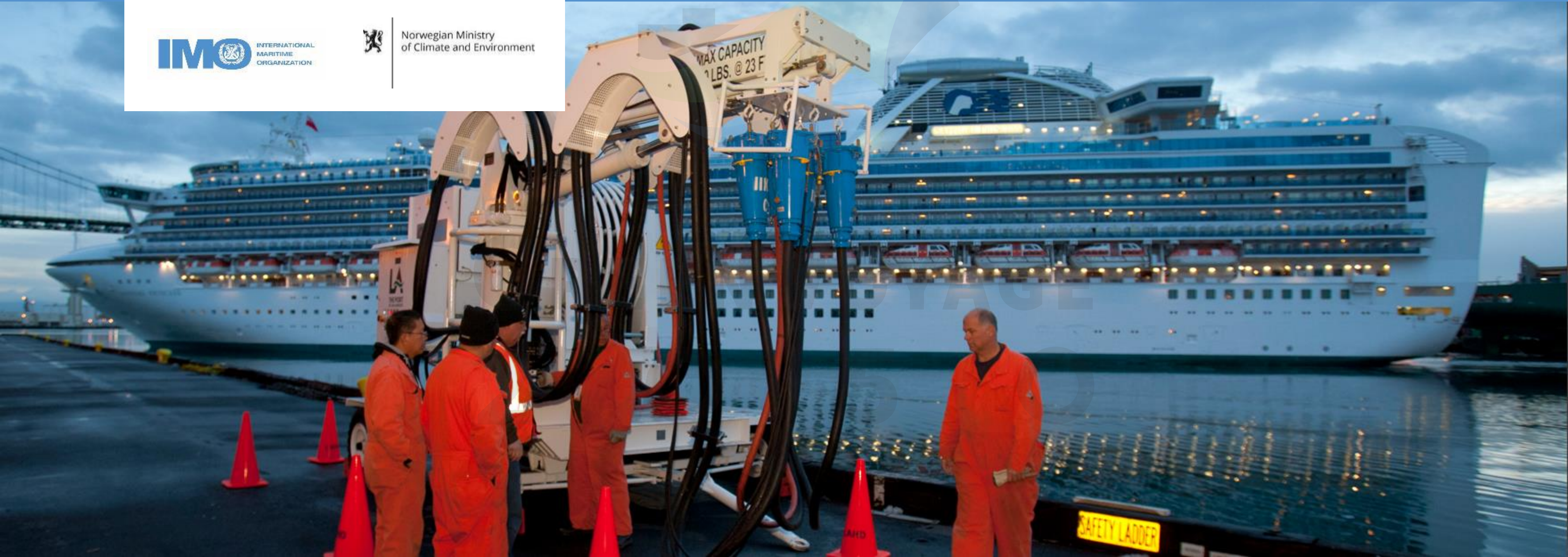
GreenVoyage 2050

INTERNATIONAL MARITIME ORGANIZATION

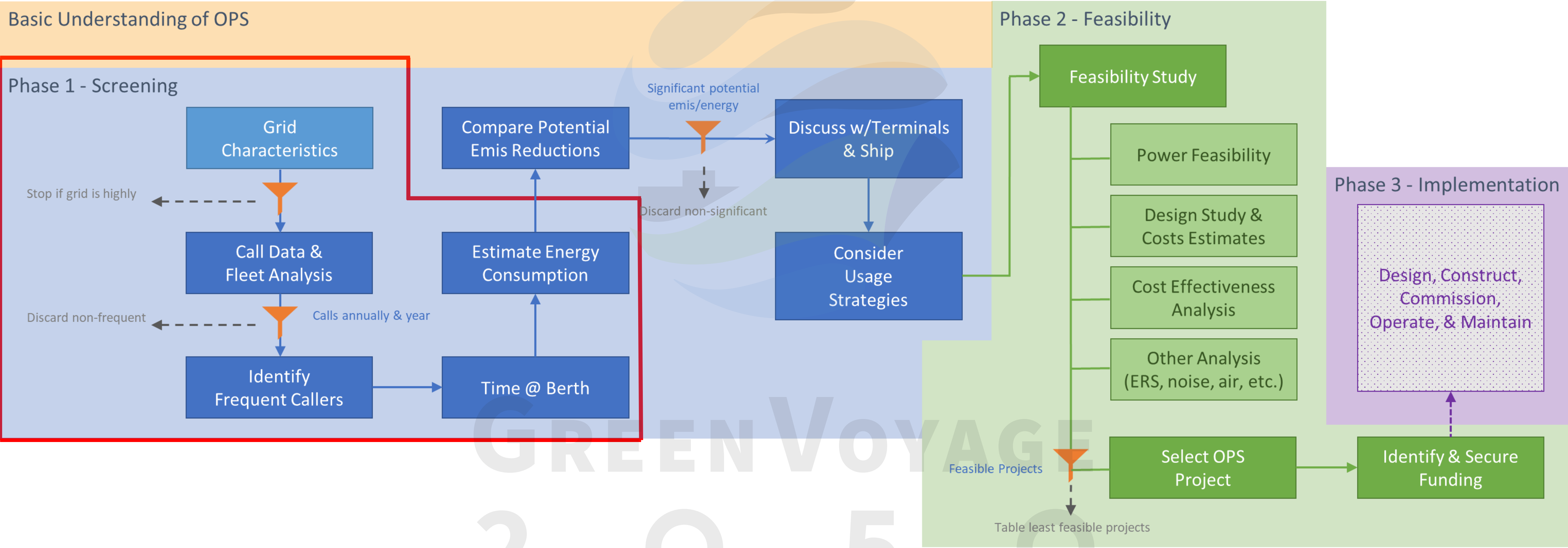
Norwegian Ministry of Climate and Environment

Onshore Power Supply Workshop

Session 2: Phase 1 Screening - Grid & Fleet Analysis



Decision pathway



Session 2 -Phase 1 Screening – Grid & fleet analysis
Learning Objectives

- Understand the importance of grid characteristics
- Understand the importance of call data and know how to conduct a fleet analysis
    - Identify frequent callers
    - Calculate time at-berth
    - Understand how to estimate energy consumption
- Know how to compare potential emission reduction levels among various vessel types and fleets

Photograph by Robb Kendrick, Nat Geo Image Collection
https://www.nationalgeographic.com/science/article/150817-power-plant-pollution-depends-on-the-weather

Questions to consider

- How does the grid impact the effectiveness of OPS as a strategy?
- Are all vessel types good candidates for OPS?
- How do you know if OPS may be right for your fleet?

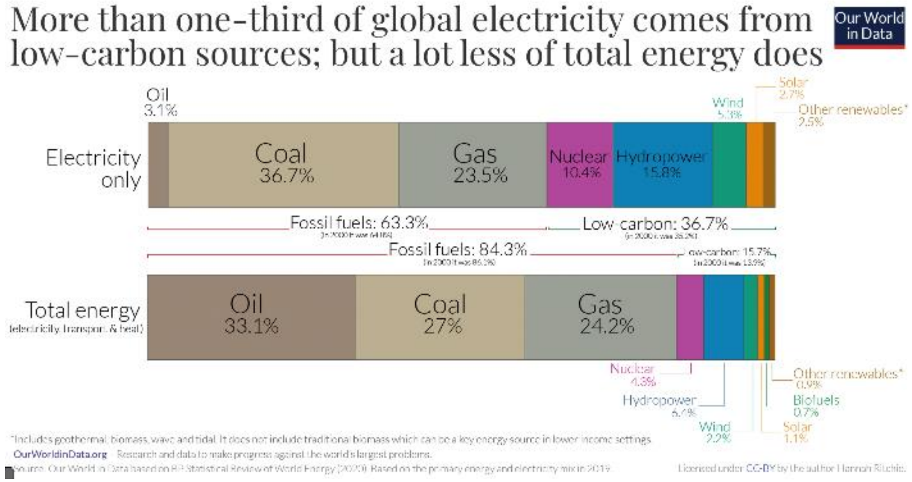
Grid characteristics

- Why is it important to evaluate grid characteristics?

- Energy generation mix
  - Conventional generation sources
  - Renewable generation sources
  - Nuclear generation
  - Other

- Power frequency
  - 50 mHz or 60 mHz
  - Implications

- Grid reliability & Capacity



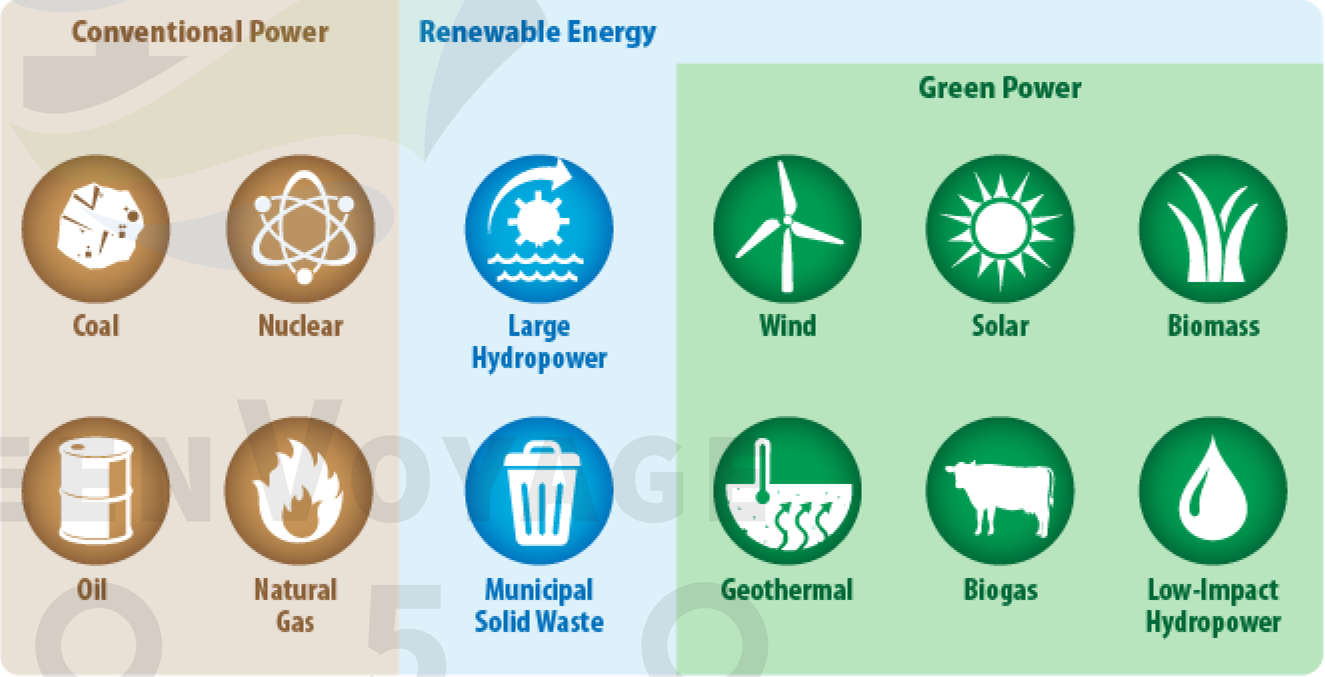
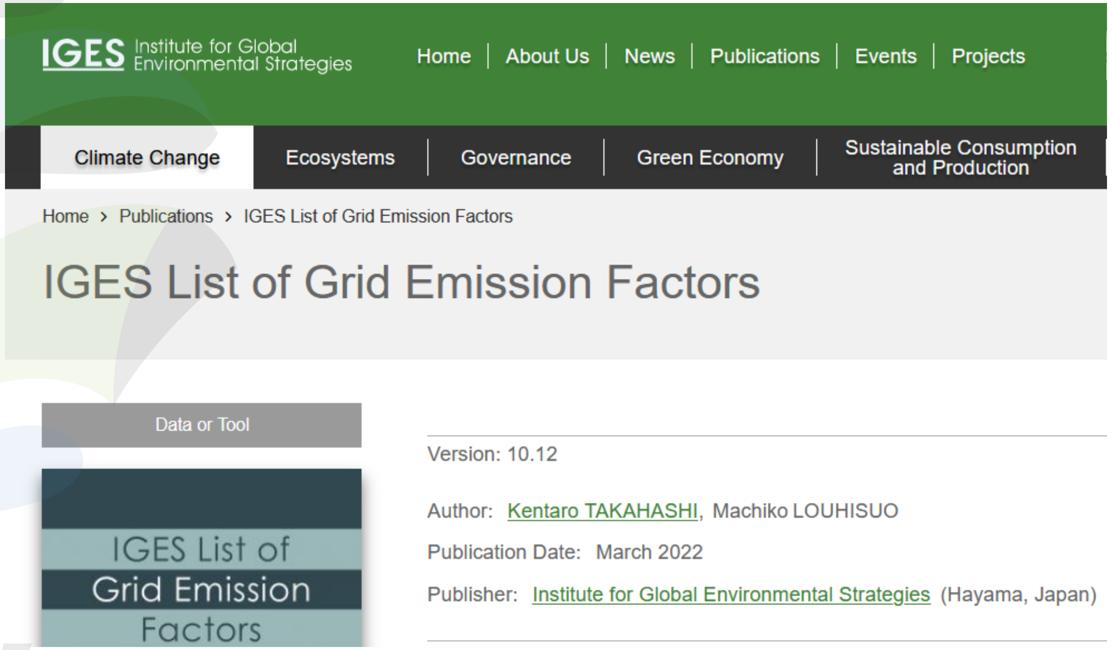


Illustration by USEPA
https://19january2017snapshot.epa.gov/greenpower/what-green-power_.html

Grid characteristics

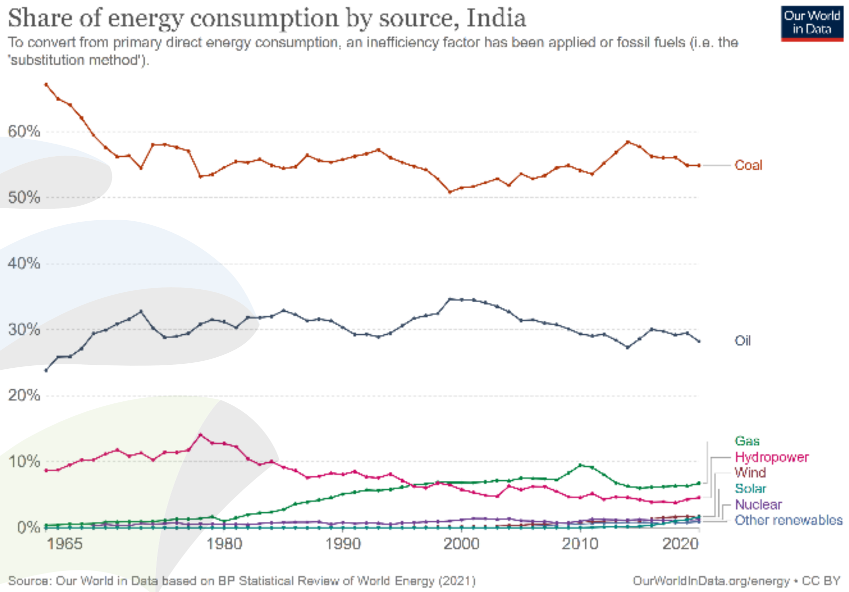
- Grid generation emissions per unit energy
  - Utilities or energy providers can provide emission rates for power generation (typically tonne per kilowatt or megawatt hour t_/kWh or t_/MWh)
    - GHG emissions
    - Pollutant emissions
  - Where to find emissions rates if your utility does not provide one:
    - National resources
    - International resources

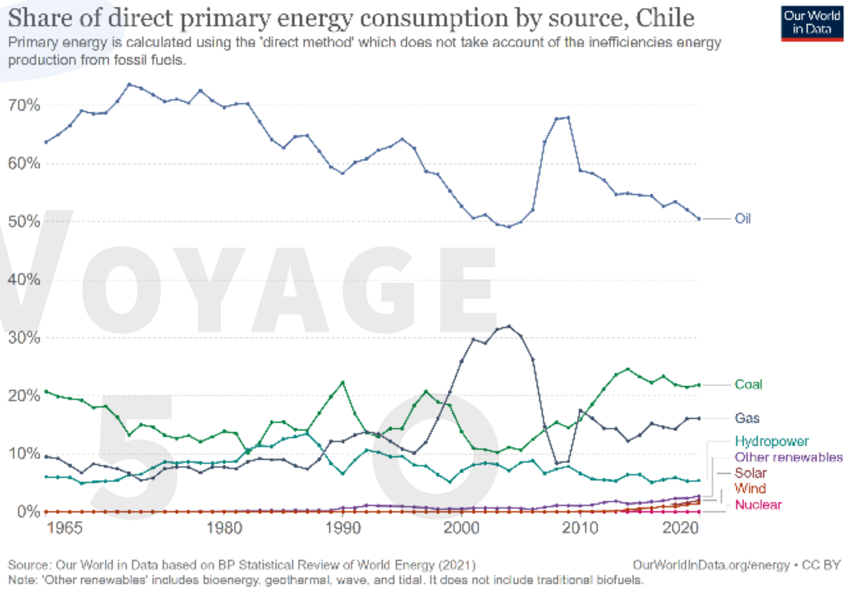


https://www.iges.or.jp/en/pub/list-grid-emission-factor/en

Grid characteristics

- Grid future improvements plans
  - Important to understand the future plans utilities have related to future emissions
    - Pollutant emissions
    - GHG emissions
    - Timelines
    - Forecasted reductions

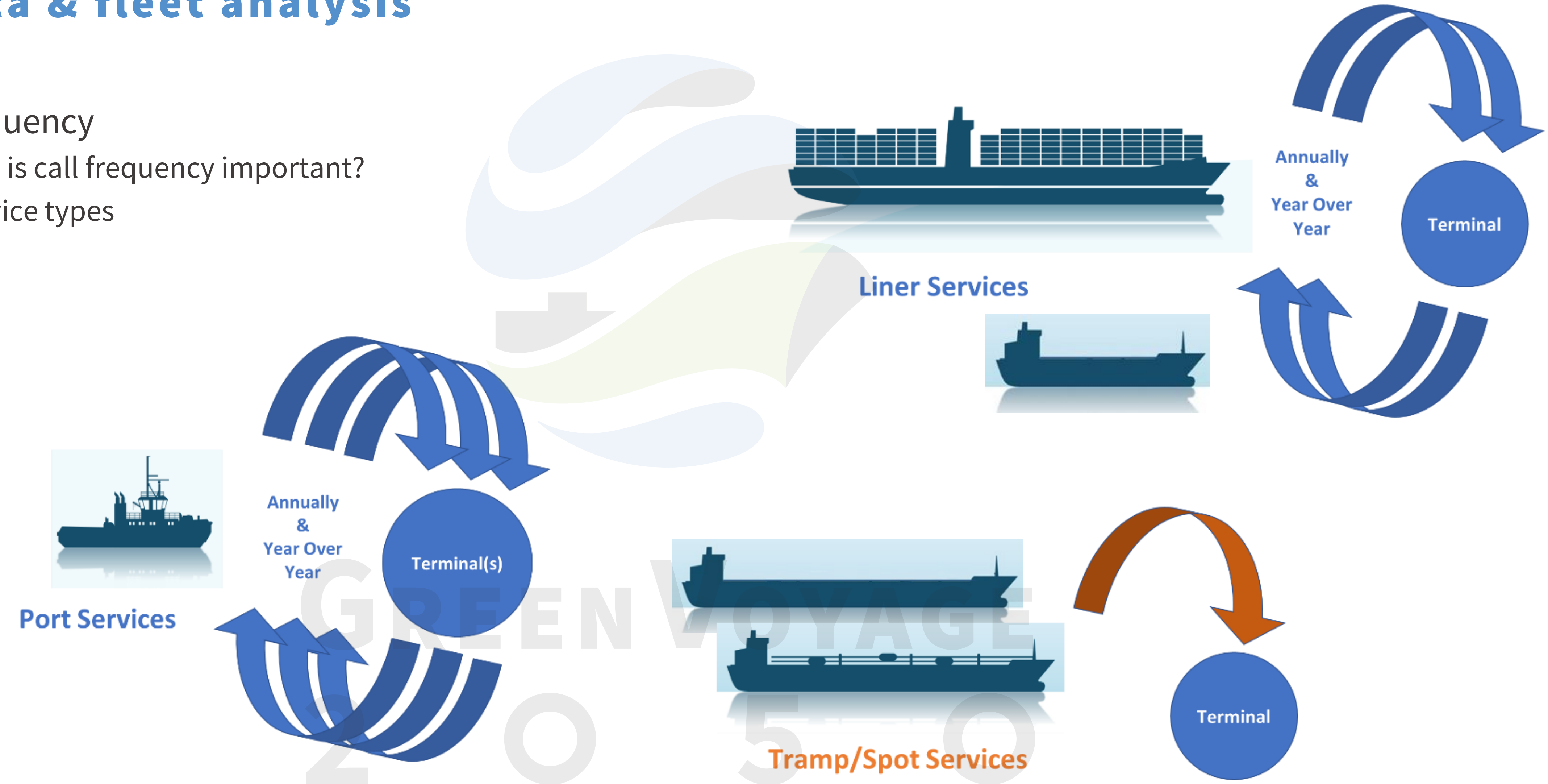




https://ourworldindata.org/energy-mix

Call data & fleet analysis

- Call frequency
  - Why is call frequency important?
  - Service types



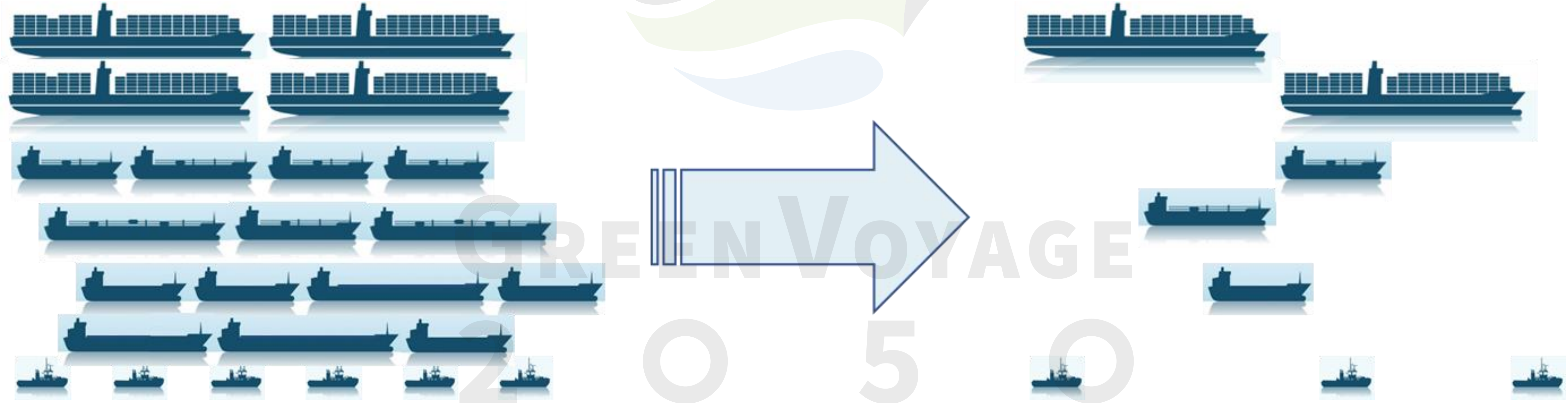
Call data & fleet analysis

- Gather port vessel call data for the past 5 years
  - IMO number or vessel identifier
  - Vessel name
  - Terminal(s) visited
  - Arrival/departure times
  - Ship type (container, tanker, bulk, tug, ferry, etc.)
  - Ship size

- Fleet analysis
  - Bin unique vessels by the number of years they have called the port over the past five years
  - For the vessels that have called multiple years, did they call sequentially or are there years in which they did not call between visits?
    - Filter out those sequentially calling vessels from those that did not call in the last two years

Identify frequent callers

- Determine the number of calls per year to filter the fleet analysis
- Take into account terminal(s) called
- Identify frequent calling vessels & terminals



Time at-berth

- Evaluate identified frequent calling vessels, by terminal to determine time at-berth
  - Per call - determine minimum, average, & maximum durations
  - Total annual time
- On a terminal basis, evaluate consistency of the call profiles & number of calls for context
- Rank identified candidate terminals based on call frequency & nature of calls

Estimate energy consumption

- Energy consumption (EC) at-berth is the next step related to identifying OPS candidates
- Energy consumption at-berth for conventional calls (CC) & OPS calls is estimated by:

$$\mathbf{EC_{CC}\ (kWh) = load_{at\text{-}berth}\ (kW)\ x\ hours_{CC}}$$

$$\mathbf{EC_{OPS}\ (kWh) = load_{at\text{-}berth}\ (kW)\ x\ hours_{OPS}}$$

- Estimate for both auxiliary engines & boilers
  - Note – boilers may not be on during a conventional call due to waste heat recovery, or the vessel has electric boilers (boiler energy is then in the auxiliary loads)
- EC_{CC} & EC_{OPS} are estimated for each call in the most recent calendar year

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Estimate energy consumption

- Example – bulk ship

Aux engine load$_{at\text{-}berth}$ = 650 kW; boiler load$_{at\text{-}berth}$ = 135 kW; call hours$_{at\text{-}berth}$ = 40 hours

Conventional call (CC)

Auxiliary$_{CC}$ EC_{CC} = 650 kW x 40 hrs = 26,000 kWh

Boilers$_{CC}$ EC_{CC} = 135 kW x 40 hrs = 5,400 kWh

OPS call: assume 1.5 hours per connect & disconnect phase

Auxiliary$_{OPS}$ EC_{OPS} = 650 kW x 3 hrs = 1,950 kWh

Boilers$_{OPS}$ EC_{OPS} = 135 kW x 40 hrs = 5,400 kWh

Grid$_{OPS}$ EC_{grid} = 650 kW x (40-3) hrs = 24,050 kWh

For this example, OPS covers ~93% of the ships auxiliary $EC_{at\text{-}berth}$ & boilers remain the same

Estimate energy consumption

- Example – cruise ship

  Aux engine load$_{\text{at-berth}}$ = 7,500 kW; boiler load$_{\text{at-berth}}$ = 0 kW (WHR); call hours$_{\text{at-berth}}$ = 8 hours

  Conventional call (CC)

  Auxiliary$_{CC}$ EC_{CC} = 7,500 kW x 8 hrs = 60,000 kWh

  Boilers$_{CC}$ EC_{CC} = 0 kW x 8 hrs = 0 kWh

  OPS call: assume 1.5 hours per connect & disconnect phase

  Auxiliary$_{OPS}$ EC_{OPS} = 7,500 kW x 3 hrs = 22,500 kWh

  Boilers$_{OPS}$ EC_{OPS} = 1,000 kW x 8 hrs = 8,000 kWh

  Grid$_{OPS}$ EC_{grid} = 7,500 kW x (8-3) hrs = 37,500 kWh

  For this example, OPS reduced the net energy consumption at-berth of auxiliary engines & boilers by ~38%

Emissions comparison conventional call vs OPS call

- Example – cruise ship – CO_2 – Kenya grid 0.4999 t CO_2/MWh

Conventional call (CC)

$Auxiliary_{CC}$ $Emiss_{CC}$ = 60,000 kWh x 609 g CO_2/kWh x t / 10^6 g = 36.5 t CO_2

$Boilers_{CC}$ $Emiss_{CC}$ = 0 kWh = 0.0 t CO_2

$Total_{CC}$ = 36.5 t CO_2

OPS call

$Auxiliary_{OPS}$ $Emiss_{OPS}$ = 22,500 kWh x 609 g CO_2/kWh x t / 10^6 g = 13.7 t CO_2

$Boilers_{OPS}$ $Emiss_{OPS}$ = 8,000 kWh x 1,026 g CO_2/kWh x t / 10^6 g = 8.2 t CO_2

$Grid_{OPS}$ $Emiss_{grid}$ = 37,500 kWh x 1 MWH / 1,000 kWh x 0.4999 t CO_2/MWh = 18.8 t CO_2

$Total_{CC}$ = 40.7 t CO_2

For this example, OPS reduced auxiliary engine emissions by 63%, increased boiler emissions from 0, & increased total emissions by 10%

Homework

Which of these scenarios would OPS

- be most effective in terms of fleet usage?
- realize the most energy savings?

Scenario A

- 126 general cargo calls
- 33% of calls made by frequent callers
- Call characteristics:
  - Aux eng load$_{at\text{-}berth}$ = 950 kW
  - Boiler load$_{at\text{-}berth}$ = 125 kW
  - Call hours$_{at\text{-}berth}$ = 54 hours
  - Assume 2 hour per c/d phase
  - India – 903 g CO_2/kWh

Scenario B

- 120 RoRo calls
- 40% of calls made by frequent callers
- Call characteristics:
  - Aux eng load$_{at\text{-}berth}$ = 1,200 kW
  - Boiler load$_{at\text{-}berth}$ = 140 kW
  - Call hours$_{at\text{-}berth}$ = 36 hours
  - Assume 2.5 hour per c/d phase
  - Malaysia – 585 g CO_2/kWh

Scenario C

- 150 cruise ship calls
- 50% of calls made by frequent callers
- Call characteristics:
  - Aux eng load$_{at\text{-}berth}$ = 5,500 kW
  - Boiler load$_{at\text{-}berth}$ = 0/950 kW
  - Call hours$_{at\text{-}berth}$ = 8 hours
  - Assume 3 hour per c/d phase
  - Belize – 420 g CO_2/kWh