NTNU – Trondheim
Norwegian University of Science and Technology

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Design of sustainable integrated energy systems for green ports – selection and sizing

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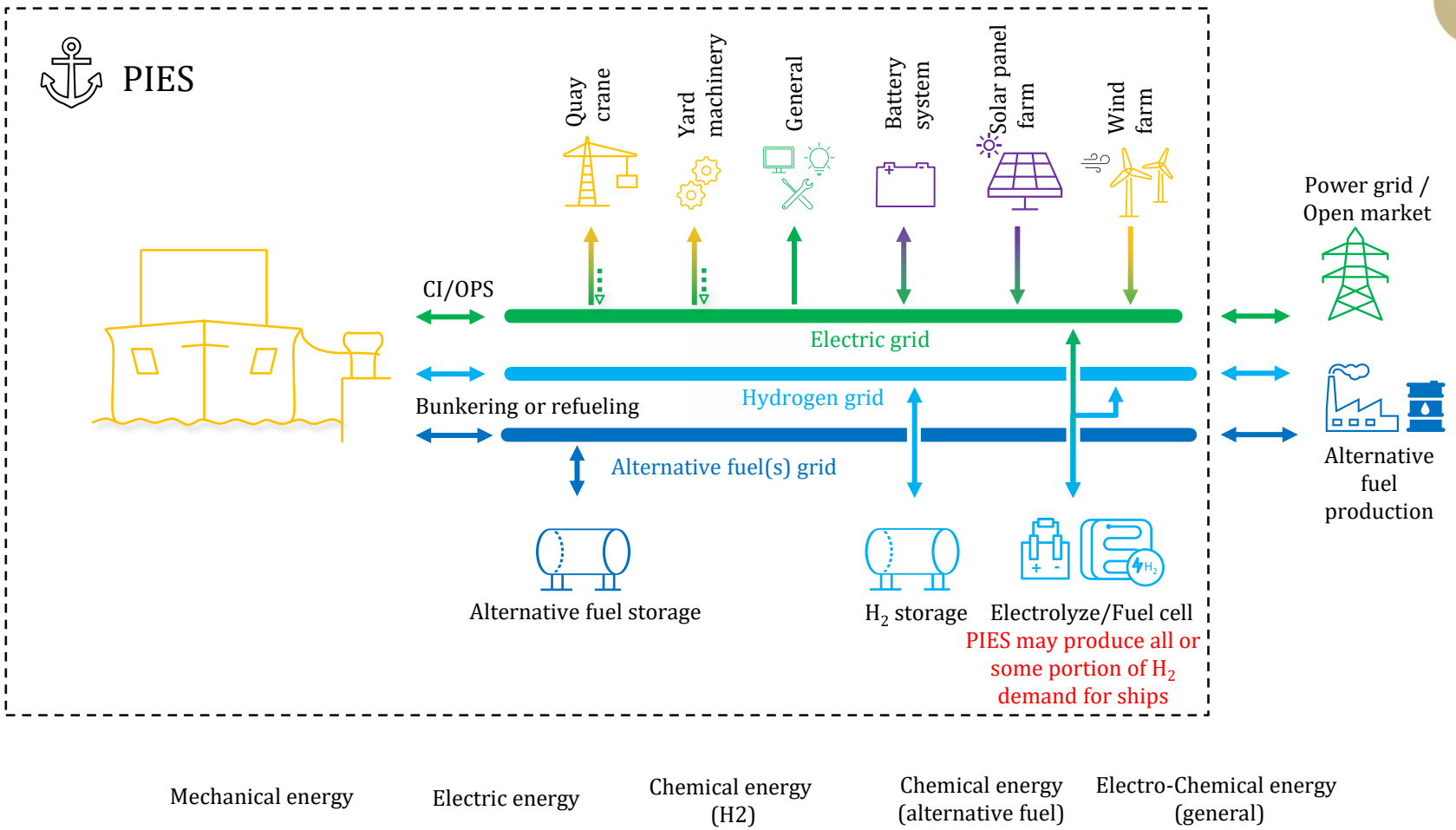
Outline

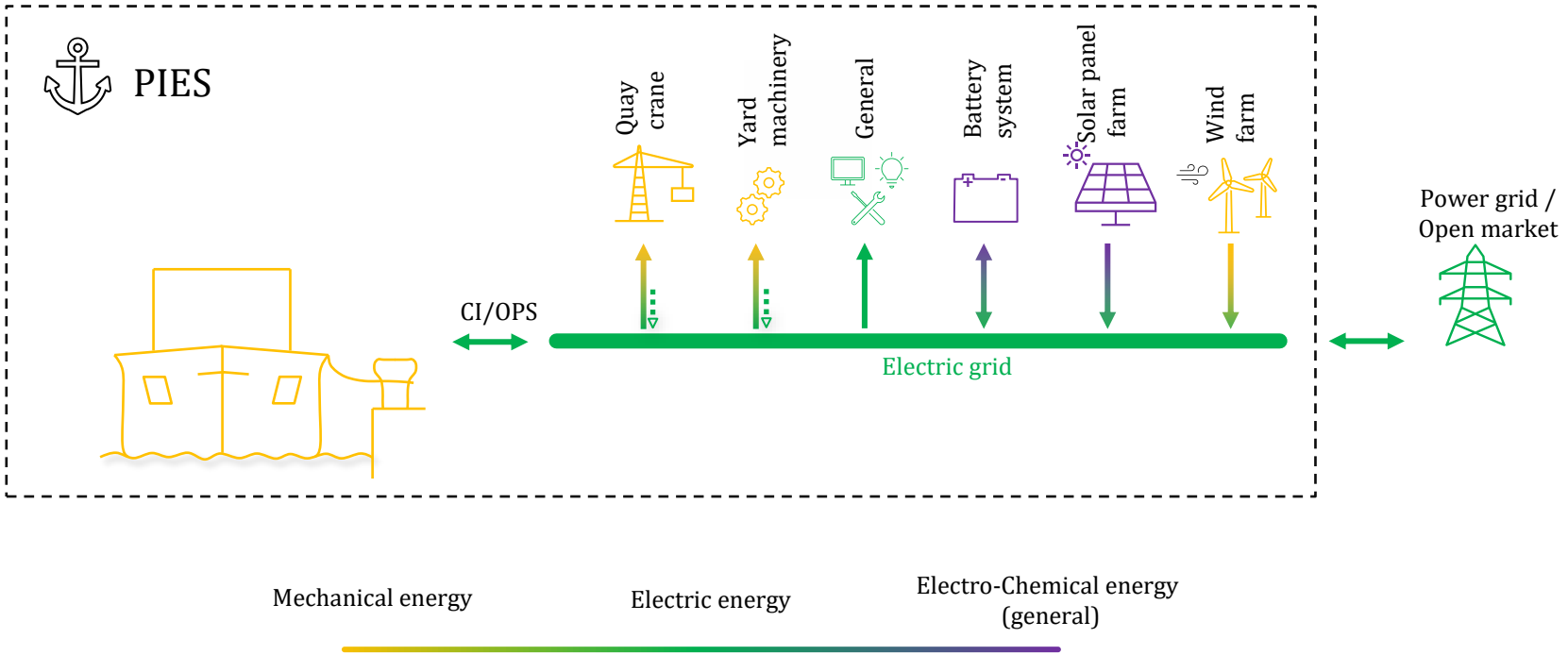
- Port Integrated Energy System (PIES)
- Modelling and sizing methodology
  - Deterministic and stochastic energy forecasting approaches
- Case studies ports
- Results
  - Sizing of systems
  - CAPEX
  - Comparison of deterministic and stochastic OPEX
  - Levelized cost of energy (LCOE)
- Conclusions
- Ongoing work

Port Integrated Energy System (PIES)



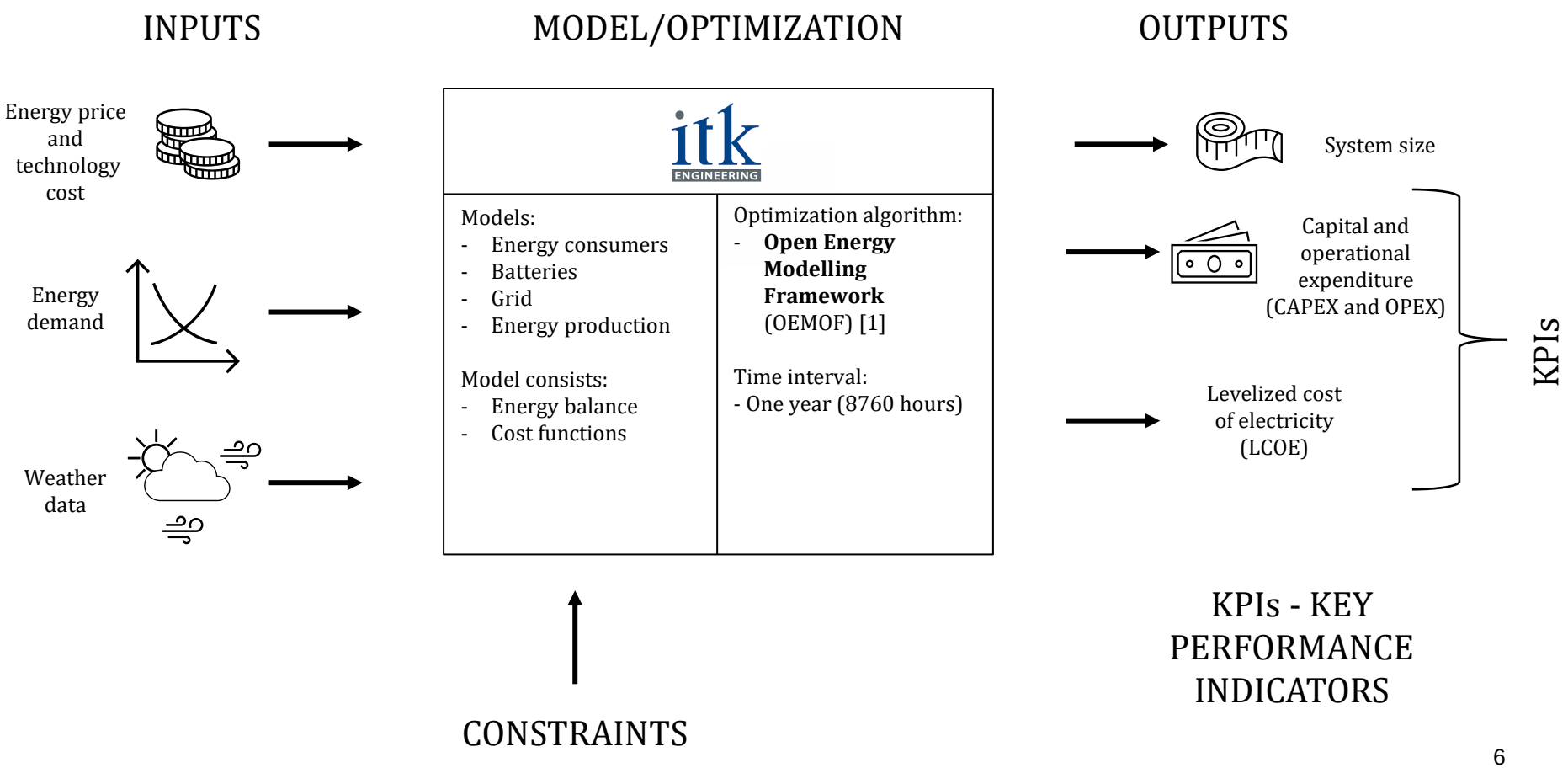
Port Integrated Energy System (PIES)

- PIES considered in the paper



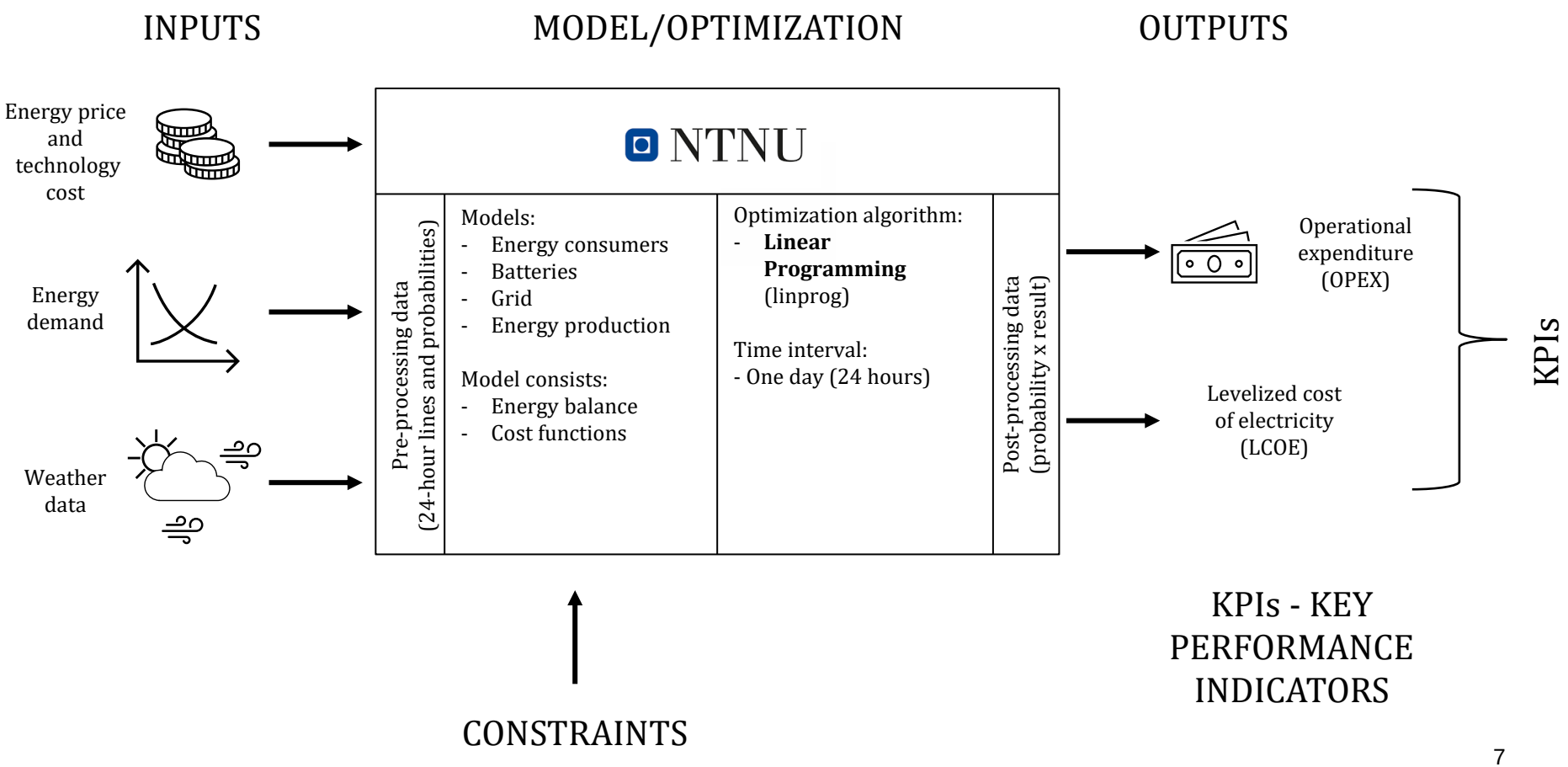
Methodology

- Deterministic approach



Methodology

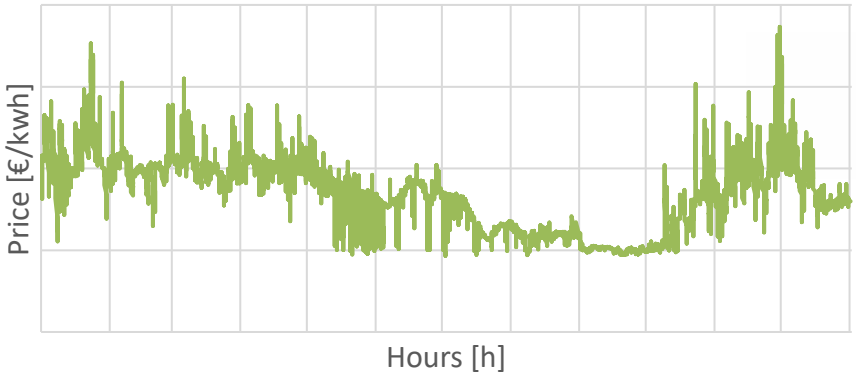
- Stochastic approach



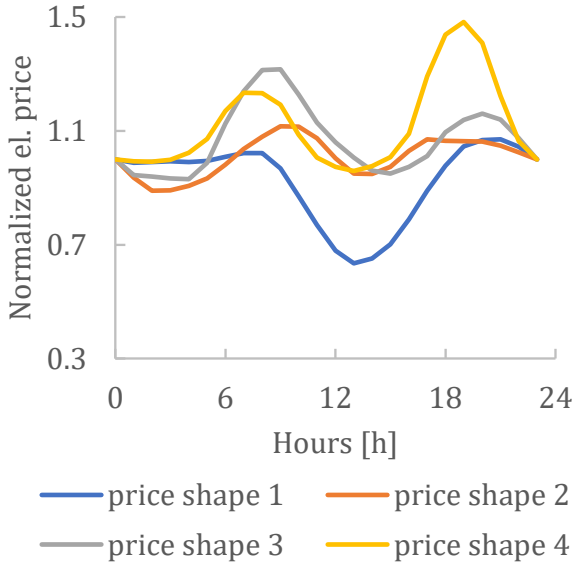
Methodology

- Stochastic approach
  - Pre-processing data, e.g., Market 1 electricity price

Annual electricity price



24-hour electricity price pattern



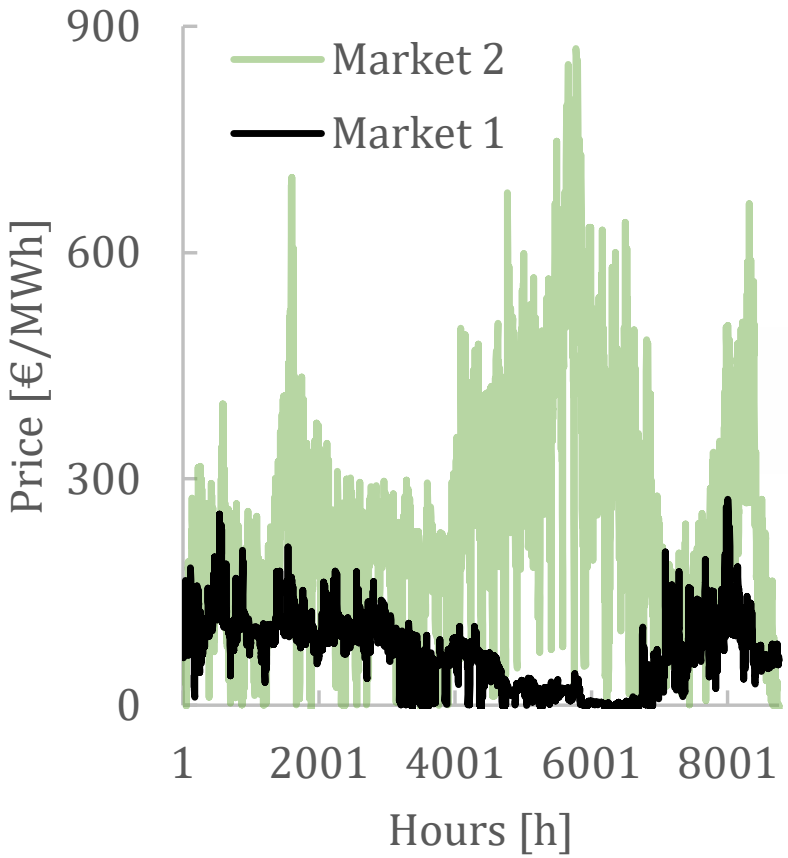
Probability distribution

mean daily price €/MWh	price dynamic			
	price shape 1	price shape 2	price shape 3	price shape 4
-20	1 %	8 %	2 %	0 %
69	4 %	28 %	18 %	3 %
158	2 %	14 %	13 %	3 %
247	1 %	2 %	1 %	1 %

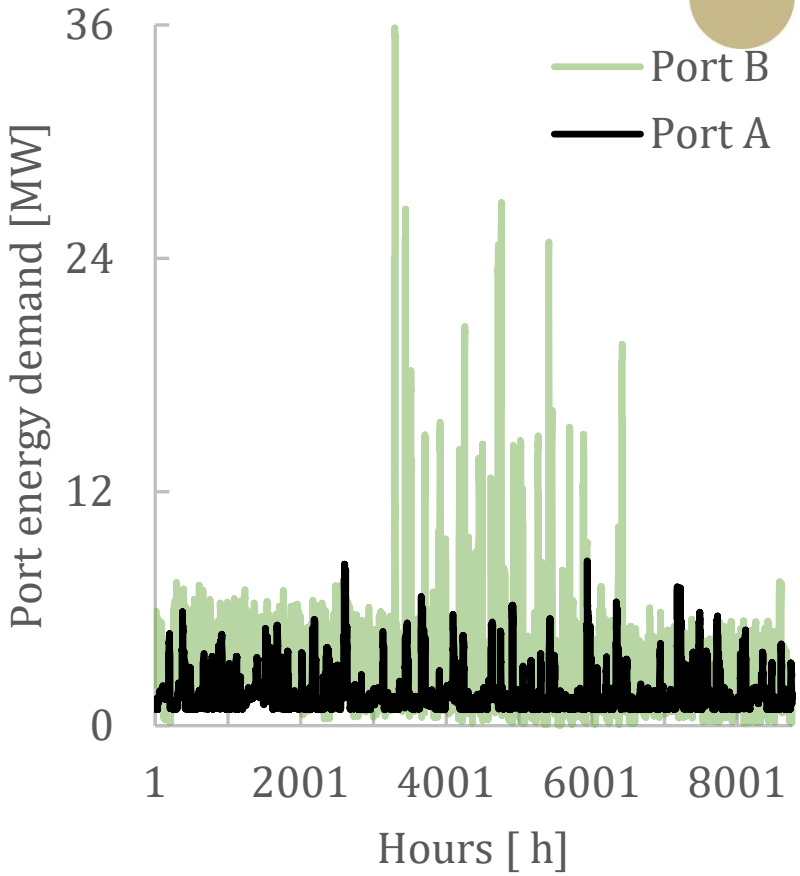
Methodology

- Stochastic approach
  - Post-processing data
    - Weighting results according to the probability of each 24-hour data set
  - Benefits of processing data
    - Decouples energy demand from price fluctuations
    - Allows for easy incorporation of future uncertainties

Case studies ports



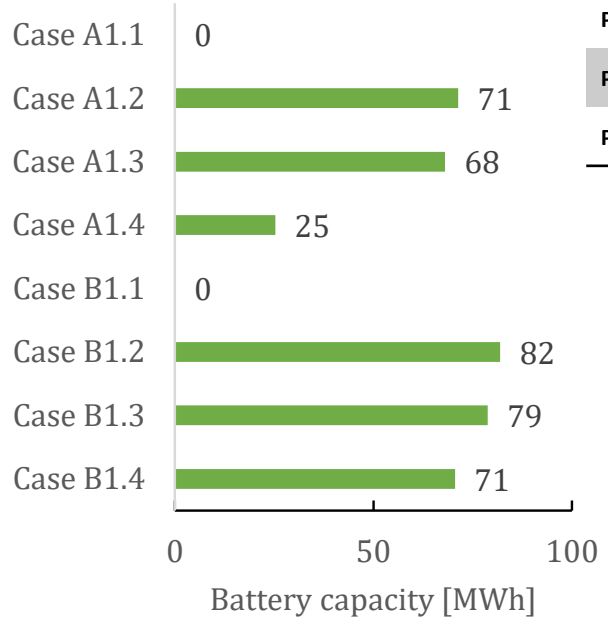
Electricity purchasing price



Energy demand

Results

- Sizing of systems



Optimal battery capacity size

	Market 1	Market 2	Grid only	Grid+BESS	Grid+BESS+PV	Grid+BESS+PV+WT
Port A	Yes	No	Case A1.1	Case A1.2	Case A1.3	Case A1.4
Port A	No	Yes	-	-	-	Case A2.4
Port B	Yes	No	Case B1.1	Case B1.2	Case B1.3	Case B1.4
Port B	No	Yes	-	-	-	Case B2.4

Overview of cases

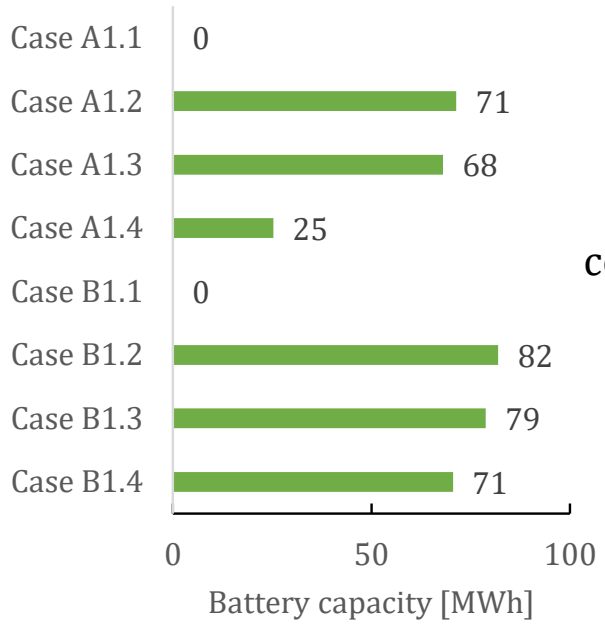
Size constraints

	Grid (drawn/feed-in)	PV (east/west/south)	WT
Port A	5/5 MW	0.6/0.6/1 MWp	4.5 MWp
Port B	25/5 MW	0.6/0.6/1 MWp	4.5 MWp

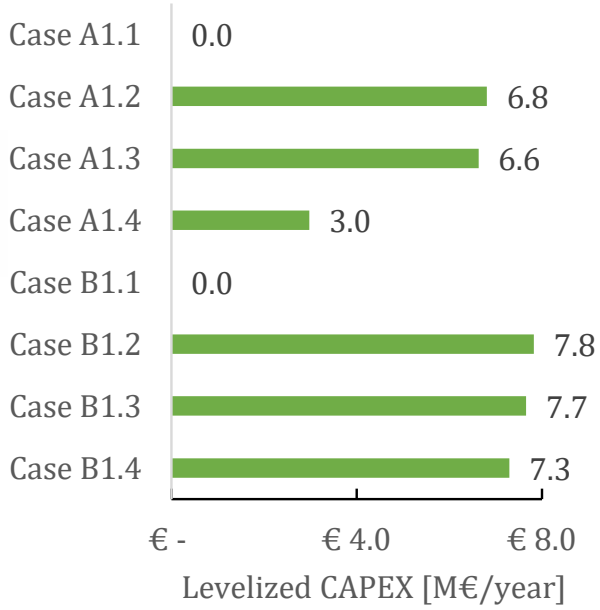
Optimal photovoltaic panel (PV) and wind turbine (WT) sizes are equal to maximum constraint size, listed in the table above

Results

- CAPEX



correlated

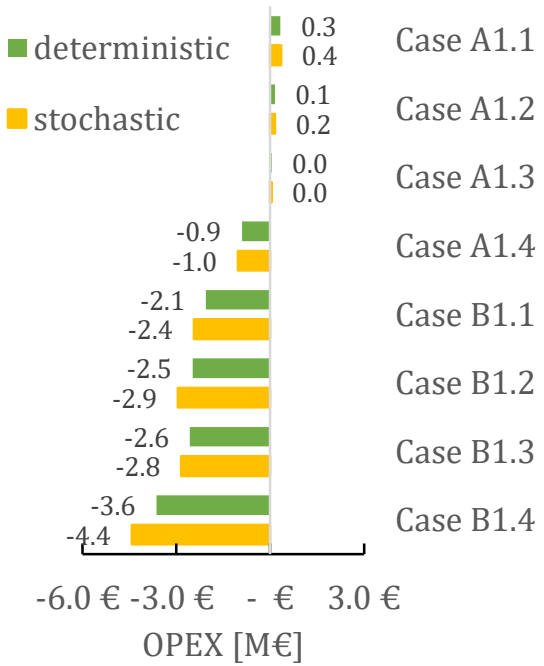


Optimal battery capacity size

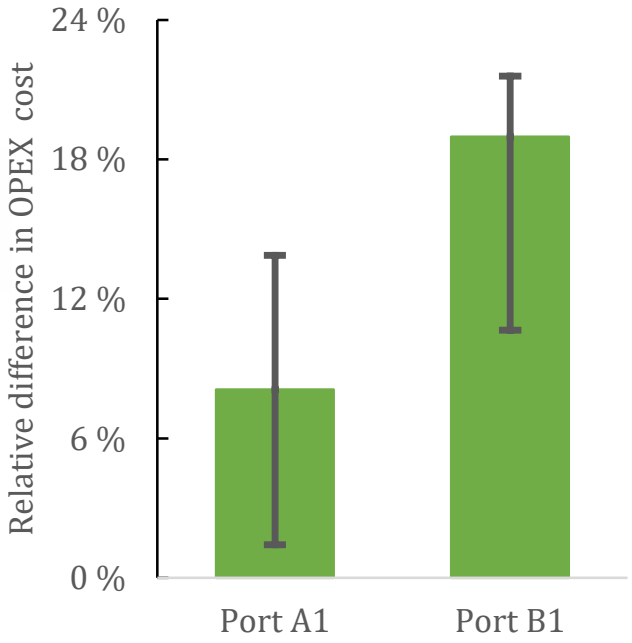
Levelized CAPEX cost to build the system

Results

- Comparison of deterministic and stochastic OPEX



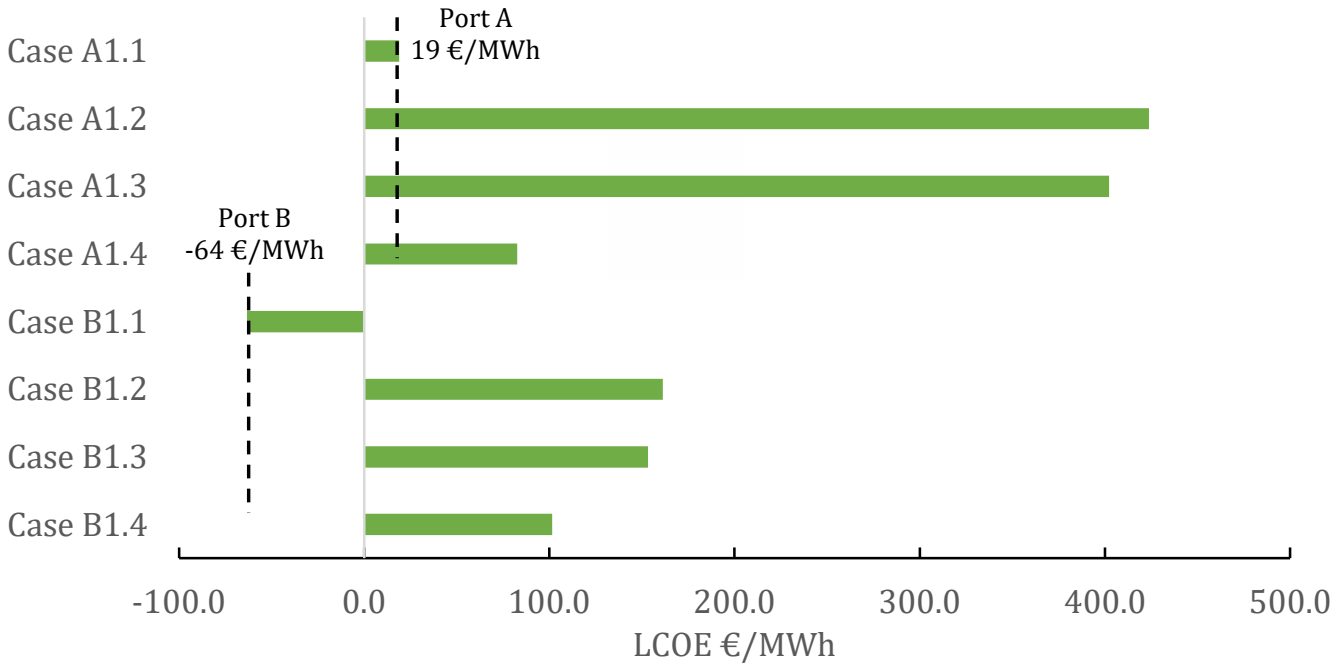
Annual OPEX cost for port A and B exposed to electricity Market 1



Relative difference between two approaches

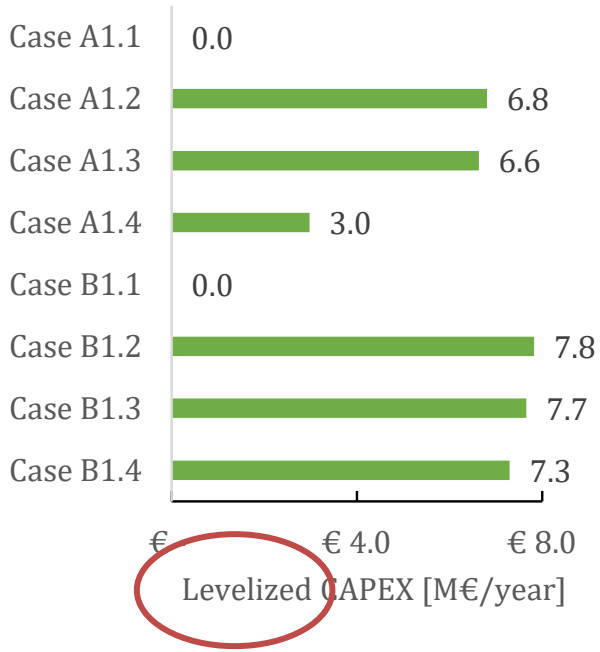
Results

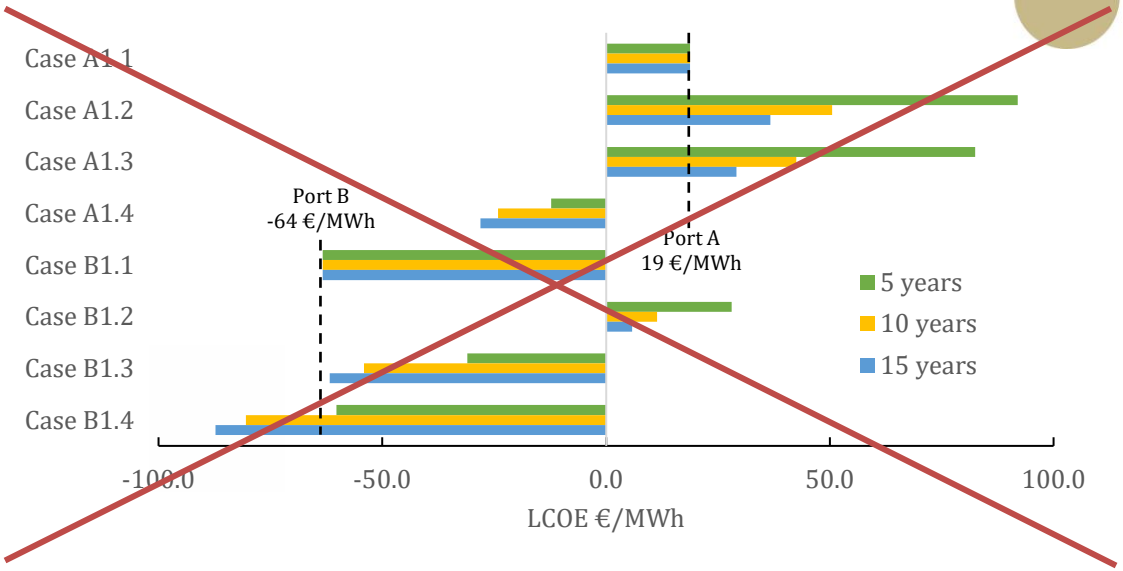
- Levelized cost of energy (LCOE)

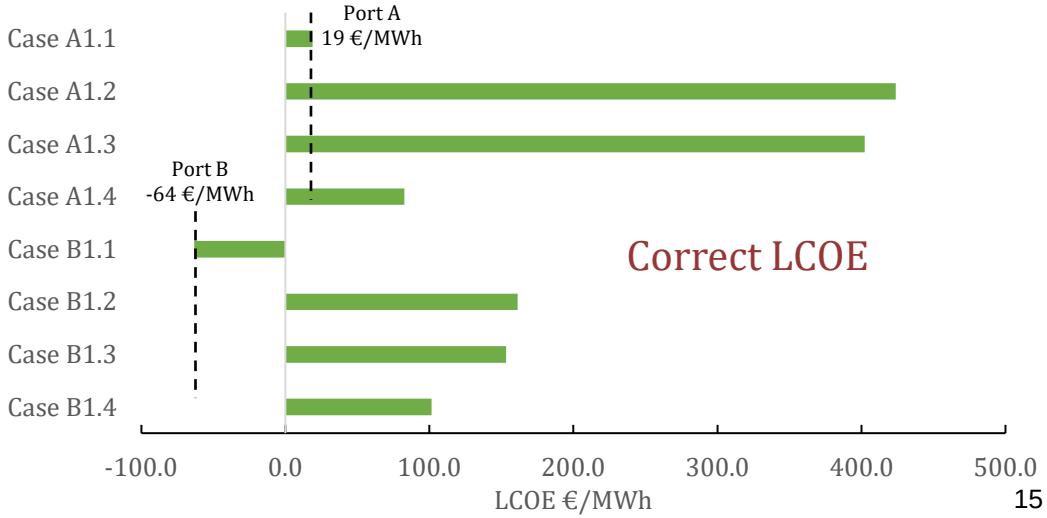


Results

- Errata







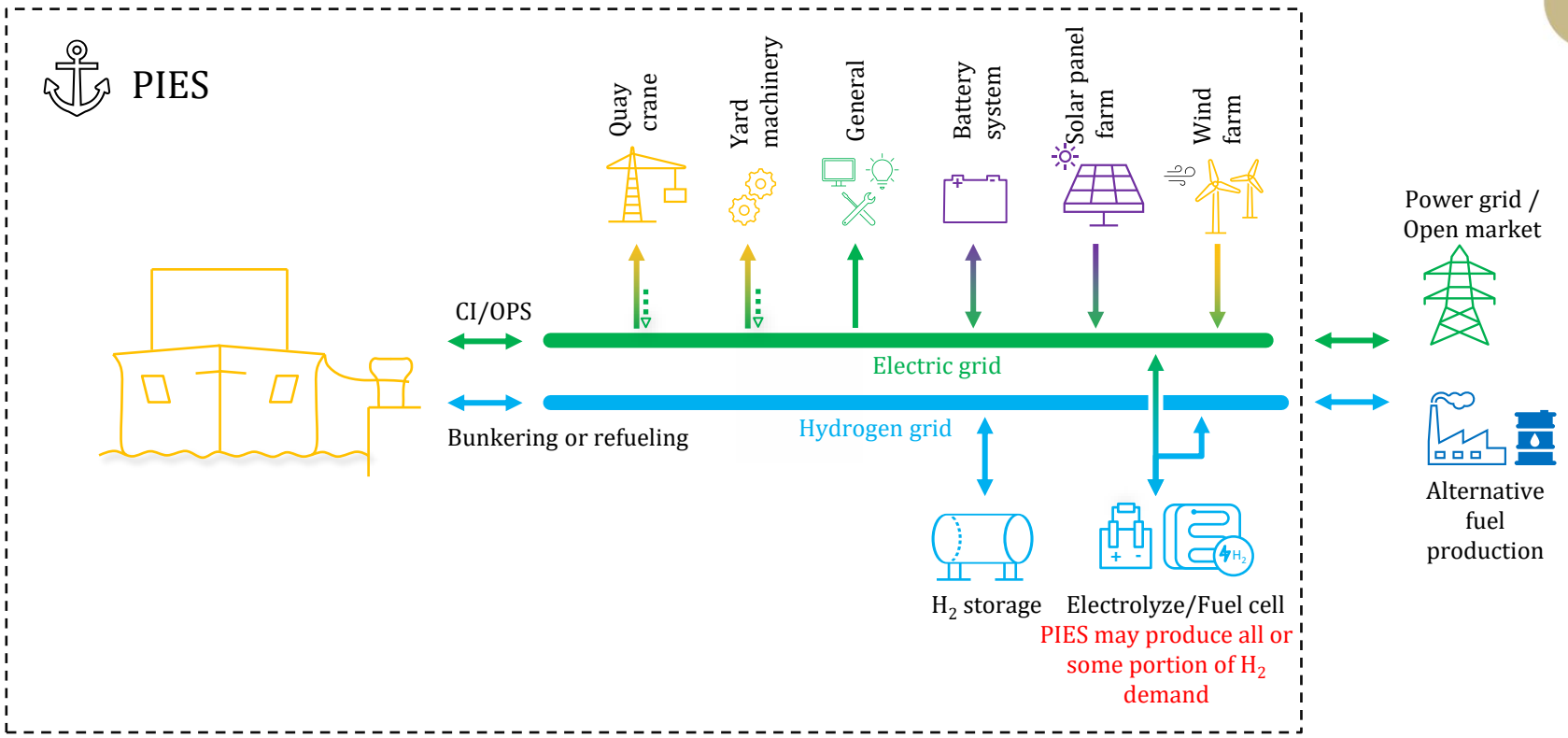
Conclusions

- The deterministic approach offers a precise foundation for sizing renewable energy components
- The stochastic approach provides a reasonably accurate assessment of the economic viability of PIES
- The analysis indicates that a combined PV, WT, and BESS system offers the most cost-efficient solution for grid lock
- Increasing the capacity of renewable energy sources significantly diminishes the required capacity for BESS
- The BESS+PV+WT system solution is viable only if grid electricity is generated from carbon-intensive sources

Reference list

[1] Hilpert, S., Kaldemeyer, C., Krien, U., Günther, S., Wingenbach, C. and Plessmann, G., 2018. The Open Energy Modelling Framework (oemof)-A new approach to facilitate open science in energy system modelling. Energy strategy reviews, 22, pp.16-25.

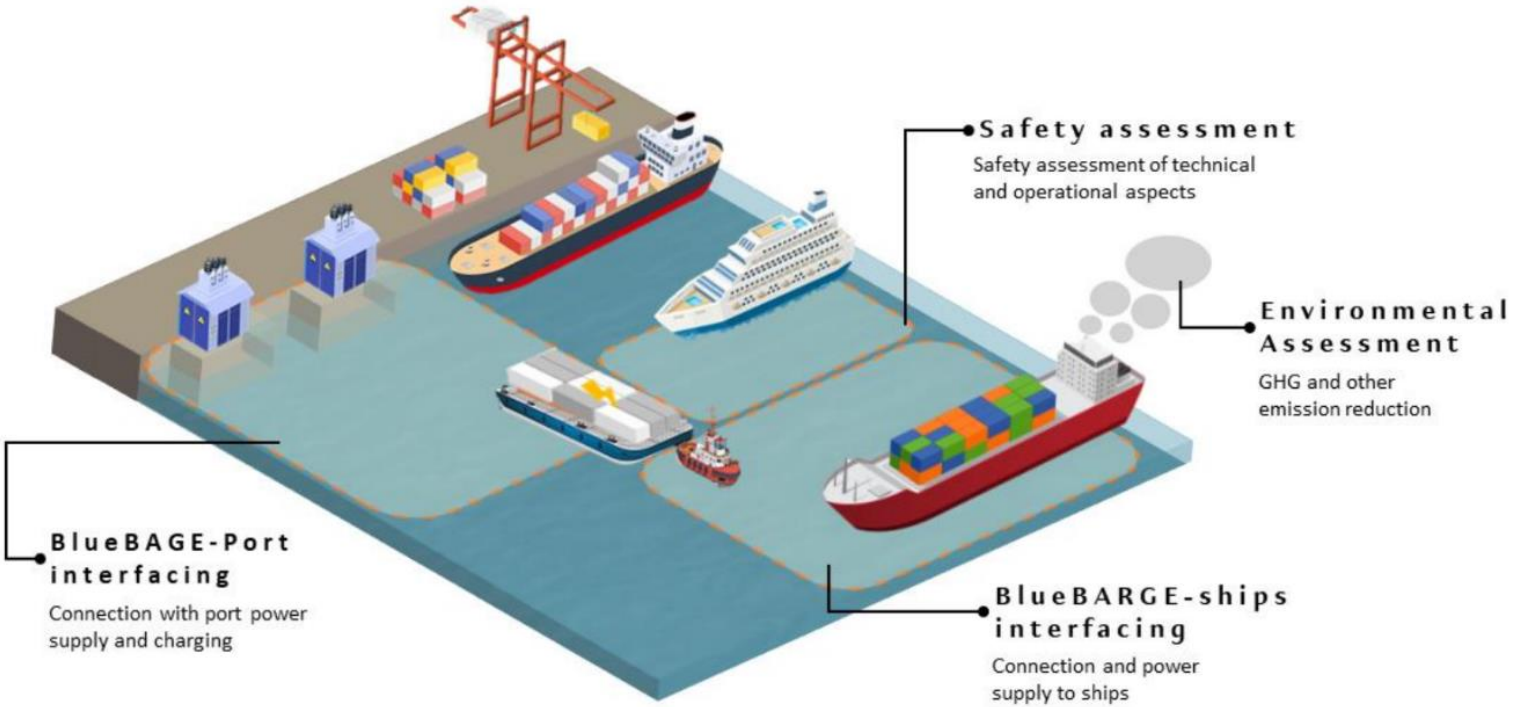
Ongoing work



Mechanical energy | Electric energy | Chemical energy (H2) | Chemical energy (alternative fuel) | Electro-Chemical energy (general)

Ongoing work

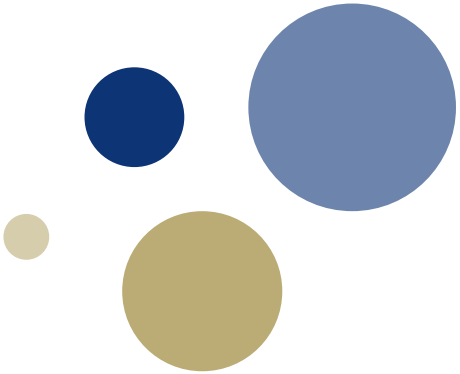
NTNU



Project 101138694 — BlueBARGE

bluebarge

Thank you!



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