

IPART
**Cost of Emissions for NSW Light
Rail**
Final Report

Issue | 19 November 2014

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.

Job number 239386

Arup
Arup Pty Ltd ABN 18 000 966 165



Arup
Level 17
1 Nicholson Street
Melbourne VIC 3000
Australia
www.arup.com

ARUP

Document Verification

ARUP

Job title		Cost of Emissions for NSW Light Rail		Job number	
				239386	
Document title		Draft Report		File reference	
Document ref					
Revision	Date	Filename	Draft Report.docx		
Draft 1	14 Nov 2014	Description	First draft		
			Prepared by	Checked by	Approved by
		Name	Bas Simpson	Joan Ko	Simon Farnbach
		Signature			
Final	19 Nov 2014	Filename	Light rail report.docx		
		Description	Final report		
			Prepared by	Checked by	Approved by
		Name	Bas Simpson	Simon Farnbach	Simon Farnbach
		Signature			
Issue	19 Nov 2014	Filename	ARUP_Light_Rail_Report_Final.docx		
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
Issue Document Verification with Document					
<input checked="" type="checkbox"/>					

Contents

	Page
Executive Summary	1
1 Introduction	2
2 Scope	3
3 Sydney light rail services	4
3.1 Network overview	4
3.2 Methodology	4
3.3 Results	8
3.4 Discussion	9

Appendices

Appendix A

Project brief

Appendix B

Assumptions and limitations

Appendix C

References

Executive Summary

Sydney's light rail network currently runs services between Central Station and Sydney's Inner Western Suburbs. 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 emission factors associated with electricity generation in NSW, as well as electricity consumption per kilometre for the light rail network. Our results are shown in Table 1 below.

Table 1 Emission costs for Sydney light rail \$ 2012/2013

	Light rail network
Cost of GHG per vehicle kilometre (cents/vkm)	29.06
Cost of air pollution per vehicle kilometre (cents/vkm)	36.81

1 Introduction

IPART has engaged Arup to estimate the cost of air pollution and greenhouse gas (GHG) emissions generated by Sydney's light rail services 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 light rail services.

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 light rail network.

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.

.

2 Scope

This project seeks to measure the cost of GHG emissions and air pollution generated by Sydney's light rail services 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 light rail services

3.1 Network overview

Sydney's light rail currently links Sydney's Central Station to the Inner Western Suburbs, with an extension to services in the Inner West completed in March 2014. Significant investment in Sydney's light rail network has been undertaken by the NSW Government to modernise the fleet, improve information accessibility, introduce an electronic ticketing system and to significantly expand the reach of the network. Central to the network's expansion is a new rail line expected to be completed by 2019/2020 that will link the CBD and Sydney's South East.

3.2 Methodology

3.2.1 Summary

As with Sydney Ferries, the approach used for light rail in calculating both GHG emissions and air pollution is similar and summarised in Figure 1.

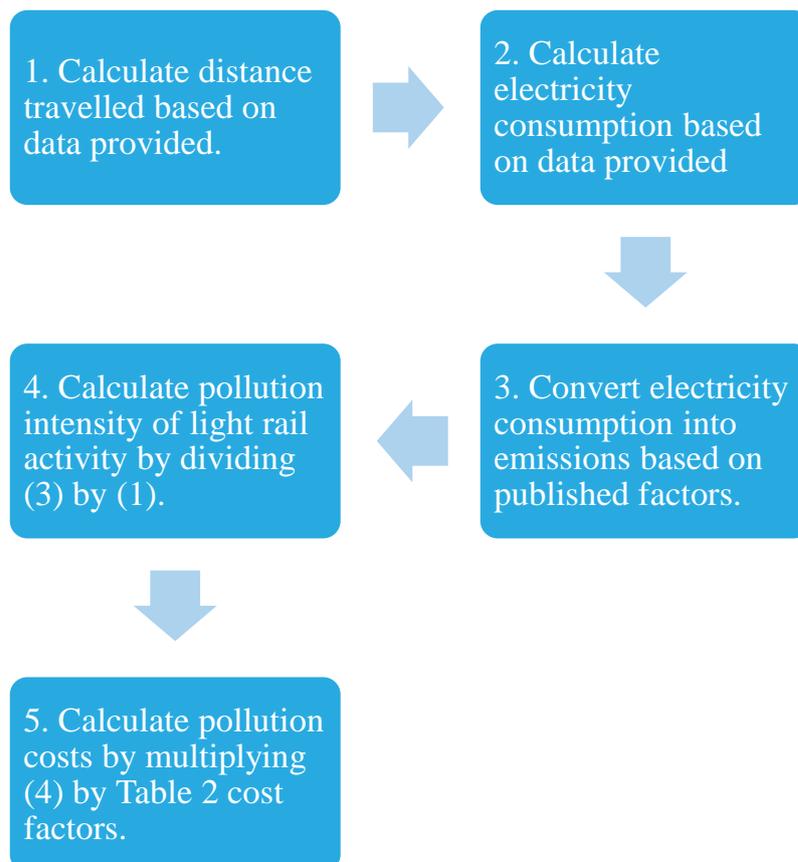


Figure 1 Sydney light rail services methodology summary

Both primary (collected) and secondary (published) data was used to calculate GHG and other emissions per kilometre travelled by Sydney light rail services.

3.2.2 Electricity consumption and vehicle kilometres

In determining both GHG and other air pollution costs, electricity consumption per kilometre was required for Sydney's light rail fleet. The steps leading to this calculation are detailed below:

Step 1: Determine total vehicle kilometres travelled by the light rail network

	Method	Output	Data source	Assumptions detailed in Appendix B
1.1	Retrieved total vehicle kilometres from Transport for NSW for the 20-month period between 2012 and 2014.	Vkms travelled by the light rail network over the 20-month period	TfNSW data request	Refer to assumption one

Step 2: Determine total electricity consumption by the light rail network

	Method	Output	Data source	Assumptions detailed in Appendix B
2.1	Retrieved total electricity consumption from Transport for NSW. Annual data was provided for 2012/2013 and 2013/14. The electricity consumption across this 20-month continuous period was summed.	MWh of electricity consumed by light rail network over the 20-month period	TfNSW data request	Refer to assumption one

Step 3: Determine MWh consumed per vehicle kilometre travelled by the light rail network

	Method	Output	Data source	Assumptions detailed in Appendix B
3.1	Divided total electricity consumption by total kilometres travelled	MWh/vkm	Arup calculation	n/a

3.2.3 Greenhouse gas (GHG) emissions

The following steps are specific to GHG calculations:

Step 4A: Determine GHG rate for NSW electricity generators

	Method	Output	Data source	Assumptions detailed in Appendix B
4A.1	Researched the GHG emission rate for NSW electricity generators	tCO ₂ -e/MWh	AEMO Carbon Dioxide Equivalent Intensity Index	n/a

Step 5A: Determine GHG emissions for light rail network per kilometre travelled

	Method	Output	Data source	Assumptions detailed in Appendix B
5A.1	Multiplied GHG emission rate by the MWh consumed by the light rail network	tCO ₂ -e	Arup calculation	n/a
5A.2	Divided total CO ₂ -e emitted by vehicle kilometres travelled by the light rail network	tCO ₂ -e/vkm	Arup calculation	n/a

Step 6A: Determine GHG emission costs for light rail network per kilometre travelled

	Method	Output	Data source	Assumptions detailed in Appendix B
6A.1	Multiplied GHG emitted per kilometre travelled by the cost of GHG emissions	Cents/vkms	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 pollutant calculations:

Step 4B: Determine CO, NO_x, PM10 rate for NSW electricity generators

	Method	Output	Data source	Assumptions detailed in Appendix B
4B.1	Researched air pollution emission rate for each of NSW coal, gas and other electricity generators. Data on hydrocarbons was unavailable: see step 5B	tCO/year for coal, gas & other tNO _x /year for coal, gas &	EPA NSW (2013) <i>Air Emissions Inventory for GMR in NSW 2008 Calendar</i>	Refer to assumption two

		other tPM ₁₀ /year for coal, gas & other	<i>Year – Industrial Emissions</i>	
4B.2	Researched separate electricity generation from coal, gas and other generators in NSW	MWh for coal MWh for gas MWh for other	EPA NSW (2013) <i>Air Emissions Inventory for GMR in NSW 2008 Calendar Year – Industrial Emissions</i>	Refer to assumption two
4B.3	Calculate air pollutant rate for NSW electricity generation by dividing air pollutants from coal, gas and other generators by electricity generated by coal, gas and other generators	tCO/MWh tNO _x /MWh tPM ₁₀ /MWh	Arup calculations	n/a

Step 5B: Determine THC rate for NSW electricity generators

	Method	Output	Data source	Assumptions detailed in Appendix B
5B.1	Calculated THC emission rate for NSW electricity generators using a lifecycle inventory database. Most recent data was from 1995/96	tTHC/MWh	Australian lifecycle inventory database (AusLCI)	Refer to assumption three

Step 6B: Determine air pollution emissions for light rail network per kilometre travelled

	Method	Output	Data source	Assumptions detailed in Appendix B
6B.1	Multiplied air pollution emission rate by the MWh consumed by the light rail network	tCO tNO _x tPM ₁₀ tTHC	Arup calculation	n/a
	Divided total air pollutants emitted by vehicle kilometres travelled by the light rail network	tCO/vkm tNO _x /vkm tPM ₁₀ /vkm tTHC/vkm	Arup calculation	n/a

Step 7B: Determine air pollution costs for light rail network per kilometre travelled

	Method	Output	Data source	Assumptions detailed in Appendix B
7B.1	Multiplied air pollution emitted per kilometre travelled by the cost of air	Cents/vkms	TfNSW (2013) <i>Principles and</i>	n/a

	pollution emissions. Summed the costs per kilometre of the four calculated sources of air pollution		<i>Guidelines for Economic Appraisal of Transport Investments and Initiatives</i>	
--	---	--	---	--

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 the light rail network. The results reflect the data results for the 20-month period from Nov-12 to Jun-14.

Table 4 Light rail network results

	Light rail network
Annual distance travelled (vkm)	805037
Annual electricity consumption (MWh)	4487.79
Energy consumption per kilometre (MWh/vkm)	$5.57 * 10^{-3}$
CO ₂ -e rate for NSW electricity generators (tCO ₂ -e/MWh)	0.93
CO ₂ -e emitted per kilometre (tCO ₂ -e/vkm)	$5.21 * 10^{-3}$
Cost of CO ₂ -e emissions (cents/tonne)	5580
Cost of GHG per kilometre (cents/vkm)	29.06
CO rate for NSW electricity generation (tCO/MWh)	$4.21 * 10^{-3}$
CO emitted per kilometre (tCO/vkm)	$2.35 * 10^{-5}$
Cost of CO emissions (cents/tonne)	350
NO _x rate for NSW electricity generation (tNO _x /MWh)	$4.73 * 10^{-3}$
NO _x emitted per kilometre (tNO _x /vkm)	$2.64 * 10^{-5}$
Cost of NO _x emissions (cents/tonne)	222440
PM ₁₀ rate for NSW electricity generation (tPM ₁₀ /MWh)	$1.47 * 10^{-4}$
PM ₁₀ emitted per kilometre (tPM ₁₀ /vkm)	$8.18 * 10^{-7}$
Cost of PM ₁₀ emissions (cents/tonne)	35402510
THC rate for NSW electricity generation (tTHC/MWh)	$3.16 * 10^{-3}$
THC emitted per kilometre (tTHC/vkm)	$1.76 * 10^{-5}$
Cost of THC emissions (cents/tonne)	111450
Cost of air pollutants per kilometre (cents/vkm)	36.81

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

Table 5 Emission costs for Sydney light rail services

	Light rail network
Cost of GHG per vehicle kilometre (cents/vkm)	29.06
Cost of air pollution per vehicle kilometre (cents/vkm)	36.81

3.4 Discussion

The pollutant PM₁₀ contributes the majority of costs to air pollutants (79%) with 16% from NO_x, 5% from THC and less than 1% from CO. The relatively high contribution of PM₁₀ to overall costs reflect the cost per tonne of the pollutants emitted rather than the volume of pollutants; less PM₁₀ was produced per vehicle kilometre than all other pollutants but it is the most expensive pollutant per tonne.

Sydney's light rail network is in the process of a significant upgrade. The Inner West Light Rail was opened in March 2014, with planning approved for further expansion in Sydney's CBD and South East. As such, the emission rates of Sydney's light rail fleet are likely to change as factors such as track gradient, passenger loading, vehicle size and acceleration rate change to suit the new expanded network.

The increased efficiency of Sydney's new light rail fleet along with the extent energy consumption sourced from renewables is likely to reduce the cost of GHG emissions and air pollution per vehicle kilometre travelled. For example, Transport for NSW anticipates that greenhouse gas emissions will fall from 18,418.4 to 14,903.2 tonnes of CO₂-e per year if 20% of Sydney's energy is sourced from renewables by 2020. As the City of Sydney established a target of 30% renewables contribution by 2030, such a reduction in greenhouse gas emissions is plausible.

Given the timing of the CBD and South East line (expected for completion in 2019/20), Arup considers that the calculation of the existing light rail fleet network will be sufficient for the next five years.

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

Electricity consumption per kilometre travelled by the light rail network from November 2012 to June 2014 is representative of electricity consumption per kilometre over the next five years that will include the expanded light rail networks.

B2 Assumption two

The rate of pollutants per MWh from the greater metropolitan region of NSW is a fair representation of the rate of pollutants from NSW electricity as a whole.

B3 Assumption three

THC emitted per MWh for electricity consumption in NSW in 1995/96 is a suitable approximation for consumption levels in 2013/14.

Appendix C

References

C1

Data sourced directly from Transport for NSW

AEMO Carbon Dioxide Equivalent Index

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

EPA NSW (2013) *Air Emissions Inventory for GMR in 2008 Calendar Year – Industrial Emissions*

Australian lifecycle inventory database – 1995/96