Loy Yang B Power Station

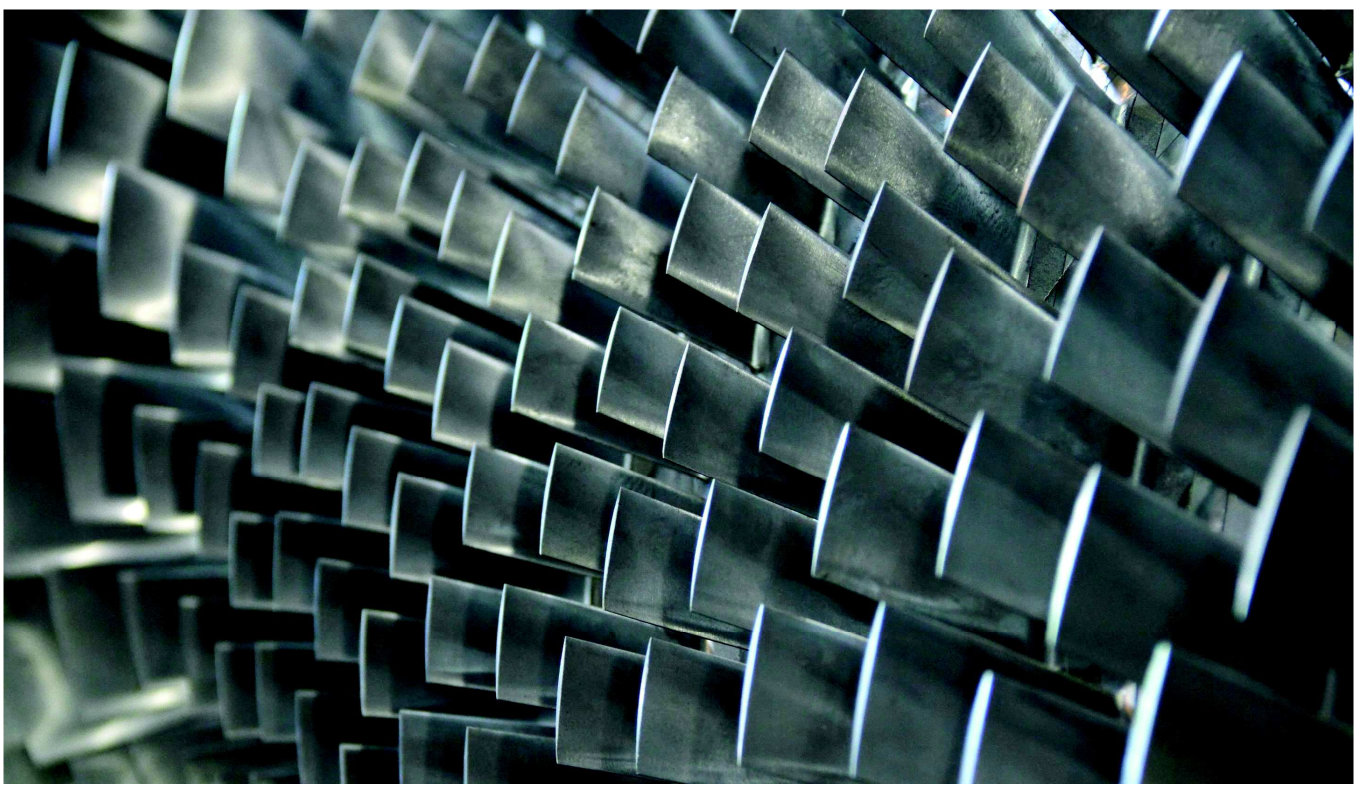
IPM Operations and Maintenance Loy Yang Pty Ltd

Turbine Retrofit Project

Energy Use and Greenhouse Gas Emissions Assessment

IS157800.RPT.R00 | Rev 0

15 August 2016



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1. Introduction

1.1 General introduction

This report outlines the findings of an energy use and greenhouse gas (GHG) emissions assessment for the Turbine Retrofit Project at Loy Yang B Power Station (LYB) in Gippsland, Victoria. This report has been prepared by Jacobs Group (Australia) Pty Limited (Jacobs) in support of IPM's Work Approval Application (WAA) to the Victorian Environment Protection Authority (Vic EPA). The objective of this report was to demonstrate how the proposed retrofit to LYB Units 1 and 2 turbines (the Project) meets the requirements of Victorian environmental legislation. It focuses on the requirements of the Victorian *State Environment Protection Policy (Air Quality Management)* 2001 (SEPP AQM) and the requirements of the *Protocol for Environmental Management – Greenhouse gas emissions and energy efficiency in industry 2002* (PEM).

The Project will require energy during construction and operation, and will also give rise to energy-related emissions of GHGs through its life cycle. The assessment aims to provide the necessary information supporting the WAA. In general, this included assessment and discussion of:

- Commonwealth and State government frameworks and responses to the management of greenhouse gases
- Expected energy and non-energy related greenhouse gas emissions from the Project, including study boundaries, calculations methodologies and activity data
- Demonstration of compliance with the requisite regulatory requirements
- Implementation of 'best practice' and eco-efficient practices with respect to GHG emissions and energy consumption.

Whilst the study focused on the construction and operation of the Project, the study boundary included emissions associated with production and supply of construction materials and also included an analysis of GHG intensity both with, and without the Project, as well as a consideration of "Best Practice" with respect to emissions and intensity.

1.2 Project description

This project would see the steam turbine on each of LYB's two (2) generating units retrofited with a higher efficiency design turbine combined with the ability to utilise spare boiler steam producing capacity. The new steam turbines will provide improved station efficiency, with increased power output capacity.

The resultant improved GHG emissions intensity of LYB following the retrofit will see LYB placed as the most efficient base-load generator in Victoria with a 5% reduction from 1.23 to 1.17 $TCO_{2\text{-}e}$/MWhr sent out power.

The increased efficiency will result from the design concepts outlined in **Table 1.1.**

Table 1.1 : Turbine Retrofit design concepts

<table>
<tr><th colspan="2">1. Improved turbine blading and seal design</th></tr>
<tr><td>

- New rotating and fixed blades utilising advanced blade design to minimise frictional losses on the blade profiles. The newer blade designs are able to extract additional energy out of the steam, thereby improving the turbine efficiency.

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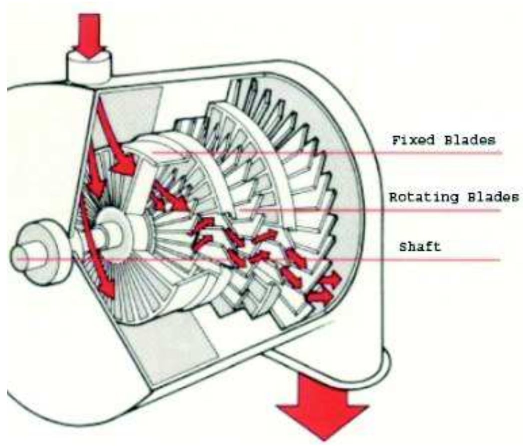

Rotating blades are attached to the shaft
Fixed blades are attached to the casing

</td></tr>
<tr><th colspan="2">2. Two extra High Pressure (HP) turbine stages</th></tr>
<tr><td>

- The steam in a turbine is expanded in mutiple stages, with each stage consisting of a fixed set of blades, and a rotating set of blades. The HP turbine has room for an additional two (2) stages, which will improve the expansion efficiency.
- To facilitate fitting the additional two stages, a new HP turbine inner shell (casing) is required.
  With an inner and outer shell, the intermediate spacing is filled with exhaust pressure steam. This permits thermal expansion, and reduces cost of materials, allowing each shell to be designed for lower pressure and temperature differences.

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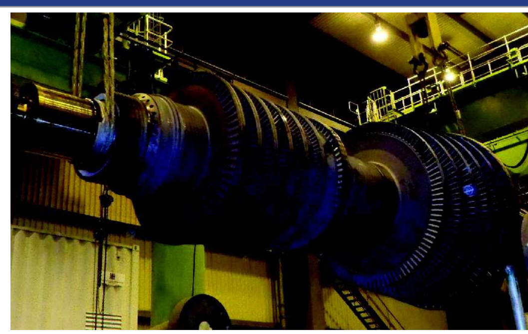

Photo of rotating blades in a high pressure / intermediate pressure turbine

</td></tr>
<tr><th colspan="2">3. Replacement of liners and seals to reduce steam leakage.</th></tr>
<tr><td>

- Steam which leaks around the blades, does not complete useful work on the blades. Newer seal designs which minimise this leakage, and guide the steam to expand through the blades, allow for an increase in the efficiency of the turbine.

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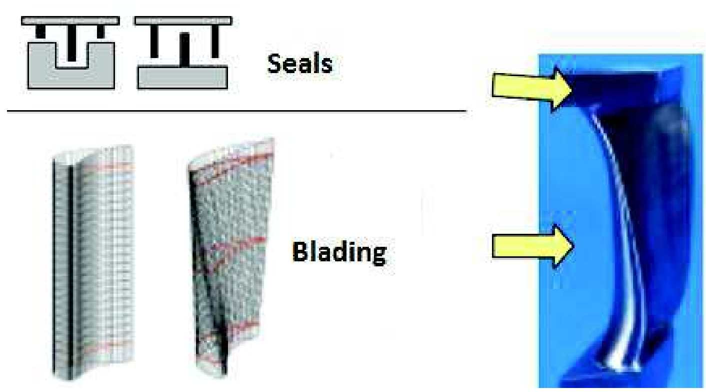

Seals minimuse steam leakage between the rotating blades and the casing

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</table>

The turbine efficiency (its ability to receive superheated steam and impart this mechanical force to the coupled generator) will increase by ~ 3.41%, as a result of the project with no change to the boiler efficiency.

The new turbine design will also provide an increased steam receiving capacity, such that additional steam flow admitted will enable further power to be generated. Spare steaming capacity within the current boilers will be utilised with no additional boiler upgrades required to supply a greater flow of steam to the turbine resulting in increased power output per unit up from 518MW (U1) and 508MW (U2) to 570MW gross output (corrected value).

1.3 GHG and climate change

The GHG inventory has been calculated in accordance with the principles of the Greenhouse Gas Protocol (GHG Protocol) by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) WBCSD; WRI 2004.

Greenhouses gases include:

- Carbon dioxide (CO_2) – by far the most abundant GHG, primarily released during fossil fuel combustion
- Methane (CH_4) – from the anaerobic decomposition of carbon based material (including enteric fermentation and waste disposal in landfills)
- Nitrous oxide (N_2O) – from industrial activity, fertiliser use and production
- Hydrofluorocarbons (HFCs) – commonly used as refrigerant gases in cooling systems
- Perfluorocarbons (PFCs) – used in a range of applications including solvents, medical treatments and insulators
- Sulphur hexafluoride (SF_6) – used as an insulator in heavy-duty electrical switchgear.

The key GHG relevant to this assessment were CO_2, CH_4 and N_2O.

The GHG emissions that form the inventory can be split into three categories known as 'Scopes'. Scopes 1, 2 and 3 are defined by the GHG Protocol and can be summarised as follows:

- Scope 1 – Direct emissions from sources that are owned or operated by a reporting organisation (examples – combustion of coal for the generation of electricity, combustion of diesel in company-owned vehicles or used in on-site generators).
- Scope 2 – Indirect emissions associated with the import of energy from another source (examples – import of electricity or heat).
- Scope 3 – Other indirect emissions (other than Scope 2 energy imports), which are a direct result of the operations of the organisation but from sources not owned or operated by them (examples include business travel (by air or rail) and product usage).

Figure 1.1 shows graphically the different GHG emission scopes.

The initial action for a greenhouse gas inventory is to determine the sources of GHG emissions assess their likely significance and set a provisional boundary for the study.

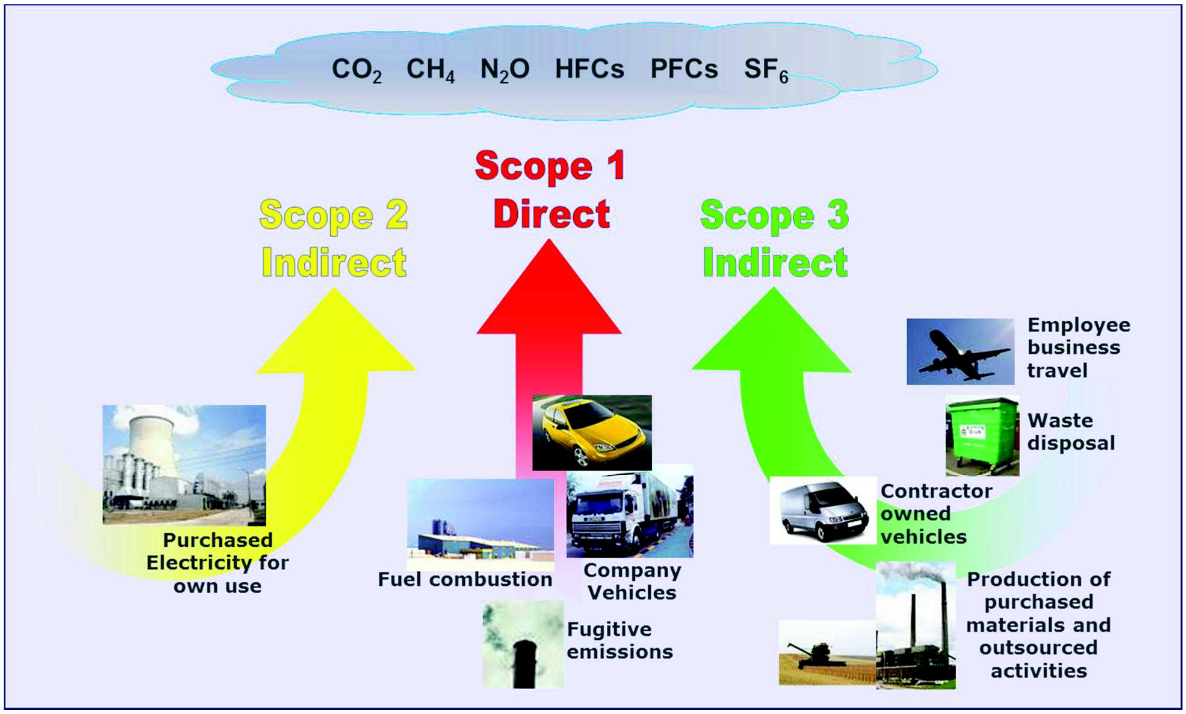

Figure 1.1 : Sources of greenhouse gases

1.4 IPM Greenhouse Gas Policy and reporting

IPM at an organisational level triggers the threshold for reporting under the *National Greenhouse Gas and Energy Reporting Act 2007* (NGER) and as such, reports the GHG emissions from its operations to the Commonwealth Government annually.

The Commonwealth Government, in turn uses NGER legislation for the measurement, reporting and verification of Australian greenhouse gas emissions. This legislation is used for a range of purposes, including international greenhouse gas reporting. Corporations which meet the threshold for reporting under NGER must register and report their greenhouse gas emissions.

IPM's approach to the greenhouse gas intensity of its operation is encapsulated in its Environmental Policy (June 2014 (*note IPM was formerly GDF SUEZ*)) - https://www.engie.com/wp-content/uploads/2014/06/gdf-suez-environmental-policy-january-2014.pdf, an extract of which is as follows:

> ***The Group environmental challenges***
>
> ***Greenhouse gases***
>
> *Climate change, caused by the rising concentration of greenhouse gases in the atmosphere, is recognized as one of the major threats to our planet in this century. The business model for energy producers has been so far focused on increasing generation capacities, which, how efficient they could be, emit greenhouse gases. Given the high weight of energy activities within its business, the Group has a responsibility to address this issue. At the same time, the shifts brought about by climate change pose a risk to the Group markets and to the operation of its facilities, and mean that adjustments are required. The Group addresses this twofold challenge by developing a diversified, balanced and market-oriented energy mix combining the lowest possible CO_2 content and flexibility. In addition, GDF SUEZ devises and implements energy efficiency solutions, and expands Research and Development into the capture and storage of CO_2. The Group contributes also to reduce emissions thanks to its waste-recovery processes.*

Managing energy

Managing energy consumption is a priority, addressing not only the issue of climate change but also that of the foreseeable depletion of some energy resources. On one hand, it's a matter of communication to educate people to consume energy wisely and, on the other hand, it involves managing demand as efficiently as possible, for example thanks to smart metering. The Group is active on various levels, by optimizing its own energy consumption, sensitizing its customers to rational use of energy, promoting highly efficient energy services as a world leader in its field, and investing in tomorrow's solutions such as "smart grids".

Renewable energies

Renewable energies are a key aspect of GDF SUEZ development and a dedicated renewable energy strategy is in place within the Group. They help preserve energy resources, meet energy needs and ensure security of supply, combat climate change and reduce various forms of pollution. The diversity of the Group businesses enables to set systematic approaches and overarching in order to manage environmental challenges more effectively. Renewable energies are a key component of these broad-based offers.

Saving resources

Beyond purely environmental concerns, saving resources is a factor of economic performance. The Group is committed to making savings in terms of the raw materials it uses and to developing the complementarity of its businesses in order to establish a circular economy wherever possible: promoting bio-methane is an example. To apply these principles in practice, the Group is looking into life-cycle projects and uses eco-designed products wherever possible.

The LYB Turbine Retrofit is consistent with, and delivers on these challenges in that it is specifically relevant to "greenhouse gases", "managing energy" and "saving resources".

1.5 Brief overview of current energy generation and GHG emissions

During years where there are no significant planned outages or downtime, the current LYB operations dispatch ~8,000,000 MWh energy per annum to the National Electricity Market (NEM). Dispatched or sent out generation to the network is the difference between the gross generation less the in-house or auxiliary energy required to operate the plant. Typically the in-house energy requirements for the station are around 7.2% of the gross output.

Annually LYB consumes an ~ 9,900,000 tonnes of coal with an equivalent of ~ 9,800,000 tCO_2e per annum. The current greenhouse intensity of the LYB site varies[1] between ~1.20 to 1.25 $TCO_{2\text{-}e}$ /MWh on a sent out basis.

Further detail is provided in Section 4.2.1.

[1] GHG intensity varies due to changes in generating profile, seasonal conditions, plant performance & availability and fuel quality.

2. Legislative requirements

2.1 Overview

This section presents the regulatory requirements against which the Victorian EPA assesses compliance of the WAA with GHG policy and legislation.

The facility is designated a Scheduled Premise under the Victorian *Environment Protection (Scheduled Premises and Exemption) Regulations 2007*. The Project is also subject to the Victorian *Climate Change Act 2010*. This requires EPA, when it makes a works approval determination, to understand the potential impacts on climate change. Clauses 18, 19 and 33 of the *State Environment Protection Policy (Air Quality Management (SEPP (AQM)) 2001* also set out the regulatory requirements the Project needs to comply with.

This is supported through the implementation of the Protocol for Environmental Management (PEM) - Greenhouse Gas Emissions and Energy Efficiency in Industry, 2002. The PEM is the mechanism by which EPA will assess compliance with the SEPP (AQM) 2001 policy principles.

2.2 State Greenhouse Gas Policy

2.2.1 Climate Change Act 2010

Victoria's primary policy driver for GHG emission reduction is the *Climate Change Act 2010* (CC Act) which came into effect on 1 July 2011.

The CC Act contains measures that support the management of and adaptation to climate risks and increases the ability of individuals, businesses and communities to capitalise on opportunities. It includes a requirement of the Victorian Government to develop a Climate Change Adaptation Plan every four (4) years to outline the potential impacts and risks associated with a changing climate. The first Victorian Climate Change Adaptation Plan was released in March 2013.

The Act also requires EPA to have regard to potential impacts on climate change when it makes a works approval decision.

2.2.2 Environment Protection Act 1970

State Environment Protection Policy (Air Quality Management) 2001 (SEPP AQM)

Protocol for Environmental Management (PEM): Greenhouse gas emissions and energy efficiency in industry (2002)

The *Environment Protection Act 1970* (EP Act) provides a legal framework to protect the environment in the State of Victoria. It applies to noise emissions and the air, water and land in Victoria. Under the EP Act, SEPP AQM is subordinate legislation made under the provisions of the EP Act to provide more detailed requirements for the application of the Act. Specifically relevant to GHG emissions, the Act includes:

- Clause 18 – General Requirements – including a definition of the management of emissions, generators of emissions and requirements to comply with the policy;
- Clause 19 – Requirements for the management of new sources of emissions
- Clause 33 – Requirements to implement the *Protocol for Environmental Management (PEM)* for GHG.

The Protocol for Environmental Management (PEM): Greenhouse gas emissions and energy efficiency in industry (2002) (PEM) is an incorporated document of SEPP AQM and specifies the steps that will need to be taken by businesses to demonstrate compliance with the policy principles and provisions of SEPP (AQM) related to energy efficiency and greenhouse gas emissions. The PEM is the regulatory instrument that is used to align GHG assessment methodology and approach with the requirements under the EP Act and SEPP AQM.

GHG assessment is required as part of an EPA works approval. Satisfying the objectives of SEPP AQM and the PEM will be met with the project's commitment to the implementation of best practice GHG abatement during construction and operation.

The PEM's objectives are as follows:

> *The protocol aims to ensure that Victorian businesses subject to EPA works approvals and licensing system that have an impact on the environment in terms of their energy consumption and greenhouse gas emissions (as defined in the protocol):*
>
> - *Take up cost-effective opportunities for greenhouse gas mitigation, noting that in many cases they will achieve cost savings through greater energy efficiency; and*
> - *Integrate consideration of greenhouse and energy issues within existing environmental management procedures and programs.*

The approach set out in the protocol is intended to support these objectives, in particular, by promoting integrated environmental management, including energy management. The protocol supports businesses in addressing the greenhouse implications (including energy use) of their activities, and assists them to respond in ways that will strengthen their long-term business sustainability.

The protocol also seeks to streamline procedures in order to minimise duplication of requirements with other programs in which a business may be involved, such as the Energy Smart Business Program of the Sustainable Energy Authority, and the Commonwealth's Greenhouse Challenge Program.

2.2.3 Victorian State Government Policy announcements

In early June 2016, the Victorian Government committed to legislating a long-term target for Victoria of net zero GHG emissions by 2050. A net zero target means that by 2050 Victoria's GHG emissions will be reduced as far as possible and any remaining emissions will be offset through carbon sequestration or avoidance initiatives. The Victorian Government has committed to setting interim targets every five years to 2050 to ensure this GHG emissions target is reached.[2]

2.3 Commonwealth Greenhouse Gas Policy

2.3.1 National Greenhouse and Energy Reporting Act 2007

The *National Greenhouse and Energy Reporting Act 2007* (NGER Act) provides for the reporting and dissemination of information related to GHG emissions, GHG projects, energy production and energy consumption.

IPM at an organisational and facility level exceeds the threshold for reporting under the NGER Act, and as such annually reports the GHG emissions from its existing operations to the Commonwealth Government. GHG emissions associated with operation of the Project will need to be reported under the NGER scheme.

2.3.2 Emissions Reduction Fund (ERF)

The Commonwealth Government's Direct Action Plan aims to focus on sourcing low cost emission reductions. The Direct Action Plan includes an Emissions Reduction Fund (ERF); legislation to implement the ERF came into effect on 13 December 2014 through the *National Greenhouse and Energy Reporting Act 2007* and amendments in the *Carbon Farming Initiative Amendment Act 2014*. The ERF is now considered to be the centrepiece of the Commonwealth Government's policy suite to reduce emissions.

Within the ERF, there is a safeguard mechanism which is designed to ensure that emission reductions credited, are not offset through increases elsewhere in the economy. The mechanism works through setting baseline for emissions for facilities, which emit over 100,000 tCO_2e annually (based on historical performance) and requiring

[2] http://www.delwp.vic.gov.au/news-and-announcements/net-zero-by-2050#sthash.NQB5n6Md.dpuf – Accessed June 2016

facilities to keep their emissions below this baseline. The mechanism includes methodologies for dealing with growth and exceptional circumstances and came into practice on the 1 July 2016.

Specific to the electricity sector, the safeguard mechanism takes a sectoral approach for grid connected generators – i.e. a baseline is set for all generators, given that their operations and therefore emissions are often dependent on each other's activity. The electricity sectoral baseline is set at 198 mtCO_2e, based on the high-point in annual emissions from the sector between 2009-10 and 2013-14. Should the sectoral baseline be exceeded, individual facility limits will come into force for generators. A facility would then need to acquit liability for the difference between their limit and actual reported value in Australian Carbon Credit Units (ACCU's). IPM has advised that LYB has a safeguarding mechanism baseline of 9,759,255 tCO_2e.

2.4 International framework

On 3 December 2007, the Commonwealth Government signed the instrument of ratification of the Kyoto Protocol. Australia has met its Kyoto Protocol target of limiting emissions to 108 percent of 1990 levels, on average, over the Kyoto period 2008–2012. Over the five reporting years in the Kyoto period (2008 to 2012), Australia's net emissions averaged 104 percent of the base year level (CCA: 2014). Australia had committed to reducing its GHG emissions by 5 percent below 2000 levels by 2020, however more recently a 2030 target was announced.

In August 2015, the Commonwealth Government committed to a new target to reduce emissions by 26-28% by 2030 below 2005 levels. This target represents a 50–52 percent reduction in emissions per capita and a 64–65 per cent reduction in the emissions intensity of the economy between 2005 and 2030.

The Commonwealth Government has stated that Australia's 2030 target is achievable with Direct Action (refer to Section 2.3.2) with policies that reduce emissions, increase energy productivity and improve the health of soils and the environment.

3. Methodology

This section outlines the scope and boundary of the study, the methodology as outlined in the PEM GHGs and various sources of emissions within that boundary, details emissions factors used and the process of calculating emissions for the project. The greenhouse gas inventory has been prepared in accordance with:

- The Greenhouse Gas Protocol (GHG Protocol) by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)
- ISO 14064-1:2006 Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals.

Section 2.1 of PEM sets out compliance requirements for new applicants as follows:

- Step 1 – Estimate energy consumption– annual energy consumption by energy type and associated GHG emissions
- Step 2 – Estimate direct (non-energy related) GHG emissions
- Step 3 – Identify and evaluate opportunities to reduce greenhouse gas emissions. As the project will use more than 500GJ of energy per annum, best practice must be identified and implemented
- Step 4 – Document the information generated in Steps 1 – 3.

3.1 Scope and boundary

The scope of this study is a greenhouse gas assessment of the proposed turbine retrofit of Loy Yang B Units 1 and 2, including all material sources of emissions. Loy Yang B Units 1 and 2 are currently in operation, so the assessment makes a comparison of the proposed future operation with a current baseline of operation. The scope of the assessment includes all material emissions within the plant boundary.

The boundary therefore included all material source (and sinks) of emissions within the construction and operation (for approximately 29 years to 2047) of Loy Yang B Units 1 and 2, based on commencement of operation in 2019/2020.

3.2 Sources of emissions

The following sections identify the emission sources for construction and operation, separately, and as per PEM requirements identify those emissions which are related to energy consumption, and those that are non-energy related.

Key construction emissions included:

- Fuel used to deliver construction materials to site
- Emissions associated with the extraction and manufacture of construction materials.

Key operation emissions included:

- GHG emissions from the combustion of brown coal.

There would be other non-material emissions associated with construction and operation, and these are discussed in the following sub-sections including the rationale for excluding any emissions from the project boundary. As discussed previously, emissions are categorised as follows:

- Scope 1 – Direct emissions from sources that are owned or operated by a reporting organisation (examples – combustion of coal for the generation of electricity, combustion of diesel in company-owned vehicles or used in on-site generators)
- Scope 2 – Indirect emissions associated with the import of energy from another source (examples – import of electricity or heat).

- Scope 3 – Other indirect emissions (other than Scope 2 energy imports) which are a direct result of the operations of the organisation but from sources not owned or operated by them (examples include business travel (by air or rail) and product usage).

3.2.1 Construction

Table 3.1 identifies the sources of GHG emissions for construction of the proposed retrofits at Loy Yang B.

Table 3.1 : Sources of emissions – construction

Source	Greenhouse Gases	Included	Scope		
			1	2	3
Energy Related Emissions					
Construction Fuel – Civil Works*	CO_2, N_2O, CH_4	x	●		●
Construction Fuel – Structural, Mechanical, Piping / Electrical & Instrumentation*	CO_2, N_2O, CH_4	x	●		●
Material Deliveries	CO_2, N_2O, CH_4	✓			●
Construction Materials – Embedded Emissions ***	CO_2e	✓			●
Employee Commuting*	CO_2, N_2O, CH_4	x	●		●
Non-Energy Related					
Loss of carbon stored in vegetation*	CO_2	x	●		

* Excluded on the basis of materiality

** Excluded on the basis that it is not applicable to the project

** Construction materials – embedded emissions will contain a mixture of fugitive process and energy related emissions. However, it is not feasible to separate these due to the emissions factors used, which do not separate the individual GHGs or provide a breakdown of the process steps which give rise to these gases (and whether they are energy related or not)

3.2.2 Operation

Table 3.2 identifies the sources of GHG emissions for operation of the LYB Power Station. The emissions are the same as those reported under NGER by IPM.

Table 3.2 : Sources of emissions – operation

Source	Greenhouse Gases	Included	Scope		
			1	2	3
Energy Related Emissions					
Brown Coal Consumption	CO_2, N_2O, CH_4	✓	●		●
Natural Gas Consumption	CO_2, N_2O, CH_4	✓	●		●
Diesel (Stationary) Consumption	CO_2, N_2O, CH_4	✓	●		●
Diesel (Transport) Consumption	CO_2, N_2O, CH_4	✓	●		●
LPG (Stationary) Consumption	CO_2, N_2O, CH_4	✓	●		
Petrol (Transport) Consumption	CO_2, N_2O, CH_4	✓	●		●
Electricity Purchased from the Grid	CO_2e	✓		●	
Acetylene*	CO_2, N_2O, CH_4	X	●		●
Oils and Greases*	CO_2e	X	●		●

Source	Greenhouse Gases	Included	Scope		
Non-Energy Related					
Fugitives - SF_6 Emissions, Natural Gas Pipeline leakage*	CO_2e	X	-	-	-

* Excluded on the basis of materiality

It is noted that only the brown coal consumption is potentially affected by the retrofit. All other sources of emissions are assumed to stay the same.

3.3 Emissions factors

Emissions factors are used to determine emissions of greenhouse gases from processes or activities, where it is impractical to directly measure (or model) emissions. Standard factors are published by numerous sources for a range of common emission-generating activities, and it is appropriate to use them in the calculation of greenhouse gas footprints where direct measurement is not possible or practical. Emissions factors for the activities considered in this assessment are presented in **Table 3.3**.

Table 3.3 : Emissions factors

Activity	Emissions Factor	Reference
Brown Coal Consumption	92.33 $kgCO_2e$ / GJ or 0.9867 tCO_2e / tCoal (Scope 1) 0.30 $kgCO_2e$ (Scope 3)	Scope 1 – NGER Method 2 (2014-15 LYB average) – refer below for calculation methodology Scope 3 – National Greenhouse Accounts Factors – August 2015
Natural Gas Consumption	50.59 $kgCO_2e$ / GJ (Scope 1) 3.9 $kgCO_2e$ (Scope 3)	Scope 1 – NGER Method 2 (2014-15 LYB average) Scope 3 – National Greenhouse Accounts Factors – August 2015
Fuel Combustion – Diesel – Stationary Use	2.721 $kgCO_2e$ / litre (Scope 1) 0.123 $kgCO_2e$ / litre (Scope 3)	National Greenhouse Accounts Factors – August 2015
LPG (Stationary) Consumption	59.90 $kgCO_2e$ / GJ 5.0 $kgCO_2e$ / GJ	National Greenhouse Accounts Factors – August 2015
Fuel Combustion – Diesel – Mobile Use	2.710 $kgCO_2e$ / litre (Scope 1) 0.123 $kgCO_2e$ / litre (Scope 3)	National Greenhouse Accounts Factors – August 2015
Fuel Combustion – Petrol – Mobile Use	2.319 $kgCO_2e$ / litre (Scope 1) 0.139 $kgCO_2e$ / litre (Scope 3)	National Greenhouse Accounts Factors – August 2015
Electricity Consumption – Purchased from Grid	1.18 $kgCO_2e$ / kWh (Scope 1) 0.15 $kgCO_2e$ / kWh (Scope 3)	National Greenhouse Accounts Factors – August 2015
Material Manufacture – Steel for Turbine and Associated Balance of Plant upgrades	2.12 (tCO_2e / tSteel) (Scope 3)	Bath Inventory of Carbon and Energy v2.0 – Jan 2011, Rest of World Steel (35.5% recycled). Steel Section used as a proxy.
Material Transport – Shipping, International Freight	0.00000891 tCO_2e / t.km	Infrastructure Sustainability Council of Australia (ISCA) 2016

* Note that Scope 3 emissions factors associated with fuel combustion relate to the upstream emissions associated with extraction and processing of the crude fuel.

The NGER methodologies for the calculation of GHG emissions provide four methods of calculation, Method 1 to Method 4, where Method 1 is the simplest, and applies direct National Greenhouse Account (NGA) emission factors as set out in **Table 3.3**. However, as relevant to Loy Yang B power station the NGER Determination states that:

Method 1 must not be used for estimating emissions of carbon dioxide for the main fuel combusted from the operation of the facility, if:

a) *the principal activity of the facility is electricity generation (ANZSIC industry classification and code 2611); and*

b) *the generating unit:*

   i. *has the capacity to produce 30 MW or more of electricity; and*

   ii. *generates more than 50 000 megawatt hours of electricity in a reporting year.*

In such circumstances a higher order method is required.

With respect to the calculation of GHG emissions from combustion of brown coal at Loy Yang B, the following provides an overview of the methodology applied by IPM, consistent with NGER methodologies.

Specifically Method 2 is derived from the methodologies published in the Technical Guidelines for the Generator Efficiency Standards program, released in December 2006 by the Australian Greenhouse Office, Department of Environment and Heritage and is designed to enable more accurate estimates of emissions to be made at a particular facility.

Under Method 2, representative and unbiased samples of fuels consumed must be obtained for analysis. Analysis of the fuels for carbon, energy, ash or moisture content must be done in accordance with listed Australian or international documentary standards or equivalent. These higher order methods provide a more accurate estimate of the carbon dioxide emissions than under Method 1, the default method.

Division 2.2.3 of the NGER Technical Guidelines (2014) also sets out a further choice for the estimation of emissions from solid fuel combustion, which is to estimate emissions with a) an assumed oxidation factor (sub-division 2.2.3.1) or b) to estimate the oxidation level by reference to additional information about the fuels combusted by the facility (Sub-division 2.2.3.2).

For sub-division 2.2.3.1, oxidation factors are drawn from default factors utilised in the National Greenhouse Accounts.

Once the analysis of the fuel for carbon, ash and moisture has been completed, emissions may then be estimated in accordance with the equations specified in Section 2.5 (1) or 2.6 (1).

1) *For subparagraph 2.3 (1) (a) (ii), method 2 is:*

$$E_{ico_2} = \frac{Q_i \times EC_i \times EF_{ico_2oxec}}{1\ 000} - \gamma RCCS_{co_2}$$

where:

- E_{ico2} *means the emissions of carbon dioxide released from the combustion of fuel type (i) from the operation of the facility during the year measured in* CO_2*e tonnes.*
- Q_i *is the quantity of fuel type (i) measured in tonnes and estimated under Division 2.2.5.*
- EC_i *is the energy content factor of fuel type (i) estimated under section 6.5.*
- $EF_{ico2oxec}$ *is the carbon dioxide emission factor for fuel type (i) measured in kilograms of* CO_2*e per gigajoule as worked out under subsection (2).*
- *γ is the factor 1.861 × 10 3 for converting a quantity of carbon dioxide from cubic metres at standard conditions of pressure and temperature to* CO_2*e tonnes.*
- $RCCS_{co2}$ *is carbon dioxide captured for permanent storage measured in cubic metres in accordance with Division 1.2.3.*

2) For $EF_{ico2oxec}$ in subsection (1), estimate as follows:

$$EF_{ico_2oxec} = \frac{EF_{ico_2ox,kg}}{EC_i} \times 1\,000$$

where:

- $EF_{ico2ox,\,kg}$ *is the carbon dioxide emission factor for fuel type (i) measured in kilograms of* CO_{2e} *per kilogram of fuel as worked out under subsection (3).*
- EC_i *is the energy content factor of fuel type (i) as obtained under subsection (1).*

3) For $EFico_2ox$, kg in subsection (2), work out as follows:

$$EF_{ico_2ox,kg} = \frac{C_{ar}}{100} \times OF_s \times 3.664$$

where:

C_{ar} *is the percentage of carbon in fuel type (i), as received for the facility or as combusted from the operation of the facility, worked out under subsection (4).*

OF_s*, or oxidation factor is:*

a) *if the principal activity of the facility is electricity generation — 0.99; or*

b) *in any other case — 0.98.*

4) *For Car in subsection (3), work out as follows:*

$$C_{ar} = \frac{C_{daf} \times \left(100 - M_{ar} - A_{ar}\right)}{100}$$

where:

- C_{daf} *is the amount of carbon in fuel type (i) as a percentage of the dry ash free mass of the fuel estimated using the sampling and analysis provided for in Subdivision 2.2.3.3.*
- *Mar is the amount of moisture in fuel type (i) as a percentage of the as received or as combusted mass of the fuel estimated using the sampling and analysis provided for in Subdivision 2.2.3.3.*
- *Aar is the amount of ash in fuel type (i) as a percentage of the as received or as fired mass of the fuel estimated using the sampling and analysis provided for in Subdivision 2*

For the purposes of annual NGER reporting GHG emissions are calculated based on actual measurement of brown coal received (weightometer), brown coal analysis including carbon, ash, moisture and energy content based on automated composite sampling and dispatched generation to the network in MWHrs. This is consistent with the requirements of Method 2 under NGER.

Forward estimations of GHG emissions are based on a historic emission factor of 0.9867 tonnes CO_2e per tonne of coal consumed. This emission factor has been calculated in accordance with the NGER methodology set out above. Based on changes to overall station efficiency (combination of boiler & turbine efficiency) in conjunction with future estimates of electrical generation dispatched, total energy requirements can be calculated. Long-term average calorific values of the brown coal then allow the quantity or tonnes of brown coal to be determined to achieve that generation. Lastly the emission factor of 0.9867 is multiplied by the coal tonnages to estimate the projected GHG emissions into the future.

For all other emission sources where there is no change between pre and post-project emissions are based on the 2014-15 NGER reporting year.

4. PEM Step 1 – Energy use and greenhouse gas emissions

This section details current and expected energy use respectively, including the types of energy or fuel used, the annual quantity of each, and the associated GHG emissions. This section is split up into the following sections:

Section 4.1 – Energy consumed during construction (associated with the project)

Section 4.2 – Energy consumed during operation, including both current operations (pre-project) and after implementation of the project (post-project).

4.1 Construction

Construction of the Project involves the retrofitting of turbine components and associated balance of plant upgrades. Whilst energy will be consumed to support the project process itself on site, this is not projected to be significant, and the major source of emissions is expected to be associated with embodied emissions in steel used for construction. The mass of steel used during construction was derived from current (Hitachi) components, as technical details were not available for the replacement equivalent at the time of reporting. It is noted that there will be minor variation in the mass of components, but this is not expected to be material.

A standard emissions factor for steel manufacture has been used in the absence of available emissions factors for the specific parts being used in the project. This is intended to provide an assessment of materiality of these emissions in the context of the life cycle emissions of the Project, as it is noted later in the report that construction emissions are immaterial in the context of both annual and life cycle operational emissions.

In addition to emissions associated with steel for component manufacture, emissions associated with international shipping of the materials are also presented. Again, due to expected materiality of these emissions, no additional transport emissions are modelled. It is assumed that the majority of the turbine components will be manufactured and shipped from Europe. Last stage blading of the LP Rotor will be likely manufactured and shipped from China.

Both embodied emissions in manufactured components and emissions from shipping are classified as being related to energy use.

A breakdown of the results by greenhouse gas source is presented in **Table 4.1** and **Figure 4.1.**

Table 4.1 : Construction embodied energy-related emissions summary – by source

Element	Quantity (Embodied Energy)	Scope 3 GHG Emissions (tCO_2e)	Total GHG Emissions (tCO_2e)
HIP Rotor (x2)	56t	59.36	59.36
HP inner casings (x2)	48t	50.88	50.88
IP inner casings (x2)	22t	23.32	23.32
LP Rotor (x2)	122t	129.32	129.32
Diaphragms and diffusers (x2)	74t	78.44	78.44
Bolting	50t	53.00	53.00
Balance of Plant	9t	19.21	19.21
International Shipping (Assumed delivery from Europe)	11,913,795 t.km	106.13	106.13
Total		**517**	**517**

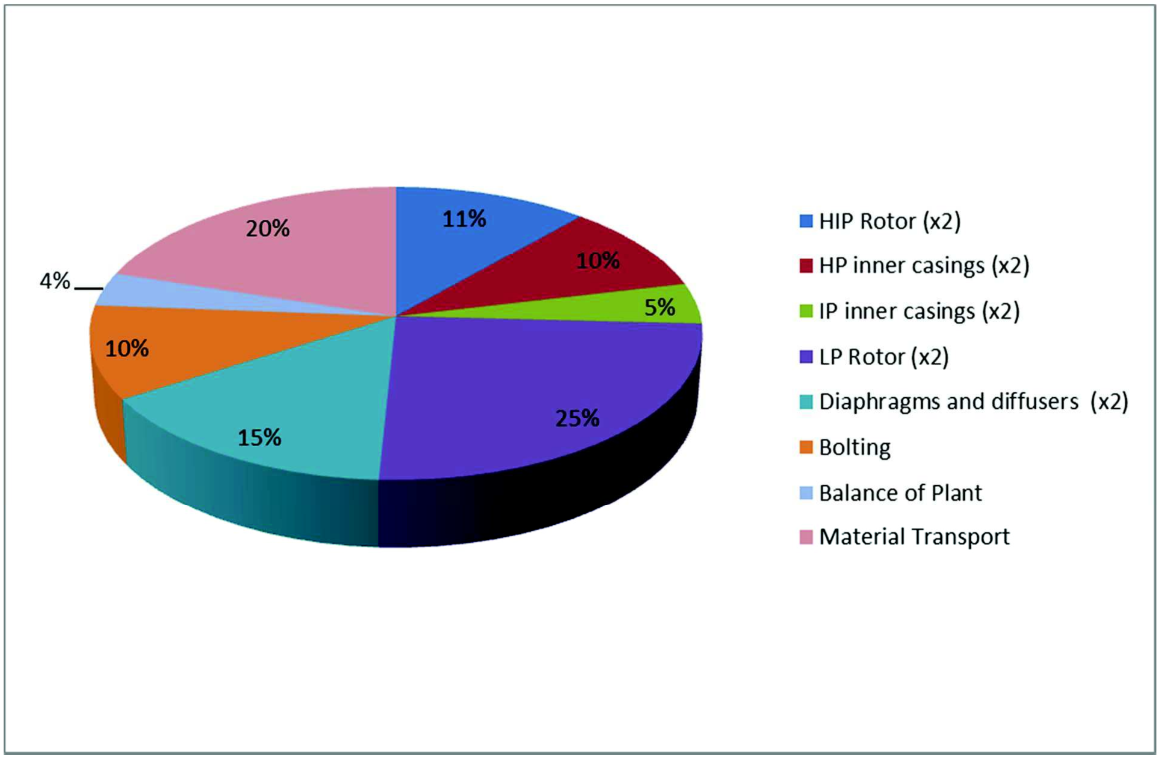

Figure 4.1 : Breakdown of construction phase GHG emissions

4.2 Operation

This section presents both the current pre-retrofit emissions profile of LYB, and the future emissions profile associated with the proposed turbine retrofit.

4.2.1 Loy Yang B Power Station pre-retrofit

A breakdown of the current energy consumption and greenhouse gas emissions by source is presented in **Table 4.2** and **Figure 4.2**.

Table 4.2 : Annual operational energy-related emissions summary – by source

Activity	Energy Consumption (GJ)	Scope 1 GHG Emissions (tCO_2e)	Scope 2 GHG Emissions (tCO_2e)	Scope 3 GHG Emissions (tCO_2e)	Total GHG Emissions (tCO_2e)
Brown Coal Consumption	87,919,470	9,791,212		26,376	9,817,588
Natural Gas Consumption	67,721	3,424		264	3,688
Fuel Combustion – Diesel – Stationary Use	81	6		0.26	6
LPG (Stationary) Consumption	105	6		0.52	7
Fuel Combustion – Diesel – Mobile Use	601	42		2	44
Fuel Combustion – Petrol – Mobile Use	242	16		1	17
Electricity Consumption – Purchased from Grid	5,681		1,932	237	2,169
Total	**87,993,901**	**9,794,706**	**1,932**	**26881**	**9,823,519**

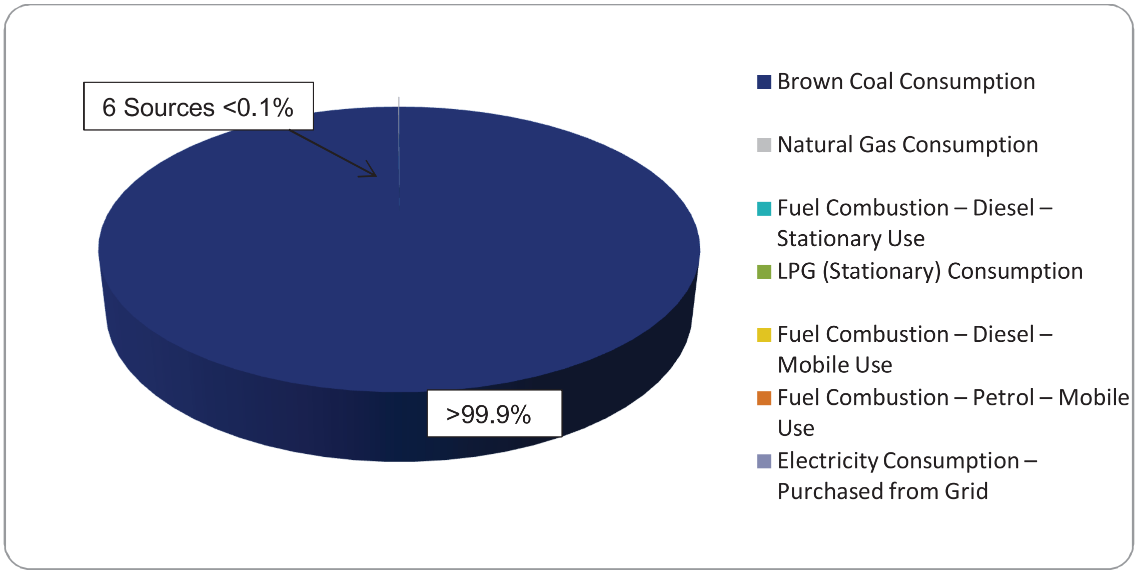

Figure 4.2 : Current operation energy / emissions summary – by source

Figure 4.2 shows that >99% of the operational emissions are from brown coal combustion. Annual direct (energy-related) emissions are in the order of 9,800 ktCO_2e / annum, and when indirect emissions are added, this rises to ~9,820 ktCO_2e / annum.

4.2.2 Loy Yang B Power Station post-retrofit

Units 1 and 2 steam turbines are scheduled for a major overhaul in 2019 / 2020, respectively. Major overhaul events occur six (6) yearly. Smaller overhaul events occur at 18 month and three (3) yearly cycles; these are insufficient in duration to undertake signficant works like a steam turbine retrofit. The opportunity exists to take advantage of the next major overhaul outage (plant shutdown) and improve the performance of the turbine at the same time. It is proposed to retrofit each unit's turbine blading and seals to give improved plant output capacity (MW) and increase their efficiency. The units currently can operate at 508 / 518 MW (corrected values), and it is proposed to increase this to 570MW. The improved output capacity is achieved through a combination of improved blading/seal design (the efficiency component of the project) plus the ability to receive additional steam mass flow from the boiler further increasing the generating output. The capability to provide additional steam mass flow already exists but is currently not utilised due to limitations on the existing steam turbines steam receiving capacity. No upgrades are required to the boiler to produce this additional steam mass flow. Should the total 8.6% increase in annual generation be utilised, an annual increase in coal usage of ~3.3% is projected.

Two additional stages will be added to the high pressure turbine, which will require the installation of a new inner casing. Key items of plant that require no upgrades include the turbine outer casings or shell, generator, condenser, valving, feedheaters, cooling systems and the control system. The following will receive minor capacity upgrades: boiler feedpumps, safety valves and flue gas induced draft fans, cooling water pumps to accommodate the additional steam mass flow, coal and flue gas increases. All other plant equipment, including coal conveyors, ash handling, electrostatic precipitators have been assessed and will be able to accommodate the additional coal and subsequently projected ash/dust increases.

A breakdown of the future energy consumption and greenhouse gas emissions by source is presented in **Table 4.3** and **Figure 4.3**.

Table 4.3 : Future annual operational energy-related emissions summary – by source

Activity	Energy Consumption (GJ)	Scope 1 GHG Emissions (tCO_2e)	Scope 2 GHG Emissions (tCO_2e)	Scope 3 GHG Emissions (tCO_2e)	Total GHG Emissions (tCO_2e)
Brown Coal Consumption	90,785,548	10,110,395		27,236	10,137,631
Natural Gas Consumption	67,721	3,424		264	3,688
Fuel Combustion – Diesel – Stationary Use	81	6		0	6
LPG (Stationary) Consumption	105	6		1	7
Fuel Combustion – Diesel – Mobile Use	601	42		2	44
Fuel Combustion – Petrol – Mobile Use	274	16		1	17
Electricity Consumption – Purchased from Grid	5,681		1,932	237	2,168
Total	**90,860,011**	**10,113,889**	**1,932**	**27,740**	**10,143,561**

Figure 4.3 shows that ~99.9% of the operational emissions are from brown coal combustion. Annual direct (energy related) emissions are 10,114 $ktCO_2e$ / annum, and when indirect emissions are added, this rises to 10,144 $ktCO_2e$ / annum.

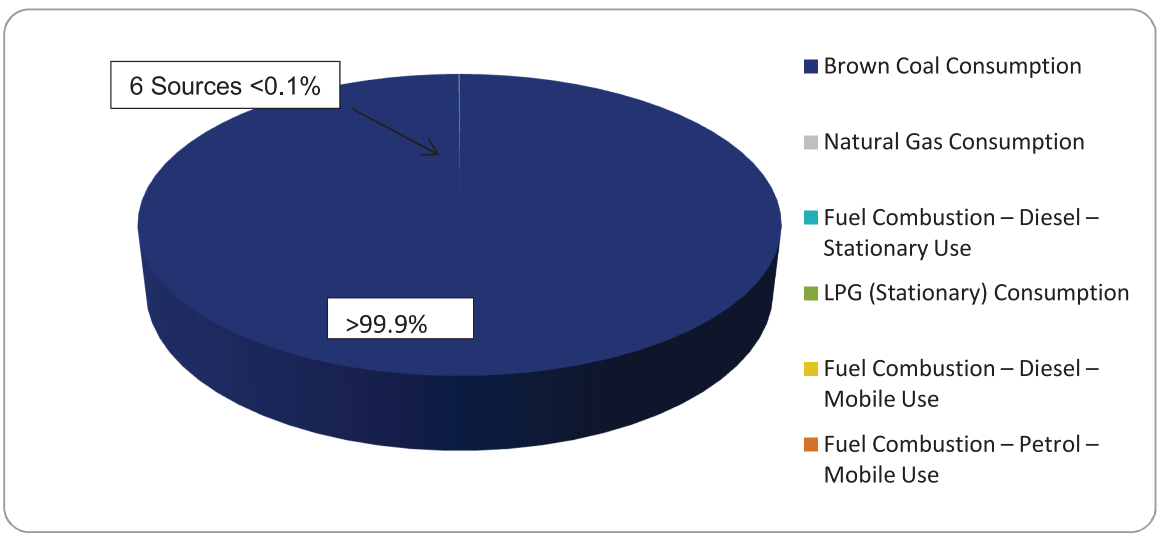

Figure 4.3 : Future operation energy / emissions summary – by source

As previously noted – the direct emissions (and specifically those from brown coal combustion) represent ~99.9% of the emissions and are therefore the only material source for consideration.

5. PEM Step 2 – Non-energy related greenhouse gas emissions

Based on the activities identified as being within the scope of this assessment – no non-energy related emissions are material, and this step is therefore not required to be completed.

6. PEM Steps 1 and 2 – Cumulative emissions profile

6.1 Emissions profile

Based on forward projections[3] the cumulative emissions from construction and brown coal combustion over the lifetime of the project are presented in **Table 6.1**. Variances occur largely due to programmed maintenance intervals of varying durations and frequency. Should the total 8.6% increase in annual generation be achieved GHG emissions are projected to increase ~3.3% above existing. Note that comparisons in any given year are not representative, due to change in outage schedule and planned generation profile.

Table 6.1 : Cumulative emissions summary

	Construction emissions (tCO_2e)	Fugitive Emissions (tCO_2e)	TURBINE RETROFIT Energy-Related emissions if maximum increased generation is realised (brown coal combustion) (tCO_2e)	DO NOTHING Energy-Related emissions (brown coal combustion) (tCO_2e)
Construction (2019 / 2020)	517	NA		
2021		NA	10,268,681	9,933,933
2022		NA	10,266,979	9,932,287
2023		NA	9,975,627	9,650,432
2024		NA	10,124,170	9,794,133
2025		NA	10,266,979	9,932,287
2026		NA	10,151,460	9,820,534
2027		NA	10,268,681	9,933,933
2028		NA	9,826,861	9,506,516
2029		NA	9,689,382	9,373,519
2030		NA	10,268,681	9,933,933
2031		NA	10,266,979	9,932,287
2032		NA	10,004,395	9,678,263
2033		NA	10,095,402	9,766,303
2034		NA	10,266,979	9,932,287
2035		NA	10,151,460	9,820,534
2036		NA	10,297,449	9,961,763
2037		NA	9,651,566	9,336,936
2038		NA	9,544,983	9,233,827
2039		NA	10,268,681	9,933,933
2040		NA	10,295,747	9,960,117
2041		NA	9,975,627	9,650,432
2042		NA	10,095,402	9,766,303
2043		NA	10,266,979	9,932,287
2044		NA	10,180,228	9,848,364
2045		NA	10,268,681	9,933,933

[3] Forward projections based on an on-going baseload profile of generation.

	Construction emissions (tCO_2e)	Fugitive Emissions (tCO_2e)	TURBINE RETROFIT Energy-Related emissions if maximum increased generation is realised (brown coal combustion) (tCO_2e)	DO NOTHING Energy-Related emissions (brown coal combustion) (tCO_2e)
2046		NA	10,091,147	9,762,187
2047		NA	10,151,460	9,820,534
Total Lifetime Emissions (all Scopes)	**517**	**NA**	**272,980,668**	**264,081,795**

6.2 GHG intensity

The turbine retrofit will improve the GHG emissions intensity of LYB (1.23 to 1.17) tCO_2e / MWh as a direct result of a more efficient turbine design. Should the total increase in annual generation be achieved the absolute GHG emissions from the LYB facility are projected to increase by ~3.3%.

6.2.1 Intensity pre-retrofit

Pre-retrofit, LYB is projected to generate annually an average of ~8,000,000 MWh sent out (2016 – 2019 projections). Greenhouse gas emissions from brown coal combustion over this period are projected to be an average of ~9,800,000 tCO_2.e per annum. This gives a greenhouse gas intensity of ~1.23 tCO_2e / MWh sent out.

6.2.2 Intensity post-retrofit

Should the total increase in annual generation be achieved post-retrofit, LYB is projected to generate an average of 8,690,000 MWh sent out (2021 – 2047 average) and GHG emissions from brown coal combustion over this period are projected to be an average of 10,167,000 tCO_2e per annum.

This gives a greenhouse gas intensity of 1.17 tCO_2e / MWh sent out, which is an improvement in greenhouse intensity of approximately 5%.

7. PEM Step 3 – Best Practice energy and greenhouse gas management

7.1 Best Practice considerations

An assessment of Best Practice is outlined in the Works Approval Application (WAA), consistent with the requirements of *EPA Publication 1517– Demonstrating Best Practice*.

A number of options for reducing greenhouse gases from LYB were considered. These are outlined in **Table 7.1** below.

Table 7.1 : Summary of Best Practice considerations for each project option

Option	Best Practice analysis of each project option	Best Practice assessment
Option 1	Do Nothing This option would still require an overhaul of the turbines in 2019.	This option does not achieve any improvement in GHG emissions from the site, or improvement in carbon intensity per unit of energy generated.
Option 2	Increase boiler efficiency only To increase boiler efficiency would require installation of a 'flue gas to feedwater heat exchanger. This would extract current waste heat losses from the boiler flue gas to offset the need for low pressure pre-heating steam of the feedwater. This requires additional equipment including heat exchanger, pipework and requires integration into the existing steam cycle. This has not been undertaken by any Australian brown coal fired power station.	This upgrade would still require an overhaul of the turbines in 2019, and the benefits would be at a much higher cost. IPM reports that there is no viable economic business case for this option.
Option 3	Use of modified brown coal only (partial coal drying) An increase in boiler efficiency could also be made by a partial coal moisture reduction by installing drying technology such as fluidised bed drying (FBD). The existing boiler design (without substantial modifications) is suitable for minimum coal moisture of 55%.	A reduction in coal moisture from 60% to 55% would provide a reduction in coal consumption of approximately 5%. (Further reductions to coal moisture are possible, however would require significant capital modifications to the boiler). IPM reports that this option has been assessed with no viable business case.
Option 4	Retrofit turbines without increasing power generation capacity Upgrading the turbine (retaining 531MW maximum gross output) without increasing power generation capacity was considered. This was applied at Liddell and Yallourn Power Stations.	Achieves decrease in GHG emissions intensity of the plant and should lower total coal usage and total GHG emissions. Does not allow for additional electricity produced at an improved GHG intensity. IPM reports that the "business case not comparable with Option 5 and would require the introduction of operational limitations that do not currently exist in the plant".
Option 5	Retrofit turbine and increase power generation capacity by 70MW, with additional coal consumption This option involves upgrading steam turbine blading and seals. It also involves consumption of approximately 3.3% additional coal through upgrading the boiler, dependant on maximum generation output (market demand). This has been applied at several power stations in Australia, including Loy Yang A, Mt Piper, Eraring and Stanwell power stations. These turbine retrofits have improved both capacity and efficiency.	Achieves a decrease in GHG emissions intensity (tCO_2/MWh) of the plant. Increase total coal usage and GHG emissions on a mass basis ($t\ CO_2$). Allows for additional electricity produced at an improved GHG intensity.

Option	Best Practice analysis of each project option	Best Practice assessment
Option 6	Complete replacement of boiler and turbine components New advanced super critical or ultra-super critical boiler designs operating at higher pressure and steam temperatures achieve higher net thermal efficiency outputs than the present design.	This would essentially require a new power station to be designed and built. There is no business case for completing this option.
Option 7	Co-Firing with natural gas LYB has access to limited quantities of natural gas to allow unit start up and shut down. Reduce coal consumption (and GHG emissions) by offsetting with the use of natural gas.	The market price of natural gas means this option is not financially viable. Firing natural gas in a boiler-turbine is not best practice for power generation. It only results in replacement of one non-renewable energy source with another.
Option 8	Increase Turbine Capacity with no efficiency improvement Replace existing turbine with increased steam receiving capacity allowing increased generation output but without any changes to design (no efficiency improvement).	A business case may be viable however without any efficiency gains there are no environmental improvements.

Based on the results of the best practice assessment and commercial considerations, IPM chose to pursue Option 5.

Within Option 5, a number of specific technical sub-options exist, which are listed in **Table 7.2**. The retrofit of the turbine blading and seals was chosen as having best cost-benefit.

Table 7.2 : GHG emissions intensity reduction with capacity increase

Technology Option	Opportunities	Constraints	Further evaluation
Retrofit steam turbine blades and seals	• Moderate increase output • Small increase efficiency • Reuses turbine casing, generator, condenser, feedheaters • Approx. 0.5 percentage points increase in efficiency	• Capacity limited by boiler output, and cooling system • Efficiency limited by 6 stages of feedheating	This option was selected due to the balance between cost and environmental benefit
Retrofit steam turbine and 9 stages feedheating plant	• Higher increase to output • Higher increase in efficiency • Approx. 0.9 percentage points increase in efficiency	• Capacity limited by boiler output, and cooling system • Higher efficiency by increasing to optimum number of feedheating stages	Higher cost / complexity for little benefit over previous option No further evaluation required
New steam turbine generator and condenser, 560°C main steam and reheat conditions, boiler modifications	• Highest increase to output • Highest increase in efficiency • Approx. 1.3 percentage points increase in efficiency	• Capacity limited by boiler output • Requires new turbine, feedheaters, generator, condenser • Additional boiler reheat and superheat surface	Highest cost / complexity for little benefit over previous option. No further evaluation required.

Options to offset the additional 3.3% GHG emissions

The preferred option would increase plant efficiency, but also plant generation capacity. The increase in capacity would be realised through a 3.3% increase in the consumption of additional coal, and a corresponding 3.3% increase in GHG emissions. There are several options, which could allow the additional capacity to be utilised without an increase in overall annual GHG emissions. These include fuel substitution, reduced plant operation, or GHG offsets generated by other renewable power generation. These options are presented in **Table 7.3**:

Table 7.3 : GHG reduction from fuel substitution

Technology Option	Opportunities	Constraints	Further Evaluation
Natural gas substitution or co-firing with brown coal	• Full or partial conversion of boiler to natural gas	• Best practice for utilisation of NG for power generation is a Combined Cycle technology, not in a boiler / turbine. • High operating cost of NG	Not commercially viable as not cost competitive fuel for base load power generation in the NEM. Not considered a practical solution for GHG reduction practical. Firing natural gas in a boiler-turbine is not best practice for power generation
Biomass co-firing (~4%)	• GHG neutral as the CO_2 released from firing in a power plant, is re-absorbed by the regrowth of biomass • Uses existing coal mills • Waste woodchip from Gippsland timber mills • Woodchip from C&D waste • Wood has equivalent or higher calorific value than brown coal	• Long term access to waste wood supplies • Transport cost • Materials handling facilities required • Not available in sufficient quantities • Not a reliable feed stock	Not commercially viable or practical.
Offset with renewable power	• Add additional renewable generation	• Development application for new renewable generation	Engie continually evaluate opportunities to invest in renewable power developments. This will be a consideration pursued in the GHG Action (refer Appendix E1)
Reduced operation	• Reduce power plant capacity factor to ensure no net increase in coal consumption and emissions	• Reduction in off-peak revenue	IPM to evaluate. Currently the safe minimum unit load is 320MW. IPM is evaluating if this minimum load can be reduced further, with new low minimum generating set points for future operations.

7.2 Benchmarking greenhouse gas intensity

The GHG emissions intensity of LYB before retrofit is ~1.23 tCO_2e / MWh sent out, and post retrofit is projected to be ~1.17 tCO_2e / MWh sent out.

Table 7.4 provides details of other coal fired power projects in Australia, highlighting where LYB would sit pre and post-retrofit. GHG emissions intensity is implicitly linked to:

a) The boiler and turbine design

b) The fuel type

c) The generating profile.

On this basis comparisons of LY B can only be made with other brown coal fired power stations. Typically older power stations will have lower efficiencies due to original design and material considerations. LYB post retrofit will have the lowest GHG emissions intensity of any brown coal fired power station operating within the NEM.

Table 7.4 : Estimation of the greenhouse gas intensity and efficiencies of other coal fired power projects

State / System	Station	Scope 1 emission intensity (tonnes CO_2-e/MWh sent-out)	Capacity (gross MW)	Commissioned	State / System
QLD	Tarong North	0.846	443	2002	QLD
NSW	Mt Piper	0.850	1,340	1993	NSW
QLD	Stanwell	0.894	1,440	1995	QLD
QLD	Millmerran	0.898	851	2002	QLD
QLD	Kogan Creek	0.902	750	2007	QLD
NSW	Bayswater	0.905	2,720	1983	NSW
NSW	Eraring	0.910	2,880	1983	NSW
NSW	Vales Point B	0.913	1,320	1978	NSW
QLD	Tarong	0.916	1,400	1985	QLD
QLD	Callide B	0.927	700	1989	QLD
SWIS	Bluewaters	0.928	441	2009	SWIS
SWIS	Collie	0.931	333	1999	SWIS
QLD	Callide C	0.937	810	2001	QLD
SA	Northern	0.939	530	1985	SA
QLD	Gladstone	0.942	1,680	1980	QLD
SWIS	Muja D	0.942	454	1986	SWIS
SWIS	Muja C	0.970	398	1981	SWIS
NSW	Liddell	0.988	2,100	1972	NSW
VIC	Loy Yang B Post Retrofit	1.165	1,140	1995	VIC
SWIS	Worsley	1.197	0	1990	SWIS
VIC	Loy Yang A	1.211	2,180	1986	VIC
SWIS	Muja A&B	1.216	220	1968	SWIS
VIC	Loy Yang B Pre Retrofit	1.226	1,026	1995	VIC
VIC	Yallourn	1.417	1,538	1980	VIC
VIC	Hazelwood	1.522	1,640	1968	VIC

7.2.1 GHG inventory (comparison with State)

Should the total 8.6% increase in annual generation be achieved the total annual emissions from the project following retrofit will be an average of ~10,100 ktCO_2e per annum. In 2014, Victoria's state emissions were 118,100ktCO_2e / annum (with a longer term trend shown in **Figure 7.1**). Emissions from the project therefore represent 8.5% of Victorian state emissions at 2014 levels (assuming that emissions remain steady until the point of commissioning).

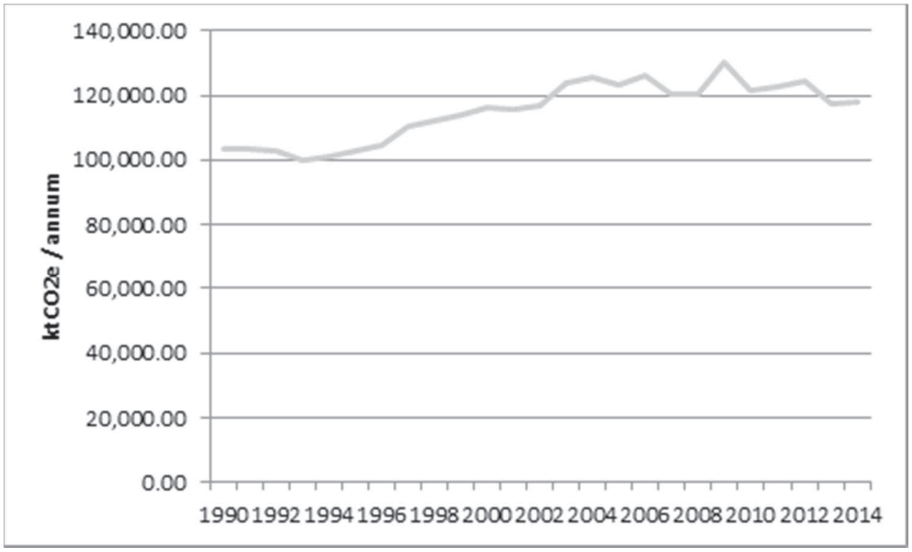

Figure 7.1 : Victoria greenhouse gas emissions - 1990 to 2014

7.3 Greenhouse gas management

Based on the decision to progress with the option to retrofit the turbines and increase in power capacity (Option 5), IPM is required by the PEM to consider options to manage and/or further reduce GHG emissions. These options will be outlined in the GHG Action Plan.

7.3.1 GHG action plan

IPM is committed to GHG management associated with the operation of LYB, and will prepare a GHG Action Plan consistent with the requirements of the PEM. The plan will be undertaken as follows:

- Stage One: Preparation of an Action Plan
  - Step 1: Conduct an energy audit (Level 2) and estimate energy consumption
  - Step 2: Estimate direct greenhouse gas emissions
  - Step 3: Identify opportunities to reduce greenhouse gas emissions
  - Step 4: Document steps 1 to 3
- Stage Two:
  - Step 5: Implementation of action plan
  - Step 6: Ongoing reporting to EPA
  - Step 7: Regular review.

A GHG Action Plan will be prepared and integrated within the Loy Yang B Environmental Management System framework. Environmental opportunity and improvement initiatives as they relate to 'identification of opportunities to reduce greenhouse gas emissions" will be tracked by the business and communicated to key stakeholders including the community through the annual Environment Improvement Plan (EIP) and stakeholder engagement strategy.

8. Conclusions

This assessment demonstrates how the Project meets the requirements of the SEPP AQM and the requirements of the *Protocol for Environmental Management – Greenhouse gas emissions and energy efficiency in industry 2002* (PEM) in support of IPM's WAA to the Vic EPA.

The total GHG emissions for construction of this project are 517 tCO2e. Should the total 8.6% increase in annual generation be utilised, the total GHG emissions for the site will be an average of 10,120,000 tCO_2e per annum following completion of the retrofit compared with the current average emissions of 9,800,000 tCO2e. This represents an average increase of 320,000 tCO2e.

The resultant improved greenhouse gas intensity of Loy Yang B following the retrofit will see it placed as the most efficient baseload generator in Victoria with a 5% reduction from 1.23 to 1.17 $TCO_{2\text{-}e}$/MWhr sent out.

A GHG Action Plan will be prepared and integrated within the LYB Environmental Management System framework.

9. References

Acil Allen Consulting Pty Ltd 2013 Electricity Sector Emissions Modelling Of The Australian Electricity Generation Sector

DoE 2014 State and Territory Greenhouse Gas Inventories 2011-12, Australian Government Department of the Environment, April 2014

DoE 2015a: National Greenhouse Accounts Factors, Australian Government Department of the Environment, August 2015

DoE 2015b: Quarterly Update of Australia's National Greenhouse Gas Inventory: March 2015, Australian Government Department of the Environment, August 2015

IPM 2014 Environmental Policy (June 2014 (*note IPM was formerly GDF SUEZ*)) - https://www.engie.com/wp-content/uploads/2014/06/gdf-suez-environmental-policy-january-2014.pdf

IPM Data 2016: TurbineGenerationV2.xlsx; GH Database R14 1

ISO 14064-1:2006 Greenhouse gases -- Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals

The Department Of Innovation, Industry, Climate Change, Science, Research and Tertiary Education - Electricity sector emissions modelling of the Australian electricity generation sector – Sept 2013 - https://www.environment.gov.au/system/files/resources/65462f51-a20a-4f35-bdd0-d88d6ee5ac4e/files/electricty-sector-emissions.pdf

TurbineupgradeGenerationHeatRateModel.xls – Excel file outlining projections for coal combustion both pre and post upgrade provided by IPM.

Vic EPA 2001 State Environment Protection Policy (Air Quality Management) (SEPP AQM)

Vic EPA 2002 Protocol for Environmental Management – Greenhouse gas emissions and energy efficiency in industry

Vic EPA 2007 Environment Protection (Scheduled Premises and Exemption) Regulations,

Victorian Climate Change Act 2010.

WBCSD; WRI 2004: A Corporate Accounting and Reporting Standard Revised Edition, World Business Council for Sustainable Development and the World Resources Institute, 2004