Sydney Metro North West

Design and Construction of Surface and Viaduct Civil Works

Carbon and Energy Management Plan

Sub-plan to Sustainability Plan

NWRLSVC-ISJ-SVC-PM-PLN-120301

Revision 7.0

29 May 2017

Document Control

Controlled copy of the **Carbon and Energy Management Plan** will be distributed to the Principal's Representative, Independent Certifier and other relevant stakeholders and will available to all ISJV employees in a soft copy format through the digital document control management system.

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Document Revision History

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Revision	Description	Prepared by	Reviewed by	Approved by	Date
1.0	Issued for Approval	R Palmer WSP	Omar Faruqi	Sam Turnbull	20-Apr-14
2.0	Second Submission	R Palmer WSP	Tim Cullen	Graeme Tait	11-Aug-14
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6.0	6 monthly review	Antony Glambedakis	Brad Tucker	George Perdikaris	6-Mar-17
7.0	Update in response to TNSW comments	Antony Glambedakis	Brad Tucker	George Perdikaris	29 May 17
Signature					

Plan Compliance

Cl.	Description	Where Addressed
SVC Project Deed		
24.4 (o)	This Carbon and Energy Management Plan complies with the requirements of Exhibit A Appendix 24.4(o) of the Surface and Viaduct Civil Works (SVC) Project Deed. The Carbon and Energy Management Plan must as a minimum address and detail:	
24.4(o) (i)	low carbon strategies and initiatives that will be implemented to minimise the carbon emissions associated with the construction of the Project Works and Temporary Works;	Refer Section 4.4
24.4(o) (ii)	energy efficiency strategies and initiatives that will be implemented to minimise energy use associated with the construction of the Project Works and Temporary Works;	Refer Section 4.3
24.4(o) (iii)	a carbon emission baseline determined using a carbon footprint assessment undertaken in accordance with ISO 14064-1 Greenhouse gases - Part 1, ISO 14064-2 Greenhouse gases - Part 2, ISO 14064-3 Greenhouse gases - Part 3 that incorporates direct and indirect emissions associated with electricity and fuel consumption, on-site process emissions and embodied emissions for all concrete and steel used in the construction of the Project Works and Temporary Works;	Refer Section 3
24.4(o) (iv)	a carbon emission reduction target as a percentage of the carbon emission baseline;	Refer Section 3
24.4(o) (v)	an energy use baseline determined using energy modelling that incorporates electrical energy consumption and fuel consumption as well as on-site renewable energy generation and renewable energy sourced from the main electricity grid for the construction of the Project Works and Temporary Works;	Refer Section 3
24.4(o) (vi)	an energy reduction target as a percentage of the energy use baseline;	Refer Section 4
24.4(o) (vii)	a life cycle assessment undertaken in accordance with ISO 14040 Environmental management - Life cycle assessment – Principles and framework for all concrete and steel used for the construction of the Project Works and Temporary Works and identify material selection strategies and initiatives that will be implemented to minimise the environmental impacts associated with the construction of the Project Works and Temporary Works; and	Refer Section 3
24.4(o) (viii)	processes and methodologies for monitoring, auditing and the taking of corrective action.	Refer Section 5
Appendix 10	In addition to Exhibit A Appendix 24.4 (o) of the Deed, Appendix 10 contains the sustainability requirements that the SVC Contractor must comply with during the performance of the SVC Contractor's activities. In particular the relevant requirements for this plan from Section 10.5 of Appendix 10 which relates to carbon management and energy efficiency are detailed below:	

Cl.	Description	Where Addressed
(a)	The SVC Contractor must identify and implement low carbon and energy efficiency strategies and initiatives that minimise carbon emissions, energy use and embodied lifecycle impacts associated with the construction of the Project Works and Temporary Works.	Refer Section 4.3
(b)	The SVC Contractor must undertake carbon footprint assessments in accordance with the requirements in ISO 14064-1:2006: Greenhouse gases - Part 1, ISO 14064-2:2006: Greenhouse gases - Part 2, ISO 14064-3:2006: Greenhouse gases - Part 3 that incorporate direct and indirect emissions associated with electricity and fuel consumption, on-site process emissions and embodied emissions for all concrete and steel used in the construction of the Project Works and Temporary Works.	Refer Section 3
(c)	The SVC Contractor must undertake energy modelling that incorporates electrical energy consumption and fuel consumption as well as any on-site renewable energy generation and renewable energy sourced from the main electricity grid for the construction of the Project Works and Temporary Works. The energy modelling must establish a baseline against which the benefits of energy efficiency initiatives can be measured.	Refer Section 3
(d)	The SVC Contractor must undertake life-cycle assessments in accordance with ISO 14044:2006 Environmental management - Life cycle assessment – Requirements and guidelines for all concrete and steel used in the construction of the Project Works and Temporary Works. The life-cycle assessments must be used by the SVC Contractor in selecting the most appropriate low-impact materials to be used in the construction of the Project Works and Temporary Works.	Refer Section 3
(e)	The SVC Contractor must incorporate energy efficiency into all aspects of the Project Works, the Temporary Works and the SVC Contractor’s Activities, including reducing fuel usage associated with the SVC Contractor’s Activities.	Refer Section 4.3
(f)	The SVC Contractor must minimise construction and embodied carbon emissions and maximise energy efficiency for all aspects of the Project Work, the Temporary Works and the SVC Contractor’s Activities.	Refer Section 3
(g)	The SVC Contractor must minimise carbon emissions using: (i) energy avoidance and reduction strategies; (ii) low carbon transportation options; and (iii) alternate fuels.	Refer Section 4.3
(h)	The SVC Contractor must ensure that refrigerants and fire suppression systems within temporary site facilities have low or zero global warming potential.	Refer Section 4.3
(i)	The SVC Contractor must incentivise public and shared transport use and develop and implement green travel plans for the SVC Contractor's personnel and Subcontractor’s personnel engaged in the SVC Contractor’s Activities.	Refer Section 4.3
(j)	The SVC Contractor must identify and implement opportunities for using onsite sources of renewable or low carbon energy.	Refer Section 4.4

Cl.	Description	Where Addressed
(k)	The SVC Contractor must ensure that, as a minimum, 20 % of the electricity needs of the SVC Contractor's Activities is offset through either one or a combination of the following: (i) purchase of Australian carbon offsets credits; and/or (ii) purchase of renewable energy from an Australian Government accredited renewable energy supplier.	Refer Section 4.3
(l)	The SVC Contractor must ensure that all vehicles, plant and equipment, are: (i) selected and operated for optimum energy efficiency; (ii) not left idling when not in use; (iii) fitted with catalytic converters, diesel particulate filters or equivalent devices where reasonable and feasible; and (iv) well maintained and serviced in accordance with relevant equipment maintenance documentation to reduce emissions due to poor engine performance.	Refer Section 4.3
(m)	The SVC Contractor must ensure that, where reasonable and feasible, all plug-in electrical equipment within any temporary site facilities provided by the SVC Contractor, including the temporary site facilities provided for the Principal and the Independent Certifier, comply with the requirements of the Equipment Energy Efficiency Program (E3) "Minimum Energy Performance Standards" and has at least a five star Energy Rating Label.	Refer Section 4.3

Contents

Definitions and Abbreviations

Abbreviation	Definition
CEMP	Construction Environmental Management Plan
CaEMP	Carbon and Energy Management Plan
CM	Construction Manager
EIS	Environmental Impact Statement
EM	Environmental Manager
IC	Independent Certifier
ISJV	Impregilo S.p.A. (Australia) and Salini (Australia) Joint Venture
ISJV-PMS	Impregilo S.p.A. (Australia) and Salini (Australia) Joint Venture – Project Management System
IS Rating Tool	Infrastructure Sustainability Rating Tool
NSW SDG	New South Wales Sustainable Guidelines for Rail v2.0
NWRL	North West Rail Link
PD	Project Director
PMS	Project Management System
SE	Site Engineer / Site Supervisor
SP	Sustainability Plan
SVC	Surface and Viaduct Civil Works
SWTC	Scope of works and technical criteria
TfNSW	Transport for New South Wales

1 INTRODUCTION

1.1 Purpose

This Carbon and Energy Management Plan (CaEMP) describes the processes, procedures and initiatives that the Impregilo Salini Joint Venture (ISJV) will implement to reduce carbon and energy use during the construction works per the obligations specified in the Surface and Viaduct Civil Works (SVC) Project Deed (‘the Deed’) for the NWRL SVC Package.

The CaEMP represents the management plan for control of carbon and energy during construction. This forms a sub-plan of, and should be read in conjunction with, the Sustainability Plan (SP).

1.2 Scope

This plan specifically addresses the requirements detailed in the Deed, in particular Exhibit A Appendix 24.4 (o) Project Plan Requirements. Additionally, the CaEMP provides effective data collection and management process for the SVC contractor to comply with Exhibit A Appendix 10.5 of the Deed.

The CaEMP will address the following items through sections in the plan:

(i) low carbon strategies and initiatives that will be implemented to minimise the carbon emissions associated with the construction of the Project Works and Temporary Works;
(ii) energy efficiency strategies and initiatives that will be implemented to minimise energy use associated with the construction of the Project Works and Temporary Works;
(iii) a carbon emission baseline determined using a carbon footprint assessment undertaken in accordance with ISO 14064-1 Greenhouse gases – Part 1, ISO 14064-2 Greenhouse gases – Part 2, ISO 14064-3 Greenhouse gases - Part 3 that incorporates direct and indirect emissions associated with electricity and fuel consumption, on-site process emissions and embodied emissions for all concrete and steel used in the construction of the Project Works and Temporary Works;
(iv) a carbon emission reduction target as a percentage of the carbon emission baseline;
(v) an energy use baseline determined using energy modelling that incorporates electrical energy consumption and fuel consumption as well as on-site renewable energy generation and renewable energy sourced from the main electricity grid for the construction of the Project Works and Temporary Works;
(vi) an energy reduction target as a percentage of the energy use baseline;
(vii) a life cycle assessment undertaken in accordance with ISO 14040 Environmental management - Life cycle assessment – Principles and framework for all concrete and steel used for the construction of the Project Works and Temporary Works and identify material selection strategies and initiatives that will be implemented to minimise the environmental impacts associated with the construction of the Project Works and Temporary Works; and
(viii) processes and methodologies for monitoring, auditing and the taking of corrective action.

The Sustainability Manager will control revisions of this plan, which will be authorised by the Project Director.

1.3 Plan Preparation and Review

The Sustainability Manager will control revisions of this plan which will be authorised by the Project Director. In addition to complying with the requirements of the Deed, SWTC and TfNSW policy requirements, including Appendix 24.4 (o), the Plan will be reviewed and updated as required taking into account:

- Changes in design or construction sequence, staging, methodology or resourcing
- The status and progress of the SVC Contractor's Activities
- Changes in access to the Construction Site
- Changes directed by Principal's Representative under the Deed

1.4 Objectives

The following carbon and energy management objectives will apply to the construction of the project:

- Reduce construction and embodied carbon emissions
- Identify low carbon energy generation and procurement options
- Promote energy efficient design and construction, including reducing fuel usage

The purpose of this plan, in conjunction with the use of other environmental control documents (principally the SP) associated with the Sydney Metro Northwest project, is to ensure that TfNSW fulfills its contractual and social obligations by capturing and reporting on relevant carbon emissions and energy consumption data for the duration of the construction phase of the project.

1.5 Relationship to Other Plans

The CaEMP is a sub-plan to the SP. The CaEMP applies to all aspects of the SVC Works and provides the goals and objectives for the Sustainability Plan. The Sustainability Plan interfaces across the whole SVC project through a number of other plans and systems, as illustrated in Figure 1 below.

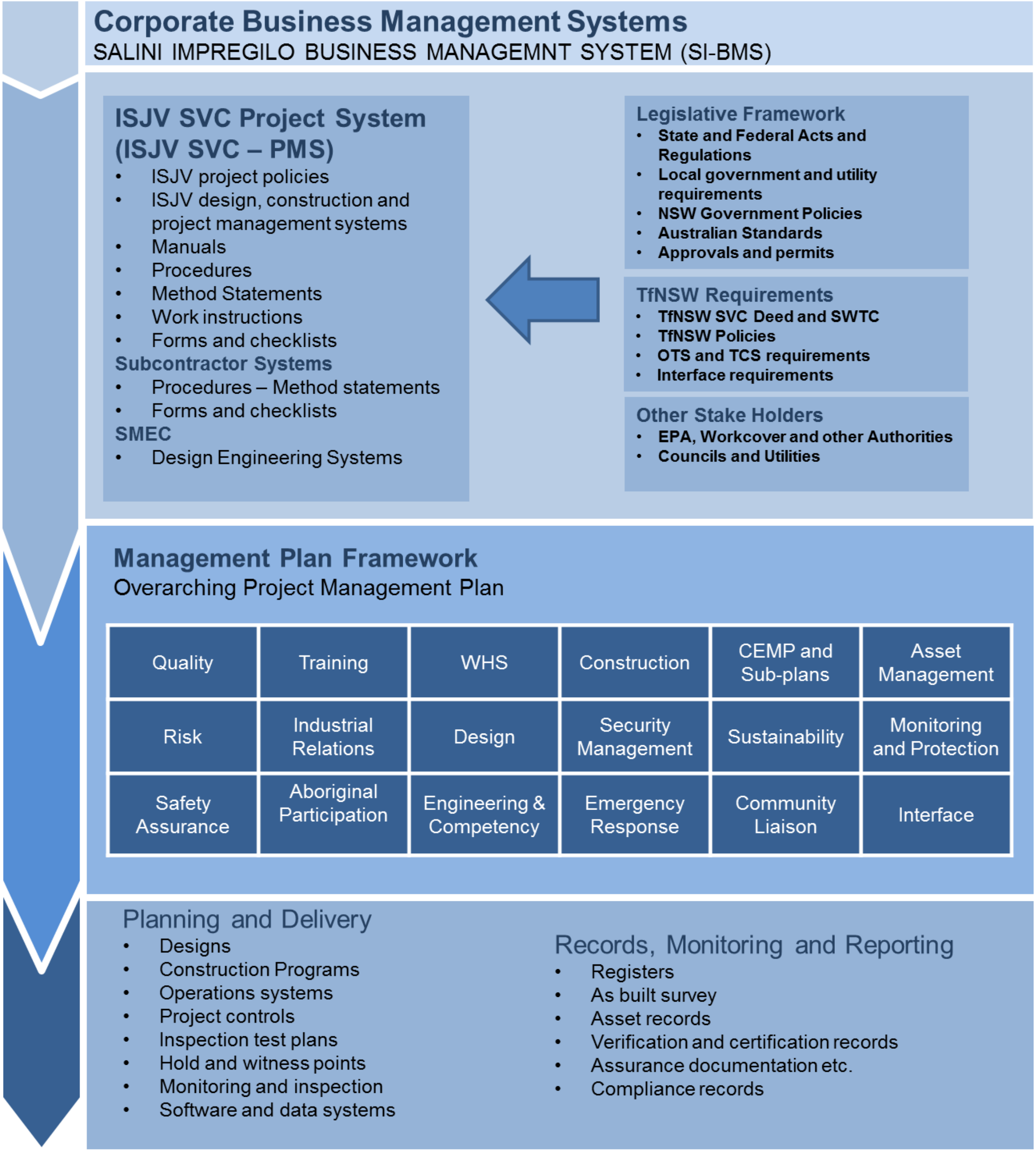


Figure 1 – ISJV SVC Management Systems and Document Framework

The Carbon and Energy Management Plan is a sub-plan to the Sustainability Plan and interfaces will all management plans. The relationship of this plan to the other plans is indicated in the Figure 2.

Project Management Plan			
Risk Management Plan including Technical Risk Management Plan	Design Plan	Construction Plan	Construction Environmental Management Plan
Project Quality Plan	Engineering and Competency Management Plan	Earthworks Plan	inputs to Compliance Tracking Procedure
Project Records Management Plan including Technical Data Management Plan and Project Purchasing Plan	Engineering Management Plan	Spoil Management Plan	Construction Compound Ancillary Facilities Management Plan
	Requirements Management Plan	Waste Management and Recycling Plan	Construction Noise and Vibration Management Plan
Safety Assurance Plan including RAMs	Competency Management Plan	Sustainability Plan	Construction Noise Impact Statement
Assurance Documentation Management Plan	Urban Design & Corridor Landscape Plan	Carbon and Energy Management Plan	Construction Traffic Management Plan Including
Project Training Management Plan	Services Management Plan	Stormwater and Flooding Management Plan	Construction Soil and Water Management Plan
Workplace Relations Management Plan	Community Liaison Implementation Plan	Pollution Incident Response Management Plan	Soil Salinity Management Plan
Project Aboriginal Participation Plan	Stakeholder and Community Involvement Plan	Monitoring and Protection Plan	Water Quality Monitoring Program
	Business Management Plan	Visual Amenity Management Plan	Construction Heritage Management Plan
		Security Management Plan	Construction Flora and Fauna Management Plan
		Project WHS Management Plan Including Site Specific WHS Management Plan and Project WHS Development Plan	Nest Box Management Plan
			Ecological Monitoring Program
		Project Emergency Plan	Construction Air Quality Plan
	Asset Management Information Delivery Plan		
	Technical Maintenance Plan	BIM Execution Plan	
	Interface Management Plan		

KEY:

Plan	Sub Plan	This Plan
TfNSW Plan	Sub - Sub Plan	

Figure 2 – Hierarchy of SVC Management Plans

2 Roles and Responsibilities

2.1 Organisation Chart

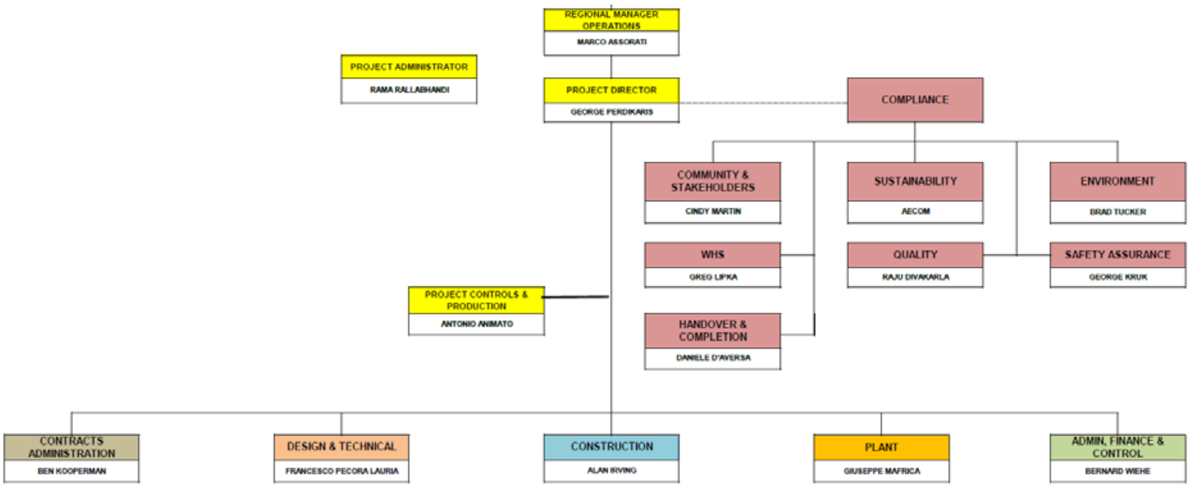


Figure 3 – Organisation Chart

2.2 Roles and Responsibilities

The responsibilities for the reduction of carbon and energy fall within the remit of the Sustainability Manager. They include the following:

- Working with contractors to identify and assess low carbon and energy efficient options during the design and construction phases
- Development of the ISCA rating
- Monitoring, reviewing and reporting against energy and carbon targets
- Undertaking spot checks and audits of the energy use and carbon data from contractors during the construction phase

Minimum skill levels: At least 5 years identifying and implementing energy efficiency opportunities as well as experience at auditing energy use and carbon emission data.

2.3 Supporting Personnel

In addition to the aforementioned roles and responsibilities:

- Designers are responsible for investigating energy efficient options and incorporating into the design where feasible/cost-effective
- The Project Director is responsible for driving sustainability (including energy and carbon reduction) throughout the project and ensuring relevant individuals are responsible for sustainability through performance targets

- The Procurement team is responsible for embedding sustainable procurement requirements (including carbon and energy requirements) into the supply chain management process, reporting on these requirements and attending relevant workshops
- Site supervisors are responsible for implementation of the Sustainability Plan (incorporating the carbon and energy plan) on a day-to-day basis and providing verification documentation for construction-stage reporting
- Site agents and engineers are responsible for attending project sustainability workshops which will incorporate energy efficiency and low carbon strategies
- Sub-contractors will be required to regularly provide energy usage information
- All employees are responsible for complying with the carbon and energy commitments in relation to the work they are undertaking

2.4 Lines of Communication Internally and with Client

Design Stage Communication

During the design stage, sustainability personnel will maintain regular contact with the broader project team in a number of regular and ad hoc meetings and workshops including, but not limited to:

- Attending coordination meetings as appropriate to the project stage
- Facilitating workshops with design consultants (civil, structural and architectural) at key design milestones (in line with the methodology for embedding sustainability in the design – see Section 3.1)
- Facilitating workshops relating to critical sustainability initiatives (such as procurement of concrete and steel) with the major relevant work-stream, including but not limited to, Design, Procurement, Construction and Workforce

During the design stage, sustainability and design personnel will:

- Maintain regular contact with the Client through regular scheduled meetings
- Attend monthly sustainability forum meetings with the Client and representatives from the other Sydney Metro Packages
- Provide monthly written reports to the Client on the progress of implementation of sustainability as required by the project deed

Construction

During the construction stage, Sustainability staff will maintain regular contact with the construction team to:

- Track performance against the sustainability requirements
- Meet with the Construction Manager to review progress against sustainability targets, assess risks and red-flags and review monthly reporting

Additionally, sustainability personnel will maintain regular contact with the Client by:

- Submitting monthly reports of progress against the sustainability targets
- Attend meetings with the Client as required to gauge progress against sustainability targets

3 Life Cycle Assessment and Carbon Footprint

The targets committed to by ISJV, as identified in Table 24.1 in Exhibit A Appendix 24 of the Deed, that are related to Life Cycle Assessment and the carbon footprint are detailed below.

App 24 Item No	Sustainability Targets	Target Value
1	Percentage reduction on the Reference Design carbon footprint of 82,420 tCO_{2-e}.	2.5%
11	Embodied energy of concrete and steel based on ISO 14044 Environment Management – Life Cycle assessment – Requirements and Guidelines.	55,739 tCO_{2-e}

An estimation of GHG emissions was undertaken by TfNSW prior to the tender stage of the project. Based on the reference design and the boundaries documented, it was estimated that the SVC works will have a carbon footprint of approximately 82,420 tCO_{2-e}.

The quantities and selection of construction materials of the design is of critical importance to the overall carbon footprint of the project, as 65% of the reference design emissions are from this category. The remaining emissions are associated with the operation of plant and equipment during the construction process.

Note there are two elements to this aspect of the plan:

- The Life Cycle Assessment (LCA) – covering the concrete and steel used in the construction of the Project Works and Temporary Works, and
- The carbon footprint – covering direct and indirect emissions associated with electricity and fuel consumption, on-site process emissions and embodied emissions for all concrete and steel used in the construction of the Project Works and Temporary Works

In essence, the total emissions determined in the LCA will be a sub-set of the emissions in the carbon footprint.

An LCA and a carbon footprint have been undertaken and various scenarios reviewed to ensure that the GHG emissions are minimised. ISJV engaged the services of Energetics, a specialist LCA consultant, to undertake the LCA and carbon footprinting in accordance with ISO 14040:2006 (Environmental management – Life cycle assessment – Principles and framework) and ISO 14044:2006 (Environmental management – Life cycle assessment – Requirements and guidelines).

The LCA Report is included in Appendix 1. The table on the following page outlines the compliance of this LCA with ISO14040/ISO14044/ISO14064-2.

Segment of ISO14040 / ISO14044 / ISO14064-2	Report compliant with ISO standards?	Energetics comments
LCA report		
General	Yes	The LCA report contains all the mandatory elements as required by the ISO standards.
Step 1. Goal and Scope Definition		
Objective State intended application, reasons for carrying out the study, intended audience, whether results are intended to be used in comparative assertions intended to be disclosed to the public.)	Yes	Compare impacts of various design stages against the Reference Design
Selection of indicators Selection of impact categories, category indicators and characterisation models shall be consistent with the goal of the study.	Yes	The ISO standards do not prescribe particular indicators need to be included. The LCA covers the carbon footprint of key energy and materials flows Note that Ecopoints assessment has been added at a later stage.
Scope Selection of the system boundary shall be consistent with the goal of the study. Criteria used shall be identified and explained. Deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study.	Yes	Key materials (concrete and steel) only Based on earlier assessment it was decided that these two materials dominate the impacts
Scope Deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study.	Partial	Comparisons should be undertaken on cradle-to-grave whilst a cradle-to-gate assessment was undertaken here.
Independent critical review The use of LCA results to support comparative assertions raises special concerns and requires critical review.	Yes	An independent critical review is not strictly required and has not been undertaken
Step 2. Life Cycle Inventory		
LCI data A check on data validity shall be conducted during the process of data collection to confirm and provide evidence that the data quality requirements for the intended application have been fulfilled.	Partial	GHG factors were sourced from ISCA tool (for materials) and the National Greenhouse Accounts (for fuels/energy). Some GHG factors in the ISCA tool contain significant errors and there is an opportunity to improve the LCI data quality.

Segment of ISO14040 / ISO14044 / ISO14064-2	Report compliant with ISO standards?	Energetics comments
LCI transparency All calculation procedures shall be explicitly documented and the assumptions made shall be clearly stated and explained.	Partial	There is transparency in that the original LCI data are accessible. However, there is limited transparency of how the original BPIC LCI data have been translated into GHG factors. We are able to assess that the concrete and steel materials GHG factors are in the right ballpark, but an exact reproduction (and thus verification) is impossible. The original concrete LCI data do not allow for variation in the %fly-ash, which means additional steps have been taken to get to the factors in the ISCA tool.
LCI completeness The LCIA phase shall be coordinated with other phases of the LCA to take into account the following possible omissions and sources of uncertainty: • whether the quality of the LCI data and results is sufficient to conduct the LCIA in accordance with the study goal and scope definition.	Yes	The LCI data appear to be complete enough for a GHG assessment. Any omissions are expected to have a minor influence only. The LCI data are shown to be unsuited for an ecopoints analysis.
LCI appropriateness The LCIA phase shall be coordinated with other phases of the LCA to take into account the following possible omissions and sources of uncertainty: • whether the environmental relevance of the LCIA results is decreased due to the LCI functional unit calculation, system wide averaging, aggregation and allocation.	No	Reasonable alignment between materials used for the Skytrain project and materials available in the ISCA tool. Materials where there is no alignment (e.g. 50MPA concrete) are unfortunately the principal materials used for the Skytrain. Using a GHG factor representative of 40MPa concrete when 50MPa concrete is used is likely not compliant. Ideally, the appropriateness of the materials would also take the actual cement content into account.
LCI scope Deletion of life cycle stages, processes, inputs or outputs is only permitted if it does not significantly change the overall conclusions of the study. The LCIA phase shall be coordinated with other phases of the LCA to take into account the following possible omissions and sources of uncertainty: • whether the environmental relevance of the LCIA results is decreased due to the LCI functional unit calculation, system wide averaging, aggregation and allocation.	Partial	Inconsistency in scope is not allowed for comparisons. The factors for concrete products cover a cradle-to-gate scope. The factors for steel products appear to include a benefit for recycling at end-of-life.

<table>
<tr><th>Segment of ISO14040 / ISO14044 / ISO14064-2</th><th>Report compliant with ISO standards?</th><th>Energetics comments</th></tr>
<tr><td colspan="3">Step 3. Life Cycle Impact Assessment</td></tr>
<tr><td><u>Carbon footprint</u>
Whenever impact categories, category indicators and characterisation models are selected in an LCA, the related information and sources shall be referenced.</td><td>Yes</td><td>The carbon footprint is based on the IPCC's Global Warming Potentials, which are the internationally accepted impact assessment.
The ISCA tool contains no reference to the version of the IPCC GWPs that have been used.</td></tr>
<tr><td><u>Ecopoints</u>
Weighting is an optional element (of LCIA – red.). Weighting steps are based on value-choices and are not scientifically based. Weighting shall not be used in LCA studies intended to be used in comparative assertions intended to be disclosed to the public.
The LCIA phase shall be coordinated with other phases of the LCA to take into account the following possible omissions and sources of uncertainty:
• whether the environmental relevance of the LCIA results is decreased due to the LCI functional unit calculation, system wide averaging, aggregation and allocation.
If LCI results are unavailable or if data are of insufficient quality for the LCIA to achieve the goal and scope of the study, either an iterative data collection or an adjustment of the goal and scope is required.</td><td>No</td><td>A weighted single score indicator (such as the ecopoints) is an optional step in impact assessment that comes after characterisation and normalisation of the LCI data.
The ISO standards provide specific guidance on when subjective single score indicators are allowed to be used and what best practice looks like.
Energetics thinks that a single score indicator is in principle allowed for this kind of analysis (which is NOT a comparative assertion). However, the BPIC LCI data show significant gaps in the inventory data and internal discrepancies (between concrete and steel) to make the resulting ecopoints score a false representation of environmental impacts. (This was recently confirmed by the Australian Life Cycle Assessment Society – ALCAS – in a similar, though unrelated, incident.)
The ecopoints presented in the ISCA tool are unfortunately misleading and should not be used.
An extensive alignment of LCI data and impact assessment methods should be conducted for it to be acceptable within ISO requirements.</td></tr>
<tr><td colspan="3">Step 4. Interpretation</td></tr>
<tr><td><u>Interpretation</u>
The results of the LCI or LCIA phases shall be interpreted according to the goal and scope of the study, and the interpretation shall include an assessment and a sensitivity check of the significant inputs, outputs and methodological choices in order to understand the uncertainty of the results.
The life cycle interpretation phase of an LCA or LCI study comprises several elements as follows:
• identification of the significant issues based on the results of the LCI and LCIA;
• an evaluation that considers completeness, sensitivity and consistency checks;
• - conclusions, limitations and recommendations.</td><td>Yes</td><td>The interpretation has taken all relevant aspects (including limitations) from the previous three steps into account.</td></tr>
</table>

3.1 LCA Methodology

The LCA investigates the cradle-to-gate life cycle of the concrete and steel components of the SVC Works Package. The SVC contract covers 4 kilometres of surface track, including 1.1 kilometres viaduct, 0.4 kilometres of cut and cover tunnel and 2.5 kilometres in cutting and embankment.

The life cycle stages considered for the steel and concrete products cover the cradle-to-gate stages of:

- Raw material extraction (e.g. iron ore, limestone, gravel, sand)
- Transport to cement, concrete and steel manufacturing plants
- Cement and basic steel manufacturing processes
- Concrete and steel product manufacturing processes.

The Life Cycle Inventory Data was sourced from the BPIC LCI database where possible. This is based on the TfNSW response to NWRLSVC-NWR-ISJ-RFI-R-000001 dated 11 March 2014 where it was agreed to use the BPIC LCI database. This will also ensure that there is consistency across the project as the BPIC LCI database was used with the Tunnel and Stations Civil (TSC) Works Package.

Throughout the LCA process, Energetics facilitated a number of workshops where various scenarios were discussed and the carbon implications determined. Key design decision makers were present to ensure that other considerations such as cost and material strength were taken into account.

3.2 LCA System Boundary

The system boundary describes which processes are included and excluded in the LCA. As instructed by TfNSW, this stage of the LCA project only covers the steel and concrete used in the construction works (see Figure 4). The system boundaries cover the cradle-to-gate life cycle of steel and concrete products.

Transport to site (fuel use) and construction processes (fuel and electricity use) are not included in the LCA but are measured as part of our monthly carbon reporting, which is included in our monthly sustainability report.

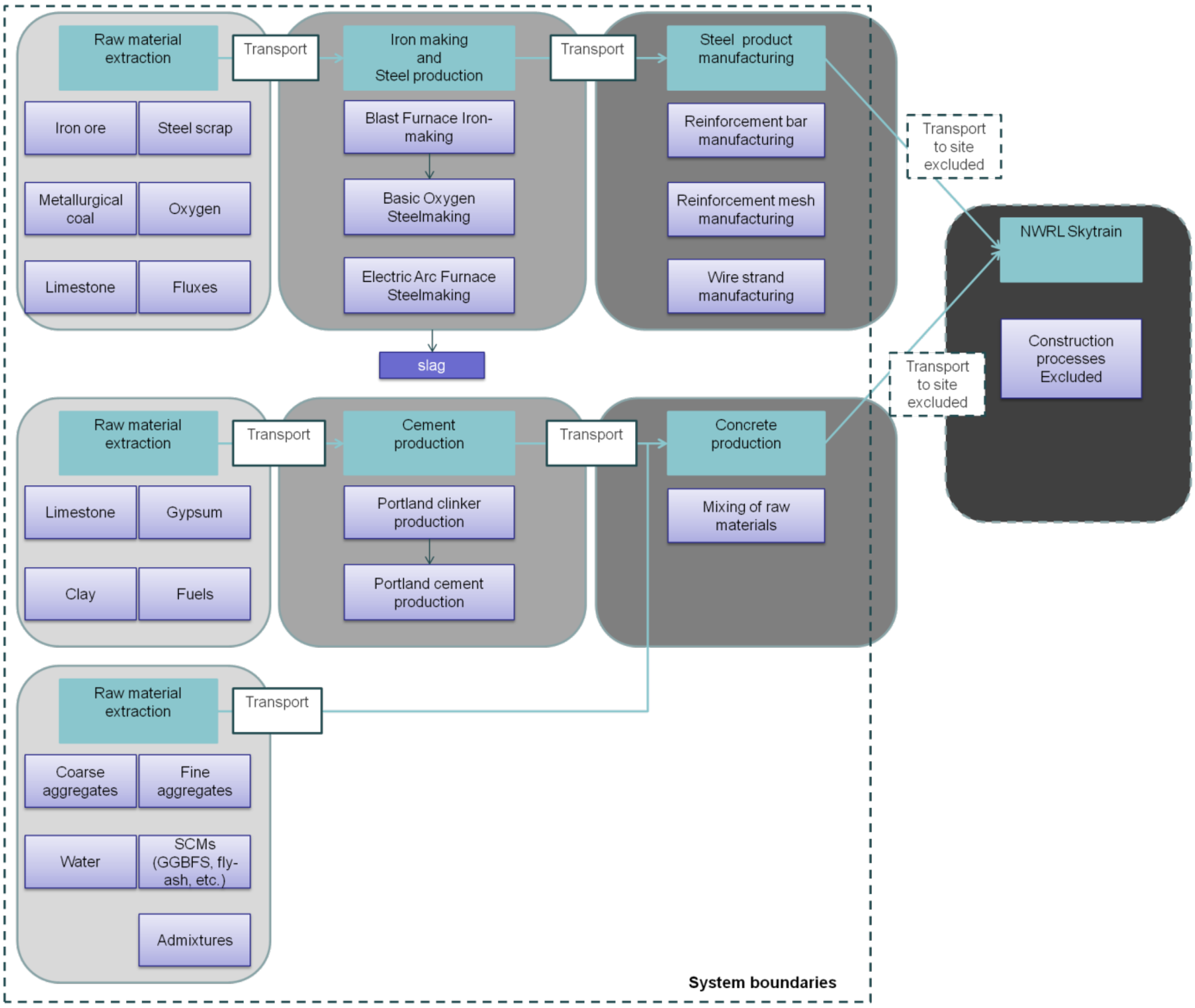


Figure 4 – Detailed system boundary diagram for the concrete and steel LCA

3.3 LCA Results

The carbon footprint analysis of the cradle-to-gate production of concrete and steel products gives a total materials footprint of 50,588 t $CO_{2\text{-}e}$. This includes raw material extraction, intermediate materials production, transport of raw materials and intermediate products, and concrete and steel products manufacturing. The transport of materials to the construction site is not included in this assessment. This will be covered in the carbon footprint.

The current materials footprint arising from the LCA of 50,588 t$CO_{2\text{-}e}$ is 6% below the target embodied energy of concrete and steel value of 53,828 t $CO_{2\text{-}e}$.

Examples of design or material selection decisions that have either been considered and/or included in the design are:

- Alternative materials will be used in concrete for the deck, piers, piles and pile caps in order to reduce the use of Portland cement. In accordance with Green Star credit Mat-4, the use of Portland cement will be reduced by a minimum of 30% across all concrete used in the project compared to a reference case. Fly ash or Ground Granulated Blast-Furnace Slag (GGBFS) to be

used, where practicable. ISJV will ensure an optimal % of fly ash / GGBFS is used in collaboration with designers to meet colour requirements, in all concrete mixes relevant to their applications

- The use of full length, pre-cast box girders
- The deck will be prefabricated (although piers will be case in-situ)
- Viaduct span sizes have been optimised to use the least amount of concrete to meet structural and durability requirements over a100 year design life

3.4 Carbon Footprint Methodology

In addition to the areas considered in the LCA of the concrete and steel used, the carbon footprint includes the carbon emissions from the other direct and indirect emissions resulting from the Project Works and Temporary Works.

Emission sources were categorized into Scope 1, 2 and 3 (as outlined in the following section) and the relevant emission factors used.

3.5 Carbon Footprint Boundary

To enable comparison with the TfNSW Greenhouse Gas Emissions Baseline, ISJV have used the same reporting boundary as the Baseline. This boundary is in accordance with the Greenhouse Gas Inventory Guide for Construction Projects (TCA 2010) and is shown in the Figure 5 on the following page.

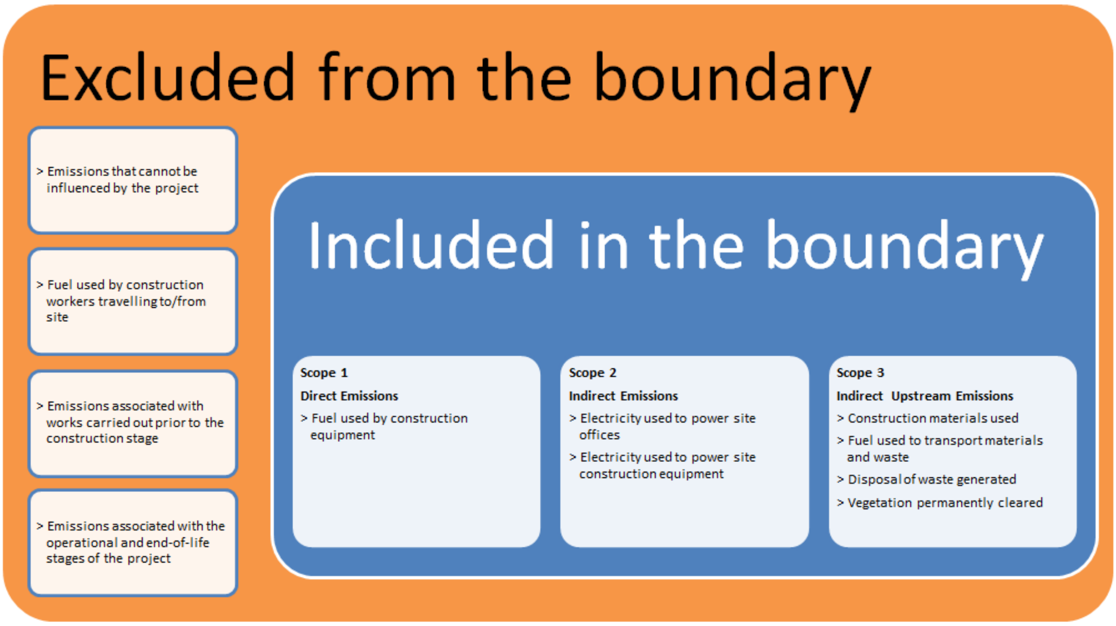


Figure 5 – Carbon Footprint Reporting Boundary

This baseline ensures that all Scope 1 and Scope 2 emissions are included, as well as those Scope 3 emissions that ISJV has a reasonable element of control over, including (but not limited to):

- Amount of vegetation permanently cleared
- Energy use of the concrete batching plant, owned and operated by a third party

- Embedded emissions in the concrete and steel used for construction
- Disposal of waste generated
- Transport of materials to and from site by contractors engaged by ISJV

Note that energy used at sites outside the control of ISJV are not included in Scope 1 and 2. For instance, the energy used in the production of the concrete is not a direct emission for ISJV and this is included in the generic factors for embedded emissions. The forming yard where the concrete is poured into the moulds is under the control of ISJV and this energy use will be included in the Scope 1 and 2 emissions.

3.6 Energy Use Baseline and Target

The energy baseline is 238,168GJ of energy. This is in line with the TfNSW Estimate of Greenhouse Gas Emissions for the electricity and fuel use.

The energy use reduction of 11,908GJ is targeted, resulting in a target energy use of 226,260GJ.

An energy model has been developed based on the TfNSW Estimate of Greenhouse Gas Emissions for the electricity and fuel use, however is modified with various scenarios to reflect actual electricity emissions and targets can be fine-tuned to reflect these variations.

3.7 Carbon Emission Baseline and Target

The carbon emission baseline is 82,420 tCO^2e. This is in line with the TfNSW Estimate of Greenhouse Gas Emissions for the project.

A reduction of 2,060.5 tCO^2e is targeted, resulting in a target carbon emissions of 80,359.5 tCO^2e.

3.8 Carbon Footprint Results

The carbon footprint results indicate a total carbon footprint of 77,806 $tCO_{2\text{-}e}$, which is a 5.6% reduction of the total carbon footprint compared to the Reference Design of 82,420 $tCO_{2\text{-}e}$.

This baseline takes into account the requirement of Appendix 10 of the Deed, that 20% of electricity needs will be offset by either the purchase of Australian carbon offsets or renewable energy from an accredited renewable energy supplier. This is documented further in Section 6 of this plan.

3.9 Ecopoints

Taking into account the range of impact categories in the LCA, the overall environmental impact as calculated in the IS Rating Tool is 45,391 ecopoints. A more detailed table outlining to composition of this total is included in Appendix 2.

4 Carbon Management and Energy Efficiency Initiatives for Reduction in Construction Works

The targets committed to by ISJV as identified in Table 24.1 in Exhibit A Appendix 24 of the Deed are detailed below.

4.1 Carbon Management and Energy Efficiency Targets

Item No	Sustainability Targets	Target Value
2	Percentage reduction on the Reference Design electricity consumption of 15,027,720 kWh	5%
3	Percentage reduction on the Reference Design fuel consumption of 4,770 kL	5%

4.2 Approach to Identifying and Implementing Opportunities

Throughout the design and build stages, opportunities to reduce carbon and energy will be identified and considered in order to reduce our footprint. At every stage of the SVC progression, the relevant ISJV manager responsible will engage with the sub-contractors during the procurement and contract works to identify and assess energy reduction opportunities as they arise.

Areas that may be considered to reduce our carbon and energy footprint are:

- The site office and associated works
- Construction energy usage
- Key contractors to understand what activities they undertake to reduce energy and carbon emissions
- The concrete batching plant operator and the precast facility operations to identify opportunities and determine feasibility

Any alterations that may be considered in order to reduce our footprint, will not be progressed if, in the opion of ISJV senior management, they may compromise the integrity of the project and any of its components.

4.3 Summary of Carbon Management and Energy Efficiency Strategies and Initiatives during Construction Works

4.3.1 Excavation

Major excavations on the SVC project are at the south end from the tunnel portal to Balmoral Road, and at the north end from Windsor Road to Cudgegong Road. Excavation will be reduced by:

- Adopting the maximum allowable grades within rail design parameters
- The introduction of retaining structures or slope retention measures to minimise the amount of soil to be excavated in cuttings

Substructures (pile caps) to the Skytrain piers will be placed with the minimum cover to ground level or replaced with large diameter piles integrated into columns for shallow footings.

4.3.2 Construction Fuel Consumption

ISJV is committed to the 5% reduction of fuel consumption use on the Reference Design fuel consumption of 4,770 kL. Alternative fuels will be used in construction vehicles, where possible, and low carbon transportation options will be implemented, where practicable. In addition, the following measures will be implemented to assist in meeting the target:

- All plant and machinery operators will be advised to turn off equipment when not in use to reduce idling for excessive periods of time
- Lights will be switched off when not in use
- Light vehicle operators will be advised to drive in a manner that minimises emissions, i.e. no excessive revving, gentle braking and slow, even acceleration.
- Vehicles, where possible and reasonable, will be fitted with catalytic converters, diesel particulate filters or equivalent devices
- All plant and vehicles will be well maintained and serviced in accordance with relevant equipment maintenance documentation to reduce emissions.

It is acknowledged that in SWTC Appendix 10 10.9.1 (l), a 5% biodiesel mix for all diesel powered plant and equipment and a minimum 10% blended ethanol mix for all petrol powered plant and equipment are to be used where practicable. ISJV will support this requirement unless it voids warranty or breaches contractual obligations.

Daracon, as one of the main civil contractors, has also committed to using two technologies to minimise energy use and carbon emissions. The first is Visionlink™ which is a web based application that tracks hours and location of assets, idling vs working time and fuel burn rates. This data is then analysed to optimize the maintenance schedules and reduce fuel use.

The second technology is fuel injection technology called ACERT. A number of trucks and other heavy machinery use this technology which will result in greater fuel economy and therefore lower carbon emissions.

4.3.3 Construction Electricity Consumption

ISJV is committed to the 5% reduction of electricity use on the Reference Design electricity consumption of 15,027,720 kWh. The main areas of electricity use in the project are the concrete batch plant and precast facility and the temporary site offices. The process of reducing electricity use at these facilities is outlined below.

Concrete Precast Facility

The concrete precast facility will be operated by ISJV on a leased site located adjacent to the batch plant. The main use for electricity in the precast facility is associated with use of gantry cranes and other equipment on the precast site.

Ranges of curing methods were assessed and it was discovered that there is no requirement for any form of artificial heating or cooling of the concrete to aid curing; thus the main electricity usage will be in the reticulation of water as well as the reuse and recycling of the water. There is a facility (BetterGrow) adjacent to the precast yard that allows for the pumping and reuse of water on the site, however, they are unable to provide the capacity that is required.

Temporary Site Offices

A contract with ATCO has been finalised for the provision of site offices and the associated facilities. A small number of the facilities have been purpose built for this project; however, they will remain under ATCO ownership and will be reused after this project. As most of the structures are second hand, there is limited ability to retrofit high efficiency features.

ISJV has worked with ATCO to ensure that the following items are addressed, where cost effective:

- Passive design measures implemented to reduce the need for artificial heating and cooling
- High efficiency lighting used, such as LED, CFLs and T5 battens
- Occupancy controls of HVAC and internal lighting, and PE cell control of external lighting

The purchase of all plug-in equipment will, where reasonable and feasible, comply with the Equipment Energy Efficiency Program Minimum Energy Performance Standards and have at least a 5 star Energy Rating where a suitable rating applies.

Concrete Batch Plant

The concrete batch plant is owned and operated by the contractor providing the concrete. This batch plant is not exclusively for SVC Works, as other customers will be supplied concrete from this same plant. While not covered by the carbon baseline, this option will result in significantly less embodied carbon emissions than alternative options of building a new plant or moving a plant from another construction site for this project alone. These embodied emissions are not included in the boundary of the project carbon footprint, however nevertheless important in the overall project sustainability.

Carbon dioxide emissions arising from the operation of the concrete batch plant is included in the embodied emissions of the concrete. The contractor involved has significant experience at concrete batching plants and, as a large energy user, they have been involved in the Federal Government Energy Efficiency Opportunities Program for the last 10 years (since the program’s inception).

Based on many energy audits of their concrete batch plants, the operator is fully aware of the cost effective energy reduction opportunities and will bring this knowledge to the existing plant, as well as the plant upgrade that will be required to produce the required output for this project.

At an operational level, ISJV will work with the batch plant operator to:

- Encourage just in time delivery of materials to avoid double handling
- Develop and implement a proactive maintenance program to reduce the potential for waste
- Implement a fault management program to ensure that areas of wastage, once identified, are acted on in a timely manner (part of the accredited Environment Management System)

4.3.4 Other Carbon and Energy Related Items

Fire suppression systems

ISJV will ensure that fire suppression systems have low or zero global warming potential (GWP). This will be partly impacted by any specific fire suppression systems that may only be possible with higher GWP gases.

Refrigerants

ISJV will try to utilise zero or low GWP refrigeration within temporary site facilities for refrigeration and air conditioning units for the site offices.

Supply Chain

ISJV will be centrally contracting for key materials such as steel and concrete to all three of the SVC sub-contractors. The sustainability performance requirements for these materials will be embedded within the procurement documentation.

During the procurement process, the ability of the contractors to introduce innovative processes which further improve on the targets and efficiently manage their energy use and carbon emissions will be included in the evaluation criteria along with the other key factors such as quality, reliability and price.

Travel of SVC Staff and Contractors

Green Travel initiatives are reflected in the Motor Vehicle Management Document and are supported through a car share program, promotion of public transport and supporting literature along with the promotion of cycling opportunities and supporting change room shower facilities.

4.3.5 Contractor Engagement

In addition to the above mentioned initiatives, workshops will be held with contractors and sub-contractors to identify and promote awareness of good housekeeping measures, as well as utilising their experiences to identify further opportunities to reduce energy and carbon emissions.

Some of those opportunities that have already been engaged are outlined in Section 4.3.2.

4.4 Low and No Carbon Energy Opportunities

The process that ISJV is following is similar to the approach to energy efficiency opportunity identification outlined in Section 4.2.

With respect to renewable energy generation, all site sheds have been leased. The use of solar PV and solar hot water on the site sheds has been evaluated and has been determined to be not viable given the temporary site sheds will only be used for a period of approx. 2 years before being handed back to the leasing company.

There is an opportunity for solar PV powered mobile road signs with backup battery. This requirement will be included in the procurement process for the mobile signs.

Low carbon opportunities are very limited given the short nature of the works. Section 4.3.2 outlined the use of alternative fuels, as well as further investigations of even better replacement fuels throughout the project. Apart from the combustion of on-site generated waste (which is not feasible), there are no opportunities for use of alternative fuels for on-site electricity generation.

The use of gas for cogeneration and trigeneration is not feasible given there is limited requirements for the waste heat on site and the relatively short timeframe in the use of the site. Even with large scale commercial buildings these systems rarely have a return on investment, even less so with the recent increases in the price of natural gas.

All other forms of renewable and low carbon energy were deemed not cost effective.

5 Monitoring and Reporting

5.1 Reporting Regulatory Requirements

Based on forecasting of GHG emissions for the project, it is not expected that ISJV would trigger any of the National Greenhouse and Energy Reporting Scheme (NGERS) reporting thresholds, and therefore will not be required to report under NGERS.

This position is based on the boundaries of the SVC Package and would need to be reviewed should ISJV undertake additional work or extend the scope of the SVC Package.

There are two types of thresholds to determine which corporations are affected by the National Greenhouse and Energy Reporting Act 2007 (NGER Act):

- Facility thresholds:
    - 25 kilotonnes (kt) or more of Scope 1 and 2 greenhouse gases (GHG) - carbon dioxide equivalence ($CO_{2\text{-}e}$);
    - production of 100 terajoules (TJ) or more of energy, or
    - consumption of 100 TJ or more of energy.
- Corporate group thresholds:
    - 50 kt or more of Scope 1 and 2 greenhouse gases ($CO_{2\text{-}e}$)
    - production of 200 TJ or more of energy, or
    - consumption of 200 TJ or more of energy.

Corporations are only required to register and report under the NGER scheme should they meet or exceed one or more of the above thresholds for a reporting year (reporting is based on financial year, i.e. 1 July to 30 June). The corporation must then report for each year it remains registered.

The forecasting of GHG emissions shows that the project is expected to generate a Scope 1 and 2 GHG emissions total of 25,452.24 $tCO_{2\text{-}e}$. Given that this total is based on the entire duration of the project construction (approximately 2 years or greater) it is expected that ISJV would not trigger either of the reporting thresholds, and therefore would not be required to report under NGERS.

5.2 Data Capture

Data will be collected on a monthly basis from all contractors. This will be in the form of a simple data capture form filled out by a responsible person from each contractor. The monthly contractor form will then be entered into iTWOcx, the project management software platform used for the project. This will store all data in a database and monthly reporting will be undertaken from this platform.

The data entry form covers all energy and other sources of Scope 1 and Scope 2 emissions, as well as a range of other data that needs to be collected for reporting under the Sustainability Plan.

5.2.1 Electricity Consumption

ISJV electricity consumption data will be sourced from tax invoices collected from our electricity provider. The total electricity (in kWh), including equipment, offices, workshops, storage and lighting will be collected.

5.2.2 Renewable Electricity Generated

Any renewable energy generated on site will be metered and separately reported where meters are able to be installed. If solar PV is installed on portable signs where meters are not able to be installed, an estimate will be made based on operating time.

5.2.3 Fuel Usage

Fuel usage totals pertaining to plant, equipment and fleet vehicles used in the course of the works will be obtained from ISJV subcontractors, fleet car providers and our accounting system. The types of fuel are categorized as follows:

- Purchased diesel (Litres)
- Purchased biodiesel (Litres)
- Purchased e10 (Litres)
- Purchased Unleaded (including premium unleaded) (Litres)
- Purchased LPG (Litres)
- Purchased oil (Litres)

5.2.4 Tracking Material Use

The recording and collecting of the data for tracking materials used in the SVC Package, especially concrete, contribute significantly to monitoring the performance against the agreed target for embodied energy of concrete and steel. The following data sets will be collected:

- Concrete unspecified (tonnes)
- Concrete 32 Mpa (tonnes)
- Concrete 40 Mpa (tonnes)
- Concrete 50 Mpa (tonnes)
- Structured steel (tonnes)
- Reinforcing steel (tonnes)
- % tonnes recycled materials

Additional data sets may be included as required under the LCA.

5.3 Reporting

There is a requirement in Exhibit A Appendix 23.1.5 for the performance of the SVC Package to be reported on a monthly basis. The data collected as part of this plan and the SP will be collated and reported together to comply with the Deed. Please refer to Section 3.5.3 in the SP for details of reporting requirements.

5.4 Monitoring, Auditing and Corrective Action

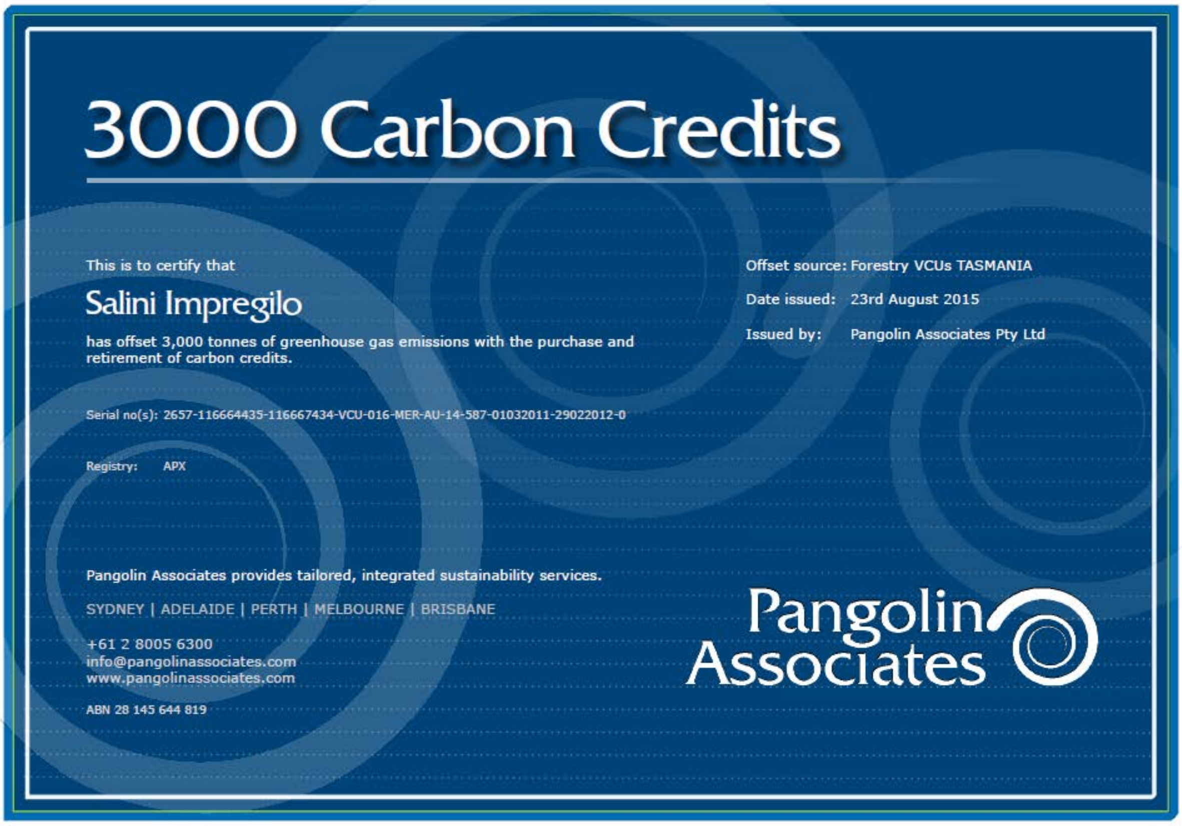
Monitoring of energy and carbon data will be in line with the monitoring processes outlined in Section 3.2.4 of the Sustainability Plan. Specifically for energy and carbon, the contractors making up 80% of the emissions to March/April 2015 will be audited to confirm the accuracy of their data and to review their data collection methods. Corrective action procedures will be the same as outlined in Section 3.2.4 of the Sustainability Plan.

Regular auditing procedures for energy and carbon will be in line with procedures outlined in Section 3.2.4 of the Sustainability Plan.

6 Carbon Offset

It is a requirement of Appendix 10 that 20% of electricity needs will be offset by either the purchase of Australian carbon credits or renewable energy from an accredited renewable energy supplier.

In August 2015, ISJV purchase suitably priced credits to offset the projected 20% requirement. As construction completion approaches, extra credits will be purchased if needed, and certificates or similar evidence provided.


3000 Carbon Credits

This is to certify that

Salini Impregilo

has offset 3,000 tonnes of greenhouse gas emissions with the purchase and retirement of carbon credits.

Serial no(s): 2657-116664435-116667434-VCU-016-MER-AU-14-587-01032011-29022012-0

Registry: APX

Offset source: Forestry VCUs TASMANIA

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Pangolin Associates

Appendix 1 - LCA Report

21 July 2014| REF: J/N 121551

WSP Environment and Energy

NWRL Skytrain
Updated Carbon & Energy assessment (concrete and steel)

northwestraillink

energetics

Project details

WSP Environment and Energy Contacts	Energetics Contacts
Tim Parker, Alan Davis, Richard Palmer, Laura Crawford	Mary Stewart, Peter Holt, Rob Rouwette

Description	Prepared By	Reviewed By	Approved By	Approval Date
Substantial Detailed Design stage v2 0	Rob Rouwette	Peter Holt	Peter Holt	21/07/2014

About Energetics

Energetics is a specialist energy and carbon management consultancy. Our experts help clients to

Be leaders. Develop and implement strategy
Be informed. Make data-driven decisions
Be efficient. Drive business improvement and realise savings
Buy better. Leverage energy supply and carbon markets

2014

- Winners of BRW Client Choice Awards: - Best Professional Services Firm (revenue < $50M)
  - Best Consulting Engineering Firm (revenue < $50M)
  - Best value
- Finalists: BRW Client Choice Awards for Best Client Service, Most Friendly and Most Innovative

2013

- Finalist: BRW Client Choice Award for Best Client Relationship Management
- Finalist: Leading in Sustainability Banksia Award

2012

- Winner: Australian Business Award for Recommended Employer
- Winner: Australian Business Award for Service Excellence

2011

- Winner: BRW Client Choice Award for Best Value
- Finalists: BRW Client Choice Awards for Exceptional Service, Most Innovative, Outstanding Client Care and Best Consulting Engineering Firm (revenue <$50 Million)

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Executive summary

The $8.3 billion North West Rail Link (NWRL) is Australia's largest public transport infrastructure project currently under construction and a priority rail project for the NSW Government. The Impregilo-Salini joint venture (ISJV), of which WSP Environment and Energy is a partner, was awarded a $340 million contract on 17 December 2013 to construct a 4 km skytrain between Bella Vista and Rouse Hill.

The Surface and Viaduct Civil Works (SVC) project deed requires ISJV to undertake a greenhouse gas Life Cycle Assessment (LCA) of the project, which covers key materials (concrete and steel), fuel use related to transport of materials and equipment to site, electricity and fuel use during construction and land clearing emissions. This report covers the cradle-to-gate LCA of concrete and steel as reportedly used according to the Substantial Detailed Design. It is an update from our earlier assessment of the concrete and steel emissions related to the Contract Design [Energetics 2014].

Objectives

The LCA needs to compare the greenhouse gas (GHG) emissions, or carbon footprint, of the materials used in the Substantial Detailed Design with the Reference Design[1] and indicate whether ISJV has achieved a 2.50% reduction on the Reference Design carbon footprint of 82,420 t CO_2e.

Methodology

As much as possible the carbon footprint LCA methodology conforms to relevant ISO standards [ISO14040] and [ISO14044]. This report contains all the mandatory elements as required by those standards although Energetics has not been able to find appropriate details to complete each of these elements.

Life Cycle Inventory data

The LCI data need to be sourced from the Building Products Innovation Council's Life Cycle Inventory (BPIC LCI) database where possible.

[1] These terms relate to various design stages for the skytrain SVC project. The Reference Design has been developed by TfNSW to gain an understanding of the material requirements and associated GHG emissions. The Contract Design has been developed by ISJV to outline their proposal for how the skytrain will be built. ISJV was awarded the contract from TfNSW based on that version. The assessment in this report relates to the Substantial Detailed Design.

We have used GHG emission factors for concrete and steel products sourced from the Infrastructure Sustainability Council of Australia (IS) materials calculator, which is based on BPIC LCI data.

Results

The total carbon footprint of the Substantial Detailed Design equals 50,588 t CO_2e (materials) plus 27,219 t CO_2e (other components as detailed), resulting in a total footprint of 77,806 t CO_2e.

Comparison of Substantial Detailed Design against Reference Design

Energetics calculates the GHG emissions of the Substantial Detailed Design to be 5.6% below the emissions of the Transport for NSW (TfNSW) Reference Design (82,420 t CO_2e). This result is based on the same methodology (emission factors) as used in the Reference Design calculations.

It should be noted that Energetics' earlier recommendation to change the emission factor for 50MPa concrete products to a more relevant and accurate estimate, rather than using 40MPa concrete as a proxy, has not been approved. Our sensitivity analysis shows that when specific emission factors for 50MPa concrete are applied, the Substantial Detailed Design (81,166 t CO_2e) reduces emissions by 8.8% compared to the revised Reference Design (89,027 t CO_2e).

Conclusions

In [Energetics 2014] we have indicated a number of possible pathways for ISJV to achieve a 2.50% reduction on the Reference Design carbon footprint of 82,420 t CO_2e. ISJV has applied this knowledge in their tender specifications and supplier selection and worked with the selected supplier to minimise emissions.

Recommendations

Energetics recommends that:

- Care is taken when interpreting the results of this cradle-to-gate footprint assessment. Taking a full life-cycle approach (e.g. including durability and potential recycling at end-of-life) might enhance or change the outcome of this assessment.
- Changes are made to this assessment and ultimately to the IS materials calculator to reflect the large variability in concrete compositions, strength grades and associated emissions intensities.
    - As a minimum, an appropriate emission factor for 50MPa concrete needs to be applied to both the Reference Design and subsequent designs (Contract Design, Substantial Detailed Design, Final Design) to evaluate ISJV's carbon footprint reduction efforts.
    - To assess the concrete mixtures applied in the Final Design, we might require emission factors for concretes with different types of supplementary cementitious materials (SCMs) (other than fly-ash) and different (higher) percentages of cement replacement.
    - Ideally, the IS materials calculator would provide a specific emission factor for each concrete mix design.

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Background

The $8.3 billion North West Rail Link (NWRL) is Australia's largest public transport infrastructure project currently under construction and a priority rail project for the NSW Government. The Impregilo-Salini joint venture (ISJV), of which WSP Environment and Energy is a partner, was awarded a $340 million contract on 17 December 2013 to construct a 4 km skytrain between Bella Vista and Rouse Hill, along with other surface works such as bridges, embankments and railway cuttings. The skytrain contract is one of three major contracts for the construction and operation of the NWRL (see Figure 1).

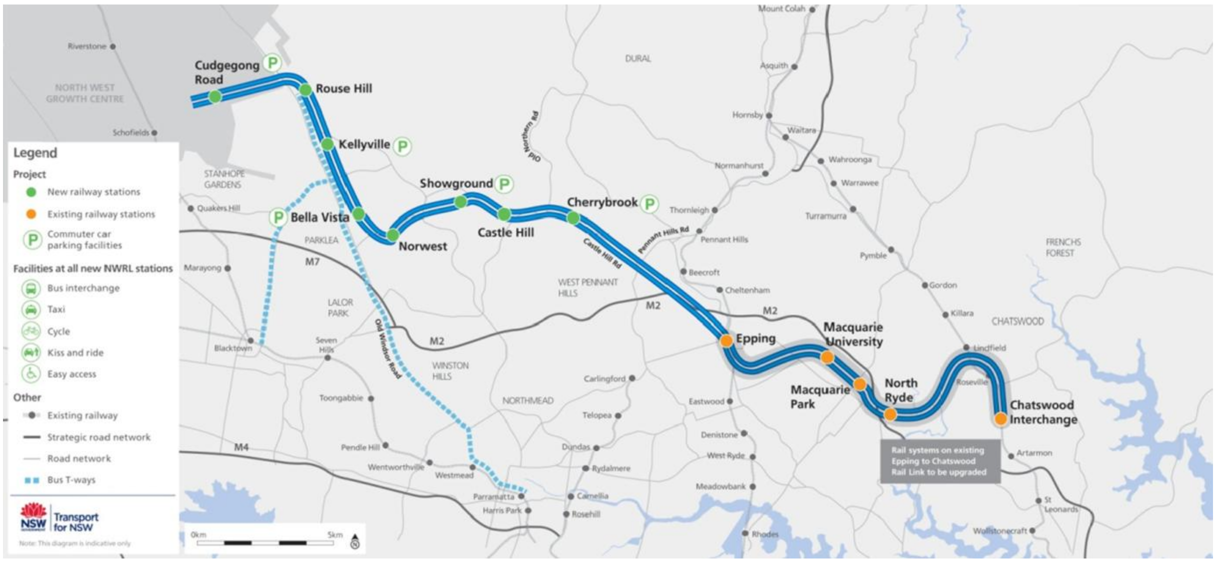

Figure 1. The North West Rail Line service proposed alignment (indicative). Source: Transport for NSW.

A general overview of the Surface and Viaduct Civil Works (SVC) for the skytrain project is included in Appendix A.

Involved parties

ISJV, through WSP Environment and Energy (WSP), have commissioned Energetics to undertake a Life Cycle Assessment (LCA) based carbon footprint of the key materials (concrete and steel) used within the SVC project.

Structure of this report

This report covers the cradle-to-gate LCA of concrete and steel used according to the Substantial Detailed Design[2]; see Appendix B for an overview of the project timeline. It is based on ISO14040:2006 [ISO14040] and ISO14044:2006 [ISO14044] standards for Life Cycle Assessment (LCA) and follows the four-step procedure from these standards:

1) Goal and Scope description
2) Life Cycle Inventory
3) Life Cycle impact Assessment
4) Interpretation.

1. Goal and Scope of the Study

1.1. Goal of the study

The LCA needs to compare the greenhouse gas (GHG) emissions, or carbon footprint, of the materials used in the Substantial Detailed Design with the Reference Design[2] and indicate whether ISJV has achieved a 2.50% reduction on the Reference Design carbon footprint of 82,420 t CO_2e.

Further requirements are:

- The methodology to which the energy and carbon footprint LCA is undertaken needs to conform to relevant ISO standards [ISO14040] and [ISO14044].
- The Life Cycle Inventory data need to be sourced from the BPIC LCI database where possible[3].

1.2. Reasons behind, and intended use of, the study

The underlying reason for this LCA study is to assist WSP to deliver a tender which is compliant with the aims of Transport for NSW (TfNSW) in specific aspects of the tender requirements.

The carbon footprint reports of the various design stages will be used to demonstrate compliance with these requirements.

1.3. The intended audience of the study

The intended audiences of this study are Transport for NSW and ISJV (through WSP).

The results (e.g. carbon footprints) may be communicated to other stakeholders.

1.4. Product system description

The LCA investigates the cradle-to-gate life cycle of the concrete and steel components of the Surface and Viaduct Civil Works (SVC) for the skytrain project. The SVC contract covers 4 kilometres of surface track, including 1.1 kilometres viaduct, 0.4 kilometres of cut and cover tunnel and 2.5 kilometres in cutting and embankment.

The scope for the LCA is in line with directions from Transport for NSW.

[2] Throughout the report we will reference various design stages for the skytrain SVC project. The Reference Design has been developed by TfNSW to gain an understanding of the material requirements and associated GHG emissions. The Contract Design has been developed by ISJV to outline their proposal for how the skytrain will be built. ISJV was awarded the contract from TfNSW based on that version. The assessment in this report relates to the Substantial Detailed Design.

[3] Energetics understands that WSP has sought further clarification from Transport for NSW regarding the use of underlying Life Cycle Inventory (LCI) data, emission factors and ISO14044 compliancy. Transport for NSW has directed WSP to use BPIC LCI data where available. If the use of the BPIC LCI data leads to a conflict in complying with ISO14044, then conformity to BPIC LCI is currently our first priority.

Figure 2. Artist impression of the skytrain's cable bridge (Source: Transport for NSW)

Figure 3. Artist impression of the skytrain's elevated rail line (Source: Transport for NSW)

The life cycle stages considered for the steel and concrete products cover the cradle-to-gate stages of the life cycle:

- Raw material extraction (e.g. iron ore, limestone, gravel, sand)
- Transport to cement, concrete and steel manufacturing plants respectively
- Cement and basic steel manufacturing processes
- Concrete and steel product manufacturing processes.

A description of the processes in each life cycle stage is provided hereafter.

Concrete

Raw material extraction and cement production

Concrete consists of cement, coarse aggregates and fine aggregates mixed with water.

- Cement is produced by grinding Portland clinker (sintered limestone and clay) and gypsum into a fine powder. In some cases a mineral addition (raw limestone) is added.
- Coarse aggregates are typically selected from natural gravel, crushed rock, blast furnace slag or recycled (concrete) aggregates.

- Fine aggregates typically consist of sand or "manufactured sand" (the fine fraction that remains when crushing rocks).
- The water used in concrete production is often tap water, but reclaimed water can be used when it is of sufficient quality.

Limestone, clay, sand, gravel and rocks are extracted from the earth using typical mining equipment. Some quarries require removal of a top layer before the mineral can be extracted. Diesel used to power equipment is the main greenhouse gas emission source.

Admixtures (mostly plasticizers, air-entraining, water-reducing, retarding and accelerating) can be added to a concrete to create the desired properties (e.g. workability). They are typically added in relatively small volumes that do not have a significant impact on the carbon footprint of the concrete. For this reason admixtures have been excluded from the assessment.

Because cement is known to be the most greenhouse gas intensive component of concrete, alternatives (supplementary cementitious materials or SCMs) are often used to reduce the environmental impacts of the concrete, while potentially delivering additional benefits (lower costs, reduced permeability, increased durability, etc.). The most common SCMs used are pulverised fly-ash (PFA), ground granulated blast furnace slag (GGBFS) and silica fume.

- Fly-ash is a by-product of thermal power generating stations that combust pulverised coal. It is a fine residue that is extracted from exhaust gases.
- GGBFS is a glassy, granular material formed when molten, iron blast-furnace slag is rapidly chilled - typically by water sprays or immersion in water - and subsequently ground to cement fineness.
- Silica fume is a finely divided residue resulting from the production of elemental silicon or ferro-silicon alloys that is extracted from exhaust gases. Silica fume is often used to make high-strength concrete.

All these SCMs are by-products (or sometimes considered waste products) from other industries.

Transport of raw materials to concrete plants

All raw materials for the concrete batching plant and concrete precast plant are transported by truck. Transport of raw materials is included in the emission factors of the IS materials calculator.

Concrete manufacturing

In a precast concrete plant, the raw materials are mixed and casted into a mould. The green (unhardened) concrete may be cured by using steam, although this depends on the type of product produced. When the products have developed enough strength in their mould, the cast is taken off and the products are stored for transport to the construction site.

In the concrete batching plant, the required raw materials are ready mixed. The mixed concrete needs to be delivered to a construction site within a defined timeframe; otherwise the mixture will harden in the concrete delivery truck and has to be discarded. For this reason, the maximum distance between a concrete batching plant and construction site is limited.

Steel

Raw material extraction

The key materials used in steel production are iron ore, steel scrap, metallurgical coal (for coke), limestone, manganese and dolomite. Steel scrap is collected through recovery and recycling processes, while the other raw materials are extracted from quarries and mines.

Transport of raw materials to steel plants

Raw materials for the steel furnaces are delivered by ship, train, truck and pipeline.

Basic steel production (billets)

There are two main methods for producing steel:

- Blast Furnace and Basic Oxygen Furnace steelmaking (BF-BOS),
- Electric Arc Furnace steelmaking (EAF).

The Blast Furnace route uses primarily raw materials such as iron ore, metallurgical coal and limestone to produce molten iron. In the Basic Oxygen Furnace steel scrap (about 20%), oxygen and fluxing materials are added to the molten iron. The EAF process does not rely on iron ore, but remelts steel scrap into new steel.

The distinction between these two routes is important because EAF steelmaking uses significantly less energy (and resources). It should be noted though that all scrap at one stage was produced from iron ore (and thus through the BF-BOS route).

Steel product manufacturing

The key steel products used by ISJV are reinforcement steel (bars and mesh) and steel wire strands.

These products are manufactured by milling steel billets from either BF-BOF or EAF into hot rolled steel bars or rod coils, which are then shaped through a cold drawing or rolling process.

1.5. Function of the product system

The scope of the SVC Project works consists of the detailed design, construction and handover of the viaducts, bridges and associated civil works required for the NWRL between Bella Vista and Cudgegong Road and includes establishment end reinstatement of surfaces, spoil removal and disposal and all required utility relocations and adjustments at construction sites. (Source: [Impregilo/Salini, 2013])

1.6. Reference and functional units

The reference unit of the current part of this LCA study is defined as the cradle-to-gate impacts of:

the entire quantity of steel and concrete used in the Surface and Viaduct Civil Works (SVC) package of the NWRL skytrain construction.

There are various design alternatives that can fulfil the SVC package requirements, and we are comparing the Substantial Detailed Design against a Reference Design (TfNSW Baseline) to indicate whether improvement targets are met.

1.7. System boundary

The system boundary describes which processes are included and excluded in the LCA. As instructed by Transport for NSW, this stage of the LCA project only covers the steel and concrete used in the construction works (see Figure 4). The system boundaries cover the cradle-to-gate life cycle of steel and concrete products.

Transport to site (fuel use) and construction processes (fuel and electricity use) will be added to the carbon footprint at a later stage.

When considering the overall GHG reduction target, energy consumption during construction and transport of materials is included as well (see Appendix B).

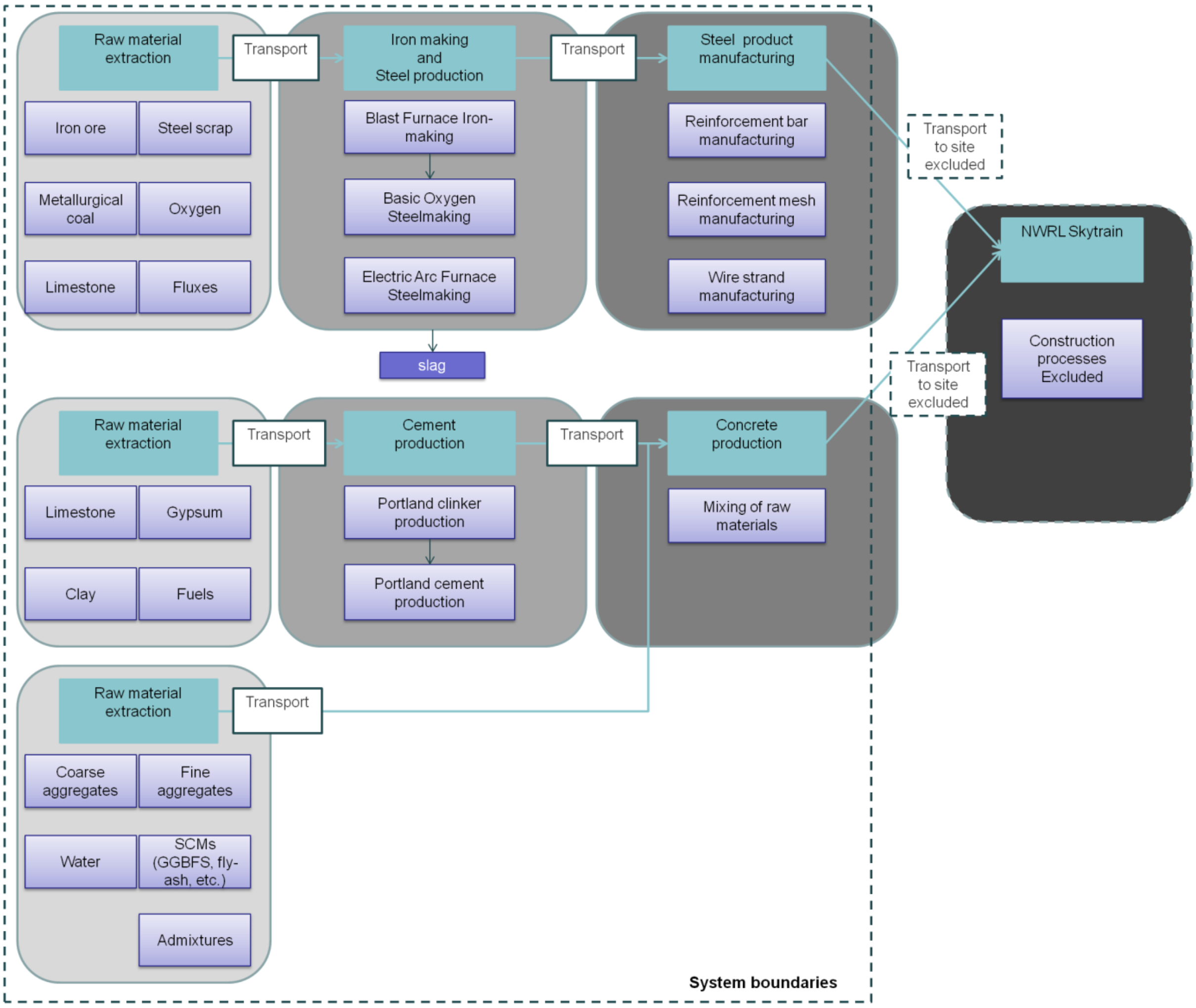

Figure 4. Detailed system boundary diagram for the concrete and steel LCA

As the carbon footprint is established on the basis of greenhouse gas emission factors that cover cradle-to-gate production of steel and concrete products, Energetics is not able to identify and/or quantify specific material flows to and from the environment. The system boundary diagram can thus be simplified, see Figure 5. As shown in the figure, based on the original BPIC data we find that the

cradle-to-gate emission factors for (some of) the steel products take steel's recyclability at the end-of-life into account. In effect this means that a credit is applied, lowering the emission factor. This approach raises questions about the consistency of the scope of the emission factors found in the IS materials calculator and used in this study.

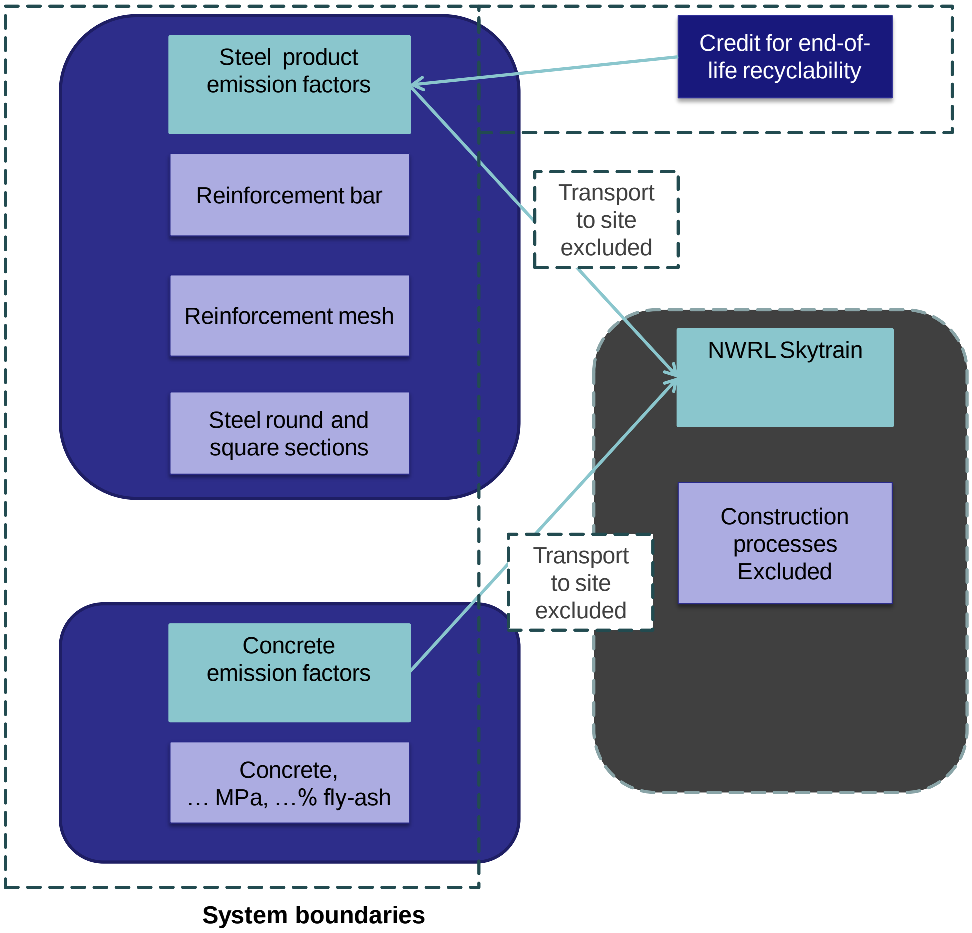

Figure 5. Actual system boundary diagram for the concrete and steel LCA

1.8. Allocation procedures

Allocation is the procedure of partitioning input and/or output flows of a process between the product system under study and other product systems. This is potentially relevant for multi-input and multi-output processes and recycling/reuse processes. As the allocation procedure can have major impacts on the results of an LCA, it is important to record the approach followed and its impacts on the results.

The key processes in the product system of this concrete and steel LCA that require allocation are:

- Production of co-products (manufactured sand, fly-ash, GGBFS, etc.),
- Manufacturing of secondary products from recycled or reclaimed materials (steel scrap, reclaimed aggregates, etc.).

As the scope of this LCA covers cradle-to-gate processes only, the following processes typically relevant for allocation are not included:

- Recycling or reuse processes at end-of-life,
- Multi-input processes, e.g. landfill at end-of-life.

Transport for NSW has directed the project team to apply emission factors to be sourced from the IS materials calculator [ISCA, 2013]. As the relevant emission factors for steel and concrete inherently contain an approach to allocation (as almost all products contain secondary materials such as steel scrap and fly-ash), we have attempted to clarify the allocation approach embedded within the factors.

Because the IS materials calculator data are based on BPIC LCI data, we believe they (should) follow the same allocation approach as stipulated in the BPIC methodology guidelines [BPIC, 2010]. For multi-output processes an economic allocation principle is applied (see Figure 6). Allocation of recycling processes is treated more ambiguously. According to [BPIC, 2010], primary production of recyclable materials is allocated across multiple life cycles based on the residual value of scrap and the (expected) number of subsequent life cycles. In effect this means that assumptions regarding the end-of-life scenario of steel products are now included in their emissions factors. Energetics is not able to reproduce the allocation formulas based on the published BPIC data[4].

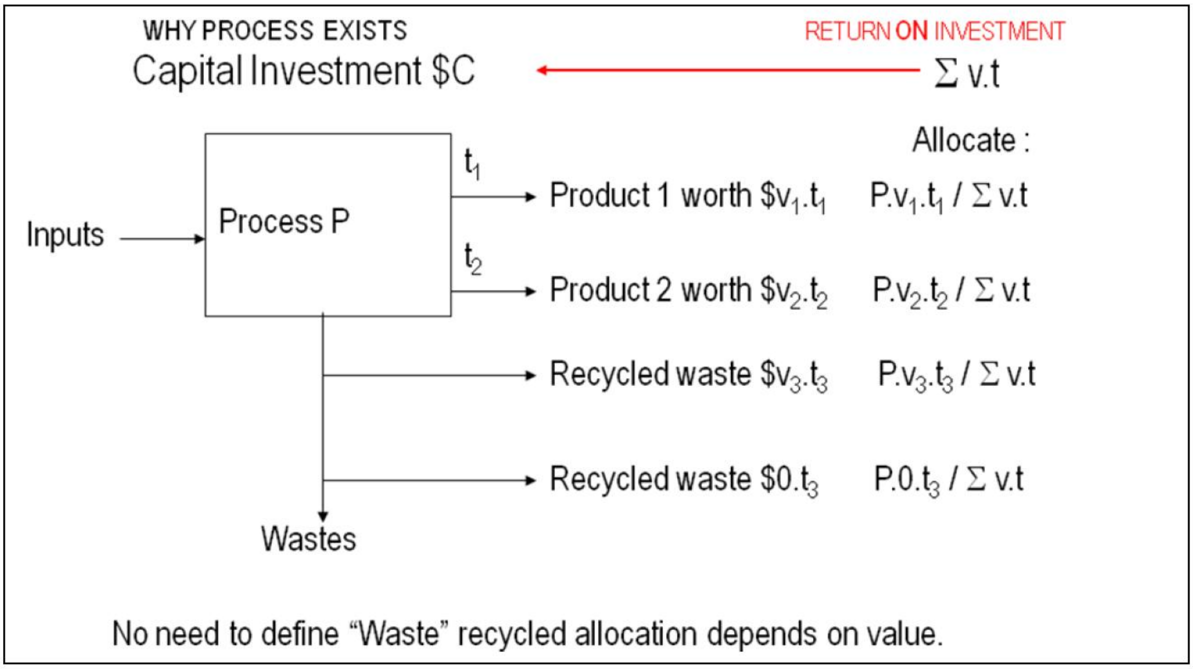

Figure 6. Co-product allocation principle as applied to BPIC LCI data

[4] Energetics believes this could be problematic when attempting to establish ISO14040/ISO14044 compliancy for this LCA. Both transparency and consistency in scope are important in order to comply with ISO14040/ISO14044.

1.9. Life Cycle Impact Assessment methodology

This study considers the emission of greenhouse gases (carbon footprint), expressed in carbon dioxide equivalents (kg CO_2e).

The emission factors published in the IS materials calculator [ISCA, 2013] are expressed in t CO_2e. However, it is not clear whether the underlying Global Warming Potentials (GWP) have been taken from the Intergovernmental Panel for Climate Change (IPCC) Second Assessment Report (SAR) [Houghton et al., 1996] or Fourth Assessment Report (AR4) [Forster et al., 2007], using a 100 year time horizon[5]. This is relevant as there was a change in the Global Warming Potentials. Most pertinent the GWP for methane increased from 21 kg CO_2e per kg methane to 25 kg CO_2e per kg methane.

We do know that the same factors have been used in the baseline assessment [Transport for NSW, 2013], thus ensuring consistency across the comparison.

1.10. Interpretation to be employed

Energetics performed an analysis of the main contributors (significant issues) to the climate change impacts of the steel and concrete products. This shows which products are responsible for the majority of the greenhouse gas emissions and thereby enable ISJV to undertake further action if required in order to meet their contractual targets.

1.11. Data requirements

The key data requirements for the LCA are summarised in Table 1.

Table 1: Data requirements

Component	Data related to the LCA	Data source
Bill of Quantities for the NWRL Skytrain SVC package	Detailed Bill of Quantities for steel and concrete components	ISJV Substantial Detailed Design
Cradle-to-gate manufacturing of various steel products	GHG emission factors for steel products; as a minimum specified by type of steel product	IS materials calculator
Cradle-to-gate manufacturing of various concrete products	GHG emission factors for concrete products; as a minimum specified by concrete strength grade and % cement replacement	IS materials calculator

[5] Note that the GHG Protocol requires users to apply the most recent GWP factors from the IPCC (i.e. currently the Fourth Assessment Report, 2007).

1.12. Assumptions, Choices and Limitations

The key choices and assumptions in the steel and concrete LCA are related to the data (emission factors) that are used.

The ISJV has been directed to use the emissions factors from the Infrastructure Sustainability Council of Australia (ISCA) materials calculator tool (http://www.isca.org.au/) in order to maintain compatibility with calculations for the Reference Design and other stages of the NWRL project. Energetics has identified the following issues that required further assumptions:

- Selection of concrete grades: The ISCA tool contains a range of different concrete grades for which emissions factors are available (see Appendix C). The maximum concrete strength grade for which an emission factor is available is 40MPa. The largest volume of concrete used in both the Reference Design and the Substantial Detailed Design is of 50MPa strength. In our default comparison we use the 40MPa factors as a proxy, as was done in the Reference Design calculation. A sensitivity analysis will show the impact of this decision, through the use of extrapolated emission factors for 50MPa concretes.
- Selection of steel products: The ISCA tool contains a range of different steel products for which emissions factors are available (see Appendix C). We note that “Steel Plate” was chosen as a proxy for structural steel in the Reference Design footprint calculations. The Substantial Detailed Design hardly uses structural steel, but mainly steel reinforcement bars and mesh and steel wire strands. We have selected the most appropriate steel products from the ISCA calculator in the SVC footprint calculation (see Appendix D).
- The scope of the assessment is cradle-to-gate as per TfNSW requirements. A comparative assertion based on cradle-to-gate data is typically not allowed as this does not comply with system boundary requirements defined in [ISO14044]. Therefore Energetics recommends readers take extreme care when interpreting the results of this footprint assessment.
- Generally, Energetics would recommend applying emission factors that are relevant, transparent and accurate. We have concerns about these characteristics regarding the emission factors in the ISCA tool.
  - We are not able to accurately reproduce the emission factors for steel and concrete products by using the original BPIC LCI data.
  - The emission factor for Steel Plate (material used in the Reference Design footprint) in the ISCA tool is 1.91 t CO_2e per tonne of steel plate. The BPIC data for steel plate show scope 1 emissions of CO_2 amount to 2.38 t CO_2 per tonne of steel plate. The emission factor published in the ISCA tool appears to be a significant underestimate.
  - The emission factor for Steel Universal Beams & Columns (material has been avoided in the Reference Design footprint) in the ISCA tool is 4.65 t CO_2e per tonne of steel Universal Beams & Columns. This factor is about twice as high as any other steel product in the BPIC LCI database, even though production of beams is not particularly energy intensive. We suspect it is based on erroneous data in the BPIC LCI database.
  - The BPIC LCI data for Steel Plate indicate that allocation of end of life recycling has been incorporated into the data (credits have been applied). This is not the case for most other steel products. This discrepancy leads to an underestimate of the Reference Design footprint.

1.13. Data Quality Requirements

The data quality requirements have been assessed as follows:

Table 2: Data quality requirements

Data quality indicator	Data quality requirement
Technological representativeness	The data for concrete and steel products need to reflect the actual products used in the NWRL project as closely as possible, while using the emission factors available from the IS materials calculator
Geographical representativeness	The data need to reflect production and/or supply of concrete and steel products in Australia
Temporal representativeness	The data should be representative for the current situation
Precision	There should be minimum variability between the data sources and actual materials used
Completeness	The scope of the LCA is limited to steel and concrete products. All steel and concrete products used in the SVC package are to be included. All greenhouse gases need to be covered.
Consistency	Methodologies, data, and assumptions should be applied consistently throughout the carbon footprint assessment
Reproducibility and transparency	The data should be transparent enough to allow an independent practitioner to reproduce the carbon footprint The data should be transparent enough to allow evaluation of the underlying methodology, data and assumptions

1.14. Type of Report and Critical Review

This LCA report is presented in line with ISO14040 / ISO14044 structure, although an independent critical review is required to confirm compliancy before ISJV can make such claims. An independent critical review is recommended but not compulsory, as the study does not cover a direct comparison between products[6].

During the goal and scope definition, Energetics has indicated that the LCA might not comply with these ISO standards due to a lack in relevance, transparency and accuracy related to the emission factors (and their underlying data) used in this assessment.

[6] The ISO standards impose an independent critical review for comparative assertions disclosed to the public.

2. Life Cycle Inventory

The product system of the SVC Package designs has been described in section 1.4.

The reference unit of this LCA study is defined as the cradle-to-gate impacts of:

> *the entire quantity of steel and concrete used in the Surface and Viaduct Civil Works (SVC) package of the NWRL skytrain construction.*

2.1. Data Collection and Data Quality

Energetics has received the Bill of Quantities for the Skytrain SVC Package from ISJV (see Appendix E). We have converted these data into tonnages of concrete and steel (see Table 3). The final quantities have been checked and approved by WSP[7].

These material quantities have been combined with GHG emission factors to complete the footprint assessment. The data sources and indicative data quality indicators are described in Table 4.

Table 3: Material quantities

Material	% SCMs in concrete	Quantity used in Skytrain SVC Package, Substantial Detailed Design
Concrete 5 MPa	60%	905 m^3
Concrete 20 MPa	60%	1,060 m^3
Concrete 25 MPa	60%	6,580 m^3
Concrete 32 MPa	50%	73 m^3
Concrete 40 MPa	45%	710 m^3
40 MPa shotcrete	20%	1,037 m^3
No Fines	30%	563 m^3
40MPa B1 - Precast GP/FLYASH	30%	7,202 m^3
50MPa B1 - Precast GP/FLYASH	30%	37,137 m^3
40MPa B1/B2 - in-situ GP/SLAG	65%	16,457 m^3
50MPa B1/B2 - in-situ GP/SLAG	65%	2,813 m^3
Reinforcement steel – rebar		14,161 tonnes
Reinforcement steel – mesh		130 tonnes
Steel wire strands		1,751 tonnes

[7] As confirmed by e-mail from Tim Parker (WSP) to Rob Rouwette (Energetics), 17 July 2014

Table 4: Data sources and data quality indicators

Component	Data description	Data source	Indicative data quality[8]
Bill of Quantities	Quantities of steel and concrete materials used in the SVC Package Substantial Detailed Design	ISJV	Very good
Concrete emission factors (EF)			
Concrete 5 MPa	Assuming EF similar to 20 MPa concrete	ISCA tool	Poor/Fair
Concrete 20 MPa	EF of 20 MPa concrete, 30% fly-ash	ISCA tool	Poor/Fair
Concrete 25 MPa	EF of 25 MPa concrete	ISCA tool	Poor/Fair
Concrete 32 MPa	EF of 32 MPa concrete, 30% fly-ash	ISCA tool	Poor/Fair
Concrete 40 MPa	EF of 40 MPa concrete, 30% fly-ash	ISCA tool	Poor/Fair
40 MPa shotcrete	Assuming EF similar to 40 MPa concrete, 20% fly-ash	ISCA tool	Poor/Fair
No Fines	Assuming EF similar to 32 MPa concrete, 30% fly-ash	ISCA tool	Poor/Fair
40MPa B1 - Precast GP/FLYASH	Assuming EF similar to 40 MPa concrete, 30% fly-ash	ISCA tool	Poor/Fair
50MPa B1 - Precast GP/FLYASH	Assuming EF similar to 40 MPa concrete, 30% fly-ash	ISCA tool	Poor
40MPa B1/B2 - in-situ GP/SLAG	Assuming EF similar to 40 MPa concrete, 30% fly-ash	ISCA tool	Poor
50MPa B1/B2 - in-situ GP/SLAG	Assuming EF similar to 40 MPa concrete, 30% fly-ash	ISCA tool	Poor
Steel emission factors (EF)			
Reinforcement steel – rebar	Steel Reinforcing Bar	ISCA tool	Fair/Good
Reinforcement steel – mesh	Steel Welded Reinforcement Mesh	ISCA tool	Fair/Good
Steel wire strands	Steel Round and Square Sections	ISCA tool	Poor

[8] See Appendix F for data quality scoring criteria

Representativity of the data

The emission factors in the ISCA tool are based on the BPIC LCI data, which have been collected from the relevant Australian industries in 2007. The BPIC LCI data are meant to represent the average Australian situation.

Due to a lack of transparency regarding how the original BPIC LCI data have been translated into the emission factors in the ISCA tool, as well as known omissions and errors in the LCI data, we have assessed the indicative data quality as fair or in some cases as poor or fair to good.

One of the key issues in using the emission factors is the potential discrepancy between the actual materials used in the ISJV project and the generic materials to which the emission factors relate. The key issue for concrete is the lack of emission factors for 50 MPa concrete grades and mixes with more than 30% fly-ash.

2.2. Validation of the Data

Energetics has attempted to validate the emission factors by performing a check with the original BPIC LCI data. This has led to the discovery of a number of (potential) data issues (see section 1.12). It is outside the scope of this project to repair the uncovered issues or to use different data.

2.3. Allocation

There are a number of underlying processes in the steel and concrete supply chains that require allocation. As explained in section 1.8, allocation has taken place in the determination of the emission factors. Due to limited transparency, Energetics does not have the ability to validate the procedures and the data used.

3. Life Cycle Impact Assessment

The Life Cycle Impact Assessment results have been calculated for the reference unit (steel and concrete used in the Surface and Viaduct Civil Works (SVC) package of the NWRL skytrain construction). In this chapter the results are presented for the carbon footprint (greenhouse gas emissions), expressed in t CO_2e.

The results of the Substantial Detailed Design life cycle impact assessment are included in section 3.1. A comparison against the Reference design is presented in section 3.2.

3.1. Carbon Footprint of the Substantial Detailed Design

The carbon footprint analysis of the cradle-to-gate production of concrete and steel products is presented in Table 5. The total materials footprint of 50,228 t CO_2e includes raw material extraction, intermediate materials production, transport of raw materials and intermediate products, concrete and steel products manufacturing.

Note: Transport of materials to the construction site is not included in this assessment. This will be covered in a later report.

Table 5: Cradle-to-gate carbon footprint of concrete and steel used in the Substantial Detailed Design

Material	Quantity	Emission factor (t CO_2e/unit)	Emission factor based on IS calculator product	Emissions (t CO_2e)
Concrete 5 MPa	905 m^3	0.220	20 MPa concrete, 30% fly-ash	199
Concrete 20 MPa	1,060 m^3	0.220	20 MPa concrete, 30% fly-ash	233
Concrete 25 MPa	6,580 m^3	0.318	25 MPa concrete	2,092
Concrete 32 MPa	73 m^3	0.281	32 MPa concrete, 30% fly-ash	21
Concrete 40 MPa	710 m^3	0.343	40 MPa concrete, 30% fly-ash	244
40 MPa shotcrete	1,037 m^3	0.378	40 MPa concrete, 20% fly-ash	392
No Fines	563 m^3	0.281	32 MPa concrete, 30% fly-ash	158
40MPa B1 - Precast GP/FLYASH	7,202 m^3	0.343	40 MPa concrete, 30% fly-ash	2,470
50MPa B1 - Precast GP/FLYASH	37,137 m^3	0.343	40 MPa concrete, 30% fly-ash	12,738
40MPa B1/B2 - in-situ GP/SLAG	16,457 m^3	0.343	40 MPa concrete, 30% fly-ash	5,645

Material	Quantity	Emission factor ($t\ CO_2e$/unit)	Emission factor based on IS calculator product	Emissions ($t\ CO_2e$)
50MPa B1/B2 - in-situ GP/SLAG	2,813 m^3	0.343	40 MPa concrete, 30% fly-ash	965
Reinforcement steel – rebar	14,161 tonnes	1.61	Steel Reinforcing Bar	22,800
Reinforcement steel – mesh	130 tonnes	1.74	Steel Welded Reinforcement Mesh	227
Steel wire strands	1,751 tonnes	1.37	Steel Round and Square Sections	2,404
TOTAL - materials				**50,588**

3.2. Comparison between Substantial Detailed Design and Reference Design

The carbon footprint of the Reference Design has been calculated for TfNSW by Aecom, Cox, Grimshaw and Parsons Brinckerhoff (see Appendix G).

The carbon footprint of the Reference Design materials amounts to 53,828 t CO_2e, while all other components have a footprint of 28,592 t CO_2e, resulting in a combined footprint of 82,420 t CO_2e.

Although the other components (e.g. transport fuel use, on-site fuel use, electricity use and vegetation clearing) have not been studied for the Substantial Detailed Design at this stage, they have to be taken into account as the emissions target (2.50% reduction compared to the Reference Design) is set over the total footprint. For now we assume that the emissions related to transport fuel, stationary diesel and electricity used on-site are 5% lower as established for the Reference Design as this is in line with the minimum performance required by the ISJV contract deed. This hypothesis will be tested in later stages of the LCA project.

The total carbon footprint of the Substantial Detailed Design equals 50,588 t CO_2e (materials) plus 27,219 t CO_2e (other components), resulting in a combined footprint of 77,806 t CO_2e.

As shown in Figure 7, the changes made in the Substantial Detailed Design result in a 5.6% reduction of the total carbon footprint compared to the Reference Design.

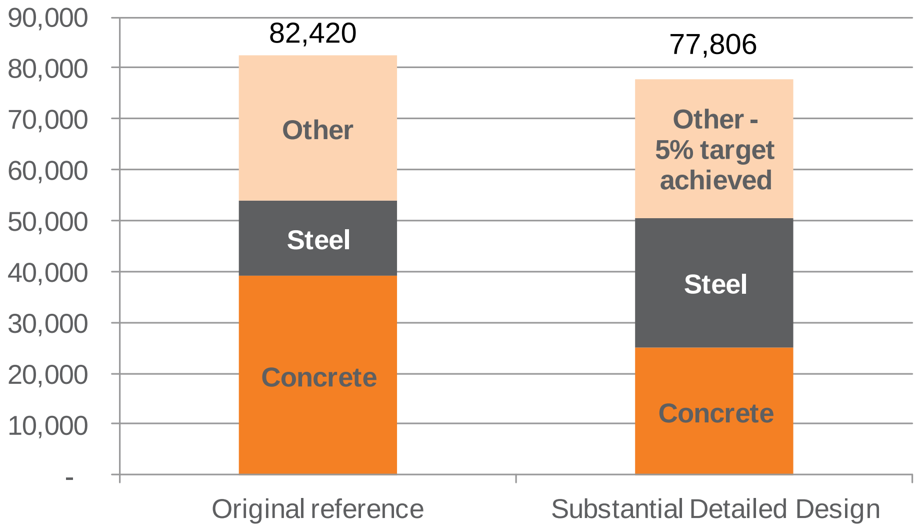

Figure 7. Comparison of total GHG emissions of the Reference Design and the Substantial Detailed Design

4. Interpretation

The life cycle interpretation phase comprises several elements, such as:

- Identification of significant issues
- Conclusions, limitations and recommendations
- Evaluation considering completeness, sensitivity and consistency checks.

4.1. Identification of significant issues

The key contributors to the materials carbon footprint are presented in Figure 8.

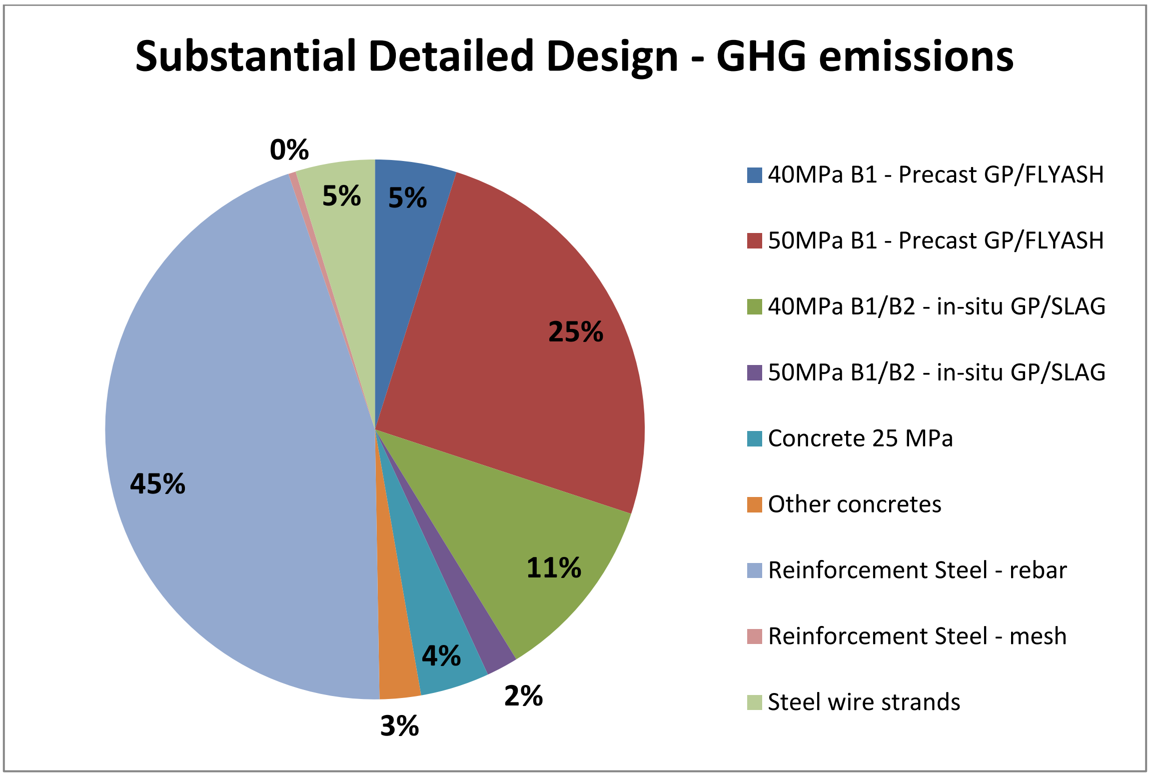

Figure 8. Contribution of materials to the Substantial Detailed Design concrete and steel carbon footprint

Both steel and concrete contribute equally to the materials footprint.

The emission factors for steel products vary in line with the share of the basic steel production route (electric arc furnace or blast iron / basic oxygen furnace) and to a lesser extent the amount of processing required to manufacture the final products. The variation in emission factors between rebar, mesh and round and square sections is relatively small (± 10% from the three product average) and therefore the share in emissions is mainly influenced by the quantity of steel.

When analysing the individual concretes it becomes clear that:

- Precast concrete contributes 30%, of which 50MPa concrete is used for segments (25% contribution) and 40MPa concrete is used for parapets and station platforms (5%).
- In-situ concrete contributes 13%, of which 50MPa concrete is used for piles (2%) and 40MPa concrete is used for piers, pile caps and abutments (11%).
- Other types of concrete (mostly in-situ) contribute 7%, of which 25MPa concrete used for pavements is the largest contributor (4%), while all other concretes used for pavements, drainage and stabilisation of excavations combined make up 3%.

As with steel, the share in the emissions is strongly influenced by the volume of concrete used. The emission factors confirm the common principle that emissions intensity of concrete increases with the strength grade (caused by increasing cement content). It is therefore no surprise that 50MPa and 40MPa concrete are the two largest concrete contributors to the materials footprint.

Since emission factors have been used to determine the footprint, it is not possible to study the underlying causes in more detail.

4.2. Assumptions, Choices and Limitations

Important assumptions, choices and limitations have already been identified during the goal and scope stage, see section 1.12.

4.3. Sensitivity analyses

A number of sensitivity analyses have been undertaken in order to address areas of data uncertainty and in order to test emission reduction scenarios.

4.3.1. Concrete emission factors – strength grade

There is substantial variation in concrete GHG emission factors depending on strength grade. For example, the IS materials calculator emission factor for 40MPa concrete (no fly-ash) is 59% higher than the emission factor for 20MPa concrete (no fly-ash). For an accurate estimate of the GHG emissions it is therefore important to match the strength grade (based on concrete composition; mainly cement content) of the emission factor with the strength grade of the actual concrete used. As can be seen in Table 5, we have not been able to find emission factors with equal strength grades for 5MPa and 50MPa concretes.

For these two products we have used the nearest available strength: 20MPa emission factor for the 5MPa concrete and 40MPa emission factor for the 50MPa concrete. This results in an overestimate of emissions for 5MPa concrete and an underestimate for 50MPa concrete in the Substantial Detailed Design footprint. The volume of 5MPa concrete is small (ca. 1%) and therefore the overestimate is considered insignificant. 50MPa concrete on the other hand represents the largest volume of concrete (ca. 54%). We believe it is therefore crucial that we use a better estimate for the emissions of 50MPa concrete.

To remain consistent with the values and methodology used in the other emission factors, we have extrapolated the GHG intensity of concretes from various strength grades available in the IS materials calculator (see Appendix C). The correlation is remarkably strong (R^2 = 0.997).

We are now able to recalculate the carbon footprint of the Substantial Detailed Design based on our best estimate. The results presented in Table 6 lead to a total materials carbon footprint of 53,947 t CO_2e.

Table 6: Cradle-to-gate carbon footprint of concrete and steel used in the Substantial Detailed Design, using extrapolated factor for 50MPa concrete

Material	Quantity	Emission factor ($t\ CO_2e$/unit)	Emission factor based on IS calculator product	Emissions ($t\ CO_2e$)
Concrete 5 MPa	905 m^3	0.22	20 MPa concrete	199
Concrete 20 MPa	1,060 m^3	0.220	20 MPa concrete, 30% fly-ash	233
Concrete 25 MPa	6,580 m^3	0.318	25 MPa concrete	2,092
Concrete 32 MPa	73 m^3	0.281	32 MPa concrete, 30% fly-ash	21
Concrete 40 MPa	710 m^3	0.343	40 MPa concrete, 30% fly-ash	244
40 MPa shotcrete	1,037 m^3	0.378	40 MPa concrete, 20% fly-ash	392
No Fines	563 m^3	0.281	32 MPa concrete, 30% fly-ash	158
40MPa B1 - Precast GP/FLYASH	7,202 m^3	0.343	40 MPa concrete, 30% fly-ash	2,470
50MPa B1 - Precast GP/FLYASH	37,137 m^3	0.427	*50 MPa concrete, 30% fly-ash*	15,861
40MPa B1/B2 - in-situ GP/SLAG	16,457 m^3	0.343	40 MPa concrete, 30% fly-ash	5,645
50MPa B1/B2 - in-situ GP/SLAG	2,813 m^3	0.427	*50 MPa concrete, 30% fly-ash*	1,201
Reinforcement steel – rebar	14,161 tonnes	1.61	Steel Reinforcing Bar	22,800
Reinforcement steel – mesh	130 tonnes	1.74	Steel Welded Reinforcement Mesh	227
Steel wire strands	1,751 tonnes	1.37	Steel Round and Square Sections	2,404
TOTAL - materials				**53,947**

It should be noted that 50MPa concrete is also used in the Reference Design and therefore the Reference Design carbon footprint also needs to be adjusted for a fair comparison.

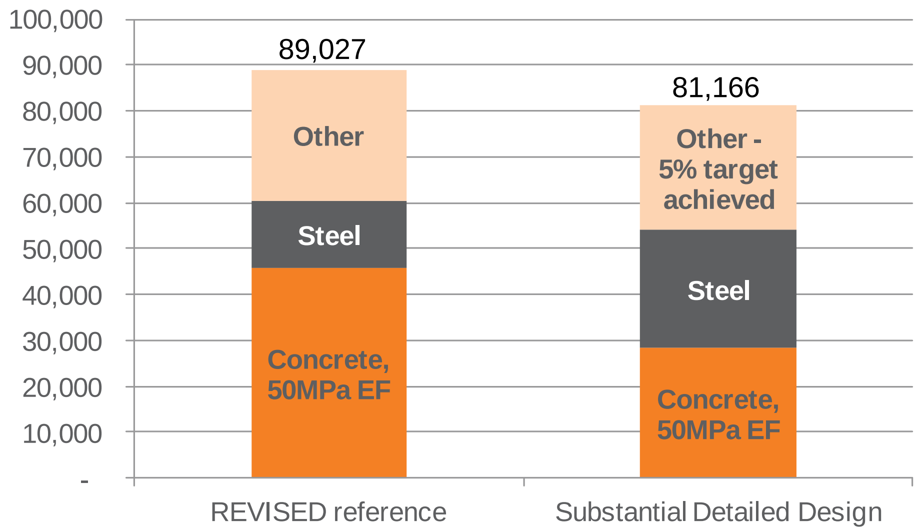

Figure 9. Comparison of total GHG emissions of the Reference Design and the Substantial Detailed Design, using extrapolated factor for 50MPa concrete

Figure 9 shows that after correction of the emission factors for 50MPa concrete, the total emissions for the Reference Design amount to 89,027 t CO_2e and for the Substantial Detailed Design 81,166 t CO_2e. By changing the design and selecting low carbon materials, ISJV have achieved a 8.8% reduction in greenhouse gas emissions for the skytrain project.

4.3.2. Concrete emission factors – cement replacement

Apart from the strength grade, there is also substantial variation in concrete GHG emission factors depending on the percentage of cement replacement (%fly-ash used). The impact of the %fly-ash in the IS materials calculator emission factors for various concrete products is shown in Figure 10.

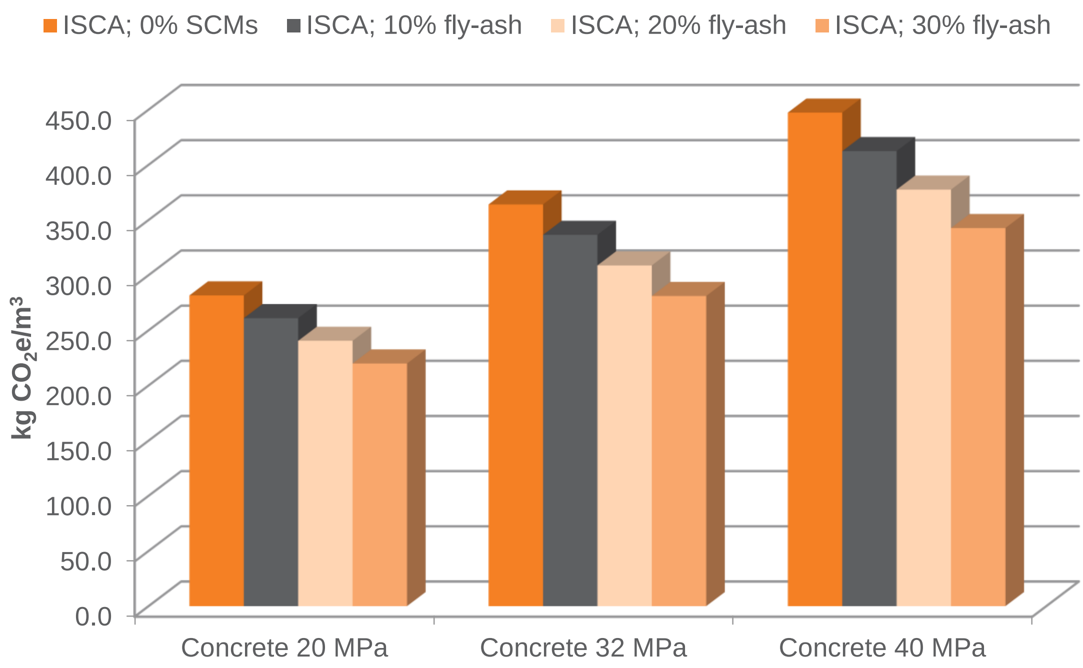

Figure 10. Concrete emission factors: impact of strength grade and %fly-ash

For an accurate estimate of the GHG emissions we need to know the percentage of fly-ash used, or even better the percentage of SCM's (fly-ash, ground granulated blast furnace slags, silica-fume). In fact, these percentages aim to provide more information on the Portland cement content of a concrete, which is commonly known to be the largest driver of greenhouse gas emissions in concrete. Because the actual cement content of a concrete mix design can vary considerably, there is still significant variability in the emissions of concrete products with a given percentage of cement replacement. The most accurate assessment of a concrete product's GHG intensity can be undertaken when considering its exact composition, including cement content (in kg/m^3 concrete).

ISJV's Deed requirements stipulate that concrete mixes need to have a minimum cement replacement of 30% across all strength grades. The actual concrete mixes used in the Substantial Detailed Design have a weighted average SCM content of 43%. This is considerably higher than the maximum available through the ISCA materials calculator: 30% fly-ash. Therefore we conclude that the emissions calculated for the Substantial Detailed Design are an overestimate compared to the actual emissions associated with the concretes used.

4.3.3. Steel wire strands emission factor

As explained in section 1.12 and Appendix D, we have selected “Steel Round and Square Sections” as a proxy for wire strands. This appears to be the best estimate within the constraints of using a limited set of emission factors such as exists in the IS tool.

The emission factor for steel round and square sections sits at the low end of the range for steel products. To study the potential impact of this decision, we have performed a sensitivity assessment using the highest available emission factor (for steel angles)[9].

The analysis shows that the change in emission factor for wire strands would lead to a maximum increase of the project’s carbon footprint of 2,047 t CO_2e. This illustrates the importance of having a good match between products and emission factors.

4.4. Completeness and consistency check

A completeness and consistency check has not been performed as the required information is not provided with the emission factors or the related LCI data.

We do note that this analysis covers cradle-to-gate only, although this scope has not been applied consistently in the emissions factors (e.g. steel plate contains aspects of the end-of-life).

4.5. Uncertainty

The main aspects for uncertainty in the underlying LCA are:

- The GHG emission factors for various materials
- quantification of building materials used in the two designs
- the impact assessment model.

Energetics is not able to quantitatively assess the uncertainty.

4.6. Conclusions

The key objective of the LCA is to indicate whether ISJV meets its energy and carbon targets: the project needs to achieve a 2.50% reduction on the Reference Design carbon footprint of 82,420 t CO_2e.

The Life Cycle Inventory data needed to be sourced from the BPIC LCI database (IS materials calculator) where possible.

Based on the preliminary life cycle assessment results, Energetics lead a workshop for ISJV in Sydney on 14 April 2014 to indicate possible emission reduction pathways based on material selection. The results as presented in this report are a snapshot of the Substantial Detailed Design emissions. Ultimately, ISJV will work towards a Final Design.

The total carbon footprint of the Substantial Detailed Design equals 50,588 t CO_2e (materials) plus 27,219 t CO_2e (other components), resulting in a combined footprint of 77,806 t CO_2e.

[9] The emission factor for universal beams and column is actually the highest, but considered incorrect.

Energetics calculates the GHG emissions of the Substantial Detailed Design to be 5.6% below the emissions of the TfNSW Reference Design (82,420 t CO_2e). This result is based on the same methodology (emission factors) as used in the Reference Design calculations.

It should be noted that Energetics' earlier recommendation to change the emission factor for 50MPa concrete products to a more relevant and accurate estimate, rather than using 40MPa concrete as a proxy, has not been approved. Our sensitivity analysis shows that when applying specific emission factors for 50MPa concrete, the Substantial Detailed Design (81,166 t CO_2e) reduces emissions by 8.8% compared to the revised Reference Design (89,027 t CO_2e).

4.7. Limitations

The key limitations in the steel and concrete LCA are related to the data (emission factors) that are used:

- The ISJV has been directed to use the emissions factors from the Infrastructure Sustainability Council of Australia (ISCA) materials calculator tool (http://www.isca.org.au/) in order to maintain compatibility with calculations for the Reference Design and other stages of the NWRL project.
- The available emission factors don't necessarily match the materials and products used. There is limited to no ability to alter any of the data or emission factors, resulting in a static estimate. Energetics would recommend applying emission factors that are relevant, transparent and accurate.
- The scope of the assessment is cradle-to-gate as per TfNSW requirements. A comparative assertion based on cradle-to-gate data is typically not allowed as this does not comply with system boundary requirements defined in [ISO14044]. Therefore Energetics recommends readers take extreme care when interpreting the results of this footprint assessment.

4.8. Recommendations

Energetics recommends that:

- Care is taken when interpreting the results of this cradle-to-gate footprint assessment. Taking a full life-cycle approach (e.g. including durability and potential recycling at end-of-life) might enhance or change the directional outcome of this assessment.
- Changes are made to this assessment and ultimately to the IS materials calculator to reflect the large variability in concrete compositions, strength grades and thus emissions intensities.
    - As a minimum, an appropriate emission factor for 50MPa concrete needs to be applied to both the Reference Design and subsequent designs (Contract Design, Substantial Detailed Design, Final Design) to evaluate ISJV's carbon footprint reduction efforts.
    - To assess the concrete mixtures applied in the Final Design, we might require emission factors for concretes with different types of SCMs (other than fly-ash) and different (higher) percentages of cement replacement.
    - Ideally, the calculator would provide a specific emission factor for each mix design.

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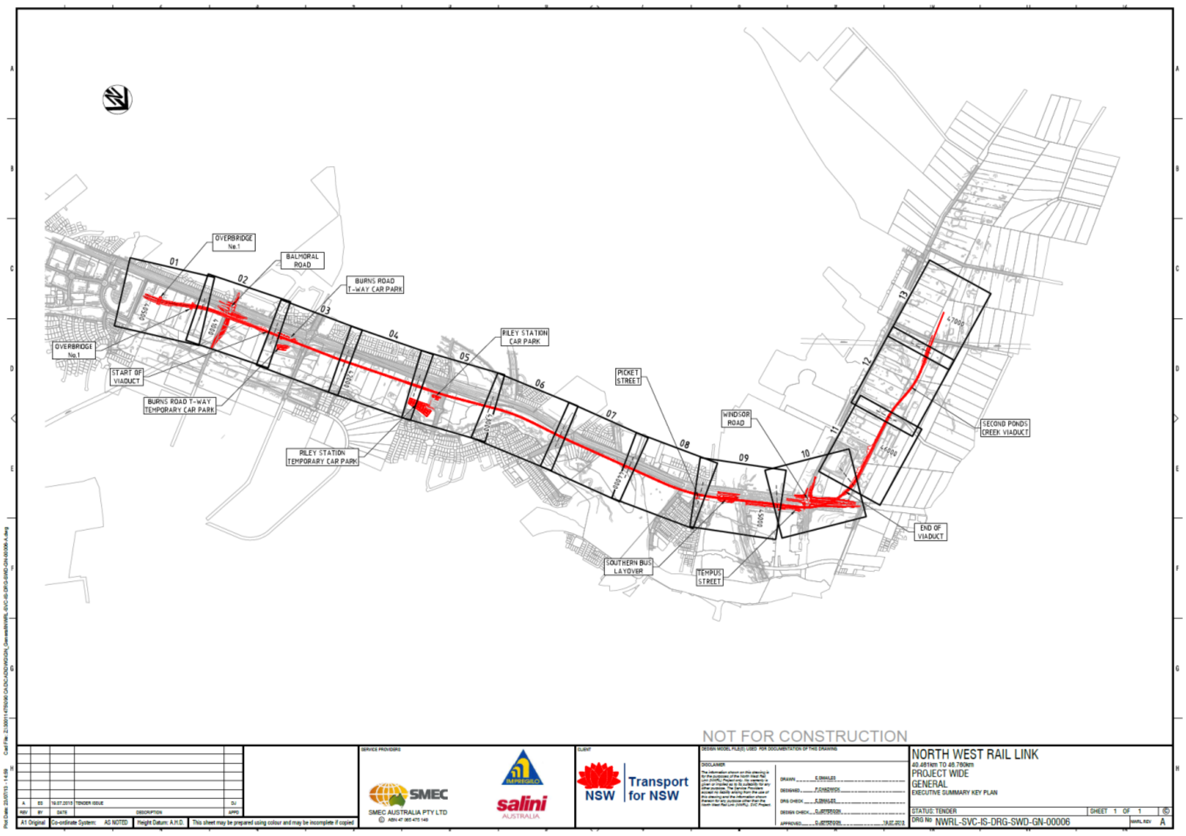
List of Acronyms

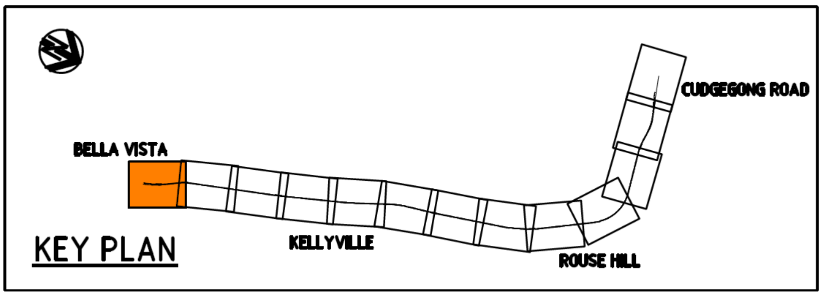
Acronym	Description
BPIC	Building Products and Innovation Council
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalents
CH_4	Methane
EF	Emission factor
GHG	Greenhouse gas
GJ	Giga Joules
IPCC	Intergovernmental Panel on Climate Change
IS materials calculator	Calculator that forms part of the ISCA rating tool
ISCA	Infrastructure Sustainability Council of Australia
ISJV	Impregilo-Salini Joint Venture
ISO	International Organization for Standardization
kg	kilogram
kWh	kilo Watt hour
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
m^2	Square meter
m^3	Cubic meter
MJ	Mega Joules
MPa	Mega Pascal
N_2O	di-nitrogen oxide
NGA	National Greenhouse Accounts Factors
SCM	Supplementary Cementitious Material
SVC	Surface and Viaduct Civil Works
t	tonnes
TfNSW	Transport for New South Wales
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WSP	WSP Environment and Energy consultants

Appendix A. NWRL skytrain SVC project wide general overview

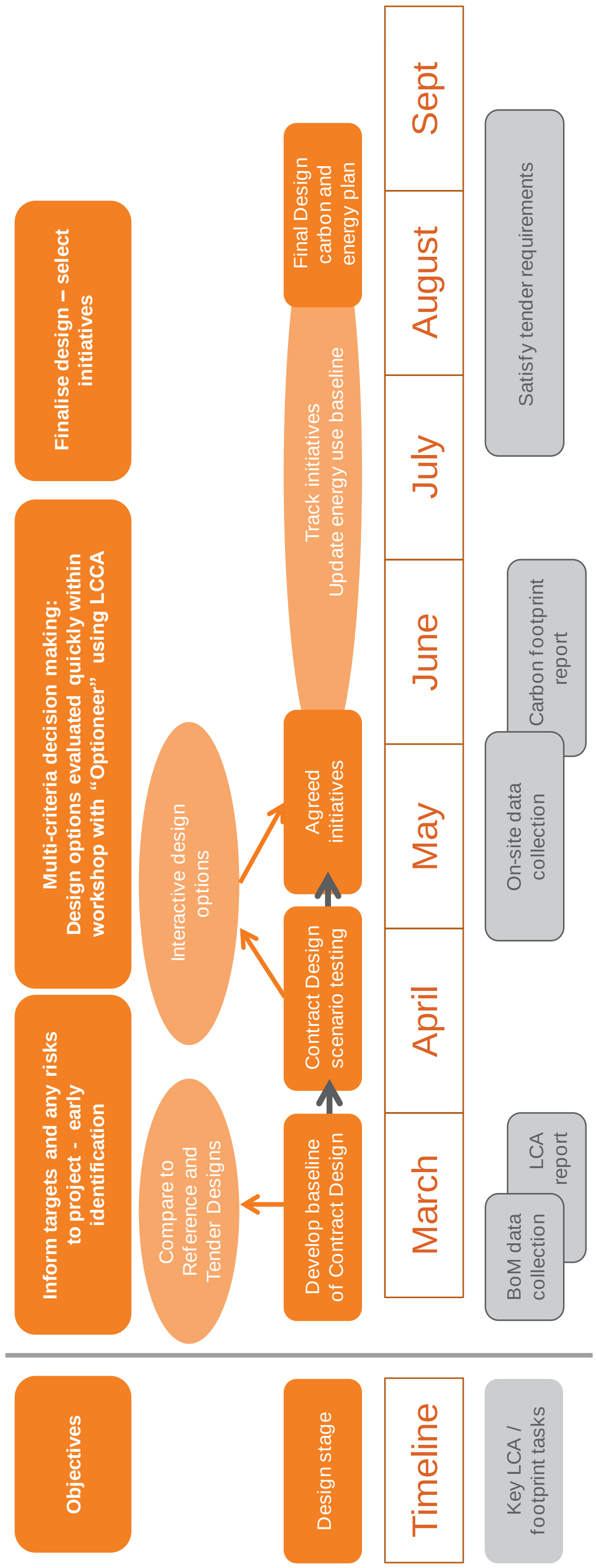


NORTH WEST RAIL LINK
40.461km TO 46.760km
PROJECT WIDE
GENERAL
EXECUTIVE SUMMARY PLAN - SHEET 1

STATUS: TENDER	SHEET 1 OF 13	©
DRG No NWRL-SVC-IS-DRG-SWD-GN-00201	NWRL REV	A



Appendix B. LCA project timeline



Appendix C. GHG emissions factors

Concrete

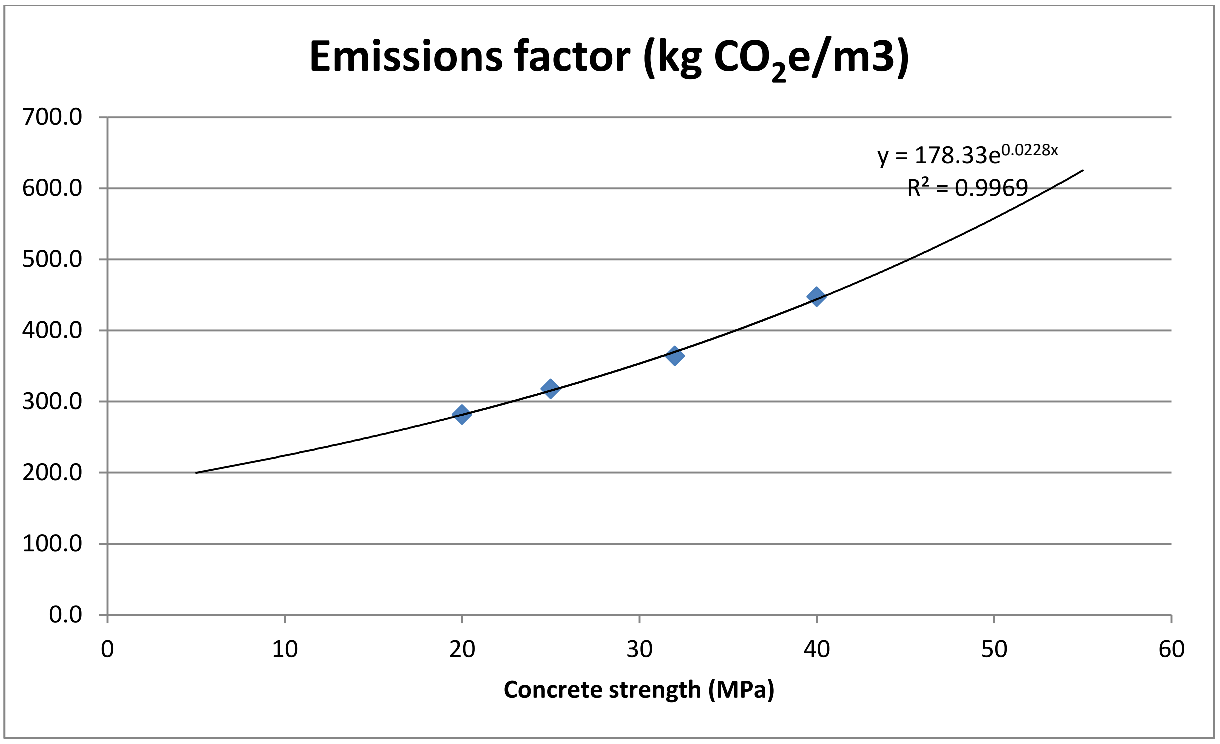
The following table shows the greenhouse gas emission factors for various concrete types as derived from the ISCA rating tool - materials calculator (version 1.0; released 06/06/2013).

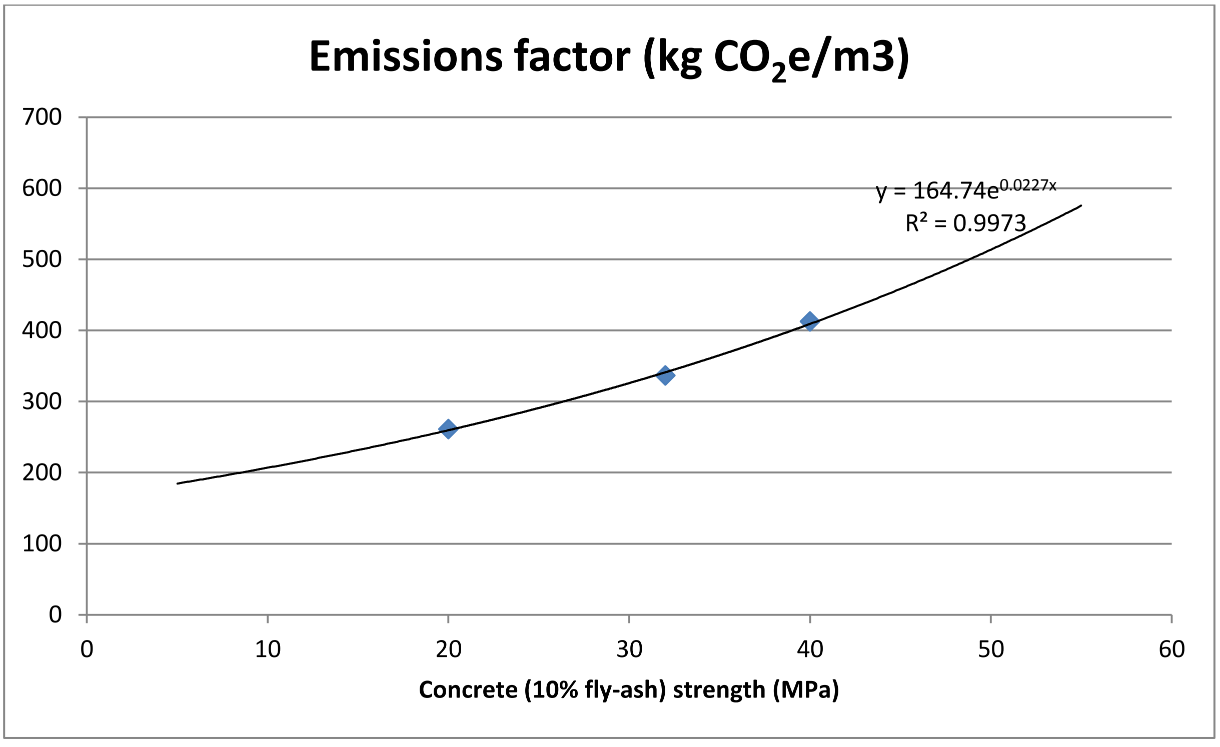
Concrete type	Emissions factor (kg CO_2e/m^3)
Concrete Strength Grade 20 MPa	281.6
Concrete Strength Grade 20 MPa, 10% fly-ash	261.0
Concrete Strength Grade 20 MPa, 20% fly-ash	240.5
Concrete Strength Grade 20 MPa, 30% fly-ash	219.9
Concrete Strength Grade 25 Mpa	317.7
Concrete Strength Grade 32 MPa	364.1
Concrete Strength Grade 32 MPa, 10% fly-ash	336.5
Concrete Strength Grade 32 MPa, 20% fly-ash	308.8
Concrete Strength Grade 32 MPa, 30% fly-ash	281.1
Concrete Strength Grade 40 MPa	447.3
Concrete Strength Grade 40 MPa, 10% fly-ash	412.4
Concrete Strength Grade 40 MPa, 20% fly-ash	377.5
Concrete Strength Grade 40 MPa, 30% fly-ash	342.7

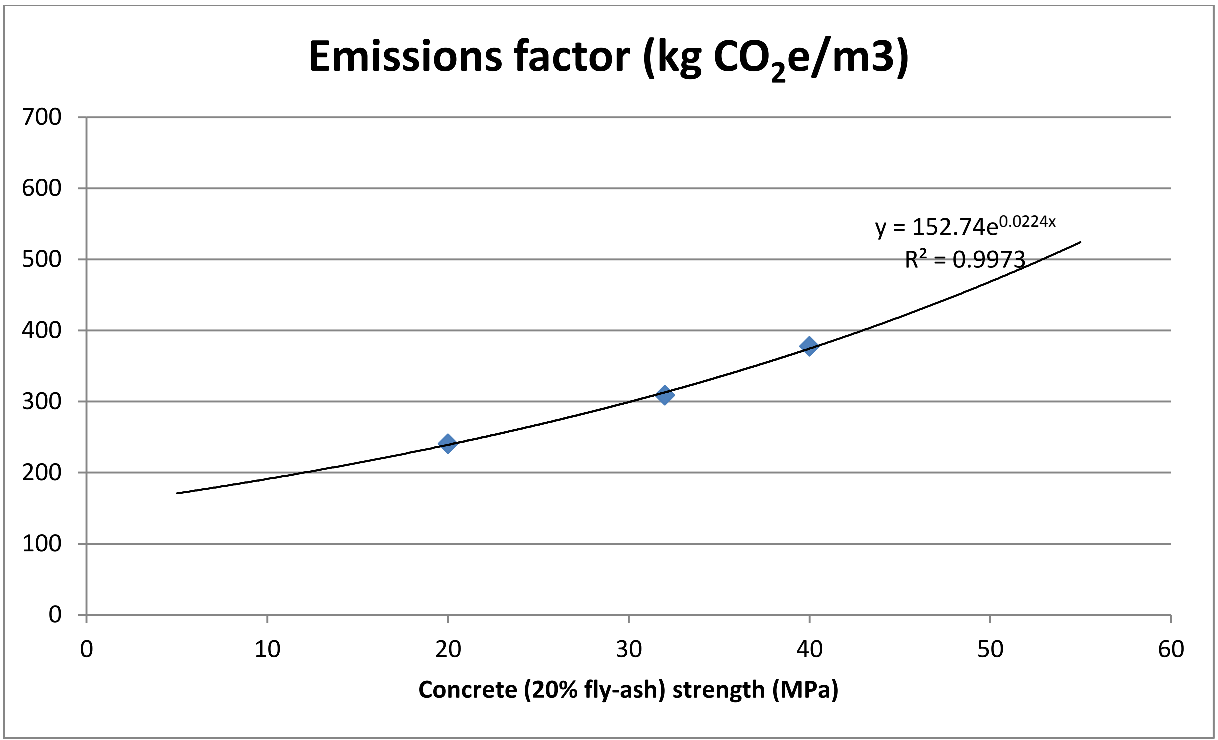
The main concrete grade used in the NWRL skytrain's SVC project has a 28-day compressive strength of 50 MPa. The ISCA materials calculator does not provide an emissions factor for this concrete grade. Therefore, Energetics has studied the relationship between concrete strength and greenhouse gas emission factors with the intention to extrapolate a suitable emission factor for 50MPa concrete (per fly-ash percentage).

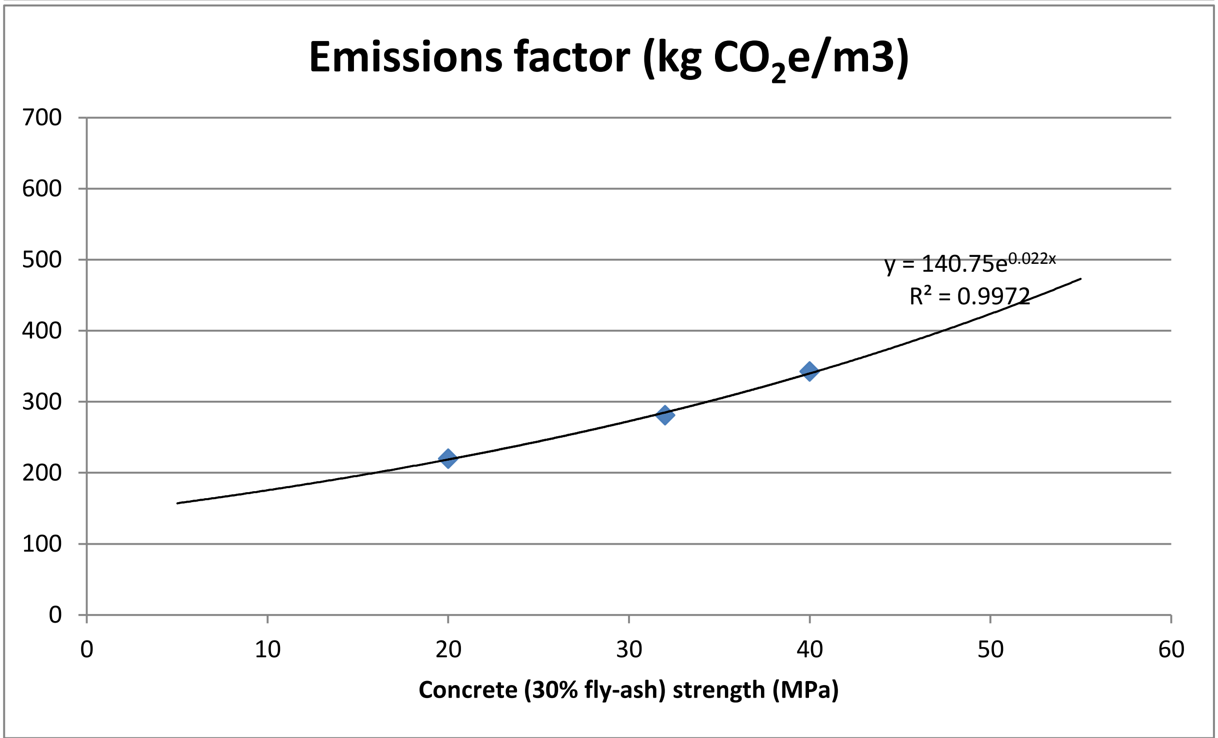
The strong correlation between the strength grade and emissions factor (as indicated in the following four figures) leads us to believe that a formula was used to calculate the emissions factors.

Across all concrete types (regardless of the percentage of fly-ash), we find that a 50MPa concrete is likely to have a 24-25% higher emission factor than a 40MPa concrete with the same fly-ash content.






Emissions factor (kg CO_2e/m3)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
$y = 152.74e^{0.0224x}$
$R^2 = 0.9973$
Concrete (20% fly-ash) strength (MPa)


Emissions factor (kg CO_2e/m3)
700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
$y = 140.75e^{0.022x}$
$R^2 = 0.9972$
Concrete (30% fly-ash) strength (MPa)

Steel

The following table shows the greenhouse gas emission factors for various steel types as derived from the ISCA rating tool - materials calculator (version 1.0; released 06/06/2013).

Steel type	Emissions factor (kg CO_2e/tonne)
Steel Angle	2,542
Steel Black Pipe & Tube	2,267
Steel Galvanised Pipe & Tube	2,322
Steel Hot Rolled	1,830
Steel Plate	1,914*
Steel Rail Lines	1,373
Steel Reinforcing Bar	1,606
Steel Round and Square Sections	1,373
Steel Slab	1,183
Steel Universal Beams & Columns	4,655**
Steel Welded Reinforcement Mesh	1,739

* Steel Plate was used in the baseline assessment [Transport for NSW, 2013]

** The emissions factor for “Steel universal beams and columns” appears incorrect and the dataset has been (temporarily?) taken out of the online BPIC LCI dataset (March 2014).

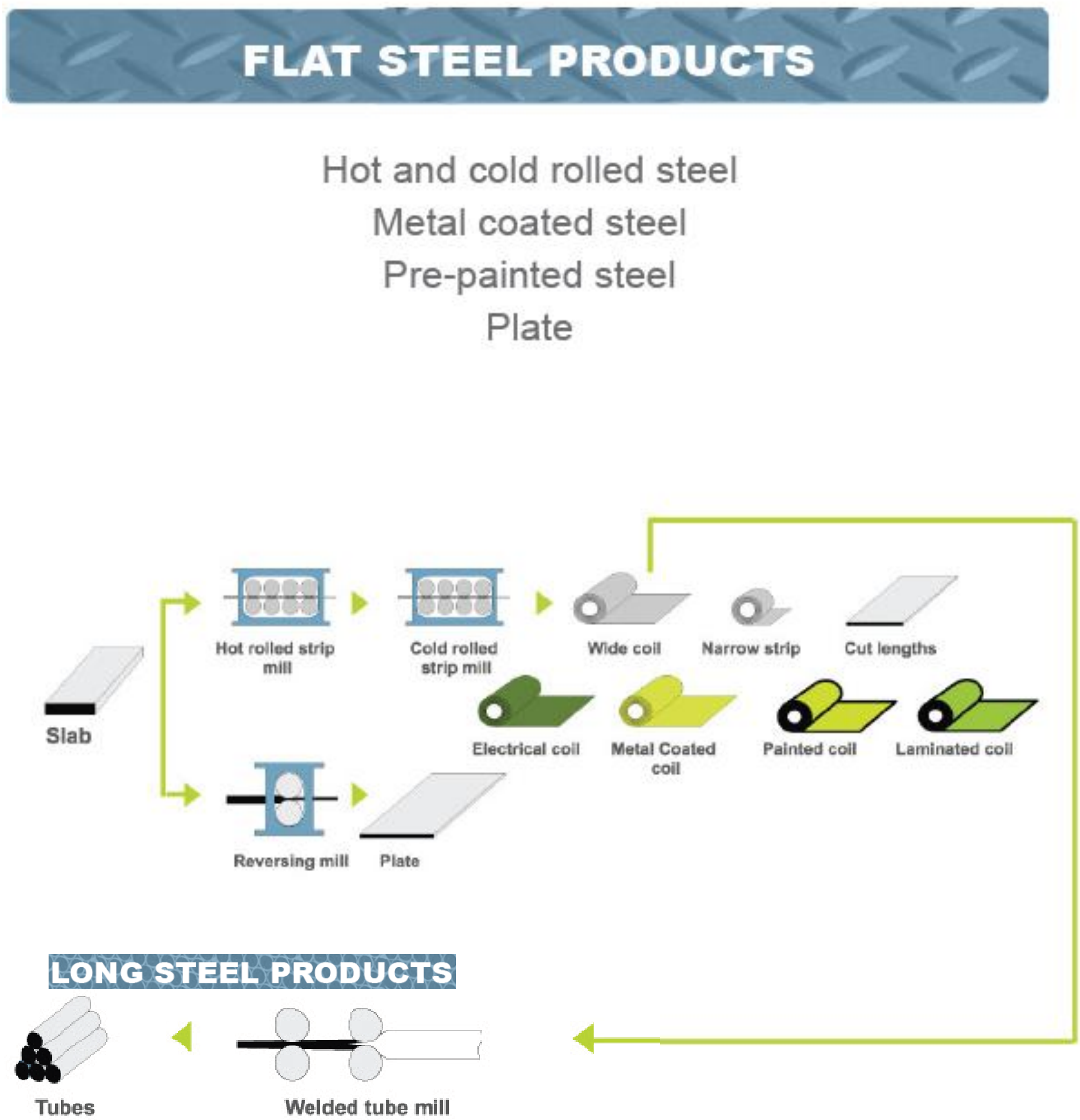
Appendix D. Selection of steel products

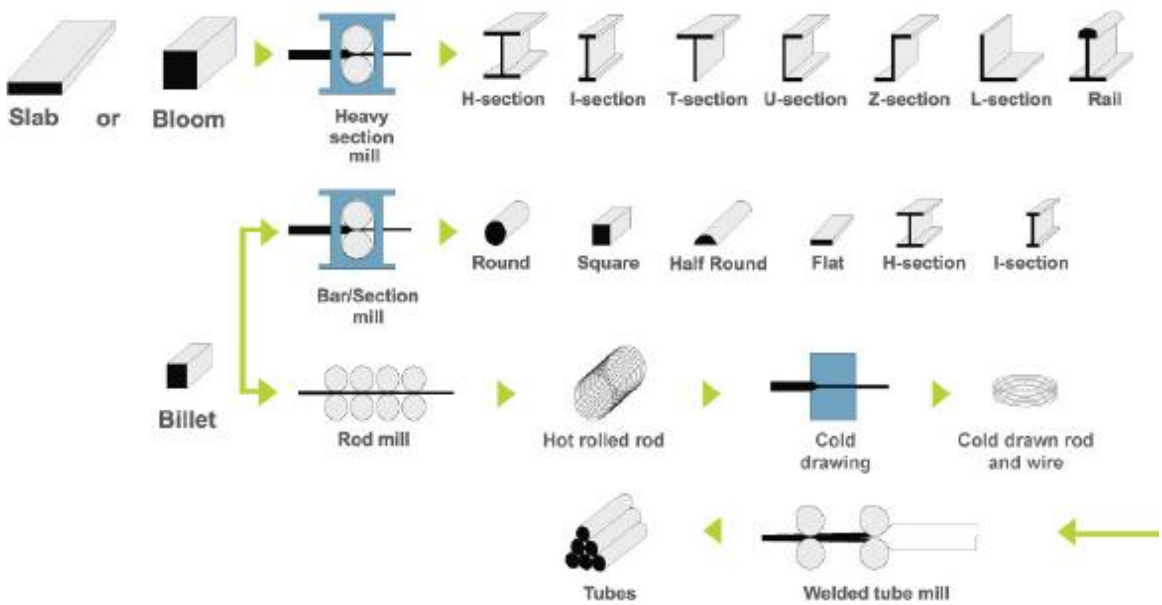
In order to select the most appropriate steel product from the ISCA tool, we have used the following explanation from the Steel Stewardship Forum (SSF) regarding the production pathways for steel products. (Source: http://steelstewardship.com/lifecycle/product-manufacturing/)

Semi-finished steel is converted to a wide range of finished products. The flat products to long products split is around 60:40.

Flat products include: hot and cold rolled sheet (uncoated, metal coated, painted) and plate. These are manufactured by BlueScope, with some imports.

Long products include: reinforcement steels, (rebar, mesh) structural steels (beams, channels), pipe and tube, wire, engineering steels. These are manufactured by OneSteel, with some imports.





Based on these production routes, and in lieu of wire strand data in the ISCA tool, we believe that "Round and Square sections" are the most appropriate proxy product for steel wire strands. The following emission factors have been used in the SVC calculations:

Material used in Substantial Detailed Design	Steel wire strands	Steel reinforcement bars	Steel reinforcement mesh
Product in ISCA-tool	Steel Round and Square Sections	Steel Reinforcing Bar	Steel Welded Reinforcement Mesh

Appendix E. Bill of Quantities

The following data are taken from the Bill of Quantities as provided to Energetics. The values provided have been converted into tonnes of steel and concrete by Energetics using an assumed density for concrete (2.4 t/m^3; consistent with ISCA calculator) and standard values for steel mesh (kg/m^2; sourced from http://www.meshbar.com.au/reinforcing-fabrics.html).

NORTH WEST RAIL LINK - Sydney (Australia)

RESOURCE SUMMARY (detailed)

Subtotal Code		Code		Description	U.M.	Qty
74	Materials	7408	.01	RE STEEL: Rebar	TN	13,555.03
		7408	.02	RE STEEL: Rebar Cage 1200	TN	601.931
		7408	.03	RE STEEL: Rebar Galv	TN	4.51
		7409	.01	WIRE MESH: Mesh SL72	M2	23,329.44
		7409	.02	WIRE MESH: Mesh SL82	M2	16,112.16
		7409	.03	WIRE MESH: Mesh SL81	M2	1,018.28
		7465	.01	STRAND CABLE: Strand Custom	VA	
		7465	.02	STRAND CABLE: Strand Anchors	VA	
		7465	.03	STRAND CABLE: Strand 15.7mm	VA	

Note: the costs for the strand cables and related items have been blocked for confidentiality reasons.

Structural Element / Mix Ref.	Volume (m^3)	GP cement (kg/m^3)	SCMs (kg/m^3)	Uses
40MPa B1 - Precast GP/FLYASH	7202.0	350	150	Parapets and Station Platforms
50MPa B1 - Precast GP/FLYASH	37137.0	385	165	Segments
40MPa B1/B2 - in-situ GP/SLAG	16457.0	140	260	Piers, pile caps and Abutments
50MPa B1/B2 - in-situ GP/SLAG	2813.0	195	360	Piles
5MPa	905.0	58	87	Pavements
20MPa	1060.0	103	155	Pavements
25MPa	6580.0	114	171	Pavements
32MPa	73.0	177	177	Pavements
40MPa	710.0	247	201	Pavements
40MPa shotcrete	1037.0	436	109	Stabilisation of excavations
NO FINES	563.0	175	75	Drainage

Note: the SCMs can consist of fly-ash and/or GGBFS.

Appendix F. Data quality criteria

The data quality scoring criteria presented below have been taken from the GHG Protocol Product Standard [GHG Protocol, 2011].

Score	Representativeness to the process in terms of:				
	Technology	**Time**	**Geography**	**Completeness**	**Reliability**
Very good	Data generated using the same technology	Data with less than 3 years of difference	Data from the same area	Data from all relevant process sites over an adequate time period to even out normal fluctuations	Verified[4] data based on measurements[5]
Good	Data generated using a similar but different technology	Data with less than 6 years of difference	Data from a similar area	Data from more than 50 percent of sites for an adequate time period to even out normal fluctuations	Verified data partly based on assumptions or non-verified data based on measurements
Fair	Data generated using a different technology	Data with less than 10 years of difference	Data from a different area	Data from less than 50 percent of sites for an adequate time period to even out normal fluctuations or from more than 50 percent of sites but for shorter time period	Non-verified data partly based on assumptions or a qualified estimate (e.g., by sector expert)
Poor	Data where technology is unknown	Data with more than 10 years of difference or the age of the data are unknown	Data from an area that is unknown	Data from less than 50 percent of sites for shorter time period or representativeness is unknown	Non-qualified estimate

NOTE: Adapted from Weidema and Wesnaes, 1996.

Appendix G. Reference Design carbon footprint

The Reference Design carbon footprint is presented in [Transport for NSW, 2013].

We have copied the key information from the Reference Design carbon footprint calculations hereafter.

Material Use

Estimates of the quantities of main materials to be used in the SVC works, provided by the project cost advisers, are summarised in Table 1-6. It has been assumed that only quantities of steel and concrete will be material to the estimation of greenhouse gas emissions. The majority of the water which will be used for the SVC scope will be embodied in concrete. It is estimated that small additional quantities of water will be utilised at the pre-casting plant (approximately 10% over and above that which is embodied in the concrete) and for dust suppression activities. Water which will be consumed in the pre-casting plant and for dust suppression has not been allowed for as this is unlikely to be material to the estimation of greenhouse gas emissions (TAGG 2011).

In allowing for concrete and steel required to construct the pre-casting plant, it has been assumed that a concrete hardstand with an area of 2,500m2 will be constructed. This would require approximately 625m3 concrete and 75t of reinforcing steel.

Table 1-6 – Key materials quantities

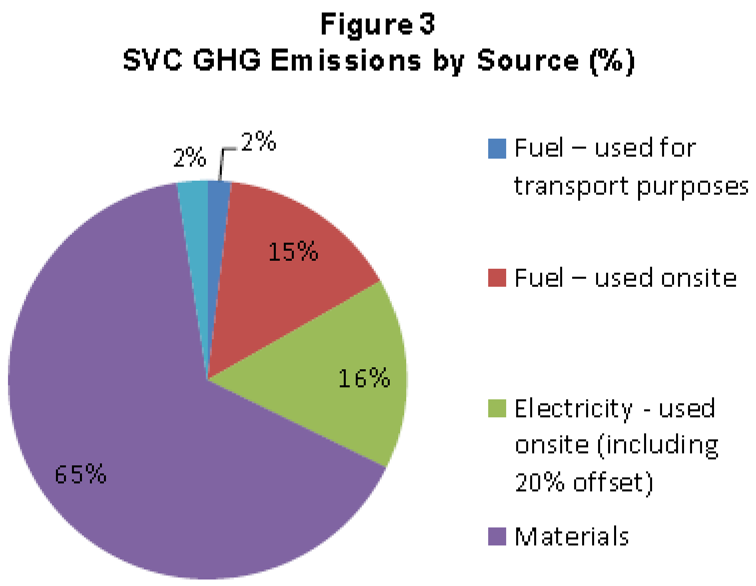
Material	Quantity	Unit	Quantity	Unit
Concrete unspecified	15,200.0	cubic metres	36,480	Tonnes
Concrete 32 Mpa	4,725.0	cubic metres	11,340	Tonnes
Concrete 40 Mpa	18,400.0	cubic metres	44,160	Tonnes
Concrete 50 Mpa	63,200.0	cubic metres	151,680	Tonnes
Structural Steel	400.0	Tonnes	400.0	Tonnes
Reinforcing Steel	8,575.0	Tonnes	8,500.0	Tonnes

Note: Assumes 2.4t/m3 for concrete

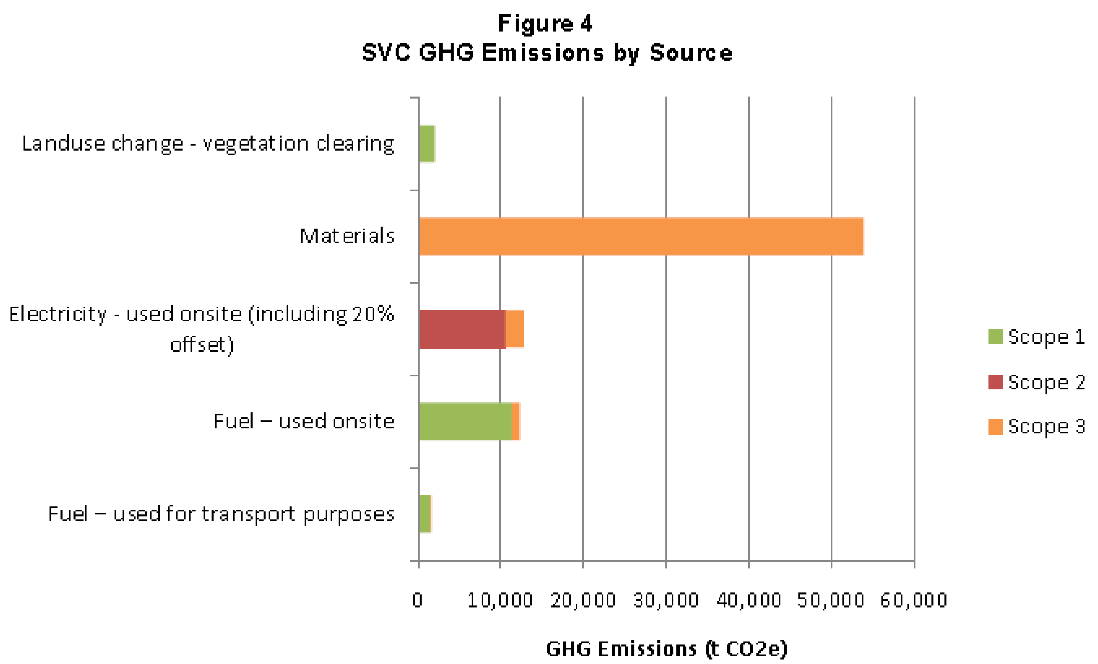
Table 2-1 – Emission Factors for Materials

Materials	Unit	Emission Factor	Assumption (Note 1)
Concrete unspecified	t Co2e/t	0.12	Concrete Strength Grade 20 Mpa - 0% fly ash
Concrete 32 Mpa	t Co2e/t	0.14	Concrete Strength Grade 32 Mpa - 10% fly ash
Concrete 40 Mpa	t Co2e/t	0.17	Concrete Strength Grade 40 Mpa - 10% fly ash
Concrete 50 Mpa	t Co2e/t	0.17	Concrete Strength Grade 40 Mpa - 10% fly ash
Structural Steel	t Co2e/t	1.91	Steel plate
Reinforcing Steel	t Co2e/t	1.61	Steel reinforcing bar

Note 1: Source is ISCA IS Rating Tool Materials Calculator



(Note: vegetation clearing - 2% contribution - is missing from the legend.)



The carbon footprint of the materials amounts to 53,828 t CO_2e, while all other components have a footprint of 28,592 t CO_2e, resulting in a combined footprint of 82,420 t CO_2e.

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Energetics is a carbon neutral company

Appendix 2 - Ecopoint Summary

Material	% SCMs in Concrete	Quantity Used in SVC Package, Substantial Detailed Design (m3)	Tonnes	ISCA Materials Calculator Selection Name	EcoPoints
Concrete 5 Mpa	60%	905	101.36	Concrete 20MPa with 60% SCM	7.79
Concrete 20 Mpa	60%	1060	118.72	Concrete 20MPa with 60% SCM	9.13
Concrete 25 Mpa	60%	6580	815.92	Concrete 25MPa with 60% SCM	67.39
Concrete 32 Mpa	50%	73	13.14	Concrete 32MPa with 50% SCM	1.37
Concrete 40 Mpa	45%	710	171.82	Concrete 40MPa with 40% SCM	23.59
40 Mpa Shortcrete	20%	1037	365.024	Concrete 40MPa with 20% SCM	59.43
No Fines	30%	563	141.876	Concrete 32MPa with 30% SCM	17.65
40 Mpa B1 - Precast GP/FLYASH	30%	7202	2218.216	Concrete 40MPa with 30% SCM	332.85
50 Mpa B1 - Precast GP/FLYASH	30%	37137	14297.745	Concrete 50MPa with 30% SCM	2676.16
40 Mpa B1/B2 - in-situ GP/SLAG	65%	16457	2534.378	Concrete 40MPa with 60% SCM	283.3
50 Mpa B1/B2 - in-situ GP/SLAG	65%	2813	541.5025	Concrete 50MPa with 60% SCM	74.4
Reinforcement Steel – rebar	NA		14161	Steel Reinforcing Bar	37544.71
Reinforcement Steel – mesh	NA		130	Steel Welded Reinforcement Mesh	369.6
Steel wire strands	NA		1751	Steel Round and Square Sections	3,924.33
				Total EcoPoints	45,391.7