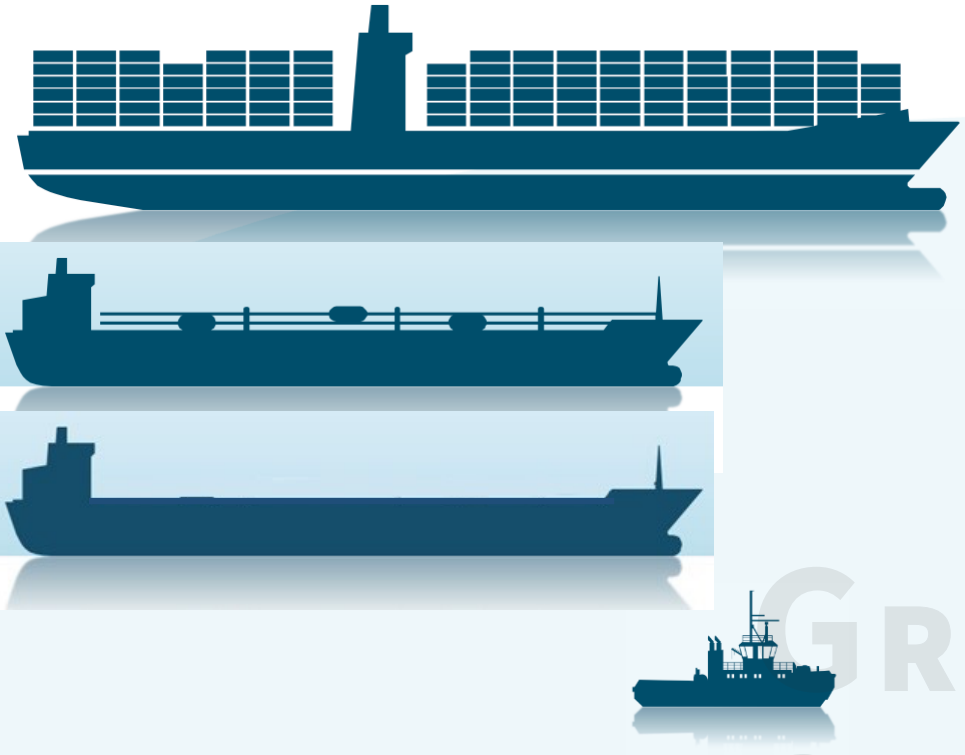
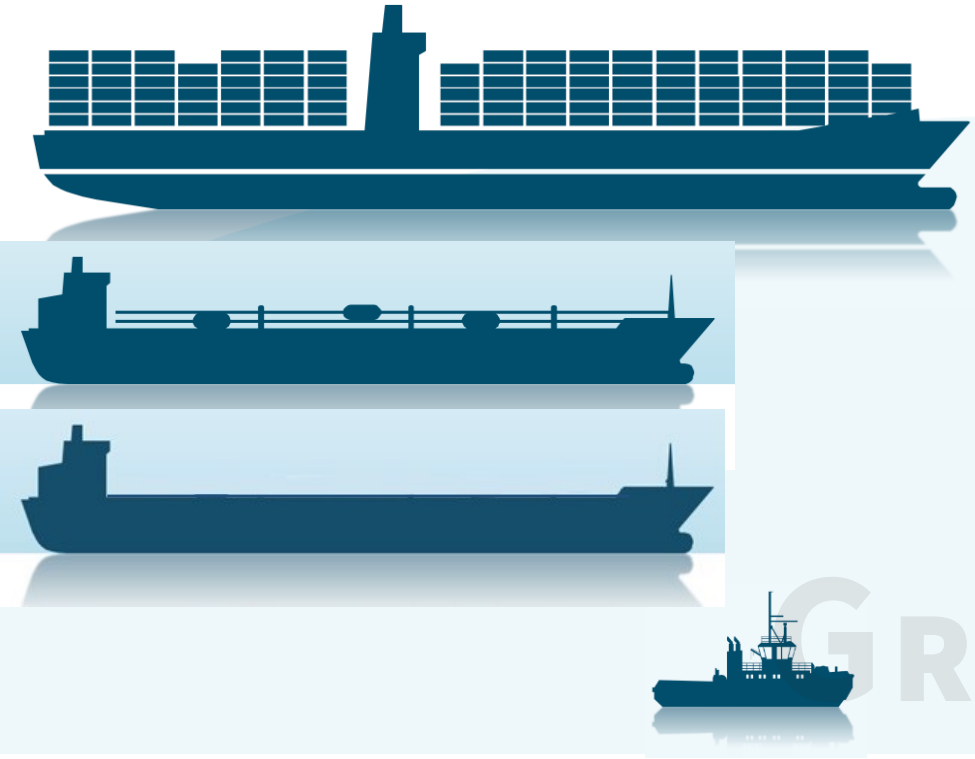
What's the basic concept?

Conventional Port Call



Maneuvering to dock	At-berth	Maneuvering away from dock
Main Engines ON	Main Engines OFF	Main Engines ON
Auxiliary Engines ON	Auxiliary Engines ON	Auxiliary Engines ON
Boilers ON/OFF	Boilers ON/OFF	Boilers ON/OFF
N/A	N/A	N/A

What's the basic concept?



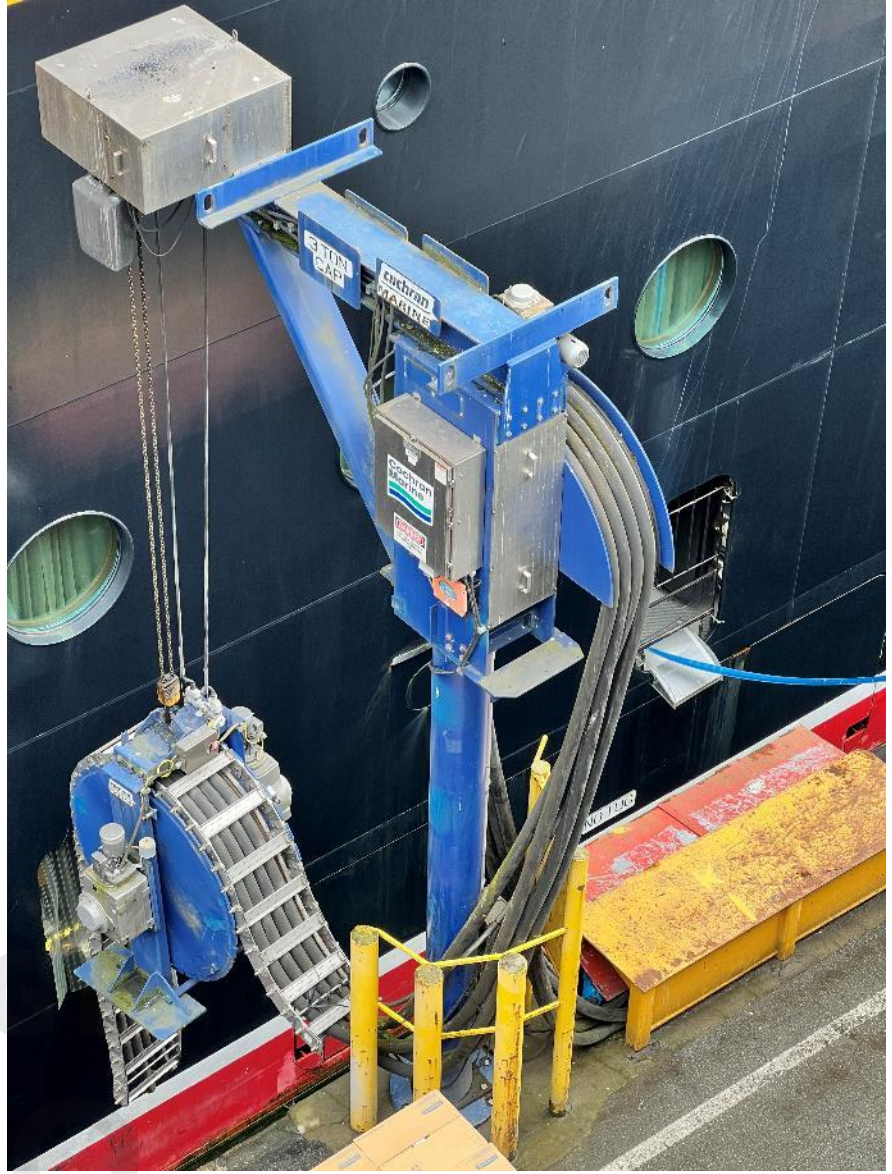
OPS Port Call

Maneuvering to dock	Connect	At-berth Connected	Disconnect	Maneuvering away from dock
Main Engines ON	Main Engines OFF	Main Engines OFF	Main Engines OFF	Main Engines ON
Auxiliary Engines ON	Auxiliary Engines ON	Auxiliary Engines OFF - Energy from Grid	Auxiliary Engines ON	Auxiliary Engines ON
Boilers ON/OFF N/A	Boilers ON/OFF N/A	Boilers ON N/A	Boilers ON/OFF N/A	Boilers ON/OFF N/A

Brief history

- Has it origins with military & commercial ships that spend long periods of time at berth
- First regulated in 2001 in Alaska related to opacity limits from the funnels of cruise ships berth in Alaska
- Was a condition agreed to in the settlement of a law suit for a terminal expansion project at the Port of Los Angeles → first container ship application
- Was put in by cruise lines Seattle in 2005 because of the favorable business case (cost of shore-side electricity was well below equivalent fuel costs at the time)
- Was first broadly regulated as an air quality emission reduction strategy for container, reefer, & cruise by the California Air Resources Board (CARB) in 2007; amended & expanded to RoRo (2025) & tankers (2027)
- Has since blossomed in North America, Europe, & Asia in both regulatory & voluntary emission control strategies
- China will requires its use since October 2022, if the ship has OPS onboard & calls in Domestic Emission Control Areas (DECAs)
- Has more recently become a GHG emissions reduction strategy, which can have mixed results depending on how clean the grid/energy generation fuel

IMO does not mandate or have any regulations related to OPS



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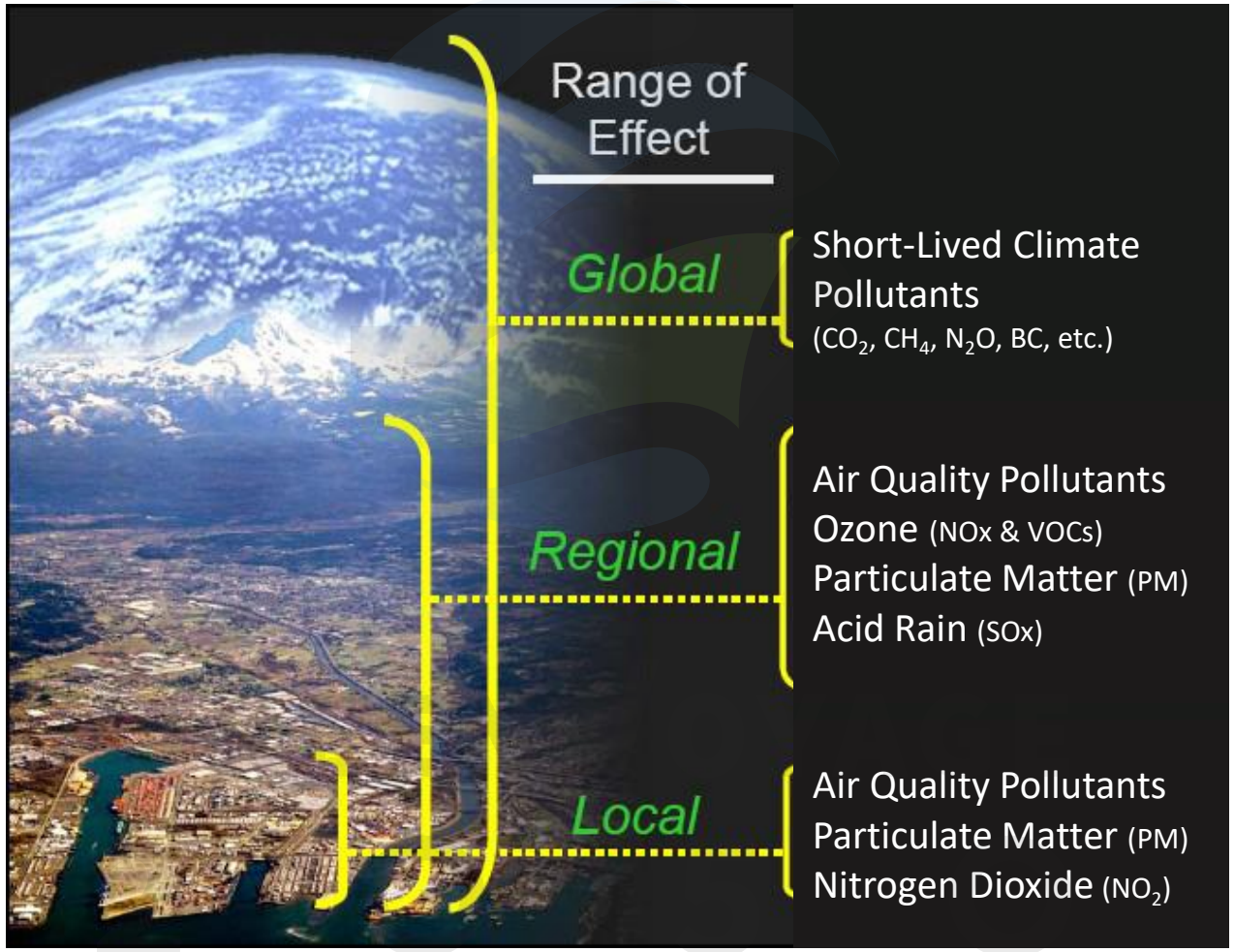
Air Quality & Greenhouse Gases 101



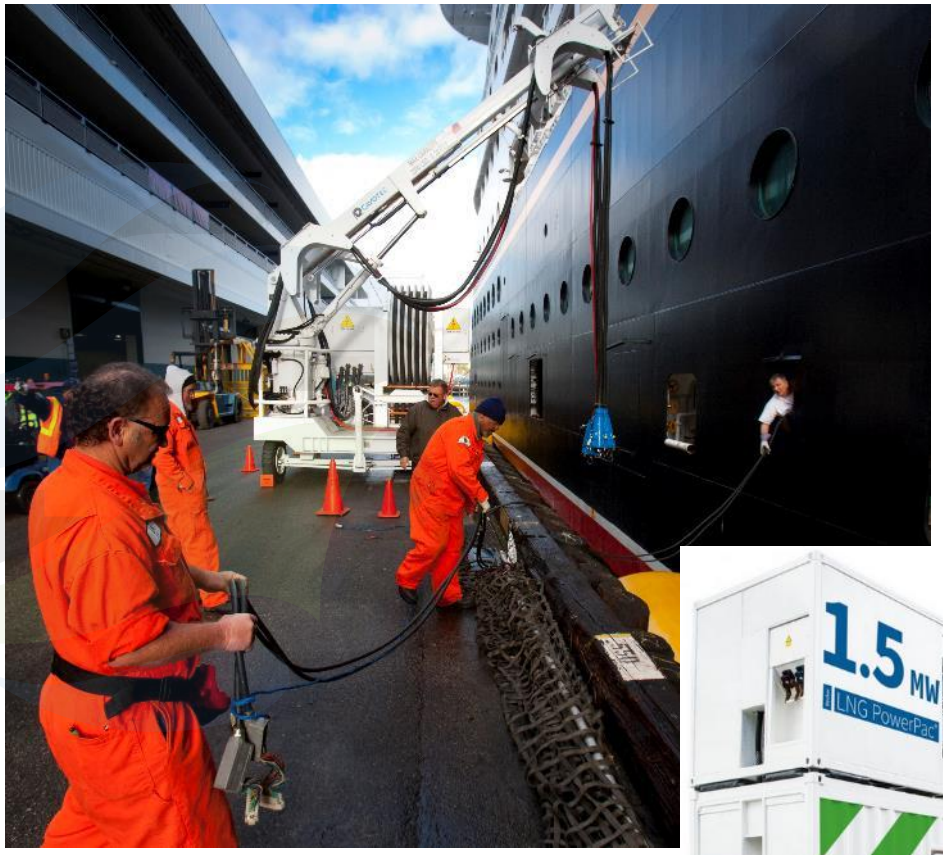
Common drivers

- Regulation
- Business case
- Stakeholders
  - Public/neighbours
  - Government
    - Local
    - State
    - Regional
    - National
    - Multinational
  - NGOs
  - Tenants
  - Ship owners/operators
  - Port boards
- Proactive reduction in impacts/social responsibility/license to operate
- ….

NABU

What's involved?

- OPS is considered a vessel + port-based emission reduction strategy
  - For OPS to work, both the vessel & port/terminal need to have equipment
- Port/terminal side OPS types
  - Grid-based – requires port infrastructure to connect the vessel to the electrical grid
  - Non Grid-based – can be a variety of options including: alternative fuelled generators, battery banks, fuel cells, battery swapping, etc.
- Vessel side OPS
  - Both types require infrastructure on-board a vessel to connect to land side OPS to transfer power, recharge batteries, or replace batteries to/on the vessel



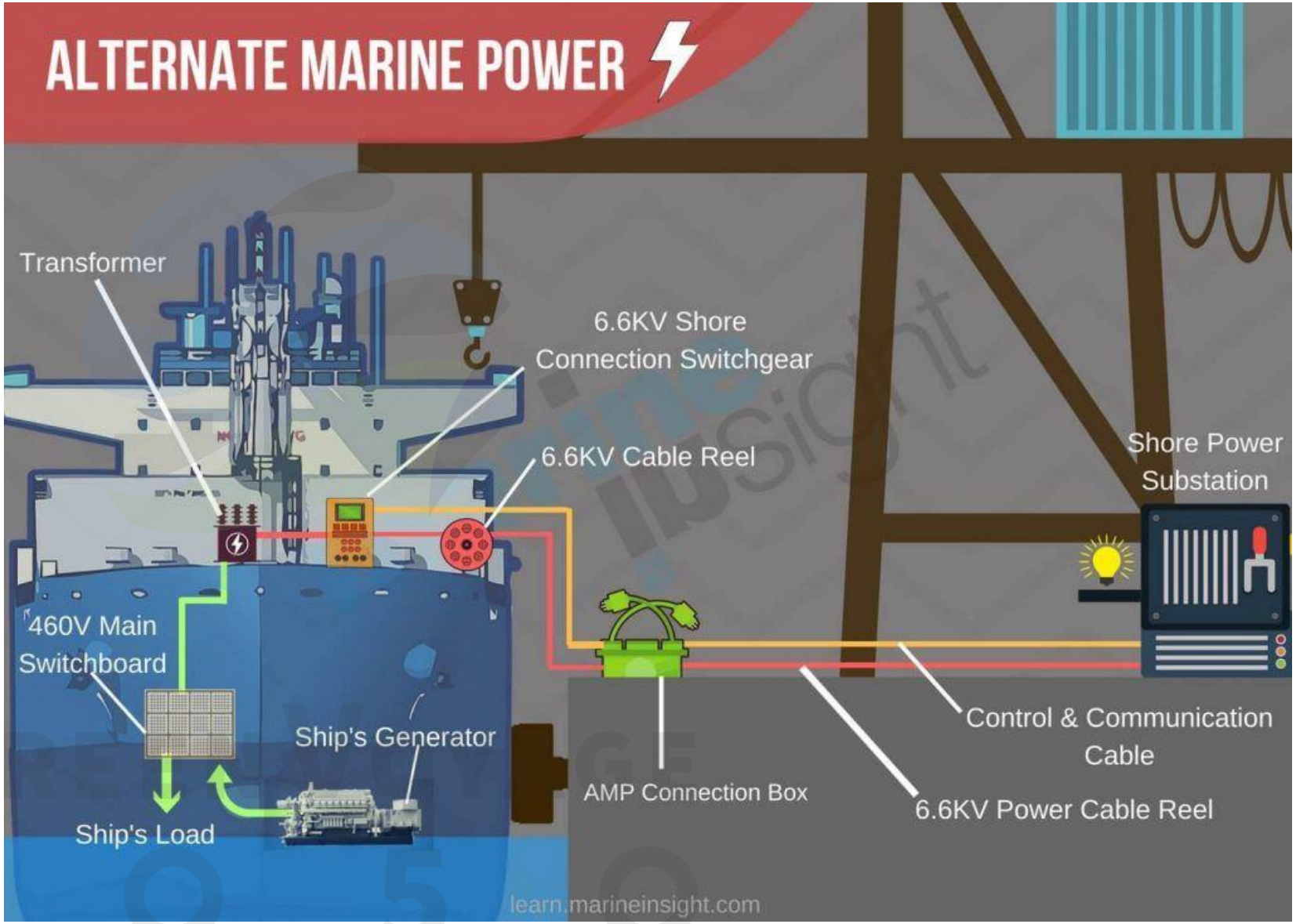
©Port of Los Angeles, 2021

https://www.becker-marine-systems.com/products/product-detail/becker-lng-powerpac.html

What's involved?
Grid-based

- Port/terminal Infrastructure
  - Low/high voltage grid connection to port
  - Low/high voltage power substation at port
  - Frequency and voltage converters
  - Transformers & power conditioning equipment
  - Control panels & connection vaults
  - Cable connectors (fixed, mobile, barged mounted, etc.)

- Ship Infrastructure
  - Control panels
  - Conduit access
  - Transformers
  - Connection switch gear
  - Cable reel /management system



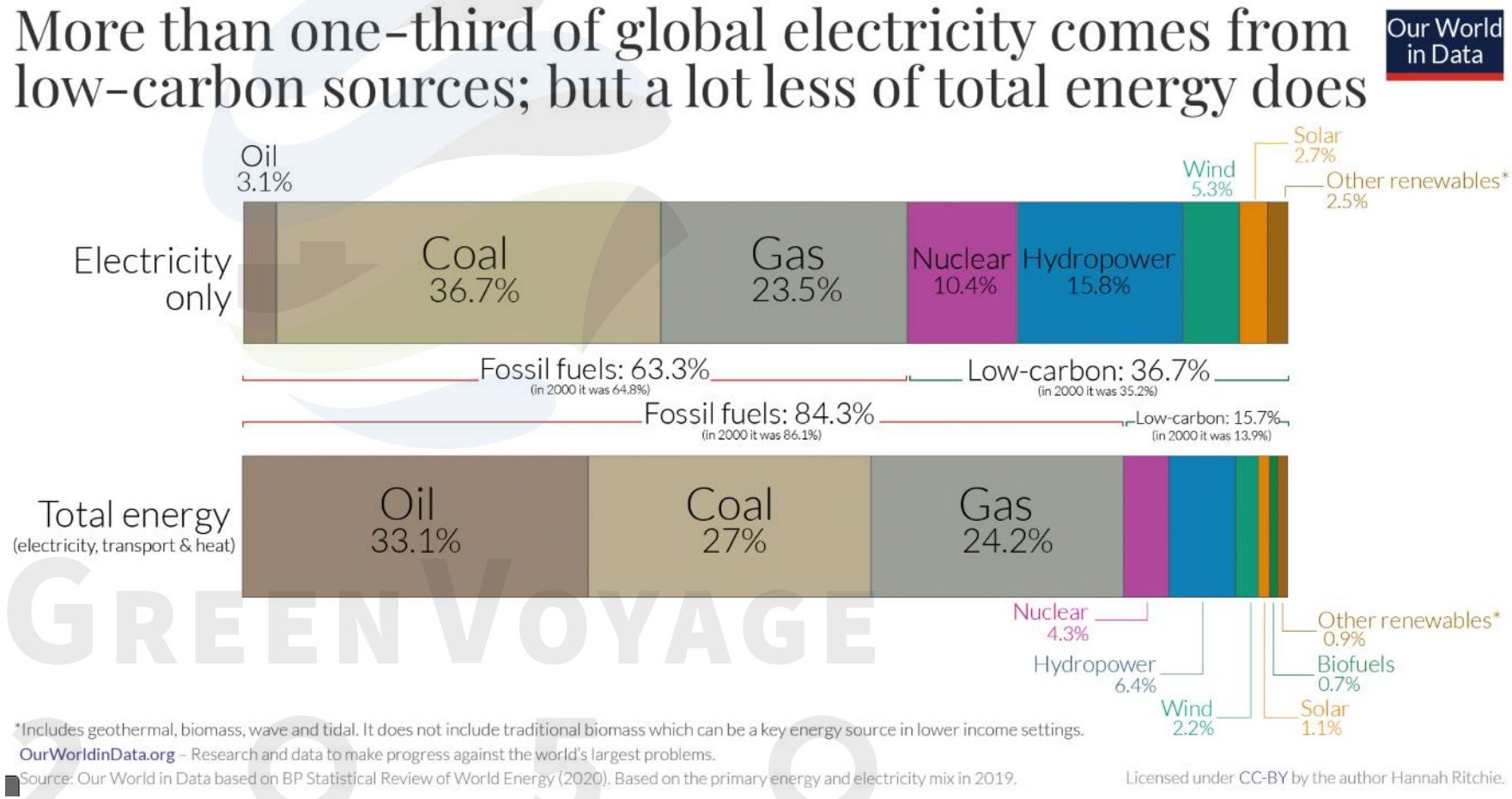
https://www.marineinsight.com/marine-electrical/what-is-alternate-marine-power-amp-or-cold-ironing/

Technical standards

- Low voltage shore connection (LVSC) systems 220-480 V Loads <1 MW
  - Applicable ISO Standard: IEC/PAS 80005-3:2014 Standard is in the process of being updated
- High voltage shore connection (HVSC) systems 6.6 kV or 11 kV up to 20MVA Loads ≥1 MW
  - Applicable ISO Standard: IEC/IEEE 80005-1:2019 Standard is published with two amendments:
    IEC/IEEE 80005-1:2019/Amd 1:2022 Published
    IEC/IEEE 80005-1:2019/AWI Amd 2 Underdevelopment
- Ship onboard frequencies 50 or 60 Hz
  - Most ships are 60 Hz
  - Frequency converter to 60 Hz for Ports supplied by 50 Hz grid power

How clean is your grid?

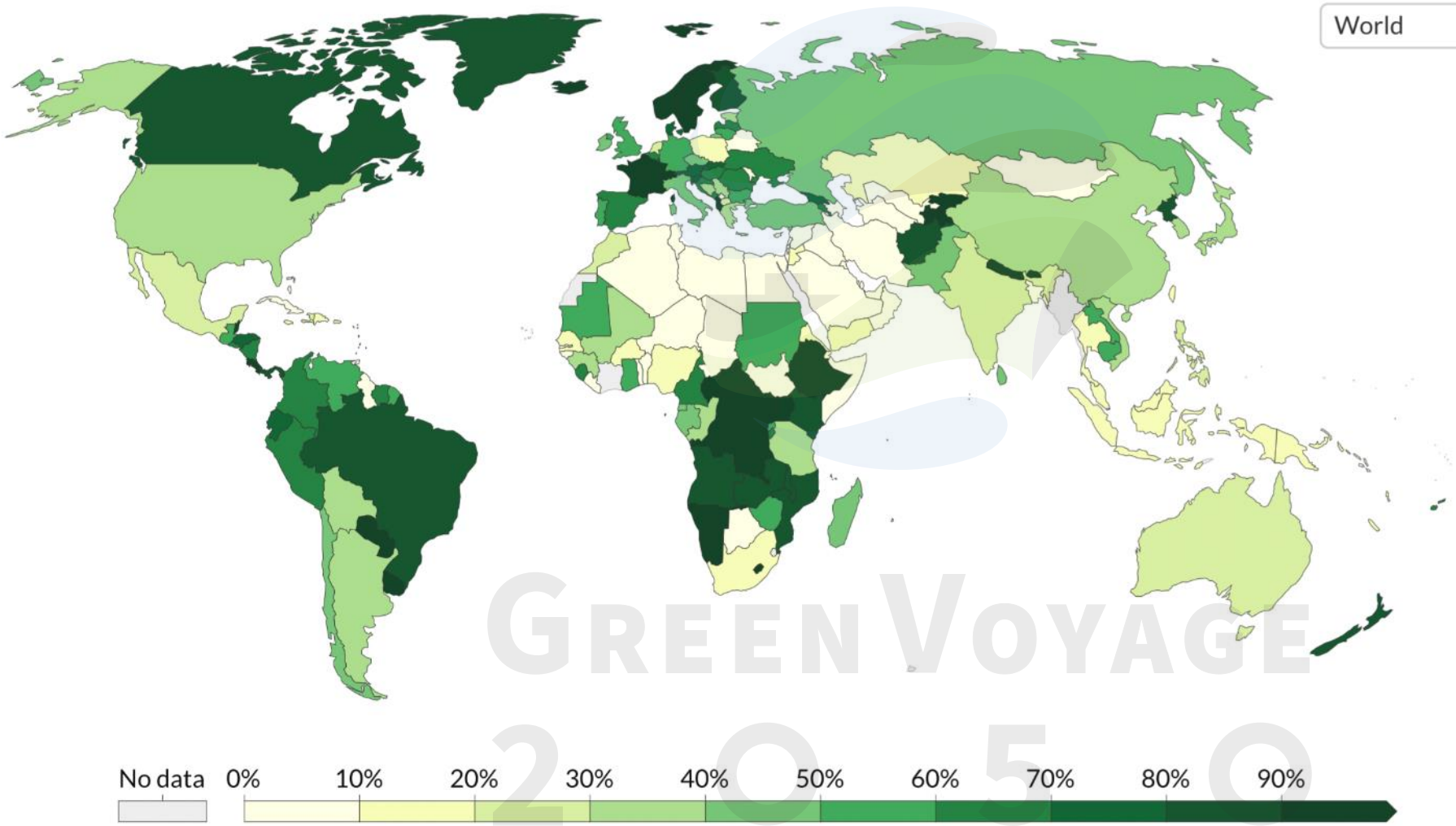
- Grid emissions
  - How clean is the grid that will power the ships?
  - The grid is not always cleaner than onboard generation.
  - Depending on the target pollutant or GHG, it is important to determine the emission rates.
  - Utility/power providers may provide their generation mix & emission rates for pollutants + GHGs



Share of electricity from low-carbon sources, 2020

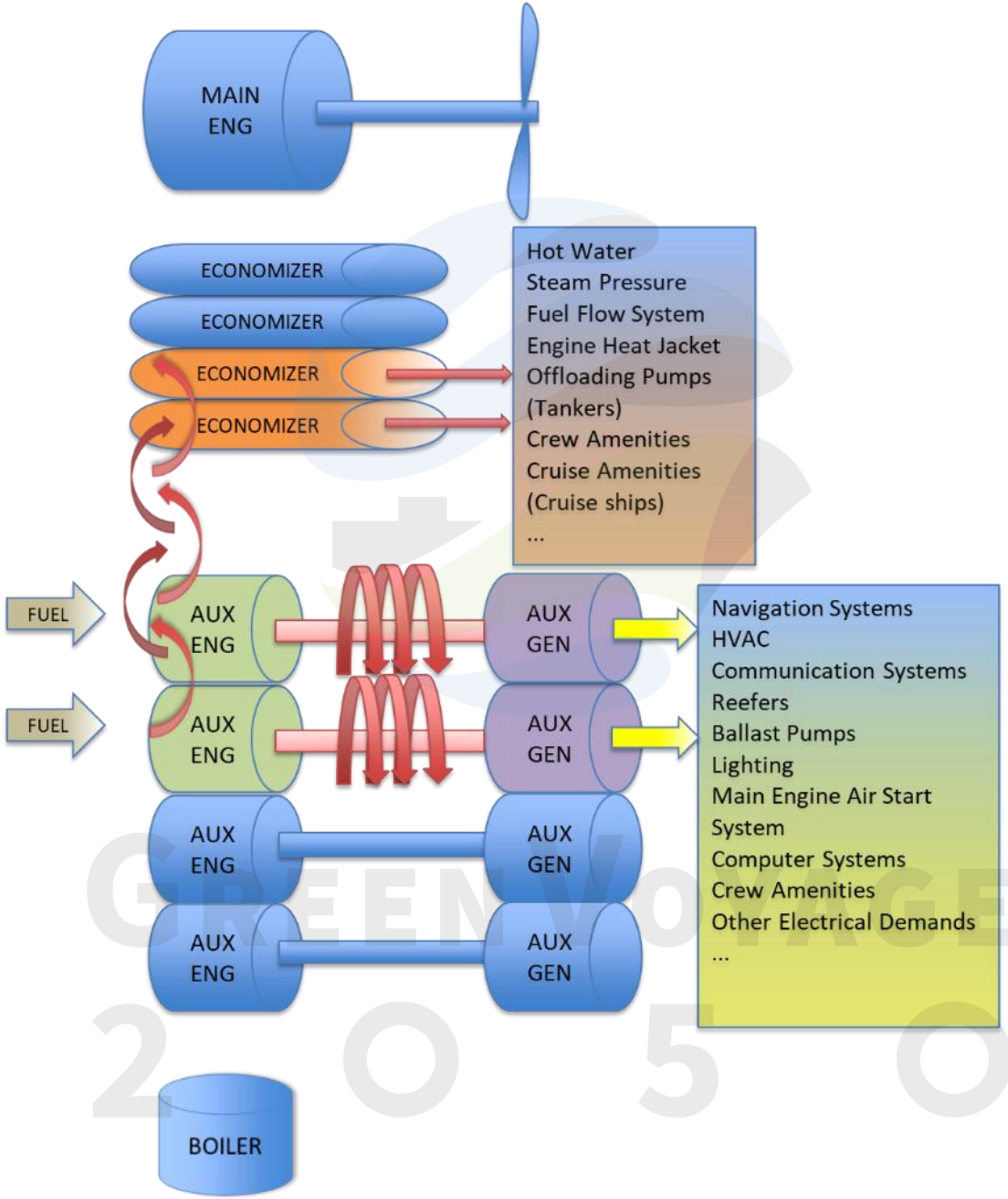
Low-carbon electricity is the sum of electricity from nuclear and renewable sources (including solar, wind, hydropower, biomass and waste, geothermal and wave and tidal).

Our World in Data



Source: Our World in Data based on BP Statistical Review of World Energy & Ember (2021)

What is the emission reduction premise?

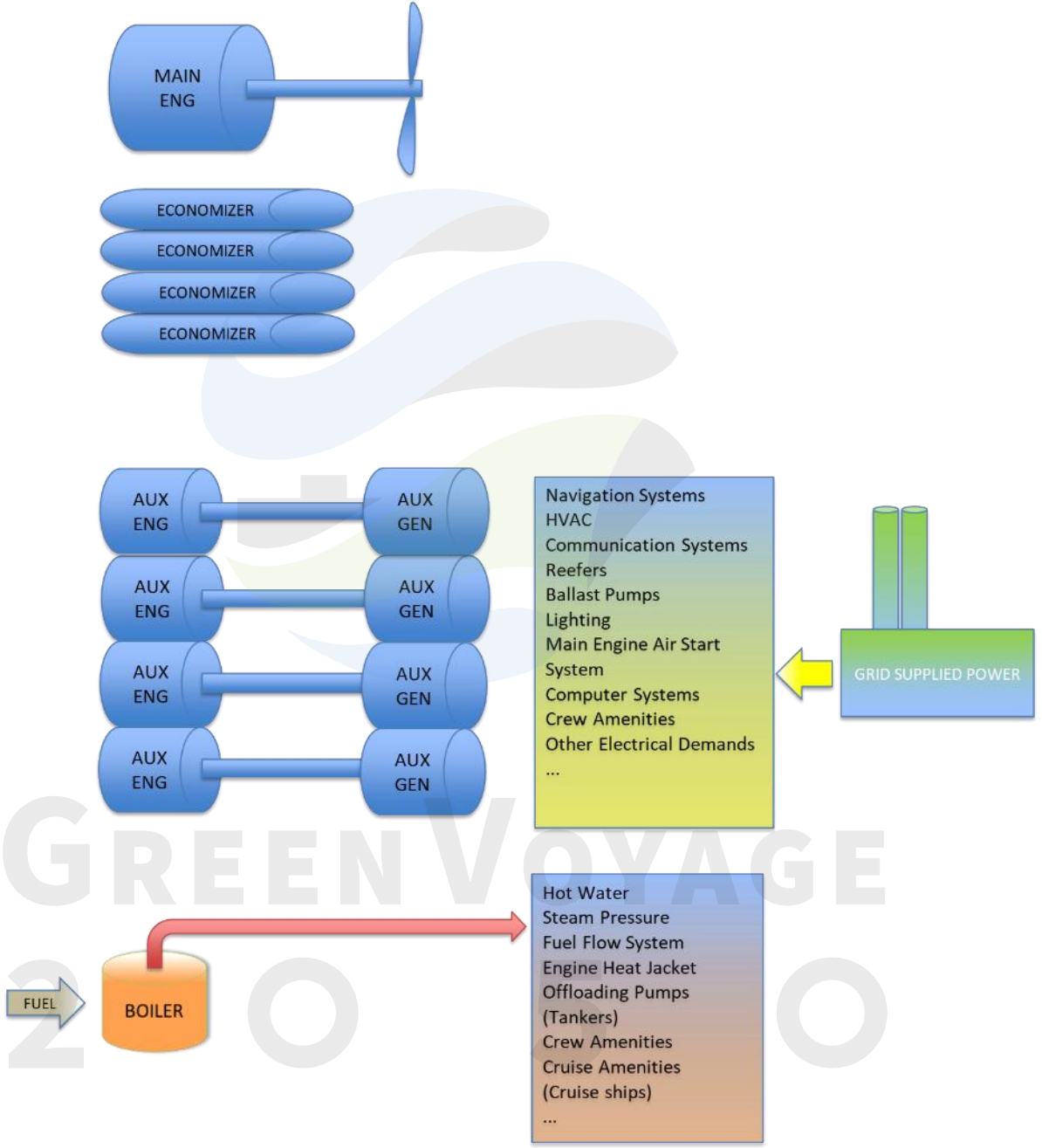


Conventional Port Call

Blue – equipment off
Colored – equipment on

What is the emission reduction premise?

OPS Port Call



Blue – equipment off

Colored – equipment on

Strengths & limitations

Grid-based

Strengths

- Reduces all auxiliary engine emissions while connected to OPS at-berth
- Technical standards exists for OPS which minimized compatibility uncertainty
- OPS has been in use for nearly two decades for cruise & a broadening number of ship types
- Low voltage systems are significantly less expensive than the high voltage systems
- Works well with frequent calling ships
- Benefits depend on how clean the grid supplying the power is compared to onboard generation

Limitations

- Does not eliminate ship emissions while at-berth (aux engines run during c/d time & boilers operate)
- High voltage systems can typically be one of the most expensive emission reduction strategies for ships (both capital & O&M)
- Port & Ship-based strategy, which means both Ports & ships need to have the equipment in place prior to arrival in order for the strategy to work
- Does not work for non-frequent calling ships
- Benefits depend on how clean the grid supplying the power is compared to onboard generation

Strengths & limitations

Non grid-based vs grid-based

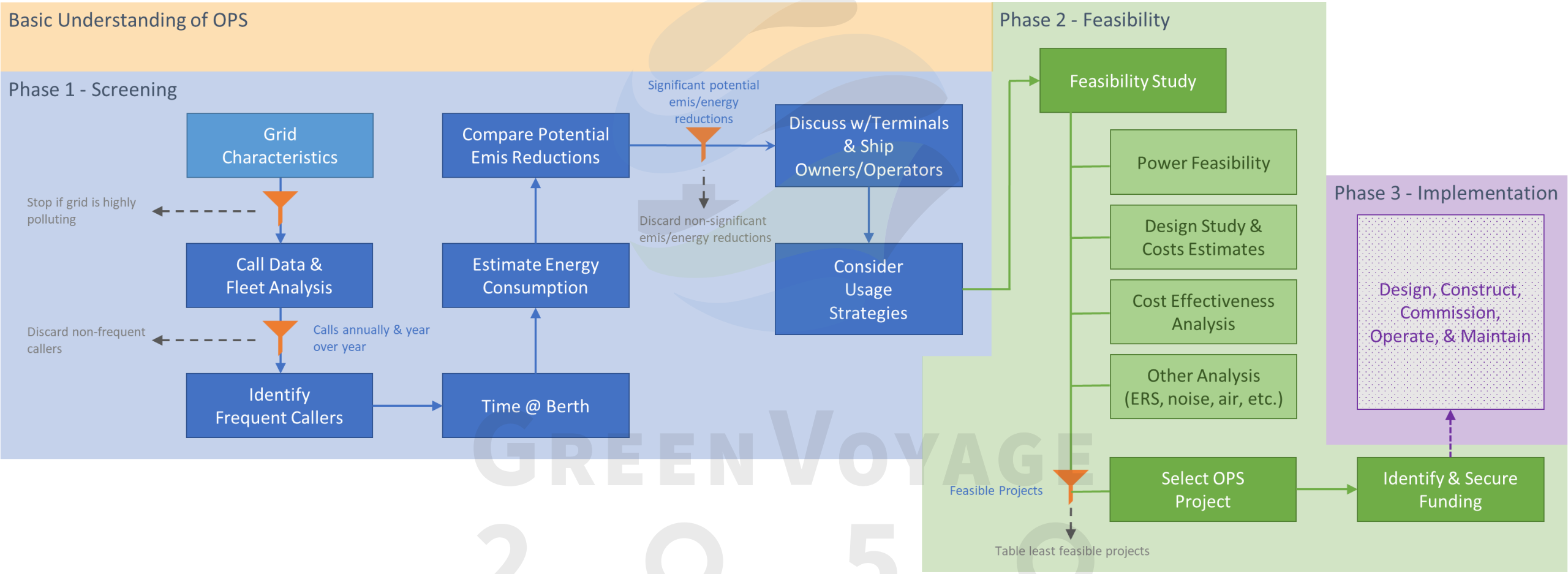
Strengths

- Can significantly reduce infrastructure capital costs compared to grid-based OPS
- Benefits depend on how clean the non grid power source is compared to onboard generation
- Can be relatively easily repositioned on the terminal or to another terminal
- The system could be maintained by the equipment provider
- The system could potentially leased instead of purchased

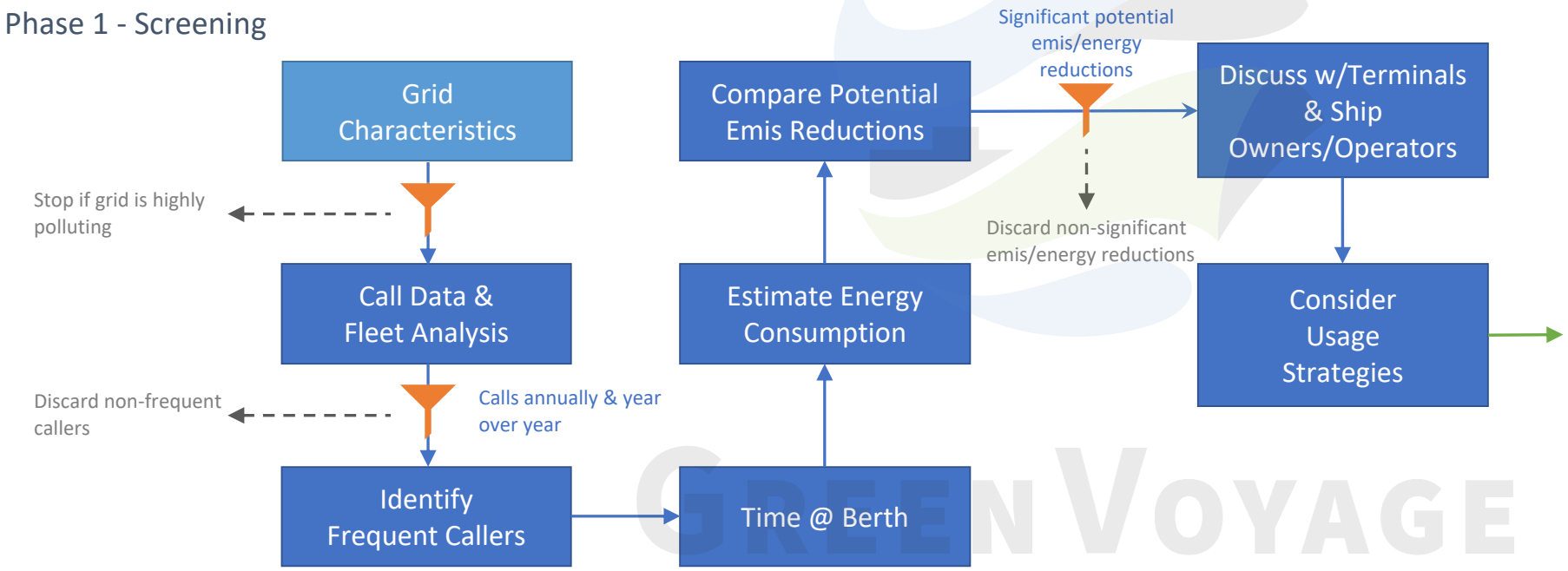
Limitations

- Requires a dependable supply of alternative energy source/fuel to power generators, recharge batteries, etc.
- Benefits depend on how clean the non grid power source is compared to onboard generation
- Terminal space may not be available for the system
- Noise on terminal from power generation
- Third-party costs maybe uncertain over time & market is just emerging

Phased port/terminal approach



Phase 1 - Screening



- How clean is your grid?
- Are there any frequent calls?
- What are the characteristics of the fleets calling your port?
- What are the potential emission reductions?
- What are the terminals & shipping lines thinking?
- Which implementation options are available?

Usage strategies

- How do you ensure OPS usage?
  - *Regulations*
  - *Incentives*
  - *Port requirements*
  - *Appeal to the business case*
  - *Appeal for environmental stewardship*
  - …

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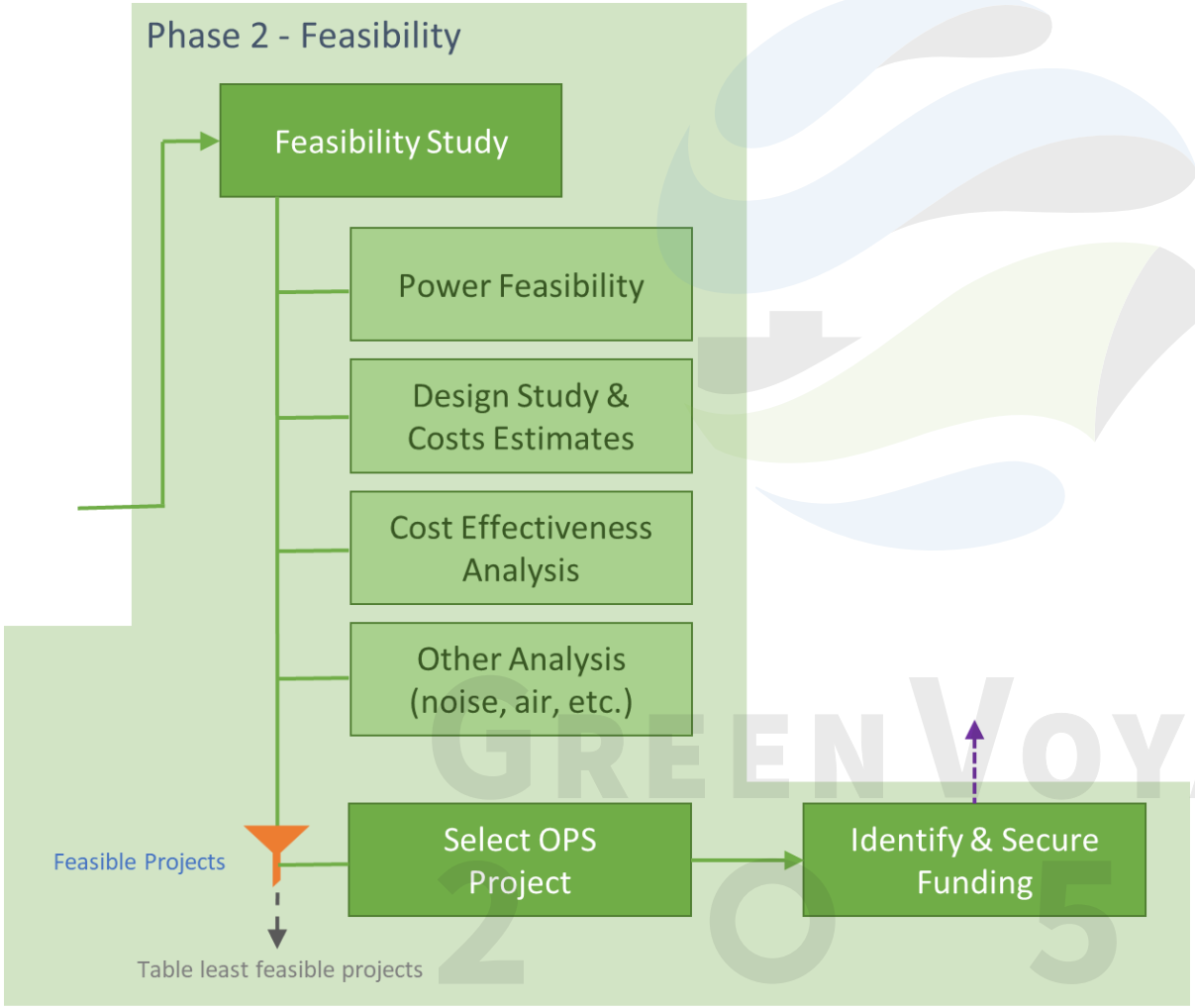
Phase 2- Feasibility



- Phase 2 – Feasibility
  - Select various project scenarios
  - Discuss project scenarios with terminals & shipping lines associated with frequent calling ships
  - Identify which feasibility studies are needed to evaluate projects
  - Evaluate costs on both port-side & ship-side
  - Baby steps

Phase 3 - Implementation

- Phase 3 - Implementation
  - Final Designs
  - Permitting
  - Construction
  - Commissioning
    - Land side
    - Ship side
  - Operations
  - Maintaining
  - Staffing
  - ….

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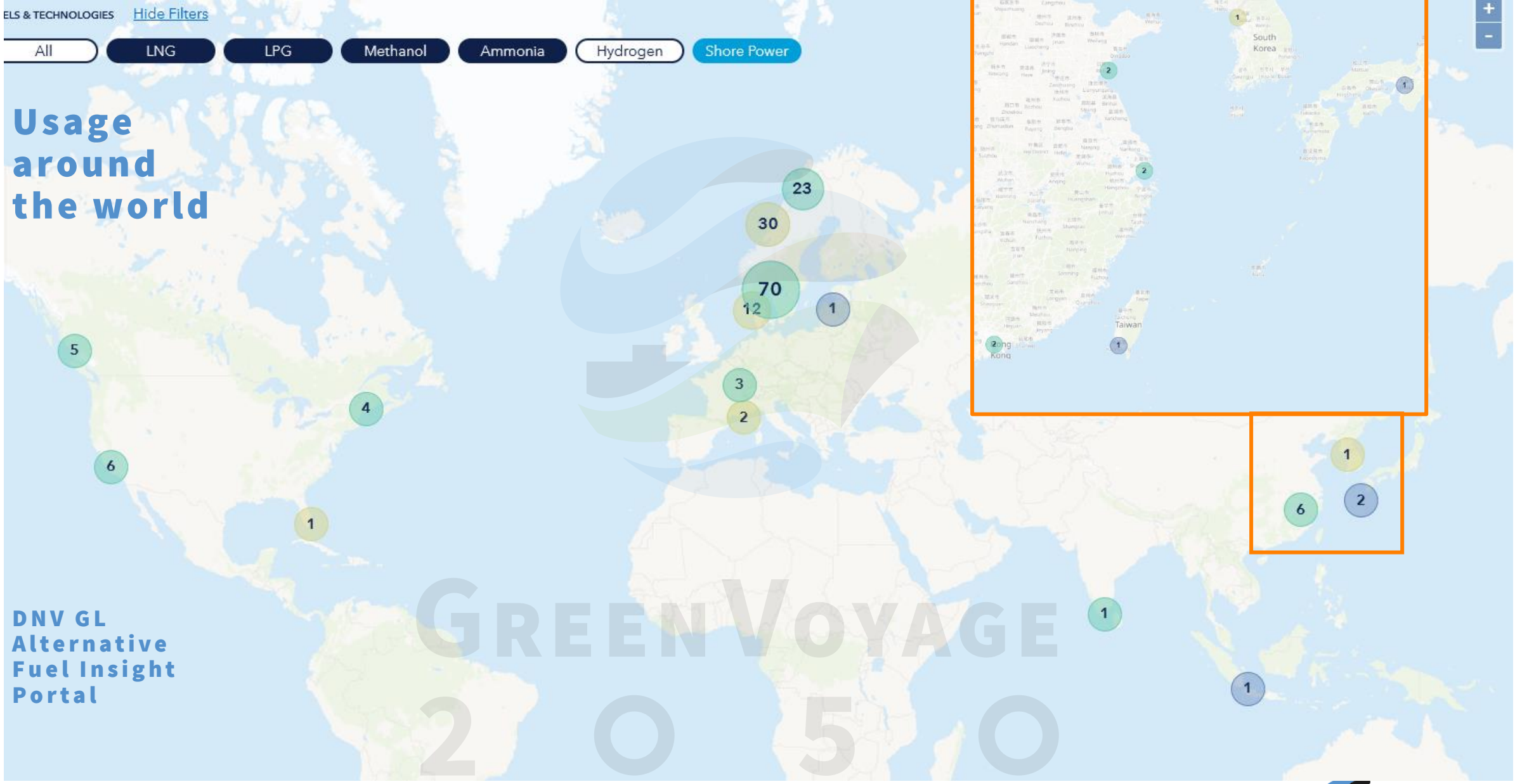
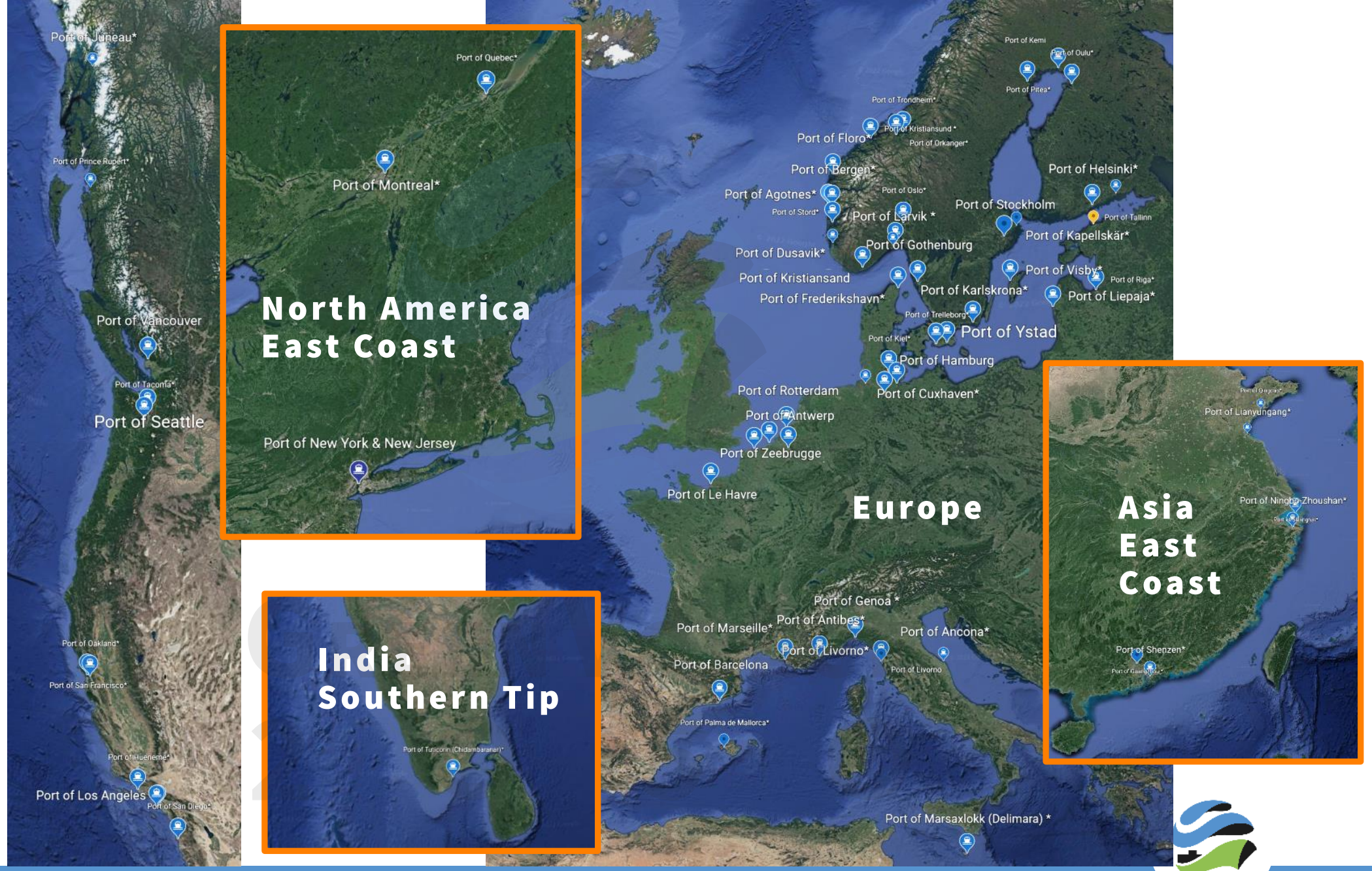


https://afi.dnvgl.com/

Usage around the world

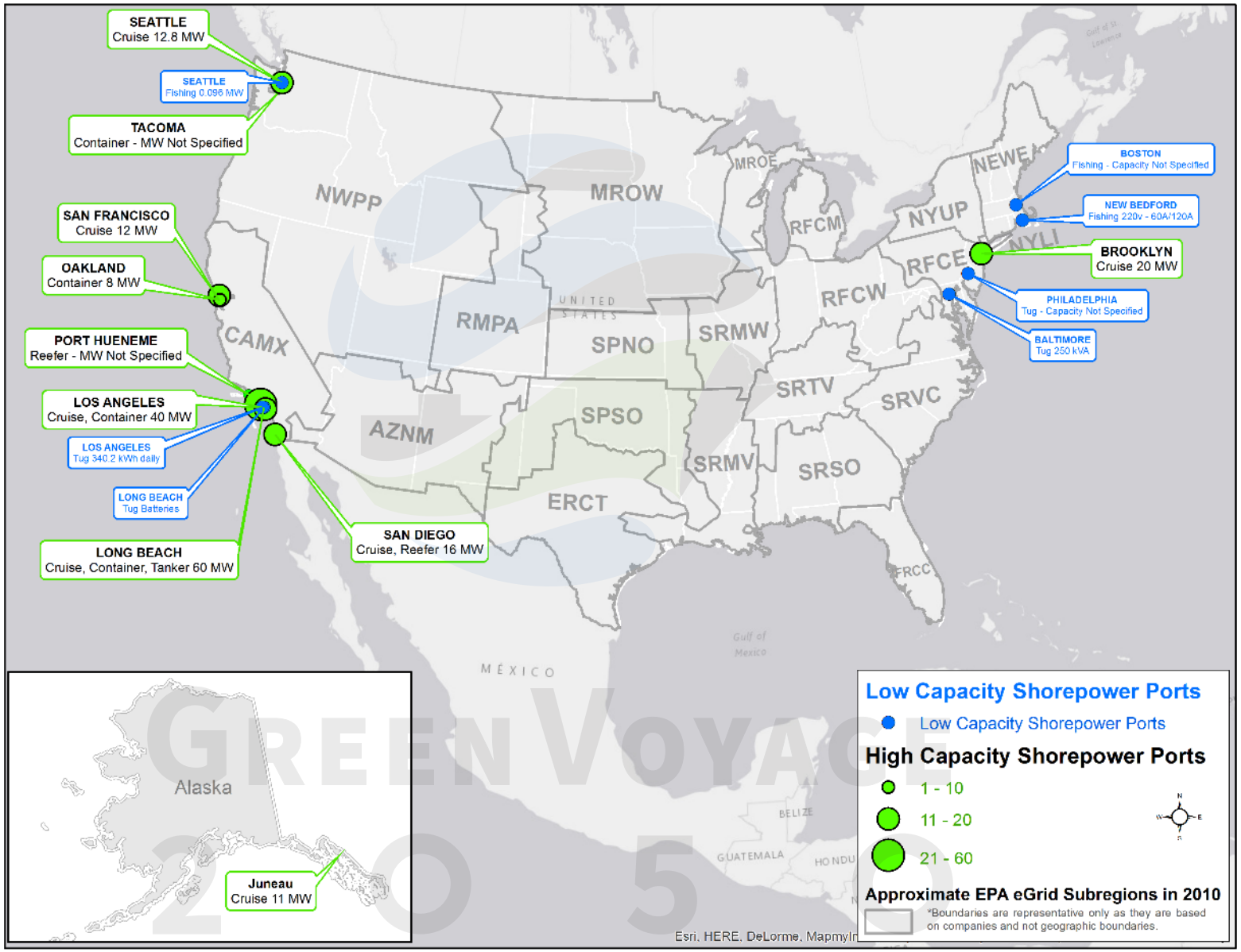
North America – West Coast



WPCAP Power2Ship Portal

https://sustainableworldports.org/wpcap/wg-3/wpcap-power2ship-dynamic-google-earth-map/

Usage around the world



US EPA, https://www.epa.gov/ports-initiative/shore-power-technology-assessment-us-ports