QUICK-REFERENCE GUIDE FOR DEVELOPMENT OF SHORE-SIDE ELECTRICITY/ OPS IN MARITIME PORTS

EMSA

The SSE/OPS Quick-Reference Guide provides a step-by-step technical guide for how to plan for, install, and use Shore-Side Electricity (SSE), with a focus on Onshore Power Supply (OPS). It provides pointers for all port stakeholders to help bring SSE/OPS from the drawing board to the berth, and from the plan to the plug. Developed by EMSA in close cooperation with the European Sea Ports Organisation (ESPO) and experts from port authorities and the wider port sector, this guide is based on the gathered experience in European ports on how to best introduce shore-side electricity for ships at berth. Together with the EMSA SSE Guidance, the guide covers the key steps towards safe, cost-effective, and future-proof OPS.

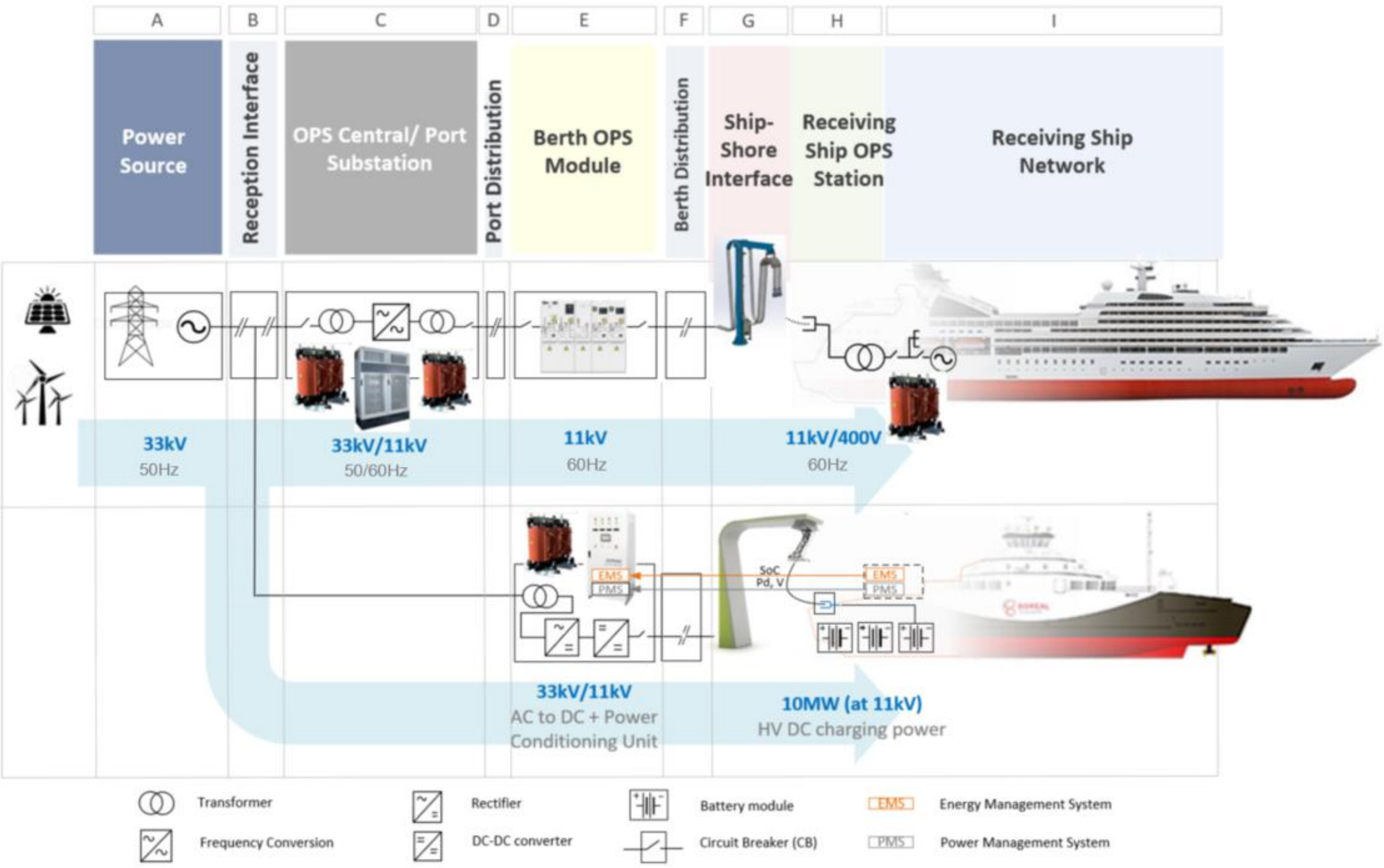
WHOM DOES THE GUIDE ADDRESS?
Port Authorities and Administrations, operators and other stakeholders involved in OPS development/operation

WHAT DOES THIS GUIDE TELL YOU?
High-level baseline best practices in the preparation, implementation, and control of shore-side electricity/OPS infrastructure projects

KEY DEFINITIONS

- **OPS**: Onshore Power Supply – the supply of electrical power to ships at berth, directly to the receiving ship, from a shore-side electrical power source, at a given voltage and frequency, feeding the onboard main distribution switchboard. OPS replaces primarily the onboard electricity generation from auxiliary generators.
- **SBC:** Shore-side Battery Charging – Charging of onboard Battery Energy Storage Systems (BESS) by shore power supply, either AC or DC, using a connection protocol suitable for the specific BESS onboard, at a specified charging power.

1. GENERAL The diagram below identifies the key infrastructure elements for SSE, both for OPS and SBC arrangements. The key elements are identified from a generic perspective. Electrical power infrastructure can follow a variety of different architecture layouts. The legend identifies the key infrastructure/equipment elements:



A. Power Source - A shore connection system can be supplied either from the national grid or a local port internal distributed energy system, through a power frequency conversion or not, depending on the application.

B. Reception Interface – Connection of the Port Grid to the external upstream utility grid. Electricity custody transfer

C. OPS Central/ Substation – including Step-Down Transformer, Frequency Converter, Main Circuit Breaker and Earth Switch

D. Port Distribution Network – Port-scale distribution (either above or underground)

E. Berth OPS Module – Local OPS Module, close to supply point at berth – Shore-side protection transformer, Frequency Converter. Step-down/ Protection Transformation for required ship voltage supply.

F. Berth Distribution Network – Berth-scale distribution (close to OPS supply shore connection)

G. Ship-Shore Interface - Shore-to-ship connection, interface, and control equipment (cable reel, sockets, communication and control wires, earth relays) – All mechanisms to ensure compatibility, connectivity and communication included in the interface.

H. Receiving Ship OPS Station- Circuit breaker and onboard receiving earth switch. Where applicable (if ship’s voltage is different from shore connection voltage) an onboard transformer to adjust the high voltage electricity to the ship’s main switchboard voltage; this transformer is preferably located near the main switchboard in the engine room.

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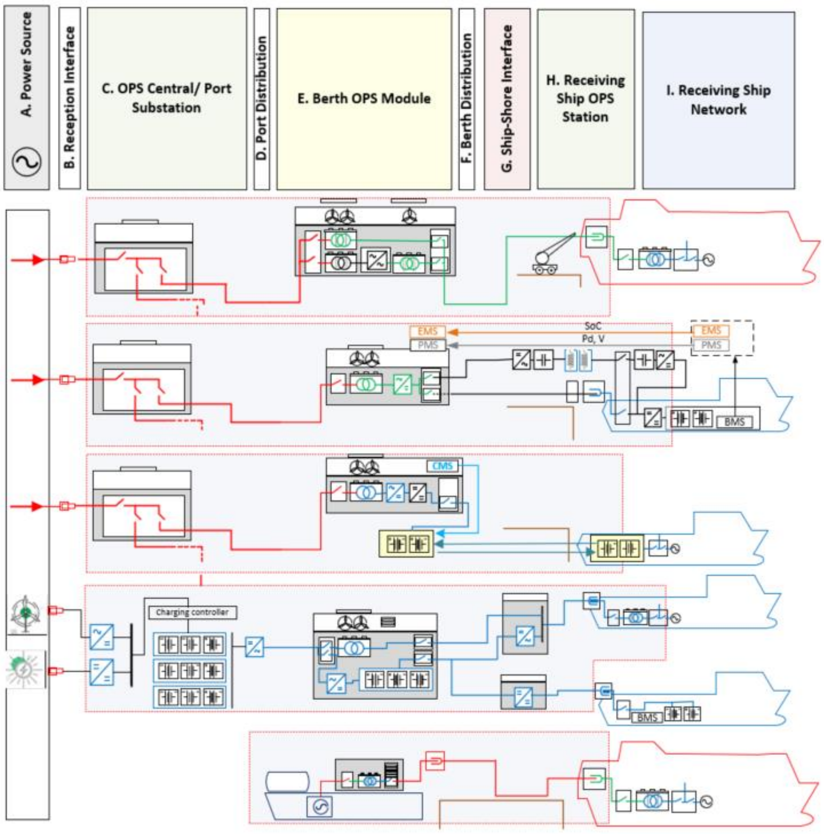
2. SSE TYPES The diagram below identifies different types of SSE arrangements. The key elements are identified in a generic arrangement and the actual situation will vary between ports, individual installations, and different user/operational requirements. Electrical power infrastructure can follow a variety of different architecture layouts. The legend identifies the key infrastructure/equipment elements.



OPS is the supply of electrical power across the ship-shore interface, in AC or DC, HV or LV, directly to the ship's main distribution switchboard, in replacement of onboard electrical power generation.

Onshore Power Supply (OPS)

SBC is the supply of electrical power across the ship-shore interface, in AC or DC, HV or LV, with the objective of charging Electrical Energy Storage (EES) units onboard, involving power and battery management ship-shore interconnectivity.

Shore side Battery Charging (SBC)

BS represents the swapping of modular Electrical Energy Storage (EES) systems between ship and shore, where a charged modular unit is embarked and connected onboard, in replacement of na identical/ compatible unit to be charged at shoreside.

Battery Swapping (BS)

SPB is the use of Battery Bank systems to provide energy for SSE services, when used as a main power source. Power Banking can be either 1) from shore-to-ship, with EES ashore and otherwise standard OPS/ SBC connection or 2) via embarkation and onboard connection of modular EES.

Shore side Power Banking (SPB)

Power Generation, is the combination of microgeneration power solutions arranged in such a manner that are used in direct supply of electricity to SSE services.

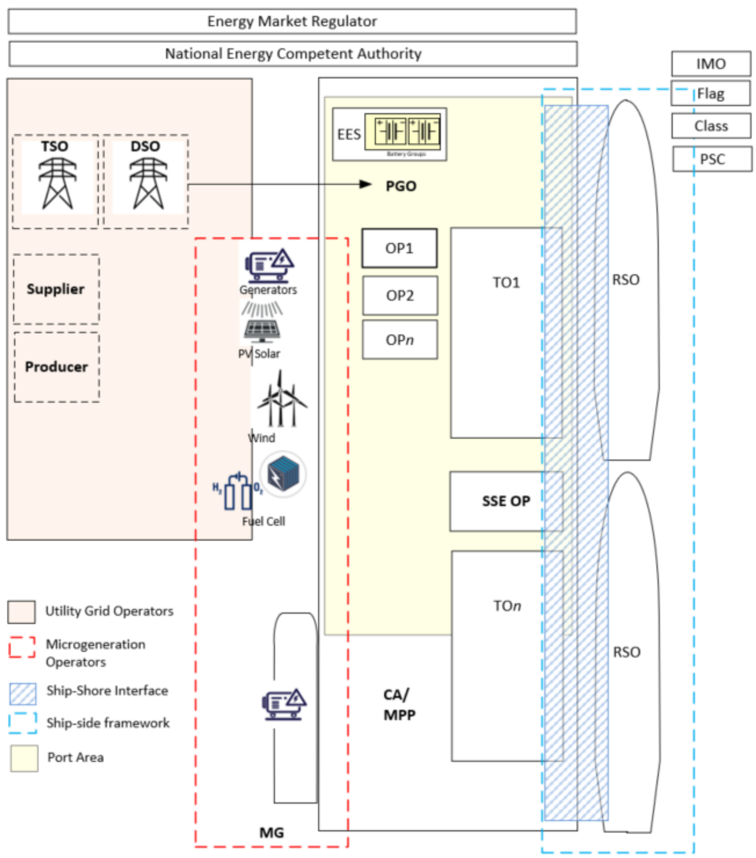
Port Generation (PG)

LEGEND

Transformer	BMS	Battery Management System	Inverter	Cooling	Rectifier	PV Energy Source	Circuit Breaker (CB)	Battery module	Induction Coils
Frequency Conversion	EMS	Energy Management System	Parallel socket-plug connections LV – feeder CBs		DC-DC converter	Wind Generator	Mobile shore-side Cable Management System (mobile CMS)	Battery bank	Capacitor – Capacitance Compensation (inductive charging)
	PMS	Power Management System							

3. STAKEHOLDERS Relevant stakeholders can be identified playing a role in different stages of SSE infrastructure projects. These are presented below, in a non-exhaustive list. Central reference is made to the EU Regulation 2017/352 (Port Services Regulation), which includes within its scope the provision of shore-power in ports as a port service. Different combinations and port-specific arrangements are possible and both diagram and table below include generic references to possible stakeholders in SSE. As different port management arrangements are possible, it is important to adapt/interpret the table/diagram below with due consideration for this fact.

Stakeholders		Responsibilities in SSE context
TSO	Transmission System Operator	Transmission of electrical power at national/regional level, between generation plants (upstream) and distribution (downstream)
DSO	Distribution System Operator	Maintenance of both short- and long-term capability of equipment, installations, and networks to supply electricity in a continuous and reliable way while meeting the quality requirements in force.
CA/ MBP	(Port) Competent Authority/ Management Body of the Port	Ref. to Regulation 2017/352 - Port Services Regulation Articles 2(3) and 2(5) - organisation, administration, and management of the port infrastructure and one or more of the following tasks in the port concerned: the coordination and management of port traffic, the coordination and control of the activities of the operators.
RSO	Receiving Ship Operator	SSE Electricity ship consumer at berth, responsible to ensure interoperability and interconnectivity on ship-side. 1st connection certification and maintenance of conditions for connectivity. Responsible for keeping load
OP	Intra-Port Operator	Port Operators/ Port Service Operators, responsible for maintenance of consumer side protection devices and electrical safety, in line with Intra-port electricity electrical grid requirements.
MG	Microgeneration	Any operator developing and operating units of microgeneration of electricity, integrated within the port, supplying electrical power to the Port Grid
TO	Terminal Operator	Management and operation of Terminal Grids, dedicated to the terminal operation. Development, management, and operation of terminal based SSE systems. responsible for electrical Safety of Terminal Grids.
PGO	Port Grid Operator	Management, development, and operation of intra-port electrical power grid, including SSE/OPS/SBS grid interface infrastructure.
EES	Electrical Energy Storage	Management, development, and operation of intra-port electrical power grid, including SSE/OPS/SBS grid interface infrastructure.
SSE OP	SSE Operator	Provision of electrical power to ships at berth, on OPS or SBC, AC or DC, including maintenance, development, and operation of SSE equipment
PSC	Port State Control	Verification/enforcement of compliance of RSO statutory obligations, remarkably in context of safety, including safety and certification of SSE equipment, onboard.
Flag	Flag State	
Class	Classification Society	Third-party verification of RSO statutory responsibilities, in particular in the context of safety, including SSE equipment safety certification.
Other	International Standardization Bodies	Definition of standard technical requirements for SSE interconnectivity and interoperability.
	Regulator/ Energy Competent Authority	Definition of minimum requirements to ensure safe and integrated deployment and operation by electrical power grid operators, including in particular those in operation of SSE infrastructure.



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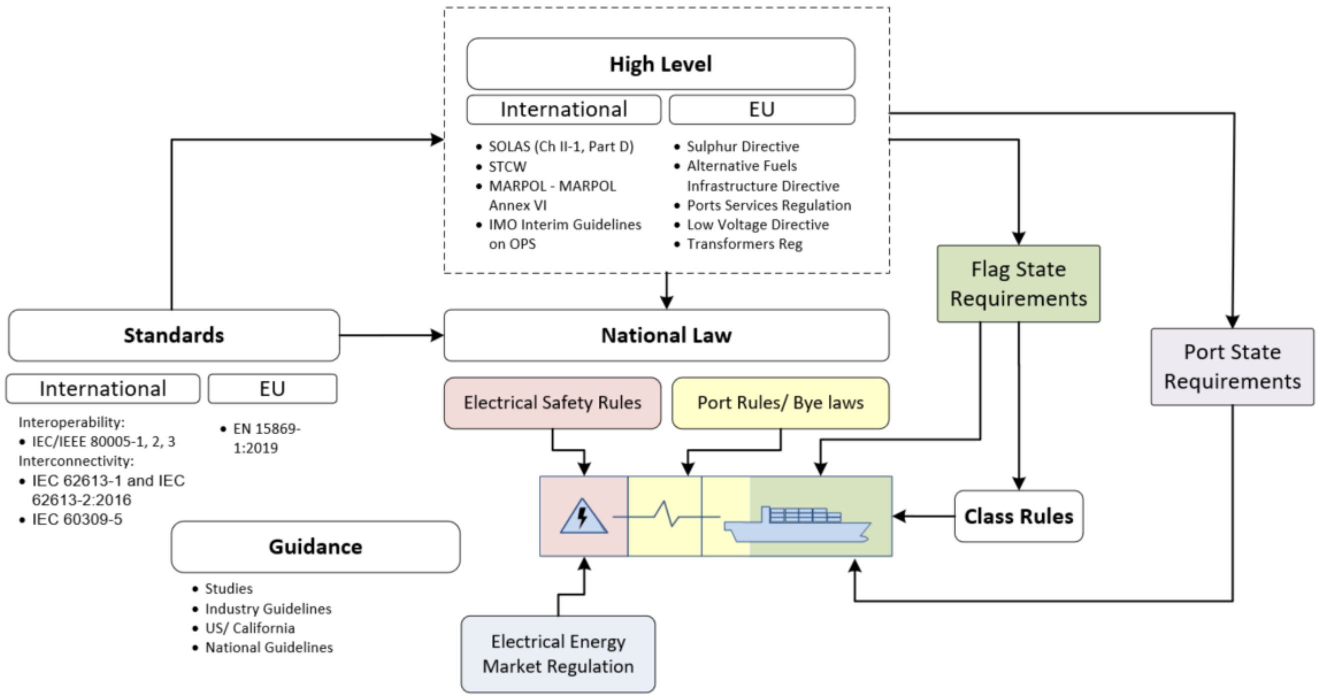
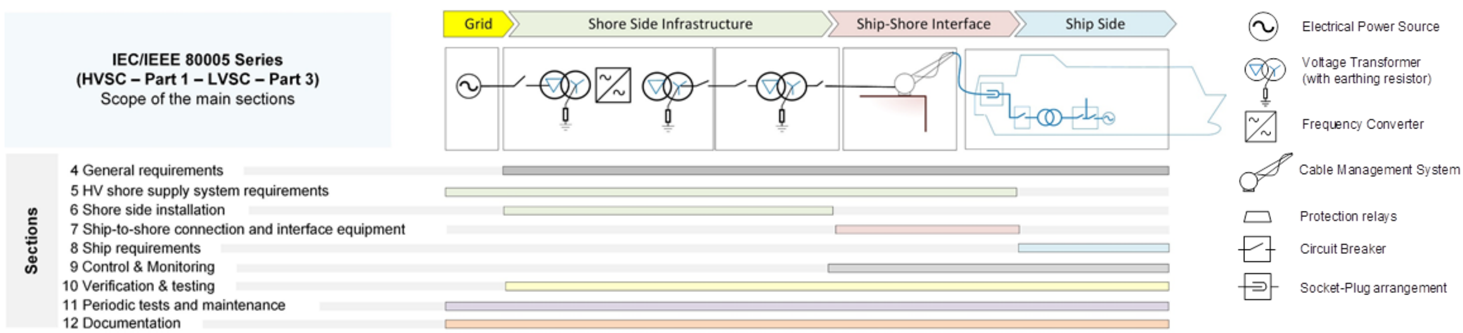
4. REGULATORY FRAMEWORK/ STANDARDIZATION Regulatory framework for SSE/OPS infrastructure project, development, and operation, needs to be assessed over the 3 dimensions: 1) Shore Side; 2) Ship-Shore interface and 3) Ship Side. High-level instruments (International and EU), national law (for electrical and port regulatory aspects), standards, class rules and guidance documents, can be considered altogether the key building blocks for SSE regulatory framework. The diagram below provides a representation of the inter-relations between the different instruments.



The table below lists the different standards supporting interconnectivity/interoperability and data exchange for different SSE types. The colour code indicates: 1) Green: standardization present/ existing reference; 2) Yellow: standardization not present but with possible close application of existing instrument and 3) Red: Still to be developed

SSE Type		Interconnectivity	Interoperability	Data Communication	International/EU Regulatory
OPS (Onshore Power Supply)	High-Voltage Shore Connection (**HVSC**)	IEC 62613-1:2016 (General) IEC 62613-2:2016 (Connector geometry/ dimensions)	IEC/IEEE 80005-1 (HVSC)	IEC/IEEE 80005-2 (Data Communication)	IMO OPS Guidelines EU AFID
	Low-Voltage Shore Connection (**LVSC**)	IEC 60309-5	IEC/IEEE 80005-3 (under review/development)	IEC/IEEE 80005-2	IMO OPS Guidelines already refer
	LVSC – Inland Waterways (IW)	EN 15869-2:2019 (up 125A) EN 16840: 2017 (above 250A)		Possible application of IEC/IEEE 80005-2	CCNR CESNI – ES-TRIN2019
	Recreational Craft/ Marinas	IEC 60309-2	Not standardized	Not standardized	Not relevant international standard applicable to
SBC (Shore-side Battery Charging)	SBC-AC (AC charging)	IEC 60309-5/ IEC 62613-2 AC connection (As standard OPS connectivity)	IEC/IEEE 80005 series As OPS – ship-side charging.	Not standardized (possible development/ applicability for IEC/IEEE 80005-2 or ISO15118)	No applicable international regulatory instrument applicable to SBC
	SBC-DC (DC Charging)	Not standardized	Not standardized		

5. IEC/IEEE 80005 series: Below, the scope of the International Standard series IEC/IEEE 80005 is presented in relation to the main block elements of SSE infrastructure covered. The standard series are primarily scoped for OPS, with Part 1 dedicated to HVSC, Part 2 to Communications and Part 3 for LVSC.



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6. SHIP TYPES Power demand and ship-specific standards for interconnectivity and interoperability are presented in the table below. To note that various ship types and sizes have different power demands at berth, which in turn has an important effect in the design of the supply in ports.

Ship Type	GT	Voltage (kV)	Power Demand Average (Peak), MW	IEC/IEEE Standards (Operability); Connectivity — LVSC	IEC/IEEE Standards (Operability); Connectivity — HVSC	Power Demand drivers/ Operating Profile/ Safety
Oil tankers 	<5,000	0.4/0.44/0.69	4 (6)	(80005-3 - annex-D) IEC 60309-5	(80005-1 - annex-F) 62613-2 - annex I	Power demand driven by cargo pumps and auxiliary systems. (majority of oil tankers use steam driven pumps/systems) Hazardous Areas in the ship-shore interface challenge the use of SSE. Critical safety and reliability of SSE during cargo operations.
	<10,000	0.69/6.6/11	6 (8)			
	>10,000	0.69/6.6/11	8 (10)			
Chemical/product tankers 	<5,000	0.4/0.44/0.69	6 (9)	(80005-3 - annex-D) IEC 60309-5	(80005-1 - annex-F) 62613-2 - annex I	
	<10,000	6.6/11	9 (12)			
	>10,000	6.6/11	10 (20)			
Gas tankers 	<5,000	0.4/0.44/0.69	5 (8)	(not defined) IEC 60309-5	(80005-1 - annex-E) 62613-2 - annex I	Cargo pumps and auxiliary systems drive the load. Critical system reliability during cargo pumping operations.
	>5,000	6.6/11	9 (12)			
Bulk carriers 	<50,000	0.4/0.44/0.69	0.5 (0.7)	(not defined) IEC 60309-5	(80005-1 - annex-E) 62613-2 - annex I	Cranes, where fitted, hydraulic systems and hatches operation.
	>50,000	0.69/6.6/11	2 (2.8)			
General cargo 	<25,000	0.4/0.44/0.69	1.5 (3)	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate	Cranes, where fitted, hydraulic systems and hatches operation.
	>25,000	0.69/6.6/11	3 (5)			
Container vessels 	<10,000	0.4/0.44/0.69	1.5 (2)	(80005-3 - annex-C) IEC 60309-5	(80005-1 - annex-D) 62613-2 - annex I	Cranes, where fitted, hydraulic systems, hatches operation, refrigerated containers. Reduced space at quay due to cargo terminal cranes pedestals.
	<50,000	0.69/6.6/11	2 (5)			
	>50,000	6.6/11	4 (6)			
Ro-Pax vessels 	<20,000	0.4/0.44/0.69	2 (4)	(not defined) IEC 60309-5	(80005-1 - annex-B) 62613-2 - annex J	Predominant Hotels loads and displacement of vehicle ramps. Short turn-around times at berth.
	>20,000	0.69/6.6/11	5 (6.5)			
Cruise ships 	<50,000	0.4/0.44/0.69	4 (4.5)	(not defined) IEC 60309-5	(80005-1 - annex-B) 62613-2 - annex H	Large Hotel load driving the power requirements . Safety and Reliability of SSE is critical for operation
	<100,000	0.69/6.6/11	9 (12)			
	>150,000	6.6/11	18 (20)			
Offshore supply vessel 	<5,000	0.4/0.44/0.69	1 (1.5)	(80005/3 - annex-B) [IEC 60309-5]	(not defined) 62613-2 – as appropriate	Load from hydraulic systems, possible refrigerated module connections. modest hotel load.
	>5,000	6.6/11	2 (3)			
Fishing vessels 	<5,000	0.4/0.44/0.69	0.5 (0.7)	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate	Refrigerated systems and possible hydraulic/cranes operation
	>5,000	6.6/11	2 (3)			

7. POWER DEMAND One of the key design variables to consider in the project for any SSE installation in a port is the estimated maximum power demand at berth. This calculation should be performed with consideration to the yearly operating profile for a given port, considering the different types of ships requiring shore-power and the number of vessels calling on the port at the same time. A possible 5-step procedure for calculation of the estimated maximum power for the SSE installation is briefly presented below.

Identify Ships at berth for SSE — Step 1

Identify the number and characteristics of ships to connect to SSE taking into account:
- Ship Type
- Gross Tonnage
- Berthing locations
- Requests for OPS operation from ships
- Preliminary agreements with Operators with a view to develop SSE/OPS.

FINAL RESULT from Step 1:
- Identification of the TYPE and NUMBER of ships to consider for SSE/OPS development on a GIVEN LOCATION (terminal/ berth)

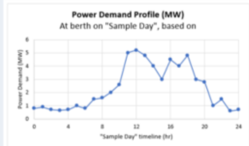
Gather data from operating profile at berth — Step 2

Data form Operating Profile at berth includes: Energy Consumption at berth, on an hourly basis (fuel or electrical energy consumption)
The following methods can be used:
1. Target surveys for fuel consumption at berth (on a selected universe of ships)
2. Using measured fuel consumption data, when made available.
3. Available Performance Records for individual ships.

FINAL RESULT from Step 2:
- Structured data for ENERGY CONSUMPTION at berth, for individual ships, over a defined period of time (ton of fuel consumption/ hour)

Power Demand Curves — Step 3

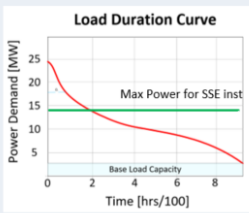
With the set of ships identified (**Step 1**) and with the energy consumption at berth, consumed per hour by individual ships (**Step 2**), develop a distribution of the power Demand in relation to a selected time scale of observation.
In the diagram below it is possible to see this power demand distribution for one ship during 24hrs.



FINAL RESULT from Step 3:
- Identification of the POWER DEMAND curves for the different ships calling at that port, under the survey/analysis.

Load Duration Curve — Step 4

With the information from all ships at berth over a given observation period it is possible to develop the Load Duration Curves for the intended ships in observation.



FINAL RESULT from Step 4:
- Plotting of the LOAD DURATION CURVE for the port, over a well defined duration of time. Determination of how long/ concentrated is peak demand.

Determine Design Factors — Step 5

At this stage it is important to determine at which point should the **green** line in Step 4 should be located.
In order to assist the decision on the installed power to project for a given SSE installation it is important to determine the relevant Design Factors.
These will allow to understand that in the majority of the cases the maximum power to install is not the sum of max power demand from ships at berth.
The following factor must be determined:
1. Power Demand Factor
2. Diversity Factor/ Simultaneity Factor (ks)
3. Load Factor
4. Utilization Factor (ku)

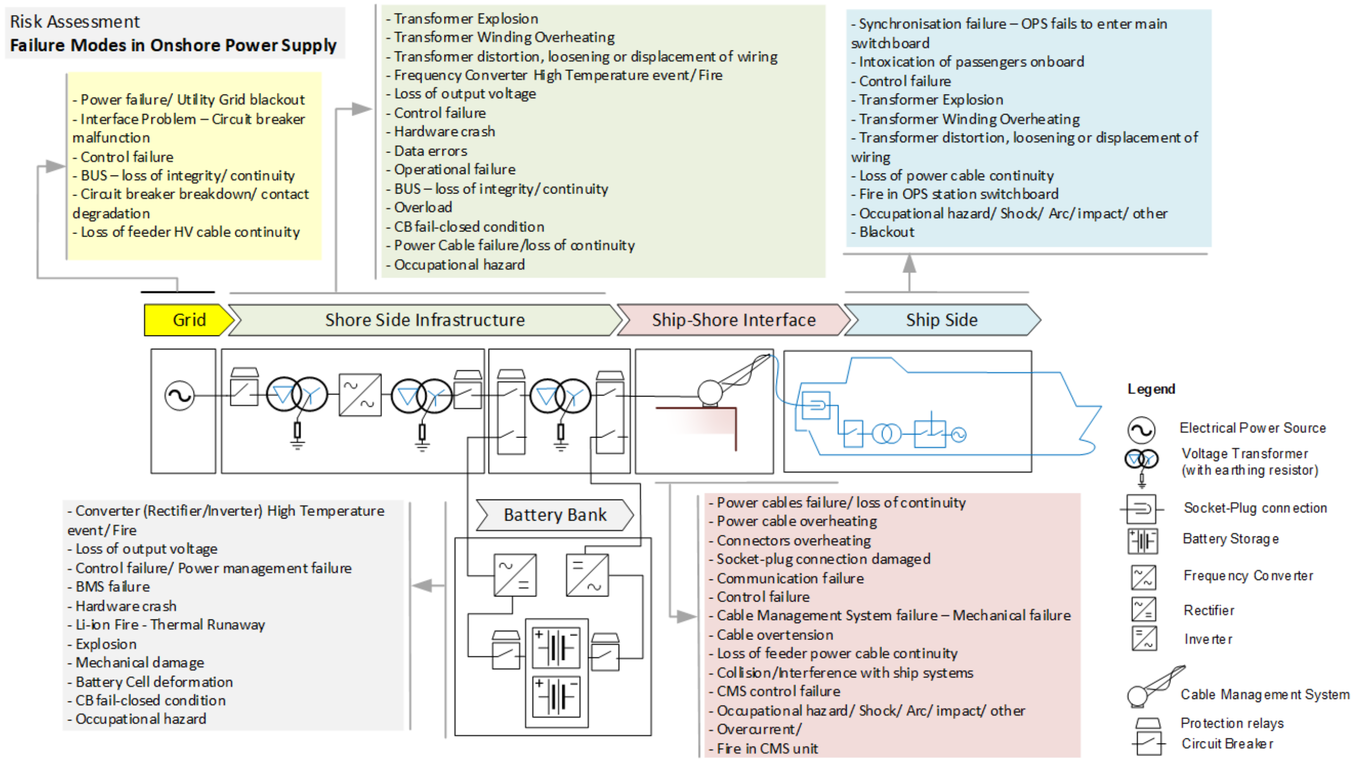
FINAL RESULT from Step 5:
- Determination of the maximum design power for the SSE installation

8. RISK ASSESSMENT SSE projects represent important realisations of electrical engineering, at low-medium-high voltage, and infrastructure. They are characterised by a system which operates on a complex multi-interface context (Utility Grid/Port Grid + Port Grid/SSE Shore side + SSE Shore side/Ship), where compatibility, interconnectivity and interoperability are essential safety building blocks. Safety has to be regarded for SSE projects with the earliest possible overview and identification of system-specific hazards, typically at the planning and design stage. At this point it is important to have a general overview of hazards to address and general safety risks to be mitigated, taking into consideration the known onsite conditions, equipment, and anticipated user-requirements/conditions. Early risk assessment should then be revised and updated at the detailed design stage and prior to construction/integration.

Safety risk assessment should include a criticality and reliability analysis (e.g., FMECA). Several instruments, methodologies and standards may be used for the realization of the safety risk studies. Important aspects to ensure should be: 1) that a recognized methodology is applied, 2) an independent risk consultant is involved (ideally the same for the different stages), 3) that all evidence is documented and made available for detailed engineering drawings, integration, and construction.

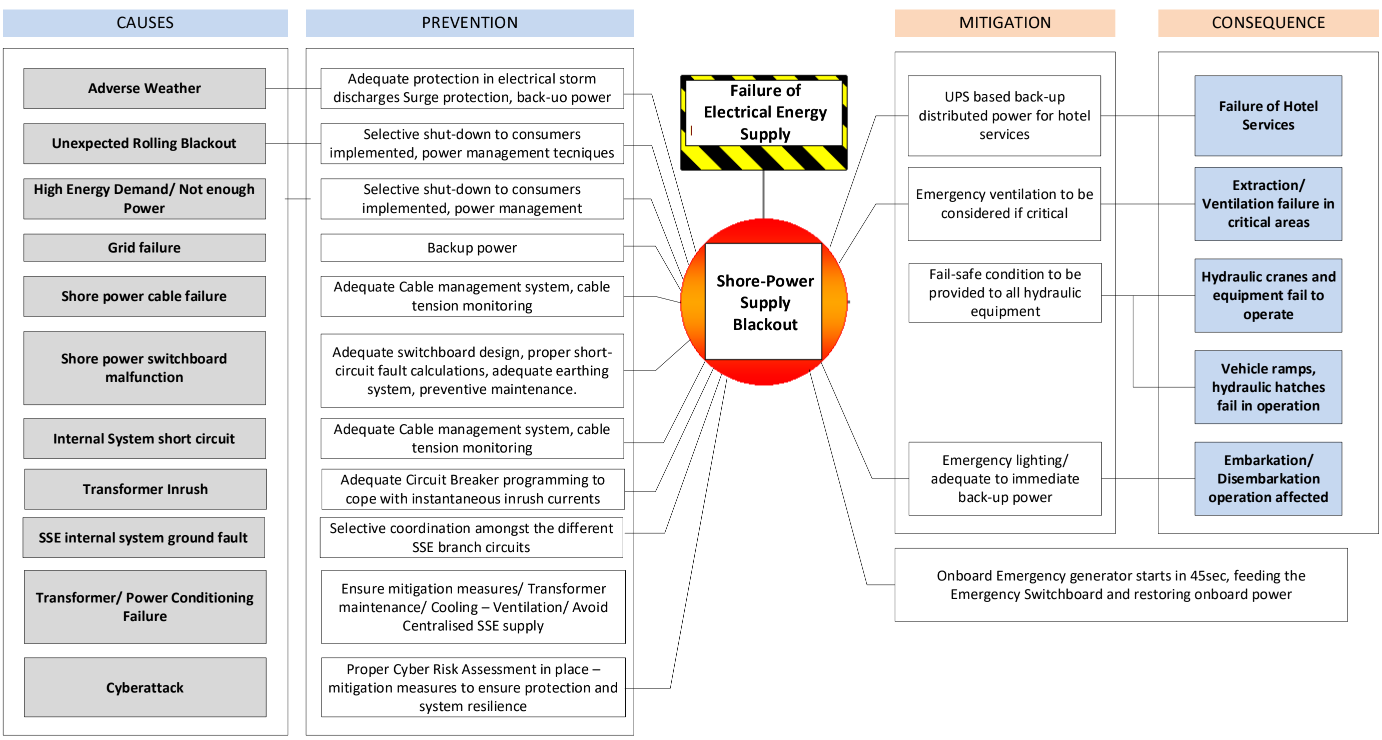
FAILURE MODE SCENARIOS

The Identification of the different possible failure modes is the basis for all risk assessment studies/ analysis. The diagram below includes the main equipment blocks of a standard SSE/OPS system with electrical energy storage/battery bank associated for grid stabilization or as power supply continuity. The identification of the failure scenarios should follow the project development from the very early concept stages and should include the widest possible range of stakeholders involved. It is fundamental to acknowledge that risk assessment is always an open exercise which needs to be re-assessed for every new ship applying for a 1st connection.



BOW TIE REPRESENTATION OF SSE BLACK-OUT

Below an example of a bow-tie diagram representing causes and consequences in relation with an SSE supply blackout.



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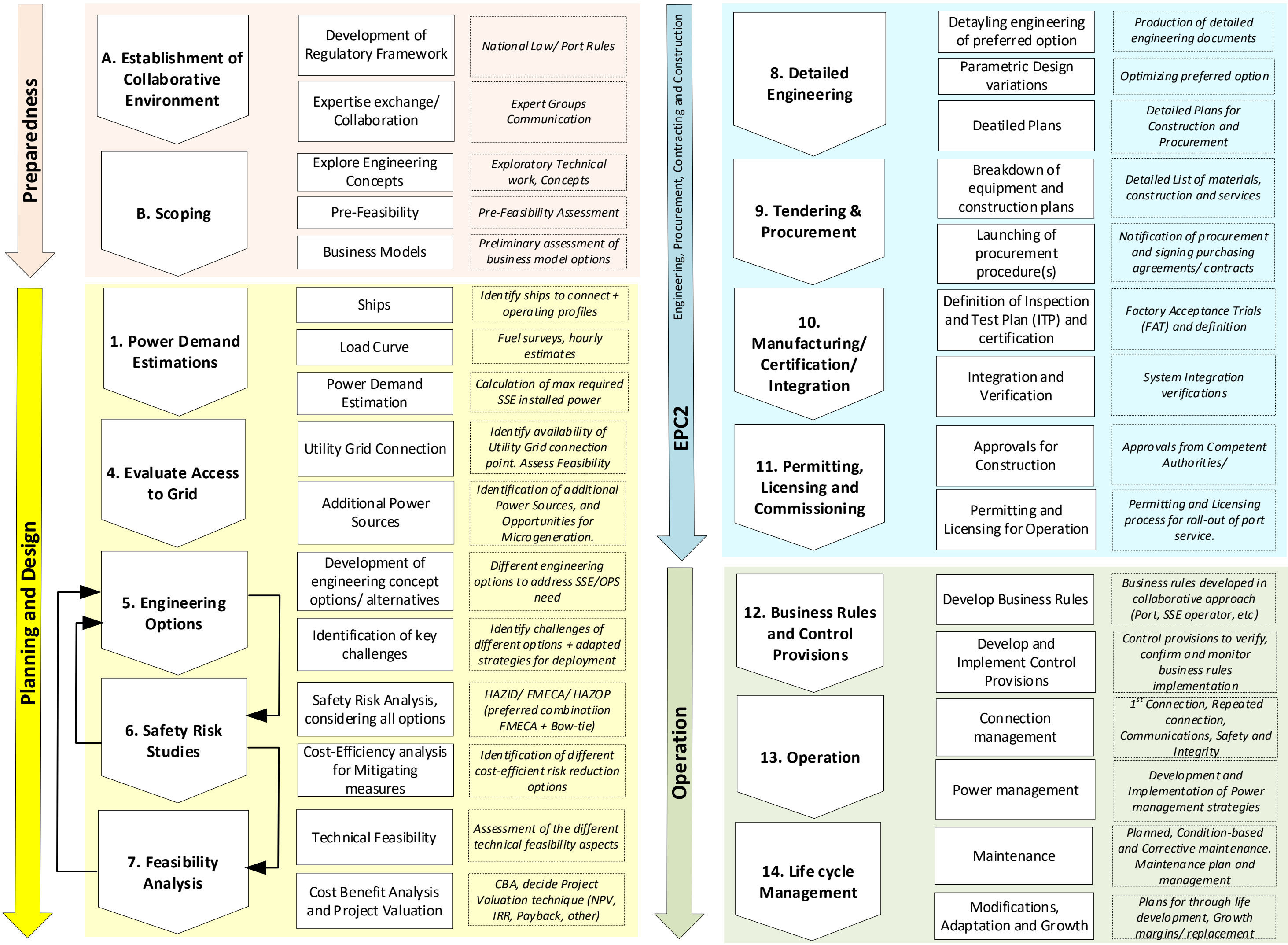
9. LIFE CYCLE PLAN The figure below identifies the different Life Cycle steps for SSE projects. Overall, the process is divided into 4 main stages: Preparedness, Planning and Design, Engineering/ Procurement/ Contracting/ Construction and Operation. Within these 4 main stages the structure presented follows the typical engineering development process, with 1) identification of initial requisites, 2) Study of options followed by 3) Feasibility Analysis and Project Evaluation. Following the identification of a preferred option the deployment of the project takes place with all detailed engineering drawings, procurement, contracting and construction and finally the Operation of the system. The structure below should not be understood as a rigid construction but rather as a *good practice* based on the structured engineering project development. Specific aspect of the shore side electricity context shall be highlighted, such as the establishment of a collaborative environment, corresponding to Step "A". This step is one that should be understood as taking place irrespective of a specific decision for project development.



10. OPERATION The process diagram for both OPS and SBC are presented below.