Circular management of dredged sediments from port maintenance

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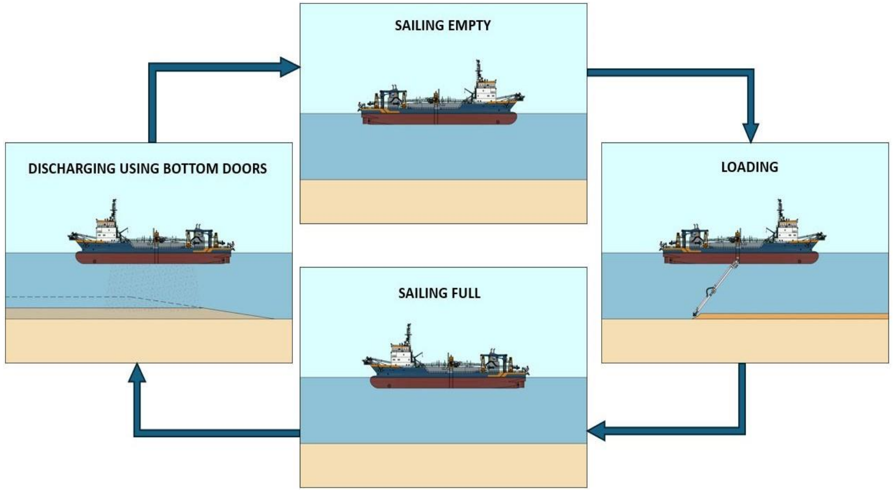
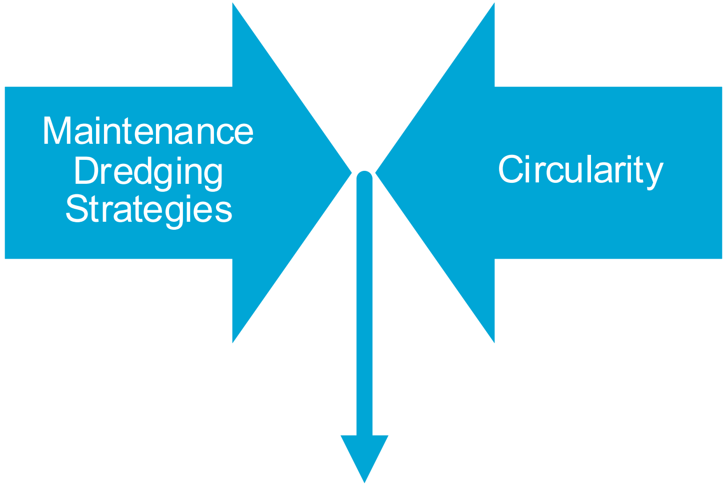
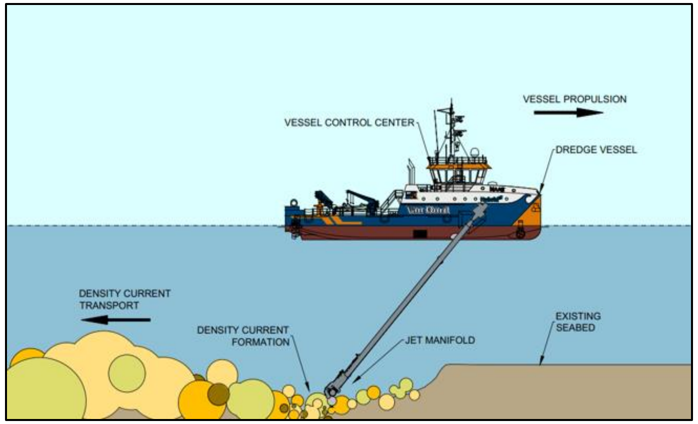
| Problem Statement |







Challenges

- Selecting work method: TSHD, WID
- Quantifying cost, production rate, energy consumption, emissions
- Quantifying circularity
- Investigate stakeholders' requirements

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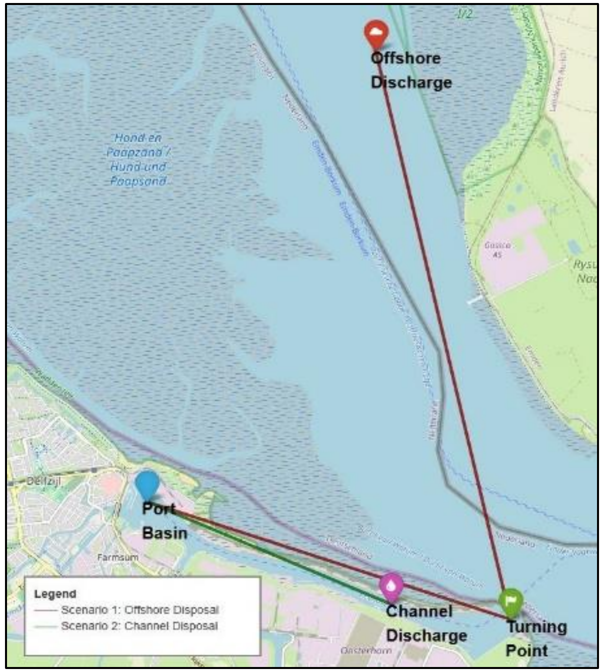
| Case Study |

Comparing two cases

Kleijrijperij (Clay Ripening) Pilot, Delfzijl, Netherlands

1. Using a TSHD with regular discharging offshore
2. Using a TSHD with an attached pump and pipeline to transport sediments onshore



| Methodology |

Event Table

Perspective	Focus	Requirements	Data and attributes
Scale	Time and space definition	• Site location specifications • Dredging time and space • Vessel movements	• Activity timestamps • Activity sequences
Conditions	Influencing indicators	• Sediment, vessel, and project properties	• Vessel speed, sailing distance • Intermediate calculations
Behavior	Activity scheduling	• Agents (sites and vessels) • Duration sequences	• Vessel and site type • Activity type • Timestamps
Dependencies	Prerequisites	• Pre and post-processing of activities	-

Circularity Index

1. Material Re-utilization Score (MRS)
2. Material Circularity Indicator (MCI)

OpenCLSim

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Estimation methods for cost, power, energy, and emissions

| Results |

Scenario	Event ID			Attributes				
	Activity name	Start time	End time	Location	Total cost [$]	Total power [kW]	Total energy [kWh]	Total CO_2 emission [tons]
1	sailing empty to turning point	00:00:00	00:25:21	discharging site to turning point	376.91	2397	1012.86	0.86
	sailing empty to the port basin	00:25:21	00:28:55	turning point to port basin	53.02	2397	142.48	0.12
	loading	00:28:55	01:43:01	port basin	1101.62	3747	4627	3.97
	sailing full to turning point	01:43:01	01:47:20	port basin to turning point	64.21	2397	172.57	0.14
	sailing full to discharging site	01:47:20	02:18:02	turning point to discharging site	456.48	2397	1226.68	1.05
	discharging offshore	02:18:02	02:24:02	discharging site	89.20	409	40.90	0.03
2	sailing empty	00:00:00	00:02:48	storage compartments to port basin	41.71	2397	112.09	0.09
	loading	00:02:48	01:16:54	port basin	1101.62	3747	4627.54	3.97
	sailing full	01:16:54	01:20:18	port basin to storage compartments	50.51	2397	135.75	0. 11
	discharging	01:20:18	01:53:14	storage compartments	489.60	1199	658.11	0.56

Material Circularity Indicator (MCI)		Material Re-utilization Score (MRS)	
$M_{loss.reuse}$ [tons]	10637	IR [%]	89.0849
$M_{reallocation}$ [tons]	0	RC [%]	84.2122
$M_{loss.dredge}$ [tons]	3283	MRS [-]	0.8746
LFI [-]	0.2358		
$F(X)$ [-]	0.9000		
MCI_p [-]	0.7877		

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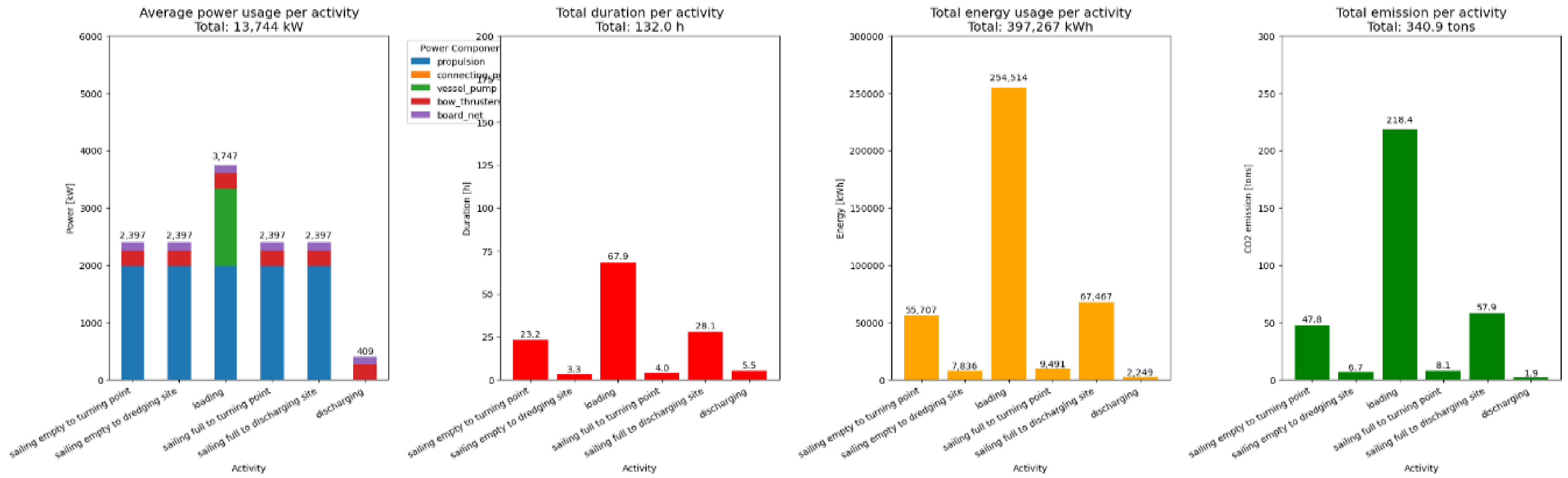
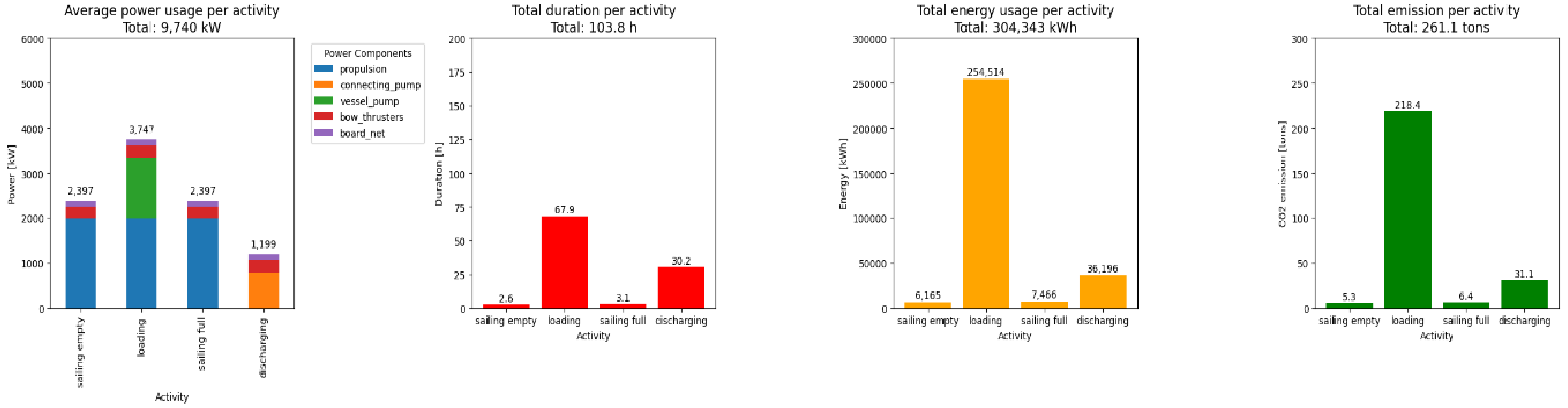
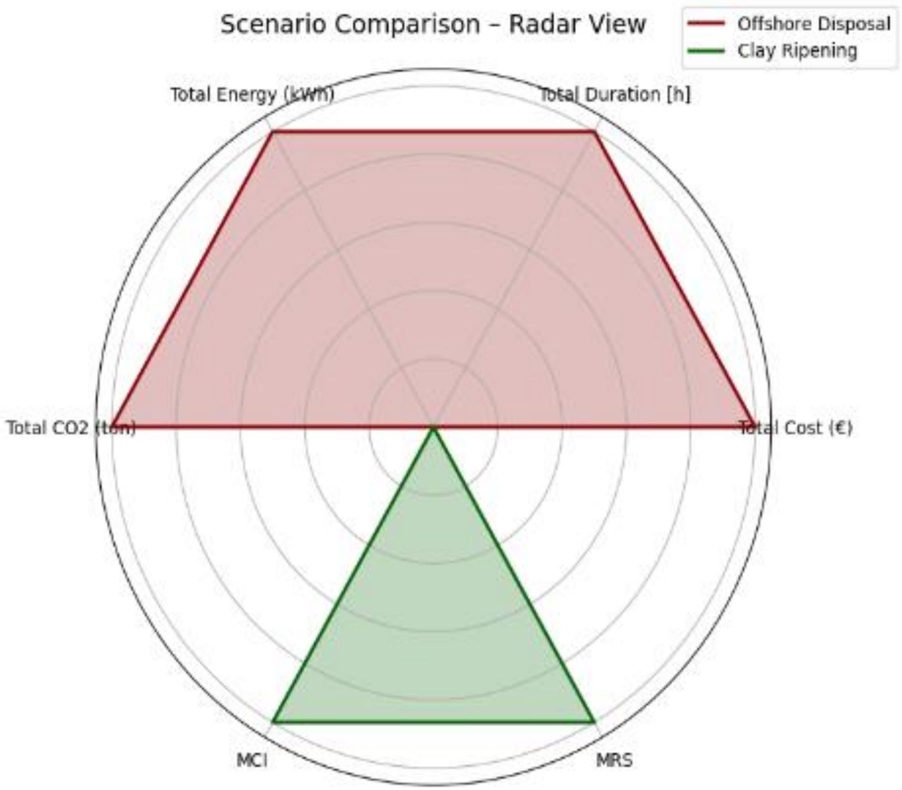
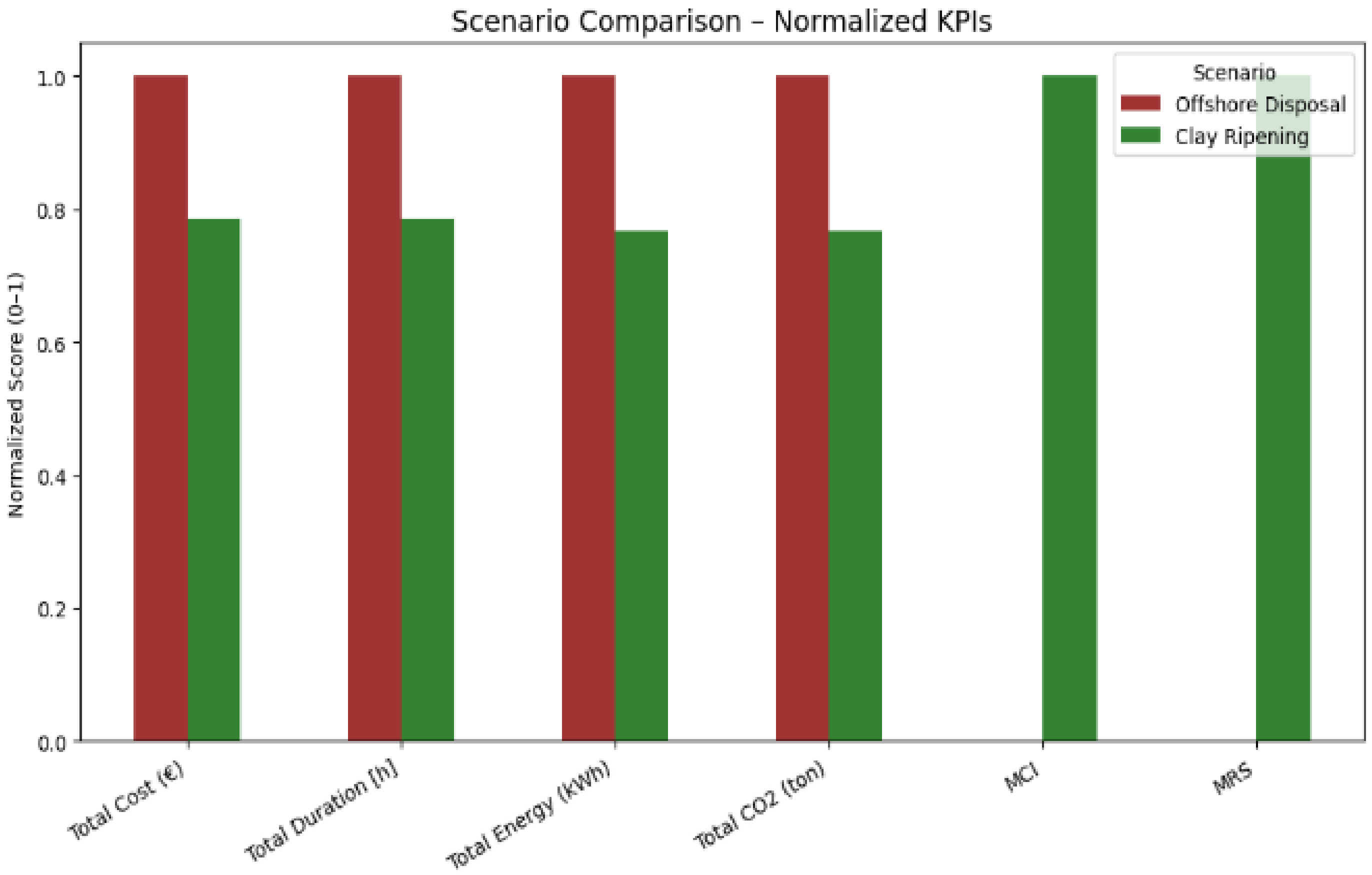

Average power usage per activity
Total: 13,744 kW
Power [kW]
Power Components
propulsion
connecting_pump
vessel_pump
bow_thrusters
board_net
2,397
2,397
3,747
2,397
2,397
409
sailing empty to turning point
sailing empty to dredging site
loading
sailing full to turning point
sailing full to discharging site
discharging
Activity
Total duration per activity
Total: 132.0 h
Duration [h]
23.2
3.3
67.9
4.0
28.1
5.5
Total energy usage per activity
Total: 397,267 kWh
Energy [kWh]
55,707
7,836
254,514
9,491
67,467
2,249
Total emission per activity
Total: 340.9 tons
CO2 emission [tons]
47.8
6.7
218.4
8.1
57.9
1.9


Average power usage per activity
Total: 9,740 kW
Power [kW]
Power Components
propulsion
connecting_pump
vessel_pump
bow_thrusters
board_net
2,397
3,747
2,397
1,199
sailing empty
loading
sailing full
discharging
Activity
Total duration per activity
Total: 103.8 h
Duration [h]
2.6
67.9
3.1
30.2
Total energy usage per activity
Total: 304,343 kWh
Energy [kWh]
6,165
254,514
7,466
36,196
Total emission per activity
Total: 261.1 tons
CO2 emission [tons]
5.3
218.4
6.4
31.1

| Results |



Scenario Comparison – Radar View
Offshore Disposal
Clay Ripening
Total Energy (kWh)
Total Duration [h]
Total CO2 (ton)
Total Cost (€)
MCI
MRS



Scenario Comparison – Normalized KPIs
Normalized Score (0–1)
1.0
0.8
0.6
0.4
0.2
0.0
Scenario
Offshore Disposal
Clay Ripening
Total Cost (€)
Total Duration [h]
Total Energy (kWh)
Total CO2 (ton)
MCI
MRS

| Discussion |

- Beneficial reuse of sediment in maintenance dredging could be more expensive but contributes to circularity practices
- Reusing sediment in infrastructure projects could return the investment done in circular dredging processes
- Alternative strategies (TSHDs with different capacities, WIDs) could result in lower emission profiles
- Stakeholders’ decision-making process can be improved by looking at the dredged sediment as an asset


Questions?