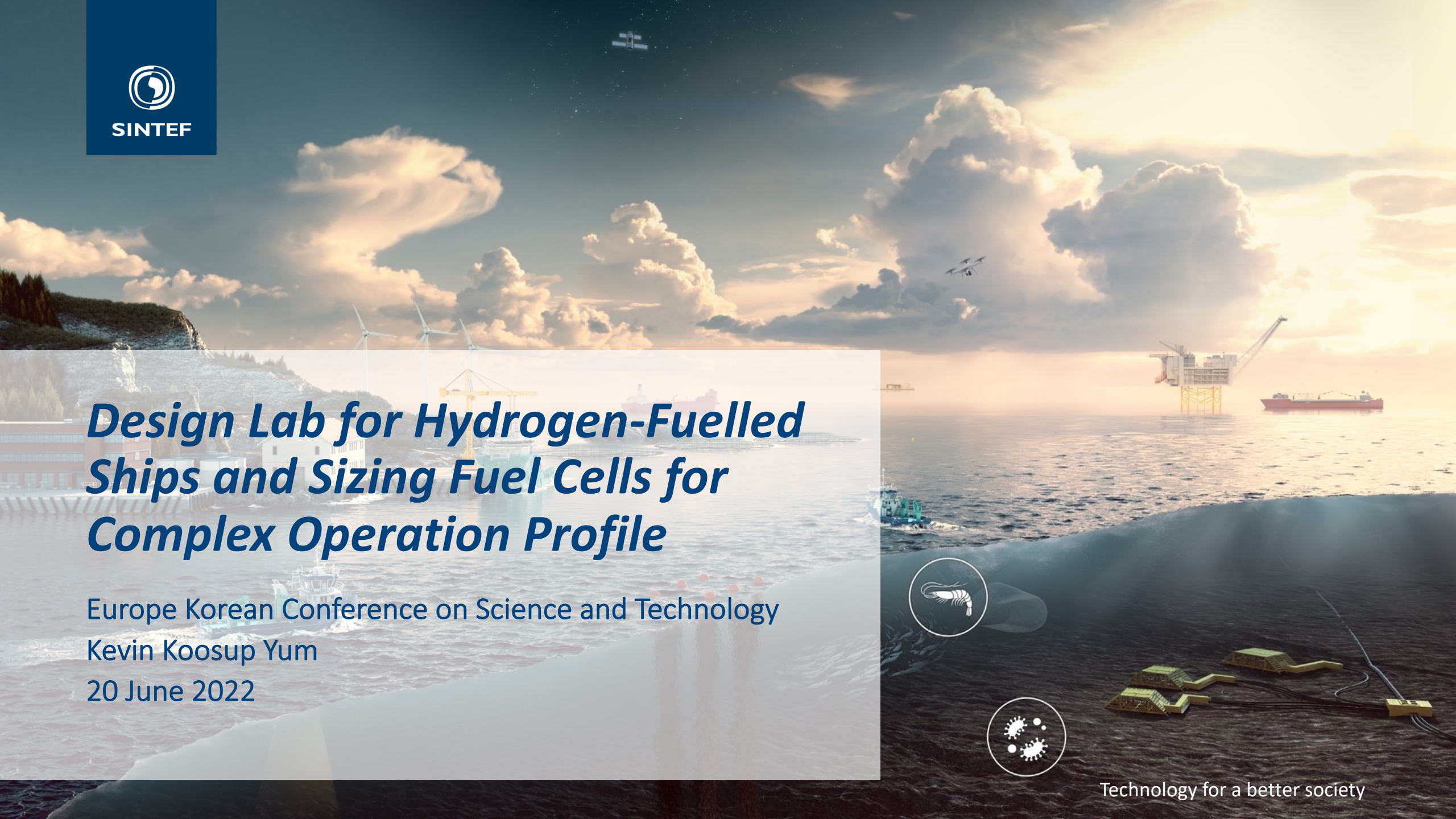


Design Lab for Hydrogen-Fuelled Ships and Sizing Fuel Cells for Complex Operation Profile

Europe Korean Conference on Science and Technology

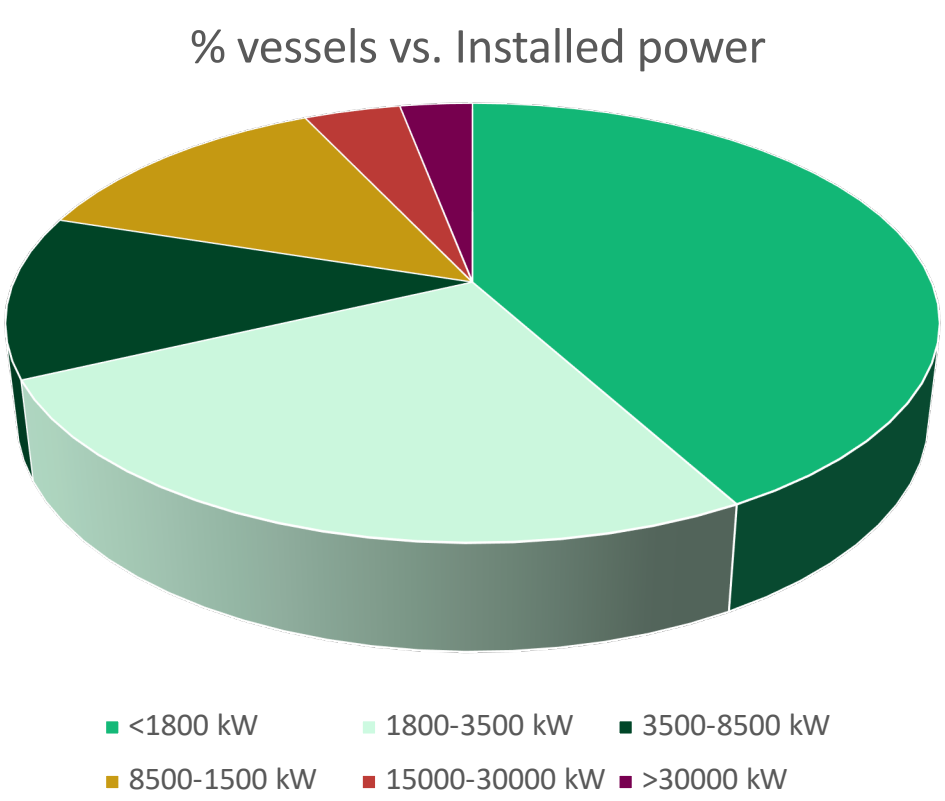
Kevin Koosup Yum

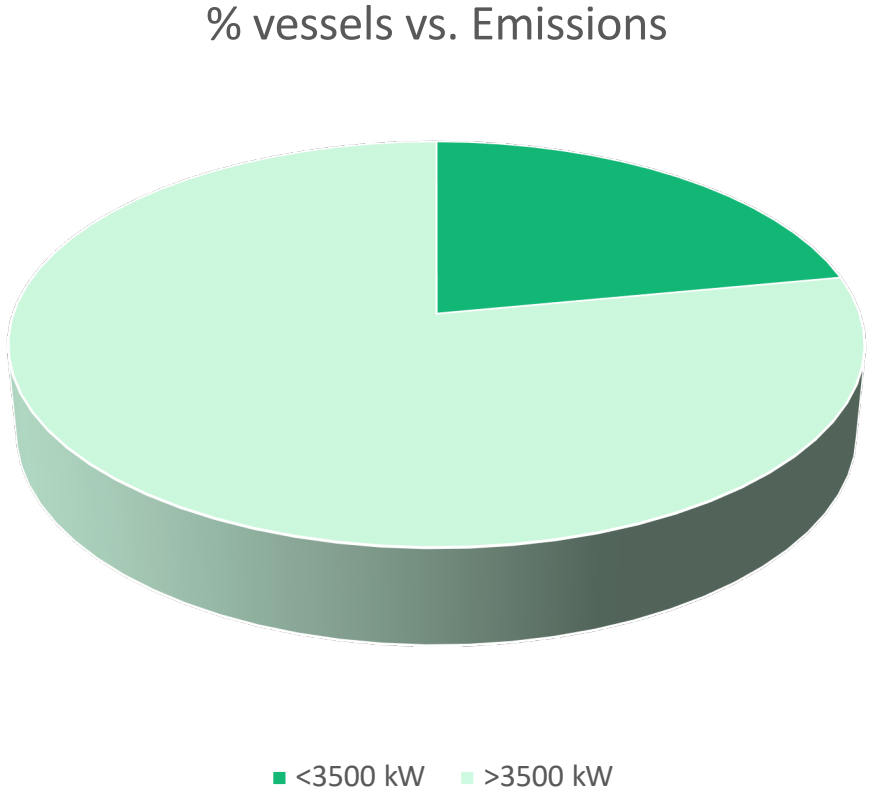
20 June 2022

Technology for a better society

Motivation

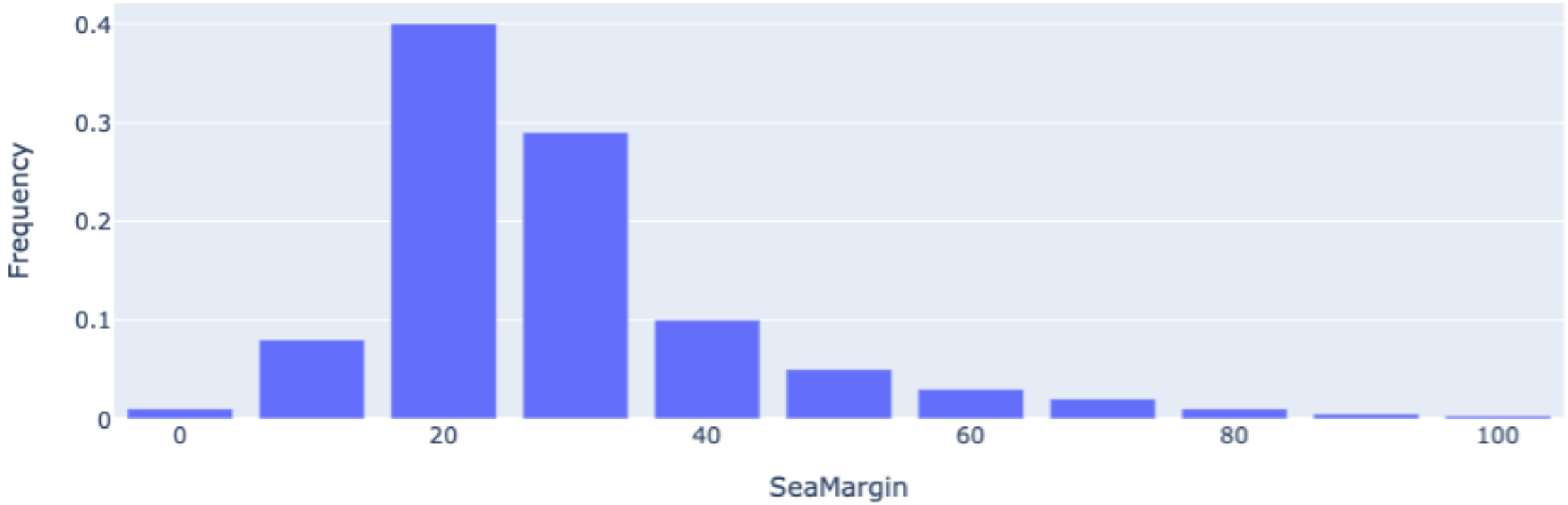
Vessel sizes and consumption



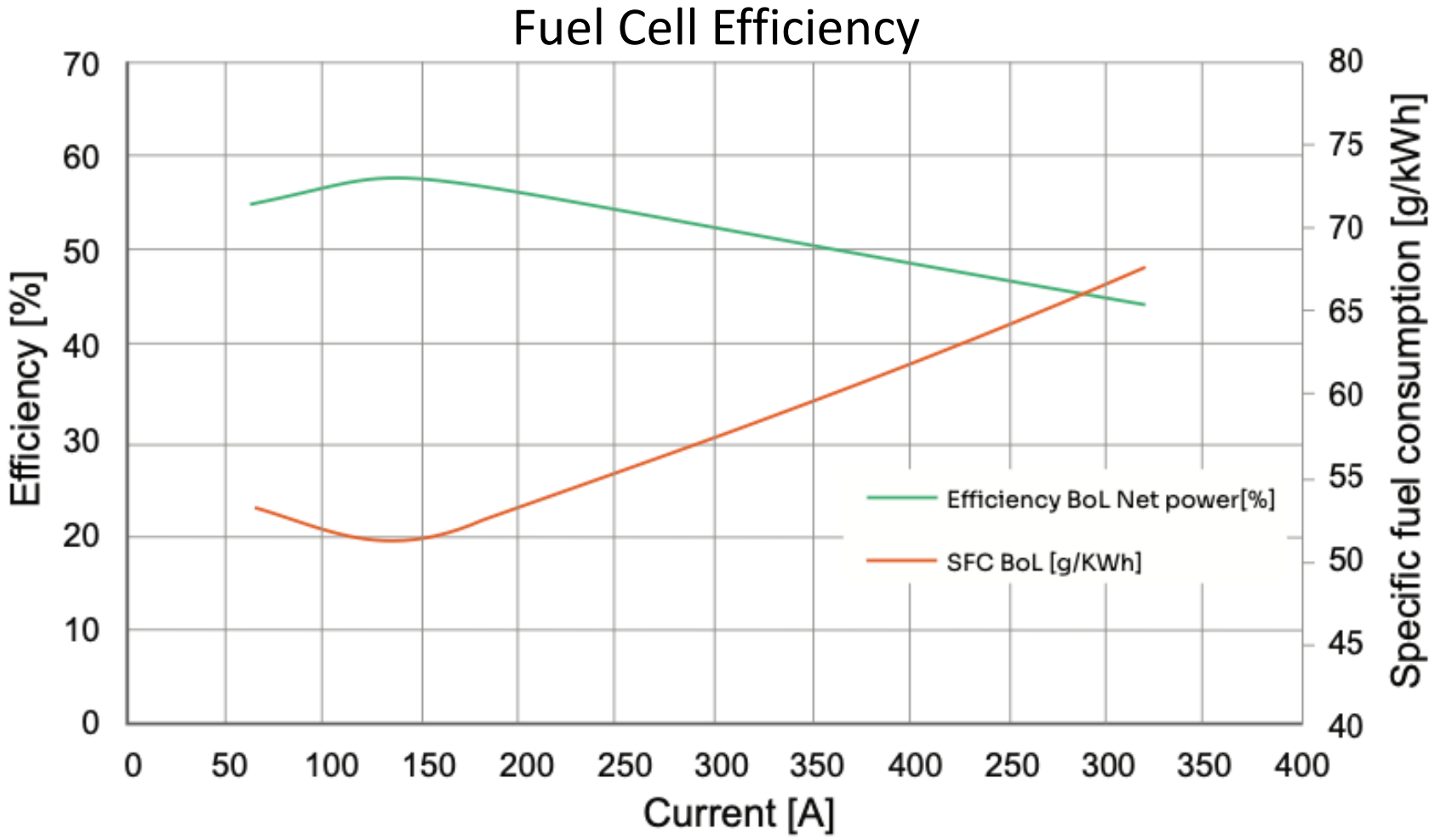


Motivation

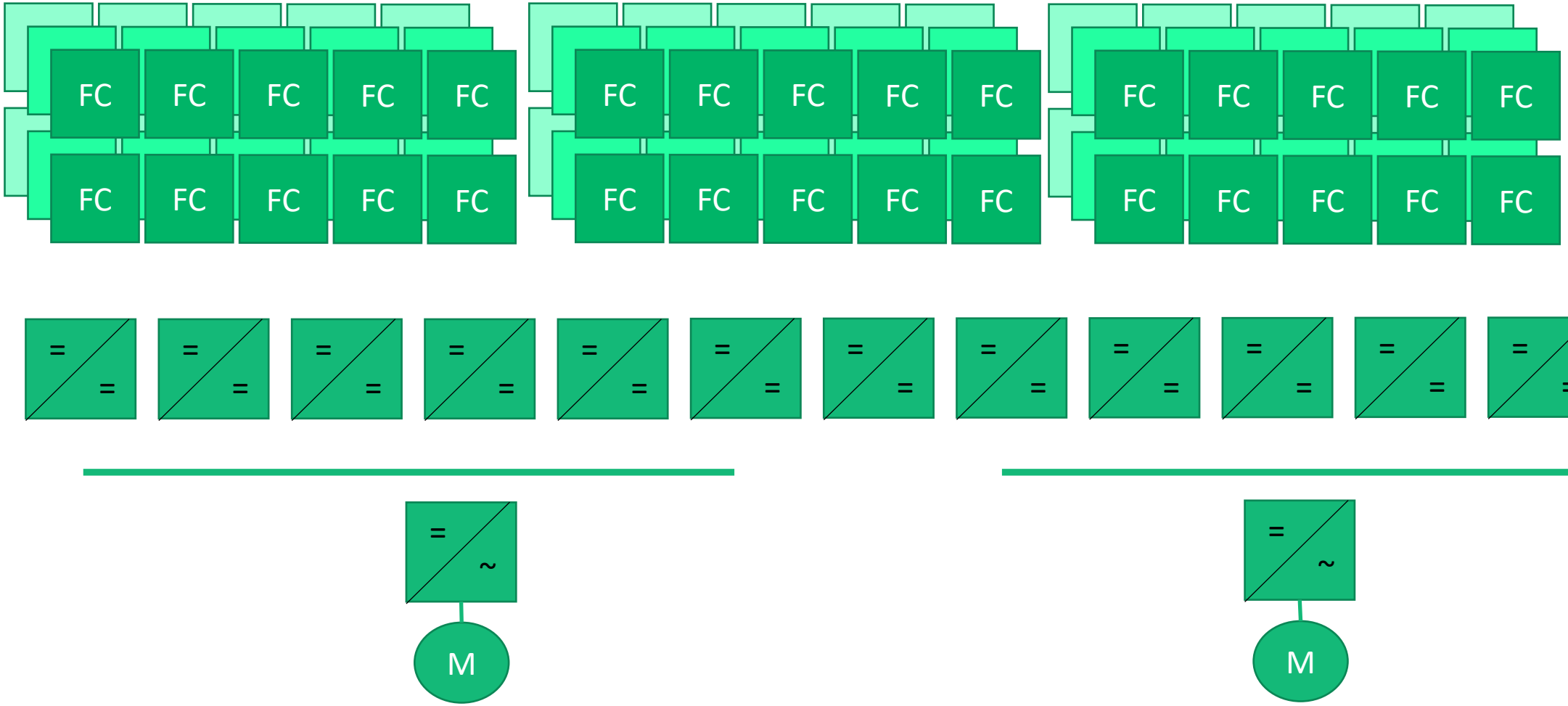
Operational Profile of a Ferry



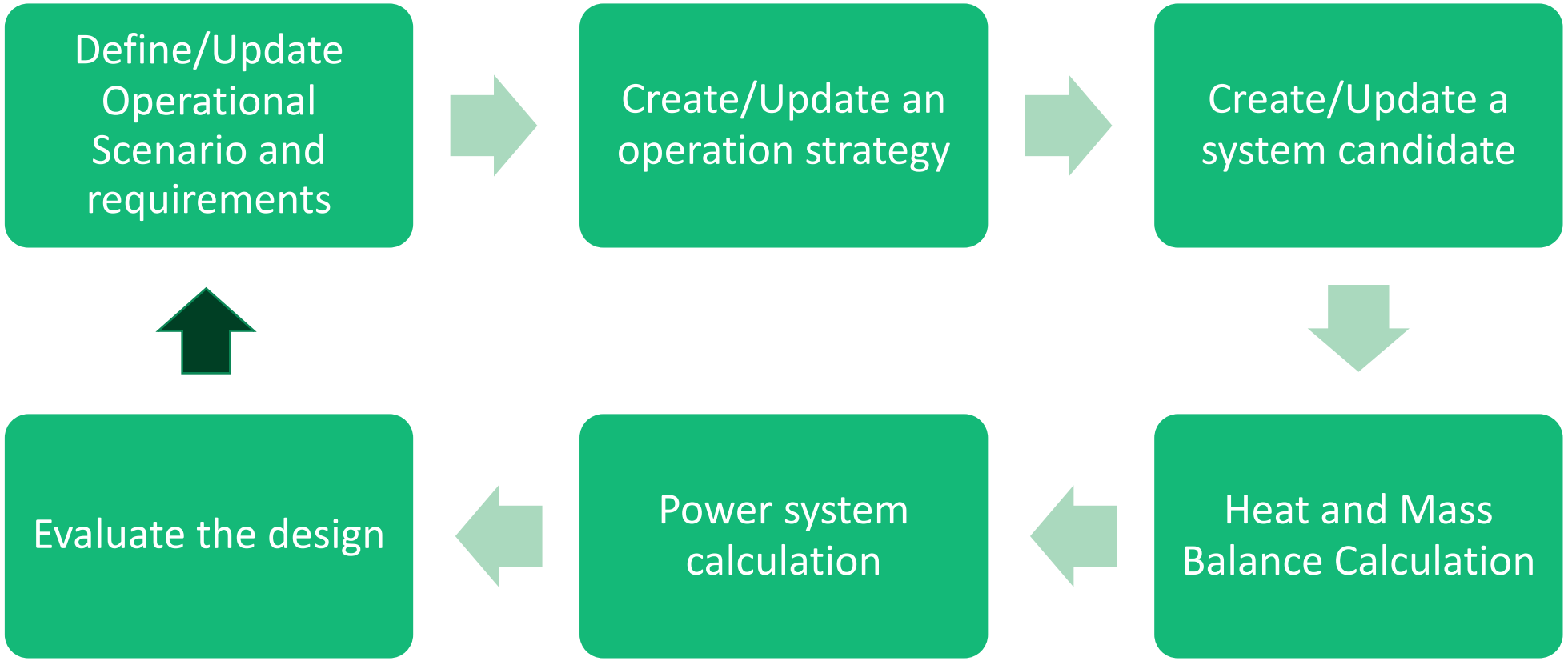
Motivation


Fuel Cell Efficiency
Efficiency [%]
Specific fuel consumption [g/kWh]
Current [A]
Efficiency BoL Net power[%]
SFC BoL [g/KWh]
0
10
20
30
40
50
60
70
40
45
50
55
60
65
70
75
80
0
50
100
150
200
250
300
350
400
250
300
350
400

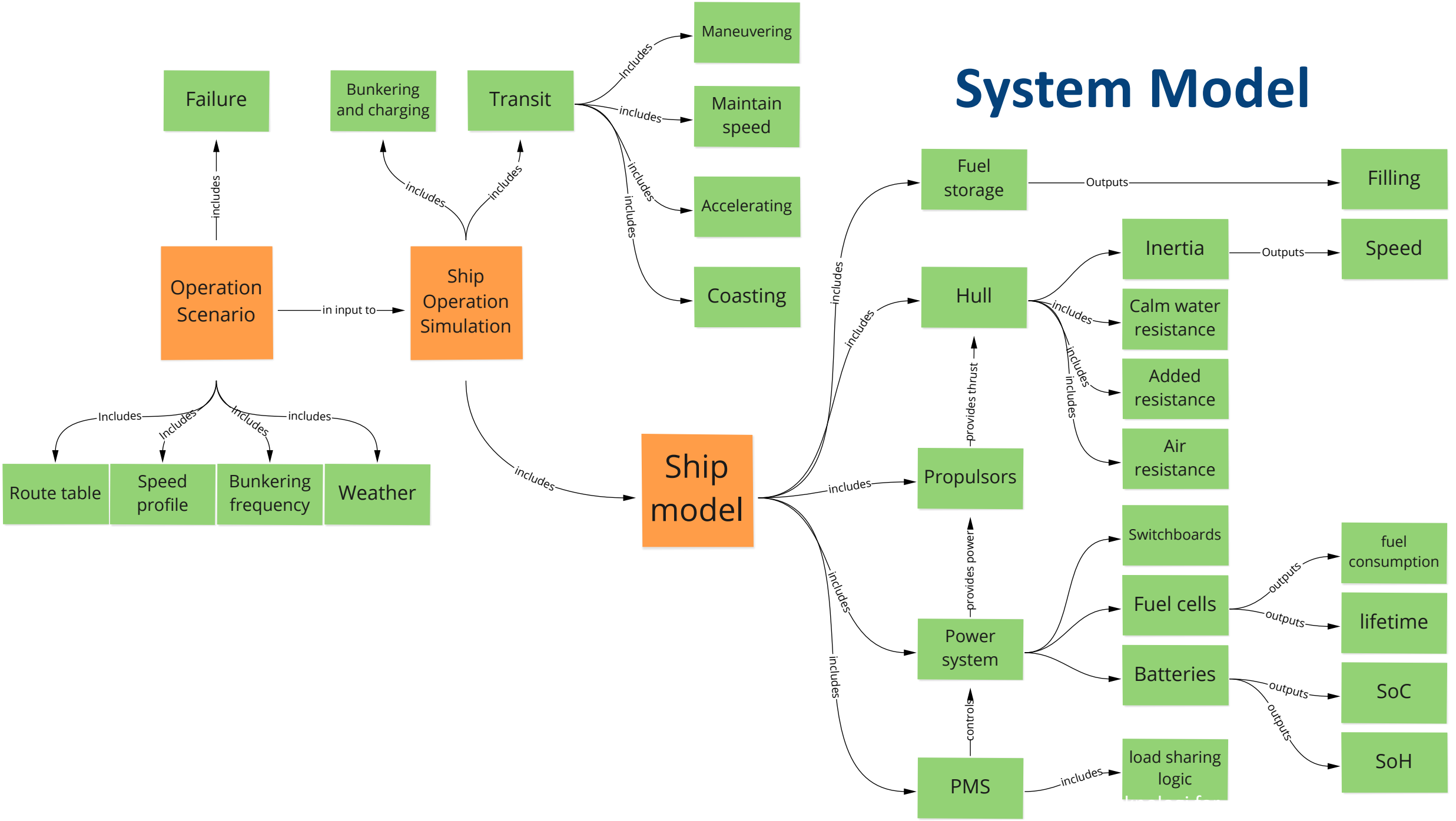
Motivation



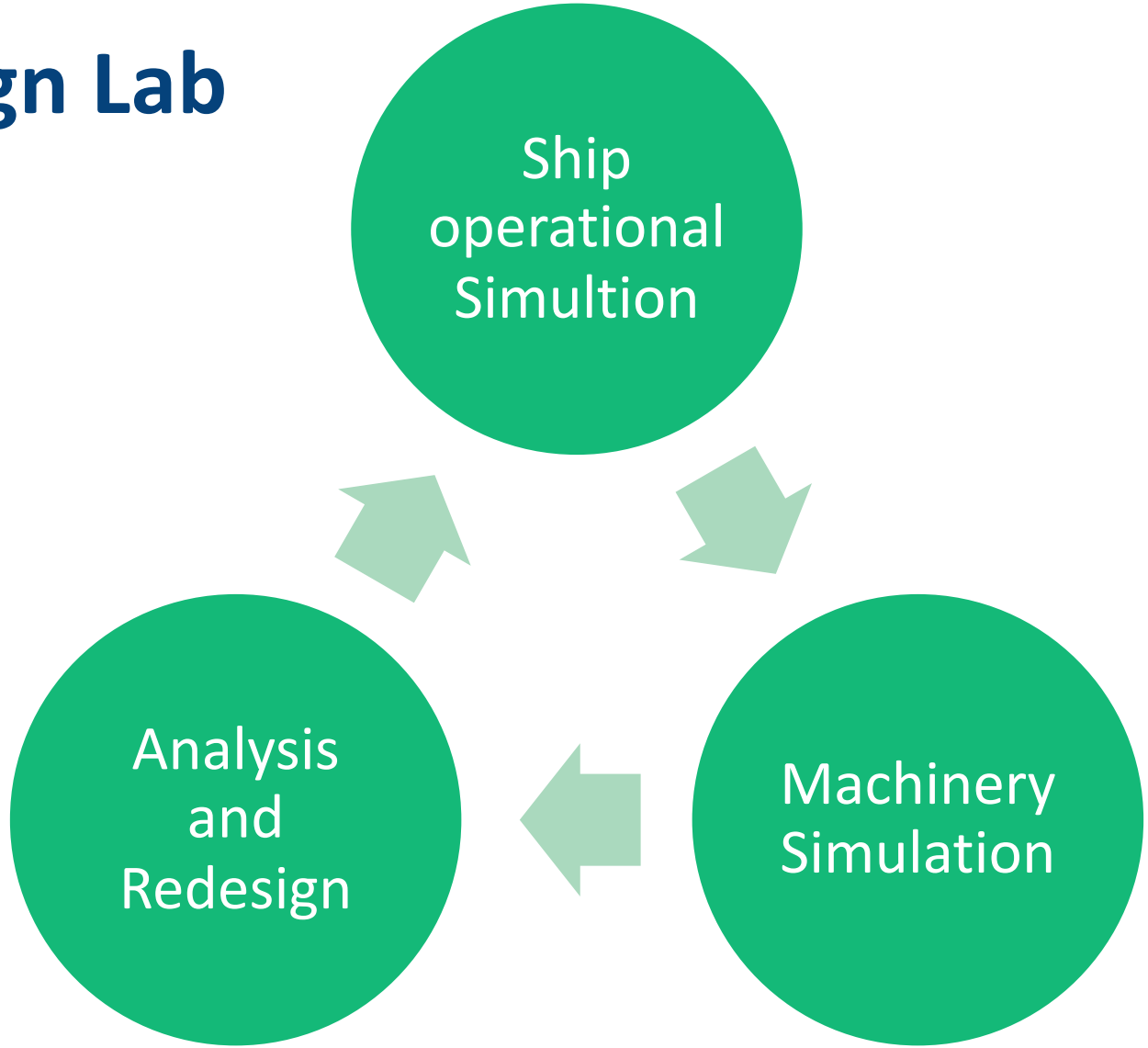
Overall Process of Evaluation



System Model



Design Lab


Ship operational Simultion
Machinery Simulation
Analysis and Redesign

Design Lab – Ship Operational Simulation: GYMIR

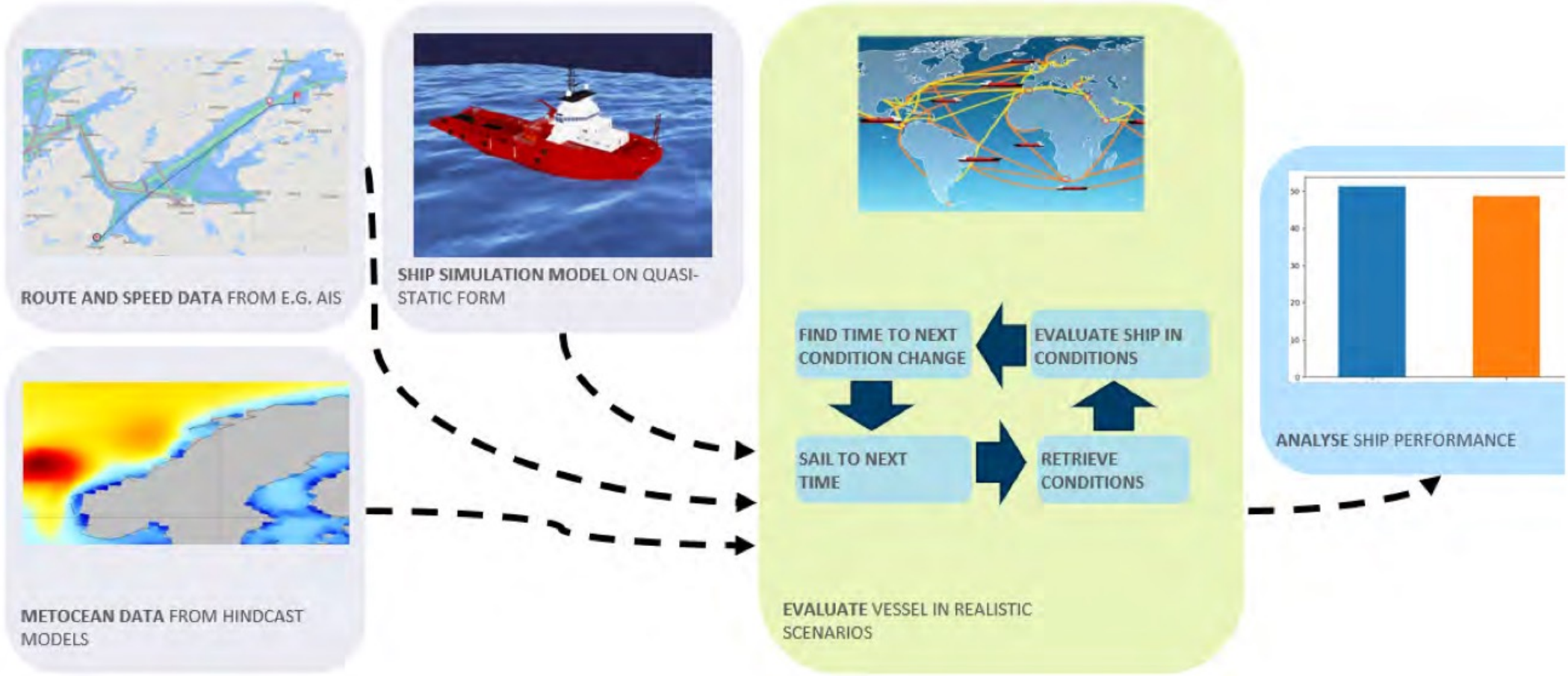
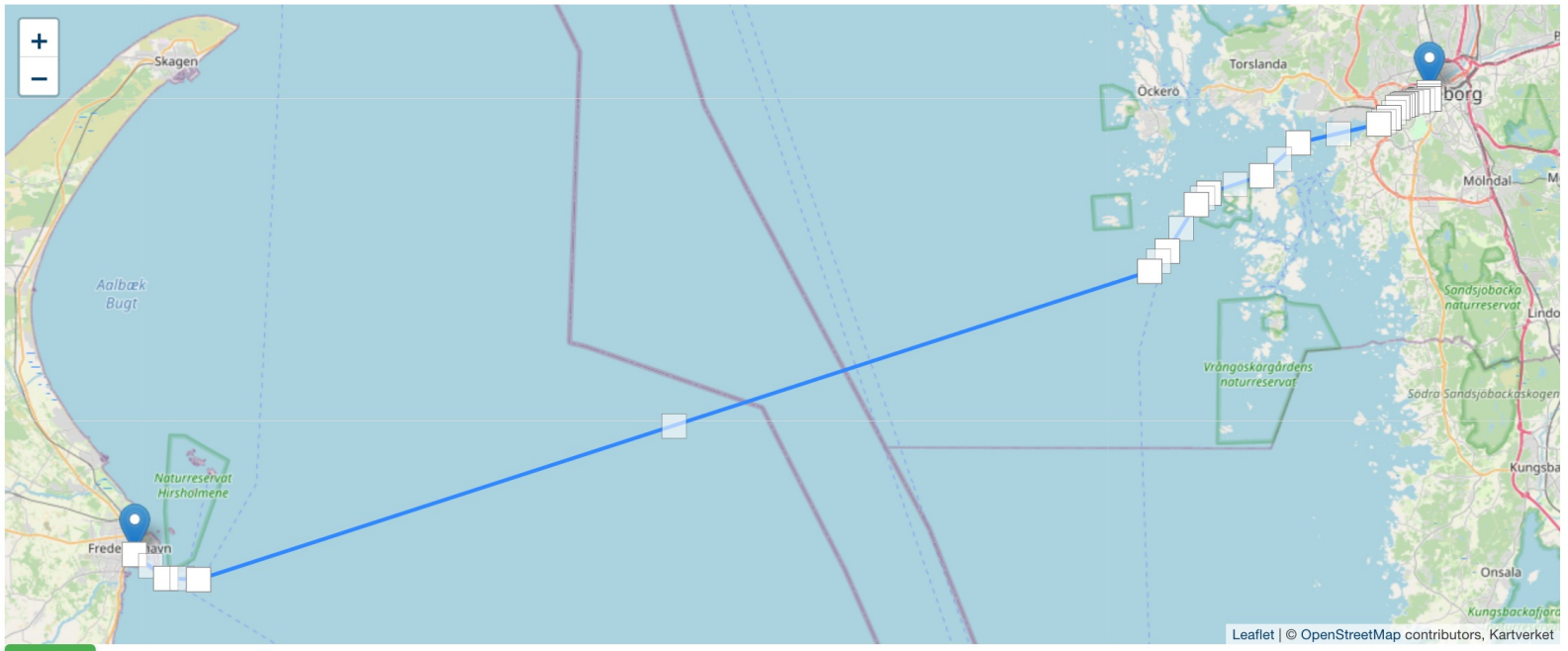


Fig.1: High-level concept sketch of the simulation method

SINTEF Energy System Configurator

PROJECT: HOPE

Map



SAVE

Places

ADD PLACE

Place name	Actions
Gothenburg	
Fredrikshavn	

Rows per page: 10 1-2 of 2

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

Maneuver time during arrival
180 seconds

Route Table

NEW ARRIVAL/DEPARTURE | NEW ITEM

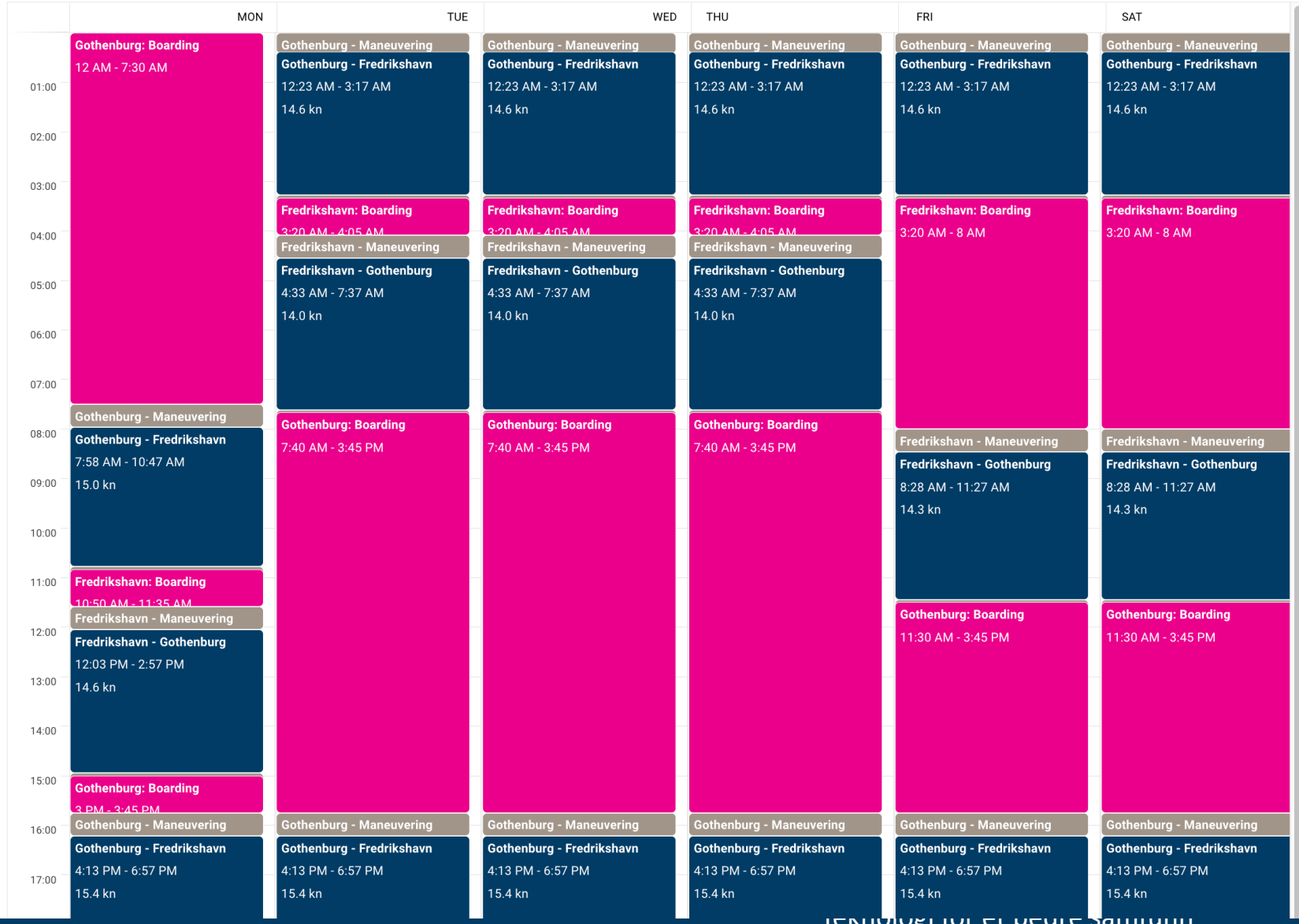
Days	Start time	Place	Event	Actions
Mon	00:00:00	Gothenburg	Boarding	
Tue, Wed, Thu, Fri, Sat	03:20:00	Fredrikshavn	Boarding	
Tue, Wed, Thu	04:05:00	Fredrikshavn	Sailing	
Mon, Sun	07:30:00	Gothenburg	Sailing	
Tue, Wed, Thu	07:40:00	Gothenburg	Boarding	
Fri, Sat	08:00:00	Fredrikshavn	Sailing	
Mon, Sun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

Rows per page: 10 1-10 of 16

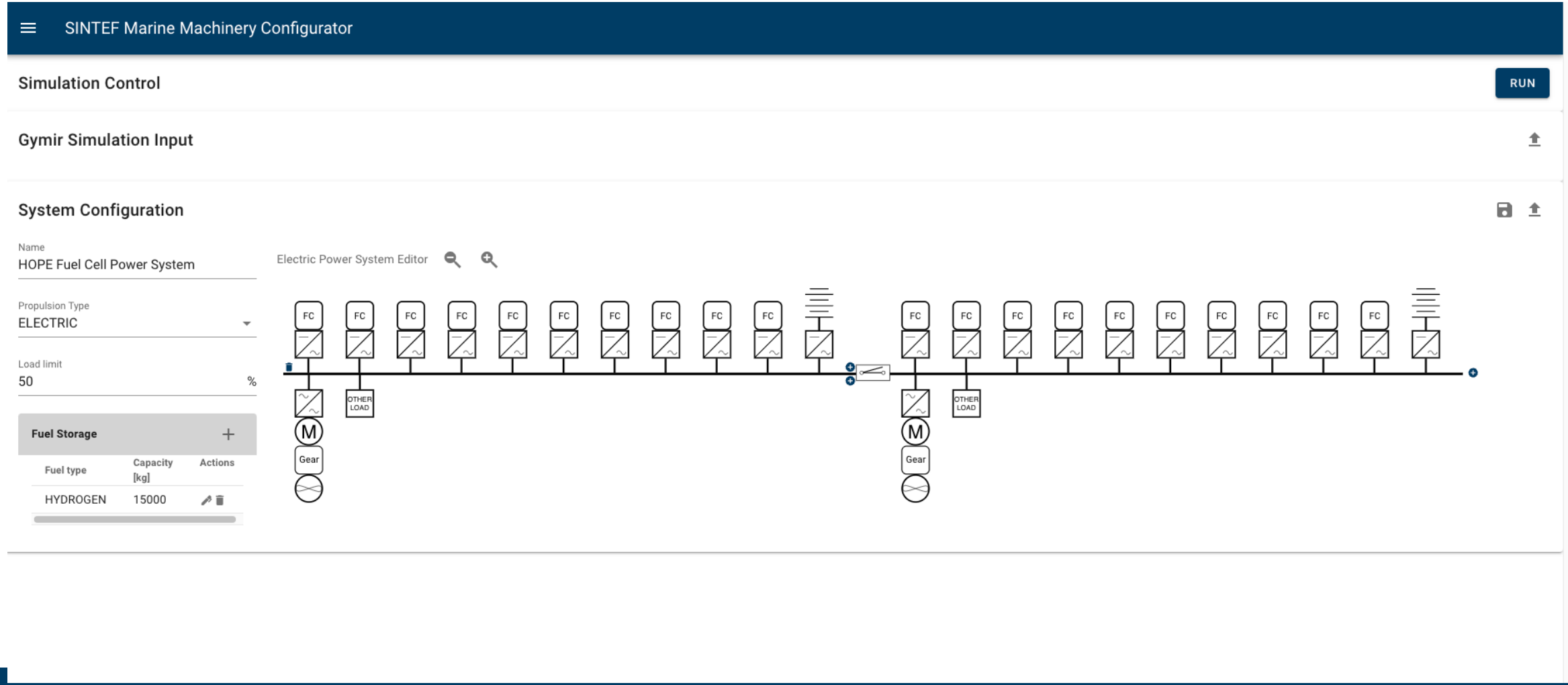
SAVE

GENERATE OPERATION PROFILE

Route calendar



Design Lab – Machinery Configuration



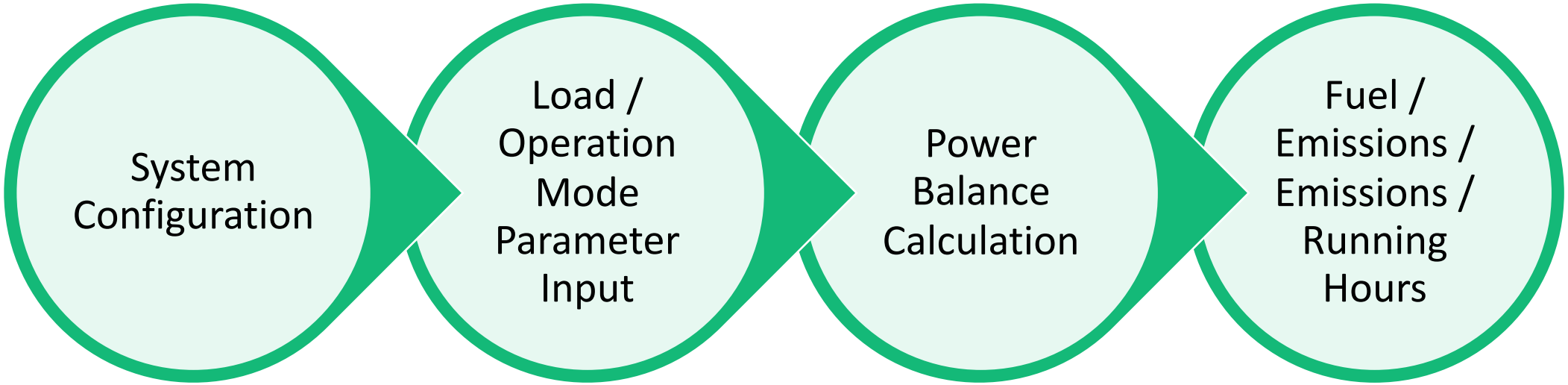
Design Lab – Fuel, Energy, Emissions Calculation for Machinery System (FEEMS)

- 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

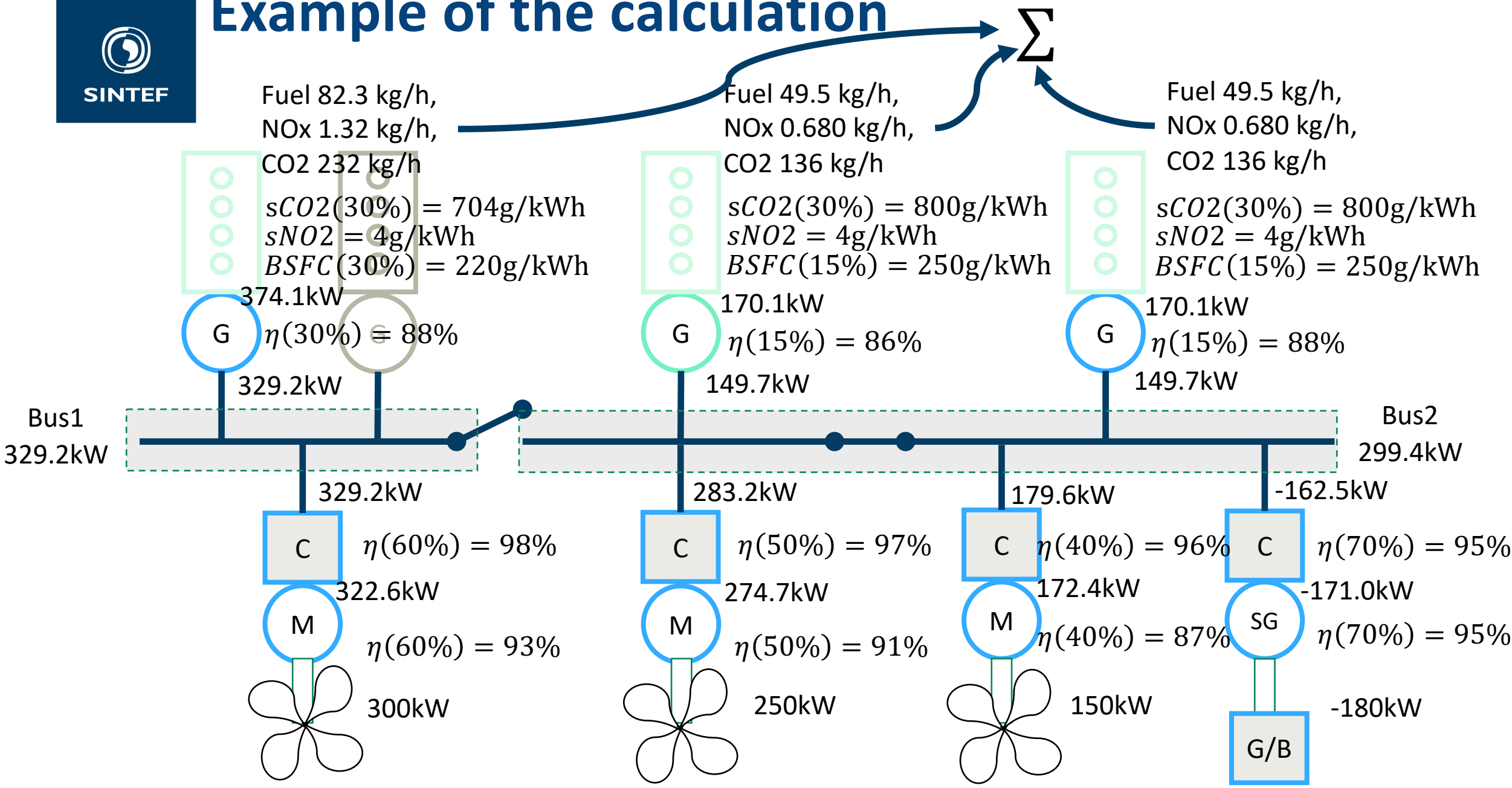
- Possible system to configure
  - Hybrid/Conventional Diesel / Fuel Cell Electric Propulsion
  - Hybrid Propulsion with PTI/PTO
  - Mechanical Propulsion with a Separate Electric Power System

- It is possible to implement an energy management strategy

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

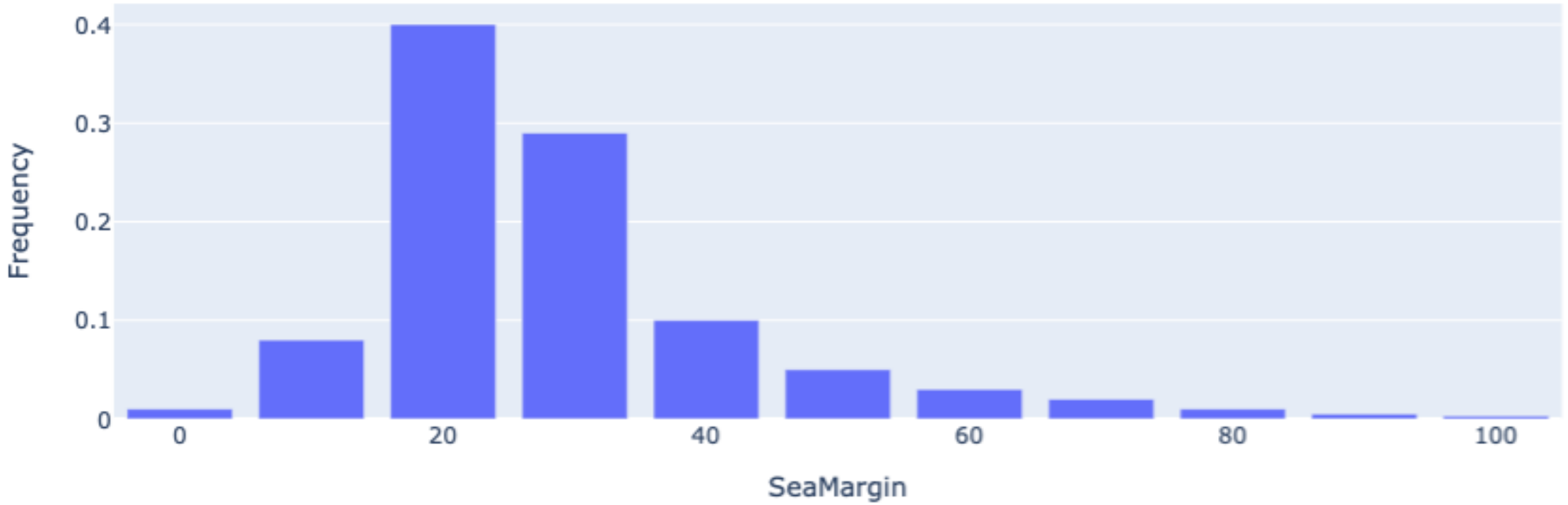


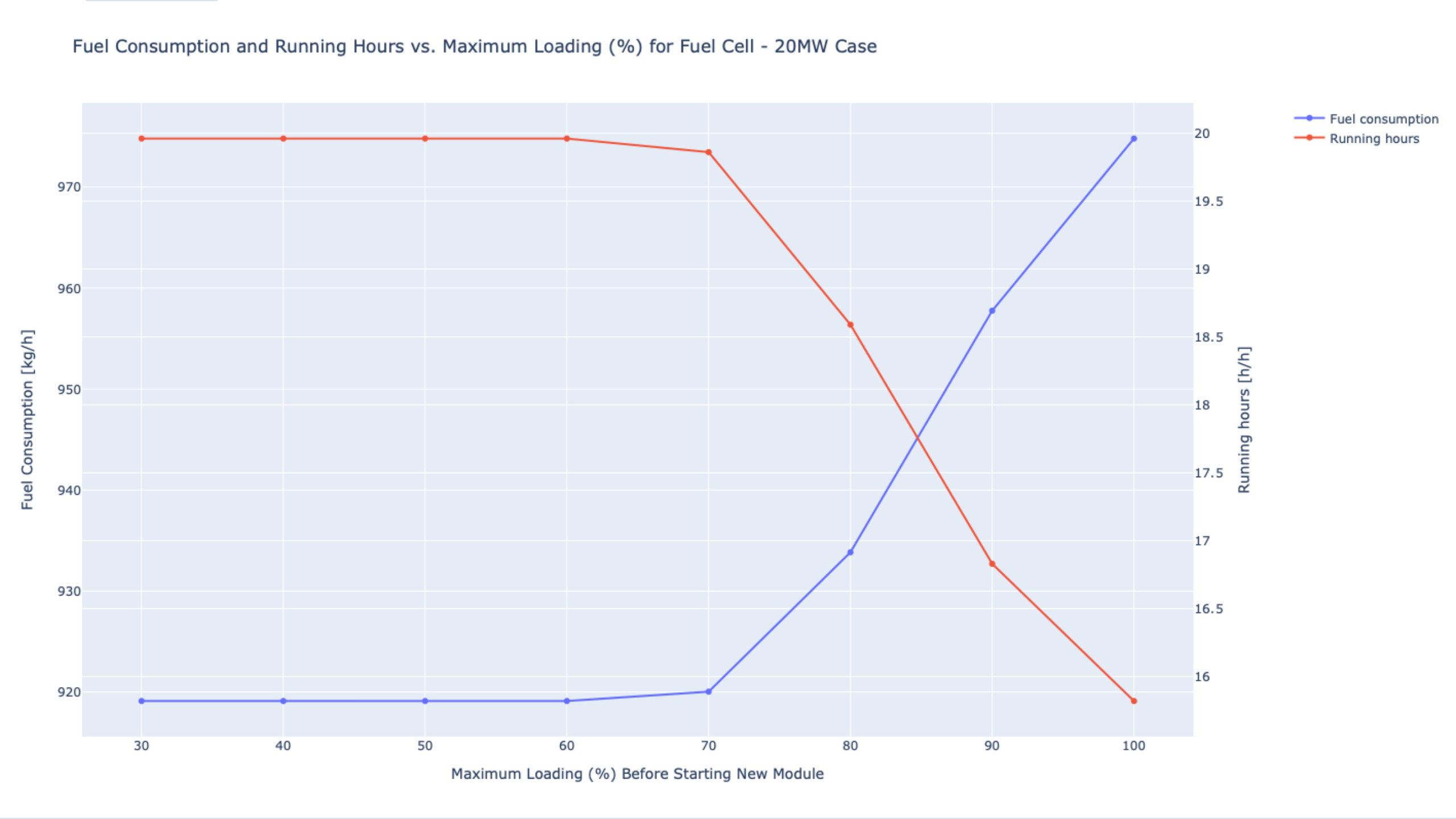
Example of the calculation

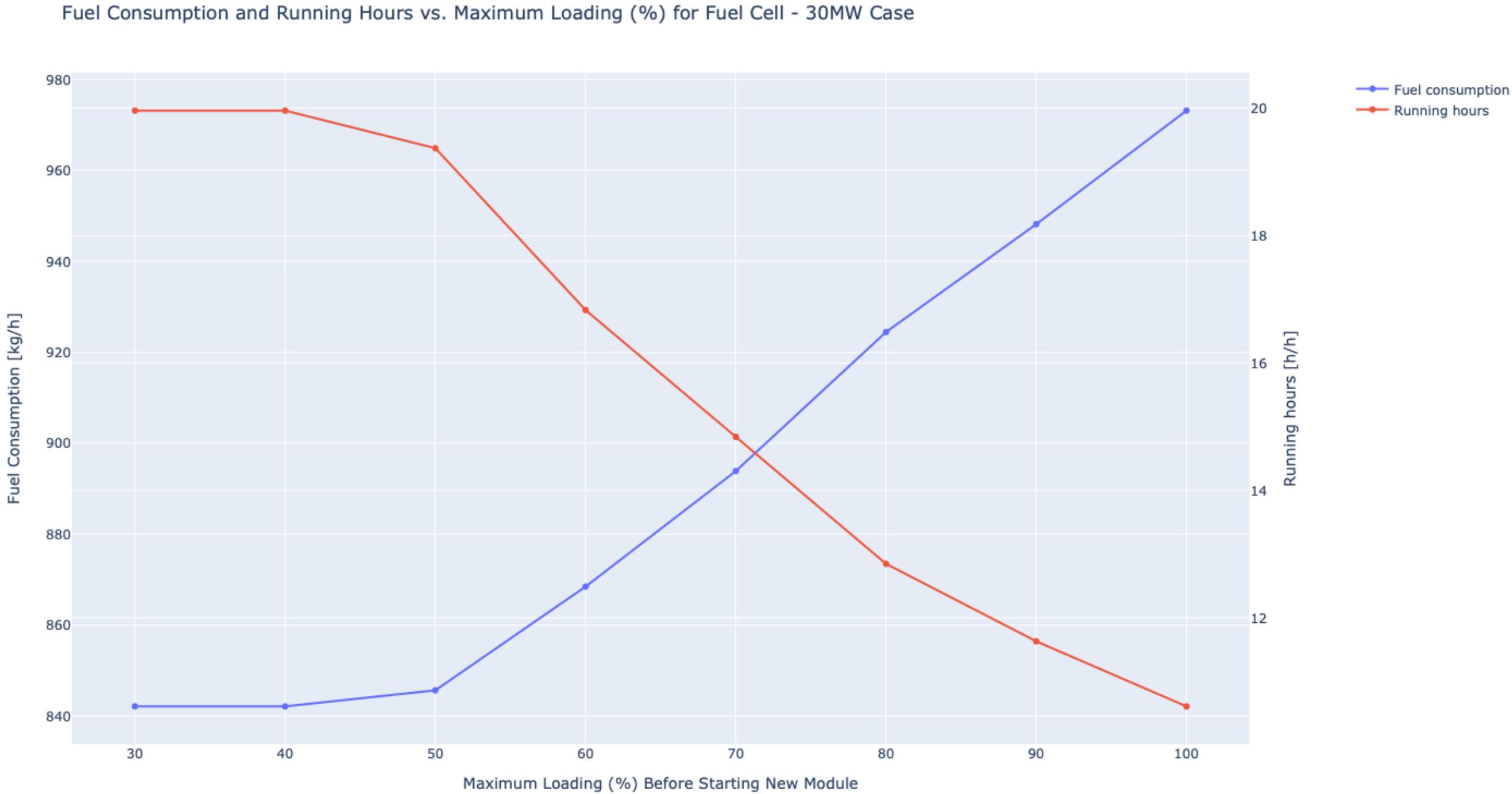


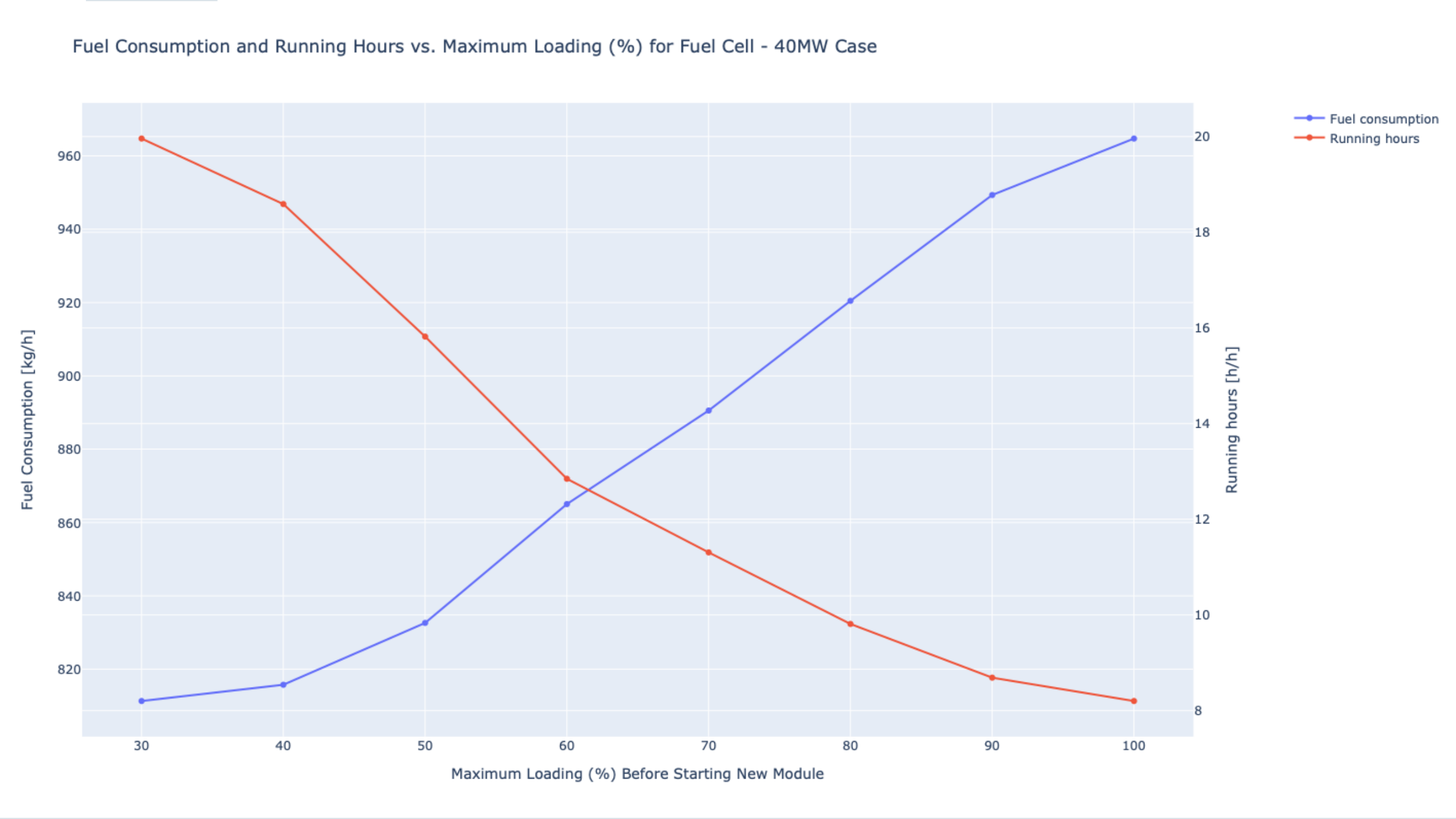
Initial Case Study

- Operational Profile Input from Statistical Data




Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 20MW Case
Fuel consumption
Running hours
Fuel Consumption [kg/h]
Running hours [h/h]
Maximum Loading (%) Before Starting New Module
920
930
940
950
960
970
16
16.5
17
17.5
18
18.5
19
19.5
20
30
40
50
60
70
80
90
100


Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 30MW Case
Fuel consumption
Running hours
Fuel Consumption [kg/h]
Running hours [h/h]
Maximum Loading (%) Before Starting New Module
980
960
940
920
900
880
860
840
20
18
16
14
12
30
40
50
60
70
80
90
100


Fuel Consumption and Running Hours vs. Maximum Loading (%) for Fuel Cell - 40MW Case
Fuel consumption
Running hours
Fuel Consumption [kg/h]
Running hours [h/h]
Maximum Loading (%) Before Starting New Module
960
940
920
900
880
860
840
820
20
18
16
14
12
10
8
30
40
50
60
70
80
90
100

Conclusion

- One needs to consider a complex operational profile to optimize the system.
- Design Lab can provide an integrated tool for operational analysis and system performance and a system design
- Sizing fuel cells for maritime application demands different perspective than the conventional internal combustion engines
-

SINTEF

Technology for a better society