

IEEE EPPC Working Group on Energy IEEE ICA “Sustainable Maritime”

Smart and Sustainable ports



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IEEE Sustainable Maritime: Smart and Sustainable ports

Policy document on smart & sustainable ports (IEEE/EPPC/GPPC)

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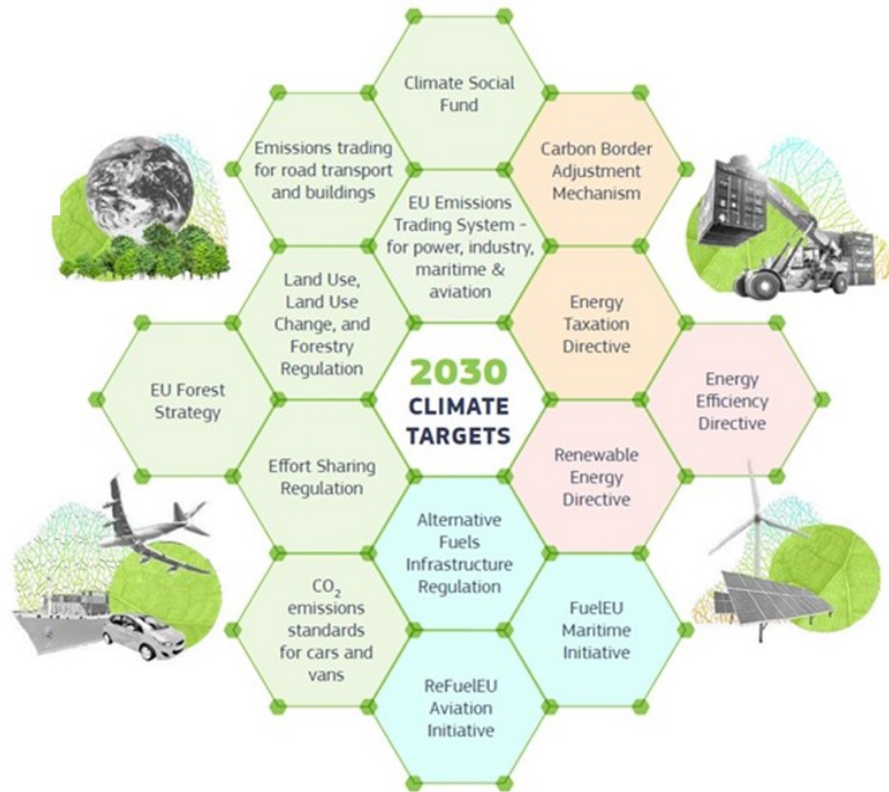
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- The biggest Technical body of engineers (supporting the science and training),
- 423,000 members,
- 160 countries,
- 150 peer reviewed journals,
- 1,800 conferences/year in 95 countries,
- 1,200 standards (e.g. IEEE 802.11: WiFi, IEEE 45: Shipboard installations, IEC/ISO/IEEE 80005: cold ironing)

Facing New challenges

Fit for
55%



Facing New challenges

- ➔ 55% fit package of directives

Documents released on July 14th, 2021 ➔ maritime related

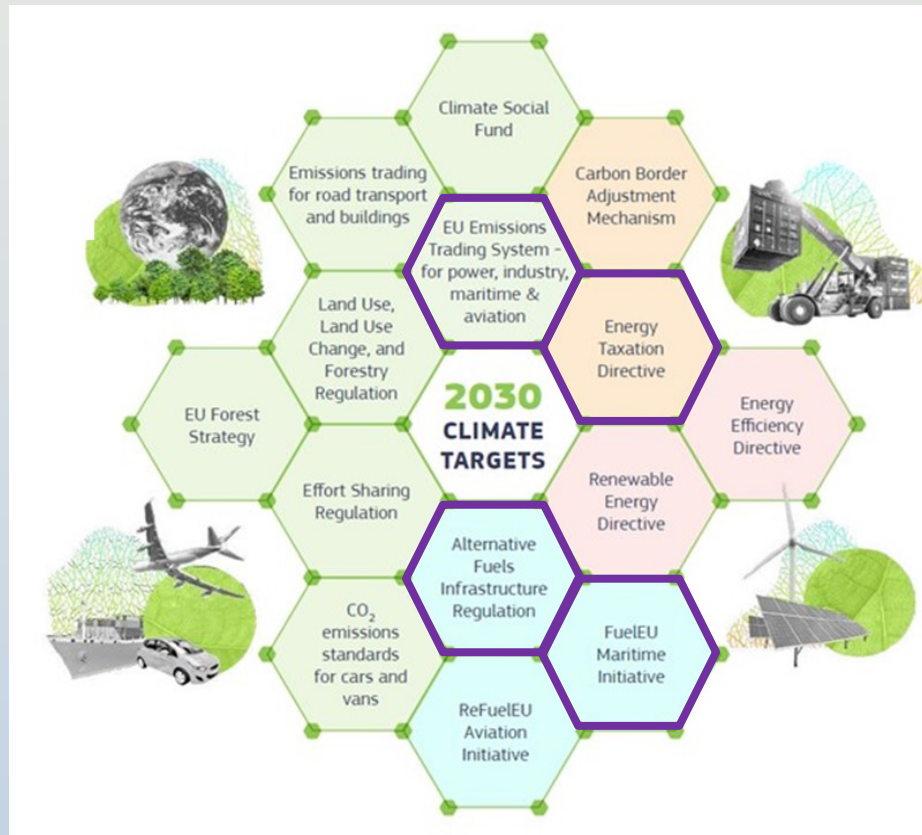
The set of documents-directives released by the European Commission is enlisted below:

- amendment-regulation-co2-emission-standards-cars-vans-with-annexes_en
- amendment-renewable-energy-directive-2030-climate-target-with-annexes_en
- carbon_border_adjustment_mechanism_0
- chapeau_communication
- fueleu_maritime - green_european_maritime_space
- notification-carbon-offsetting-and-reduction-scheme-international-aviation-corsia_en
- proposal_for_a_directive_on_energy_efficiency_recast
- proposal-amendment-effort-sharing-regulation-with-annexes_en
- refueleu_aviation - sustainable_aviation_fuels
- revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0
- revision_of_the_energy_tax_directive_0
- revision_of_the_eu_emission_trading_system_for_aviation
- revision-eu-ets_with-annex_en_0(1)
- revision-market-stability-reserve_with-annex_en
- revision-regulation-ghg-land-use-forestry_with-annex_en(1)
- social-climate-fund_with-annex_en
- strategic_rollout_plan_support_rapid_deployment_of_alternative_fuels_infrastructure

Facing New challenges



Fit for
55%
Maritime
sector
related



Mandate

AFIR+FuelEuMaritime (09/2023): electric interconnection of ships in ports 1/1/2030

Electrification is considered as the ultimate alternative towards green shipping

Facing New challenges in ports

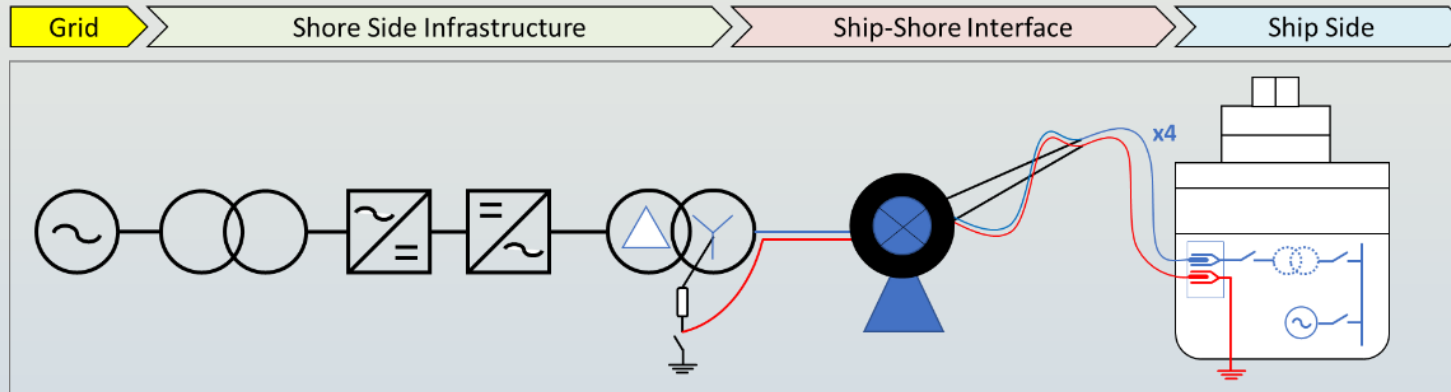
Electrification



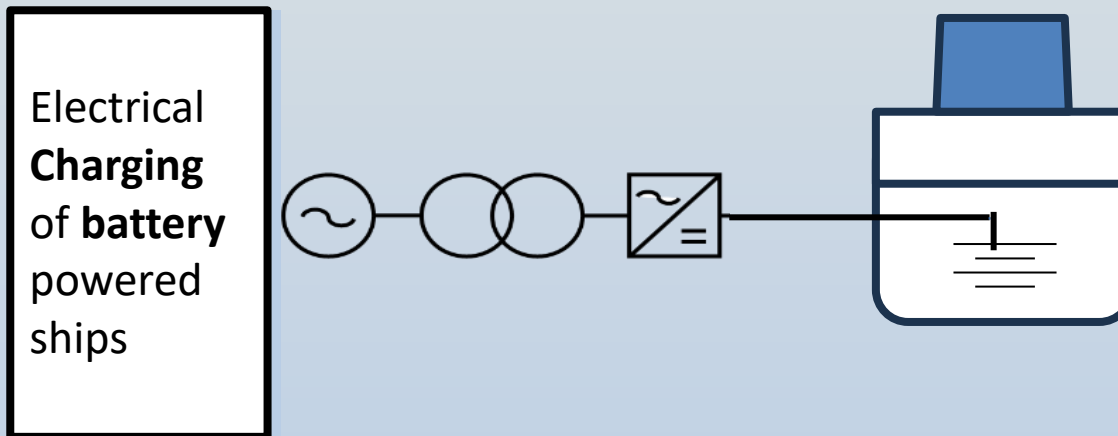
Smart
&
sustainable

Viable, Profitable, Long-lasting,...

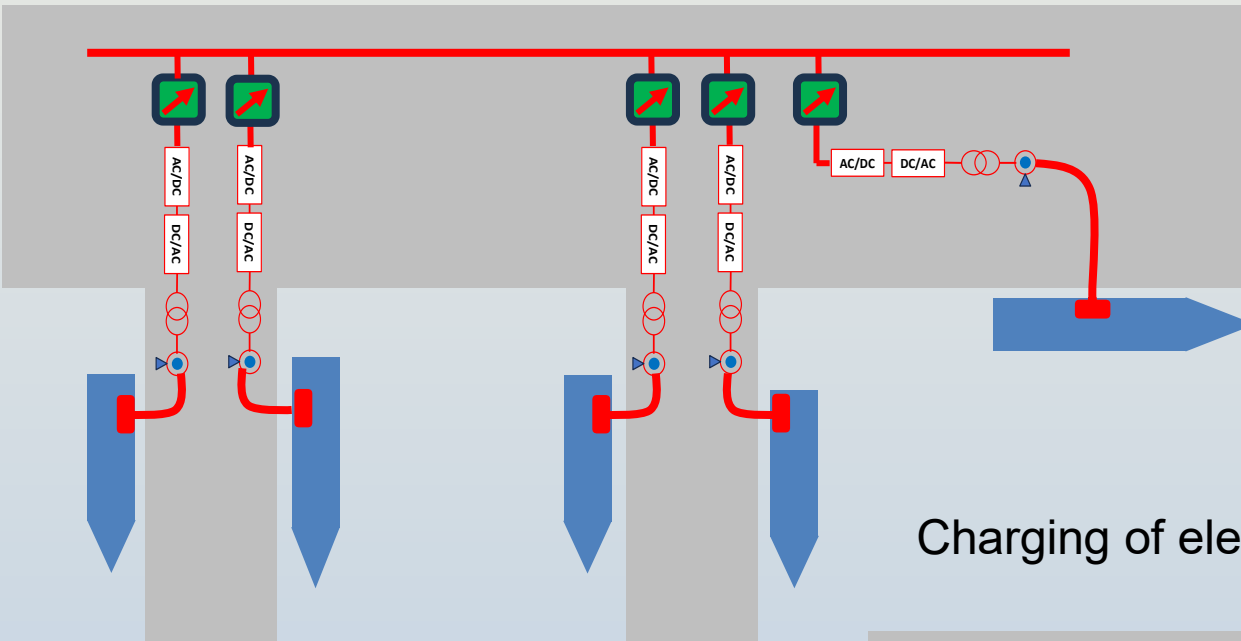
The **starting point**: Electric power interconnection between ships and shore



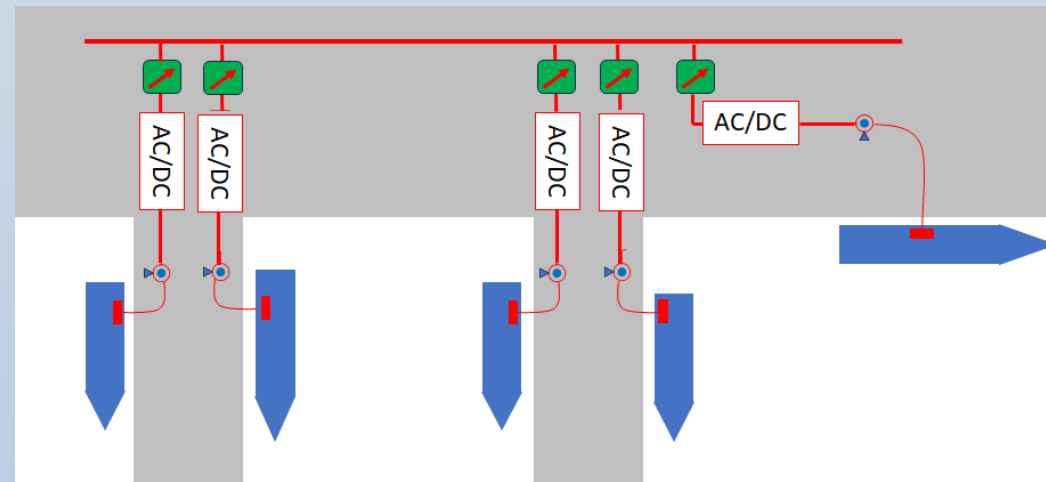
Cold ironing
(Shore Side
Electricity or
Onshore
Power
Supply)



Shore side electricity (cold ironing)



Charging of electric (battery powered) ships



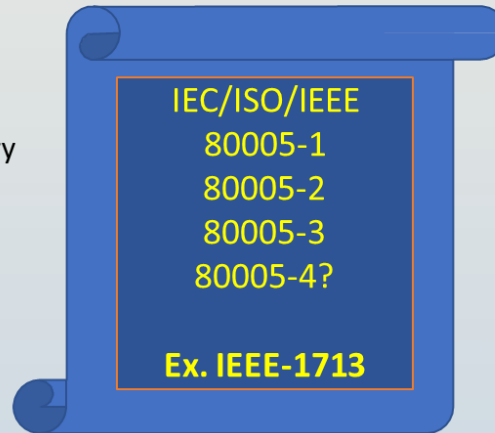
Standardization of shore-to-ship interconnection

List of standards related to 80005 series

IEC 60034 Rotating machinery
IEC 60090-151-2001 Electrotechnical Vocabulary
IEC 60076 Power transformers IEC
60079 Explosive atmospheres
IEC 60092-101 Electrical Installations in ships

IEC 60092-201 Ship System Design
IEC 60092-301 Ship Equipment
IEC 60092-503 Ship special features
IEC 60092-504 Automation Control & Instrumentation
IEC 60146-11-2000 Static Frequency converters
IEC 60332-1-2 Tests on electric and optical fibre cables under fire conditions
IEC 60364-4-41 LV electrical Installations

Amendments of IEC 80005-1,-3,-4 (DC)



MoU
IEEE
ISO
IEC

IEC 60502-2 Power cables
IEC 60947-5-1 Low voltage switchgear
IEC 61363-1 Procedures for calculating short-circuit currents
IEC 61936-1 Power installations exceeding 1 kV ac
IEC 62271-200 High voltage switchgear and control-gear
IEC 62613-2 Plugs-sockets, outlets and ship couplers for high voltage shore connection systems

IEEE Recommended Practice for Electrical Installations on Shipboard

IEEE 45.1: Design
IEEE 45.2: Automation & Control
IEEE 45.3: Systems Engineering
IEEE 45.4: Marine Sector & Mission Systems
IEEE 45.5: Safety Considerations
IEEE 45.6: Electrical Testing
IEEE 45.7: AC Switchboards
IEEE 45.8: Cable Systems

Current status of electric Grids



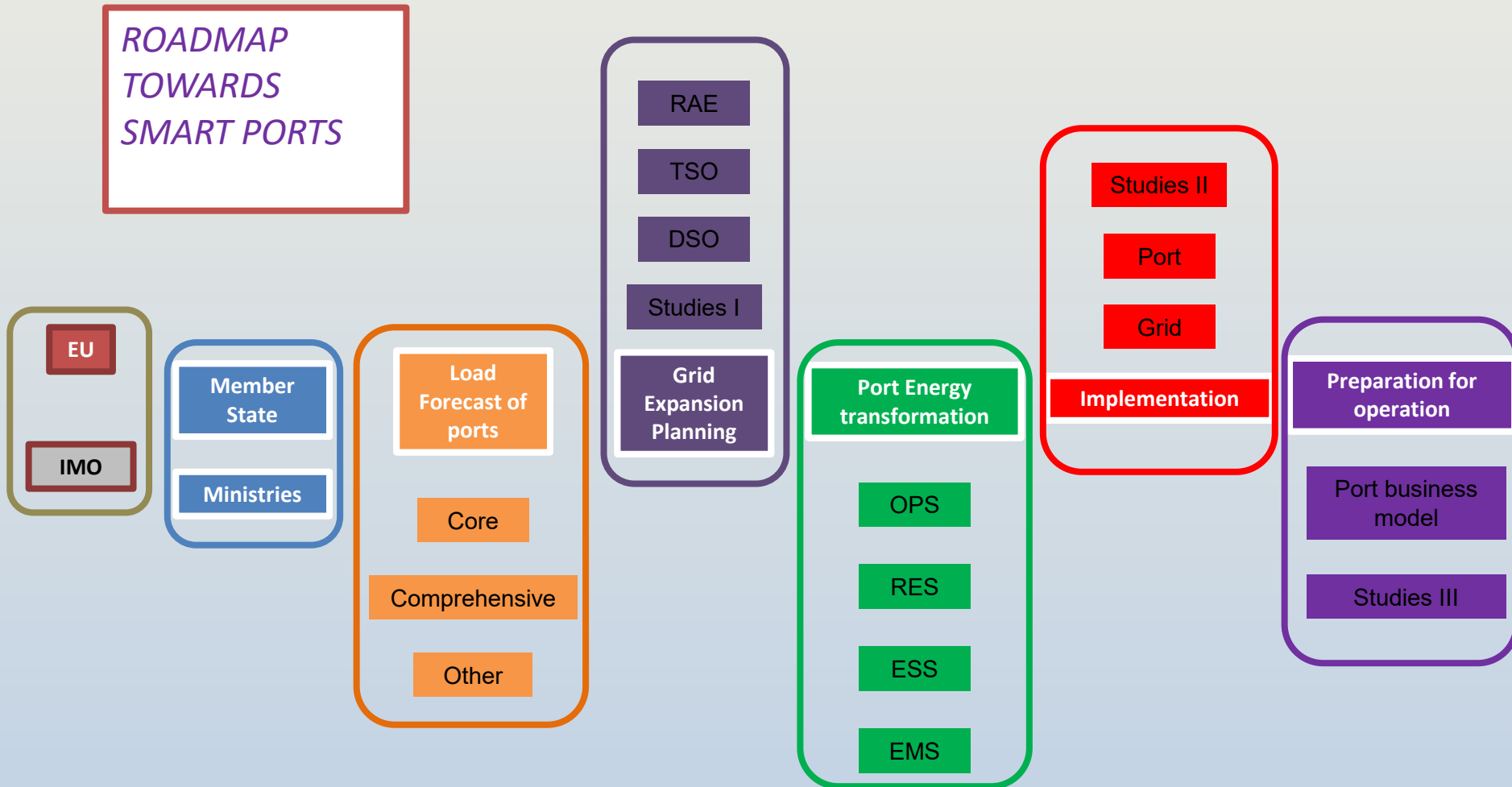
Electric Grids in the Decarbonization era



Increased demands for green electric energy

Port Electrification

ROADMAP TOWARDS SMART PORTS



Analysis of Roadmap

R O A D M A P

1. EU fit-for-55% (2030→ 2050)+ 2017/352/EU+2019/944/EU
2. Ministries of a) Energy + Environment b) Maritime Transport +...
3. Estimation of peak power demands of ports (load forecasting)
4. Accurate load forecasting of ports (case by case, all loads included)
 1. Core ports
 2. Ports of the comprehensive network
 3. Other ports
 1. Mainland
 2. Islands (electrically interconnected)
 3. Islands (electrically non-interconnected)
5. Grid expansion planning
 1. DSO (5-year development plan)
 1. Technical issues - phase 1: planning+design
 2. Regulatory issues (?)
 2. TSO (10-year development plan)
6. Port energy transformation
 1. OPS planning
 2. Energy transformation planning
7. Implementation
 1. Grid expansion
 2. Port infrastructure procurement + installation
 3. Investigation of technical issues - phase 2: before the operation
 4. Commissioning and testing
8. Preparation for Operation
 1. Establishment of port business model (energy market)
 2. Investigation of technical issues
 3. Training
 4. Operation

Following the Roadmap - Further Challenges

1. **Planning** Grid expansion

1. Future Peak Power and energy demands
2. Stability issues (frequency, voltage)
3. Power quality (e.g. harmonic distortion, EMT- transients)
4. Resilience
5. Deployment of RES+batteries

2. **SSE ship ID**

3. **SSE port ID**

4. **Power Quality** problems

1. Harmonic distortion
 1. Frequency converters
 2. LEDs
 3. Cranes
2. Inrush and sympathetic inrush
 1. Isolation transformer(s) energization
 2. Centralized configuration of frequency converters + many isolation transformers in parallel
3. Earthing, protection, equipotential bonding issues, corrosion

5. **DC and inductive charging**

6. **Port demand management + flexibility**

1. load shedding,
2. operation in economy mode: exploitation of RES, ESS

7. **Ship demand management** (load shedding, economy mode)

8. **Operating models** of ports and ships in the electric market

9. **Regulatory issues**, pricing policy, tax exemptions

10. **Re-cycling policy** (esp. batteries)

11. **Training and Education** (port electrical engineering)

The port networks must be (in brief)

Robust,
Resilient,
Reliable and
Flexible

The port must

- > help the energy supply chain
- > Comply with energy market

Holistic Energy Upgrade of Ports

- Cold Ironing (Ship-to-Shore interconnection):
 - Ports in Europe (projects: ELEMED, EALING, CIPORT, ALFION)
- Charging of battery based electric/hybrid waterborne vessels
- Energy storage (buffering, swapping)
- RES deployment
- Electric Vehicle charging stations
- Reefer power supply
- Smart LED Lighting
- Regenerative crane braking
- Energy management system
-Further steps



The *Proteus* Plan

Holistic Energy Upgrade of Ports

Towards smart green ports

- Long-term contracts
- Short-term agreements
- Emission trading
- Subsidies/discounts



- Warm/cold lighting
- Smart lighting
- Remote control/monitoring
- Lifi

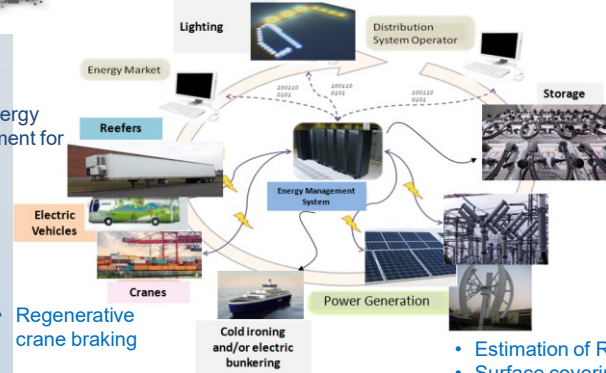
- Energy management
- Operation monitoring
- Fault identification
- Environmental Protection
- Cost reduction-Service quality
- Energy pricing

- Smart energy management for reefers



- Parking under P/V
- Storage

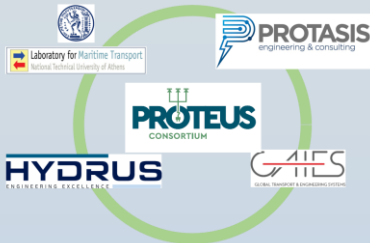
- Regenerative crane braking



- Cheap energy purchase
- RES energy storage
- Peak shaving
- Battery swapping for electric vessels
- Electric cars

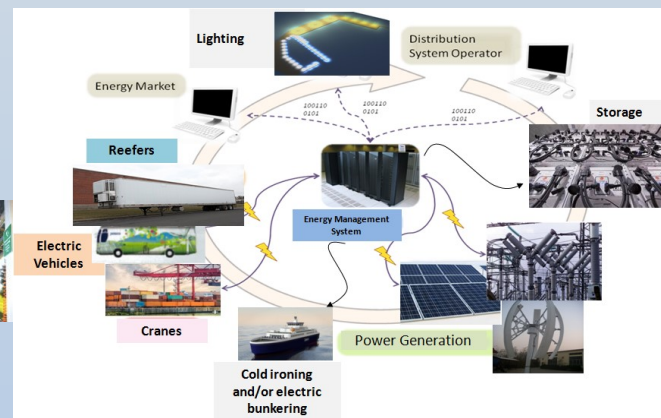
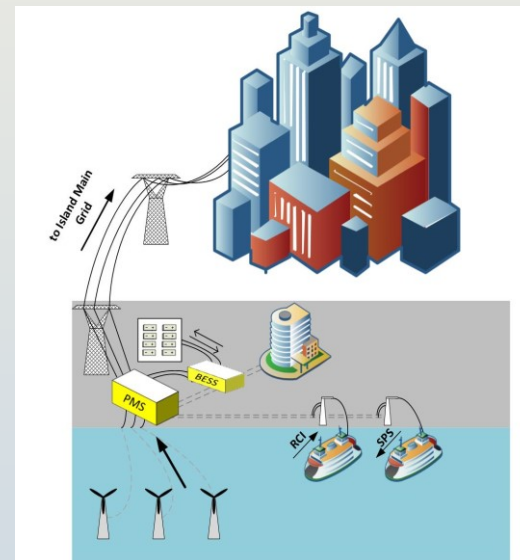
- Estimation of RES potential
- Surface covering

- IEC 80005-1/2/3
- Capacity increase/redundancy



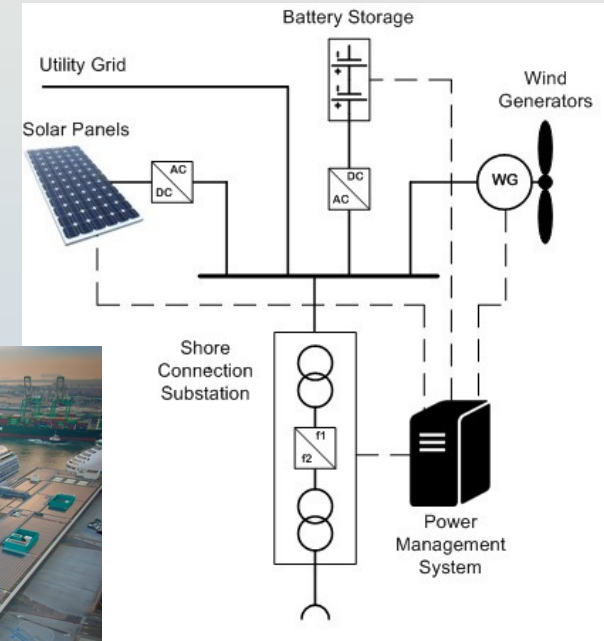
The smart & sustainable port

- Ship-to-shore interconnection(cold ironing)
 +
- **Smart grids of fairly large power capacity (flexibility)**
 - Charging battery based ships with electric propulsion
 - Electric **vehicle charging** stations
 - Interconnect off-shore or near-shore **RES**
 - **Reverse cold ironing** by green ships
 - Storage for peak shaving ḡ saving excesses of power and/or battery swapping or **cloud storage** (sharing electric energy storage capacity in win-win schemes)
 - Sophisticated **Energy Management Systems** → sustainable port **Grids**
 - **Participation in the Energy Market**



The smart & sustainable port

Deployment of **PV's** and small scale **wind generator** in port areas



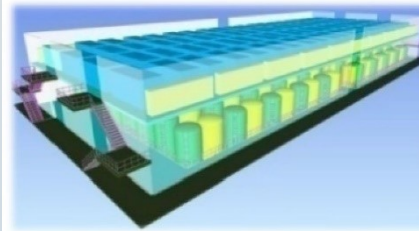
PV installation in
P.o.L.A. (USA)

The smart & sustainable port

Utilization of Energy Storage Systems at the port area



200MW/800MWh VRFB Project



Location: Dalian City, CHINA

The first floor :	Electrolyte tank
The second floor:	Power unit + control unit
The third floor:	PCS + Transformer

Not only Li-ion but **flow batteries** (e.g. VRB's) too

ESS can be used to store **off-peak energy** from the Grid, or energy from Renewable Sources **or** energy recovered from Cranes. [**Energy buffering**]

Energy Storage is a significant feature in designing a port's energy management system that can give the opportunity to the port to **participate in the energy market**.

Support to ships based on batteries [**Battery swapping**]

The smart & sustainable port

Extending *Smart – grids* concept

Energy buffering
Battery swapping

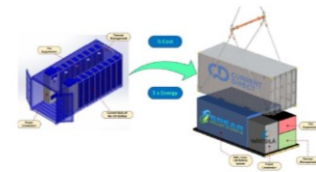


Flow Batteries + Cold Ironed Ships



Pillars of the project

- Swappable containerized waterborne transport Li-Ion battery
- EaaS (Energy as a Service) Platform



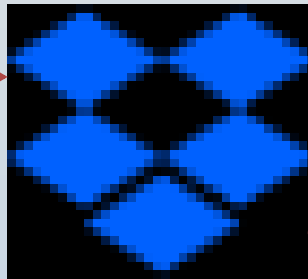
The smart & sustainable port

Future steps: following the steps of the evolution in computer systems

Cloud computing



Cloud data storage

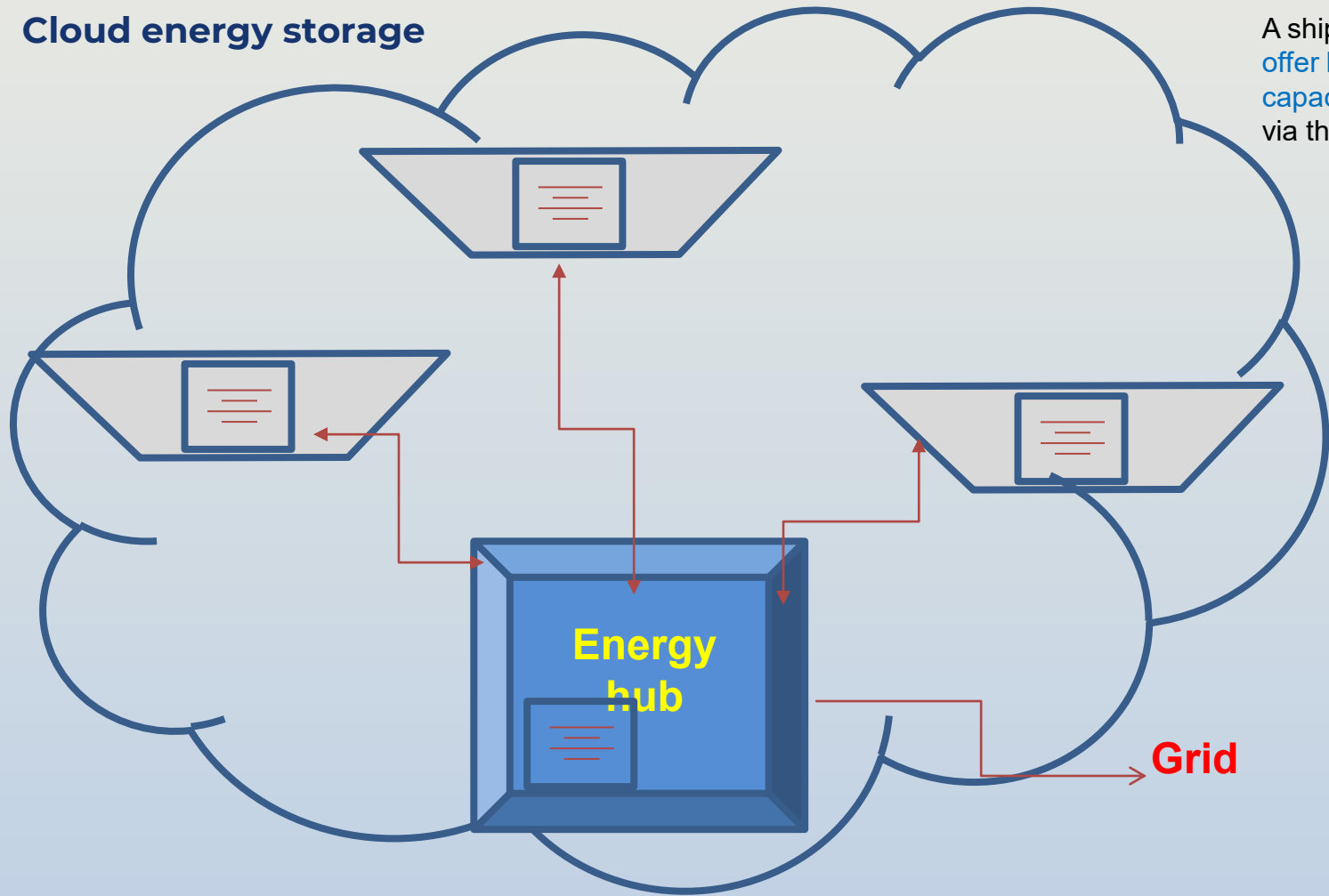


Cloud energy storage



The smart & sustainable port

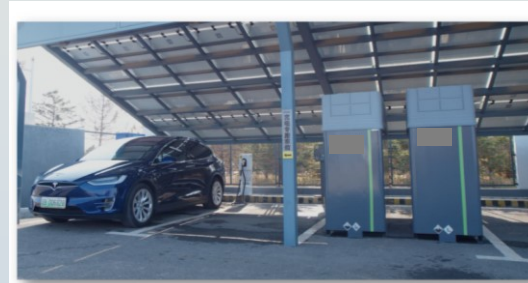
Cloud energy storage



A ship at berth can offer her storing capacity to the Grid via the port

Combination of parking/charging stations for EV's and PV's

- Parking/charging under P/V
- +
- Storage



Electric Vehicles of the ports



The smart & sustainable port

Reefers



Reefers have significant **thermal inertia**. When switched off they can hold temperature for relatively **long time**.

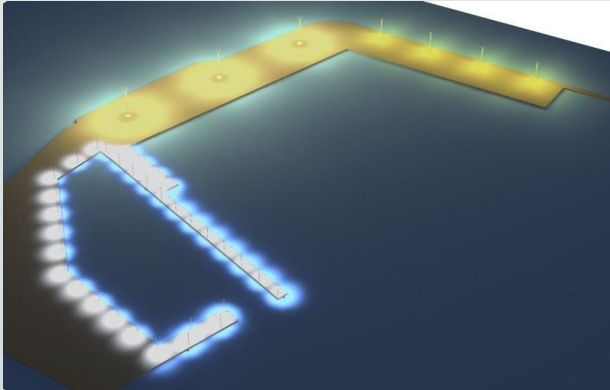
Energy conservation by Reefers is significant in designing a port's energy management system

*Small increase of temperature despite the long switching-off time intervals
(~1.5°C/9h)*

The smart & sustainable port

Lighting

LED Lighting

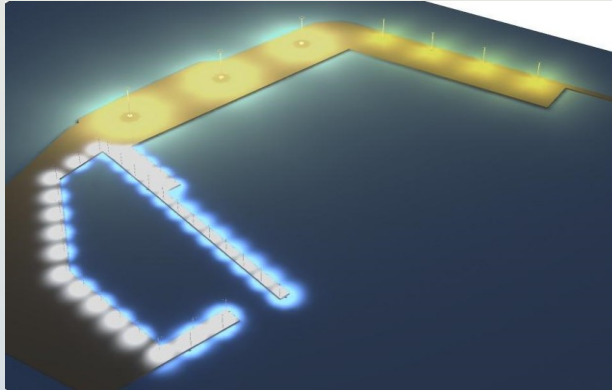


Port of Killini	Energy Consumption of LED lamps (kW)	Energy Consumption of Conventional lamps (kW)	Energy saving
Main Port	160.5	240	31.25 %
North Port	50.0	80	36.8 %
Fishing Docks	30.2	80	40.8 %

- The introduction of LED technology in ports for dock lighting has been a proven **low power consumption** alternative.
- **Different light** colors (**hot** or **cold**) are suitable for different applications.
- Attention must be paid on how to off-set the **harmonic distortion** and the high reactive power demand.
- LED lamp controls can be integrated in a **smart lighting** system that can **optimize the luminance/light efficiency** versus the cost of energy.

The smart & sustainable port

LED Lighting



Lighting

Port of Killini	Energy Consumption of LED lamps (kW)	Energy Consumption of Conventional lamps (kW)	Energy saving
Main Port	160.5	240	31.25 %
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Fishing Docks	30.2	80	40.8 %

Communication and Control → Li-Fi

- **Multiusers**
- **Terabit/s**
- optical wireless capacity **two orders** of magnitude higher than 5G

Benefits of LiFi



Military Grade Security



Ultra Low Latency



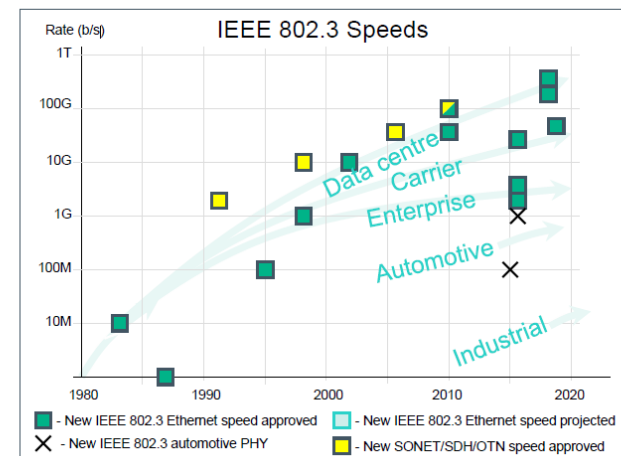
RF-Free Wireless Communications



Quality of Connection

802.11

Straightforward to integrate



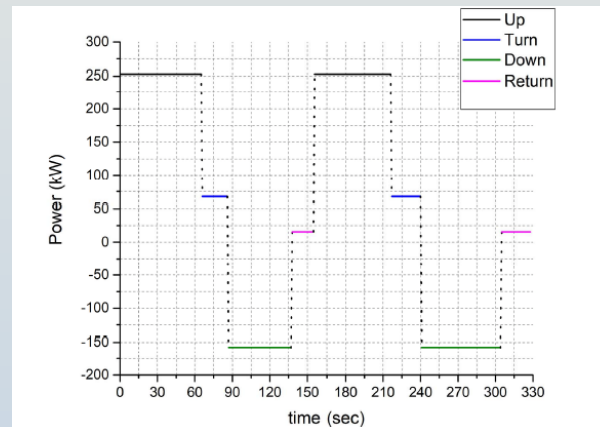
Evolution of speed in data transmission

The smart & sustainable port

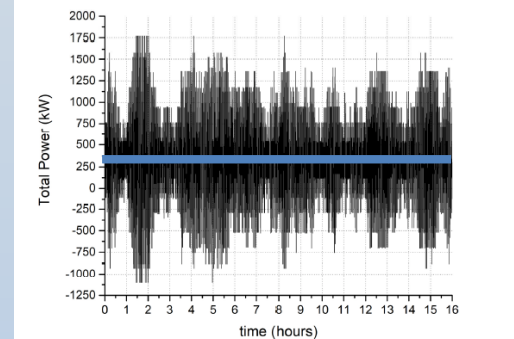


Cranes

Cranes with regenerative braking can have a significant **energy recovery** factor



Operating profile (two full cycles of operation) of **one** single port crane.



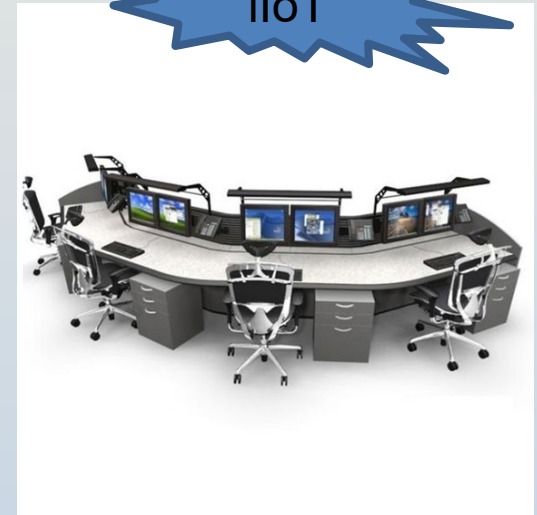
The smart & sustainable port

Port Power Management System

A Port Power Management System (P-PMS) can **improve the overall efficiency** of the system since it comprise multiple functionalities & features (**SCADA**):

- **Electric Network Monitoring – Protection & Control**
- **Power Generation Management**
- **Shore to Ship connection Management**
- **Energy Storage Management**
- **Billing** System
- **Asset** Management & **Work Force** Management
- **Incident** Management
- Automatic **Meter** Reading
- **Energy Meter** Data Management
- **Water & Gas Meter** Data Management
- **Lighting** Control & Monitoring
- **EV Charging** Management

iloT



Cyber-security



The smart & sustainable port

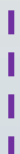
Maritime electricity market

Operating Schemes

Electricity Suppliers

Electricity Supplier 1

Electricity Supplier 2



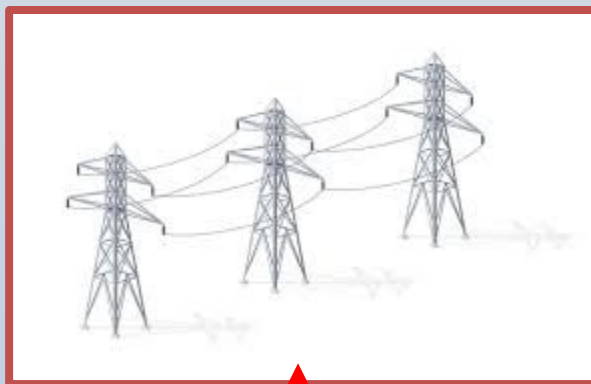
Electricity Supplier N

National Grid (TS,DS)



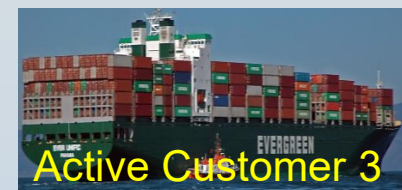
Smart metering

Port Grid

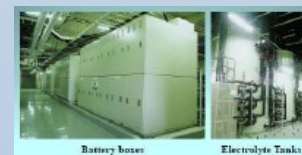


Smart metering

Aggregator(s)



Port Energy Source
Aggregator



To step further....

More standards??

- DC interconnection
- Power quality (distortion, inrush, sympathetic inrush load shedding/switching transients)
- Earthing in ports
- Corrosion in ports
- Smart grids + special type distribution networks of large power capacity
- Grid forming power converters with active front ends enabling bidirectional energy transactions + virtual inertia
- Zonal distribution networks in ports
- Smart lighting standards
- Li-fi standards

To step further....

Training/Education

Training – Port electrical engineering

- CPD programs
- MSc Program
 - Fundamental environmental issues
 - Power Transformers
 - Rotating machinery
 - Power converters
 - Synchronization & parallel operation
 - Power quality
 - Protection
 - Earthing
 - High Voltage technology
 - RES (PV's)
 - Batteries
 - Smart grids

To step further....
Training/Education

X THE PLACE OF USEFUL LEARNING

Continuing Professional Development (CPD)

Maritime Electrification



University of
Strathclyde
Glasgow



UNIVERSITY of STRATHCLYDE
**MARITIME SAFETY
RESEARCH CENTRE**

Case study: Port of Igoumenitsa (OLIG s.a.)

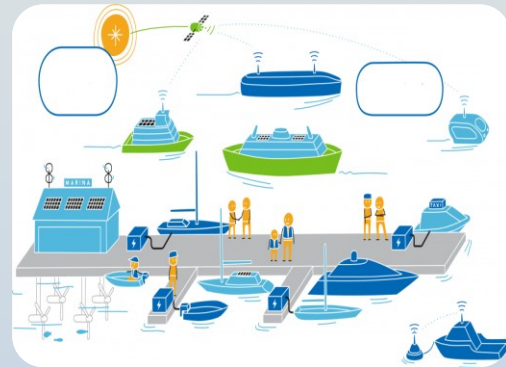




ALFION Alternative Fuel Implementation in IgOumenitsa Port

CEF-Transport-2019 – General Envelope» funding studies (up to FEED) for:

- **OPS/SSE (cold ironing)**
- **Battery swapping**
- **Electric vehicle charging stations**
- **Energy storage systems**
- **Energy management system platform**



Main Connections of the port of Igoumenitsa +



Series of possible synergies with Italian ports and other ports in the Mediterranean

- Cultivate further the maritime interconnections
- Establish a common regulatory framework and tariff policy
- Reinforce further the electric power interconnection and the energy transactions

ROADMAP TOWARDS SMART PORTS

EU

IMO

Member
State

Ministries

Load
Forecast of
ports

Core

Comprehensive

Other

RAE

TSO

DSO

Studies I

Grid
Expansion
Planning

Port Energy
transformation

OPS

RES

ESS

EMS

Studies II

Port

Grid

Implementation

Preparation for
operation

Port business
model

Studies III

ACKNOWLEDGMENTS



IEEE/EPPC



The European Climate Infrastructure and Environment Executive Agency (CINEA) for funding the projects



(CIPORT: Cold Ironing in the Port of Piraeus - Taking the Final step)



(CENTAVROS: Connectivity Infrastructure Upgrade and Environmental Viability for the Port of Volos)



(ALFION: **AL**ternative **Fuel** implementation in **IgOumeNitsa** port)

ALFION - INFRA



(EALING: **E**uropean flagship **A**ction for **coLd** iron**ING** in ports)



(ELEMED: **E**lectrifying the **E**astern **MED**iterranean Corridor)

Acknowledge the contributions from discussions and collaboration

To probe further

IEEE Electrification Magazine special issue (March 2023): *Smart ports*

Upcoming Related events – Support info

- **Roundtable**

“Operating models of ports and ships in the open electric market”

Invited panelists from DGENER and DGMOVE, (Eurelectric, ACER, NTSO-e, EU-DSO)

- **Webinar**

“Means of sustainable electrification of ships and ports in view of decarbonisation”.

Ongoing Amendments of IEC 80005-1,-3,-4 (DC), IEEE 45.1, 45.2, 45.7 (+DC) → 2023

Improvement of MRV-Thetis: collecting data of demands at berth

Electricity is the **sole alternative fuel** with a **plethora** of readily available *standards, rules, guidelines, know-how on*

planning, design, operation, control

We must help it succeed



Thank you very much for your interest

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