

# Data-driven Analysis on Energy and Emission Performance of Harbour Craft in Singapore Port Water

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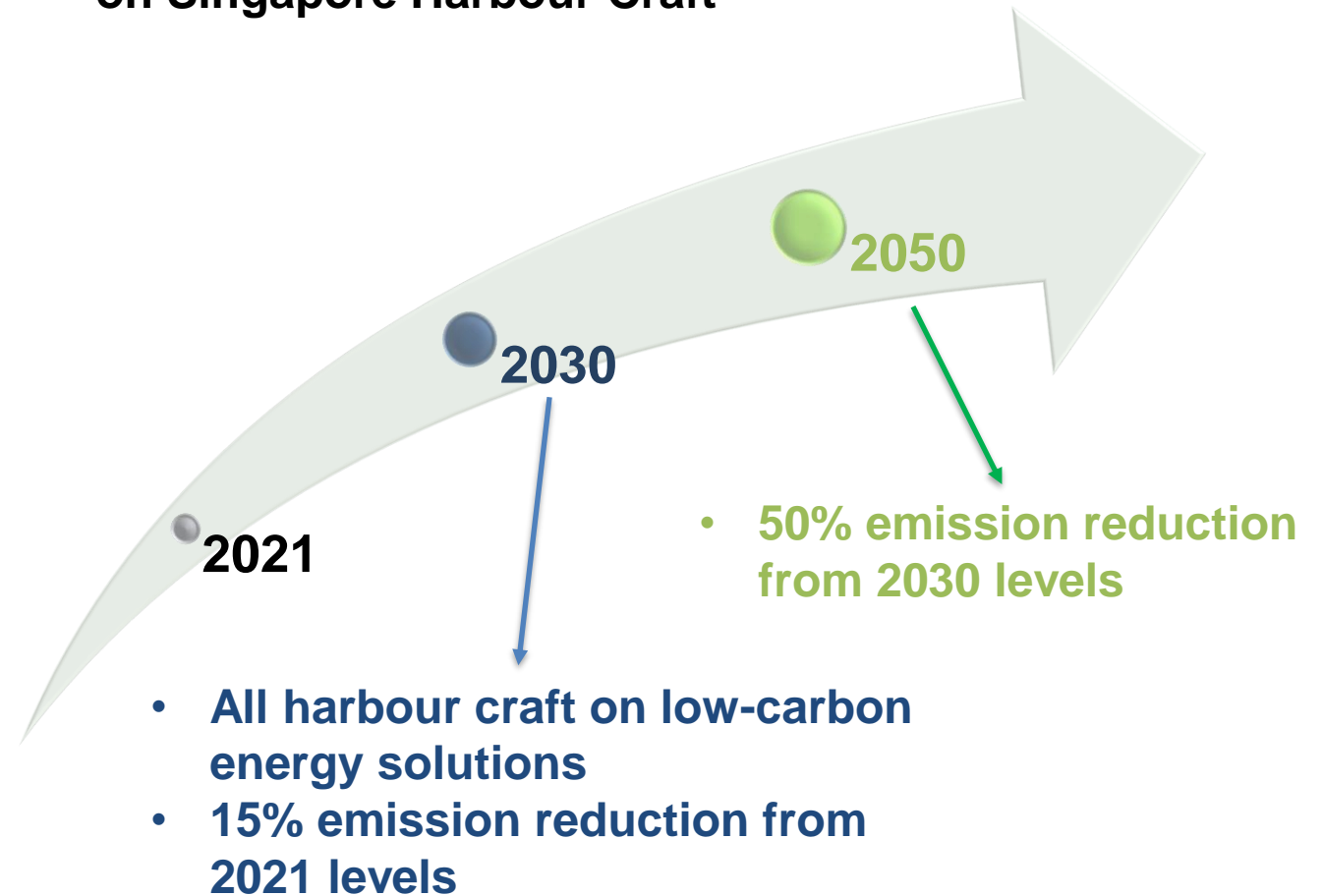
*11 October 2022*



## Overview on Types of Singapore Harbour Craft

Prefix	Description
SP	In-port limit carriage of passengers
SC	In-port limit carriage of dry or packaged cargoes
SB	In-port limit carriage in bulk of petroleum, liquefied gases, liquid chemicals or vegetable/animal oils
ST	In-port limit for towing, pushing or pulling other vessels.
SR	In-port limit for any other purposes

## MPA's Maritime Singapore Decarbonisation Blueprint on Singapore Harbour Craft



# Background and Objective

## Bunker records and tank sounding:

- The most popular ways and probably the only ways to monitor a harbour vessel's energy performance
- Cost-effective and quite reliable in monitoring fuel consumptions at aggregated level
- However, the usefulness is solely reliant on the bunkering and tank sounding frequency
- Lack data resolution, not very useful for vessel performance optimisation

### BUNKER VOUCHER

BUNKER VOUCHER No. A

Date :                     

From	: <u>                    </u>	To Boat Number	: <u>                    </u>
Time Start	: <u>9:40 AM</u>	Time Complete	: <u>9:45 AM</u>
Meter Reading (Start)	: <u>15941043</u>	Meter Reading (Complete)	: <u>15941378</u>
Quantity (L)	: <u>331</u>	Product	: <u>LSGO</u>
Units Start / End	: <u>NA</u>	Services	: <u>Top-up</u>
Remarks	: <u>                    </u>	Next Port	: <u>NA</u>

The invoice will be billed by and must be paid only to                     

Buyer Name / Company:

Supplier

Receiving boat master name / stamp

Supplier Signature

#### For MPA's purposes

The following rating is our satisfaction level of the bunkering operation (please circle)

1      2      3      4      (5)

Very Unsatisfied

Very Satisfied

*An example of bunkering record for Singapore harbour craft*

## Objective of this presentation:

- To introduce and illustrate MESD's Energy and Emission Performance Measurement (EEPM) method for Singapore Harbour Craft

# Energy and Emission Performance Measurement (EEPM)

## Physical Process Workflow

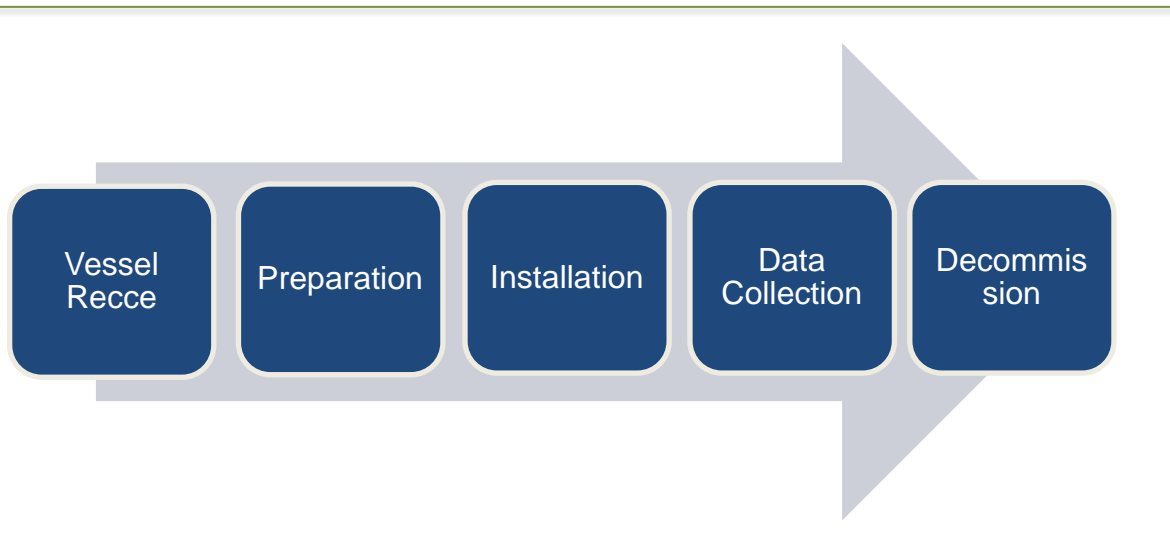


## EEPM Outcome

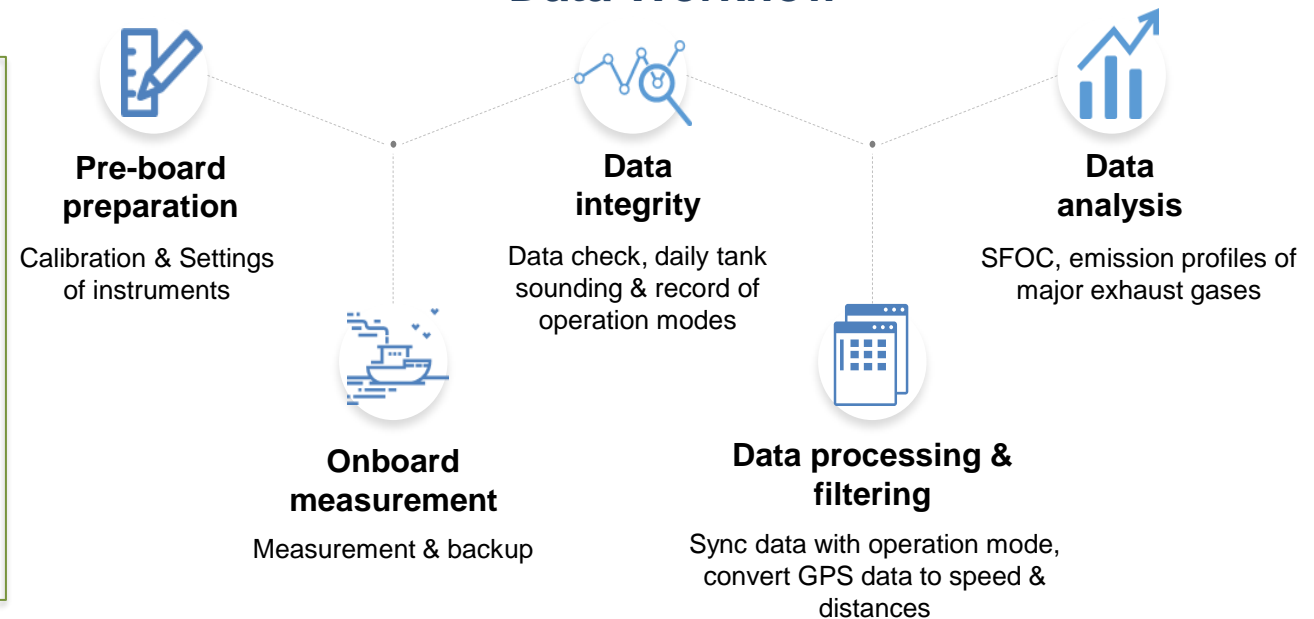
- Operational profile
- Engine performance
- Emission performance

- ✓ MESD's in-house development with a filed patent
- ✓ Patent name: ***A Method to Obtain Fuel Consumption and Emissions in Marine Propulsion Engines under Actual Operating Conditions***
- ✓ Targeting vessels that do not intend to install permanent sensors
- ✓ A holistic method from onboard data collection to data analysis

## Physical Process Workflow



## Data Workflow





## Available Instrument

GPS  
Sensor

Shaft  
Power  
Meter

FO Flow  
Meter

Exhaust  
Gas  
Analyzer  
& Flow  
Meter

Electric  
Power  
Analyzer

RH &  
Temp  
Meter

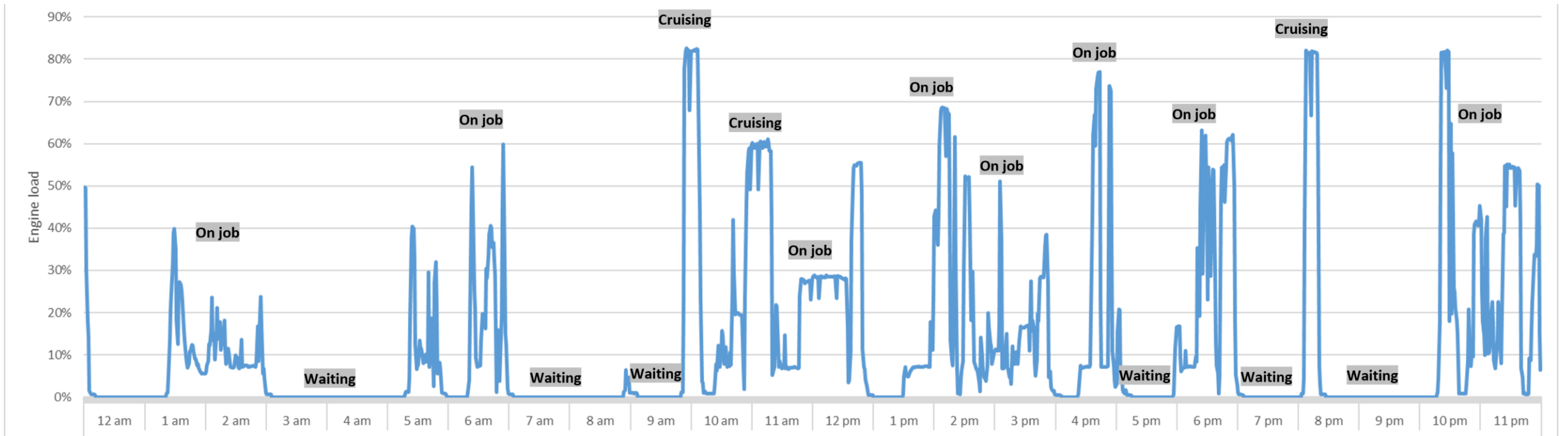


*Available instrument for EEPM*

Instrument	Parameter	Current Status
FO Flow Meter	Volumetric Flow Mass Flow Flow Velocity	Fuel consumption record manually using sounding method
Shaft Power Meter	Shaft Power Shaft Speed Torque	Not recorded
Exhaust Gas Analyzer & Flow Meter	CO <sub>2</sub> CO SO <sub>2</sub> NO <sub>x</sub> NO <sub>2</sub> O <sub>2</sub> CH <sub>4</sub> Exhaust Temp Exhaust Flow	Not recorded
Temp & RH Sensor	Temperature Humidity	Can be recorded manually by crew
Electric Power Analyzer	Ampere Voltage Frequency	Not recorded
GPS Sensor	Speed Location Time	Through AIS, but historical records may not be available

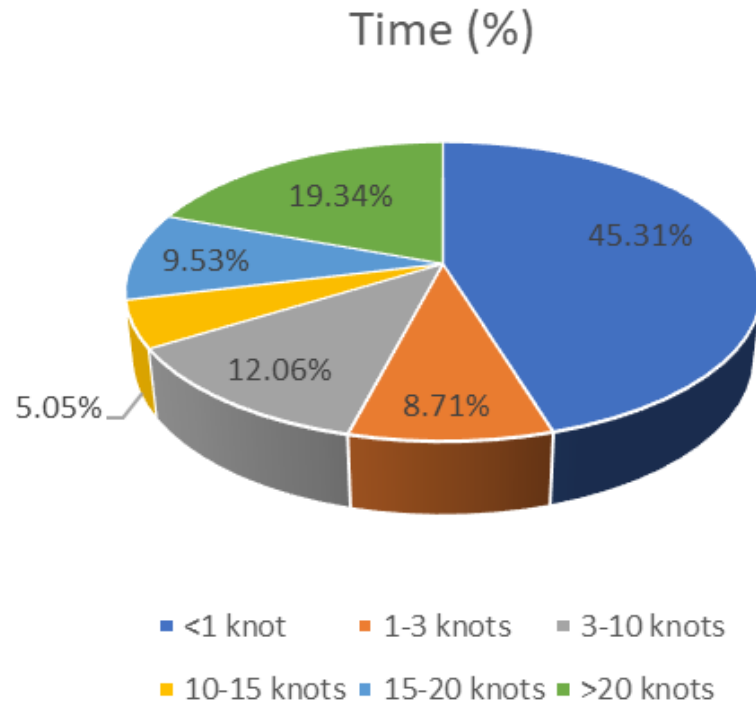
*List of key parameters that EEPM can measure*

# EEPM Results Illustration: Operational Profile



*Engine load profile of a ST vessel on a day*

# EEPM Results Illustration: Operational Profile and Emissions

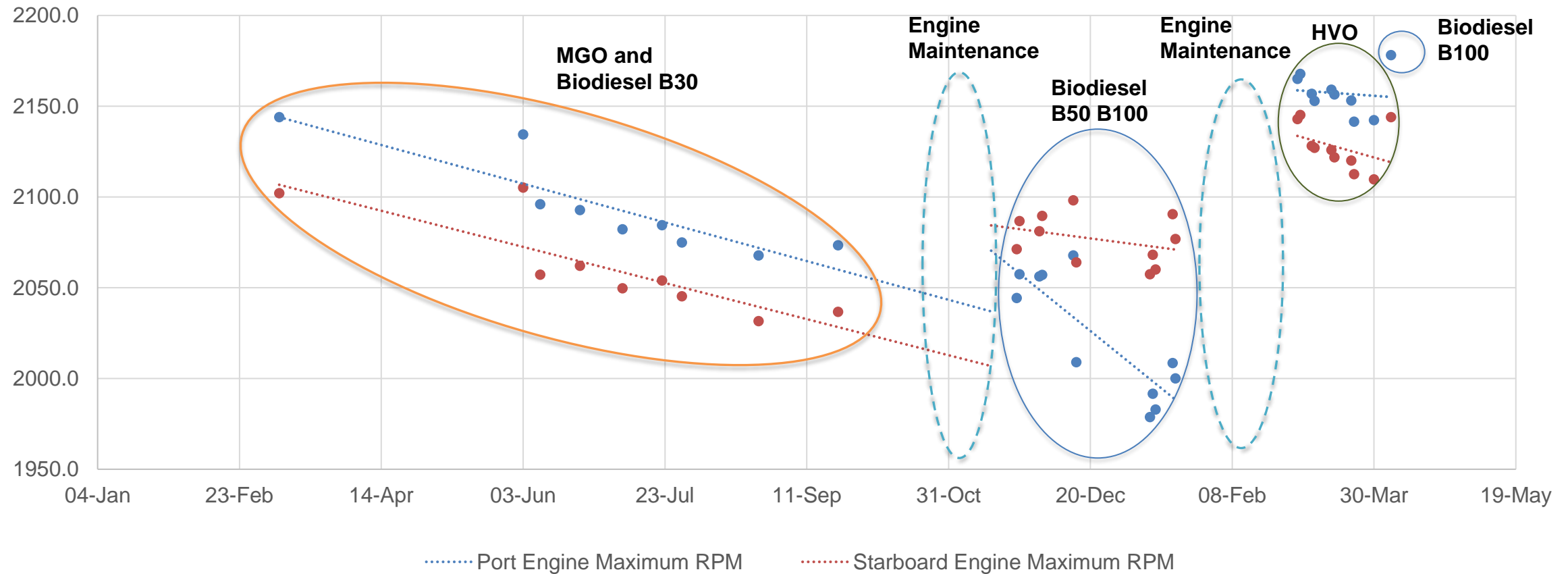


*Recorded time (%) spent in each vessel speed category for a SP (<12 Pax) vessel*

Main Engine	Engine Load 0-20%	Engine Load 20-40%	Engine Load 40-60%	Engine Load 60-80%	Engine Load 80-100%
Measured Time (min)	421.0	77.0	128.0	19.0	4.0
Average Engine Load	3.7%	32.7%	48.2%	64.3%	83.5%
Average RPM	679.8	1431.2	1643.6	1811.7	1976.9
Average Vessel Speed (knot)	1.6	12.7	15.0	17.9	19.3
Total Distance Travelled (NM)	10.9	16.3	32.0	5.7	1.3
PT Total CO <sub>2</sub> Emission (kg)	51.9	65.5	159.1	31.8	9.0
PT Total NO <sub>x</sub> Emission (g)	1499.2	1016.8	2200.9	392.7	91.3
PT Total CO Emission (g)	195.8	45.7	96.6	17.6	5.2
CO <sub>2</sub> per Hour (kg/h)	7.4	51.0	74.6	100.5	134.7
NO <sub>x</sub> per Hour (g/h)	213.7	792.3	1031.7	1240.1	1369.4
CO per Hour (g/h)	27.9	35.6	45.3	55.5	78.7
CO <sub>2</sub> per Distance (kg/NM)	4.8	4.0	5.0	5.6	7.0
NO <sub>x</sub> per Distance (g/NM)	137.8	62.2	68.8	69.2	71.0
CO per Distance (g/NM)	18.0	2.8	3.0	3.1	4.1

*An example of exhaust emissions of a SC vessel at different engine load*

# EEPM Results Illustration: Engine Performance



*Maximum engine RPM trend of a SC vessel over a year*

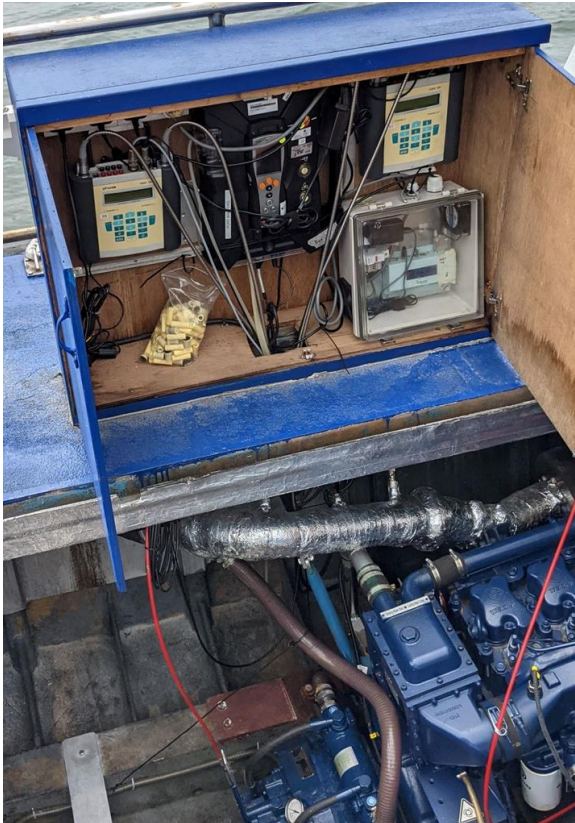


# EEPM Results Illustration: In-Depth Analysis

Dependent Variable: CO <sub>2</sub> Emissions	Coefficients	Standard Error	T-Stat	P-value
Intercept	-0.351	0.051	-6.877	<0.001
Maintenance effect	-0.377	0.021	-17.584	<0.001
Time to last maintenance	0.00154	0.00011	13.470	<0.001
Average cubic RPM	6.44E-10	1.45E-12	444.387	<0.001
Engine room temperature	0.00834	0.00114	7.336	<0.001
<b>Biodiesel blend ratio</b>	<b>0.140</b>	<b>0.014</b>	<b>10.254</b>	<b>&lt;0.001</b>
<b>HVO blend ratio</b>	<b>0.0325</b>	<b>0.0289</b>	<b>1.127</b>	<b>0.260</b>
F-value	36522.90			
Significance F	<0.001			
R-square	0.98309			
Adjusted R-square	0.98306			
Number of samples	3777			

*An example of statistical analysis on a SC vessel emission performance*

# EEPM Illustration: Actual Photos



Instrument installation



Vessel on job



Onboard data collection



# Thank you

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