TUI Cruises – Case Study

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Business Problem:

Analyse the provided dataset for two Cruise ships (Vessel 1 and 2) and develop a narrative explaining the performance trends (e.g.: efficiency, propulsion, power generation, etc.). This analysis can pertain to the vessel as a whole or its individual components. You can also select KPIs, based on international regulatory requirements for shipping.

📃 Additional Files:

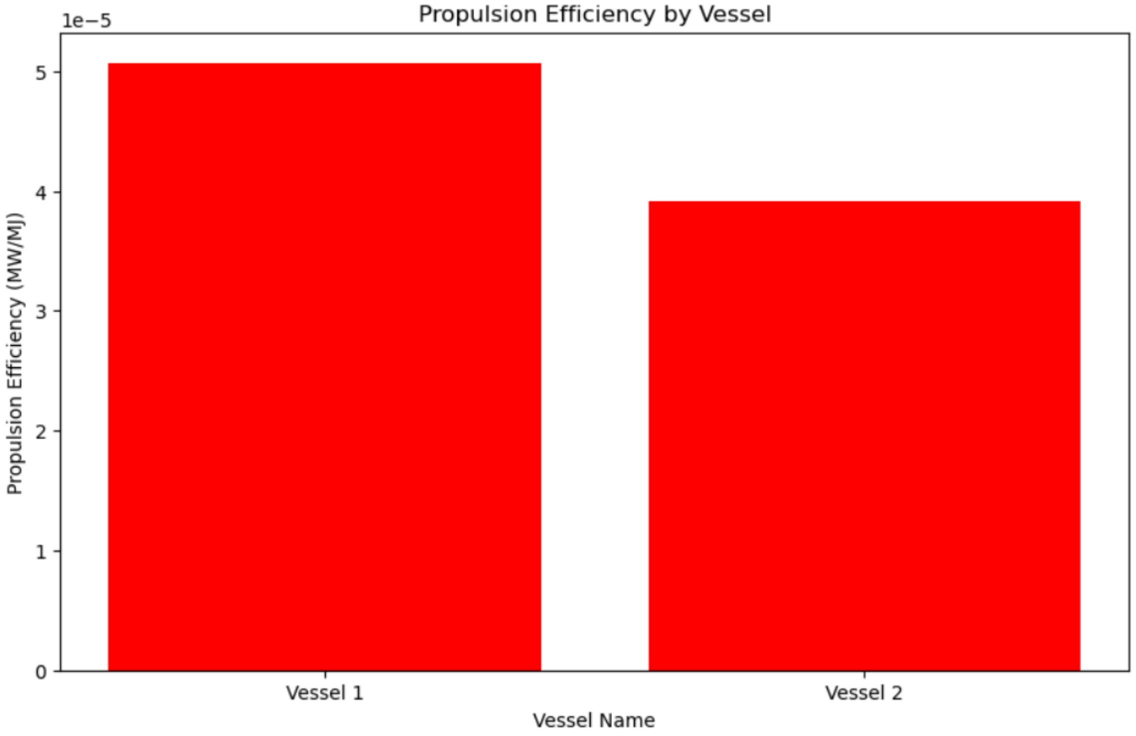
task_data.zip: This file contains following 2 files:

data.csv - The dataset to be analyzed.

schema.pdf - A document providing further details about the dataset.

Propulsion Efficiency for Vessel 1 and Vessel 2

The analysis of propulsion efficiency for the two vessels (Vessel 1 and Vessel 2) focuses on how efficiently the ship converts fuel energy into propulsion power. Propulsion efficiency is calculated as the ratio of propulsion power output to the energy input from fuel, where fuel energy input is based on the fuel's energy content (42.7 MJ per kg).



The chart shows a comparison of propulsion efficiency between Vessel 1 and Vessel 2. Here's an analysis based on the chart:

1. **Vessel 1** exhibits a higher propulsion efficiency compared to **Vessel 2**. This means that Vessel 1 is more effective at converting fuel energy into propulsion power. Higher efficiency generally indicates that the vessel requires less fuel to produce the same amount of propulsion power as compared to **Vessel 2**.

2. **Vessel 2** shows lower propulsion efficiency, which could mean that it either uses more fuel to generate the same power output or that the energy from the fuel is not being converted into propulsion as efficiently as **Vessel 1**.

3. Scale (1e-5): The y-axis has a scientific notation scale (1e-5), meaning that the propulsion efficiency values are very small. The units (MW/MJ) represent the power output in megawatts relative to the fuel energy input in megajoules, and even small differences can be significant over time in marine operations.

Energy Efficiency (Auxiliary Systems) for Vessel 1 and Vessel 2

The analysis of energy efficiency for auxiliary systems on two cruise ships, Vessel 1 and Vessel 2, focuses on four major systems: **HVAC (Heating, Ventilation, and Air Conditioning)**, **Galley (food preparation areas)**, **Scrubbers** (used for emissions control) and **Service (power consumption in the service area).** The energy efficiency of each system is measured in terms of the power consumed by that system per unit of speed over ground (in knots), giving us insight into how much energy is used relative to the ship's movement.

1. Energy Efficiency of HVAC Systems:

- **Vessel 1**: 4.10 MW per knot
- **Vessel 2**: 55.10 MW per knot

Interpretation:

- **Vessel 1** is much more energy-efficient in terms of HVAC systems, consuming far less power per unit of speed. This suggests that **Vessel 1** has a better-optimized HVAC system, which could be due to more modern equipment, better insulation, or a more efficient operational strategy.
- **Vessel 2**'s HVAC system consumes significantly more energy, indicating a potential inefficiency in its cooling and ventilation systems. This could be due to older equipment, larger internal spaces requiring more cooling, or operating in higher temperatures.

2. Energy Efficiency of Galley Systems:

- **Vessel 1**: 1.17 MW per knot
- **Vessel 2**: 10.65 MW per knot

Interpretation:

- **Vessel 1** shows much lower energy consumption in its galley system, which may be a reflection of more efficient kitchen appliances, better energy management practices, or reduced demand for food preparation at scale.
- **Vessel 2**, by contrast, consumes almost ten times more energy in its galley. This may indicate inefficiencies in equipment, higher operational demands, or more energy-intensive processes for food preparation and storage.

3. Energy Efficiency of Scrubber Systems:

- **Vessel 1**: 1.28 MW per knot
- **Vessel 2**: 8.67 MW per knot

Interpretation:

- **Vessel 1** is more energy-efficient in its scrubber systems, which are responsible for emissions control. Lower energy consumption here suggests that **Vessel 1** might have more advanced or well-maintained scrubber technology that uses less energy to achieve emissions compliance.

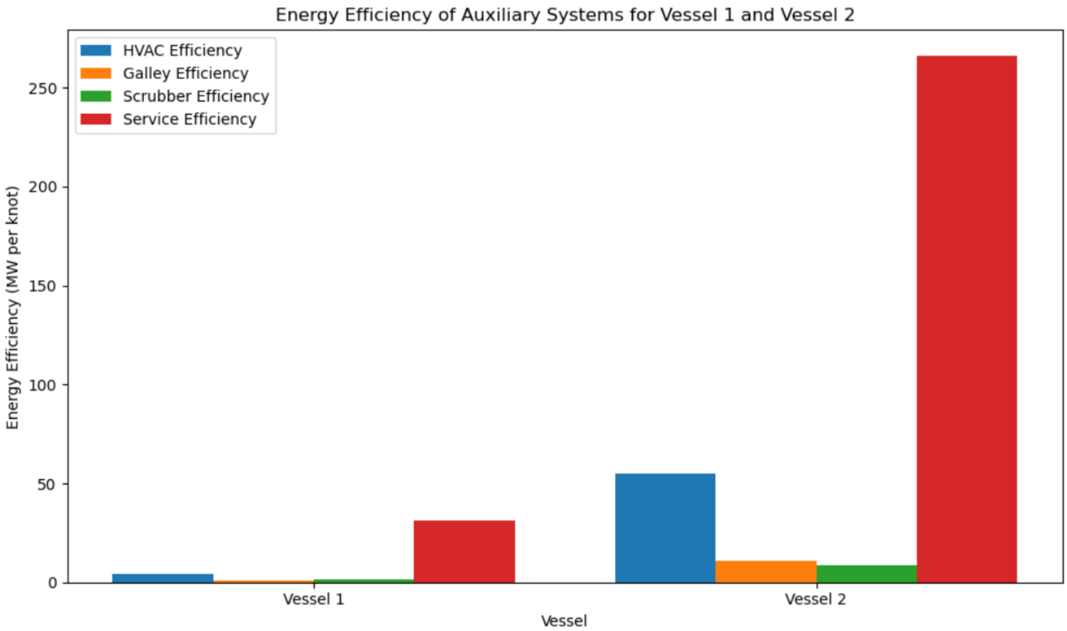
- **Vessel 2** has a significantly higher scrubber energy consumption, which could imply older scrubber systems, more extensive emissions control operations, or operating in areas with stricter environmental regulations.

4. Energy Efficiency of Service systems

- **Vessel 1**: 31.06 MW per knot
- **Vessel 2**: 265.83 MW per knot

Interpretation:

- The service area includes lighting, water supply, and other non-propulsion-related systems. **Vessel 1** is much more energy-efficient in this area, using far less power for its service needs, which could indicate better energy management practices or more energy-efficient infrastructure.
- **Vessel 2** consumes over eight times more energy in its service areas, suggesting possible inefficiencies in managing onboard services, lighting, or other auxiliary systems.



The bar chart above visualizes the energy efficiency trends for the auxiliary systems (HVAC, Galley, Scrubber, and Service) on both **Vessel 1** and **Vessel 2**. The chart highlights the significant differences in energy consumption per knot for each system, demonstrating how **Vessel 1** consistently performs better in terms of energy efficiency across all categories.

- **Vessel 1** shows lower energy consumption in all systems, especially in HVAC and Service, compared to **Vessel 2**.
- **Vessel 2** has much higher energy consumption, particularly in the HVAC and Service areas, indicating areas for potential efficiency improvements.

<u>Fuel Efficiency Analysis for Vessel 1 and Vessel 2</u>

Fuel efficiency is a metric that measures how effectively a ship converts fuel into propulsion or other useful work. It can be understood from different perspectives, such as **fuel consumption per hour**, **fuel efficiency per knot of speed**, or **fuel consumption per mile travelled**.

Different Types of Fuel Efficiency:

1. **Fuel Consumption per Hour (kg/h)**:
   - This is a measure of how much fuel the ship burns over time, independent of how fast the ship is traveling. It provides insights into the overall fuel demand of the vessel but does not account for how effectively the ship uses that fuel to move.
2. **Fuel Efficiency per Knot (kg/h per knot)**:
   - This is a measure of how much fuel is used to maintain each knot of speed. The lower this value, the more fuel-efficient the vessel is in terms of speed. A vessel that consumes less fuel per knot is considered more efficient.
3. **Fuel Consumption per Mile (kg/nm)**:
   - This is a measure of how much fuel is consumed per nautical mile travelled. It is often used to determine operational efficiency over longer voyages, where maintaining a consistent speed is critical.

Key Metrics Calculated:

1. **Fuel Consumption** (kg/h): The total amount of fuel consumed by the ship's engines per hour.
2. **Fuel Efficiency (kg/h per knot)**: The amount of fuel consumed per hour per knot of speed, giving us an idea of how much fuel is required to maintain each knot of speed.
3. **Fuel Consumption per Mile:** The amount of fuel consumed by the vessel per nautical mile travelled

Fuel Efficiency of Vessel 1:

- **Average Fuel Consumption**: 3202.25 kg/h
- **Fuel Efficiency**: 7713.12 kg/h per knot
- **Fuel Consumption per Mile**: 7713.12 kg/nm

Interpretation:

- Vessel 1 consumes approximately 3202.25 kg of fuel per hour. Its fuel efficiency is 7713.12 kg/h per knot, meaning that for every knot of speed, the vessel consumes about 7713.12 kg of fuel per hour. It’s Fuel Consumption per Mile is 7713.12 kg/nm meaning that for every nautical mile travelled, Vessel 1 consumes approximately 7713.12 kg of fuel

Fuel Efficiency of Vessel 2:

- **Average Fuel Consumption**: 2877.36 kg/h
- **Fuel Efficiency**: 62923.91 kg/h per knot
- **Fuel Consumption per Mile**: 62923.91 kg/nm

Interpretation:

- Vessel 2 consumes less fuel on average (2877.36 kg/h) compared to Vessel 1. However, it is much less efficient when we normalize for speed, consuming 62923.91 kg/h per knot and per nautical mile travelled, consuming 62923.91 kg
- Vessel 2 consumes approximately 2877.36 kg of fuel per hour. Its fuel efficiency is 62923.91 kg/h per knot, meaning that for every knot of speed, the vessel consumes about 62923.91 kg of fuel per hour. It's Fuel Consumption per Mile is 62923.91 kg/nm that for every nautical mile travelled, Vessel 1 consumes approximately 62923.91 kg of fuel

Load Balancing Efficiency for Vessel 1 and Vessel 2

Load balancing refers to how evenly propulsion power is distributed between the port and starboard sides of a ship. Efficient load balancing ensures that the ship operates smoothly, reduces fuel consumption, and minimizes wear on the propulsion systems. Based on the calculated Load Balancing Efficiency for Vessel 1 and Vessel 2, we can draw several insights into their operational performance.

Vessel 1:

- Load Balancing Efficiency: 96.33%

Interpretation:

- Vessel 1 operates with a high load balancing efficiency, with 96.33% of the total propulsion power being evenly distributed between the port and starboard sides.
- This indicates that the propulsion system is almost perfectly balanced, allowing for smooth operation with minimal energy losses. The small power imbalance (approximately 3.67%) suggests that the vessel's propulsion systems are effectively synchronized, ensuring optimal performance.
- The high level of efficiency contributes to improved fuel usage, reduced mechanical stress, and more stable sailing conditions.

Vessel 2:

- Load Balancing Efficiency: 96.71%

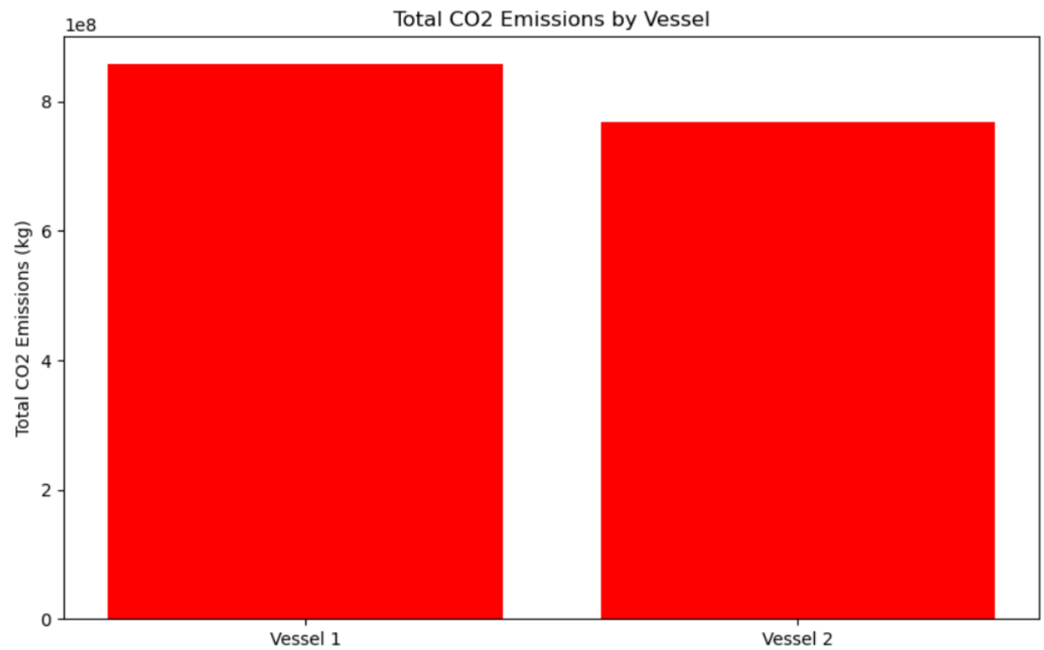
Interpretation:

- Vessel 2 shows an even higher load balancing efficiency of 96.71%. This means that the port and starboard propulsion systems are even more evenly matched compared to Vessel 1, with only a 3.29% imbalance.
- Like Vessel 1, the near-perfect load balancing ensures that energy is distributed efficiently, minimizing unnecessary fuel consumption and mechanical wear. This leads to long-term benefits in terms of reduced maintenance needs and operational costs.
- The slightly higher load balancing efficiency in Vessel 2 suggests that its propulsion systems are finely tuned to share the load more evenly, contributing to stable performance even under varying operational conditions.

CO2 Emissions for Vessel 1 and Vessel 2

This represents the total CO2 emissions produced by the vessel, based on its fuel consumption and the emission factor of the fuel.

$$\text{Total CO2 Emissions} = \text{Fuel Consumption (kg)} \times 3.114 \text{ (CO2 emission factor)}$$



Above chart compares the **total CO2 emissions** (in kilograms) for **Vessel 1** and **Vessel 2**

CO2 Emissions Overview

1. **Total CO2 Emissions for Vessel 1**:
   - **Vessel 1** exhibits higher total CO2 emissions compared to Vessel 2. This indicates that Vessel 1 consumes more fuel overall, leading to greater carbon output. The higher emissions may be a result of several factors, including more frequent operations, higher power demands, or less efficient fuel consumption practices.
   - Despite its higher **propulsion efficiency** (as discussed earlier), Vessel 1's total emissions suggest that it may operate under conditions that require more energy overall, perhaps due to higher speeds or longer operational periods.
   -
2. **Total CO2 Emissions for Vessel 2**:
   - **Vessel 2** has lower total CO2 emissions, reflecting its more efficient fuel use or fewer operational hours. Even though Vessel 2 has slightly lower propulsion efficiency compared to Vessel 1, its overall carbon footprint is reduced, possibly due to more controlled or optimized operations.
   - The lower emissions could be the result of slower speeds (e.g., adopting slow steaming practices), shorter voyages, or more effective power management in non-propulsion systems, such as auxiliary generators.

Propulsion Power Vs Speed for Vessel 1 and Vessel 2

The analysis of propulsion power for the two vessels (Vessel 1 and Vessel 2) focuses on the relationship between propulsion power consumption and speed over ground. Propulsion power represents the energy used to move the vessel through the water, and here we are examining how much power is required to achieve a given speed.

Key Findings:

1. **Vessel 1**:
    - **Average Propulsion Power**: 10.34 MW
    - **Port Side Propulsion Power**: 5.13 MW
    - **Starboard Side Propulsion Power**: 5.20 MW
    - **Average Speed Over Ground**: 14.03 knots

Interpretation:

- Vessel 1 operates at a higher average speed (14.03 knots) compared to Vessel 2. This higher speed requires more propulsion power, with an average of 10.34 MW. The power is almost equally distributed between the port and starboard propulsion systems, indicating balanced propulsion.

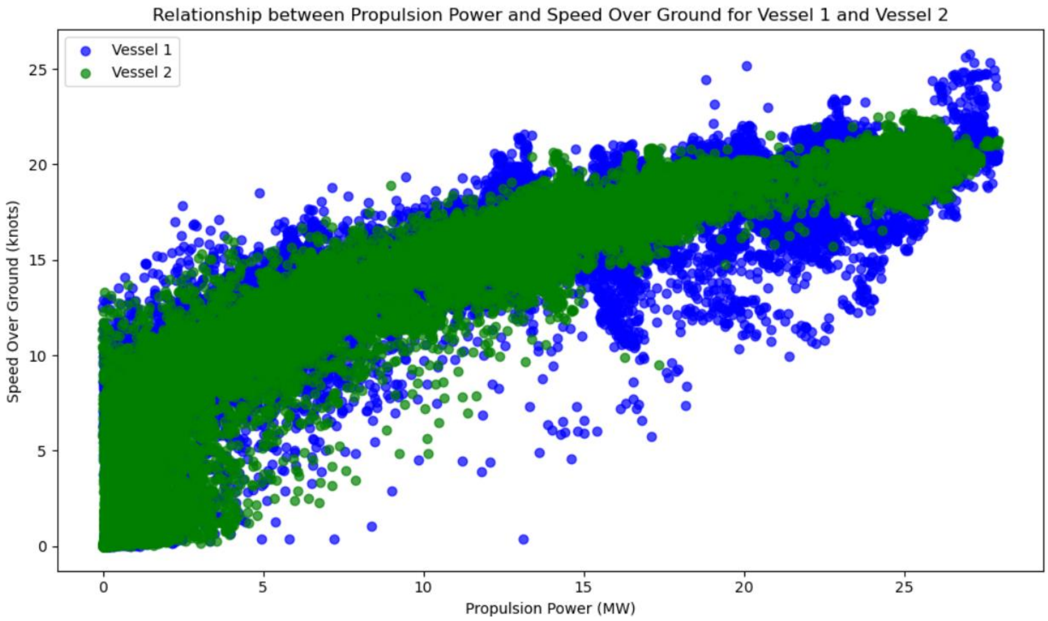
2. **Vessel 2**:
    - **Average Propulsion Power**: 8.03 MW
    - **Port Side Propulsion Power**: 4.03 MW
    - **Starboard Side Propulsion Power**: 3.99 MW
    - **Average Speed Over Ground**: 11.16 knots

Interpretation:

- Vessel 2 operates at a lower average speed (11.16 knots) and requires less propulsion power (8.03 MW) compared to Vessel 1. Similar to Vessel 1, the propulsion power is evenly distributed between the port and starboard sides, but overall, it consumes less power and moves at a slower speed.

Propulsion Power Vs Speed Comparison:

- **Vessel 1** requires more propulsion power due to its higher speed. The vessel is designed or operated to achieve faster speeds, which leads to higher power consumption. However, its efficiency could be evaluated based on the intended operational needs.
- **Vessel 2** consumes less power and operates at a slower speed, suggesting that it may prioritize energy efficiency over speed or operate in different conditions that do not demand high velocity.



The scatter plot above illustrates the relationship between **Propulsion Power** (in MW) and **Speed Over Ground** (in knots) for both **Vessel 1** and **Vessel 2**. Each point represents an observation of the ship's propulsion power at a specific speed. This visualization helps to analyse how propulsion power influences speed over time for each vessel.

- **Vessel 1** appears to operate at higher propulsion power and speed compared to **Vessel 2**, which tends to operate at lower power and slower speeds.

This comparison highlights the trade-offs between power usage and operational speed.

Propulsion Power Vs Fuel Consumption for Vessel 1 and Vessel 2:

The analysis of propulsion power for the two vessels (Vessel 1 and Vessel 2) focuses on the relationship between propulsion power and fuel consumption. Propulsion power represents the energy used to move the vessel through the water, and here we are examining how much fuel is required to achieve a given propulsion power

1. **Vessel 1**:
    - **Average Propulsion Power**: 7.66 MW
    - **Average Fuel Consumption**: 2620.36 kg/h

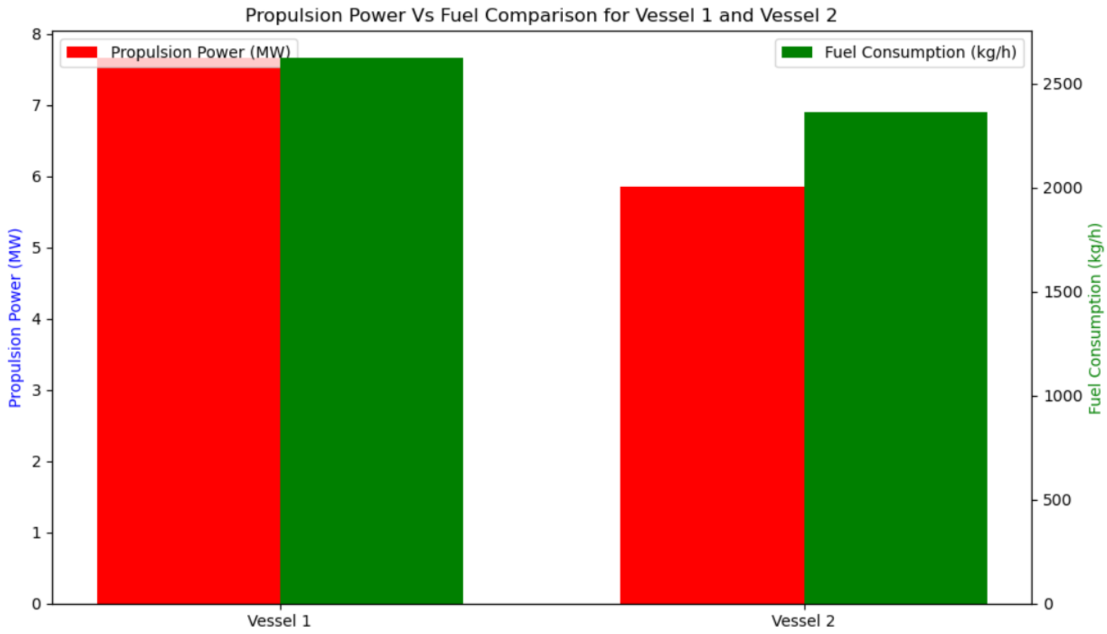
Interpretation: Vessel 1 consumes more fuel to support higher propulsion power. The vessel operates with greater power demands, and this is reflected in its fuel consumption rate.

2. **Vessel 2**:
    - **Average Propulsion Power**: 5.86 MW
    - **Average Fuel Consumption**: 2361.92 kg/h

Interpretation: Vessel 2 operates at lower propulsion power compared to Vessel 1 and consumes less fuel. This suggests that Vessel 2 is more fuel-efficient in terms of propulsion power, although it operates at a lower power level overall.

Key Insights:

- **Vessel 1** requires higher fuel consumption to sustain its greater propulsion power, indicating a direct relationship between fuel usage and propulsion power.
- **Vessel 2**, while consuming less fuel, operates at a lower propulsion power, leading to better fuel efficiency for the amount of propulsion power it produces.

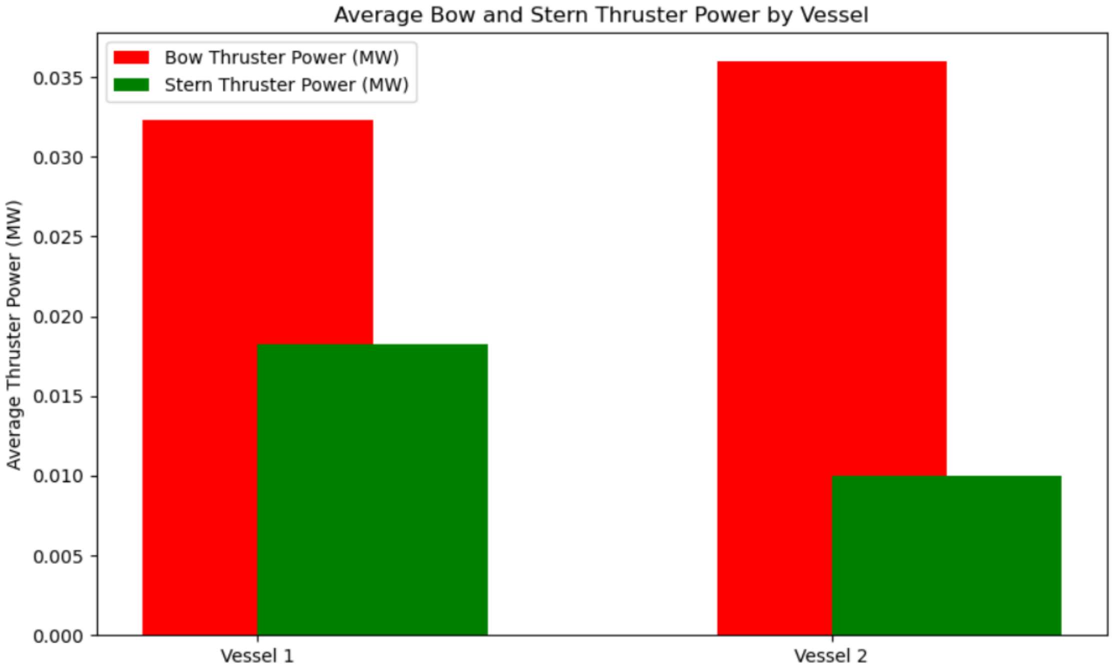


The bar chart above illustrates the comparison between **Propulsion Power** (in MW) and **Fuel Consumption** (in kg/h) for **Vessel 1** and **Vessel 2**.

- **Vessel 1** has higher propulsion power and consumes more fuel compared to **Vessel 2**.
- **Vessel 2**, while operating at lower propulsion power, also shows lower fuel consumption.

This visualization highlights the relationship between propulsion power and fuel efficiency, with Vessel 1 requiring more energy (and fuel) to achieve higher power output

Bow Thruster Power Vs Stern Thruster Power

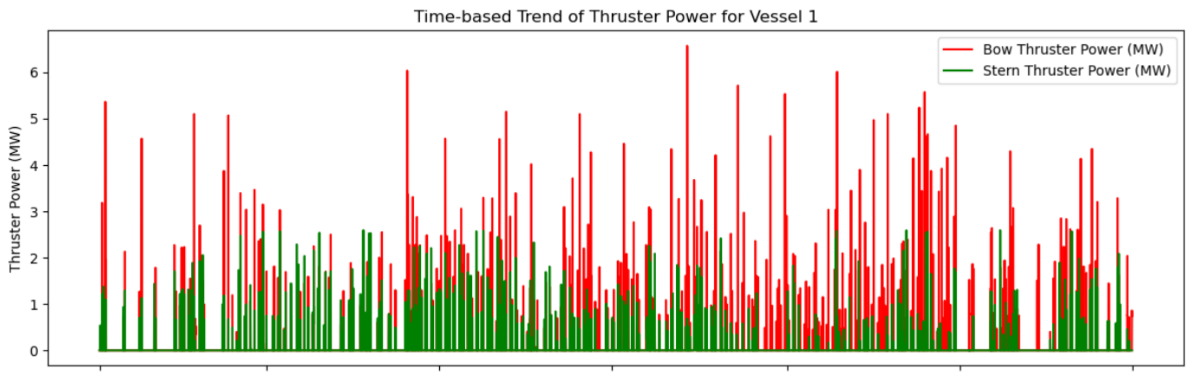


The bar chart above visualizes the average power usage for the bow and stern thrusters of Vessel 1 and Vessel 2. Here's an analysis based on the visualization:

1. **Bow Thruster Power**:
   - Both vessels have similar average bow thruster power, with Vessel 1 showing slightly higher usage than Vessel 2.
   - This usage indicates that both vessels rely on bow thrusters with comparable power levels, likely for maneuvering and positioning during docking or slow-speed operations.
2. **Stern Thruster Power**:
   - Vessel 1 shows higher stern thruster power usage compared to Vessel 2.
   - This may suggest that Vessel 1 either relies more on stern thrusters for maneuvering or has operational requirements that demand higher power from the stern thrusters.

Summary:

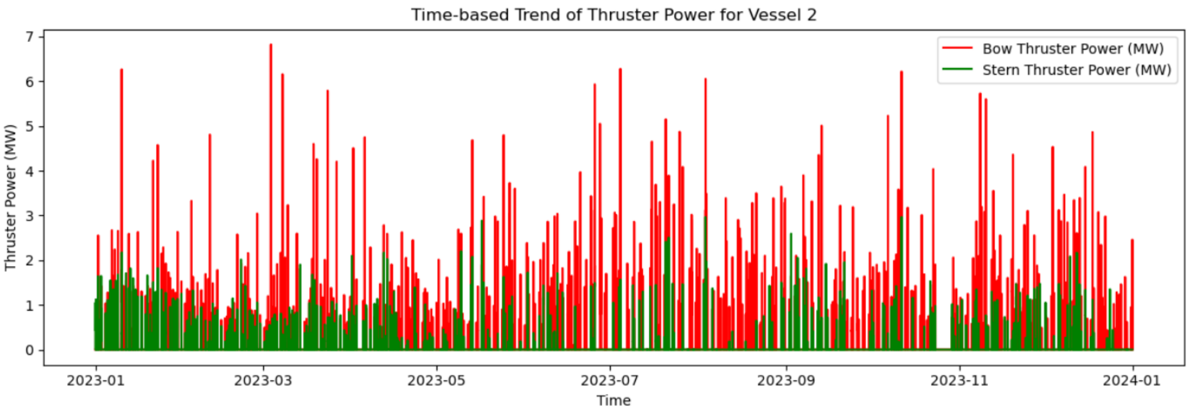
- Vessel 1 uses both bow and stern thrusters slightly more intensively than Vessel 2.
- These differences may reflect variations in vessel design, handling characteristics, or operational procedures.



This chart shows the time-based trend of thruster power usage for Vessel 1, with separate lines for bow thruster power (red) and stern thruster power (green). Here's an analysis:

Key Observations:

1. **Higher and More Frequent Bow Thruster Power Spikes**:
   - The bow thruster (in red) consistently reaches higher power levels compared to the stern thruster. This indicates that Vessel 1 relies more heavily on its bow thrusters for maneuvering, likely during docking or specific maneuvers that require forward control.
   - The frequent spikes in bow thruster power suggest recurring situations where precise or increased forward maneuvering is needed. This could be due to Vessel 1 operating in congested or challenging docking environments where fine-tuned bow control is critical.
2. **Lower, Intermittent Stern Thruster Usage**:
   - The stern thruster (in green) shows significantly lower power levels than the bow thruster, with less frequent and shorter power spikes. This indicates that Vessel 1's stern thrusters are used less intensively and potentially only in situations requiring extra control from the aft.
   - The lower intensity of stern thruster usage implies that it may be deployed only for specific maneuvers or environmental conditions, such as crosswinds or currents that affect the stern.
3. **Patterns of Variability:**
   - The chart shows periods where both bow and stern thruster power usage increases simultaneously, suggesting that certain operational or environmental conditions lead to higher demands on both thrusters.
   - The irregular peaks throughout the timeline indicate variable usage patterns, likely tied to specific maneuvers rather than continuous operation. This could reflect intermittent docking operations or maneuvering in response to environmental factors.

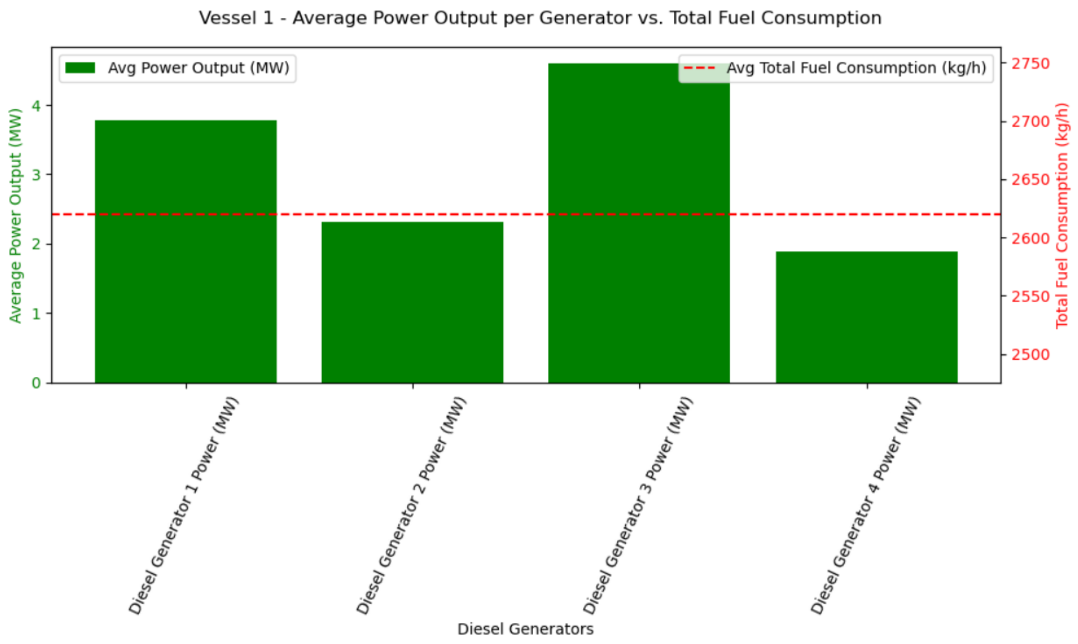


The chart shows the time-based trend of thruster power for Vessel 2, highlighting the power usage for the bow thruster (in red) and stern thruster (in green). Here's an analysis:

Key Observations

1. **Frequent, Moderate Power Spikes for Bow Thruster:**
   - Similar to Vessel 1, the bow thruster on Vessel 2 shows higher and more frequent power spikes compared to the stern thruster. This indicates that Vessel 2 also relies more on its bow thruster for forward maneuvering and positioning.
   - However, the spikes in bow thruster power tend to be more moderate, reaching levels slightly below 7 MW, with no extreme peaks. This suggests a controlled usage pattern where power levels are consistently managed.
2. **Consistent Stern Thruster Usage:**
   - The stern thruster usage, while generally lower than the bow thruster, shows a relatively consistent pattern over time. The stern thruster power stays within a lower range (mostly below 2 MW), indicating that it's used regularly but less intensively.
   - The regular use of the stern thruster implies that Vessel 2 may be balancing its thruster usage more evenly compared to Vessel 1.
3. **Stable Patterns Across the Year:**
   - The chart displays a steady pattern in thruster power usage across the timeline, with no significant seasonal changes. This consistency suggests that Vessel 2's operations are uniform throughout the year, likely involving similar docking and maneuvering routines across different months.

<u>**Power Generation Vs Fuel Consumption for Vessel 1 and Vessel 2**</u>

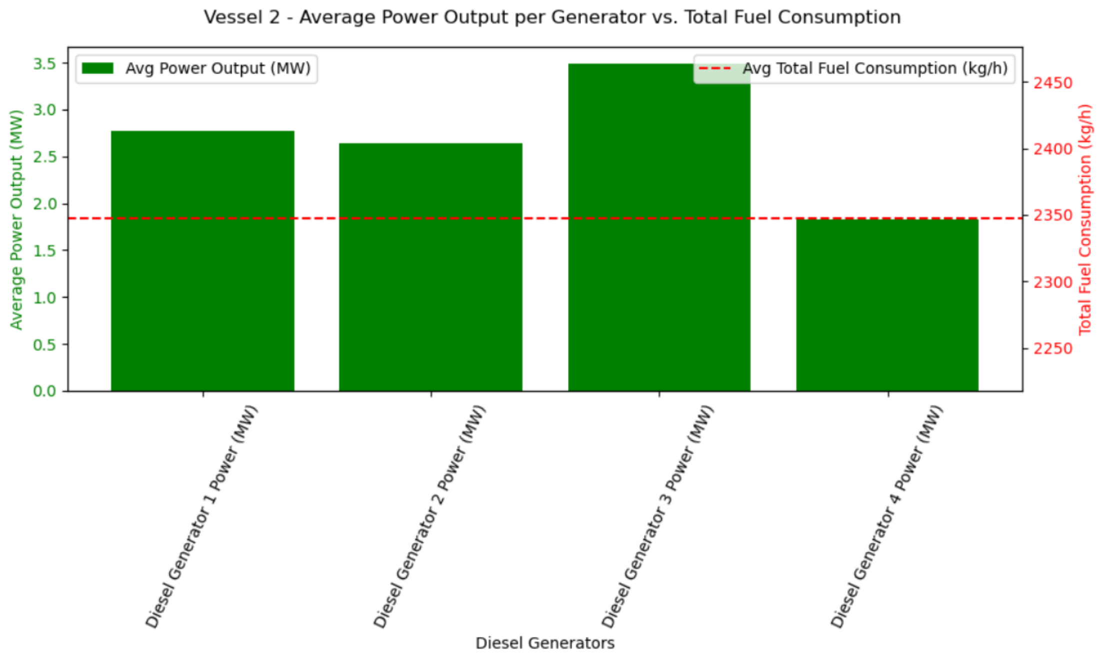


The chart illustrates the Average Power Output per Generator and the Total Fuel Consumption for Vessel 1. The dual-axis setup uses two scales to show power output in megawatts (MW) on the left y-axis and fuel Consumption in kilograms per hour (kg/h) on the right y-axis.

Key Observations:

1. **Power Output:**
   - Diesel Generator 1 and Diesel Generator 3 have the highest average power output, both exceeding 4 MW.
   - Diesel Generator 2 and Diesel Generator 4 have lower average power outputs, hovering around 2 MW or slightly above.
   - The stark difference in output between the generators suggests that Vessel 1 relies more heavily on Diesel Generators 1 and 3 to meet its power demands, while Generators 2 and 4 are used less frequently or at lower loads.
2. **Total Fuel Consumption**
   - The red dashed line represents the average fuel consumption rate, which is slightly above 2,650 kg/h.
3. **Efficiency Insights:**
   - Diesel Generator 1 and Diesel Generator 3 appear to be the primary sources of power generation. Operating these two generators at higher loads could be a strategy to improve fuel efficiency, as engines typically perform more efficiently at higher, steady loads.

- The lower average power outputs from Diesel Generators 2 and 4 suggest that these generators might only be used during specific conditions, such as peak demand or maneuvering, where additional power is needed temporarily. This selective usage helps optimize fuel consumption.

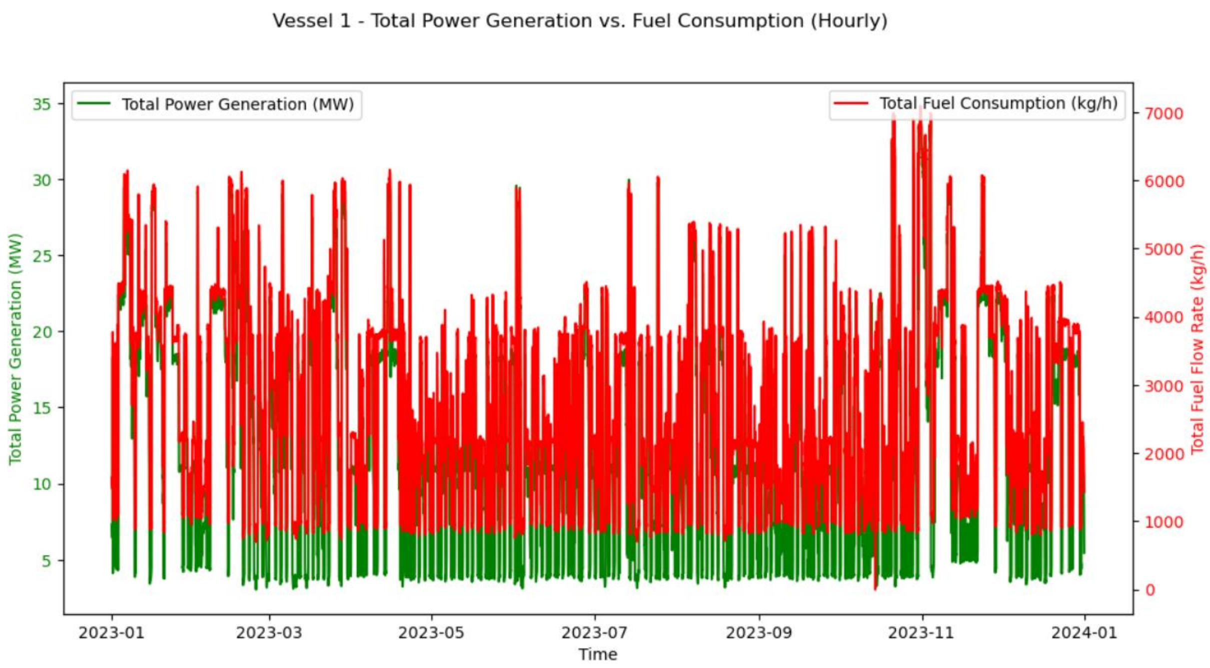


The chart illustrates the Average Power Output per Generator and the Total Fuel Consumption for Vessel 2. The dual-axis setup uses two scales to show power output in megawatts (MW) on the left y-axis and fuel Consumption in kilograms per hour (kg/h) on the right y-axis.

Key Observations:

1. **Power Output:**
    - Diesel Generators 1, 2, and 4 produce similar power outputs, each ranging between 2.5 and 3 MW.
    - Diesel Generator 3 shows a slightly higher output, exceeding 3 MW.
    - The even power distribution across all four diesel generators suggests that Vessel 2 operates its generators in a balanced manner, spreading the power load more equally across all units. This contrasts with the strategy seen in Vessel 1, where only specific generators carried the majority of the load.
2. **Total Fuel Flow Consumption Rate:**
    - The red dashed line represents the average fuel consumption rate, which is just below 2,350 kg/h.

3. **Efficiency Insights:**
    - The balanced power output among the four diesel generators suggests that Vessel 2 emphasizes operational flexibility. By distributing the power load evenly, the vessel can adapt to changing power demands without over-relying on specific generators.

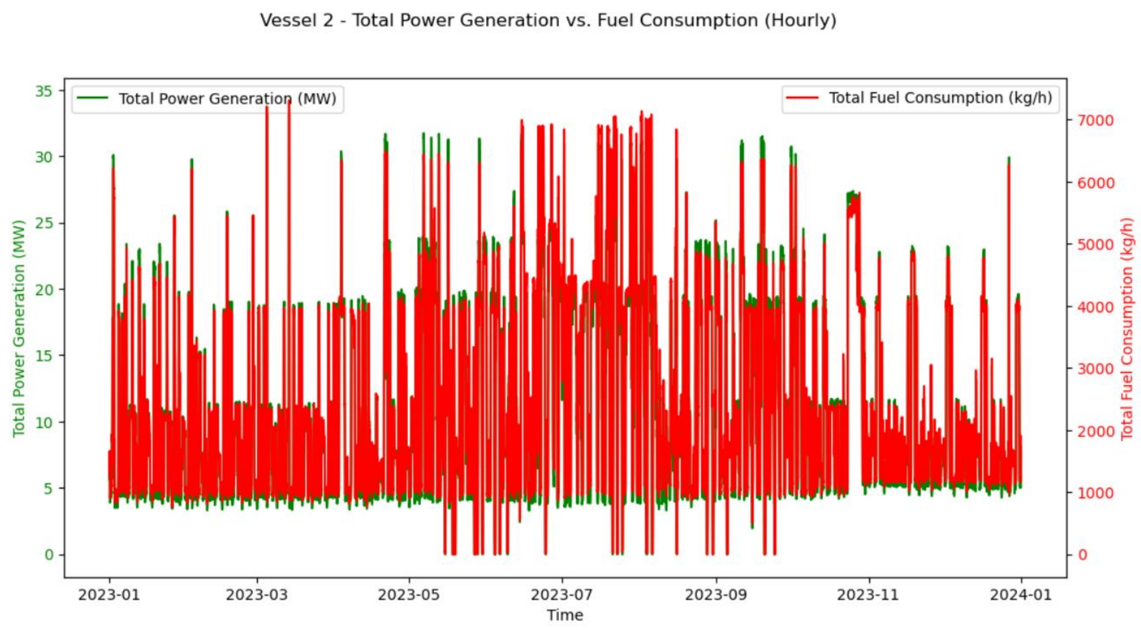


The chart shows Vessel 1's Total Power Generation (in MW) and Total Fuel Consumption (in kg/h) over time on an hourly basis. The dual-axis format uses two different scales, with Total Power Generation on the left y-axis (in green) and Total Fuel Consumption on the right y-axis (in red). Data spans from early 2023 to early 2024, capturing seasonal and operational variations.

Key Observations:

1. **Power Generation Fluctuations:**
    - Total Power Generation (blue line) shows significant variability over time, with periods where power generation fluctuates between 5 MW and over 30 MW.
    - The chart reveals frequent spikes in power output, indicating that Vessel 1 regularly experiences periods of increased demand, requiring higher power output from its diesel generators.
    - Between January and November 2023, these spikes occur consistently, reflecting changes in operational needs, such as varying propulsion requirements or changes in onboard systems during the cruise operation.

2. **Fuel Consumption Rate Fluctuations:**
    - Total Fuel Flow Rate (red line) also exhibits wide variability, frequently fluctuating between 1000 kg/h and over 7000 kg/h.
    - There is a clear pattern where spikes in power generation (blue) are closely followed by increases in fuel consumption (red). This indicates a direct relationship between higher power demands and increased fuel usage.
    - At certain times, such as during the middle of 2023, fuel consumption reaches extreme highs, suggesting that periods of peak operational demand lead to significant increases in fuel usage.
3. **Relationship Between Power Generation and Fuel Consumption:**
    - The chart illustrates a strong correlation between Total Power Generation and Total Fuel Flow Rate. Increases in power generation generally lead to corresponding rises in fuel consumption.
    - However, it's notable that fuel consumption sometimes spikes more dramatically than power generation. This could indicate periods where generators are running less efficiently, possibly due to operating at suboptimal loads or engaging additional generators to meet sudden spikes in demand.
4. **Seasonal or Operational Patterns:**
    - Over time, the chart shows that Vessel 1 experiences cycles of high power generation and fuel consumption, with more frequent spikes during certain months (such as between January and May 2023 and in October-November 2023).
    - These peaks may be linked to seasonal operational changes, such as periods of higher passenger capacity, varying environmental conditions, or changes in route difficulty (e.g., sailing through more challenging waters requiring higher propulsion power).



The chart shows Vessel 2's Total Power Generation (in MW) and Total Fuel Consumption (in kg/h) over time on an hourly basis. The dual-axis format uses two different scales, with Total Power Generation on the left y-axis (in green) and Total Fuel Consumption on the right y-axis (in red). Data spans from early 2023 to early 2024, capturing seasonal and operational variations.

Key Observations:

1. **Power Generation Fluctuations:**
    - Total Power Generation (blue line) varies significantly over time, ranging between 5 MW and 35 MW. Power generation fluctuates frequently, indicating that Vessel 2 operates under conditions where demand changes often, potentially due to varying propulsion needs or changes in onboard systems.
    - The spikes in power output are evident throughout the year, particularly in the periods between January and May 2023, and again in October and November 2023. These could reflect periods of higher operational demand, such as sailing in rougher waters or serving a higher number of passengers.
2. **Fuel Flow Rate Fluctuations:**
    - Total Fuel Flow Rate (red line) also shows substantial variability, frequently ranging from 1000 kg/h to 7000 kg/h, with occasional sharp peaks.
    - Similar to the power generation pattern, the fuel consumption rate closely mirrors the fluctuations in power output. Higher power generation leads to increases in fuel consumption, although some peaks in fuel flow rate appear to be disproportionate to the corresponding power generation increases.

- This suggests that during certain periods, fuel efficiency might drop, especially when more generators are engaged, or when operating conditions require extra fuel even without a proportional increase in power output.

3. **Relationship Between Power Generation and Fuel Consumption:**
    - The chart reveals a strong correlation between Total Power Generation and Total Fuel Flow Rate, where increases in power demand lead to corresponding increases in fuel consumption. However, there are moments where fuel consumption spikes more sharply than power generation, indicating potential inefficiencies during certain operational periods.
    - These spikes in fuel consumption, especially during April, July, and October of 2023, suggest that operational inefficiencies or the need for additional generators during peak periods may be causing higher-than-normal fuel usage.

4. **Seasonal Patterns and Cyclic Demand:**
    - The cyclical nature of power generation and fuel consumption indicates that Vessel 2 undergoes recurring high-demand periods, possibly due to seasonal factors, operational requirements, or environmental conditions.
    - The demand appears to be more consistent between June and October 2023, followed by periods of reduced power generation and fuel consumption toward the end of the year (November-December 2023). This could reflect changes in perational conditions, such as reduced passenger loads or less challenging sailing routes