FEASIBILITY STUDY OF THE HYBRIDIZATION OF SHIP CRANES

NOVEMBER 10, 2023

MEET THE TEAM

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- *Hybrid cranes and load subsystem*
- *External communications*

Jules Lamarre
- *Tests and EMS*
- *Treasurer*
- *Environmental analysis*

Maxime Normandin
- *Generators and energy storage subsystems*
- *Documentation and standards*

Marianne Côté
- *Simulation and EMS subsystem*
- *Deliverables, meetings and management*

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- *Generators and EMS subsystems*
- *Simulation*

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- *Energy storage subsystem*

PRESENTATION OUTLINE

- 1 – Introduction
- 2 – Modelling
- 3 – Economical analysis
- 4 – Environmental analysis
- 5 – Conclusion

INTRODUCTION : THE MARINE INDUSTRY

Environmental Impact

- 3% of all global GHG emissions
- 4x GHG emissions by 2050

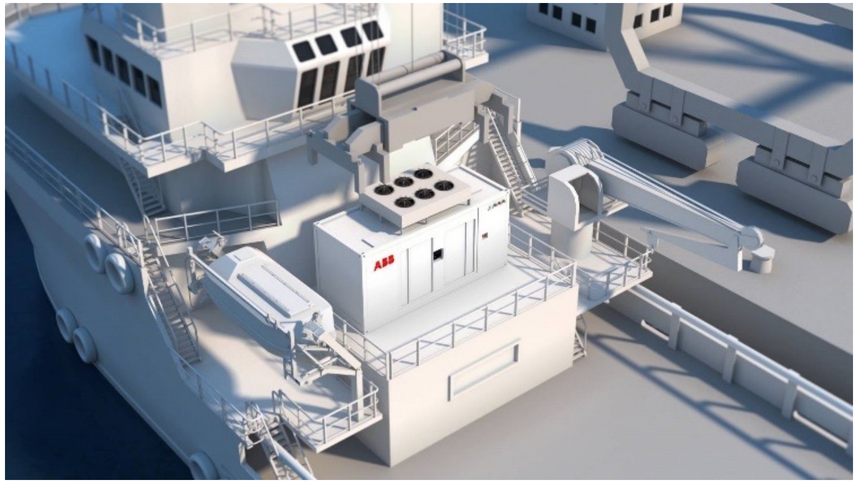
Economic Impact

- Price increase of hydrocarbons
- High diesel consumptions leads to high operation costs

INTRODUCTION: HYBRID CRANES

<u>Objectives of the hybridization:</u>

- Use regenerative braking to recover and store energy
- Reduce power demand peaks and lower diesel consumption during loading/unloading operations



Similar studies and products

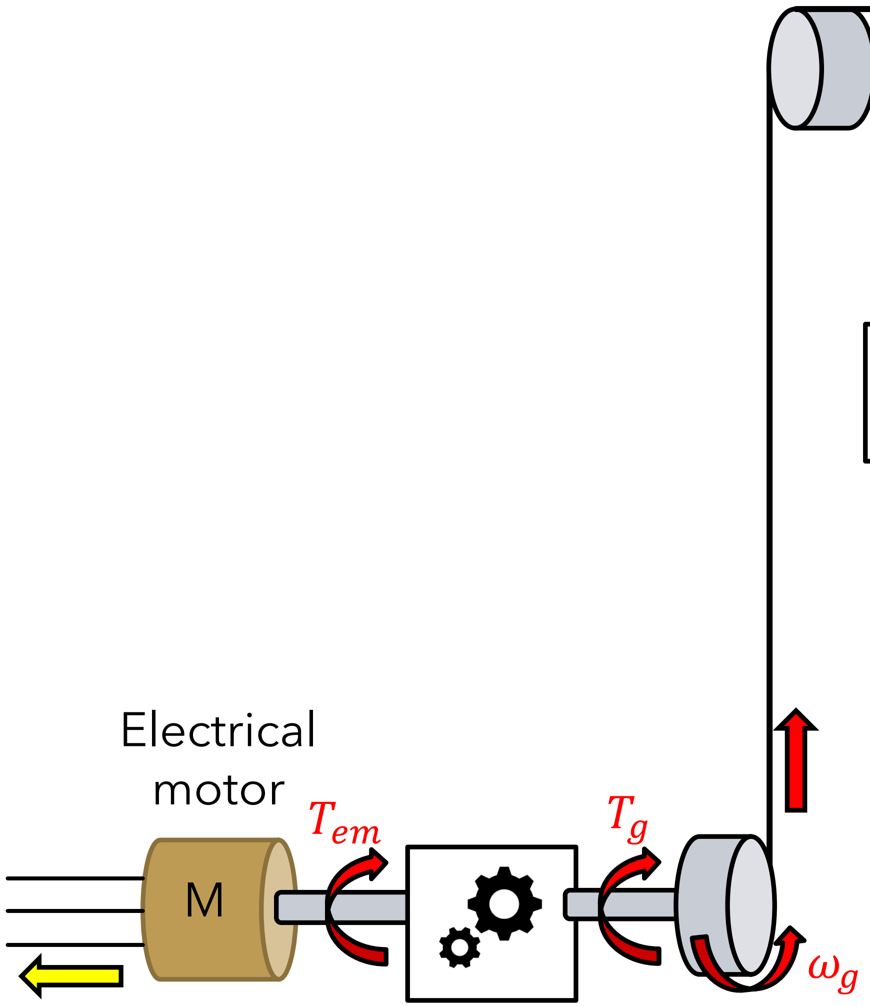
Ship battery (ABB)

- Supply electrical power to the ship's grid
- Lower power demand peaks

Hybridization

- 30% relative fuel saving potential
- $110,000 savings / year

INTRODUCTION: REGENERATIVE BRAKING



<u>What is regenerative braking:</u>

- When the load is moving toward the ground, will need a mechanism to reduce the speed or stop the load.
- Conventional braking: Transform kinetic energy into heat by friction.
- Regenerative braking (Electrical motor): Transform kinetic energy into electrical energy flowing toward the source of the motor.

PROJECT SUMMARY

- Feasibility study of the hybridization of the cranes of a bulk carrier (e.g. Federal Baltic) using regenerative braking to recover energy

Objectives

- Reduce GHG emissions through fuel savings
- Reduce operation costs

Methodology

- Simulation of the ship’s main systems
- Environmental and economic analysis

PROJECT SUMMARY

Deliverables

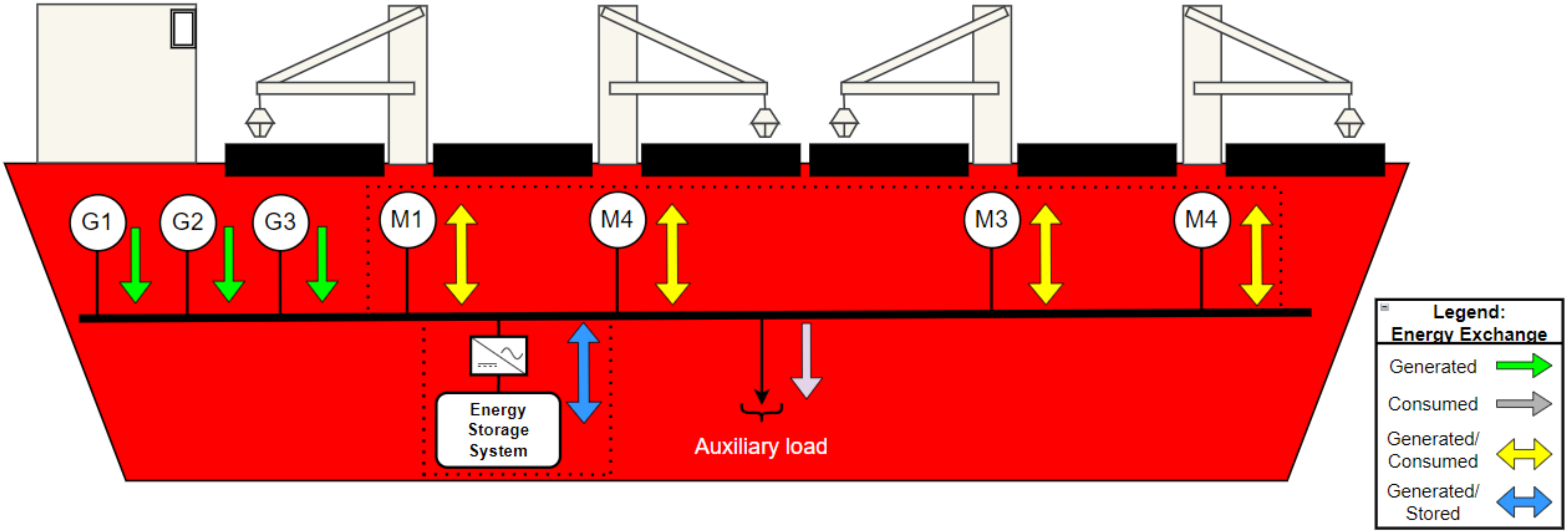
- Return on investment (ROI) report
- Assessment of the GHG emission reduction

Preliminary success metrics

- Reach 30% of fuel savings during loading/unloading operations
- Economic viability:
  - Payback 2-3 years

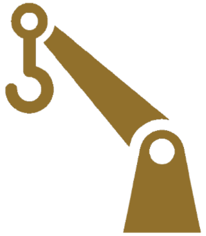
PRESENTATION OUTLINE

HIGH-LEVEL CONCEPT



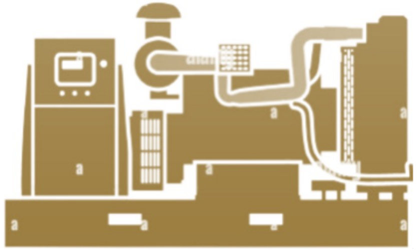
MODELLING

- Creating a Simulink model:



- Cranes and auxiliary loads

- Energy Storage System (ESS)



- Diesel generators

- Energy management system (EMS)

MODELLING – CRANES AND AUXILIARY LOADS

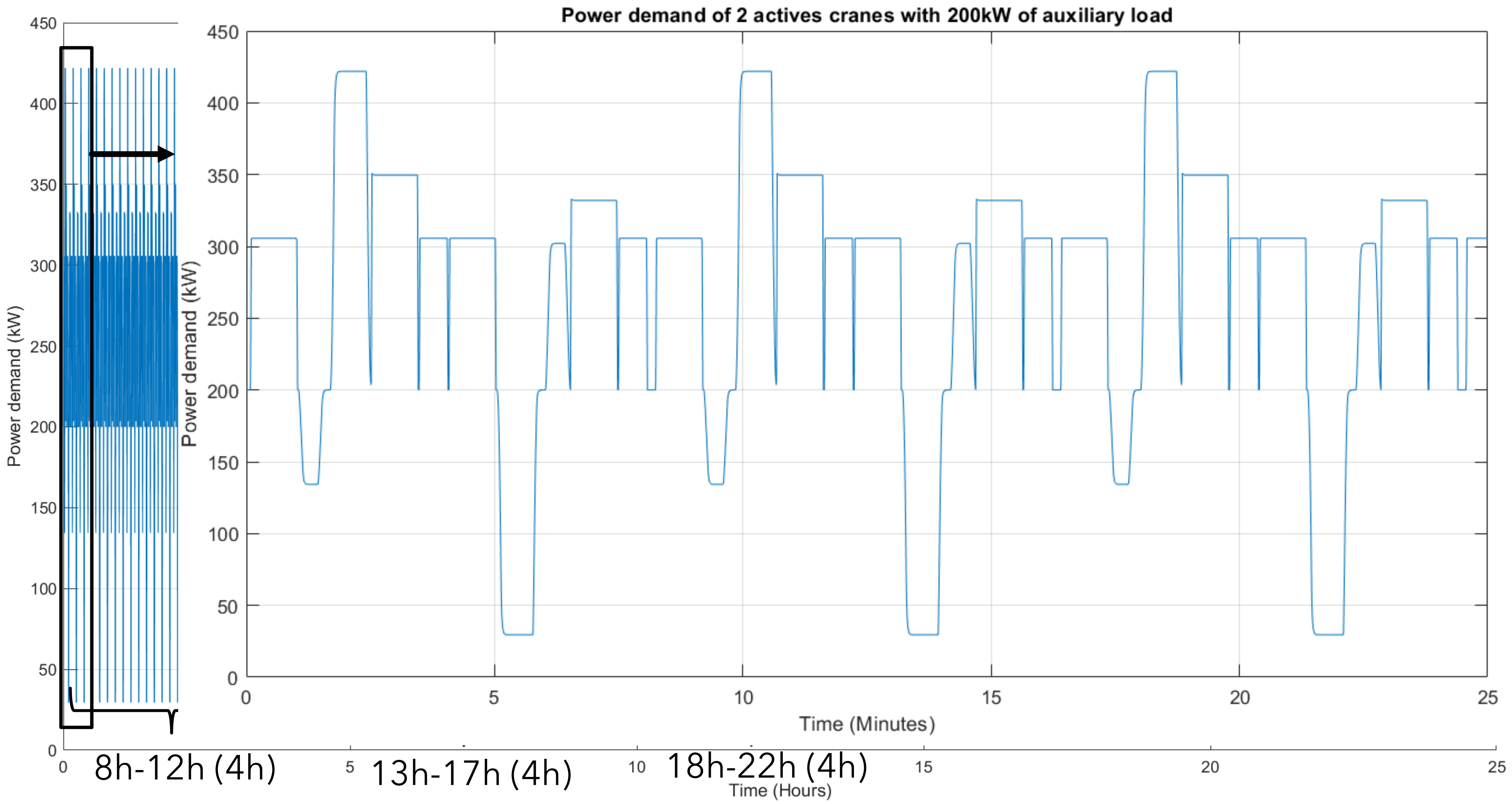
Assumptions

- Cranes : 200 kW @ 440 VAC
- Auxiliary loads : fixed at 200 kW
- Constant load of 35 tons
- The cranes are working simultaneously
- Use regenerative braking at constant 70% efficiency

Features

- 24h work schedule, variable according to the needs of the operations

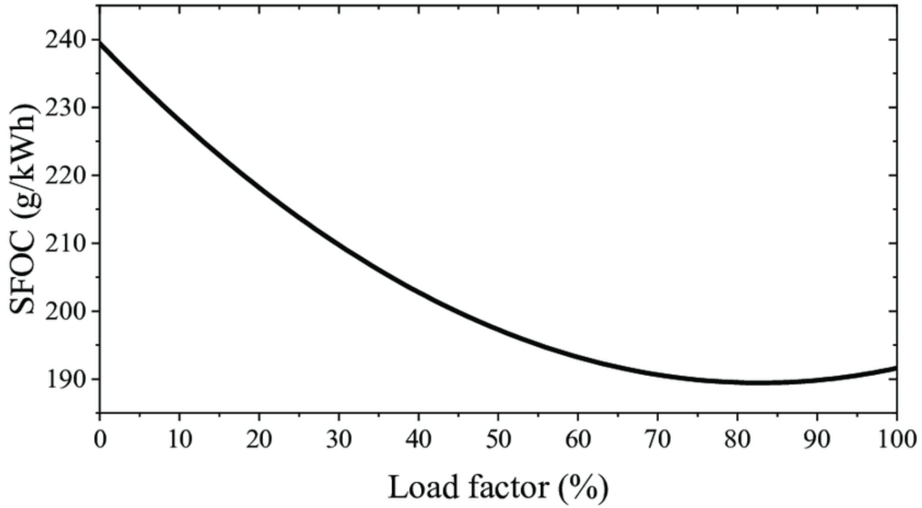
MODELLING – CRANES AND AUXILIARY LOADS



MODELLING – GENERATORS

Assumptions

- 3x600 kW (Federal Baltic)
- Constant load voltage



Features of the Simulink model

- Variable SFOC (Specific Fuel Oil Consumption) to calculate the fuel consumptions
- Variable power output

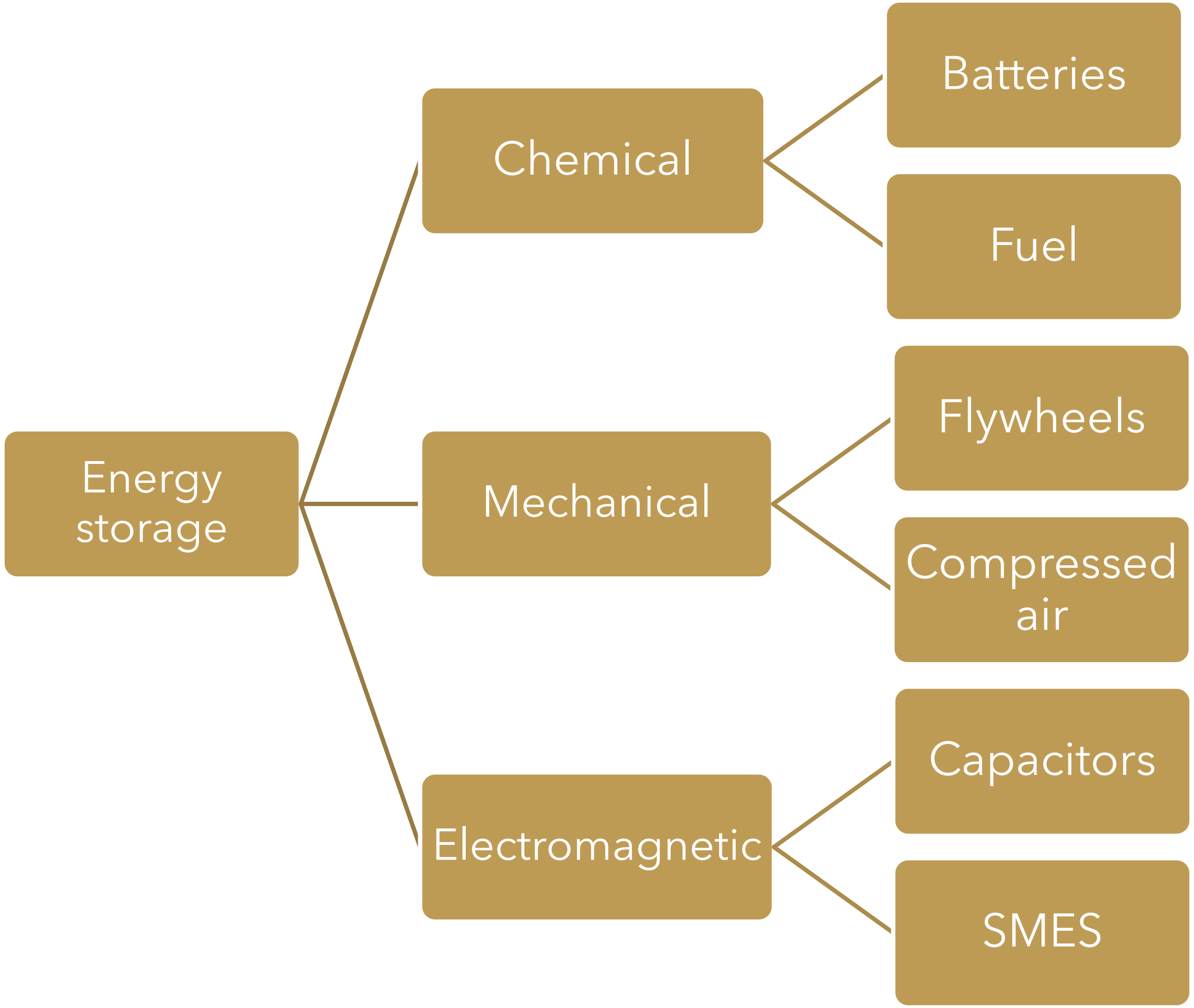
WHAT ARE ENERGY STORAGE SYSTEMS?

<u>Definition</u>:

- Device capable of storing energy at one time in order to supply electrical energy at a later time

<u>In hybrid system</u>:

- Stored energy supplied by a secondary source is used to reduce usage of a primary source



MODELLING – ENERGY STORAGE SYSTEM

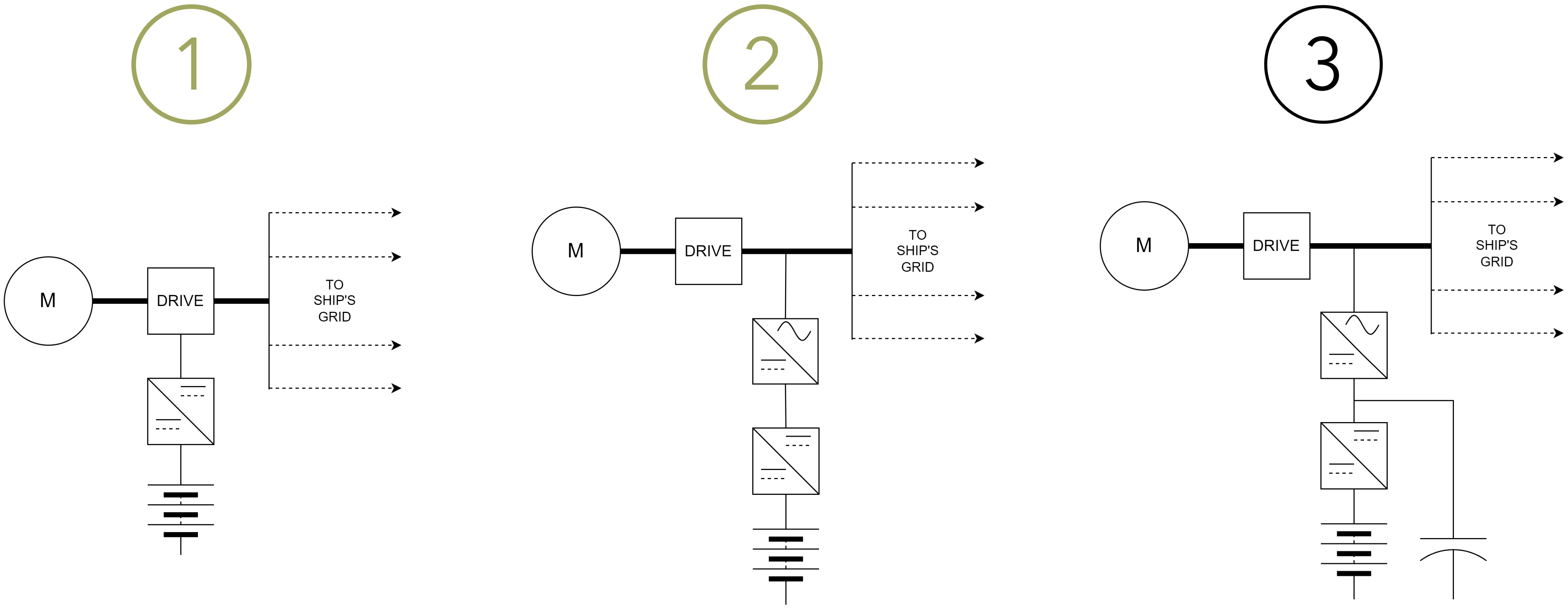
Objectives

- Store energy of regenerative breaking
- Reduce power demand peaks of generators

Feature of the Simulink model

- Simulation of different topologies
  - Fuel saving comparison
  - Efficiency comparison

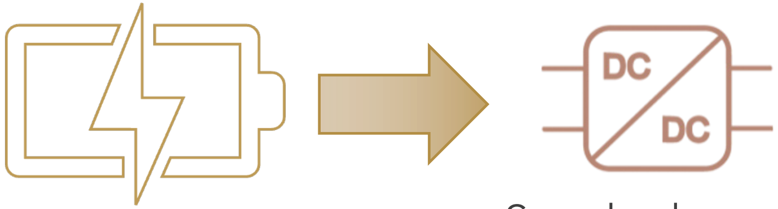
MODELLING – ENERGY STORAGE SYSTEM



Lowest CAPEX	High fuel saving	Highest fuel saving
Moderate fuel saving	High CAPEX	Highest CAPEX

MODELLING – ENERGY STORAGE SYSTEM

Number in series:



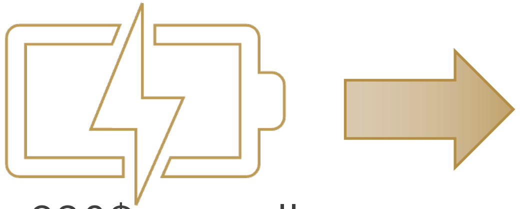
- Voltage 3,2V per cell
- Capacity 896Wh

- Standard converter available on the market 120-750VDC

- 120V/3.2V = 37 cells needed in series

Number in parallel :

- To keep the generator as constant as possible and reduce peak demand
- Reduce CAPEX and increase viability



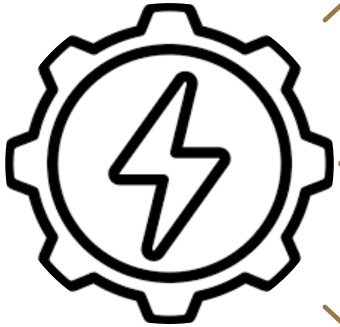
- 230$ per cell

- Higher CAPEX
- Higher fuel economy

- Choice : 2 branches in parallel

Total number of cells for our battery pack : 37x2 = 74 cells
Capacity of the battery pack : 896Wh * 74 = 66.3kWh

WHAT IS ENERGY MANAGEMENT?



Efficiency

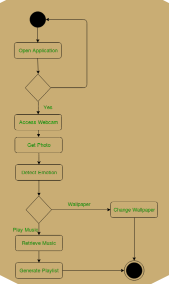
- Multiple energy source
- Optimal dispatching

Safety

- Operational constraints
- Equipment limits

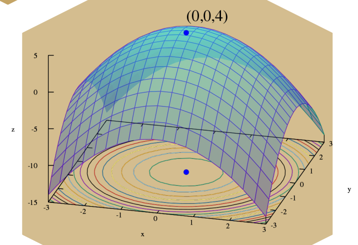
Information

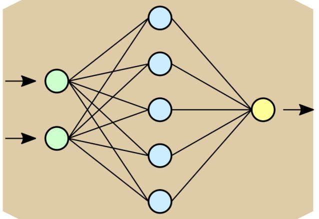
- Feedback data
- Insights



Rules

Optimization





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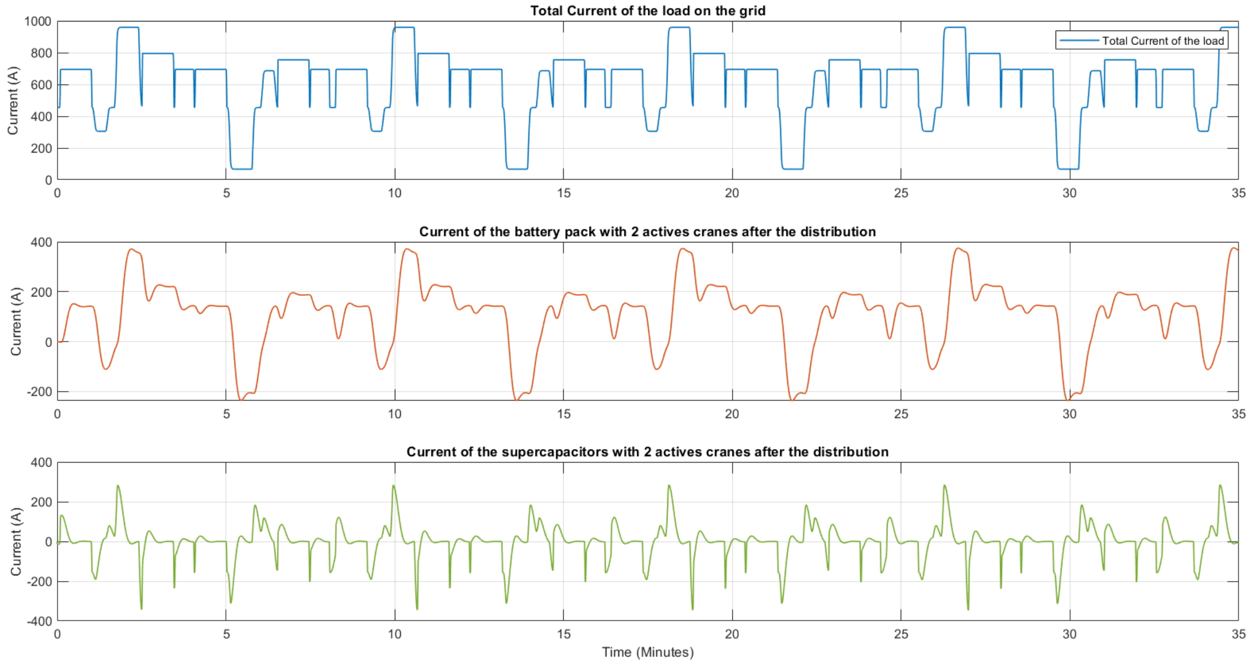
MODELLING – ENERGY MANAGEMENT SYSTEM

Objectives

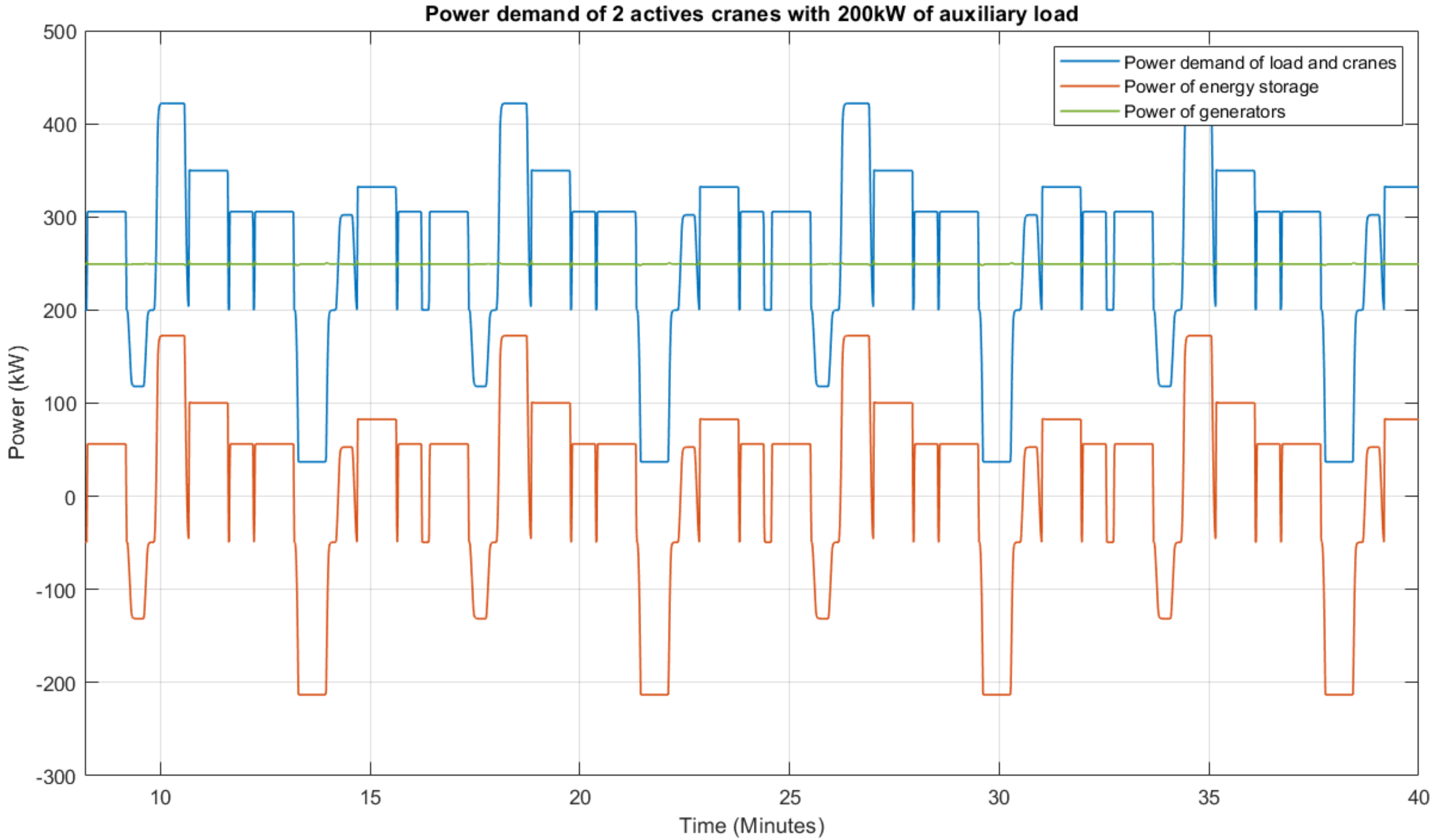
- Reduce fuel consumption
- Lower power demand peaks



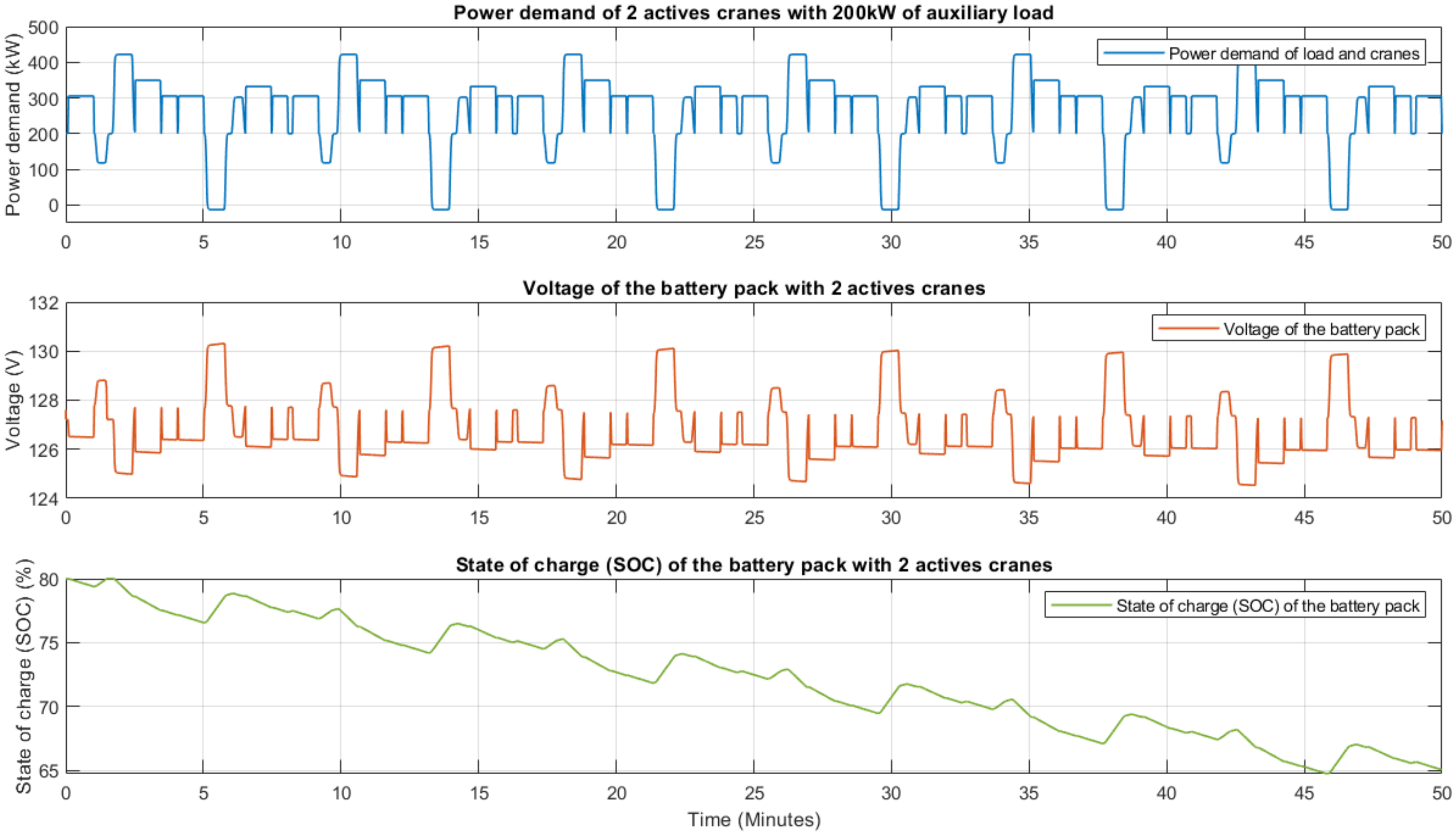
Features of the Simulink model

- Rule-based EMS
  - Splits current demand between the generators and the energy storage
  - Safety criterion: 20% < SOC < 80 %
  - High-frequency components are sent to the energy storage

MODELLING – ENERGY MANAGEMENT SYSTEM



MODELLING – ENERGY MANAGEMENT SYSTEM



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ECONOMIC ANALYSIS

Assumptions

- 20 days per year of operation
- Useful life of a marine ship of 25 years
- 5% per year inflation of the diesel price
- Estimated prices

Option 1:Bill of material with estimated prices

Equipment	**Qty**	**Cost ($ CAD)**
Asynchronous motor	2x	58 000.00 $
Drive	2x	204 000.00 $
DC/DC Converter	1x	80 000.00 $
AC/DC Converter	0x	- $
Batteries	37x2	17 000.00 $
Supercapacitors	0x	- $
Installation		30 000.00 $
Total		**390 000.00 $**

ECONOMIC ANALYSIS

	ESS on DC bus of the drive	ESS on AC bus with battery pack
Description:	- 2 actives cranes per work shift - 2 hybrid cranes	- 2 actives cranes per work shift - 4 hybrid cranes
	Cost ($)	**Cost ($)**
Fuel Economy/year	12 055.00 $ 16%	17 550.00 $ 24%
CAPEX	389 000.00 $	654 000.00 $
ROI (25 years)	3%	2%
Payback	19 years	21 years

ECONOMIC ANALYSIS

- Shore + Sea is preferred
- Ways to raise yield
- Using the stored energy when at sea
  - ESS could be used to reduce the number of generators working in parallel
  - Typically, 2 generators are used 19% of the time
  - Estimation of 7-9% fuel savings

	Shore	**Shore + Sea**
Description:	Energy storage system on the DC bus of the drive of the electric motor with battery pack only - 2 hybrid/active cranes per work shift	Utilisation of the energy storage system when at sea and for loading/unloading operation
	Cost ($)	**Cost ($)**
Fuel Economy/ year	12 055.00 $ 16%	23 164.00 $ 25%
CAPEX	389 000.00 $	389 000.00 $
ROI (25 years)	3%	8%
Payback	19 years	12 years

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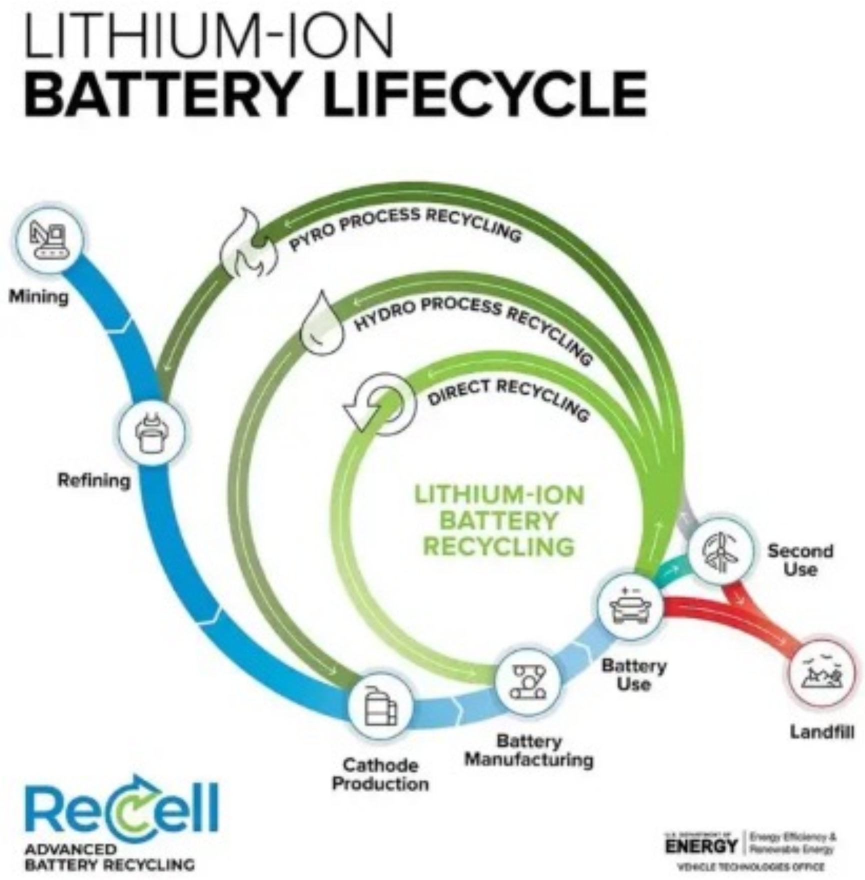
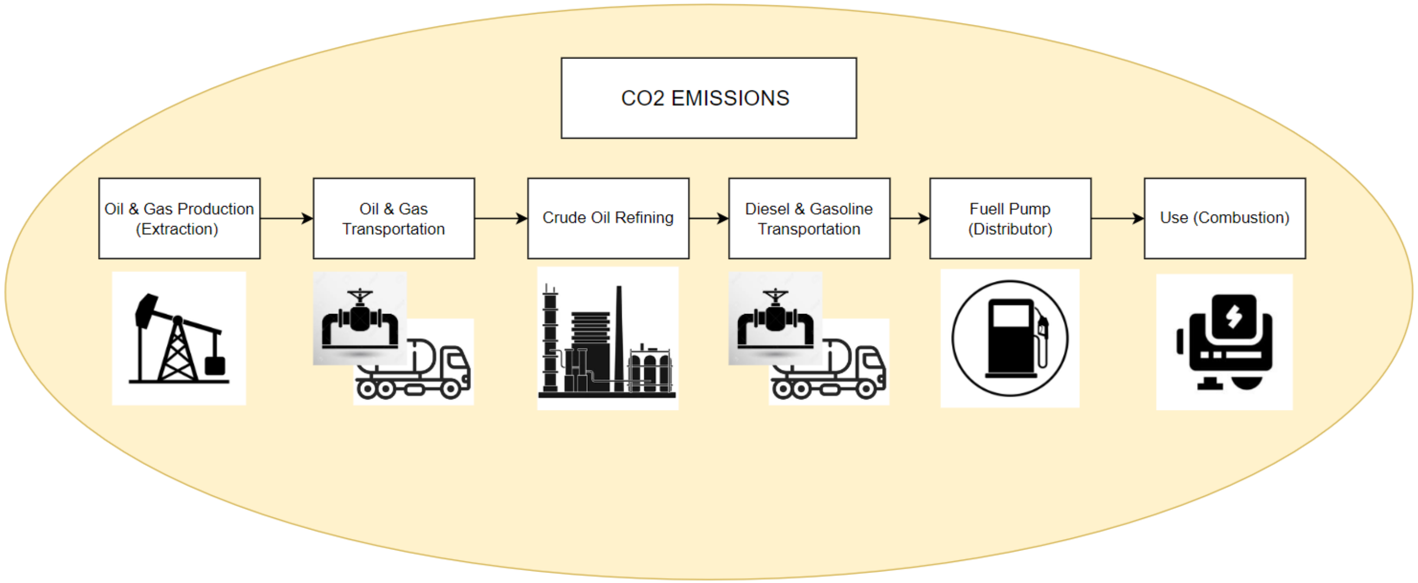
ENVIRONMENTAL ANALYSIS

- Life cycle Analysis (LCA)
- Based on scientific papers and government information
- Two life cycles considered
  - Lithium-ion battery
  - Diesel





https://www.anl.gov/article/battery-collaboration-meeting-discusses-new-pathways-to-recycle-lithiumion-batteries

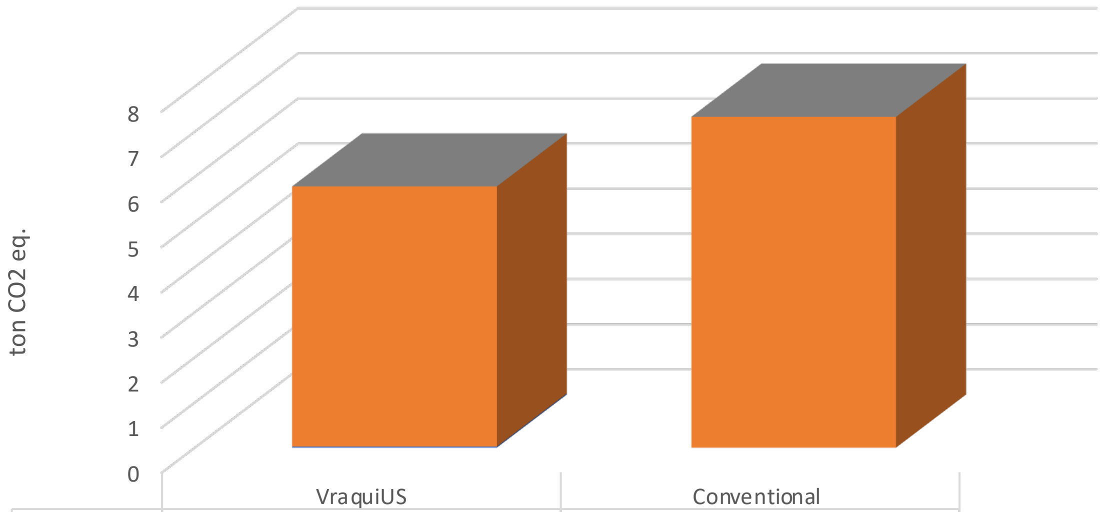
ENVIRONMENTAL ANALYSIS
EMISSION REDUCTION FOR 24 HOURS LCA

- Results represent an estimation of emissions
  - **<u>Global Warming (kg eq. CO2)</u>**
    - Quantify each substance in kg eq. CO_2

- Comparing
  - 4 active conventional cranes:
    - **7.3 tons** of eq CO_2 emissions
  - 2 active hybrid and 2 conventional cranes:
    - **5.8 tons** of eq CO_2 emissions

- **1.5 tons** eq CO2 savings, representing a **21%** reduction.

4 CRANES CO2 EMISSIONS 24H OF OPERATION (LCA)

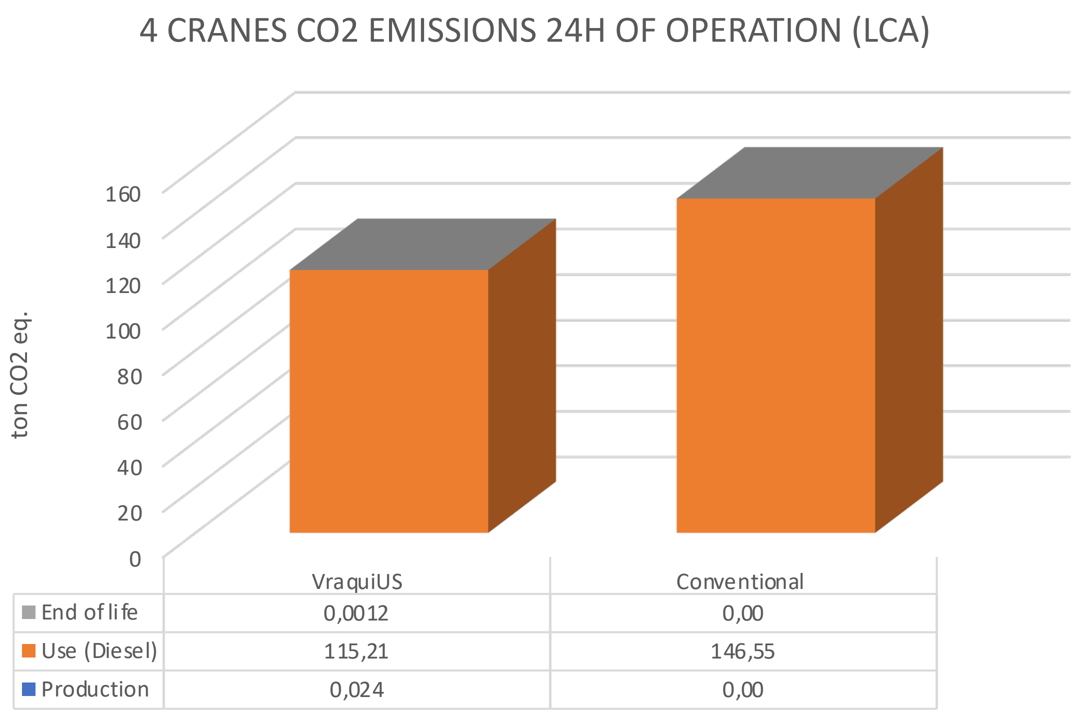


	VraquiUS	Conventional
End of life	0,0012	0,00
Use (Diesel)	5,76	7,33
Production	0,024	0,00

ENVIRONMENTAL ANALYSIS
EMISSION REDUCTION FOR 1 YEAR LCA

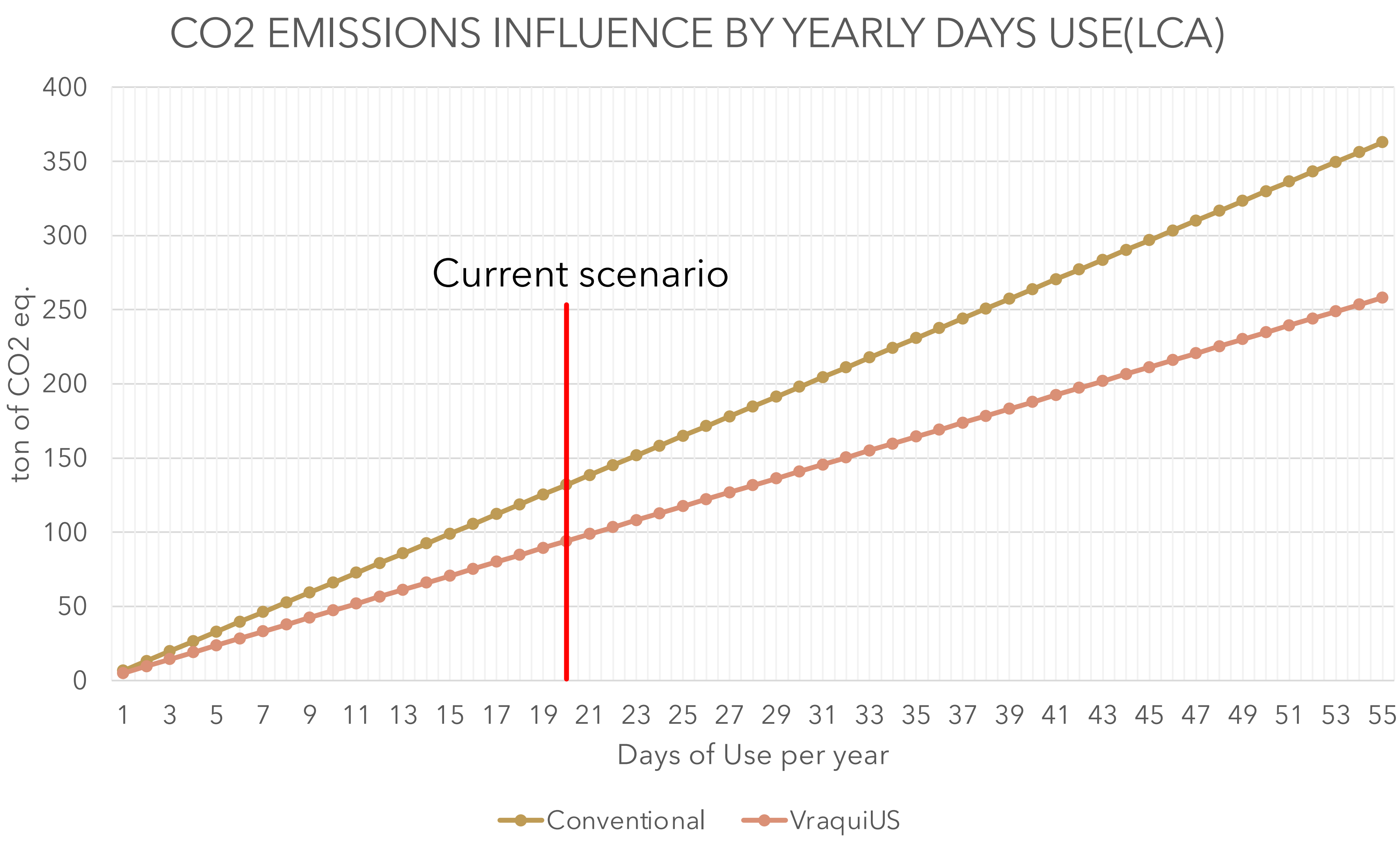
- Comparing
  - 4 active conventional cranes:
    - **146 tons** of eq CO_2 emissions
  - 2 active hybrid and 2 conventional cranes:
    - **115 tons** of eq CO_2 emissions

- **31 tons eq** CO2 savings, representing a **21 %** reduction.



ENVIRONMENTAL ANALYSIS

- Results greatly dependant on the time of use of the cranes
  - Influence the CO_2 emissions



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CONCLUSION

Use of the Energy Storage System

Objectives

- Reach 30% of fuel savings during operation of loading/unloading
- Economic viability:
  - Payback of 2-3 years

Results

- Fuel Economy of 25% during operation of loading/unloading
- Economic viability
  - Payback of 12 years

Ways to improve

- Utilization of second life battery
  - to reduce CAPEX
  - ex. Batteries from electric buses could be a viable option
- Utilization of hybrid cranes more than 20 days per year
- Use the storage system at sea

EXPO MÉGAGÉNIALE

- Canada's largest university engineering fair!
- More than 400 engineering undergraduates who present their prototypes and projects
- An audience of over 6500 people

THANK YOU

VRAQUIUS

MODELLING – ENERGY STORAGE SYSTEM