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Conceptual Framework for Integration on Renewable Energy Sources for Marine Port Electrification

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Towards a SUSTAINABLE BLUE ECONOMY

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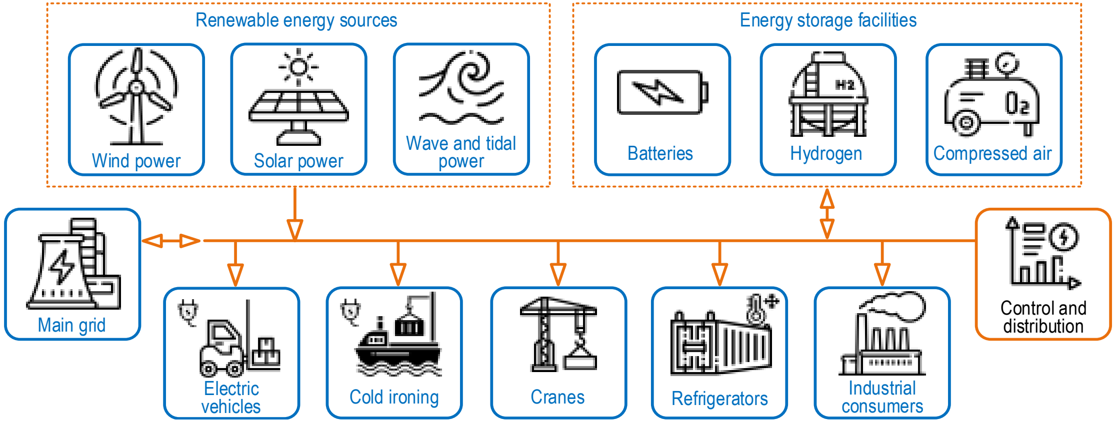
INTRODUCTION

- Marine ports connect a nation as well as the world through the maritime transport networks. ***Ports*** and **cities** are considered interdependent, where the development of port activity leads to urban development and conversely.
- Nowadays, ***most ports use diesel engines that lead to a substantial amount of pollutant gases***., Marine port operations are often associated with a variety of consequences (e.g***. noise & light pollution, water & soil pollution, etc***.) resulting from ***port and ship activities and land transport***.
- In combination with the nearby industrial activities, ports have an expected negative impact on the environment and affect the work and living conditions of residents living in cities near the port.

The paper proposes a **DSM*** for the identification and evaluation of the various RES and their integration into marine port grid using the AHP* and taking into account a number of criteria as well as the energy requirements of port activities (e.g. cold ironing, electrical moving assets, etc.). The Kaliningrad sea fishery port (Russia) is used as a case study.

- Decision Support Model
- Analytic Hierarchy Process> Multi-Criteria Decision Analysis (MCDA) technique

ZERO-EMISSION PORT



Source: Fronter, 2021

Challenges

Cold ironing	▪ Cold ironing infrastructure at marine terminals ▪ Lack of standardization ▪ Absence of concrete legislation/regulation
RES	▪ Land availability ▪ Dependence on external factors ▪ Inconsistency of RES
Energy storage	▪ High price ▪ Battery degradation in high dynamic modes

The concept

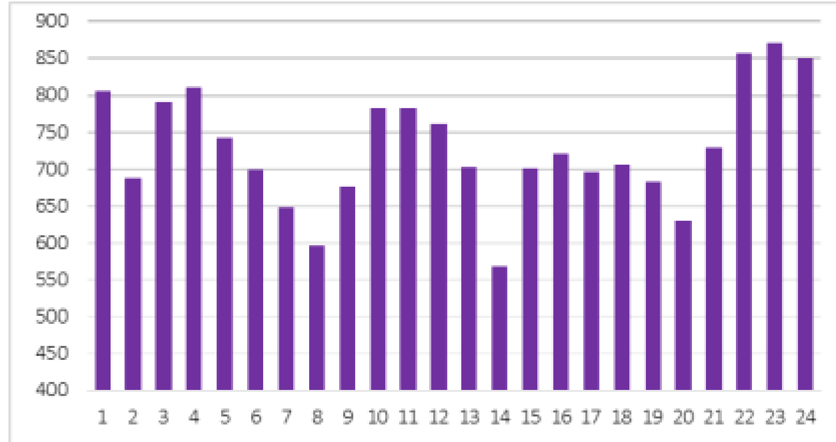
- Minimize the connection to the main grid
- Development of microgrids/smartgrids
- Use of RES mixture
- WT: mainly offshore due to land limitations in the ports
- PV: on building roofs & warehouses or floating
- Wave, tidal devices, etc.: depending on port characteristics (e.g. availability of resources, etc.)
- Use energy storage units
- Adoption of cold ironing from ports (problems addressable)
- Compliance with international environmental regulations.

GENERAL DATA: PORT OF KALININGRAD (Fishery port)

Geographical Location

Average Power Consumption (Kw)

Power Consumption (Kw)



Time of Day

Territory plan

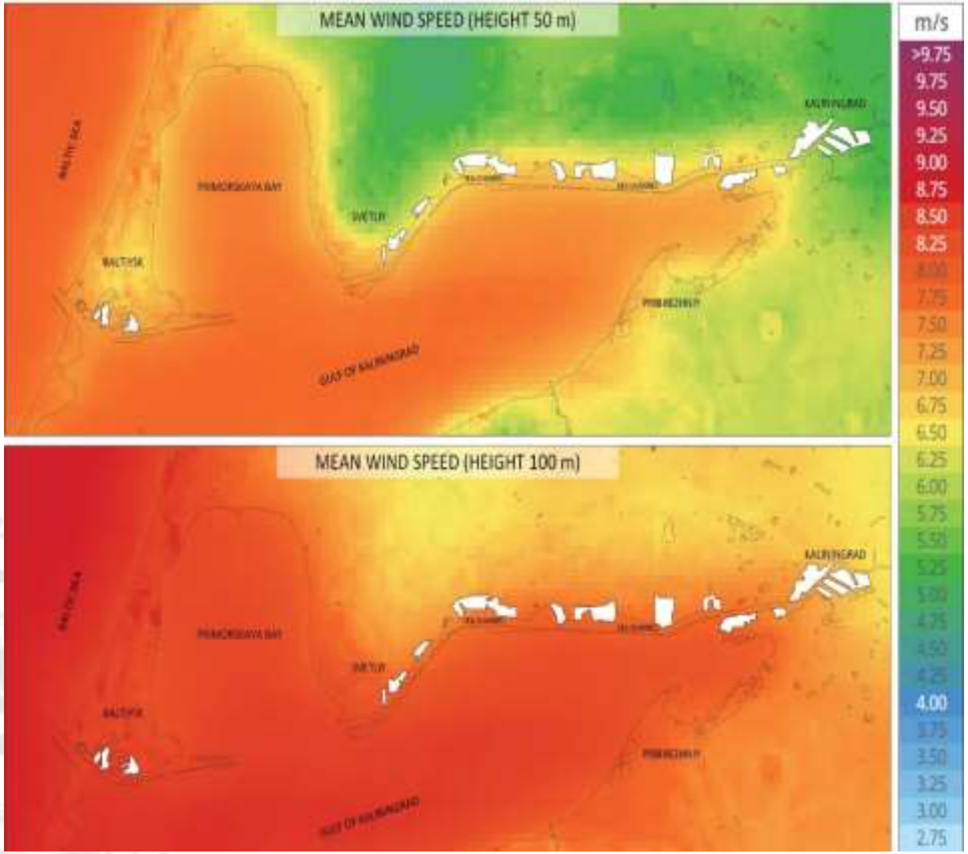
Infrastructure overview

Characteristics	Units	Value
Number of ship terminals	-	17
Liquid cargo terminal capacity	cub. m	31 400
Bulk cargo terminal capacity	tons	18 000
Covered warehouse capacity	cub. m	24 000
Open storage area	sq. m	65 000
Refrigerator capacity	tons	6 000
Number of portal cranes	units	7
Length of crane runways	m	2 100
Lifting capacity of cranes	tons	5
Number of fork and bucket loaders	units	14

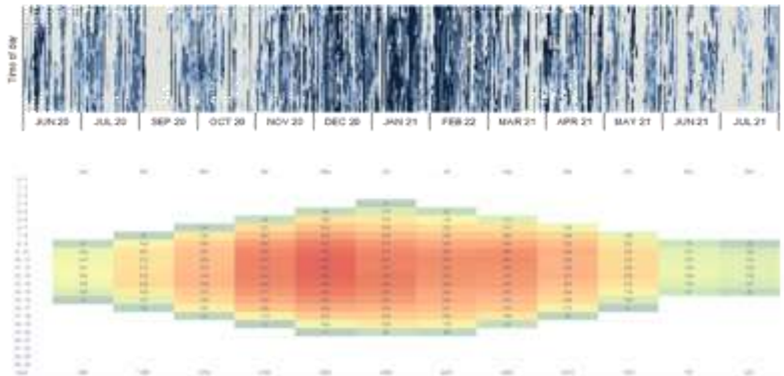
PORT OF KALININGRAD: CLIMATE & RES

Wind data

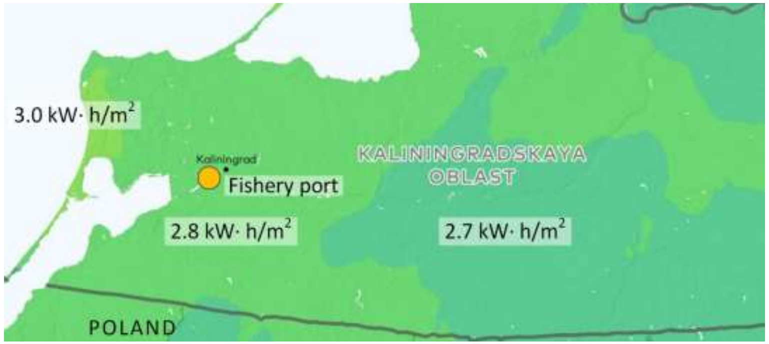
Mean Wind Speed in the Area of the Port of Kaliningrad Terminals



Solar data



Average daily direct normal irradiation in the Kaliningrad region



METHODOLOGY 1ST STAGE
Evaluation criteria

Choosing the most suitable energy alternative can be a challenging issue as many criteria have to be considered, such as ***technical***, ***economic***, ***social***, ***spatial***, and ***environmental*** that may be in ***conflict with each other***.

In order to select the most appropriate energy alternative, this stage of methodology accepts that there are ***graduations in the (5) renewable energy technologies***, which arise from the evaluation of ***energy options**** in ***various parameters*** ***.*

*****Evaluation criteria: Literature review + Interviews***	***Abbreviation***	***Type of criterion***
Resource availability	RA	Technical
Technological maturity	TM	Technical
Know-how	K-H	Technical
Capacity factor	CF	Technical
Investment cost	IC	Economic
O&M cost	O&M	Economic
Land requirements	LR	Spatial
Job creation	JC	Social
Social acceptance	SA	Social
Impact on ecosystem	IOE	Environmental

****Wind turbines (onshore & offshore)***
Solar panels (onshore & offshore)
Wave devices

METHODOLOGY 2ND STAGE
The Analytic Hierarchy Process (AHP)

The ten evaluation criteria may not be of equal importance. Therefore, the most important criteria should be weighted more than the others.
This can be achieved through the ***AHP*** & ***pair-wise comparison matrix***.

Substeps

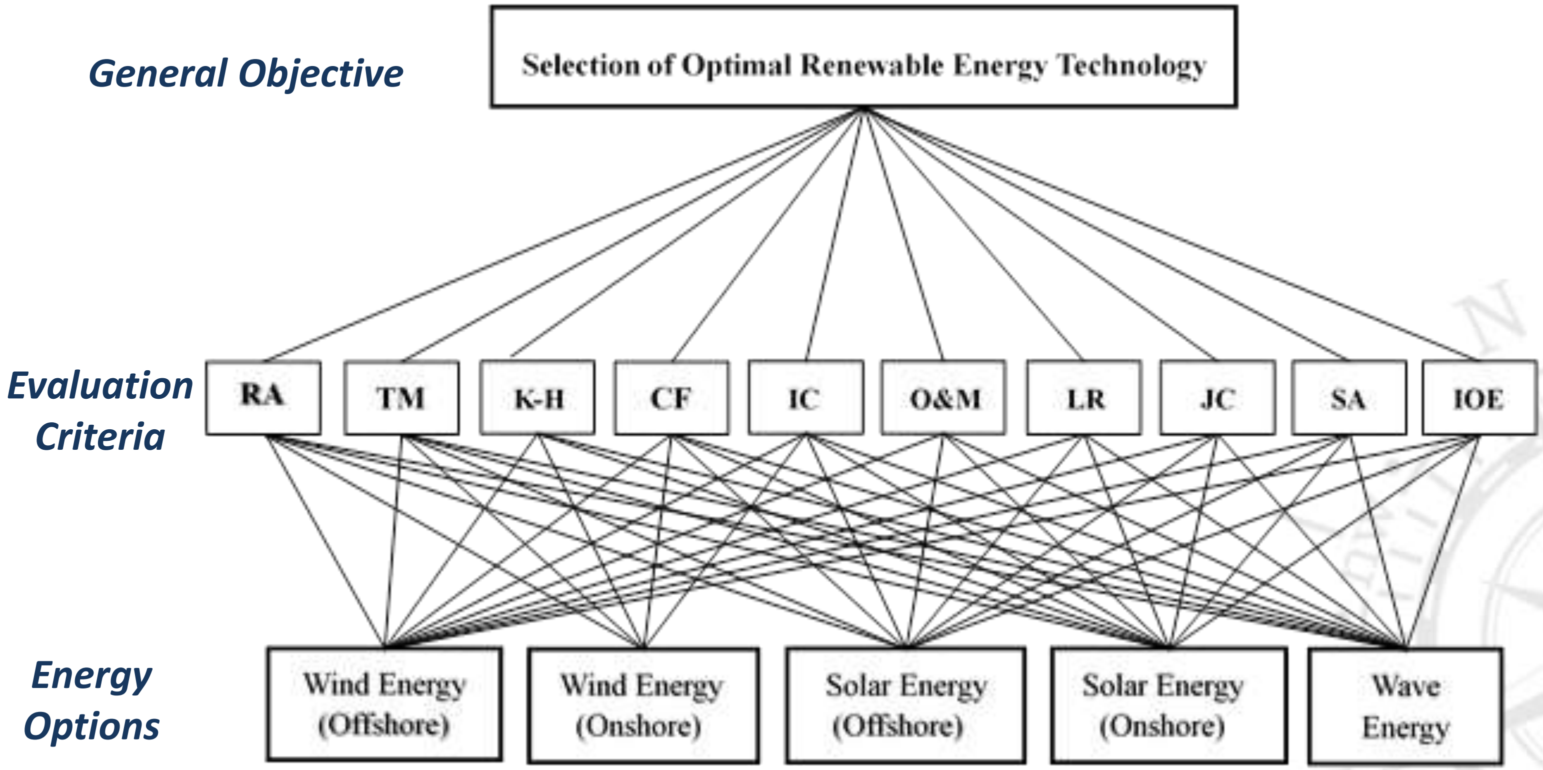
1. Development of the hierarchical structure of the selection problem
2. Creation of the pair-wise comparison matrix of (10) evaluation criteria according to 9-point scale of Saaty (1980)
3. Calculation of the weights of the (10) evaluation criteria, including a number of individual steps
4. Calculation of Consistency Ratio (CR)

9-point scale of Saaty

Intensity of importance	***Definition***
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Demonstrated importance
9	Absolute importance
2,4,6,8	Intermediate value between the two adjacent judgments

METHODOLOGY 2ND STAGE (cont.)
The Analytic Hierarchy Process (AHP)

Hierarchical structure for the selection of the most appropriate RES technology



METHODOLOGY 2^{ND} STAGE (cont.)

The Analytic Hierarchy Process (AHP)

Pair-wise comparison matrix & weights

Criteria	*RA*	*TM*	*IC*	*O&M*	*IOE*	*SA*	*LR*	*JC*	*K-H*	*CF*	***Weights (%)***
RA	0.316	0.383	0.349	0.349	0.297	0.259	0.23	0.206	0.188	0.173	***27.5***
TM	0.158	0.191	0.232	0.232	0.223	0.207	0.191	0.177	0.164	0.154	***19.4***
IC	0.105	0.097	0.116	0.116	0.148	0.155	0.153	0.147	0.141	0.134	***13.2***
O&M	0.105	0.097	0.116	0.116	0.148	0.155	0.153	0.147	0.141	0.134	***13.2***
IOE	0.079	0.063	0.058	0.058	0.074	0.103	0.115	0.118	0.117	0.115	***9***
SA	0.063	0.048	0.038	0.038	0.037	0.051	0.076	0.088	0.094	0.096	***6.3***
LR	0.052	0.038	0.029	0.029	0.024	0.026	0.038	0.059	0.07	0.077	***4.5***
JC	0.045	0.032	0.023	0.023	0.018	0.017	0.019	0.029	0.047	0.057	***3.1***
K-H	0.039	0.027	0.019	0.019	0.014	0.013	0.012	0.014	0.023	0.038	***2.2***
CF	0.035	0.024	0.016	0.016	0.012	0.01	0.009	0.009	0.011	0.019	***1.6***

Consistency Index (CI) $$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{10.37 - 10}{10 - 1}$$

Where *n*= ***number of evaluation criteria***
***λ_max*= maximum eigenvalue**

Consistency Ratio (CR) $$CR = \frac{CI}{RI} = \frac{0.041}{1.49} = 0.027$$

Where ***RI*** = ***Random Consistency Index of a random-like matrix***.

CR values <0.1 are acceptable

METHODOLOGY 3RD STAGE

Performance scores

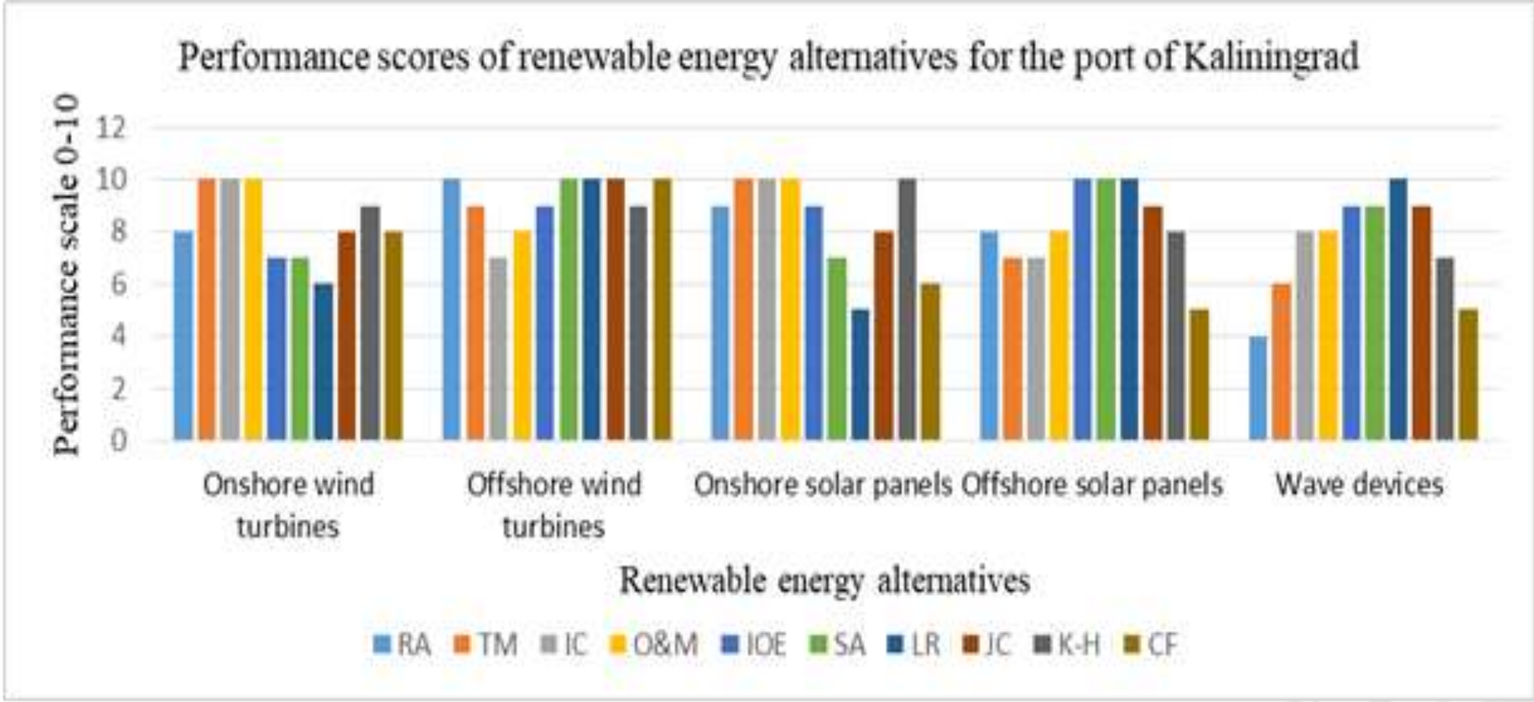
Experts were asked through ***interviews*** to evaluate the performance of each energy option in each evaluation criterion for the case study, taking into consideration the hypothetical question:

"What would be the performance e.g. of first energy option in the first evaluation criterion, if the first energy option is used in the fishery port of Kaliningrad;" *and so on.*

Performance scores of 10 evaluation criteria

Evaluation criteria	Scores	
	0	10
RA	Low and unpredictable	High and predictable
TM	Technology is still relatively new	Technology has been used for a long time
IC	Most expensive	Least expensive
0&M	Most expensive	Least expensive
IOE	Significant impact on the environment	Minor/negligible impact on the environment
SA	Negative public attitude toward specific renewable energy source	Positive public attitude toward specific renewable energy source
LR	No land available/Conflicts with other users	Spacious land available/No conflicts
JC	Few/negligible job opportunities	Substantial job opportunities
K-H	Lack of specialized human resources in the region/country	Availability of specialized human resources in the region/country
CF	Low	High

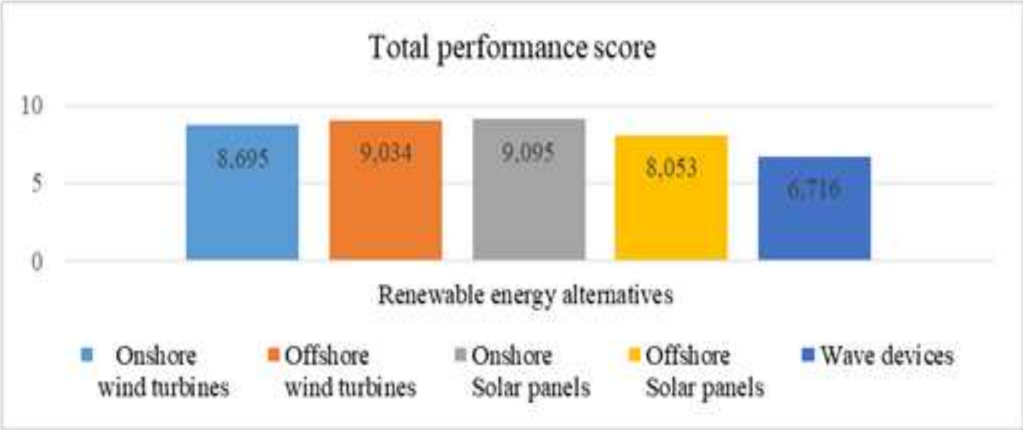
METHODOLOGY 3RD STAGE
Performance scores



METHODOLOGY
Results

Individual overall performance scores of (5) renewable energy technologies

Evaluation Criteria	Weight Factor (%)	Energy alternatives				
		Onshore wind turbines	Offshore wind turbines	Onshore Solar panels	Offshore Solar panels	Wave devices
RA	27.5	2.2	2.75	2.475	2.2	1.1
TM	19.4	1.94	1.746	1.94	1.358	1.164
IC	13.2	1.32	0.924	1.32	0.924	1.056
O&M	13.2	1.32	1.056	1.32	1.056	1.056
IOE	9	0.63	0.81	0.81	0.9	0.81
SA	6.3	0.441	0.63	0.441	0.63	0.567
LR	4.5	0.27	0.45	0.225	0.45	0.45
JC	3.1	0.248	0.31	0.248	0.279	0.279
K-H	2.2	0.198	0.198	0.22	0.176	0.154
CF	1.6	0.128	0.16	0.096	0.08	0.08



CONCLUSIONS

- DSM* provides scores & well-justified classifications for the various RES, which allow interested parties to select the most appropriate energy alternatives.
- Different classifications may arise if the proposed methodology is applied to different marine ports, due to different port characteristics.
- The use of a RES mixture can offer a more comprehensive approach to a long-term energy problem.
- Results are in line with previous studies on the development of alternative energy solutions in the light of the zero-emission port and show a clear trend in this direction.
  - PV: low investment and O&M costs, easily adoptable by ports (*e.g. on the roofs of buildings and warehouses*).
  - WT: mainly offshore, due to land limitations in the port, technology has been used for a long time.
  - Wave devices: depending on conditions in the port.
- The concept of microgrids can encourage marine ports to invest in more environmentally friendly solutions (*e.g. cold ironing, storage solutions, electric vehicles, etc*.)
- DSM can be used for other complicated decision-making issues that include expert's involvement & extensive analysis, as it is extremely flexible & could incorporate a variety of criteria and alternatives.

* Decision Support Model

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Thank YOU

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