# Creating Intelligent Framework to Analyse Port's Operational Activities and Sustainability Related Costs Allocation - Case Study of DP World (Southampton)

Rakesh Jory, Ph.D.

University of Southampton

University of Southampton

# Aims and Objectives

To apply Activity Based Costing (ABC) principles to map emissions data from electricity, fuel, and refrigerants to the activities that generate them, such as crane operations, reefer storage, and yard vehicle movement at a seaport.

To translate emissions into financial terms, such as cost per kilogram of carbon dioxide equivalent (kgCO2e), and to integrate this into management accounting tools including variance analysis, marginal costing, and break-even analysis.

# Activity Based Costing (ABC)

Activity Based Costing (ABC) assigns costs to outputs based on the resources and activities they consume.

Extend this logic to environmental costs, including carbon emissions, starting from the premise that activities drive emissions just as they drive costs.

By identifying carbon-intensive activities, ports can target improvements or investments that deliver emission reductions per pound spent.

# Cost Unit

The first step was to agree on a common unit for costing.

Because the port terminal's two core activities are (i) loading and unloading containers from vessels and (ii) transferring containers to or from trucks and trains, the natural denominator is the twenty foot equivalent unit, or TEU, which represents one standard container.

Both activity streams can therefore be costed on a per TEU basis.

# Operating Costs that drive Emissions

The operating costs that drive emissions.

The four cost categories are electricity, fuel (diesel and Hydrotreated Vegetable Oil, HVO), water, and refrigerants.

Each category has a clear physical measure: kilowatt hours for electricity, litres for fuel, cubic metres for water, and kilograms of gas for refrigerants.

For 2023, our case study port recorded both the quantities used and the amounts spent in each category.

## TABLE 1: EMISSION CONVERSION FACTORS USED FOR RESOURCE INPUTS

| Resource | Emission factor (kgCO2e per unit) | Source |
|---|---|---|
| **Electricity, grid mix** | 0.207070 per kWh | BEIS 2022 |
| **Electricity, renewable** | 0.000000 per kWh (assumed) | Internal assumption |
| **Diesel** | 2.705530 per litre | BEIS 2022 |
| **HVO** | 0.035580 per litre | BEIS 2022 |
| **Water** | 0.000344 per litre | Industry average |
| **Refrigerants** | Already recorded in kgCO2e | BEIS 2022 |

University of Southampton

| Table 2: Emissions Calculation by Resource Input | | | | |
|---|---|---|---|---|
| Resource | Total Consumption (assumed) | Unit | Emission Factor (kg $CO_2$e per unit) | Emissions (kg $CO_2$e) |
| Electricity (Grey*) | 8,000,000 | kWh | 0.20707 | 1,656,560 |
| Electricity (Green*) | 8,000,000 | kWh | 0.00000 | 0 |
| Diesel | 0 | Litres | 2.70553 | 0 |
| HVO | 6,100,000 | Litres | 0.03558 | 217,038 |
| Water | 14,000,000 | Litres | 0.000344 | 4,816 |
| Refrigerants | 400,000 | kg $CO_2$e | 1.00000 | 400,000 |
| Business Travel | 150,000 | kg $CO_2$e | 1.00000 | 150,000 |
| Total Emissions | | | | 2,428,414 |
| TEU (Annual Volume) | 2,000,000 | | | |
| Emissions per TEU | | | | 1.21 kg $CO_2$e per TEU |

**Grey electricity refers to grid-supplied power generated from fossil fuels and other non-renewable sources, while green electricity is produced from renewable sources such as wind, solar, or hydro, and is considered to have zero associated carbon emissions.*

## Table 3: Comparative Emissions Under Alternative Fuel and Electricity Scenarios

| **Scenario** | Total emissions (kg $CO_2e$) | Emissions per TEU (kg $CO_2e$) |
|---|---|---|
| **2023 actual (100% HVO, 50% green electricity)** | 2.4 million | 1.21 |
| **2022 baseline (100% diesel; 50% green electricity)** | 18.7 million | 9.36 |
| **Worst case scenario: 100% Diesel; 100% grey electricity** | 20.4 million | 10.19 |

University of Southampton

| Table 4: Carbon Emissions and Marginal Cost per Kilogram of CO2e Under Alternative Operational Scenarios | | | |
|---|---|---|---|
| **Scenario** | Total emissions (kg $CO_2e$) | Emissions per TEU (kg $CO_2e$) | Cost per kgCO2e = Total cost of emission related resources / Total emissions in kgCO2e |
| **2023 actual (100% HVO, 50% green electricity)** | 2.4 million | 1.21 | £20,000,000 / 2,428,414 kgCO2e = £8.24 per kgCO2e |
| **2022 baseline (100% diesel; 50% green electricity)** | 18.7 million | 9.36 | £20,000,000 / 18,715,709 kgCO2e = £1.07 per kgCO2e |
| **Worst case scenario: 100% Diesel; 100% grey electricity** | 20.4 million | 10.19 | £20,000,000 / 20,371,669 kgCO2e = £0.98 per kgCO2e |

Table 5: Carbon Emissions and Offset Cost Comparison

| Scenario | Total emissions (kg $CO_2e$) | Cost incurred per kgCO2e | Cost of capture per kgCO2e @ £0.18 |
|---|---|---|---|
| **2023 actual (100% HVO, 50% green electricity)** | 2428414 | £8.24 | £433,077 |
| **2022 baseline (100% diesel; 50% green electricity)** | 18715109 | £1.07 | £3,337,606 |
| **Worst case scenario: 100% Diesel; 100% grey electricity** | 20371669 | £0.98 | £3,633,033 |

# Break-Even Analysis

- If diesel costs £1.10 per litre and HVO costs £1.40 per litre, the marginal cost of switching is £0.30 per litre.
- Given that diesel emits approximately 2.7 $kgCO_2e$ per litre and HVO emits 0.036 $kgCO_2e$ per litre, the cost of reducing one $kgCO_2e$ by switching to HVO is

$$\left(\frac{£0.30}{2.70553 - 0.03558}\right) = £0.11$$

- £0.11 is the Marginal Abatement Cost (MAC).
- This figure is lower than the estimated external offset price of £0.18 per $kgCO_2e$, based on industry benchmarks and our estimate.
- Therefore, from a break-even perspective, using HVO is not only environmentally preferable but also more cost-effective than relying on offsets.

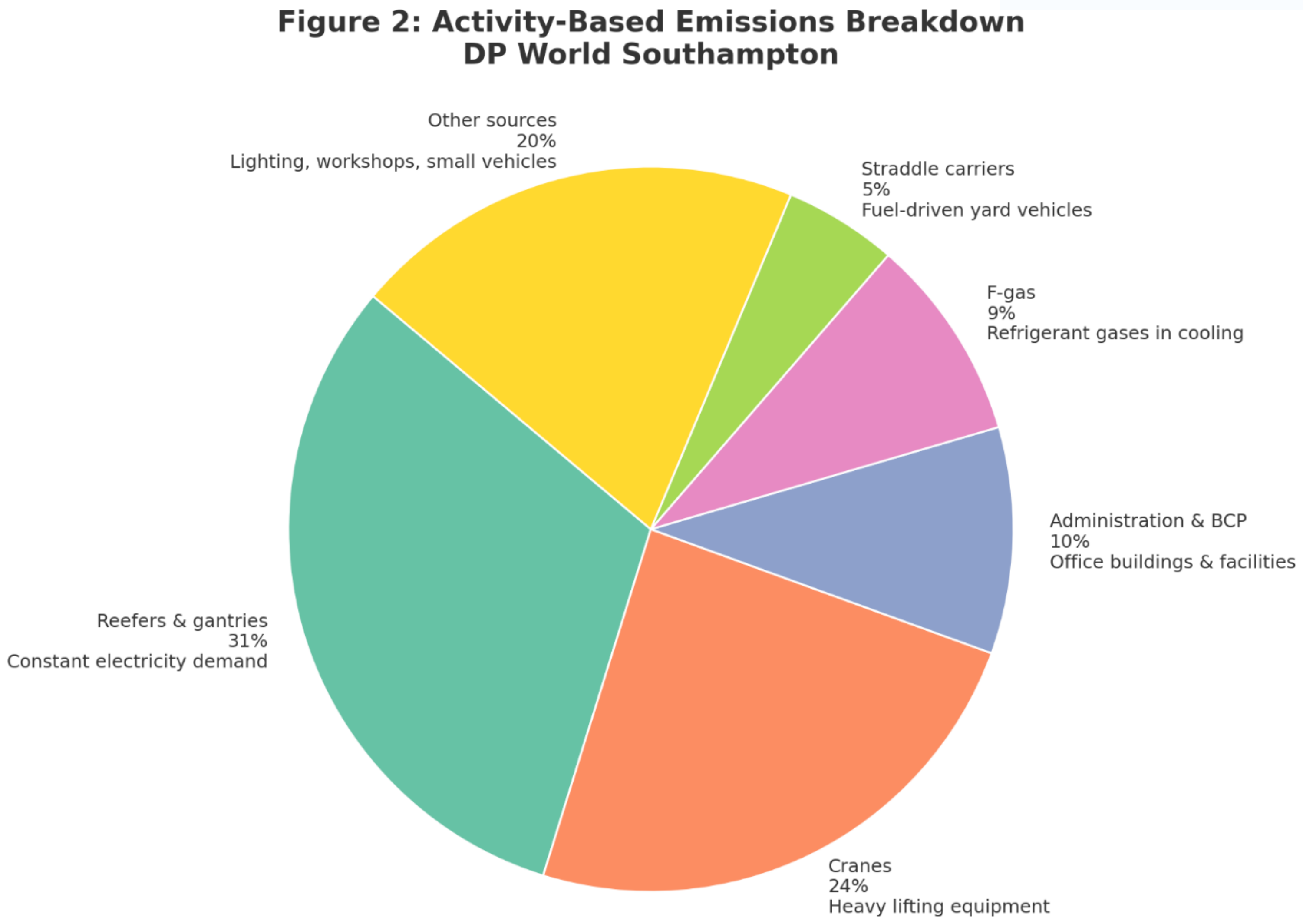
# Marginal Abatement Cost (MAC)

Ports can evaluate any operational switch using the marginal abatement cost (MAC) formula as follows:

$$MAC = \frac{Unit\ Cost_{new} - Unit\ Cost_{old}}{Emission\ Factor_{old} - Emission\ Factor_{new}}$$

If MAC < offset price (£0.11 < £0.18), internal abatement is cheaper than buying offsets.

# Activity-Based Emissions Breakdown (2023)



# Carbon Emissions Variance Analysis

| | Variance Type | Cause | Impact |
|---|---|---|---|
| 1 | Volume | Higher throughput (2.0m vs 1.8m TEUs) | +242,000 kgCO2e |
| 2 | Efficiency (Usage) | Fuel usage per TEU higher (3.5L vs 3L HVO) | +35,600 kgCO2e |
| 3 | Rate (Price) | Abatement cost increase (£0.25 vs £0.20 per kgCO2e) | +£121,141 |
| 4 | Offset Efficiency | Offset cost increase (£0.25 vs £0.15 per kgCO2e) | +£242,841 |
| 5 | Mix | Energy mix shift (50% grey vs 25% grey expected) | +828,280 kgCO2e |
| 6 | Emission Factor | National emission factor revised (0.280 vs 0.20707) | +583,440 kgCO2e |

# Interested in applying this at your port?

- Contact: 📧 S.R.Jory@soton.ac.uk 📞 +44 757 080 3505
- We can help:
  - Track all emissions-related costs and Scope 1 emissions records
  - Calculate emissions per container
  - Compare marginal abatement costs of sustainability options to support progress toward net zero
  - Apply Activity-Based Costing to identify cost drivers and improve pricing accuracy
- Get in touch — we can come to your port and support your journey.