TECHNICAL MEMO

Memo to:
Icelandic Ministry of Infrastructure

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Approved By:

Added main propulsion energy due to harsh weather for feeder size container vessels in liner operation to Iceland

1 EXECUTIVE SUMMARY

The feeder size container vessels trading to Iceland spend about 7-8% more propulsive energy due to wind and waves than similar sized vessels trading to Europe or globally. It is the leg from the last port of call outside Iceland that experiences the worst waves, but the study evaluates the total propulsive energy for each selected vessel in 2025.Actual voyages are used as basis for the calculation.

2 BACKGROUND

Iceland depends on seaborn transport. The container ships that provide the goods must cross a part of the North Atlantic, an ocean known for harsh weather conditions. A ship travelling in wind and waves needs to spend more energy for propulsion to maintain the speed. The energy per transported unit increases. This means added fuel costs, in addition to increased emissions. International regulations and mechanisms like Fuel EU Maritime and EU ETS add costs to emissions. The possible IMO Net Zero Framework will penalize vessels that consume more. The Ministry of Infrastructure asked DNV Maritime Advisory to investigate the consequences of emission costs for vessels trading to Iceland, starting with an understanding of the added energy required for main propulsion due to harsh weather.

3 OBJECTIVE

The increase in main propulsion energy spent due to wind and waves for vessels trading to Iceland will be compared with the same increase for vessels in the same capacity range involved in European and global trade.

4 METHODOLOGY OVERVIEW

An outline of the methodology is provided in the following. DNV has worked with emission modelling and reporting for the last two decades [1]. Currently, the emission calculation model MASTERv2 is considered as state-of-the-art. This model uses the vessel characteristics together with the operational parameters to estimate the required propulsive power as well as energy usage for auxiliary engines and boilers. MASTERv2 is based on first principles, where the required propeller thrust balances different resistance components, including calm water resistance from hull friction, viscous pressure loss and wave generation, wind and wave resistance and effects of hull fouling. Accurate added resistance calculations is important for this study, and the applied model for wave resistance is that of Liu and

Papanikolaou [2], added resistance from wind employs wind coefficients from 28th ITTC report [3] and the required inputs are estimated with a regression formula proposed by Kitamura et al. [4]. The air resistance for the calm water situation used an average wind coefficient, while the windage area is found based on formulas from Kitamura et al. [4]. All these methods are well recognized and validated. The model is calibrated by comparing the predicted emissions for different vessel types and sizes with reported data available to DNV as a recognized organization performing MRV and DCS verification.

The operational data is provided by access to the automatic identification system (AIS) data. This provides information about the vessel position and speed.

Weather information is obtained from the Copernicus climate data. Specifically, the ERA5 fifth-generation ECMWF atmospheric reanalysis of global climate is used.

Current is not considered, and hull fouling is assumed to follow a 5-year cycle. The vessel draft is assumed to be around 85% of max draft.

The calculations are based on the historic voyages, which means that the vessel speed reflects the possible involuntary speed-loss due to harsh weather. The evaluation considers the fraction of additional power spent due to the harsh weather, and does not consider the additional time spent if the vessel is not able to make the planned speed.

5 VESSEL SELECTION

Vessel selection was done in two rounds, for slightly different purposes.

Based on AIS data, 19 container ships were found to have visited ports in Iceland in the year of 2025. Their cargo carrying capacity varies from 508 TEU to 2150 TEU. The voyages in 2025 are plotted in Figure 5-1, which shows that most of them have been travelling within EEA and north America. A few voyages went as far as to Africa, Middle East and Antarctica.

743 container vessels from 500 TEU to 2200 TEU capacity are detected to have travelled to Europe in 2025, excluding the previous 19. Their trade routes are plotted in Figure 5-2.

In addition, 300 container vessels in the same capacity range are randomly selected to represent global seaborn trade, and their routes are showed in Figure 5-3.

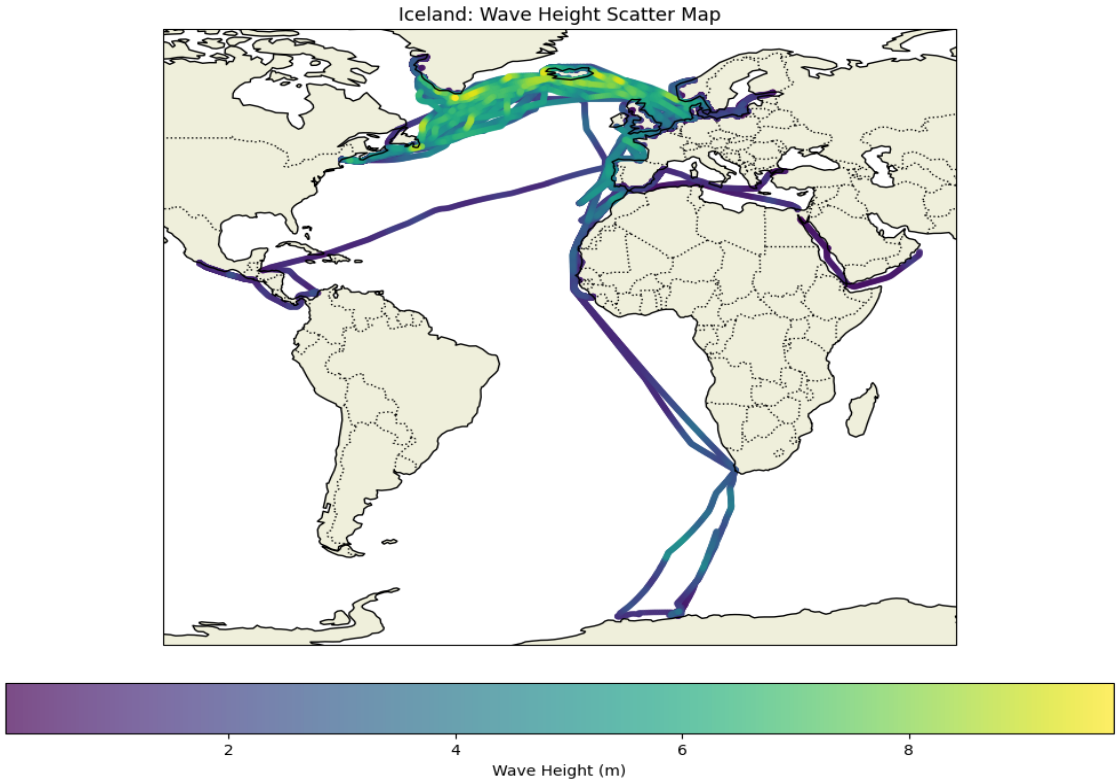

Figure 5-1 travelling routes of all 19 container ships visiting Icelandic ports

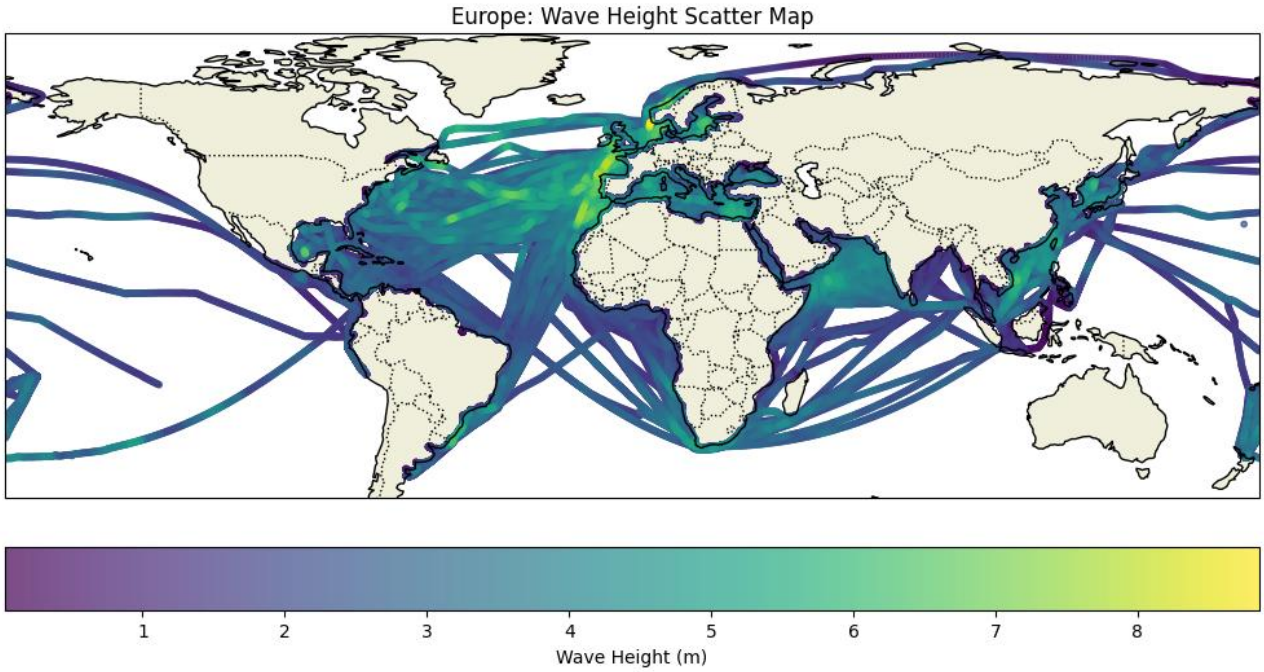

Figure 5-2 travelling routes of all container ships in the same cargo capacity range that traded to Europe (excluding Iceland)

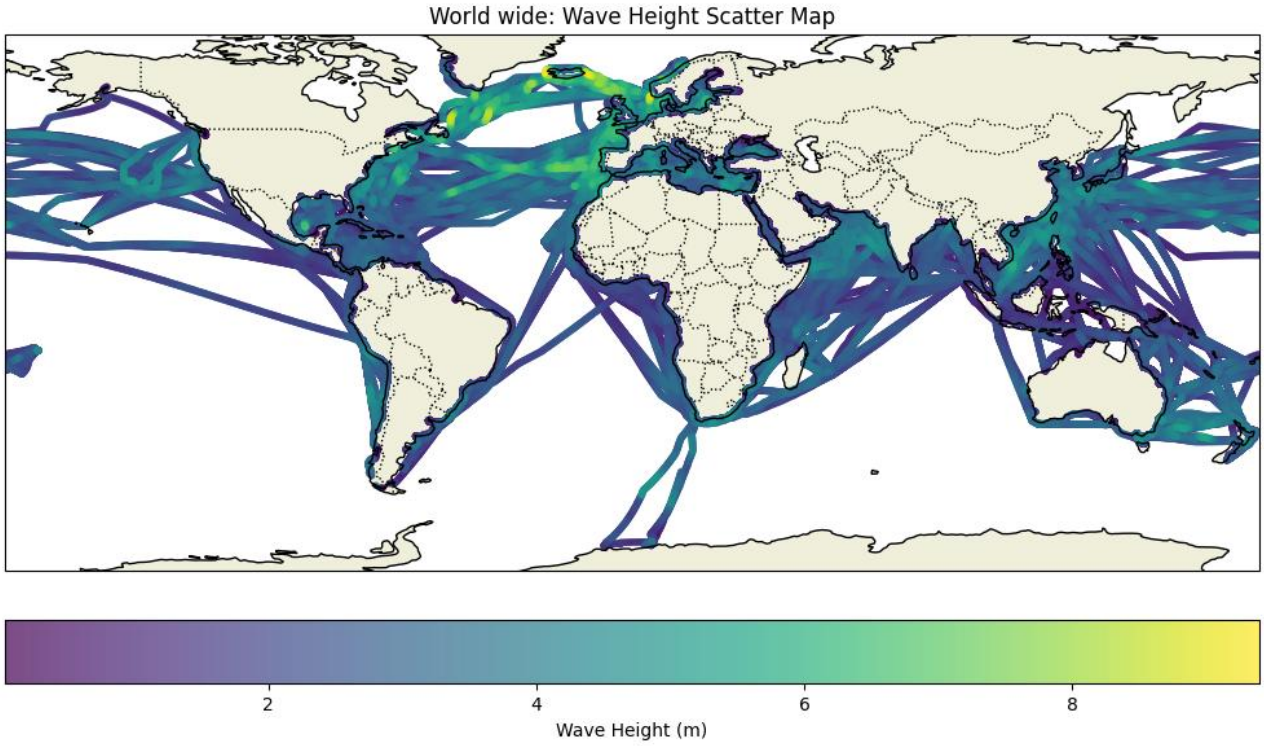

Figure 5-3 travelling routes of 300 selected container ships of the same capacity range for global trades

These first three sets representing trade to Iceland, Europe and globally were used to evaluate the typical experienced weather.

After the initial selection, a slightly different and reduced number of vessels were selected for the European and global trades. This was done to get a more manageable analysis scope for the calculated energy consumption, while retaining a data size that provided representative results.

6 EXPERIENCED WEATHER

For all vessels first selected in the three trade scenarios, the wind and waves they experienced during 2025 were queried, calculated and analysed. The travelling routes are coloured by the significant wave weight they experienced in Figure 5-1, Figure 5-2 and Figure 5-3. A summary is presented in Figure 6-1. It is evident that the waves experienced by container vessels in liner operation to Iceland are significantly higher than those on European or world-wide trade. The example included in the figure shows that the significant wave height that are likely to be exceeded 10% of the time for the vessels trading to Iceland is around 3.4m, while the same for European or global trade is just 2.1m.

The wave direction is quite uniform for trade to Iceland, with a significant wave height frequently above 2 meters from all directions. Vessels trading to Europe and globally meet less harsh conditions. This is illustrated in Figure 6-2.

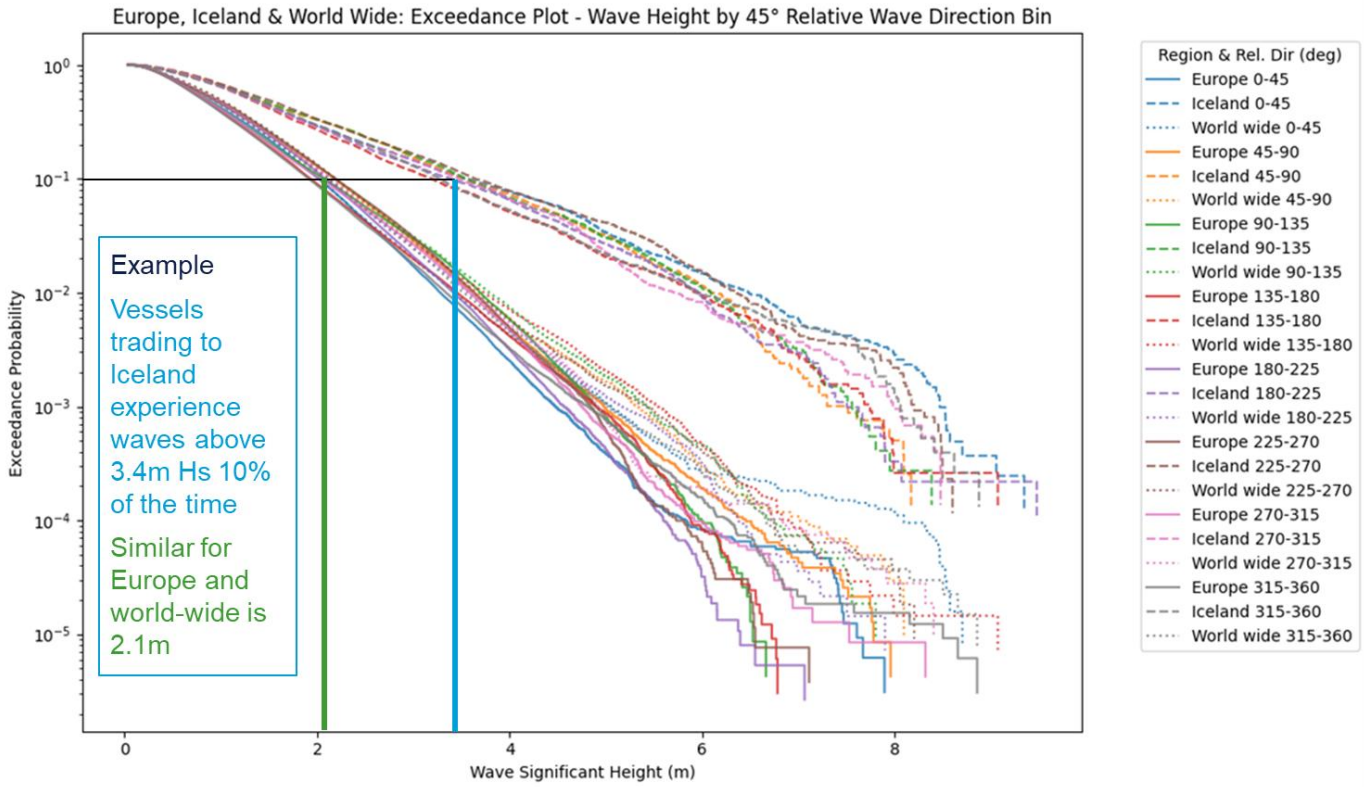

Figure 6-1 wave height exceedance plot

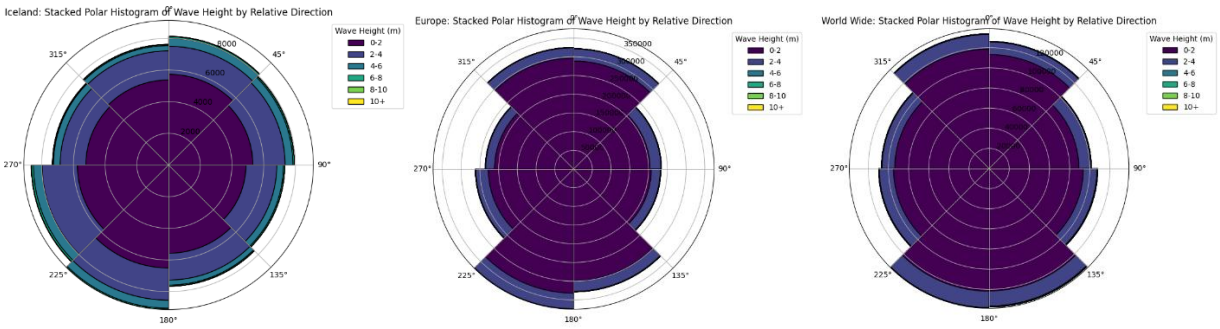

Figure 6-2 wave height and wave direction

7 ENERGY CALCULATIONS AND COMPARISON

Added energy due to wind and waves varies across different routes and seasonal conditions. Vessels may need to increase the propulsion power by 5% or less for coastal trips in the summer, while 30% or higher are common when crossing the North Atlantic in wintertime. Figure 7-1 illustrates how the energy used for main propulsion increases depending on wave direction and significant wave height for the vessels trading to Iceland. It is evident that the higher added energy occurs in head sea and high waves. Each box represents a range of wave direction and significant wave height, and the percentage is an average of the added propulsion energy for all the ships and periods within these ranges.

The vessel main propulsion energy is calculated for 3 scenarios with and without weather for the whole year travels in 2025.

Scenario 1 includes the feeder size container vessels involved in the liner operation to Iceland. The size range is from 500 to 2200 TEU capacity. The resulting list includes all 19 vessels detected. The added propulsion energy percentage (compared to no wind and no wave) is indicated by colour in Figure 7-2.

Scenario 2 considers similar sized container vessels operating more than 50% of the time within European ECA zones, excluding the vessels trading to Iceland. A random selection of 150 vessels is used to keep the analysis time at a reasonable level. This is considered enough to get accurate results. A down sampled plot of propulsion increase percentage is given in Figure 7-3.

Scenario 3 includes 150 container vessels within the defined size range. These are randomly picked among all that operate world-wide. The fraction of additional main propulsion energy spent due to wind and waves is illustrated by colour in Figure 7-4 (down sampled due to the limit of computer's memory).

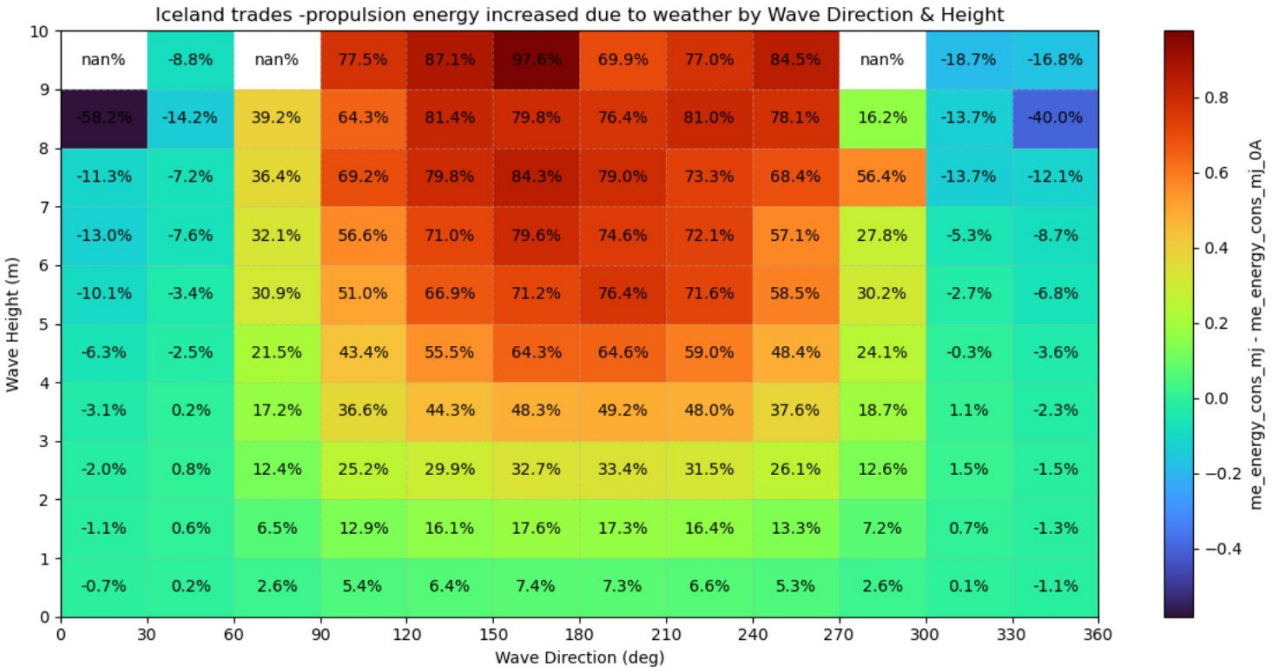

Figure 7-1 propulsion energy increased due to weather

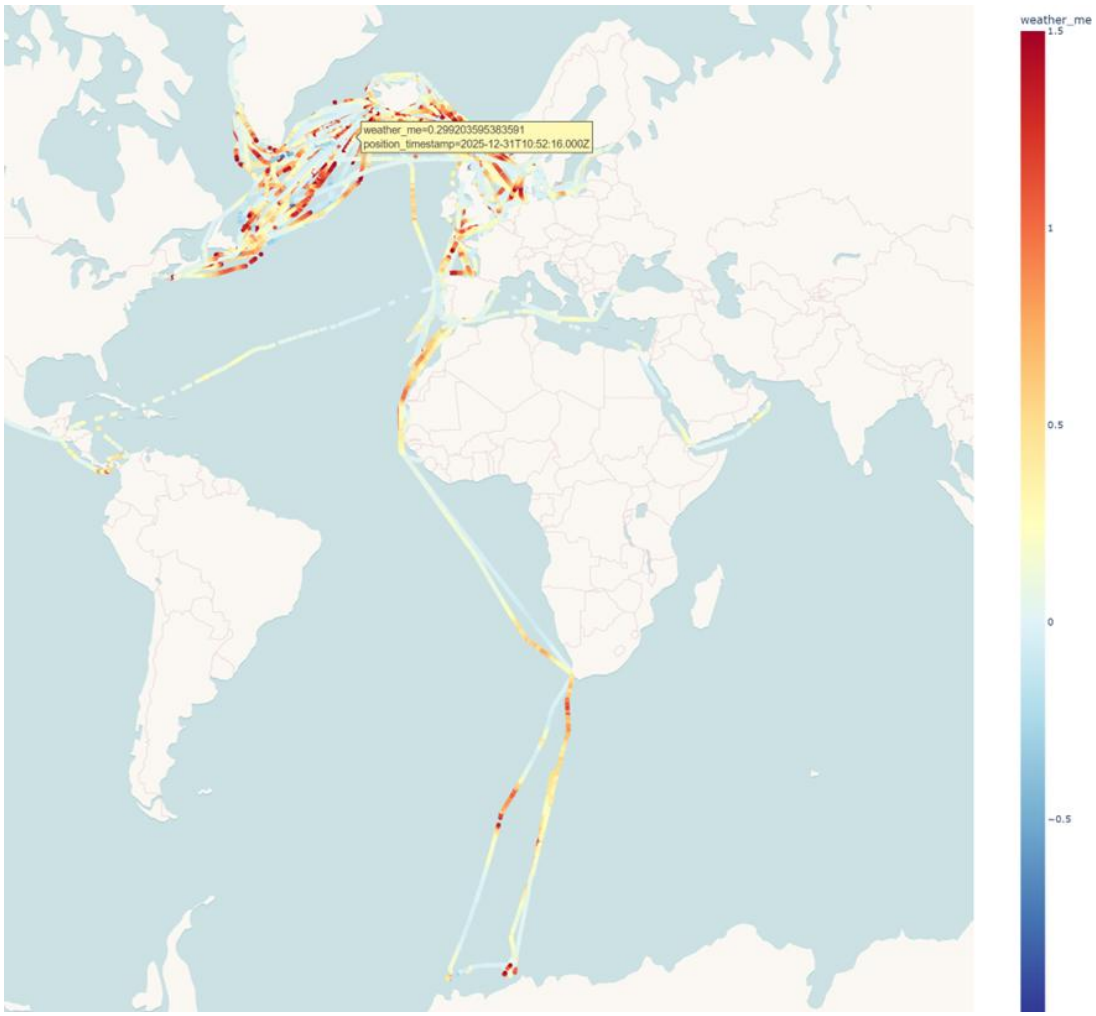

Figure 7-2 propulsion energy increase in percentage for trade to Iceland

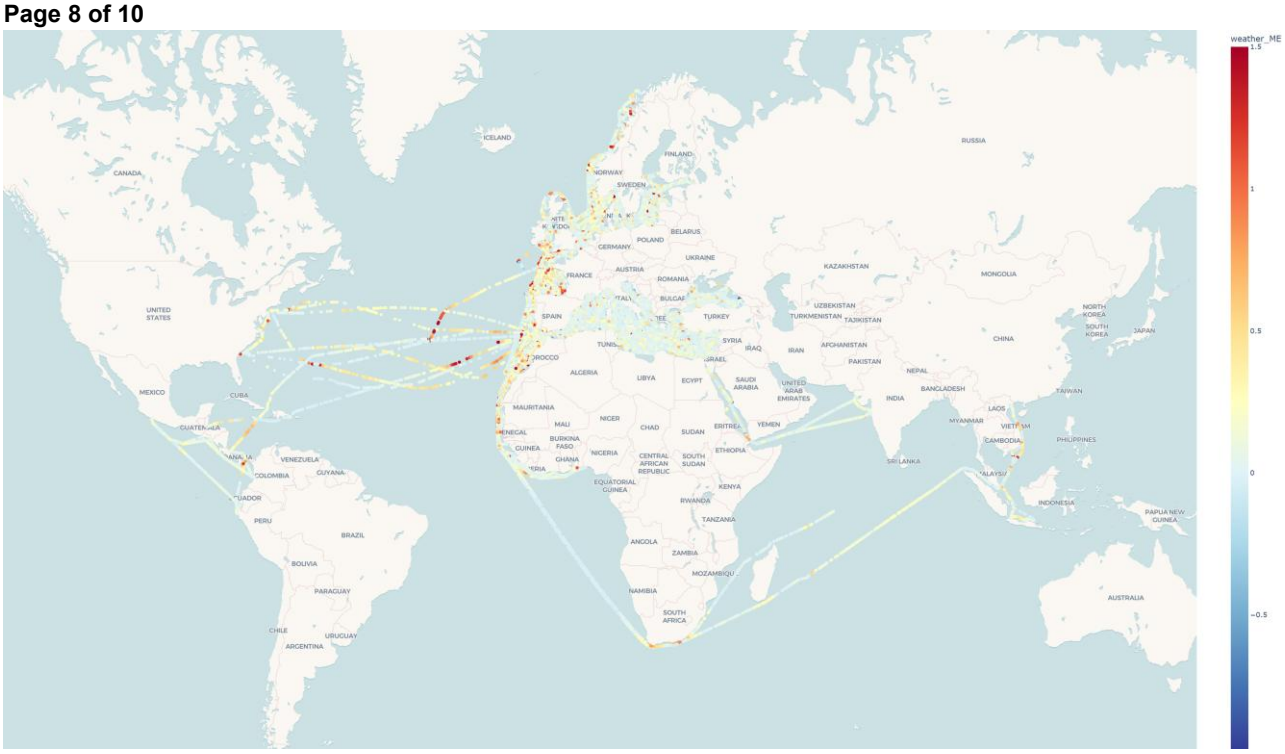

Figure 7-3 propulsion energy increase in percentage for Europe trade

Figure 7-4 propulsion energy increase in percentage for global trade

The average of increase in propulsion energy due to wind and waves for the three scenarios is given in Table 7-1. The result shows clearly that the vessels transporting goods to Iceland spend significantly more of the total propulsive energy to overcome the added resistance due to wind and waves. The difference is 7.8% comparing to Europe average and 7.3% comparing to global average, based on the 2025 numbers, with an uncertainty in the estimate of around plus/minus 1%.

Table 7-1 Mean increase of propulsion energy for different scenario

	Selection Criteria	$\frac{weather\ added\ energy\ consumption}{propulsion\ \ energy\ in\ calm\ water}$
Iceland trading vessels	All 19 vessels found having travelled to Iceland in 2025	**17.2%**
Europe trading vessels	150 vessels of the same size group randomly selected from vessels that have spent more than half of their time in Europe	**9.4%**
Global trading vessels	150 vessels of same size group randomly selected from the global fleet	**9.9%**

8 DISCUSSION

The vessels typically spend a large part of the transit time in coastal and more protected areas in Europe. This is included and leads to conservative (lower) added energy estimates. If only the last part of the voyage to Iceland would be basis for the comparison (last port of call outside of Iceland to an Icelandic port), the added energy would be much higher compared to average voyages within Europe.

For trade to Iceland the added energy is mainly due to the North-Atlantic crossing. The increase in propulsion energy percentage due to wind and waves for different geographical areas is shown in Figure 8-1. The percentages are calculated based on the operation of the selected vessels within these areas in 2025.

Other negative effects of operations in relatively harsher weather are not considered but may have a significant impact on the cost of transporting goods. The length and duration of the voyage may increase due to weather routing or speed-loss. Container vessels in a liner trade typically operate within a tight schedule, and they need to minimise speed-loss by increasing propulsive power. Still, in harsh weather conditions, the installed power may not be sufficient to maintain speed. The voyage takes longer time, and the total consumption increases.

Harsh weather affects ship motions, and the smaller container vessel operating to Iceland are more exposed than larger vessels operating to larger ports. Motions and loads affect equipment wear and tear as well as cargo securing efforts.

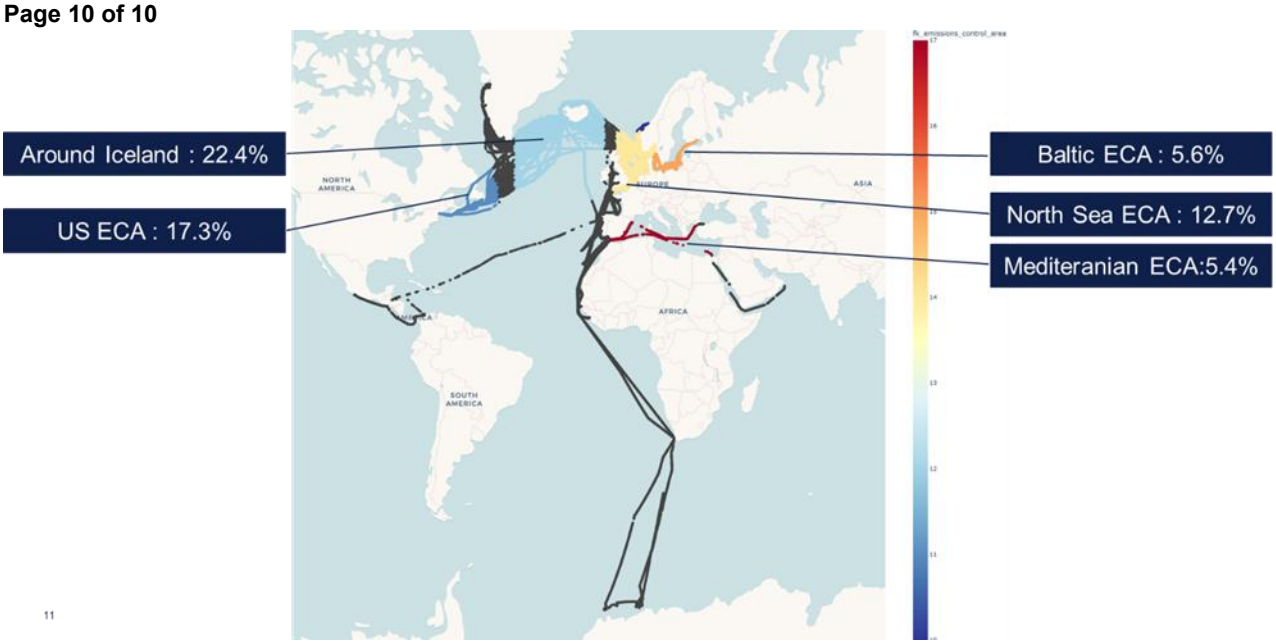

Figure 8-1 propulsive energy increase percentages due to wind and waves for different areas for the 19 vessels operating to Iceland during 2025

9 CONCLUSIONS

The result of this study supports the hypothesis that container vessels transporting goods to Iceland use more energy due to harsh weather conditions. The analyses are based on evaluation of the propulsive energy spent for vessels during 2025. The feeder size container vessels in liner operation to Iceland need around 7.5% more propulsion energy due to wind and waves compared to container vessels of similar size trading to Europe or globally.

10 REFERENCES

[1] DNV, “MASTERv2 - VERDE AIS Model Documentation form GRD,” 2021.

[2] S. K. Liu and A. Papanikolaou, “Fast approach to the estimation of the added resistance of ships in head waves,” *Ocean Engineering,* pp. 211-225, 2016.

[3] Specialist Committee on Performance of Ships in Service of 28th ITTC, “ITTC Quality Systam Manual Recommended Procedures and Guidelines,” 2017.

[4] F. Kitamura, M. Ueno, T. Fujiwara and N. Sigihara, “Estimation of above water structural parameters and wind loads on ships,” *Ships and Offshore Structures,* vol. 12, no. 8, pp. 1100-1108, 2017.