

IPART
**Cost of Emissions for NSW Ferry
Networks**
Final Report

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This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Executive Summary

Sydney's ferry fleet consists of 28 vessels across six classes, with an additional four charter ferries. Arup has calculated the cost of CO₂-e (GHG emissions) and air pollutants (CO, NO_x, PM₁₀ and THC) in cents per vehicle kilometre (c/vkm). We have done this through approximating the energy content and emission factors of diesel fuel, as well as fuel consumption per kilometre for each class within the fleet. Our results are shown in Table 1 below.

Table 1 Ferry results summary - \$ 2012/2013

	Freshwater Class	Lady Class	First Fleet Class	River Cats	Harbour Cats	Super Cats	Average across fleet
Cost of GHG per vehicle kilometre (cents/vkm)	171.72	55.17	49.42	63.34	43.47	70.41	83.42
Cost of air pollution per vehicle kilometre (cents/vkm)	1747.85	561.55	503.01	644.68	442.47	716.69	849.07

1 Introduction

IPART has engaged Arup to estimate the cost of air pollution and greenhouse gas (GHG) emissions generated by Sydney Ferries' passenger ferries to inform their future fare setting. This report sets out the results of this analysis, as well as the analysis methodology, which can be updated as key inputs (such as the cost of GHG emission and air pollution in \$/tonne) change over time.

IPART was established in 1992 to regulate NSW natural monopolies including electricity, gas and water networks. Over time its role has been redefined as functions such as energy network regulation was transferred to the Australian Energy Regulator and other functions have been taken on by the Tribunal. Today IPART is viewed as the NSW Government's policy Think Tank with responsibilities including its traditional regulatory functions but also roles such as administration of the NSW Energy Savings scheme and a range of responsibilities across the transport industry.

IPART's transport responsibilities focus on fare setting across much of NSW's public transport networks. IPART's approach to determining public transport fares has increased in sophistication over time with the current approach based on assessing the total benefits of the public transport network to the wider community, and the extent to which fares recoup the total costs to the NSW Government of providing public transport infrastructure.

This report provides IPART with data on the costs of air pollution and greenhouse gas emissions so that IPART can account for these in setting fares for Sydney's ferry network.

The report is structured as follows:

- **Section 2** describes the project's scope and outputs.
- **Section 3** covers the methodology and results for Sydney's ferry fleet.

The supporting appendices provide additional detail and are structured as follows:

- Appendix A provides the project brief as defined by IPART.
- Appendix B outlines the assumptions and limitations of the analysis.
- Appendix C includes a full set of references.

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2 Scope

This project seeks to measure the cost of GHG emissions and air pollution generated by Sydney's ferries expressed in cents per vehicle kilometres travelled (cents/vkm). This includes accounting for the significant upgrades to the transport networks occurring within IPART's forthcoming five year price setting window (2015-2020).

These costs will be used to provide a common platform for determining public transport fares and complement the existing data shown in Table 2.

Table 2 Emission costs for NSW transport modes

Urban	Car	Bus	Rail	LCV	HCV
	cents/vkm	cents/vkm	cents/car-km	cents/vkm	cents/vkm
Air pollution	2.97	33.45	4.55	37.17	173.39
GHG emissions	2.34	13.78	0.73	11.58	38.57

Source: Transport for NSW, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, March 2013

The cents/vkm factors are based on estimates (in \$/tonne) of the cost of GHG emissions (Carbon dioxide equivalent) and air pollutants (Carbon monoxide, oxides of nitrogen, particulate matter and hydrocarbons) as shown in the Table 3.

Table 3 Emission costs in NSW transport

Emission	\$/tonne
Carbon dioxide equivalent (CO ₂ -e)	55.8
Carbon monoxide (CO)	3.5
Oxides of nitrogen (NO _x)	2,224.4
Particulate matter (PM ₁₀)	354,025.1
Total hydrocarbons (THC)	1,114.5

Source: Transport for NSW, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, March 2013

The estimates produced as part of this project will be used to inform IPART's fare setting processes. In addition, there is the potential for the estimates to be applied more broadly as an input into NSW Government policies and investment decisions including those in relation to emission reduction and infrastructure investment.

3 Sydney ferry services

3.1 Fleet overview

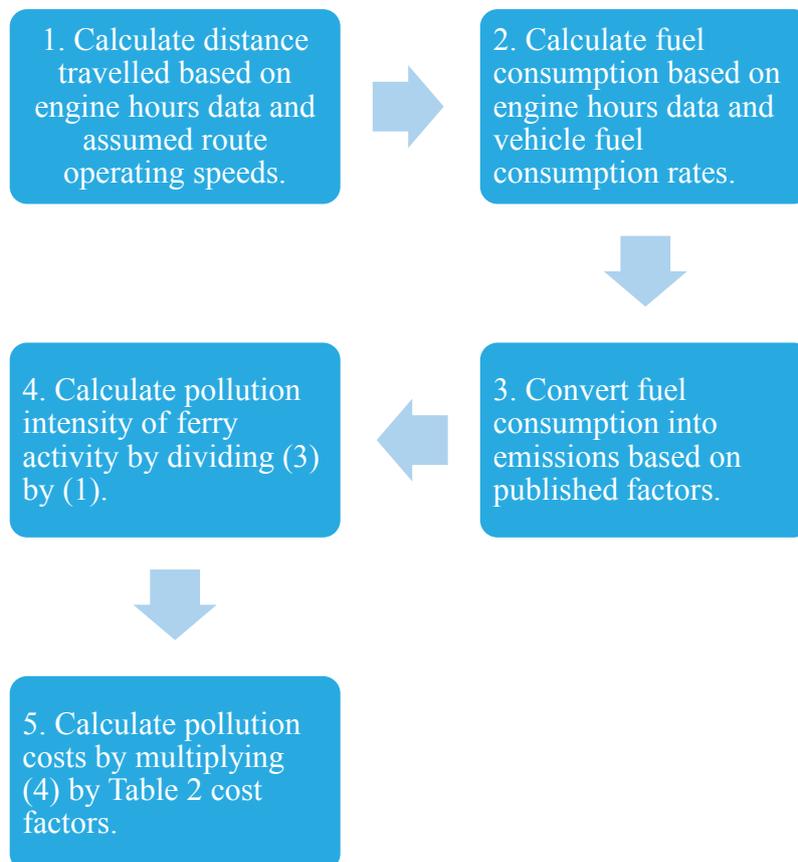
The Sydney ferry fleet comprises of 32 ferries across eight classes running on diesel fuel. Four of the ferries are charter vessels contracted through a tender process and were acquired between 2002 and 2014. The remaining 28 fall into one of the Freshwater Class (four vessels each with a capacity of 1100 people), Lady Class (two, 682¹), First Fleet Class (nine, 396), Rivercat Class (seven, 230), SuperCat Class (four, 326) and the HarbourCat Class (two, 150).

The oldest of these vessels was acquired in 1974, with the newest brought into the fleet in 2001. The NSW Government plans to modernise the fleet and improve reach and capacity, starting with the introduction of six new ferries that are expected to commence operations in 2016. Existing ferries will be upgraded through improvements in comfort, reliability, operations and maintenance.

3.2 Methodology

3.2.1 Summary

The approach for calculating both GHG emissions and air pollution is similar and summarised in Figure 1.



¹ Average across class.

Figure 1 Sydney ferry services methodology summary

Both primary (collected) and secondary (published) data was used to calculate GHG and other emissions per kilometre travelled by the ferry vehicles.

3.2.2 Fuel consumption and vehicle kilometres

In determining both GHG emissions and other air pollution costs, fuel consumption per kilometre was required for each ferry class. The steps leading to this calculation are detailed below.

Step 1: Determine total vehicle kilometres from Sydney Ferries on an annual basis for each class

	Method	Output	Data source	Assumptions detailed in Appendix B
1.1	Calculated the distance of each route run by Sydney ferries through mapping software.	Distance of each route	Arup calculations	Refer to Assumption one
1.2	Determined typical speeds for shorter inner harbour and longer services by dividing route distance by the time taken on each route according to timetable information available online.	Average speed of ferries inner harbour and other routes	'Ferry Service Plan 2014' provided by TfNSW	Refer to Assumption two
1.3	Allocated ferry classes to each route according to the routes each class services.	n/a	'Sydney Ferries Fleet Facts - Transport for NSW' provided by IPART in initial scope of work	Refer to Assumption three
1.4	Multiplied annual engine hours for each ferry class by the speed that they travel on the routes they service.	Annual distance travelled by each class (vkms)	Arup calculations	Refer to Assumption four

Step 2: Determine fuel consumption from Sydney Ferries on an annual basis for each class

	Method	Output	Data source	Assumptions detailed in Appendix B
2.1	Calculated average annual engine hours for each class (with the exception of charter classes)	Annual engine hours for each class with the exception of charter vessels	'SFEngine Hrs FY1213 and FY1314.xlsx' provided by Sydney Ferries	n/a

2.2	Multiplied annual engine hours per class by fuel consumption per hour for a representative vessel from each class	Annual fuel consumption for each class with the exception of charter vessels	'Sydney Ferries Fleet Facts - Transport for NSW' provided by IPART in initial scope of work	Refer to Assumption five
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Step 3: Determine fuel consumption per kilometre

	Method	Output	Data source	Assumptions detailed in Appendix B
3.1	Divided annual fuel consumption by annual distance travelled for each class.	L/vkm for each class	Arup calculations	n/a

Step 4: Determine weighted average fuel consumption

	Method	Output	Data source	Assumptions detailed in Appendix B
4.1	Summed fuel consumption across the fleet and summed distance travelled across the fleet. Divided litres consumed by kilometres travelled.	Weighted L/vkm across the whole fleet	Arup calculations	n/a

3.2.3 Greenhouse gas (GHG) emissions

The following steps are specific to GHG calculations.

Step 5A: Determine GHG emissions for diesel fuel

	Method	Output	Data source	Assumptions detailed in Appendix B
5A.1	Calculated GHG intensity of diesel by converting volume (litres) of diesel consumption by energy content and emissions intensity per GJ.	Emissions per diesel volume (tCO ₂ -e/L)	DECC (2014) <i>NGA Factors 2014</i>	n/a

Step 6A: Determine cost of GHG emissions

	Method	Output	Data source	Assumptions detailed in Appendix B
6A.1	Multiplied the tonnes of GHG emitted per litre of fuel by litres of	tCO ₂ -e/vkm	Arup	n/a

	fuel consumed per kilometre for each ferry class and for the weighted fleet average.		calculations	
6A.2	Multiplied GHG emitted per kilometre travelled by the cost of GHG emissions.	Cents/vkms for GHG emissions	TfNSW (2013) <i>Principles and Guidelines for Economic Appraisal of Transport Investments and Initiatives</i>	n.a

3.2.4 Air pollutants

The following steps are specific to air pollution calculations:

Step 5B: determine air pollution rates for diesel fuel

	Method	Output	Data source	Assumptions detailed in Appendix B
5B.1	Researched the air pollution rate for diesel fuel. Requested data from Sydney Ferries on ferry engine displacement in order to get data that accurately reflects Sydney's ferry engines	gCO/kWhr gNO _x /kWhr gPM ₁₀ /kWhr gTHC/kWhr	US EPA (2009) <i>Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories</i>	Refer to Assumption six
5B.2	Converted data to required units using energy content factor for diesel and basic unit conversion	tCO/L tNO _x /L tPM ₁₀ /L tTHC/L	DECC (2014) NGA Factors 2014	n/a

Step 6B: determine the cost of air pollutants

	Method	Output	Data source	Assumptions detailed in Appendix B
6B.1	Multiplied the tonnes of air pollutants emitted per litre of fuel by litres of fuel consumed per kilometre for each ferry class and for the weighted fleet average	tCO/vkm tNO _x /vkm tPM ₁₀ /vkm tTHC/vkm for each class	Arup calculations	n/a
6B.2	Multiplied air pollutants emitted per kilometre travelled by the cost of air pollutants per kilometre. Summed the costs per kilometre of the four different categories of air pollution	Cents/vkms for air pollutants emissions for each class	TfNSW (2013) <i>Principles and Guidelines for Economic Appraisal of Transport Investments</i>	n/a

			<i>and Initiatives</i>	
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3.3 Results

Table 4 reflects the steps outlined in the methodology in setting out the GHG emissions and air pollution per vehicle kilometre for each ferry class, as well as an average across the fleet. The results reflect the data received from financial years 2012/13 and 2013/14.

Table 4 Ferry results table

	Freshwater Class	Lady Class	First Fleet Class	River Cats	Harbour Cats	Super Cats	Average across fleet
Annual distance travelled (vkm)	103407.3	49701.6	58692.6	74779.20	27418.5	58706.1	1854381.6 (total)
Annual fuel consumption (L)	1179450	182131	192656	314595	79169	274560	10274709 (total)
Fuel consumption per kilometre (L/vkm)	11.41	3.66	3.28	4.21	2.89	4.68	5.54
CO ₂ -e emission rate per litre (tCO ₂ -e/L)	2.70 * 10 ⁻³						
CO ₂ -e emitted per kilometre (tCO ₂ -e/vkm)	0.0308	0.0099	0.0089	0.0114	0.0078	0.0126	.0149
Cost of CO ₂ -e emissions (cents/tonne)	5580						
Cost of GHG per kilometre (cents/vkm)	171.72	55.17	49.42	63.34	43.47	70.41	83.42
CO emission rate per litre (tCO/L)	1.72 * 10 ⁻⁵						
CO emitted per kilometre (tCO/vkm)	1.96*10 ⁻⁴	6.29*10 ⁻⁵	5.63*10 ⁻⁵	7.22*10 ⁻⁵	4.95*10 ⁻⁵	8.02*10 ⁻⁵	9.51*10 ⁻⁵
Cost of CO emissions (cents/tonne)	350						

NO _x emission rate per litre (tNO _x /L)	1.07 * 10 ⁻⁴						
NO _x emitted per kilometre (tNO _x /vkm)	1.22*10 ⁻³	3.93*10 ⁻⁴	3.52*10 ⁻⁴	4.51*10 ⁻⁴	3.10*10 ⁻⁴	5.01*10 ⁻⁴	5.94*10 ⁻⁴
Cost of NO _x emissions (cents/tonne)	222440						
PM ₁₀ emission rate per litre (tPM ₁₀ /L)	3.65 * 10 ⁻⁶						
PM ₁₀ emitted per kilometre (tPM ₁₀ /vkm)	4.16*10 ⁻⁵	1.34*10 ⁻⁵	1.20*10 ⁻⁵	1.53*10 ⁻⁵	1.05*10 ⁻⁵	1.70*10 ⁻⁵	2.02*10 ⁻⁵
Cost of PM ₁₀ emissions (cents/tonne)	35402510						
THC emission rate per litre (tTHC/L)	1.73 * 10 ⁻⁵						
THC emitted per kilometre (tTHC/vkm)	3.30*10 ⁻⁵	1.06*10 ⁻⁵	9.50*10 ⁻⁶	1.22*10 ⁻⁵	8.36*10 ⁻⁶	1.35*10 ⁻⁵	1.60*10 ⁻⁵
Cost of THC emissions (cents/tonne)	111450						
Cost of air pollutants per kilometre (cents/vkm)	1747.85	561.55	503.01	644.68	442.47	716.69	849.07

Table 5 summarises the GHG emissions and air pollution costs associated with Sydney's ferry network:

Table 5 Ferry results summary

	Freshwater Class	Lady Class	First Fleet Class	River Cats	Harbour Cats	Super Cats	Average across fleet
Cost of GHG per vehicle kilometre (cents/vkm)	171.72	55.17	49.42	63.34	43.47	70.41	83.42
Cost of air pollution	1747.85	561.55	503.01	644.68	442.47	716.69	849.07

per vehicle kilometre (cents/vkm)							
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3.4 Discussion

The results in GHG emissions and air pollution costs associated with Sydney's ferry network:

Table 5 show that the most emissions intensive class is the Freshwater class, which is consistent with the fact that it carries the most passengers. The cost of air pollution is around 10 times larger than greenhouse gas emissions. The majority (84%) of air pollution costs is due to PM₁₀, followed by NO_x (16%), with CO and THC pollutants forming the remaining <0.5%.

Comparing ferries to other vehicle types (Table 2), ferries are more emissions intensive than nearly all other types per vehicle kilometre. This may be due to the fact that ferries are diesel-powered (compared to, say, electricity powered rail).

The substantial investment in *Sydney's Ferry Future* is likely to alter the cost of GHG emissions and air pollution per vehicle kilometre travelled. The investment will restore or introduce 165 ferry services as well as gradually replacing much of the current fleet with new vessels. The modernised fleet will have better fuel efficiency, reduced noise levels and give greater flexibility in maintenance schedules.

We understand that Transport for NSW are currently investigating options for staging the introduction of these new vessels over coming years. While the timing of introduction for new vessels is yet to be finalised it is our expectation that, based on like-for-like capacity replacement, a reduction in emissions and air pollution of between 6-10% should be achievable given current vessel design specifications. The potential emissions and air pollution reductions should be confirmed with Transport for NSW and updated as additional information becomes available.

Appendix A

Project brief

Scope of work

We require estimates of the cost of emissions associated with Sydney Ferries' passenger ferries and Sydney's light rail services.

We have estimates of emission costs for other modes of transport (\$2012/13) as set out in the following table. We require an estimate for passenger ferries and light rail in Sydney for each of the categories below. We are seeking proposals from consultants with relevant experience and qualifications.

Urban	Car	Bus	Rail	LCV	HCV
	cents/vkm	cents/vkm	cents/vkm	cents/vkm	cents/vkm
Air pollution	2.97	33.45	4.55	37.17	173.39
GHG emissions	2.34	13.78	0.73	11.58	38.57

Source: Transport for NSW, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, March 2013

For ferries, we require estimates of the cost associated with air pollution and greenhouse gas emissions for both:

- ▼ Sydney Ferries' current fleet (see attached information from the Transport for NSW website)
- ▼ A modern, fuel efficient Sydney Ferries fleet based on having vessels equal to their current capacity with fuel efficient engines (we will require the consultant to provide advice on this).

For light rail, we require estimates for the current light rail network that operates in Sydney. However, we also require estimates that are applicable to any expanded light rail network in Sydney (in particular, the proposed eastern suburbs/CBD extension), if these are different from those for the existing network.

The emission cost estimates must be constructed using the following unit values (\$2012/13) for the cost of emissions:

Emission	\$/tonne
Carbon dioxide equivalent (CO ₂ -e)	55.8
Carbon monoxide (CO)	3.5
Oxides of nitrogen (Nox)	2,224.4
Particulate matter (PM10)	354,025.1
Total hydrocarbons (THC)	1,114.5

Source: Transport for NSW, *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, March 2013

Please provide a proposal that includes a detailed methodology of how you will go about this task, including information on how you will obtain the required data and any relevant experience you have in this area.

The consultant must provide a written report that we can publish on our website that includes:

- ▼ A detailed explanation of the methodology used, data relied upon and findings for each of the cost estimates
- ▼ A discussion of similar studies that have been done, if relevant, highlighting where the current study differs from past practice
- ▼ Calculations that can be updated when the unit values in the table above are updated
- ▼ Estimated pollution emitted by class/size of ferry and by light rail services
- ▼ Assumptions and justification for the ferries included in the modern, fuel efficient fleet alternative.

Timeframe and reporting milestones

Table 1 Timeframe and reporting milestones

Event	Due date
Engage consultant	29 October 2014
Estimates and supporting report due	19 November 2014
Attend IPART Tribunal meeting (if required)	TBC

Evaluation and assessment criteria

After the Closing Date IPART will evaluate each quote based on its assessment of any matters that it considers appropriate, including but not limited to the following criteria (where relevant):

- (1) the quoter's experience in providing services of a similar nature to the Services, including any prior work undertaken for IPART;
- (2) the quoter's ability to perform the Services in the required timeframe;
- (3) the total price proposed to be charged by the quoter for the Services;
- (4) the timeframe within which the quoter will perform the Services.

While IPART will have regard to the criteria above, it retains an absolute discretion as to how it will evaluate and assess quotes and may consider any other matters it considers relevant.

IPART may contact the quoter's referees.

Appendix B

Assumptions and limitations

B1 Assumption one

Where practical, ferries travel in a straight line from stop to stop. Otherwise, they travel approximately in the centre of the body of water they are on (for example, down Parramatta River).

B2 Assumption two

Inner harbour routes serviced by the First Fleet Class and HarbourCat Class ferries are travelled at 4.5 m/s. This is an approximation based on the distance and typical time taken to travel these routes.

Other routes serviced by Sydney ferries are travelled at 6 m/s. This is an approximation based on distance and typical time taken to travel these routes.

B3 Assumption three

Ferries only service the routes suggested for their class on *Sydney Ferries Fleet Facts – Transport for NSW*.

B4 Assumption four

Engine hours are fully represented by the time taken to service routes for each ferry class.

B5 Assumption five

The example ferry for each class on ‘Sydney Ferry Fleet Facts’ is representative of the class as a whole in terms of fuel consumption per hour.

B6 Assumption six

In the absence of specific ferry data from TfNSW, tier 0 and middle displacement categories have been selected to determine emission rate from ferries in accordance with Table 3-5 in *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*.

Appendix C

References

C1

Data sourced directly from Transport for NSW

DECC (2014) *NGA Factors 2014*

TfNSW (2013) *Principles and Guidelines for Economic Appraisal of Transport Investments and Initiatives*

US EPA (2009) *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories*