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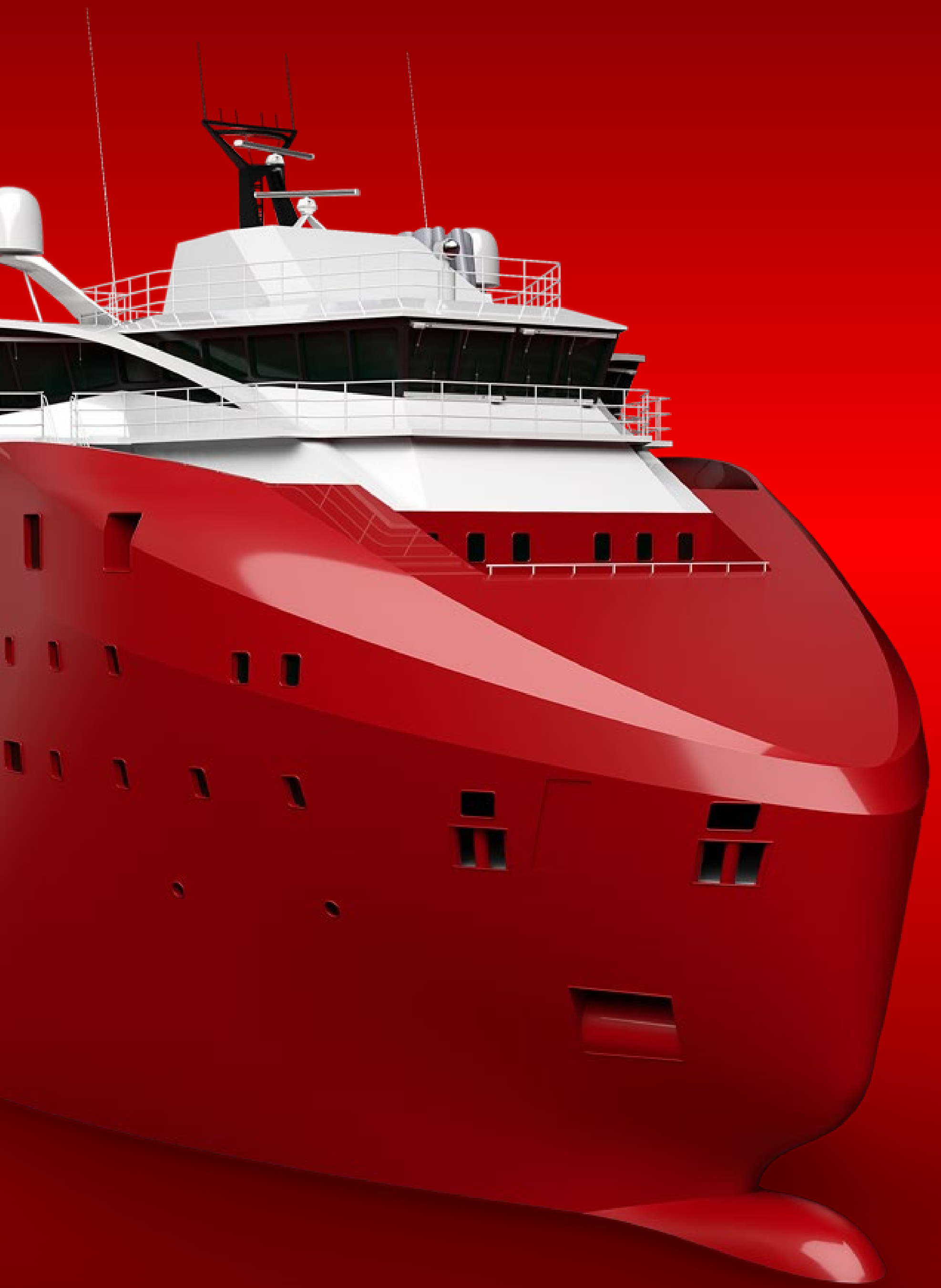

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# Ship Energy Efficiency and Underwater Radiated Noise

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18 September 2023

Image: BEAMREACH.ORG



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# Background and Rationale

- Energy Efficiency and Green House Gas are regulated by IMO via the EEDI, EEXI and CII
- Underwater Radiated Noise (URN) increasingly recognized as a threat to the marine environment (a non-mandatory guideline of IMO is released this summer).
- Transport Canada (TC) funded this study.
  - TC is internationally and nationally taking a leadership role to investigate URN.

# Scope of Work

- Provide report and matrix on treatments to:
  - increase Energy Efficiency (EE),

    and/or
  - reduce Green House Gas (GHG), and
  - their impact on Underwater Radiated Noise (URN).
- Present the findings at the IMO GHG-URN Workshop (Sept 2023)

# Treatments addressed

## Work covers:

- EE, GHG and URN treatments:
  1. Hydrodynamics
  2. Propulsor
  3. Powering
  4. Other Technologies
  5. Operational Measures



- Main URN sources:
  - Propeller Noise
  - Machinery Noise
  - Flow Noise

# EE & GHG Impacts & Relationship

- EE: the amount of energy required to transport a unit of cargo by a certain distance.
- GHG: the amount of $CO_{2equivalent}$ to transport a unit of cargo by a certain distance.

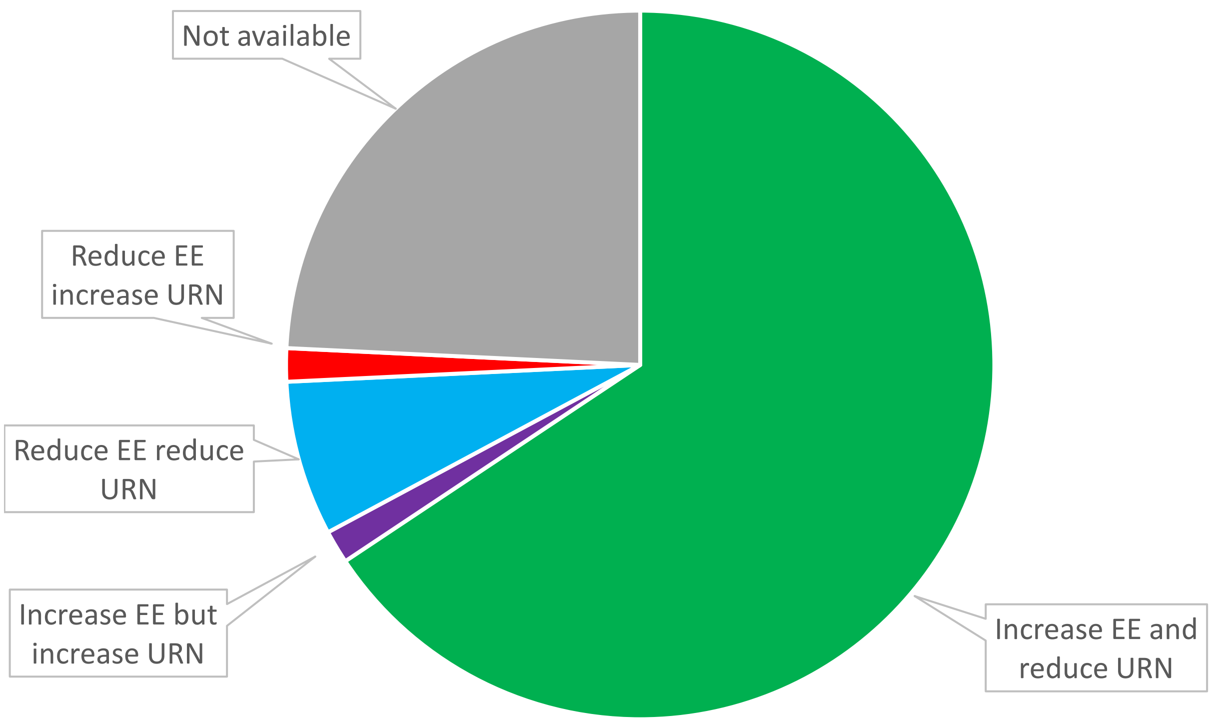
- EE and GHG are often closely correlated:

  EE↑ & GHG↓
- However, a ship with a Carbon Capture & Storage system has a reduced EE, and a reduction in GHG emissions: EE↓ & GHG↓

# EE & URN Impacts & Relationship

- EE and URN are often closely correlated:

  EE↑ & URN↓



# EE & URN Impacts & Relationship (continued)

- Noise can negatively affect marine mammals, fish and invertebrates.
- URN levels and the World Fleet Gross Tonnage have been increasing with time

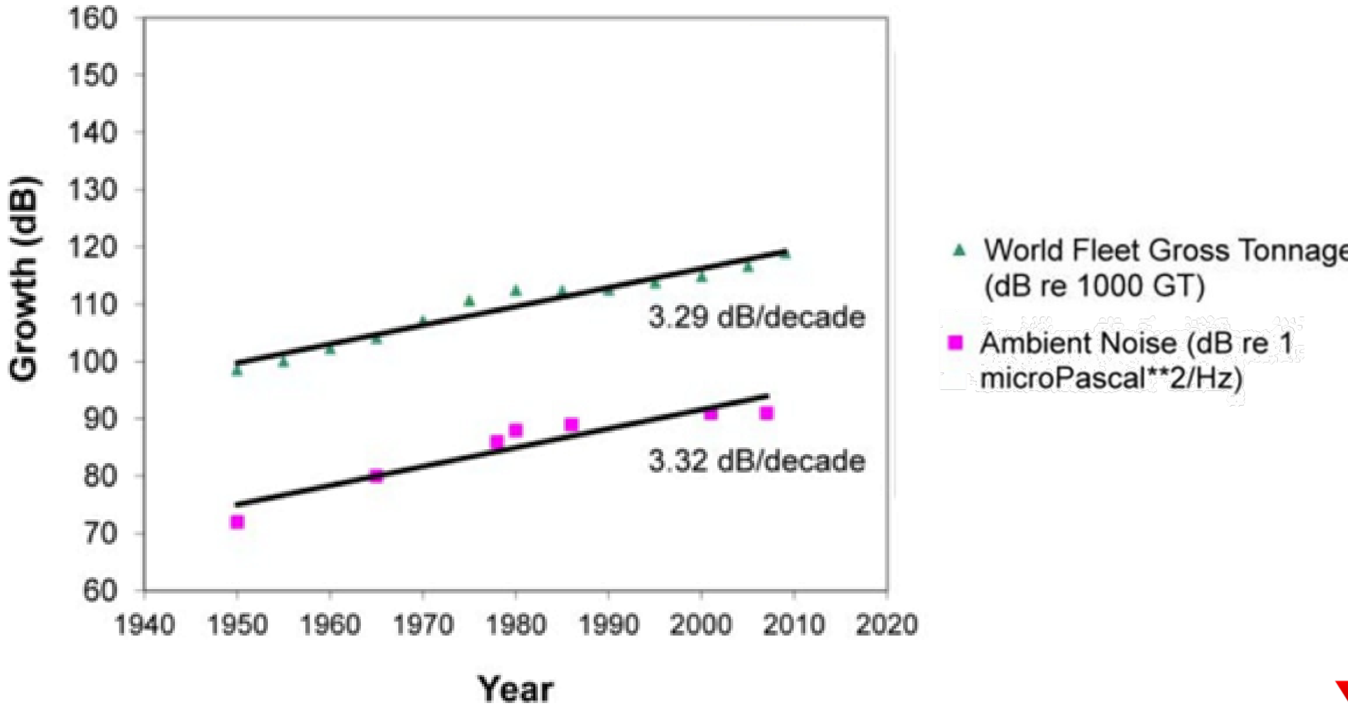



Image: Frisk, G. Noiseonomics: The relationship between ambient noise levels in the sea and global economic trends. Sci Rep 2, 437 (2012).

# Matrix Design

- Based on approach used by US National Oceanographic and Atmospheric Administration (NOAA), adapted and extended
- Each (treatment) entry covers:
  1. Description of the mechanism
  2. EE & GHG (percentage) change
  3. URN change (dB range and Frequency Range)
  4. Group (each combination of EE,GHG vs URN)
  5. Additional Advantages and Benefits
  6. Drawbacks and Disadvantages
  7. Technology Readiness Level
  8. Cost estimate
  9. Applicability (Refit and/or New Build and shiptype –size vs speed-)

# Matrix Design (continued)

- Many assessments are based on Vard’s ship design experience (and might differ from publicly available papers).
- Operational profile and ship specifics will have an influence on the presented numerical values.
- Opinions and assumptions are Vard’s and do not represent position or policy of TC or the Canadian Government.
- The Matrix does not endorse any product or service provider.
- The report does not provide a comprehensive overview of alternative fuels.
- The effectiveness of the URN reduction relates to the noise source being treated (NOT the overall ship URN).
- Vard is open to comments on the work via the provided comment form.

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# Examples – Hydrodynamics/Hull Appendage Design

| Treatment/Description | Energy Efficiency | GHG Reduction | URN | | T | Ship Impacts | | TRL | Cost Estimation | Applicability | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Change | % Change | dB Change | Freq. Rng. | | A/B | C/D | | Percentage/Range/Pay-back Period/Shorthand | RF/NB Ship Types | |
| **EFFICIENT ABOVE WATER FORMS** Aerodynamically efficient forms will reduce air and wind resistance power requirements and therefore both machinery and propulsor noise. [79] | <1 % | <1 % | None | - | N/A | C | D | 9 | low | RF / NB<br>1, 2 | May warrant more consideration for smaller and faster ships.<br>Cost is for larger ships. For smaller ships, engineering cost may be significant relative to the cost of the ship depending on the complexity of analyses. Additional cost may incur due to more streamlined hull production. |


Image:https://gcaptain.com/cma-cgm-confirms-windshield-installation-on-marco-polo/



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# Examples – Propulsor/Propeller Propulsor Design

| Treatment/Description | Energy Efficiency | GHG Reduction | URN | | T | Ship Impacts | | TRL | Cost Estimation | Applicability | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Change | % Change | dB Change | Freq. Rng. | | A/B | C/D | | Percentage/Range/Pay-back Period/Shorthand | RF/NB Ship Types | |
| **AZIMUTHING PROPULSORS**<br>Azimuthing propulsors have motors (electric or reciprocating machines) inside the hull with transmission gears in the gondola. Depending on technology may have gear noise or electric motor/converter noise to mitigate. Limited public domain information is available on the machinery noise characteristics of the podded (see 2.1.13) and azimuthing, both types claim good performance. [13] [14] | -6 to 0 %<br>Ship and installation specific | -6 to 0 %<br>Ship and installation specific. | Unknown | Unknown | 3 or 4 | C<br>MA<br>S | P<br>W | 9 | Components more expensive than shafted system but installation costs can be reduced. | NB<br>1, 2, 3 | Cost estimation is from VARD's internal assessments.<br>EE and GHG compared to a shafted solution.<br>URN during steering is relatively high.<br>Manoeuvring is improved compared to shafted system. |

Image:https://www.nauticexpo.com/prod/schottel/product-22142-488859.html

# Examples – Powering/Machinery Treatments to Noise

| Treatment/Description | Energy Efficiency | GHG Reduction | URN | | T | Ship Impacts | | TRL | Cost Estimation | Applicability | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Change | % Change | dB Change | Freq. Rng. | | A/B | C/D | | Percentage/Range/Pay-back Period/Shorthand | RF/NB Ship Types | |
| **RESILIENT MOUNTS (EQUIPMENT)** Spring mounts impede the transmission of vibration energy from machinery, and the generation of energy into the water from the hull. Requires appropriate selection and installation of mounts. Generally, not practical for heavy 2-stroke Diesel engines. [36] | None | None | > 10 dB | All | N/A | C | S W | 9 | 20 to 2000$ per mount | RF / NB 2, 3, 4 | URN reduction is best at higher frequencies. Large engines require many more mounts, increasing installation cost. |

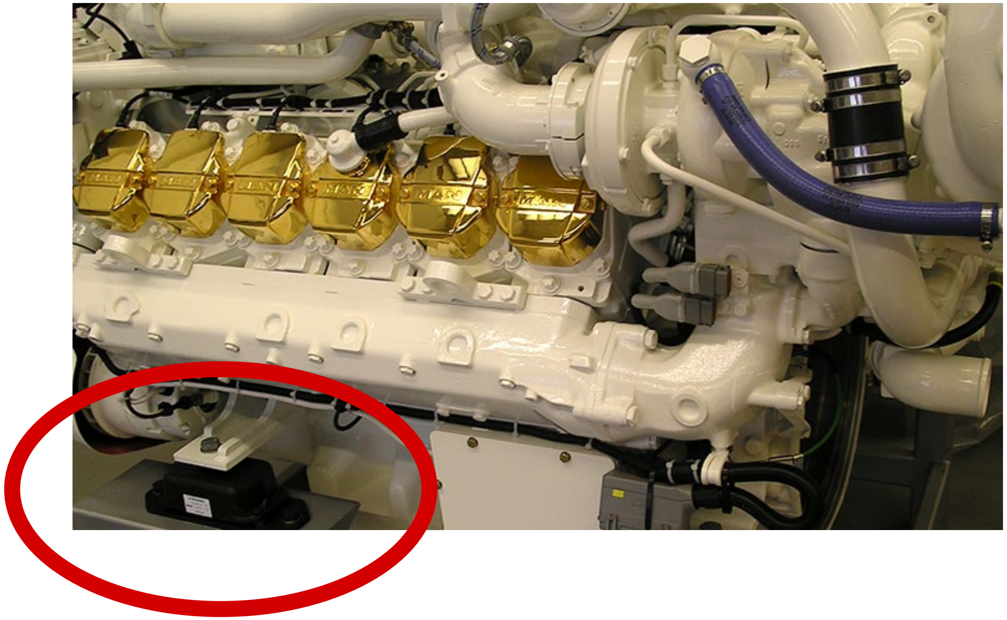


Image: https://www.continental-industry.com/en/solutions/suspension-anti-vibration/marine/engine-mounts

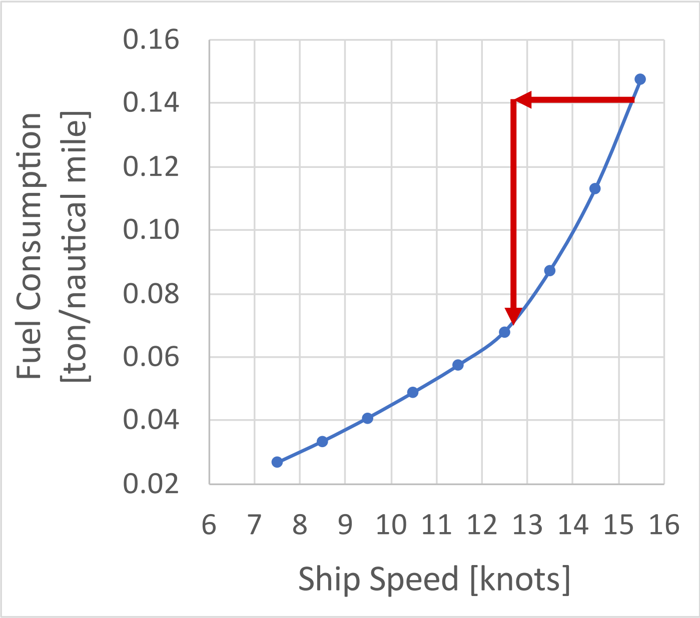
# Examples – Other Mitigating Technologies/WASP

| Treatment/Description | Energy Efficiency | GHG Reduction | URN | | T | Ship Impacts | | TRL | Cost Estimation | Applicability | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Change | % Change | dB Change | Freq. Rng. | | A/B | C/D | | Percentage/Range/Pay-back Period/Shorthand | RF/NB Ship Types | |
| **KITE SAILS**<br>Kites attached to the bow creating supplementary thrust. [22] [53] [76]<br>Noise benefits come from reduced propeller loading. | 4 to 13 % | 4 to 13 % | 5 to 10 dB | All | 1 | C | D<br>S<br>P | 8 | Payback Period:<br>15+ years (medium) | RF / NB<br>1, 4 | Peak performance and fuel reduction depend on the wind direction and intensity.<br>URN reduction depends on speed reduction and primary propulsion source.<br>Not suited to smaller ships or to operations on short routes and fixed schedules, e.g. smaller ferries. |

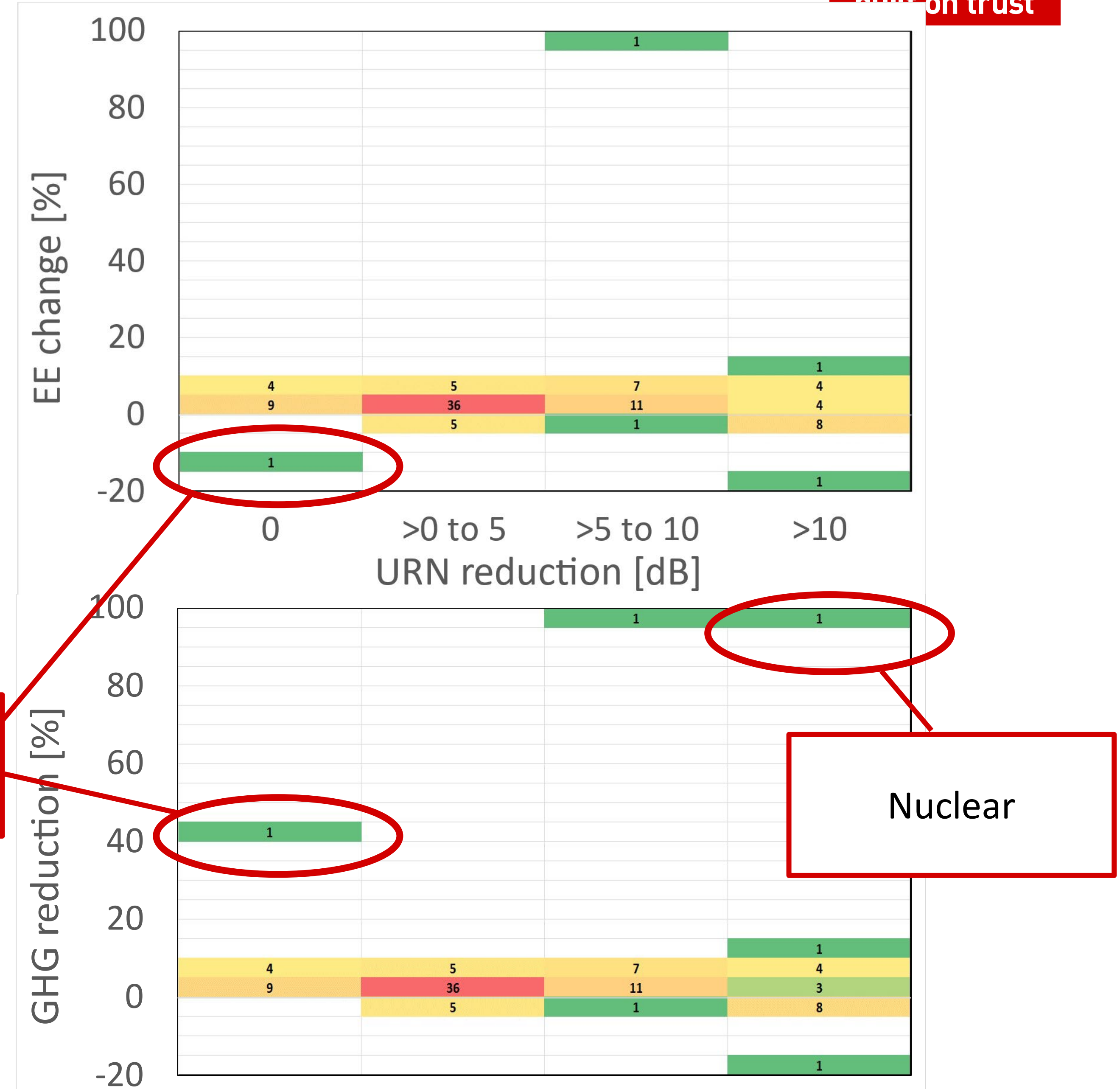

Image: https://www.cargo-partner.com/trendletter/issue-10/sails-and-kites-support-cargo-ships

# Examples – Operational Measures/Operational Planning

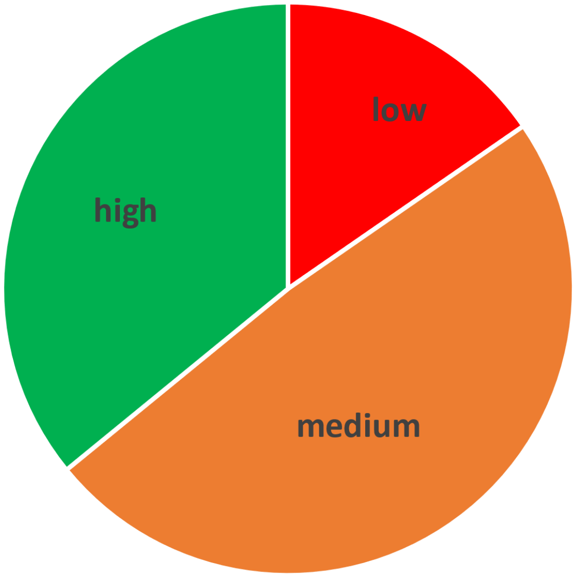
| Treatment/Description | Energy Efficiency | GHG Reduction | URN | | T | Ship Impacts | | TRL | Cost Estimation | Applicability | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Change | % Change | dB Change | Freq. Rng. | | A/B | C/D | | Percentage/Range/Pay-back Period/Shorthand | RF/NB Ship Types | |
| **SPEED REDUCTION (SLOW STEAMING)/ENGINE POWER LIMITATION (EPL)** The engine load is approximately proportional to the cube of speed, so reducing the speed of the ship will reduce its own fuel consumption. At the fleet level, more ships are required to transport the total cargo.<br>This method has already been adopted and returned good results in terms of fuel economy/emissions reduction by many ship operators. To implement a good practice at the existing fleet level, an overridable engine power limitation can be imposed (mechanically or electronically). [68] [76] [93] | Approximately proportional to square of speed reduction. | Approximately proportional to square of speed reduction. | < 5 dB | All | 1 | M | - | 9 | Cost mainly from reduction in transport efficiency – slower ships will deliver less cargo over a given time period. | RF<br>1 to 4 | Exposure duration increases for URN.<br>EE change is taking into account the transportation reduction, and hence the required additional sailing if speed is reduced.<br>Sufficient power and speed must be is maintained for safe navigation.<br>Not suited to ships designed/customized for a specific route/mission profile e.g., icebreakers |



# Visualisation



# Visualisation (continued)




| Knowledge level, engineering estimate: | | | |
|---|---|---|---|
| **SubSection #, Treatment** | **EE** | **GHG** | **URN** |
| 1.1 Hull Appendage/Design | high | high | medium |
| 1.2 Frictional Resistance Reduction | medium | medium | low |
| 2.1 Propeller/Propulsor Design | high | high | medium |
| 2.2 Wake Flow Modification | high | high | low |
| 3.1 Machinery Selection | high | high | medium |
| 3.2 Machinery Treatments to Noise | medium | medium | medium |
| 3.3 Machinery Treatments to Energy | high | high | medium |
| 3.4 Alternative Fuel Selection | medium | medium | medium |
| 3.5 Hotel Load | high | high | medium |
| 4.1 Wind Assisted Ship Propulsion (WASP) | medium | medium | medium |
| 4.2 Other Energy Source | high | high | medium |
| 5.1 Operational Planning | medium | medium | low |
| 5.2 System Montoring and Management | low | low | low |
| **Count:** | | | |
| **low** | **1** | **1** | **4** |
| **medium** | **5** | **5** | **9** |
| **high** | **7** | **7** | **0** |

# Recommendations

- EE/GHG:
  - Standards/guidelines to validate performance of EE/GHG technology
  - Provide longer-term validation
  - Provide costing information
- URN:
  - Programs like ECHO: Ship specific noise data, Baseline data (background & ship) for effectiveness URN mitigation
  - Validate performance of URN technology
  - Develop standardised URN measurement approach
  - Incentivization (URN reduction voluntary); disseminate examples
  - Share information