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System model for testing and validating maritime fuel cell application (HOPE WP 4)

Nordic Maritime Transport and Energy Research Programme

Ammonia and Hydrogen for Ships WORKSHOP

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20 April 2022

Technology for a better society



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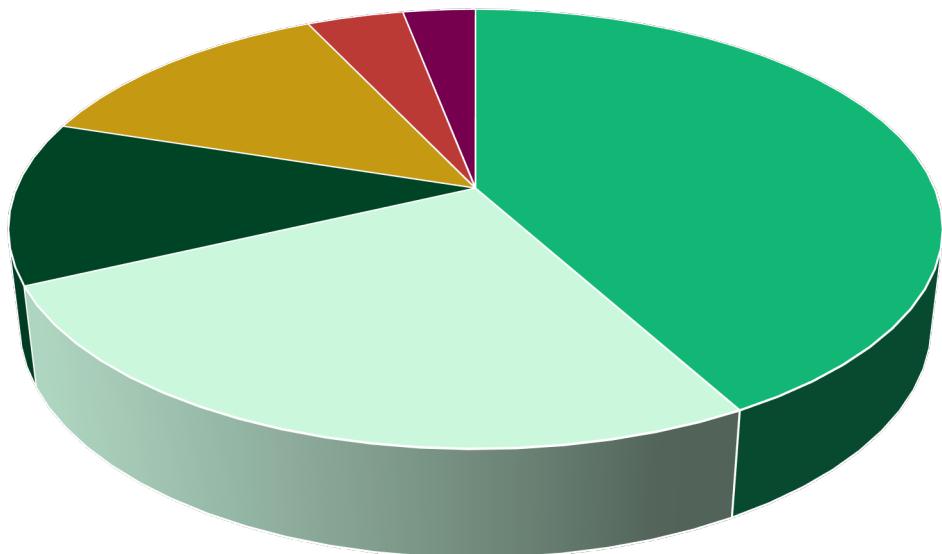
Hydrogen is coming, or has it come?



Motivation

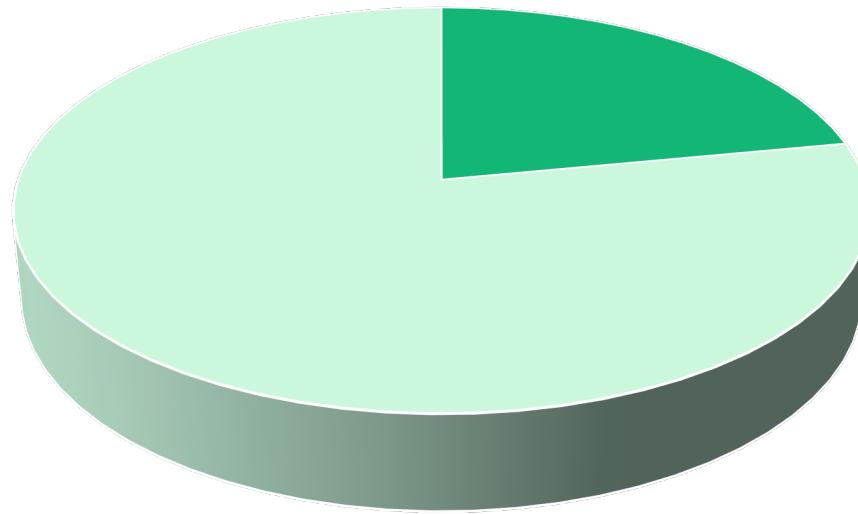
Vessel sizes and consumption

% vessels vs. Installed power



■ <1800 kW ■ 1800-3500 kW ■ 3500-8500 kW
■ 8500-1500 kW ■ 15000-30000 kW ■ >30000 kW

% vessels vs. Emissions



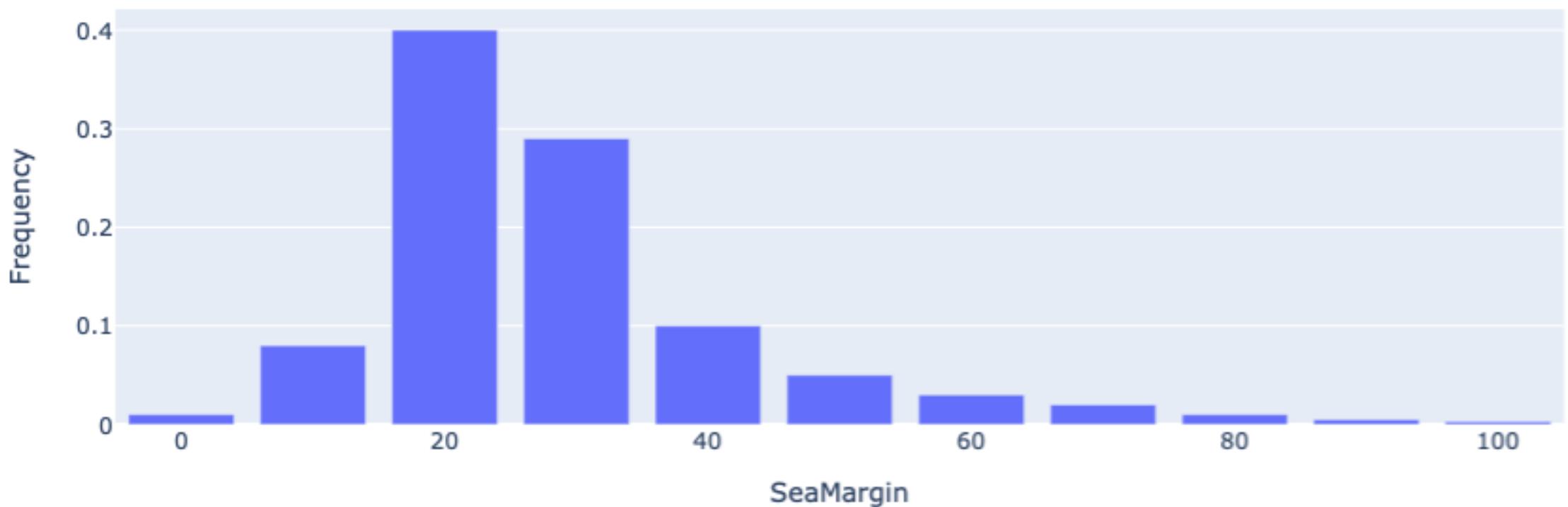
■ <3500 kW ■ >3500 kW



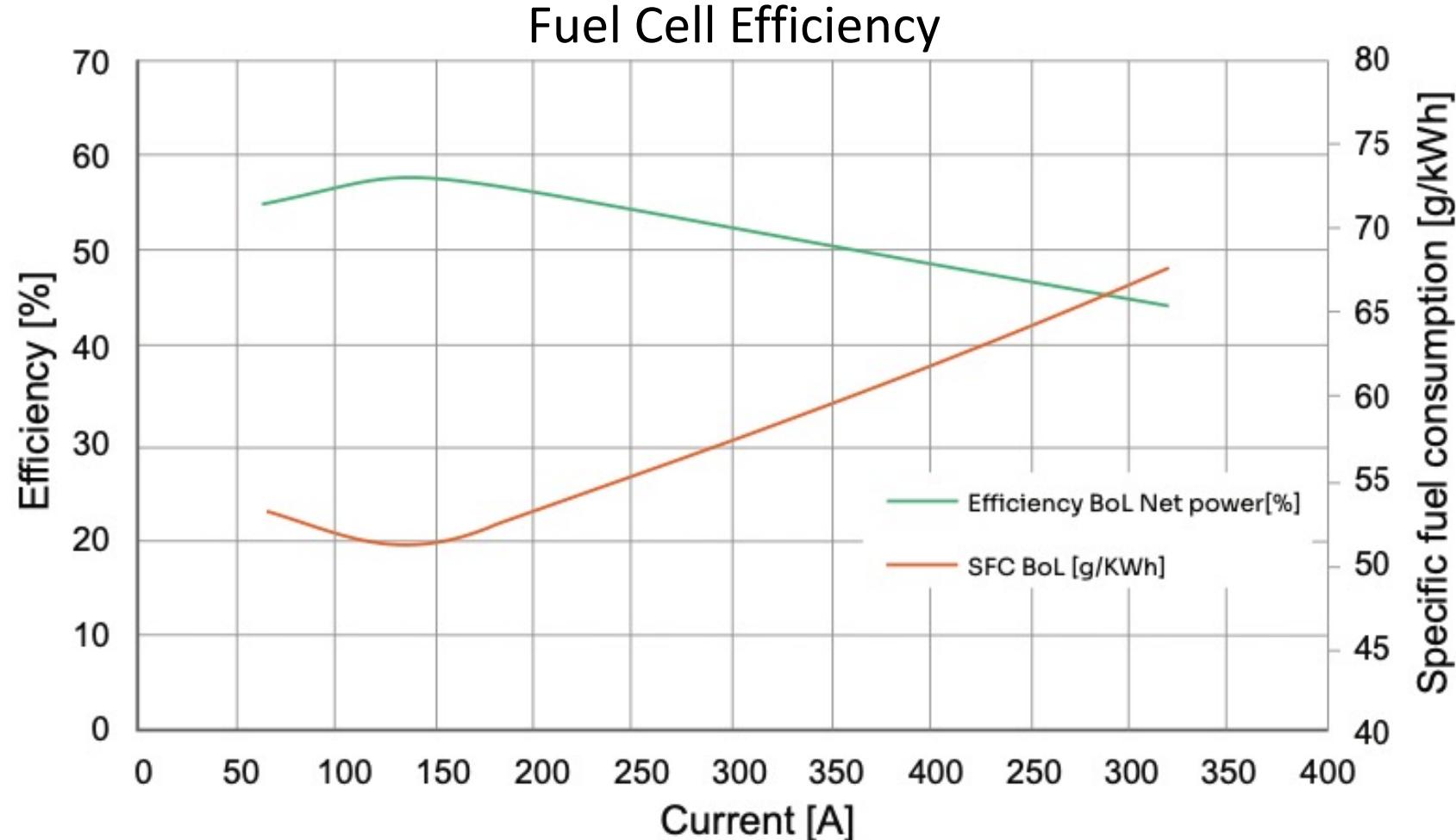
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Motivation

Operational Profile of a Ferry



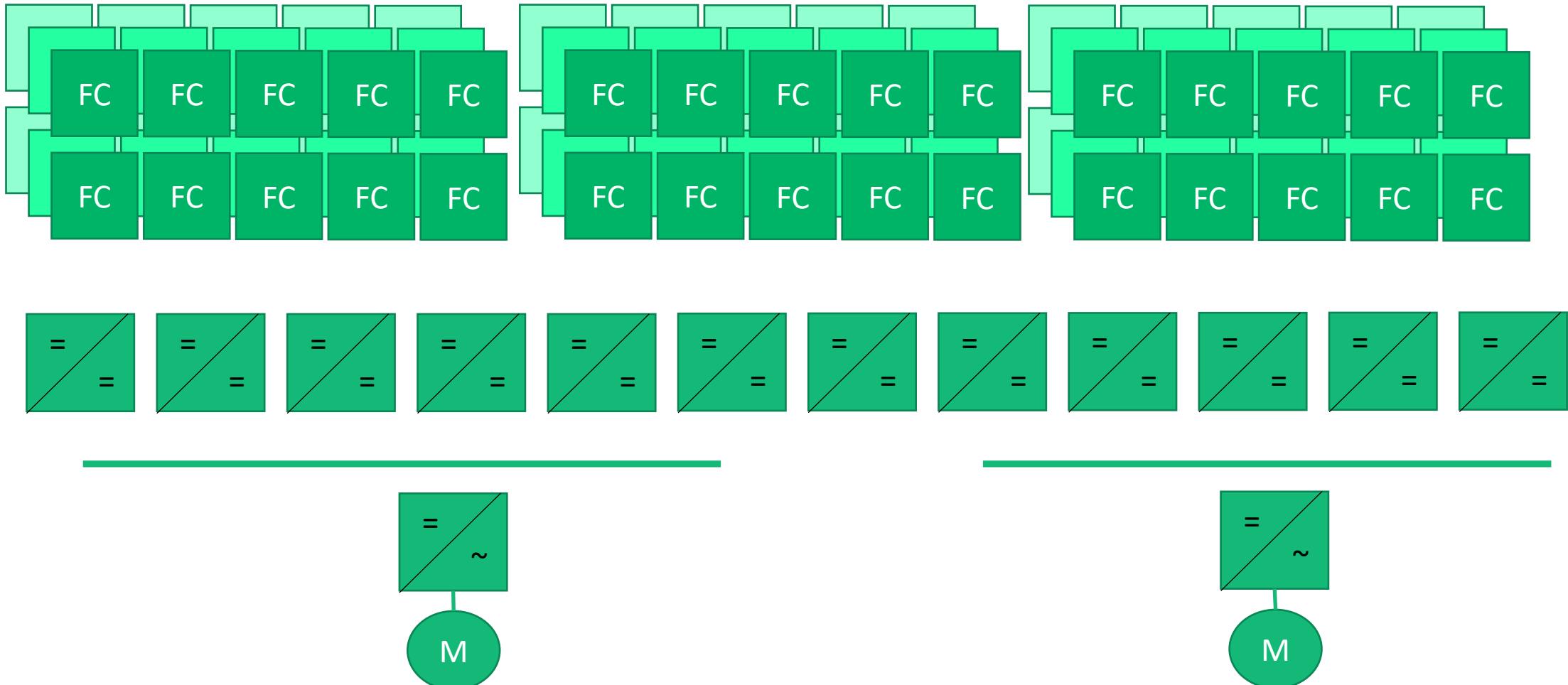
Motivation



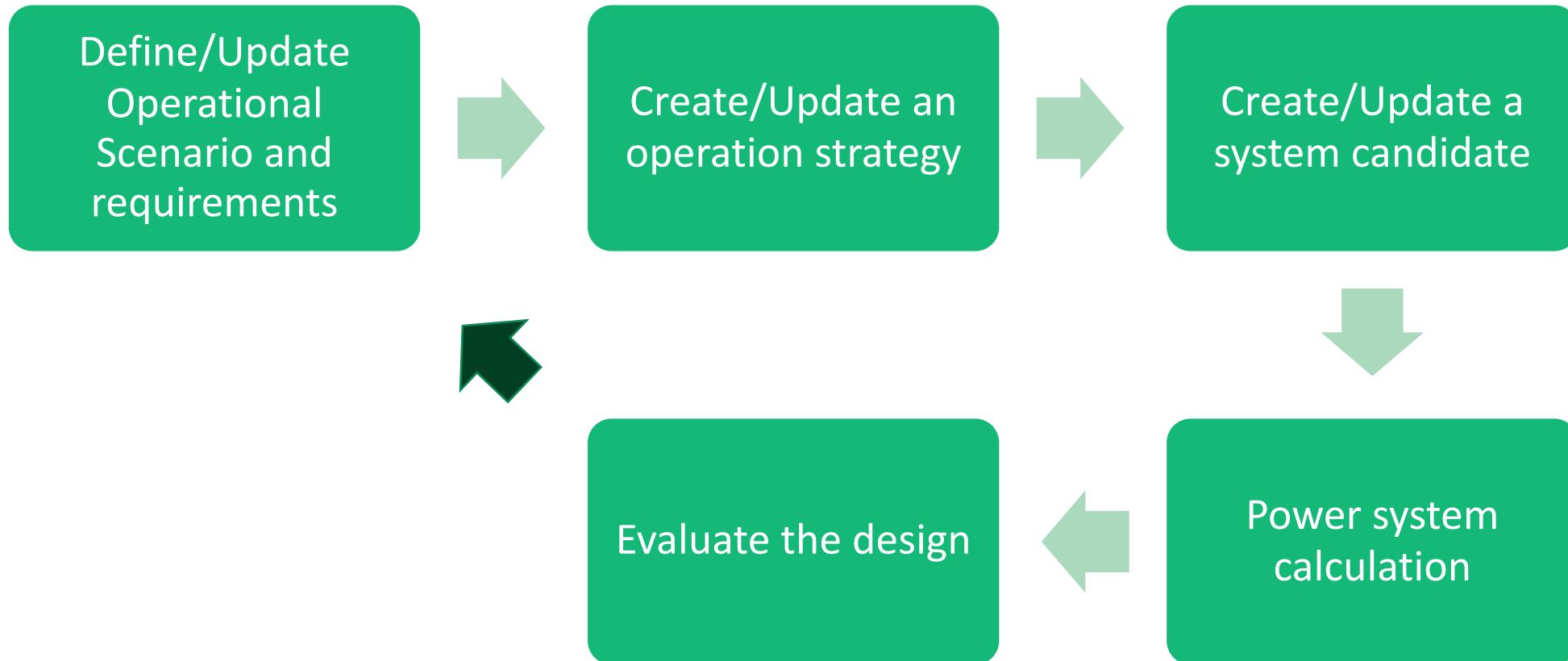


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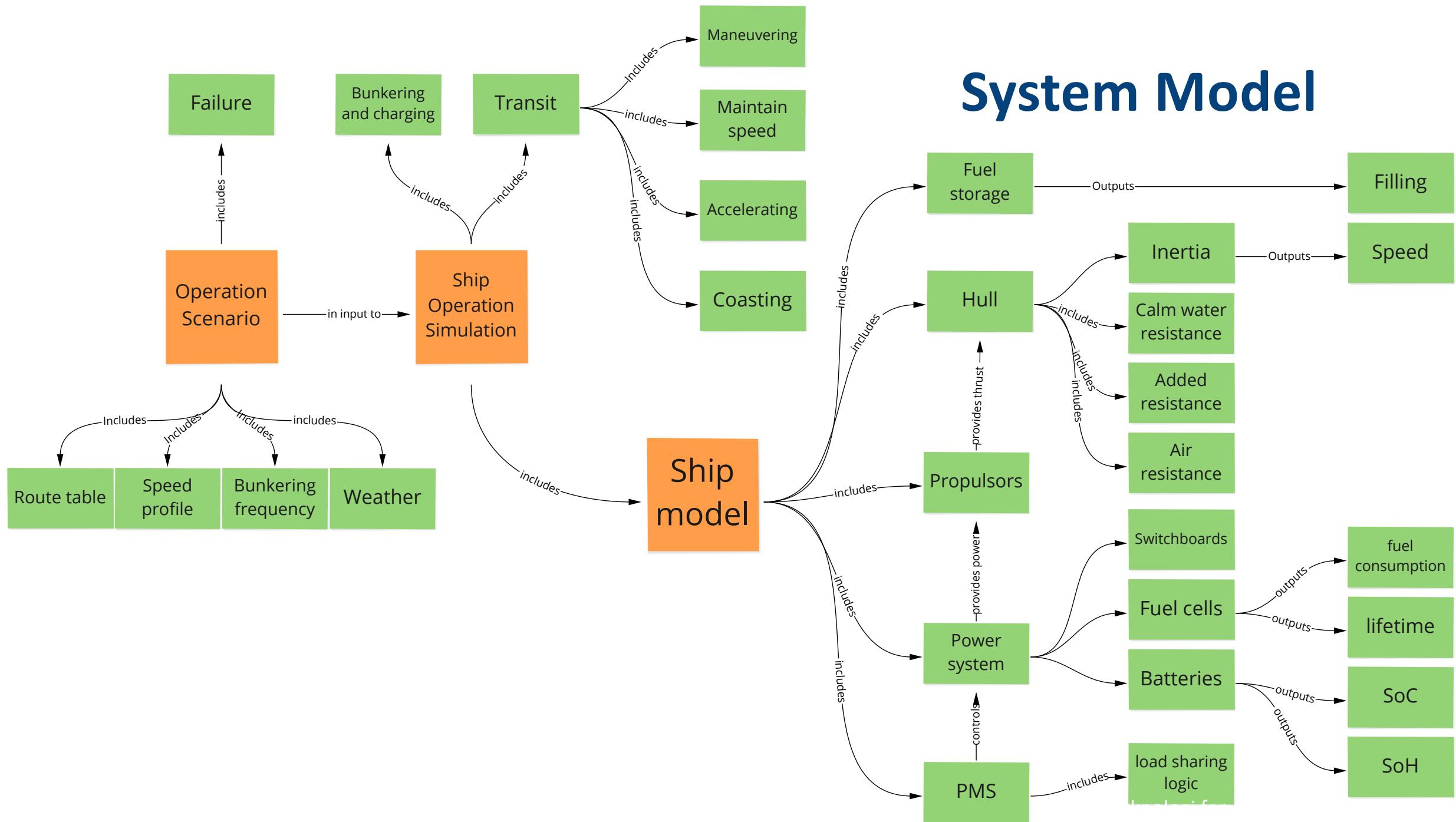
Motivation



Overall Process of Evaluation



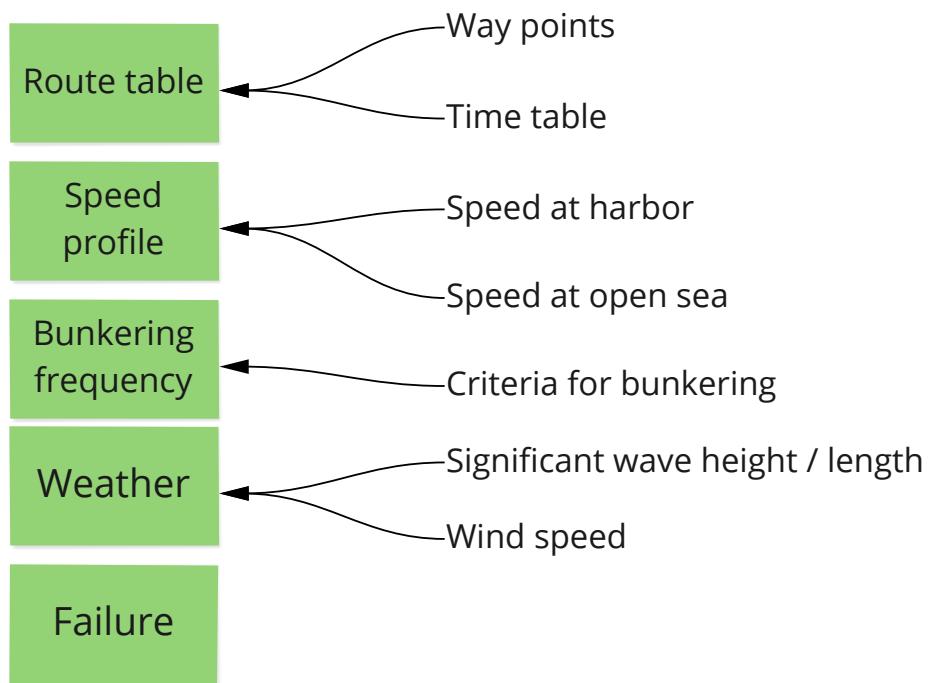
System Model



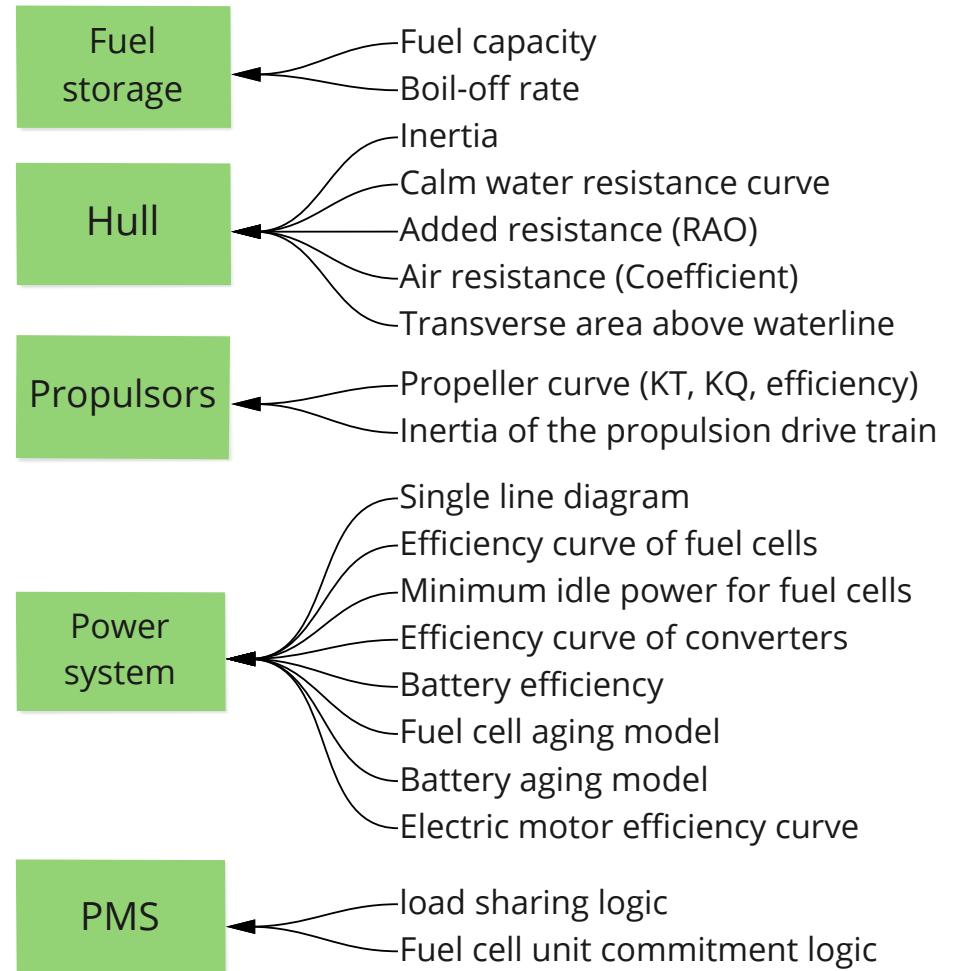


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Input Parameters



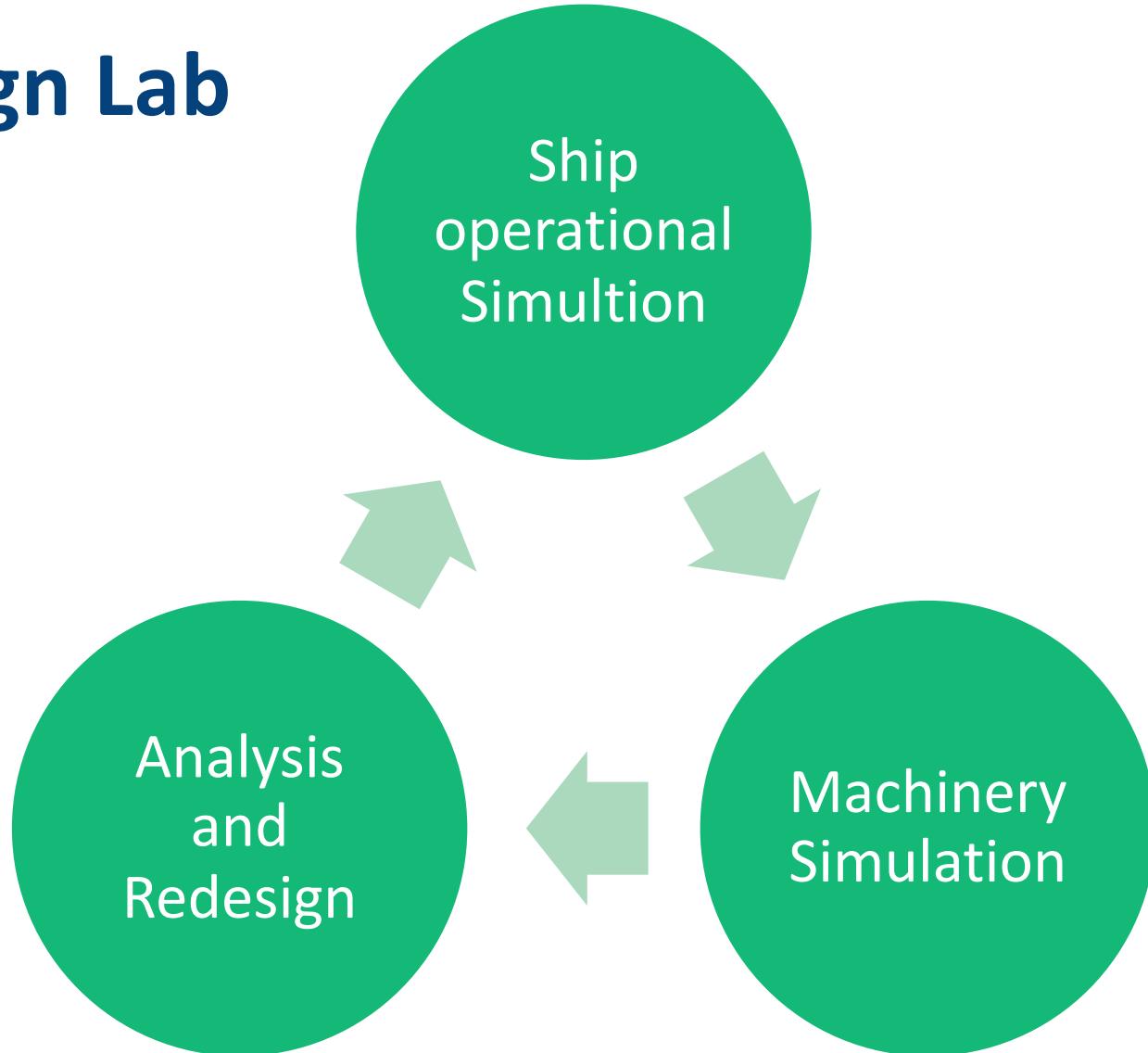
5th





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Design Lab



Design Lab – Ship Operational Simulation: GYMIR

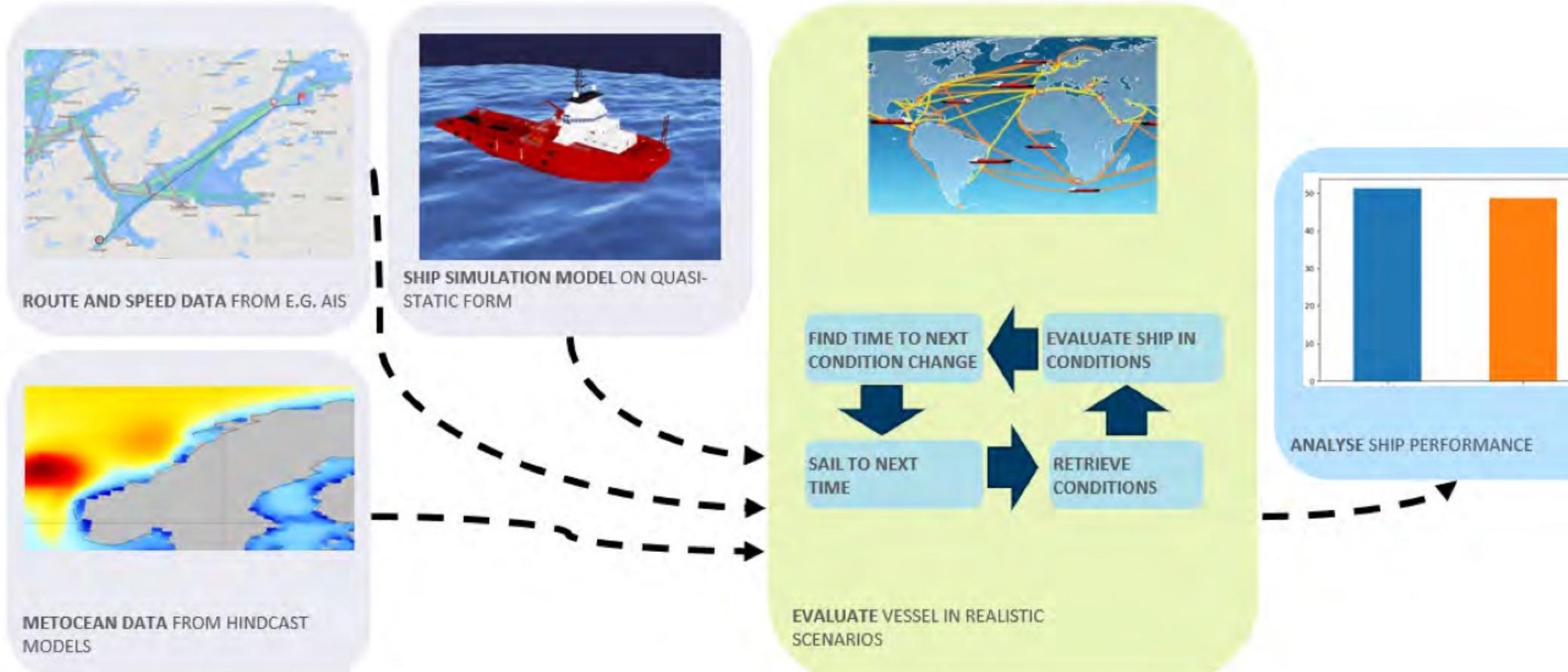
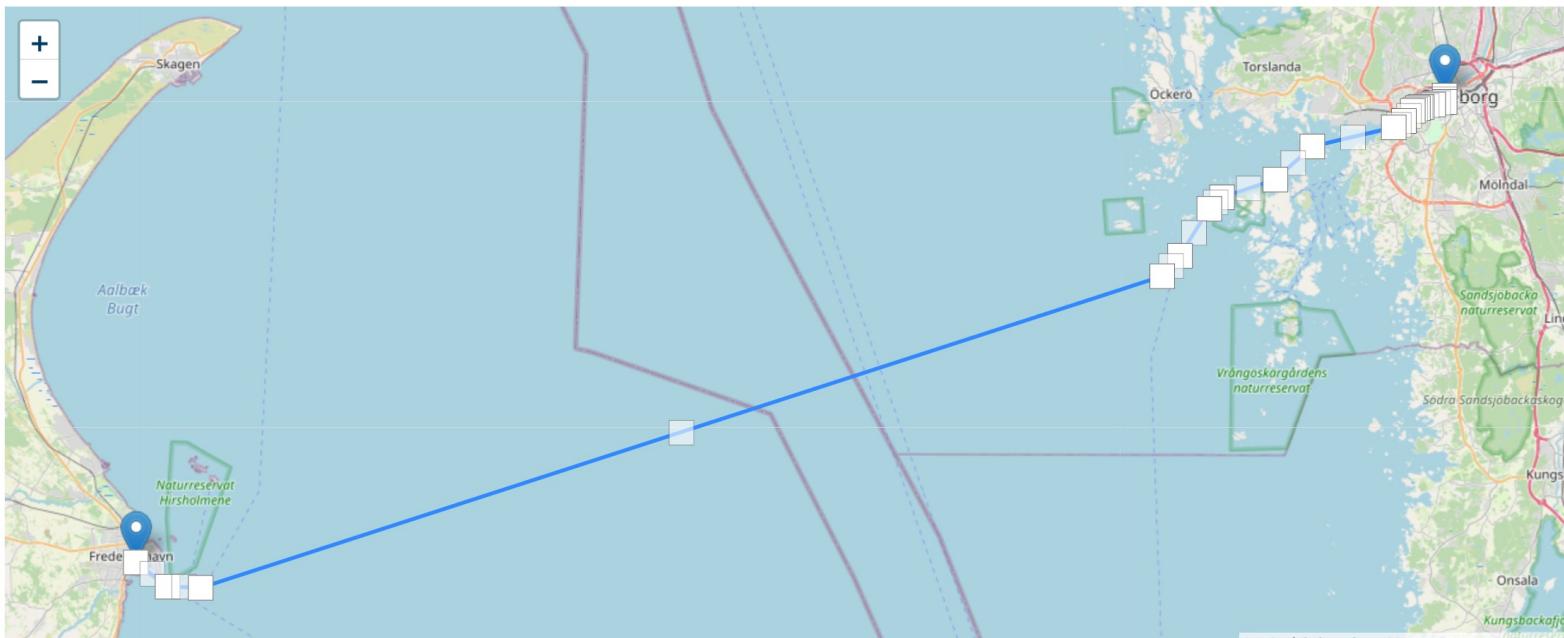


Fig.1: High-level concept sketch of the simulation method



Map

**ADD PLACE**

Places

Place name	Actions
Gothenburg	
Fredrikshavn	

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Routes

NEW ROUTE

From	To	Distance
Gothenburg	Fredrikshavn	50.0 NM

Import

Import map and route tables to this project from:

IMPORT

Route table

Name

Stena Jutlandica

Number of days in cycle

7

Maneuver time during departure

1680 seconds 180 seconds

Route Table**NEW ARRIVAL/DEPARTURE****NEW ITEM**

Days	Start time	Place	Event	Actions
Mon	00:00:00	Gothenburg	Boarding	
Tue, Wed, Thu, Fri, Sat	03:20:00	Fredrikshavn	Boarding	
Tue, Wed, Thu	04:05:00	Fredrikshavn	Sailing	
Mon, Sun	07:30:00	Gothenburg	Sailing	
Tue, Wed, Thu	07:40:00	Gothenburg	Boarding	
Fri, Sat	08:00:00	Fredrikshavn	Sailing	
Mon, Sun	10:50:00	Fredrikshavn	Boarding	
Fri, Sat	11:30:00	Gothenburg	Boarding	
Mon, Sun	11:35:00	Fredrikshavn	Sailing	
Mon, Sun	15:00:00	Gothenburg	Boarding	

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GENERATE OPERATION PROFILE**SAVE****Route calendar**

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Design Lab – Machinery Configuration

≡ SINTEF Marine Machinery Configurator

Simulation Control RUN

Gymir Simulation Input ↑

System Configuration ✖ ↑

Name: HOPE Fuel Cell Power System Electric Power System Editor 🔍 🔍

Propulsion Type: ELECTRIC

Load limit: 50 %

Fuel Storage: +

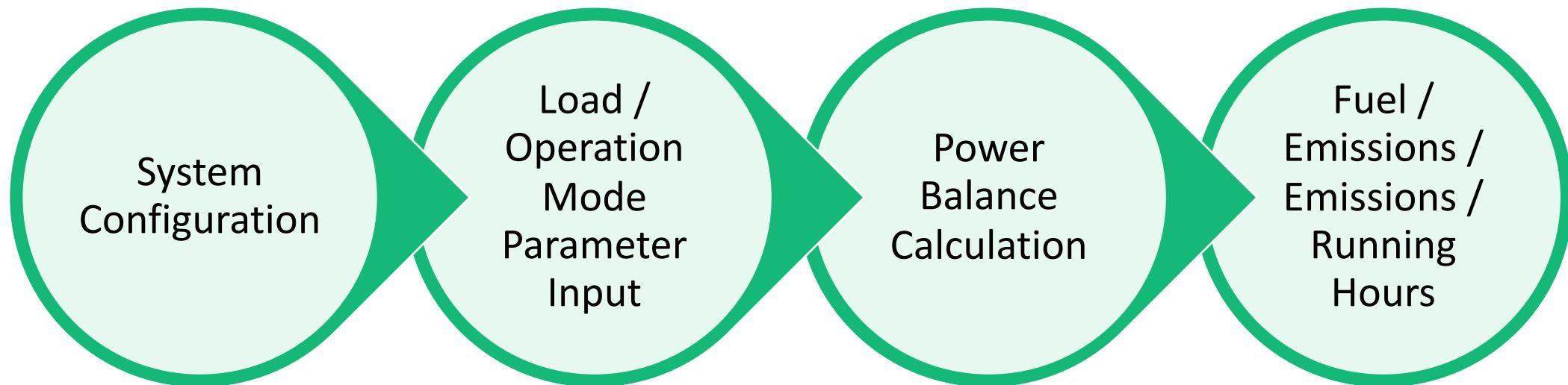
Fuel type	Capacity [kg]	Actions
HYDROGEN	15000	✎ trash

Diagram illustrating the HOPE Fuel Cell Power System configuration. The system consists of two parallel stacks of fuel cells (FC), each with an inductor symbol in the middle. On the left stack, there is a motor (M) and a gear icon. On the right stack, there is another motor (M) and a gear icon. Both stacks have 'OTHER LOAD' symbols. The bus ends with a ground symbol.

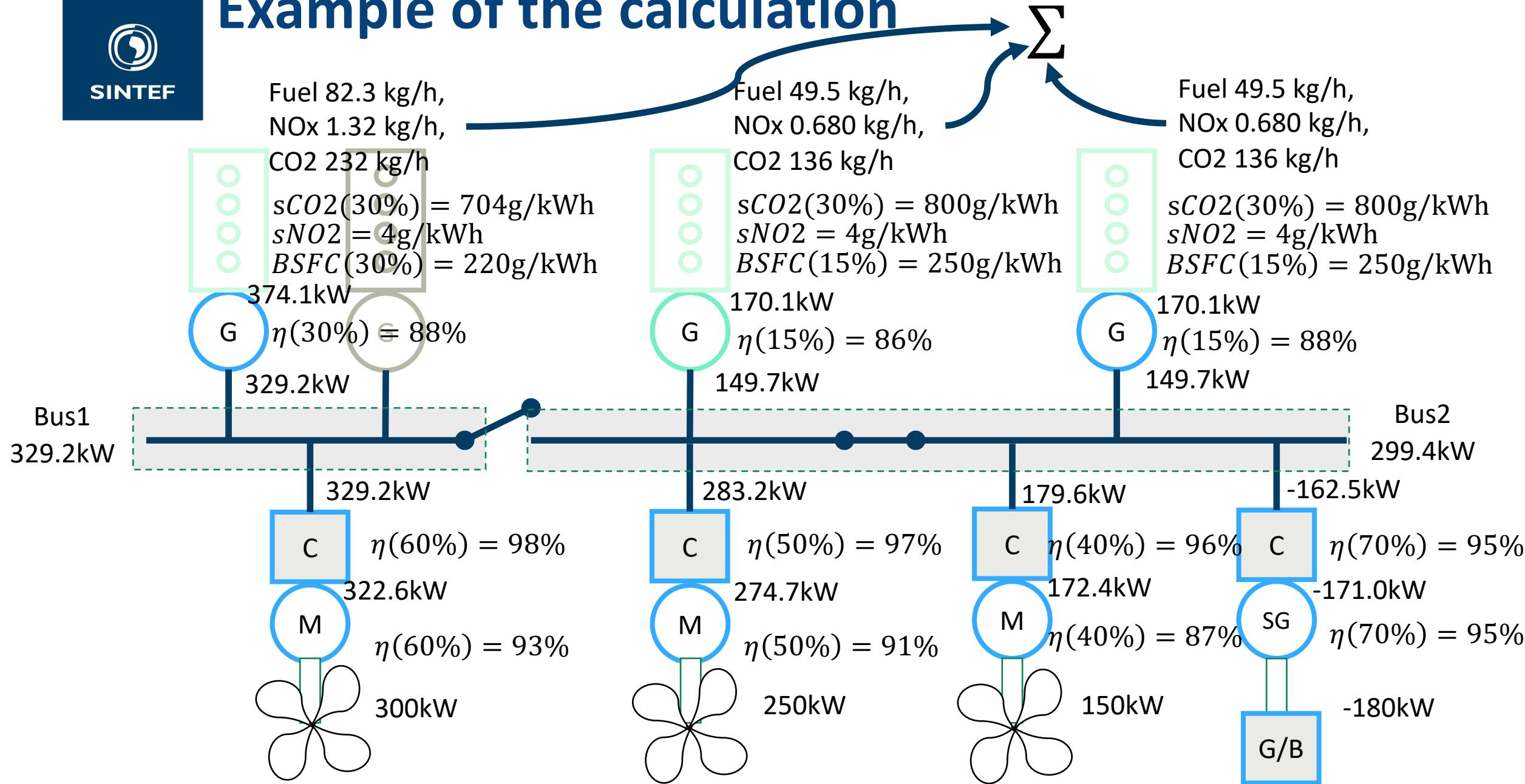
Design Lab – Fuel, Energy, Emissions Calculation for Machinery System (FEEMS)

- Modeling framework for a marine power and propulsion system for calculation of fuel consumption, emissions, and energy balance with the input of operation mode and external power load
- Possible system to configure
 - Hybrid/Conventional Diesel / Fuel Cell Electric Propulsion
 - Hybrid Propulsion with PTI/PTO
 - Mechanical Propulsion with a Separate Electric Power System
- It is possible to implement an energy management strategy

Design Lab – Fuel, Energy, Emissions Calculation for Machinery System (FEEMS)



Example of the calculation

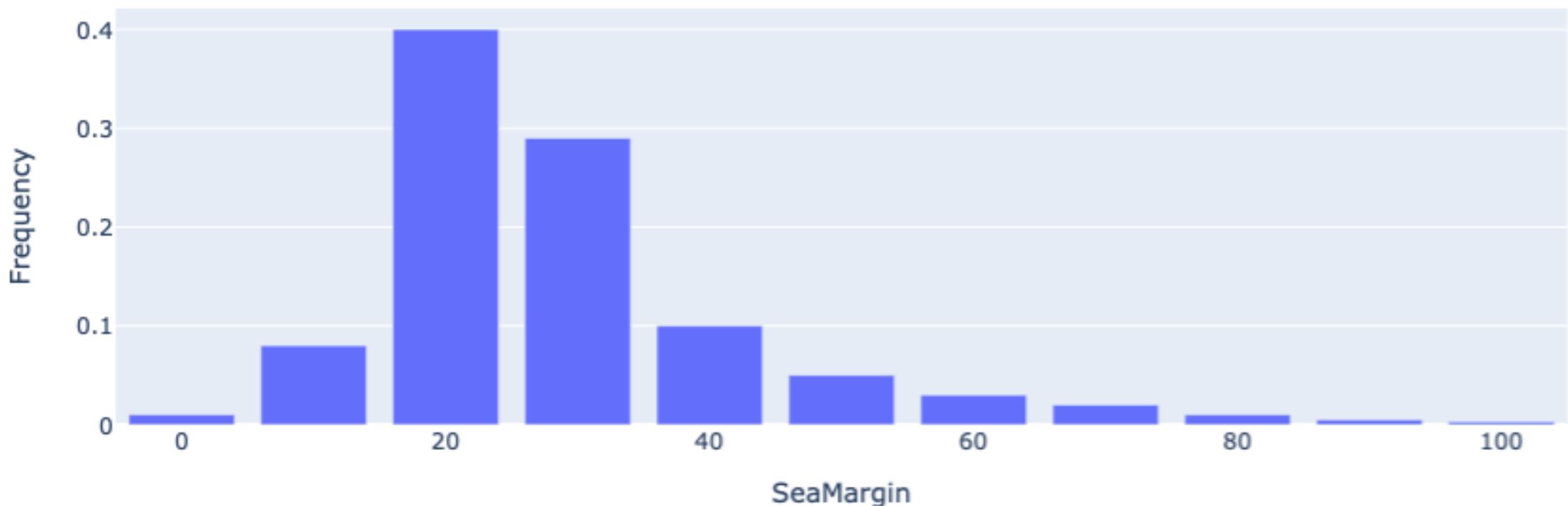




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Initial Case Study

- Operational Profile Input from Statistical Data



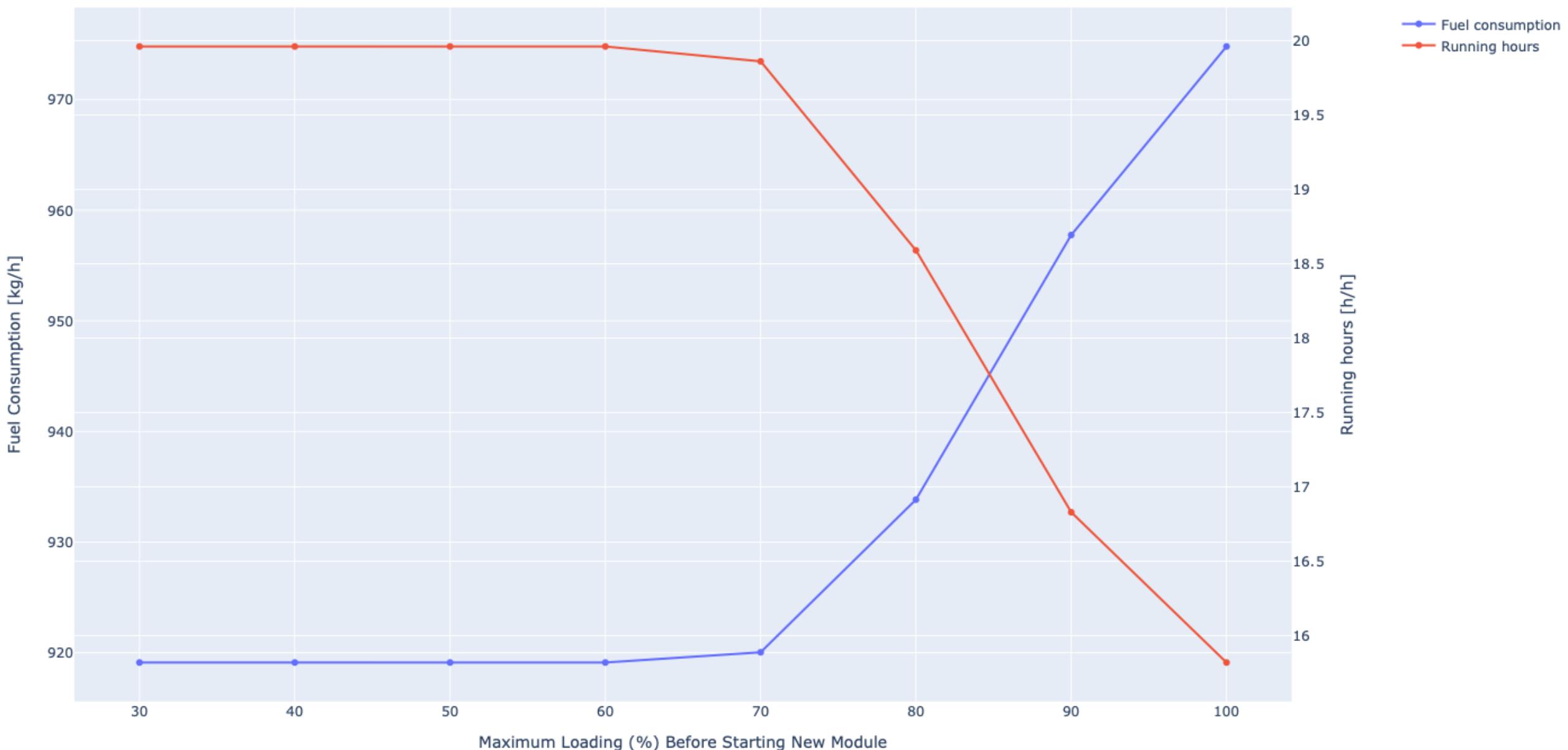


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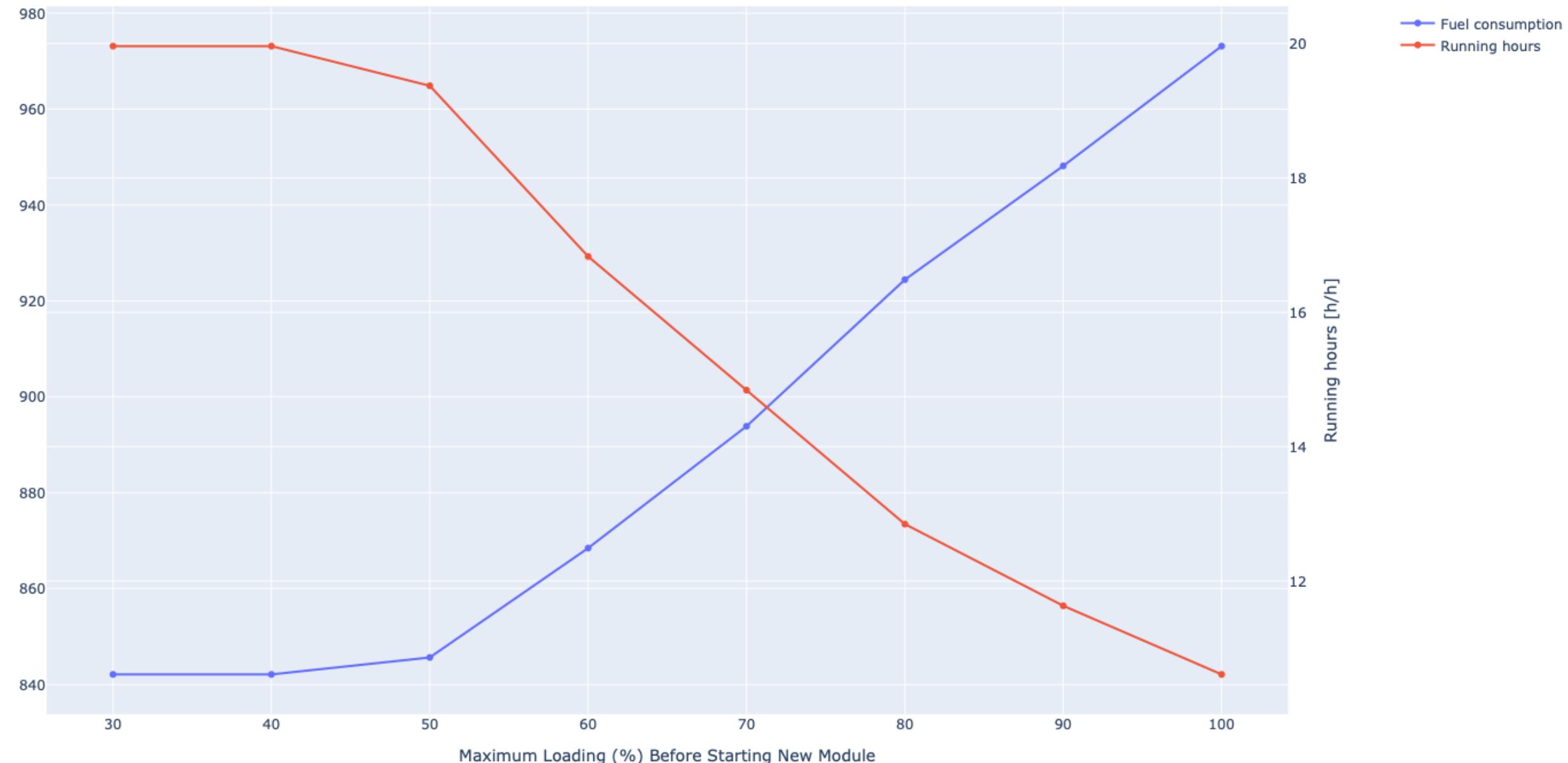
Assumptions

- Total installed power: 20MW, 30MW, 40MW
- 5 Hydrogen modules are grouped for one DC/DC converter
- Minimum number of fuel cell groups
 - Maximum load limits [%]: 30, 40, 50, 60, 70, 80, 90, 100
- Load dependent efficiency

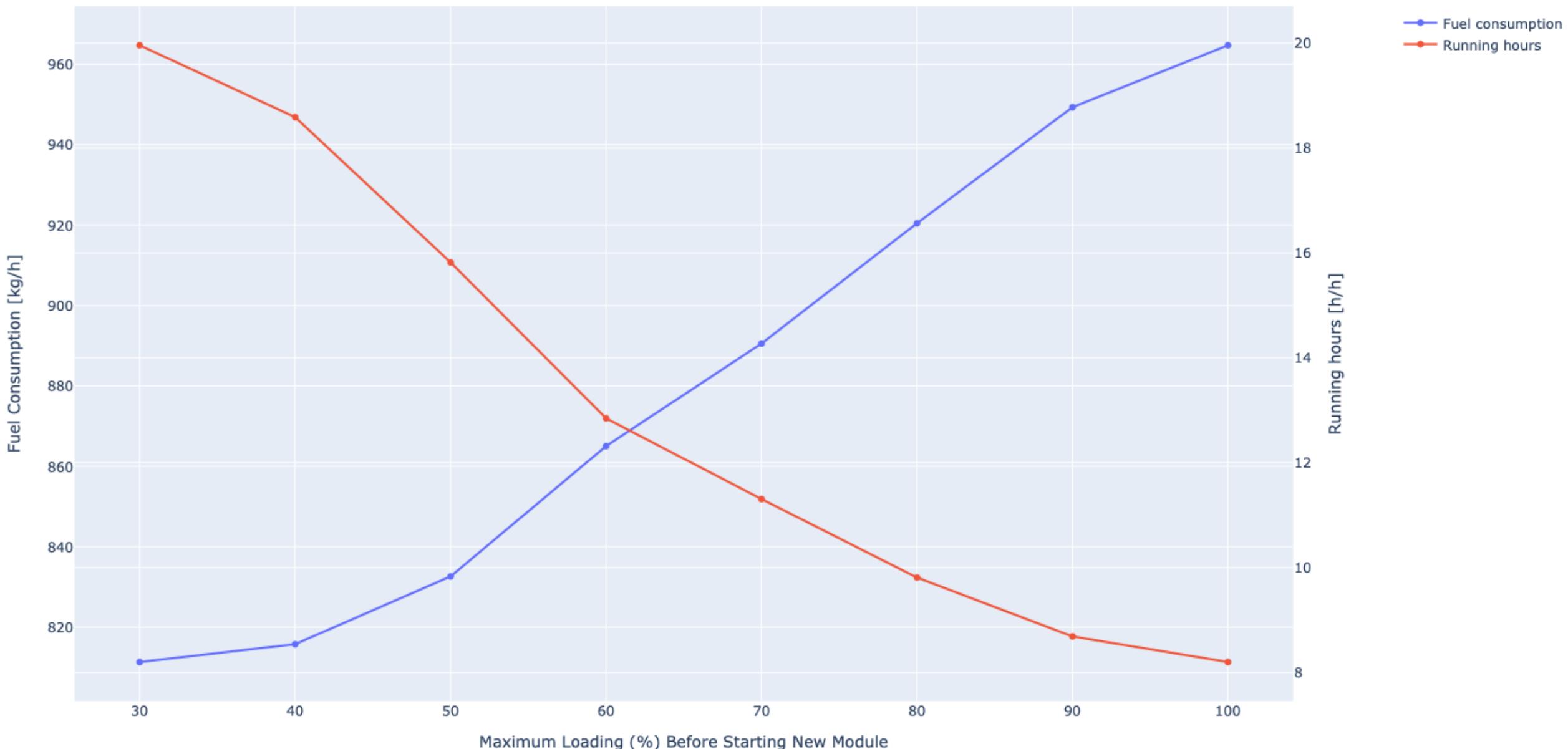
Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 20MW Case



Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 30MW Case



Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 40MW Case





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Conclusion

- Dealing with complex
 - A systematic / collaborative work needed
- Further work
 - Finish the development of the design lab
 - Develop a cost model for the design lab
 - Set up a dynamic system model for the case and test control strategies



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