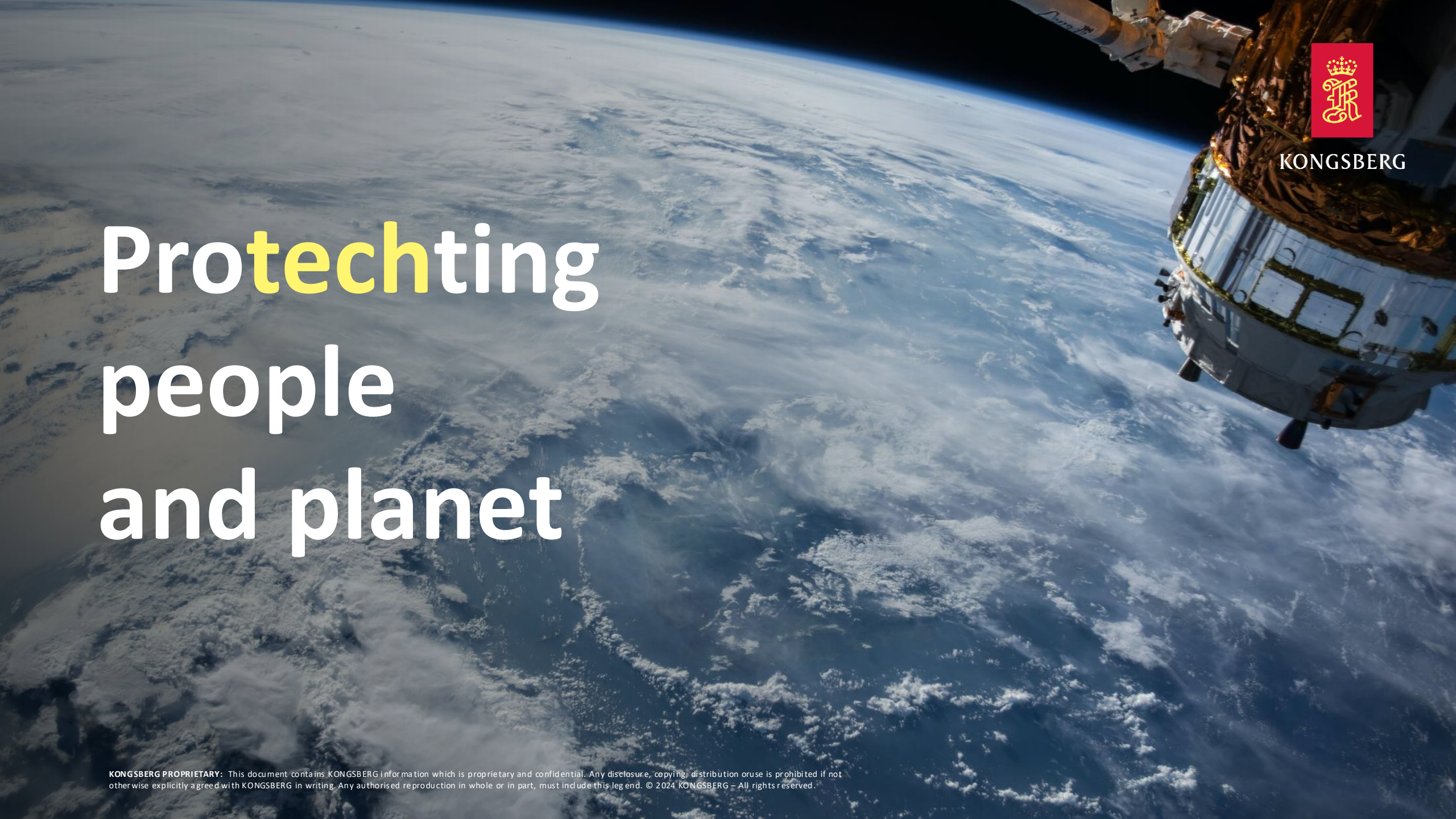

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AWO Webinar: Integration of fuel cells and batteries

Part 2

Transitioning from mechanical to electric propulsion

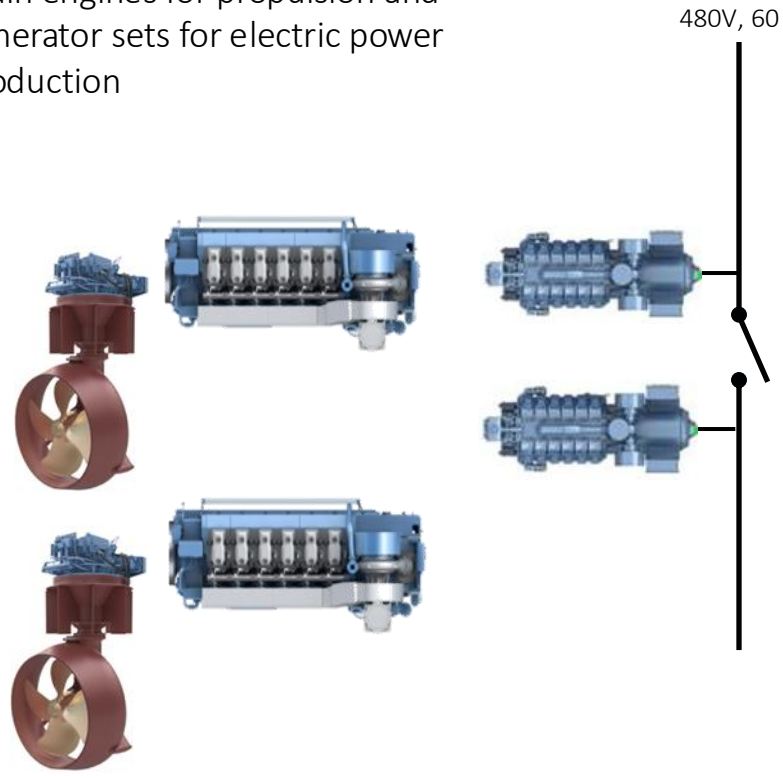
Onboard power systems with fuel cells and batteries

- New vessels will have more complex electric power systems than before. As both fuel cells and batteries are sources of electric power.
- Owners and operators needs to familiarize with electric power systems and electric drive-lines for propulsion.
- Both batteries and fuel cells are DC (Direct Current) sources of power.
- DC based power systems can invert DC to three-phase AC power for vessel auxiliaries (lights, pumps, HVAC, controls, etc.)
- DC voltage levels are typically 800V for smaller systems and 1000V DC for larger power systems
- DC based power systems are typically arranged as DC-switchboards (one or several). With individual modules for each function (propulsion, fuel-cells, batteries, aux).
- For tugs and other workboats, it’s possible to run electric winches from the DC power system.

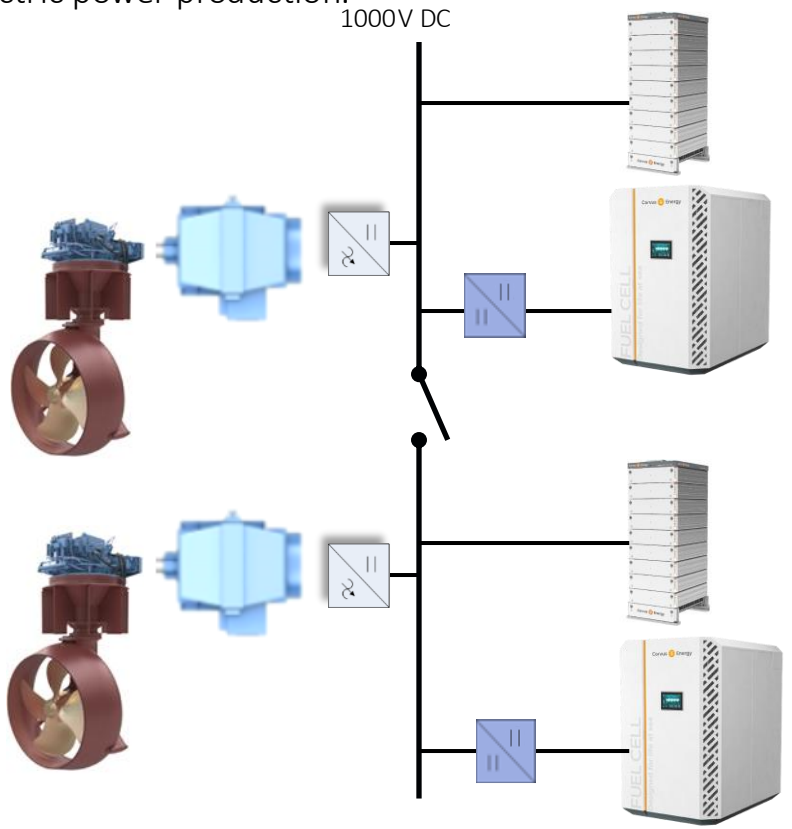
From mechanical to electric propulsion

Topology transition

Conventional power and propulsion. Main engines for propulsion and generator sets for electric power production



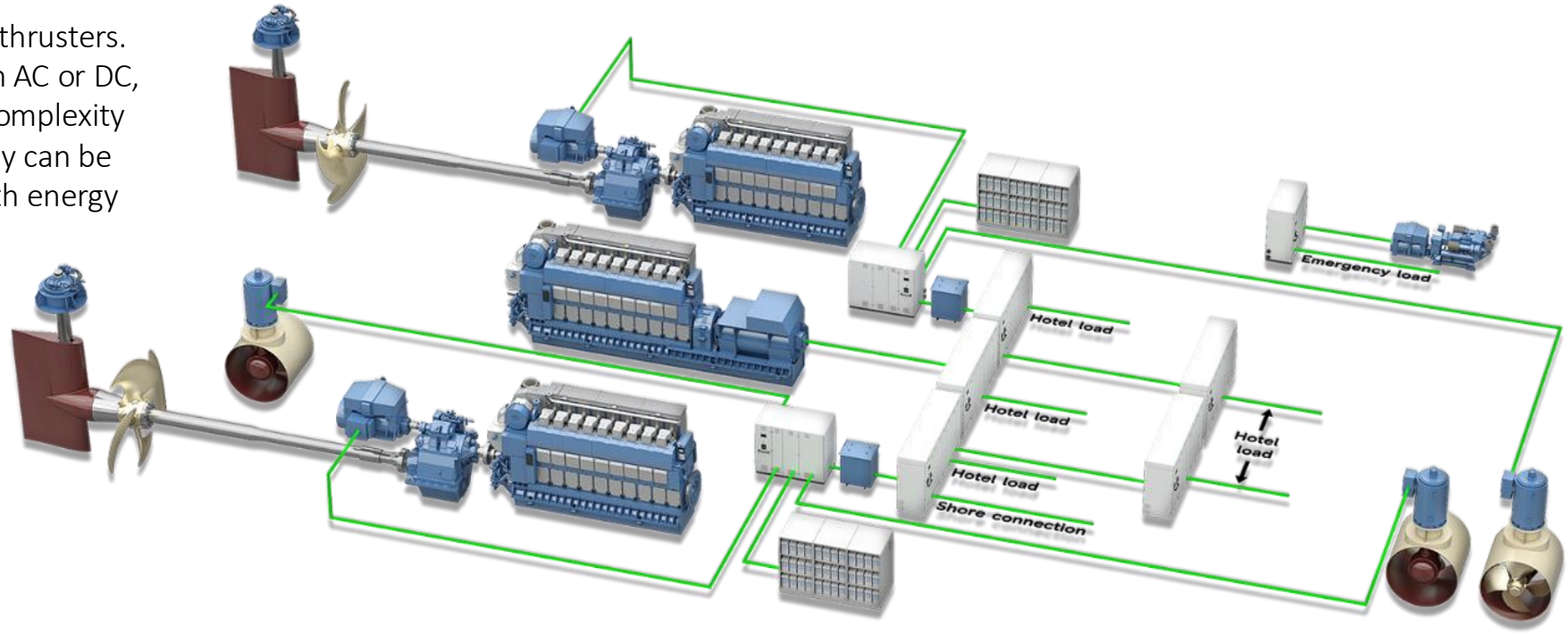
Fully electric propulsion, with fuel-cells and batteries for electric power production.



Hybrid propulsion system

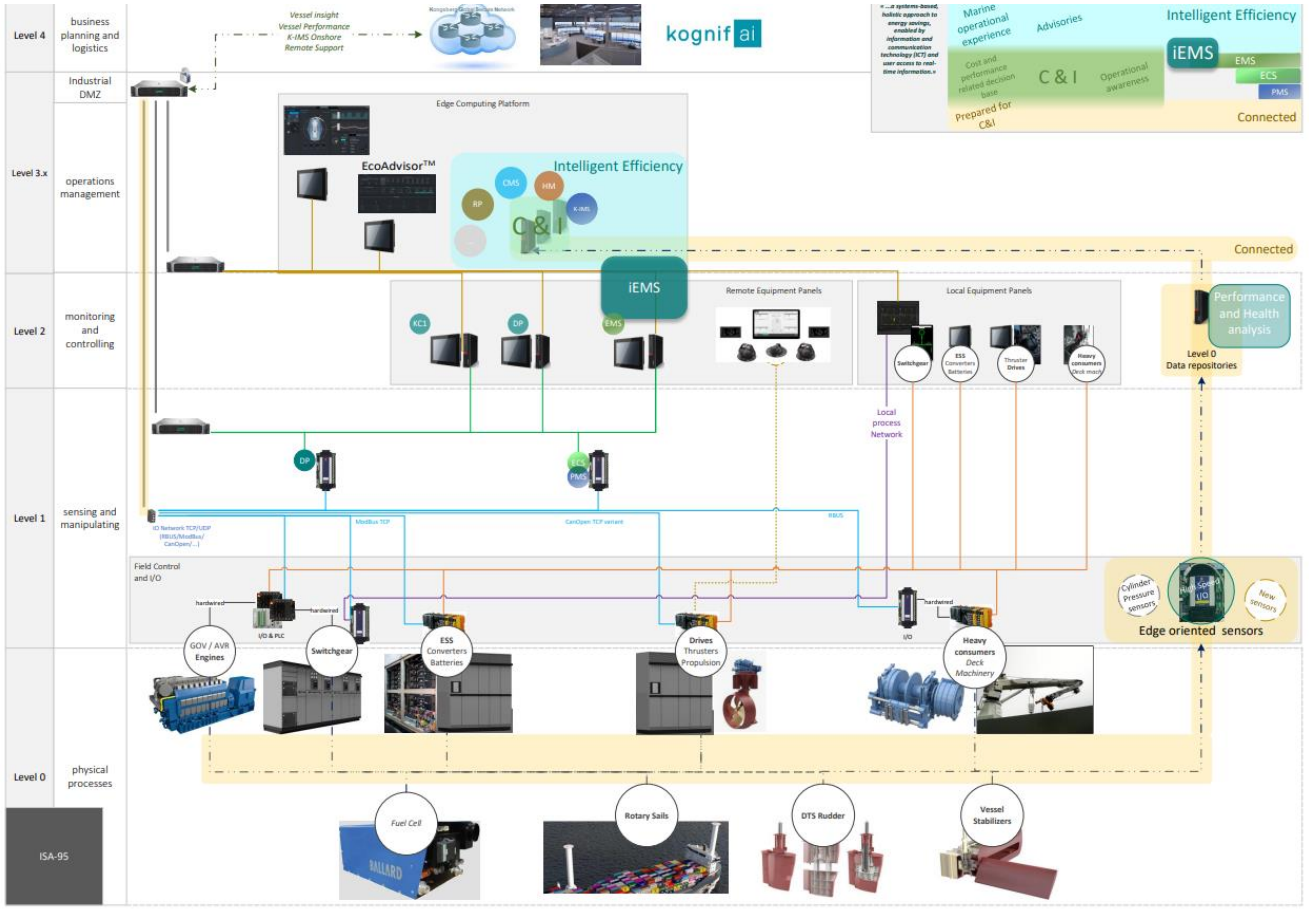
Or, something in between

- Hyrbid propulsion with shaft generators that can do both PTI and PTO (AC is shown)
- Alternatively, dual input thrusters.
- Systems can be based on AC or DC, depending on size and complexity
- Various soruces of energy can be used, in combination with energy storage (batteries)

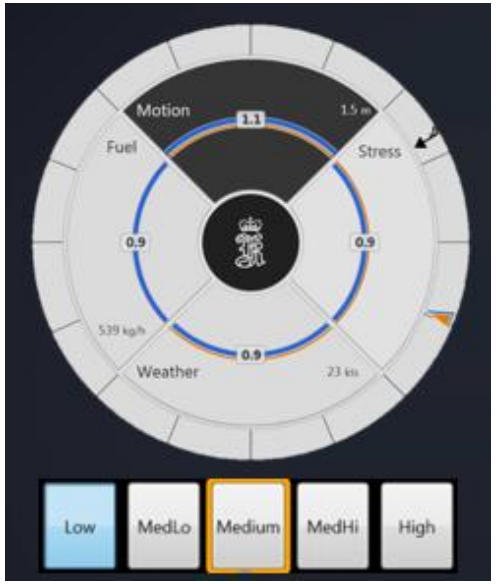


Energy Control

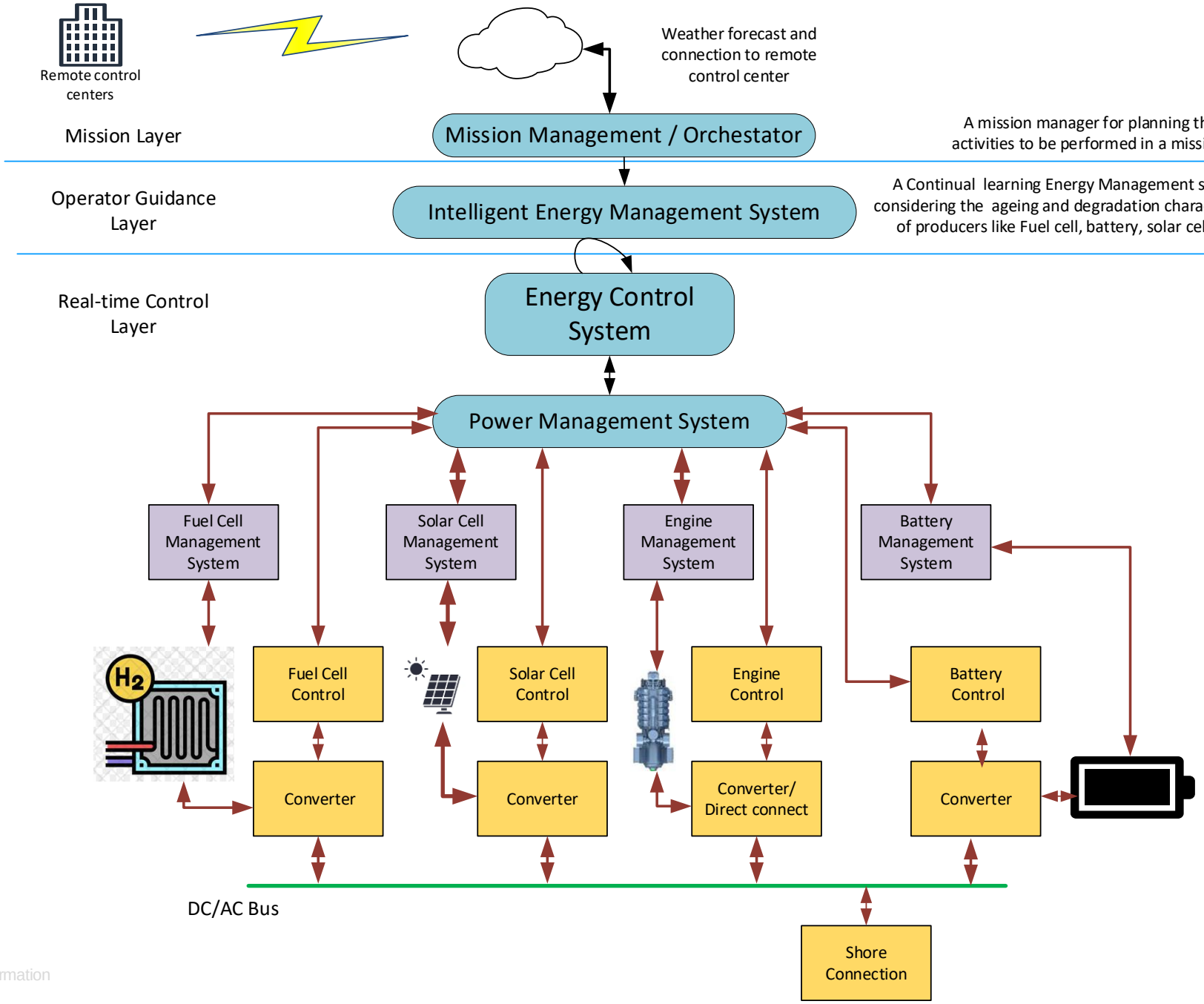
- When combining mulitiple sources and consumers of electric energy, a common control system is necessary.
- To make operations safe and robust for the operator, the power and energy management system needs to interface the various components and know their operational limits.
- A common control system interfaces all parts of the power and propulsion plant.
- It also serves as a data-provider for reporting and analytical services through cloud-based soulutions.



Utilizing the full orchestra



Mode/Responsiveness Control



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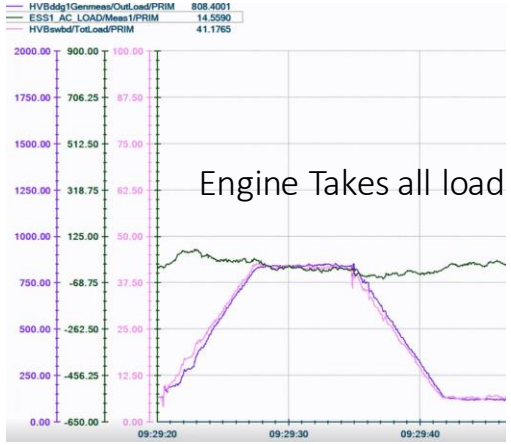
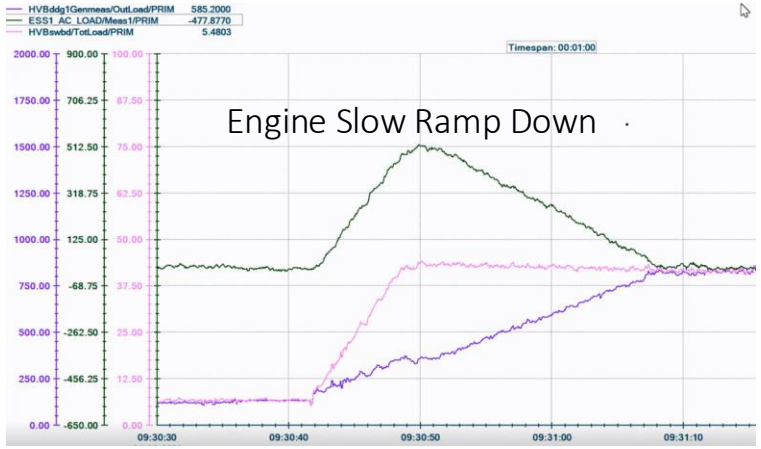
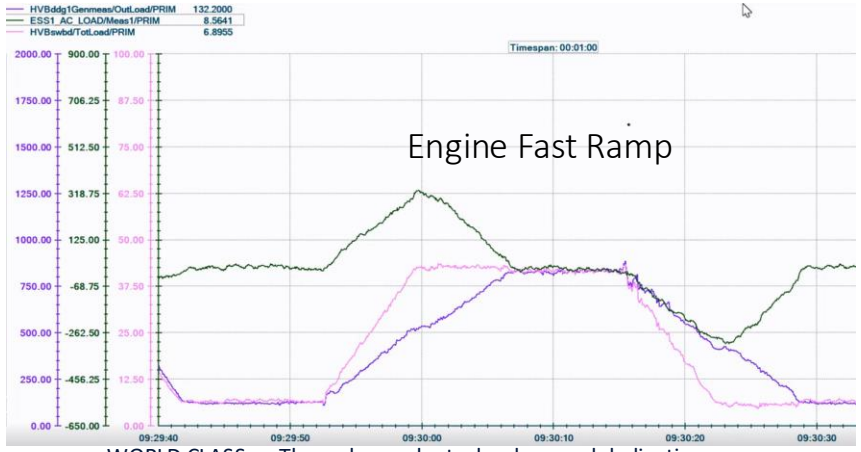
Dynamic Control of Responsiveness

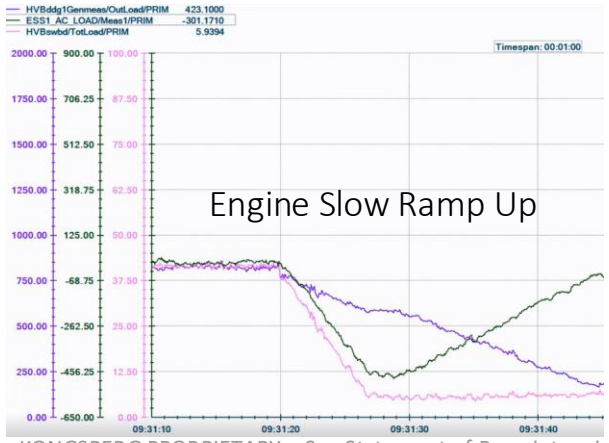
Dynamic Inertia Control

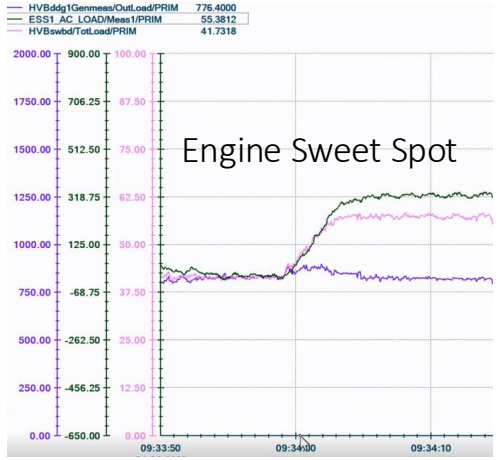
Performance Boost











HYBRID AND ELECTRIC POWER AND PROPULSION SYSTEMS

PROS & CONS

Pro's

- Depending on the level of electrification, large savings in Operating Expenses can be achieved.
- It is easier to meet both coming and current environmental regulations, especially emissions and noise.
- Possible to reduce underwater radiated noise, to meet current and possible new regulations.
- Fuel savings and reduced running hours for reciprocating engines.
- Operational reporting and analytic work is possible through better, more detailed data.

Con's

- Generally, higher capital expenditures.
- Higher complexity of electrical installations.
- Will require somewhat different skills and knowledge of crew, engineers and vessel management.

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Thank you

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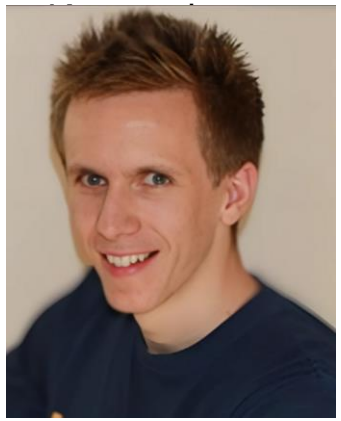
Moderated Panel Discussion

Sustainability in practice

Sveinung Odegard



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The American Waterways Operators

Audience Q & A

The American Waterways Operators

The Tugboat, Towboat & Barge Industry Association

HAVE A FOLLOW-UP QUESTION?

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Thank you!

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BUILDING TOMORROW'S LEGACY