HEGGIES

REPORT 10-5988-R1

Revision 1

West Cliff Mine
Surface Goaf Gas Drainage Project
Greenhouse Gas Assessment

PREPARED FOR

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West Cliff Mine

Surface Goaf Gas Drainage Project

Greenhouse Gas Assessment

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EXECUTIVE SUMMARY

INTRODUCTION

BHP Billiton – Illawarra Coal (hereafter, “BHPIC”) is, as part of the ongoing operations of the West Cliff Mine, planning to implement a programme to extract gas from the goaf area remaining after longwall extraction has occurred. The extraction of this gas is given as being necessary to prevent it flowing in significant quantities into the current working areas and causing a safety hazard, and raising general air body gas levels within the mine above permissible levels and also impeding longwall production performance. It is proposed that the extracted gas be either flared on the surface or vented to atmosphere.

Heggies Pty Ltd (Heggies) has been commissioned by BHPIC to undertake a Greenhouse Gas Assessment for the West Cliff Mine Surface Gas Drainage Project to address the Requirements of the Director-General, NSW Department of Planning. The main components of study were as follows:

- Quantification of greenhouse gas emissions due to the proposed project
- Qualitative assessment of greenhouse gas emissions on the environment
- Assessment of feasible alternatives for coal mine methane utilisation
- Recommend measures for greenhouse gas minimisation and management

The proposed project comprises the draining of longwall goaf gas to the surface through approximately 17 boreholes progressively installed above longwall panels number 32 to 34 of West Cliff Mine. Gas will be extracted from the goaf areas immediately after coal removal using a mobile extraction plant. The goaf gas will be either flared using two existing enclosed flare units with a combined capacity of 250 L/s, with excess goaf gas vented to the atmosphere. Six trial goaf gas extraction wells have been established to date, with gas flow calculations/measurements from such wells used in the current study.

The assessment was conducted based on an understanding of baseline greenhouse gas emissions and existing measures being implemented to reduce such emissions. Methane utilization projects already in place which draw coal seam gas from the West Cliff Mine were noted to include (i) Appin Power Station, which consumes approximately 2700 L/s of pre-drained gas (comprising ~70% methane) to contribute over 20 MW of the power generated, and (ii) WestVAMP, commissioned in 2007, which utilises 20% of West Cliff’s available mine ventilation air to generate 6MW of electricity using a steam turbine.

GREENHOUSE GAS ASSESSMENT

To evaluate the change in greenhouse gas emissions associated with the proposed project, emissions were estimated for:

- Baseline (business-as-usual) operations, and
- the Proposed Surface Gas Drainage Project.

Project-related greenhouse gas sources were identified as including:

- coal seam gas vented to atmosphere
- flaring emissions
- diesel combustion during borehole installation
- diesel combustion during power generation for mobile extraction plant operation
- off-site emissions associated with extraction operations occurring due to on-site diesel use

EXECUTIVE SUMMARY

Coal seam gas emitted during coal extraction from underground mines is comprised mainly of methane (CH_4); typically over 80% in the case of West Cliff Mine. Carbon dioxide (CO_2) and other emissions are produced during fuel combustion and have been considered as part of this assessment.

The greenhouse gas assessment considered the preferred flaring configuration proposed by BHPIC, viz. partial flaring of goaf gas from a single well, comprising two existing flaring units with a combined capacity of 250 L/s. At the completion of each Surface Goaf Well, the mobile extraction plant and flare units are to be relocated to the next well in sequence.

A synopsis of total baseline and Post-Surface Gas Drainage Project related greenhouse gas emissions, expressed in carbon dioxide equivalence, is given in the table below.

Operations	**Source**	**Greenhouse Gas Emissions in kt CO_2-e. (Given as best estimates with range indicated in brackets.)**	
		Period Total (FY08 – FY10)	**Annual Average**
Baseline Operations	Coal Seam Methane(a)	2384 kt/period (1934 – 2877)	795 ktpa (645 – 959)
	ADO Combustion(b)	5.9 kt/period	2.0 ktpa
	TOTAL	**2390 kt/period** **(1940 – 2883)**	**797 ktpa** **(647 – 961)**
Post-Project Operations (including Baseline)	Coal Seam Methane(c)	2230 kt/period (1844 – 2646)	743 ktpa (615 – 882)
	ADO Combustion(d)	7.0 kt/period	2.3 ktpa
	TOTAL	**2237 kt/period** **(1851 – 2653)**	**746 ktpa** **(617 – 884)**
Reduction due to Project		**153 kt/period** **(89 – 231)**	**51 ktpa** **(30 – 77)**

(a) Comprises coal seam gas emitted from mine vents, taking into account the 20% reduction due to WestVAMP.

(b) Baseline diesel consumption, given as 684 kL/annum.

(c) Comprises coal seam gas emitted from mine vents (taking into account the 20% reduction due to WestVAMP), in addition to the 30% of methane extracted from goaf wells which is not flared, greenhouse gases released during flaring operations and the residual methane (1% of the 70% of methane reporting to flares) which is conservatively assumed not be destroyed during flaring.

(d) Based on baseline diesel consumption of 684 kL/annum and the incremental diesel usage of 128 kL/annum related to the Project

The project has the potential to reduce Greenhouse Gas emissions from West Cliff Mine by approximately 50 kt CO_2-e pa. This constitutes a 4.6% to 8.0% (best estimate of 6.5%) reduction in West Cliff Mine greenhouse gas emissions.

ALTERNATIVES FOR UTILISATION OF COAL SEAM GAS

The need to assess energy production alternatives to coal mine methane flaring/venting is recognised. Options for the utilisation of coal seam methane generally include electrical power generation, on-site use in boilers, coal drying and space heating, local low pressure pipeline supply to industry or domestic consumers and injection into high pressure national distribution pipelines. To be commercially feasible such utilisation projects must have a reliable gas supply and a market for gas use or electrical power generation. Furthermore, the cost of supplying the coal seam methane must be competitive with other fuels in the local energy market, particularly with clean fuels such as natural gas and renewables. Irrespective of the end use, most utilisation schemes require gas to be delivered within specified flow rates and purities, with long term supplies generally more desirable particularly in cases where high capital costs are likely to be incurred.

Taking local circumstances at West Cliff Mine into account, the following potential options could be considered for alternative use of the goaf gas extracted by the proposed Surface Goaf Gas Drainage Project:

- Local power generation and distribution
- Transport of goaf gas for utilisation at power generation facilities
- Delivery of gas to regional consumers

The potential viability of integrating the proposed project with existing facilities or establishing new utilisation options was considered.

Key aspects for consideration include the availability, quality and rates of gas production associated with the proposed Surface Gas Drainage Project, the environmental impacts of alternatives, land ownership and access, stakeholder and community requirements, the proximity of the project to existing facilities and potential customers, the availability of existing infrastructure to reticulate or utilise the gas, the availability and proximity of electricity transmission systems, and the feasibility and practicalities of installing additional network pipelines and utilisation infrastructure (such as pipelines, gas conditioning equipment, electricity transmission lines and power plants etc). Other important factors are the nature, scale and life of the project, also whether the volumes, quality and consistency of gas can be beneficially, viably and routinely utilised in consideration of the projects requirement to progressively relocate to new bore sites.

In balance, the merits of how flaring a significant proportion of the extracted gas balances out in a positive sense relative to directly emitting all the extracted goaf gas directly to atmosphere is also considered.

The aim of this assessment was not to undertake a comprehensive, quantitative technical feasibility study or cost-benefit analysis but rather to determine, qualitatively, whether alternatives hold sufficient potential to warrant undertaking in addition to and integrated with the project.

A very important factor affecting the technical viability of utilising the goaf gas extracted by the Project for any of the alternatives identified is the availability, quality and rate of gas production. All of the potential utilisation schemes would require the gas to be delivered within specified flow rates and purities. Given the relatively high capital costs associated with the infrastructure required for these options, it is obvious that longer term supplies would be more desirable. Based on the projected goaf gas flows, reserve and supply duration for the proposed Surface Gas Drainage Project, and considering the costs and environmental implications associated with infrastructure requirements for the utilisation options identified, such options are considered not viable.

It is also noted that the goaf gas extraction system at West Cliff Mine is currently still under trial and investigation and that scope for improvements exist in the design, practise and management of the system to obtain consistently higher methane recovery rates.

In consideration of the lack of potential gas utilisation infrastructure in proximity to the project and the immaturity of the project in respect to the reliability and performance of the goaf gas extraction process, it is recommended that the proposed project of goaf gas extraction via surface boreholes and the associated flaring of the majority of the extracted gas be permitted, and also as the proposed project has significantly reduced Greenhouse gas implications as compared to the pre-project process of goaf gas removal from the mine via the mine ventilation system and the discharge directly to atmosphere.

Information collected during the project will improve the knowledge of the mechanics of goaf gas behaviour and also support the development of improved goaf gas capture and extraction systems longer term.

ENVIRONMENTAL IMPLICATIONS OF THE PROJECT

Although the energy content of the flared methane will not be exploited given implementation of the project, its global warming potential will be substantially reduced through partial combustion and conversion to carbon dioxide and water.

The proposed Surface Gas Drainage Project was predicted to result in a reduction in greenhouse gas emissions in the range 90 kt to 231 kt (best estimate of 154 kt) CO_2-e during the project period (financial years 2008-2010). This constitutes a 4.6% to 8.0% (best estimate of 6.5%) reduction in West Cliff Mine greenhouse gas emissions during this period. The project would therefore augment existing greenhouse gas reductions at the mine achieved through the piping of pre-drained coal seam methane to the Appin Power Station and utilisation of mine ventilation air for electricity generation at the WestVAMP facility.

Based on 2005 greenhouse gas emissions figures, the proposed project will serve to reduce NSW's total greenhouse gas emissions (158.2 Mt CO_2-e pa) by approximately 50 kt CO_2-e pa equating to a reduction in the order of 0.03%.

In relation to the whole of West Cliff mines' operational diesel fuel consumption and related emissions (within the mine's premises boundaries), the project increases annual diesel fuel consumption and related diesel fuel consumption emissions by approximately 20%. From a base total of 684 KL of diesel fuel used annually, the mine operational diesel fuel consumption will increase to 812 KL annually as a result of the project.

RECOMMENDATIONS REGARDING FLARE CAPACITY

As previously stated, the greenhouse gas assessment considered the preferred flaring configuration proposed by BHPIC, viz. partial flaring of goaf gas from a single well, comprising two existing flaring units with a combined capacity of 250 L/s. At the completion of each Surface Goaf Well, the mobile extraction plant and flare units are to be relocated to the next well in sequence.

Alternative flare options considered by BHPIC include the following:

- Extension of the currently proposed partial flaring of a goaf gas from a single well, with several wells being connected via pipeline to allow additional gas to be fed to the flares should excess flaring capacity exist.
- Full flaring at a single well achievable by one of the following means:

- Flaring all of the gas produced from an individual goaf well. This option would necessitate the installation of approximately seven 20 ft containers on site and also require an increased disturbed area (footprint) which would be repeated for each separate goaf well site.

- Establishment of a centralised flaring facility and construction of a pipe network connecting the plant to each of the separate surface goaf wells. This option would also create more land disturbance and impacts to landowners.

- Design or purchase of a high capacity mobile flare unit (with a reduced footprint) which could be relocatable to various goaf well sites, but also having the capability to flare the entire volume of gas drawn from the mine. The nature, size and scale of such a device would not be readily relocatable on lands without established heavy load capacity roadways. Such a device does not presently exist which suits the application and mobility of this project.
- Full flaring at multiple wells. Where possible existing (trial) surface goaf wells are now being connected to trial the utilisation of the existing 2 hired flare units on the site. Experience gained by BHPIC to date has shown this to be a difficult process and not able to be implemented as a standard practice due to the surface features, topography and infrastructure present throughout the site.
- Multiple-wells connected to a single flaring facility. This option would require the establishment of significant supporting infrastructure such as surface pipelines interconnecting multiple wells and the construction and installation of a significant fixed flaring facility. This option has all the issues as above including increased costs and increased landholder impacts for negligible benefit when compared to the proposed project arrangement.

Given the significant variations in the goaf gas volumes and flow rates from the trial wells influenced by longwall production rates, strata behaviour and goaf characteristics, application of options other than the proposed project cannot be justified at this time.

To continue to capture the benefits that the trial project is presently realising it is recommended that the project be permitted to continue as proposed.

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1 INTRODUCTION

BHP Billiton – Illawarra Coal (hereafter, "BHPIC") is preparing an Environmental Assessment under part 3A of the Environmental Planning and Assessment Act, 1979 for a Surface Gas Drainage Project at West Cliff Mine, NSW.

As part of the ongoing operations of the West Cliff Mine, BHPBIC plans to implement a programme to extract gas from the goaf area remaining after longwall extraction has occurred. The extraction of this gas is given as being necessary to prevent it flowing in significant quantities into the current working areas and causing a safety hazard and other operational issues.

It is proposed that a significant proportion of the extracted goaf gas (approximately 70%) be flared with the remainder being vented to atmosphere. The remainder gas being primarily associated with peak initial well flows beyond the flare units design capacity and fugitive gas emitted when flaring units are being relocated to the next well head or not available.

Heggies Pty Ltd (Heggies) has been commissioned by BHPIC to undertake a Greenhouse Gas Assessment for the West Cliff Mine Surface Gas Drainage Project to address the Requirements of the Director-General, NSW Department of Planning. According to the Director General's Requirements a full greenhouse gas assessment is needed including an assessment of feasible alternatives for the utilisation of the coal seam gas produced by the project, a quantitative analysis of the greenhouse emissions associated with the project, and a qualitative assessment of the impacts of these emissions on the environment.

1.1 Scope of Study

The Director General's Requirements formed the basis for the scope of study and methodological approach used in the assessment. The main components of study and scope of works for each component are as follows:

- Quantification of Greenhouse Gas Emissions due to the Proposed Project
  - Collation of project information including raw coal extraction volumes, coal in situ gas
  - Calculation of greenhouse gas emissions (in tonnes of CO_2-equivalent) from the Project associated with extraction and venting/flaring of goaf gas, in addition to the combustion of fuel during construction and operational activities. In the latter case, both direct emissions due to fuel combustion and indirect emissions due to fuel extraction are considered.
- Qualitative Assessment of Greenhouse Gas Emissions on the Environment
  - Assess the significance of greenhouse gas emissions for the project in relation to National greenhouse gas objectives and report on the project's greenhouse gas implications in terms of Federal and NSW Government policies and protocols.
- Assessment of Feasible Alternatives for Coal Mine Methane Utilisation
  - Taking into account the estimated volumes, composition and energy content of goaf gas to be extracted and the duration of the goaf gas extraction project (2008-2010), assess the feasibility of alternatives to flaring and venting to atmosphere for the utilisation of the coal seam gas produced by the project.
- Recommend Measures for Greenhouse Gas Minimisation and Management

1.2 Background Information on Current West Cliff Mine Coal Seam Gas Utilisation

Prior to the assessment of the proposed Surface Goaf Gas Drainage Project it is pertinent to consider briefly the existing coal mine methane utilisation projects in place at the West Cliff Mine.

1.2.1 Appin Power Station

West Cliff Mine extracts coal from the Bulli coal seam which contains high levels of methane which, for safety reasons, has been drained before mining since 1980 to ensure safe working conditions. The methane is drained through bores drilled months in advance of mining; the boreholes typically being 500 m in length but some bores exceeding 1000 m. Methane is drawn continuously to the surface by vacuum pumps. From the gas drainage vacuum plant situated at West Cliff Mine, the gas is piped under pressure along a 6.8 km overland pipeline to the Appin Power Station.

The Appin and Douglas Park Power Stations were established by Illawarra Coal over 10 years ago, in partnership with Energy Developments Limited (EDL), as a way of utilising drained coal mine methane for electricity generation. Appin and Douglas Power Stations have respective capacities of 54 and 40 MW (combined capacity of 94 MW). Utilising over 650,000 m^3/day of coal seam gas comprising 60-80% methane, these power stations are estimated to reduce greenhouse emissions by over 2.5 million tonnes CO_2-equivalent per year (Pilcher *et al*. 2003).

West Cliff Mine supplies approximately 2700 L/s of coal mine gas to Appin Power Plant, with 1700 L/s coming from pre-drainage and 1000 L/s from post-drainage of floor holes. Methane comprises 70% of this gas (i.e. 1890 L/s) (Personal Communication, Tim Meyer, Gas and Ventilation Specialist, BHPIC, 21 September 2007).

1.2.2 WestVAMP

The West Cliff Ventilation Air Methane Project (WestVAMP) was commissioned in 2007. Based upon VOCSIDIZER™ technology, WestVAMP converts low concentration methane (nominally 1%) to carbon dioxide and water vapour through an oxidation (flameless combustion) process. Heat exchangers recover the thermal energy released to produce high quality steam, which is used to drive a conventional steam turbine, thus generating electricity.

WestVAMP utilises 20% of West Cliff's available mine ventilation air to generate 6MW of electricity using a steam turbine. This results in an estimated reduction in greenhouse gas emissions of over 200 ktpa CO_2-equivalent.

It is important to note here that WestVAMP is presently fully fuelled by the available vent air and any increase in mine vent air methane volumes cannot be utilised and therefore reports directly to atmosphere.

1.3 Report Outline

An overview of the proposed Surface Goaf Gas Drainage Project is given in **Section 2**. The methodological approach and results from the greenhouse gas assessment undertaken for the project is presented in **Section 3** and the implications of the greenhouse gas emissions for the environment qualitatively assessed in **Section 4**. The feasibility of alternatives for the utilisation of the coal mine methane is discussed in **Section 5**, and recommendations and conclusions presented in **Section 6**.

2 PROJECT OVERVIEW

The project comprises the draining of goaf gas from underground mining operations to the surface at West Cliff Mine. The goaf gas extraction will remove gas from the goaf areas immediately after coal removal, with the gas extracted to the surface via a cased borehole installed prior to mining.

Following the extraction of the gas, the gas will be either flared on the surface or vented to the atmosphere. If this gas is not removed via the proposed surface goaf wells, then the majority of it will mix with the mine ventilation air and be expelled to atmosphere at the mine's exhaust shafts.

The project proposal involves the installation and use of approximately 17 boreholes above West Cliff's longwall panels number 32 to 34 over the nominal three year period between approval and mid 2010.

Specific components of the proposed West Cliff Mine Surface Goaf Gas Drainage Project include:

- Borehole installation with appropriate drilling equipment and fit out to enable gas extraction,
- Gas extraction and ventilation facility, and,
- Gas flaring equipment located at a safe distance from the ventilation points.

Information on the project pertinent to the current study was obtained from the following documents:

- BHPIC document "*West Cliff Mine Surface Gas Draining Project – Greenhouse Gas Assessment: Brief For Consultants"*, August 2007.
- Information received from Tim Meyer (Gas and Ventilation Specialist, BHPIC) on 23rd and 29th August 2007.
- *Preliminary Environmental Assessment Under Part 3A of the Environmental Planning and* Assessment Act 1979, BHP Billiton – Illawarra Coal, West Cliff Mine Surface Goaf Gas Drainage Project, Compiled by Olsen Environmental Consulting, May 2007.

A brief overview on the main components of the project is given in **Section 2.1**, with the project timeframe and more detailed information on the nature and extent of goaf gas emissions provided in **Section 2.2** and **Section 2.3** respectively. In instances where details on the project differed between the above information sources, use was made of the most current information.

2.1 Installation and Operation of Project Components

2.1.1 Borehole Installation

A specialised drilling rig will be used to install the boreholes. The holes will be located on the tailgate side of the longwall panel and will generally be within 50 m of the side of the panel, located so as to minimise the consolidating effect on the borehole as goaf creation and mining subsidence progresses.

The holes will be installed ahead of mining to enable gas extraction to commence immediately following coal removal. Drilled to depths of about 500 m, the holes will be approximately 10 m above the Bulli Seam.

2.1.2 Gas Extraction and Ventilation

Gas will be extracted from the goaf area via the pre-drilled holes by a purpose-built mobile gas extraction plant.

The mobile extraction plant will have an on-board generator. Although the possibility of using a gas-fired generator is under investigation, it is likely that a diesel-powered generator of appropriately 175 kVA capacity will be used. Typical diesel consumption rates will be in the order of 3,500 litres per operating week with an estimated 35 weeks operation per year until June 2010.

The mobile plant will have an erectable vent stack of approximately 9m high. This stack will only be utilised when flaring is not occurring or when the flares are located remotely to the mobile plant. The stack will be collapsed during relocation of the plant.

Extracted goaf gas will pass through a venturi for measurement purposes prior to being directed to either:

- the local vent stack for emission to atmospheric,
- local or remote flare units, and/or
- a remote vent stack.

To meet safety requirements, the flare units will be separated from the vent by at least 100m to minimise risk of plume ignition.

The mobile extraction plant will remain in position extracting gas until it is required to move to the next borehole in the longwall panel.

The cost-optimised spacing for the wells is anticipated to be 350 m. Although due to surface constraints it is more likely that the spacing will be 400 m apart, a spacing of 350 m will remain as the target. On a typical 3.3 km long longwall block, typical well placement is to have the first well start at around 350 m from the face install line (i.e. start point in the block) and the final well at around 600 m from the panel end. Given that the longwall moves at around 50 m per week, and taking the likely 350 m to 400 m spacing into account, it is likely that the wells will come on line every 7 to 8 weeks. The mobile extraction plant is therefore anticipated to remain at one well for a period of 7 to 8 weeks prior to moving to the next well. Extraction and subsequent flaring will commence at the next well within a day of initiating operations at that well.

The minimum number of wells likely to be in operation is given as four – comprising the four wells budgeted for in the 2007/2008 financial year. The number of additional wells during the July 2007 to June 2010 period will depend on the value and benefits of continuing the goaf gas extraction in relation to the cost. The most likely number of wells in operation during the project period, as documented in the Preliminary Environmental Assessment for the non-extended mine plan, will be 17.

Wells are shut-in (valve closed) as soon as the mobile extraction plant is turned off for mobilisation to the next well. Each well will be plugged (filled with cement) and decommissioned and the site rehabilitated in accordance with the requirements of the Department of Primary Industries (Mineral Resources)

Initial gas flows are predicted to be in the order of 700 L/s, reducing to approximately 500 L/s after one to two weeks and to about 250 L/s after 6 weeks.

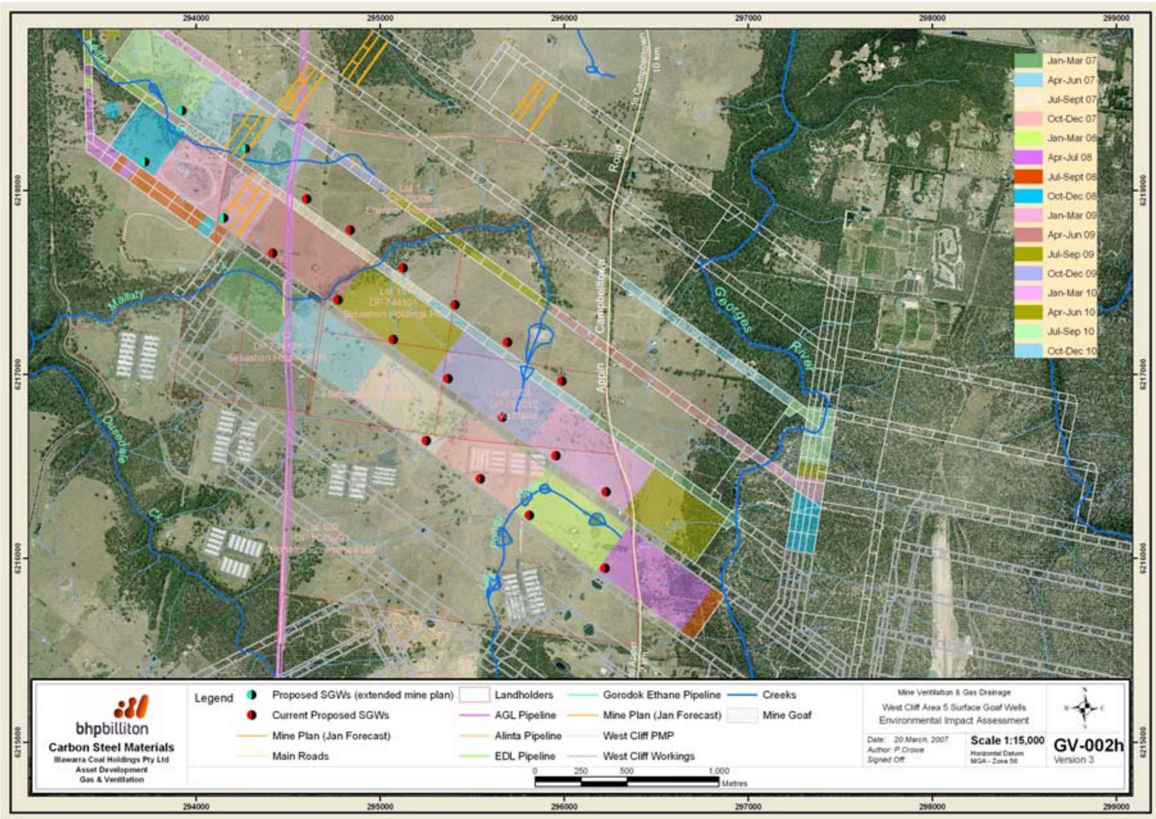
Further information on gas flows obtained from the several trial wells is given in **Section 2.3.5**.

2.1.3 Gas Flaring

When appropriate and possible, gas will be flared utilising two existing flaring units. The flares will be situated adjacent to the mobile extraction plant with excess gas being sent to a remote vent stack situated at least 100 m away.

The two units proposed for use in the project have a combined capacity of 250 L/s. Given initial gas flow measurements (**Section 2.3.5**), it is evident that there will be times, especially during the initial stages of gas extraction at each well, when venting to atmosphere will have to occur given the proposed flaring units design capacities.

Figure 1 Proposed West Cliff Mine Surface Goaf Wells for the Planned Surface Gas Drainage Project



2.2 Project Timeframe

Several trial goaf gas extraction boreholes are already in place. The project will commence following approval being received and will be completed by August 2010.

2.3 Raw Coal Extraction and Estimated Volumes of Gas Emissions

Several trial goaf gas extraction boreholes have been established to date above West Cliff Mine longwalls by BHPIC in an attempt to establish an appropriate methodology to extract goaf gas and bring it to the surface.

Measurements from these boreholes have been used by BHPIC to develop improved understanding of the composition and flow rates of the goaf gas and goaf well behaviour and performance.

Continued goaf gas extraction will enable further information to be accumulated that will assist in the development of improved systems designs and the assessment of potential utilisation options.

2.3.1 Raw Coal Extraction Volumes

Volumes of raw coal to be extracted during the period of the project are given in **Table 1**.

Table 1 Volumes of raw coal, in longwall tonnes, to be extracted during the period of the proposed project

Financial Year 2008	Financial Year 2009	Financial Year 2010
3,010,656	2,623,488	2,471,031

2.3.2 Coal in Situ Gas Content and Composition

The underground coal mine gas consists of a mixture comprising primarily methane (>85%), carbon dioxide (~8%) and lesser amounts of other gases such as oxygen, nitrogen, hydrogen, ethane, propane, argon and butane.

The mined seam is the Bulli Seam. Within the project area the Bulli Seam has a range of gas contents from 8 to 14 m^3/tonne of raw coal, with an average of around 11m^3/t. The composition of this gas ranges from 95% $CH_4/(CH_4+CO_2)$ to 10% $CH_4/(CH_4+CO_2)$. The average composition is estimated at around 70% $CH_4/(CH_4+CO_2)$.

Mining the Bulli Seam also releases gases contained in the lower seams and adjacent strata. It is estimated that gas release from these lower seams is around 30 to 35 m^3/t of Bulli Coal seam mined. This is given as the Specific Gas Emissions (SGE). A typical compositional analysis of the SGE is presented in **Table 2**.

Table 2 Composition of gas released from lower seams during mining of Bulli Coal seam (gas results from Surface Gas Well number 6)

O_2	Ar	N_2	CH_4	CO	CO_2	H_2	C_2H_6	Propane	n-butane	i-butane
0.56	0.03	3.06	86.80	0.00	7.75	0.19	1.72	0.56	0.12	0.16
0.53	0.03	2.99	86.91	0.00	7.76	0.19	1.73	0.54	0.12	0.16

2.3.3 Total Volume and Composition of Goaf Gas

Total volume of gas emitted can be calculated by the mining tonnes multiplied by the SGE. This averages out at around 3300 L/s, however due to the discontinuous mining processes and geological influences on the release of this gas, peak gas flows can be in excess of 5,000 L/s.

Most of this gas ends up in the goaf, although around 1000 L/s (~30%) is captured with methane drainage extraction holes drilled down in to the floor which intersect the lower seams[(1)].

Of the gas which ends up in the goaf, most is diluted into the mine ventilation air (able to dilute approximately 4000 L/s). Only a small fraction is drawn up the goaf wells. The composition of the goaf gas is as shown above in **Table 2**. The typical energy content of the goaf gas is of the order of 35,015 KJ/m^3.

1 These holes are drilled ahead of the longwall face. Flows from these post-drainage holes are negligible prior to mining the Bulli Seam directly overhead. It is only after the longwall has passed overhead that significant flows commence.

2.3.4 Estimated Capture Efficiency of Gas Drainage System

Approximately 35-40% of the specific gas emissions are currently captured either in the floor holes (holes drilled under the Bulli Seam to capture gas released from lower seams) or through the goaf wells. It is estimated that 25-30% of this gas is captured in the floor holes with 5% to 10% being extracted via the goaf wells.

The remaining gas (60-65% of the specific gas emissions) is diluted within the mine ventilation air, with it being ensured that the methane content of the air in the bleeder roadways (roadways taking flow from goaf area) remains below permitted levels (2%).

2.3.5 Results from Trial Goaf Gas Extraction

Six trial goaf gas extraction wells have been established to date, with gas flow calculations and measurements from the wells obtained for use in the current study. Variations in the gas flow, observed during the period 23rd March to 29 May 2006, and given as being representative of the first three surface goaf wells are presented in **Figure 2**. Gas flows recorded during the period 1st July to 14th August 2007, and given as being indicative of the last three surface goaf wells are illustrated in **Figure 3**.

The goaf gas flow profiles presented in **Figure 2** and **Figure 3** illustrate the wide range and variability of gas flows that can be achieved from the different surface goaf wells.

A comparison of the weekly-average gas flow rates recorded during the initial six weeks is presented in **Figure 4**. It is evident that substantially higher gas flows were observed to occur during the first three weeks for the initial three surface gas wells, when compared to the gas flows for the last three wells. During week 5, the average gas flows were relatively similar, with higher subsequent gas flows recorded for the last three wells during week 6. The first three surface gas wells were estimated to yield ~890 tonnes of goaf gas over the initial 6 week period, compared to only ~630 tonnes for the subsequent three wells(2). A further well drilled did not produce any goaf gas, most likely due to hole collapse.

2 The goaf gas density is given as 0.793 kg/m^3.

Figure 2 Goaf gas flow observed during the period 23rd March to 29 May 2006, given as being typical of the first three surface goaf wells

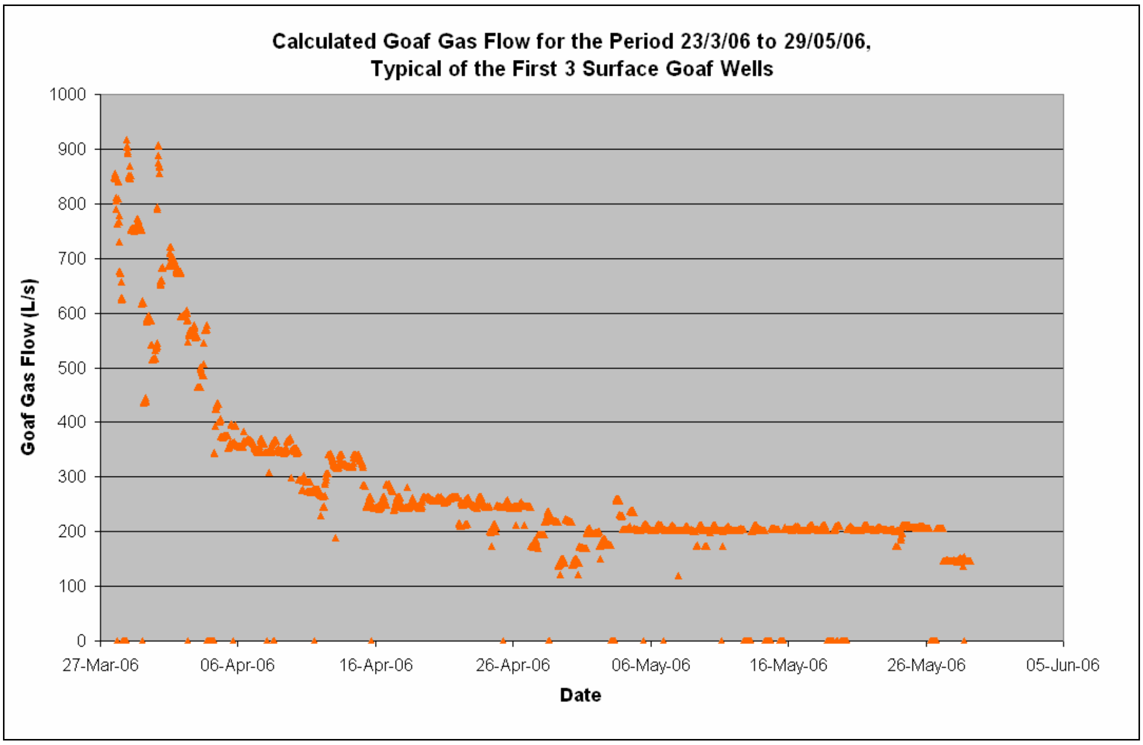


Figure 3 Goaf gas flow observed during the period 1st July to 14th August 2007, given as being typical of the last three surface goaf wells

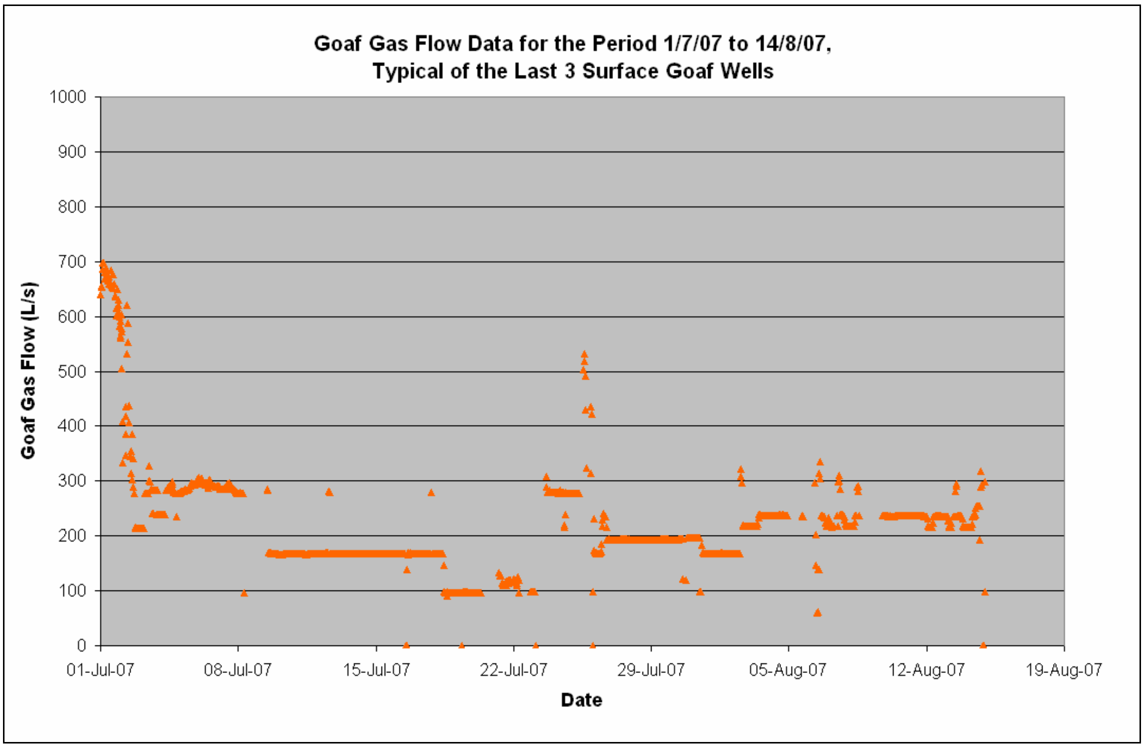
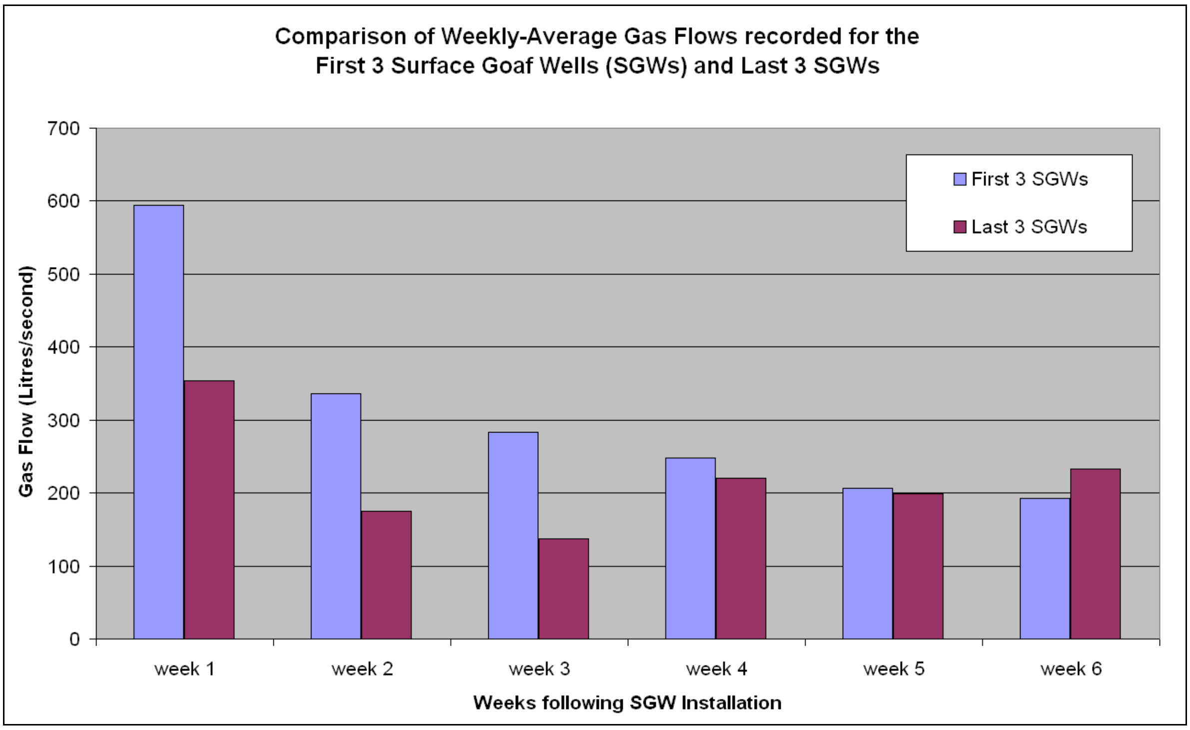


Figure 4 Comparison of weekly-average gas flow rates given as being typical of the first and final three trial surface goaf wells



3 GREENHOUSE GAS ASSESSMENT

The greenhouse gas assessment has been conducted in accordance with the methodologies established by the various policies and guidelines which are detailed in **Appendix A**. Provision is made in such methodologies for three greenhouse gas emission scopes, which are defined as follows:

- Scope 1 emissions are those which result from activities under a company's control or from sources which they own. (E.g. coal seam gas emissions occurring during coal extraction).
- Scope 2 emissions are those which relate to the generation of purchased electricity consumed in its owned or controlled equipment or operations.
- Scope 3 emissions are defined as those which do not result from the activities of a company although arise from sources not owned or controlled by the company. (E.g. off-site extraction of fuel combusted at the site.)

Project-related greenhouse gas sources include the following

- Coal seam gas emitted as a result of coal extraction (Scope 1) fugitive emissions;
- Diesel combustion during borehole installation (Scope 1);
- Diesel combustion during power generation for mobile extraction plant operation (Scope 1); and
- Off-site emissions associated with extraction operations occurring due to on-site diesel use (Scope 3).

Diesel combustion, rather than electricity, will power the proposed project. Greenhouse gas sources associated with off-site electricity generation (Scope 2) are therefore not included in the assessment.

Coal seam gas emitted during coal extraction from underground mines is comprised mainly of methane (CH_4); typically over 80% in the case of West Cliff Mine. Carbon dioxide (CO_2) is produced during fuel combustion as a result of the oxidation of the fuel carbon content. CO_2 is likely to make the largest contribution to greenhouse gas emissions from fuel combustion as approximately 99.5% of natural gas is oxidised during the combustion process (AGO, 2005).

Other greenhouse gases emitted as a result of project operations may include carbon monoxide (CO), oxides of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOCs). These are produced by incomplete fuel combustion, reactions between air and fuel constituents during fuel combustion, and post-combustion reactions. Fugitive emissions of NMVOCs may also be expected due to fuel evaporation but are considered negligible in this case.

In accordance with the Department of Climate Change *National Greenhouse Accounts (NGA) Factors – February 2008* (DCC, 2008) (hereafter NGA Factors), the greenhouse gas emissions that are required for measurement from the Project are Direct (Scope 1) emissions relating to on-site fuel combustion and fugitive coal seam methane release, and Indirect (Scope 3) emissions related to off-site extraction emissions.

For comparative purposes, non-CO_2 greenhouse gases are awarded a "CO_2-equivalence" based on their contribution to the enhancement of the greenhouse effect. The CO_2-equivalence of a gas is calculated using an index called the Global Warming Potential (GWP). The GWPs for a variety of non-CO_2 greenhouse gases are contained within Table 24 of the NGA Workbook. The GWPs of relevance to this assessment are:

- **Methane (CH_4)**: GWP of 21 (21 times more effective as a greenhouse gas than CO_2); and
- **Nitrous Oxide (N_2O)**: GWP of 310 (310 times more effective as a greenhouse gas than CO_2).

The short-lived gases such as CO, NO_2, and NMVOCs vary spatially and it is consequently difficult to quantify their global radiative forcing impacts. For this reason, GWP values are generally not attributed to these gases nor have they been considered further as part of this assessment.

An assessment of the predicted greenhouse gas emissions from project operations has been undertaken for each of the aforementioned sources. Coal seam gas emissions were estimated based on NGA Factors and on gas emission and composition data obtained from BHPIC.

To evaluate the change in greenhouse gas emissions associated with the proposed project, emissions are estimated for:

- Baseline (business-as-usual) operations (excluding goaf gas extraction and flaring), and
- the proposed Surface Gas Drainage Project.

Baseline (business-as-usual) Emissions refer to the quantity of methane that would be emitted if the proposed project did not take place. The baseline scenario comprises the following existing conditions:

- Piping of 2700 L/s of gas to Appin Power Station, with 1700 L/s drawn from pre-drainage of coal seam gas and the remaining 1000 L/s from post-drainage of floor holes. The gas comprises a methane concentration of ~70% resulting in a current greenhouse gas emission reduction of over 800 ktpa CO_2-equivalent due to methane destruction[(3)].
- Continued dilution of coal mine methane which ends up in the goaf area into the mine ventilation air with 80% of this methane being emitted to atmosphere.
- Utilisation of 20% of the mine ventilation air, and consequently 20% of the coal mine methane, to generate 6MW of electricity in the WestVAMP facility, resulting in an estimated greenhouse gas emission reduction of over 200 ktpa CO_2-equivalent.

Given the proposed **Surface Goaf Gas Drainage Project**, the pre-drainage and piping of coal seam gas to Appin Power Station and the utilisation of 20% of the coal mine methane diluted in the mine ventilation air by WestVAMP will continue.

The main change to baseline emissions will comprise the addition of post-drainage capture of some of the coal mine methane from the goaf area using vertical wells and the subsequent venting of this gas to surface with partial flaring and partial release of the gas to atmosphere. The project will however also comprise the combustion of diesel during drilling and gas extraction operations.

In the absence of the Surface Goaf Gas Drainage Project the gas would not remain underground but be drawn into the mine ventilation air system and be discharged to the atmosphere once passing the main ventilation fan.

3.1 Coal Seam Methane Emissions

The quantification of baseline coal seam gas emissions and changes in such emissions due to the proposed project necessitates the estimation of:

- Volume and methane composition of the coal seam gas entering the goaf area;
- Percentage of coal seam gas captured within the holes drilled into the floor which intersect lower seams;

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3 A portion of this reduction is offset by carbon dioxide releases from the Appin Power Station. The use of the coal seam gas to generate electricity for the grid does however also reduce the need to use other fuels such as coal.

- Percentage of the goaf gas which is diluted into the mine ventilation air (baseline operations)[4];
- Percentage of the goaf gas which is drawn up by the goaf wells;
- Percentage of the goaf gas diluted into the mine ventilation air following goaf gas extraction (proposed operations);
- Percentage of the goaf gas able to be flared, taking into account:
    - Capacity of the proposed flare units (250 L/s combined)
    - Temporal variations in borehole gas flows
    - Availability of flare units
    - Flare destruction efficiency

The volume of coal seam gas entering the goaf area, calculated based on the minimum, maximum and average specific gas emissions obtained from BHPIC for the Bulli Seam and lower coal seams (see **Section 2.3**), are given in **Table 3**. The methane content of the goaf gas is given as 86.9%.

Table 3 Minimum, average and maximum coal seam gas estimated to enter the goaf area given raw coal extraction rates for financial years 2008, 2009 and 2010

	Estimated Coal Seam Gas Entering Goaf Area		
	Minimum (L/s)	**Average (L/s)**	**Maximum (L/s)**
Financial year 2008	3628	4153	4678
Financial year 2009	3161	3619	4076
Financial year 2010	2978	3408	3839

During baseline operations, approximately 70% of the goaf gas would be diluted within the mine ventilation air with remainder captured within the floor holes. With goaf gas drainage in place, an estimated 25-30% of the goaf gas (~1000 L/s) will be captured within the floor holes, with 5-10% being drawn up by the goaf wells and the remainder (60-65%) being diluted within the mine ventilation air based on measurements conducted by BHPIC.

Estimated methane volumes, based on these percentages, and taking into account the goaf gas flow rates (**Table 3**) and average methane content of the goaf gas (86.9%), are given in **Table 4** for the project period (FY08-FY10).

Table 4 Methane volumes estimated to be retained in floor holes, be extracted by surface goaf wells and diluted within mine ventilation air for the period FY08 to FY10 given project implementation.

	Methane Volumes (ktpa)(a)			
	FY08	**FY09**	**FY10**	**Period Totals (FY08-FY10)**
Retained within floor holes (25%-30%)	20.7 (16.4 – 25.4)	18.0 (14.3 – 22.2)	17.0 (13.5 – 20.9)	55.7 (44.3 – 68.5)
Extracted by goaf wells (5%-10%)	5.6 (3.3 – 8.5)	4.9 (2.9 – 7.4)	4.6 (2.7 – 7.0)	15.2 (8.9 – 22.8)

4 Post drained gas if not captured enters the mine airway.

Diluted within mine ventilation air (60%-65%)	47.1 (39.5 – 55.1)	41.0 (34.4 – 48.0)	38.6 (32.4 – 45.3)	126.7 (106.3 – 148.4)

(a) Ranges reflect variations in specific gas emissions and uncertainties in the behaviour of coal seam gas within the goaf area (e.g. % of goaf gas extracted by wells).

Based on the gas extraction rates measured as being representative of the six trial wells (**Section 2.3**), goaf well methane extraction volumes are estimated to be in the range of 5 to 7 ktpa. This compares with the methane well extraction rates given in **Table 4.**

Taking into account temporal variations in borehole gas flows recorded in the trial wells (**Section 2.3**) and the capacity of the proposed flare units (250 L/s), the theoretical flare potential was calculated to be in the range of 70% to 90% assuming that flaring would be initiated within a day of the well becoming operational. The actual flare rate for the latter wells was given by BHPIC as being ~70%. The flare destruction efficiency is anticipated to be in excess of 99% given the high methane content of the goaf gas.

Based on the information given above, coal seam methane emissions calculated for baseline (business as usual) and project-related operations are given in **Table 5**.

The portion of the goaf gas to be flared was conservatively assumed to be 70% with the remainder being vented to atmosphere.

Table 5 Coal seam methane emissions estimated due to baseline (business-as-usual) and proposed project operations

	Coal Seam Methane Emissions due to Baseline (Business-as-usual) and Proposed Project Operations			
	FY08 (ktpa)	**FY09 (ktpa)**	**FY10 (ktpa)**	**Period Total (kt)**
Baseline Coal Seam Methane Emissions(a)	42.2 (34.2 – 50.9)	36.7 (29.8 – 44.3)	34.6 (28.1 – 41.8)	113.5 (92.1 – 137.0)
Project Coal Seam Methane Emissions(b)	39.3 (32.6 – 46.7)	34.3 (28.4 – 40.7)	32.3 (26.7 – 38.3)	105.9 (87.7 – 125.6)

(a) Taking 20% reduction due to WestVAMP into account.

(b) Includes 30% of methane extracted from goaf wells which is vented to atmosphere (not flared), and coal seam methane diluted within the mine ventilation air (taking into account reduction due to WestVAMP).

The calculated baseline coal seam methane emissions given in **Table 5** for the 2008 financial year are comparable to the estimates based on current mine ventilation air information, but greater than the emission estimates made on the basis of the generic NGA Factors 2008 (**Appendix B**).

3.2 Flaring Emissions

Given that methane emissions vented directly to atmosphere has a greater global warming potential than emissions related to methane combustion, greenhouse gas emissions due to flaring operations are frequently not accounted for.

Flare emissions were however quantified in the current study based on NGA Factors (DCC, 2008) (**Table 6**). Assuming a flare destruction efficiency of 99%, the greenhouse gas emissions associated with flaring were estimated to be in the range of 1.8 kt to 4.7 kt (average of 3.14 kt) over the project period (FY08 to FY10).

Table 6 Greenhouse gas emissions from the proposed flaring of coal seam methane

	FY08	FY09	FY10	Period Total
Coal seam methane destroyed (a)	5.78 Million m^3 (3.37 – 8.68 Million m^3)	5.04 Million m^3 (2.93 – 7.57 Million m^3)	4.74 Million m^3 (2.76 – 7.13 Million m^3)	15.56 Million m^3 (9.06 – 23.38 Million m^3)
Energy generated (GJ) (b)	227,196 GJ (132,314 – 341,230 GJ)	197,979 GJ (115,298 – 297,348 GJ)	186,474 GJ (108,598 – 280,068 GJ)	611,650 GJ (356,210 – 918,646 GJ)
Greenhouse emissions (CO_2-e) (c)	1.17 ktpa (0.68 – 1.75 ktpa)	1.02 ktpa (0.59 – 1.53 ktpa)	0.96 ktpa (0.56 – 1.44 ktpa)	3.14 ktpa (1.83 – 4.71 ktpa)

(a) Comprises 70% of surface goaf gas, combusted with a 99% efficiency.

(b) Based on the Energy Content of coal seam gas, given as 39.3 x 10^{-3} GJ/m^3 in the NGA Factor Workbook (DCC, 2008).

(c) Calculated base on the NGA emission factor given as 51.3 kg CO_2-e / GJ for Scope 1 emissions (DCC, 2008).

3.3 Diesel Combustion during the Proposed Surface Drainage Project

GHG emissions will occur as a result of diesel consumption for on-site machinery, specifically related to the drilling of the goaf wells and on-site power generation for the extraction of goaf gas. The primary fuel source on-site would be Automotive Diesel Oil (ADO). It has been assumed that the energy content of ADO is 38.6MJ/L (NGA, 2008)

It is envisaged that 3,500 litres of diesel per operational week will be combusted by the generators powering the mobile goaf gas extraction plant. Based on 35 weeks of operation per year, it is estimated that a total of 122.5 kL of diesel will be consumed annually. Diesel consumption related to the drilling of the goaf wells has been based on a generic figure for drilling of 2 litres per drilled meter. This equates to 17 kL of diesel over the life of the project related to drilling operations, or 5.7 kL annually, based on a hole depth of 500 m for the 17 goaf wells. The total diesel consumption rate for both drilling operations and extraction generators is therefore calculated to be 128.2 kL per annum.

In relation to the whole of West Cliff mines' operational diesel fuel consumption and related emissions (within the mine's premises boundaries), the project increases annual diesel fuel consumption and related diesel fuel consumption emissions by approximately 20%. From a base total of 684 KL of diesel fuel used annually, the mine operational diesel fuel consumption will increase to 812 KL annually as a result of the project.

Baseline and project-related (incremental) emissions, calculated based on the relevant emission factors listed in the NGA Factor workbook 2008, are presented in **Table 7**. Based the diesel fuel consumption rates related to the project, the incremental CO_2-equivalent emissions are estimated to be 370 t annually and 1.11 kt over the life of the project.

Table 7 Baseline and Project-related Greenhouse Gas Emissions due to Diesel Combustion

	Baseline Operations (Annual)	**Project-Related, Incremental (Annual)**	**Project-Related, Incremental (Period, FY08 – FY10)**
Diesel Usage	684 kL/annum	128 kL/annum	385
Energy Generation(a)	26,402 GJ/annum	4,947 GJ/annum	14,842 GJ/period
CO_2-e emissions(b)	1,975 tpa	370 tpa	1,110 t/period

(a) Based on the Energy Content of ADO, given as 38.6 x 10^{-3} GJ/m³ in the NGA Factor Workbook (DCC, 2008).

(b) Calculated base on the NGA emission factor given as 74.51.3 kg CO_2-e / GJ for full fuel cycle emissions (DCC, 2008).

3.4 Greenhouse Gas Emissions due to Baseline and Project Operations

A synopsis of total Baseline and Post-Surface Gas Drainage Project related greenhouse gas emissions, expressed in carbon dioxide equivalence, is given in **Table 8**.

The proposed Surface Gas Drainage Project was predicted to result in a reduction in greenhouse gas emissions in the range 90 kt to 231 kt (best estimate of 154 kt) across the FY08 to FY10 period. This constitutes a 4.6% to 8.0% (best estimate of 6.5%) reduction below baseline levels over the FY08 to FY10 period occurring as a result of the Project proposed.

Table 8 Total greenhouse gas emissions due to Baseline and Post-Project Operations

Operations	Source	Greenhouse Gas Emissions in kt CO_2-e. (Given as best estimates with range indicated in brackets.)	
		Period Total (FY08 – FY10)	**Annual Average**
Baseline Operations	Coal Seam Methane(a)	2384 kt/period (1934 – 2877)	795 ktpa (645 – 959)
	ADO Combustion(b)	5.9 kt/period	2.0 ktpa
	TOTAL	**2390 kt/period** **(1940 – 2883)**	**797 ktpa** **(647 – 961)**
Post-Project Operations (including Baseline)	Coal Seam Methane(c)	2230 kt/period (1844 – 2646)	743 ktpa (615 – 882)
	ADO Combustion(d)	7.0 kt/period	2.3 ktpa
	TOTAL	**2237 kt/period** **(1851 – 2653)**	**746 ktpa** **(617 – 884)**
Reduction due to Project		**153 kt/period** **(89 – 231)**	**51 ktpa** **(30 – 77)**

(a) Comprises coal seam gas emitted from mine vents, taking into account the 20% reduction due to WestVAMP.

(b) Baseline diesel consumption, given as 684 kL/annum.

(c) Comprises coal seam gas emitted from mine vents (taking into account the 20% reduction due to WestVAMP), in addition to the 30% of methane extracted from goaf wells which is not flared, greenhouse gases released during flaring operations and the residual methane (1% of the 70% of methane reporting to flares) which is conservatively assumed not be destroyed during flaring.

(d) Based on baseline diesel consumption of 684 kL/annum and the incremental diesel usage of 128 kL/annum related to the Project

4 ENVIRONMENTAL IMPLICATIONS OF GREENHOUSE GAS EMISSIONS

Methane emissions have historically simply been considered a safety hazard and an impediment to coal mining operations. In recent decades the environmental implications of coal mine methane, in terms of its contribution to global climate change and the various anticipated knock-on effects of such change, has received increasing attention.

In 2000, methane accounted for 15% of all human-induced greenhouse gas emissions globally, with coal mining contributing 8% of the total global methane emissions that year. Consequently, coal mine methane contributes more than 1% to global greenhouse emissions. In Australia, methane from coal mining accounts for 3.4% of total national greenhouse gas emissions illustrating the significance of the mining sector locally.

The proposed Surface Gas Drainage Project aims to flare a proportion of the coal mine methane which is currently diluted in the mine ventilation air and vented to atmosphere. This project will therefore serve to reduce greenhouse gas emissions from the coal mining sector within NSW.

The extent of this predicted reduction, expressed as a percentage decrease in NSW and National (2005) greenhouse gas emissions, is as follows:

- Reduction in total NSW 2005 GHG emissions (158.2 Mtpa CO_2-e) by 0.019% to 0.049% (best estimate of 0.032%).
- Reduction in total National 2005 GHG emissions (559.1 Mtpa CO_2-e) by 0.005% to 0.014% (best estimate of 0.009%).

The proposed project would serve to further reduce methane related greenhouse gas emissions associated with West Cliff Mine's operations by approximately 6%, augmenting the existing reductions due to the piping of coal seam methane to the Appin Power Station and utilisation of mine ventilation air for electricity generation at the WestVAMP facility.

The implications of not undertaking the project is that approximately 5-7 ktpa of methane would continue to be emitted to the atmosphere via the mine ventilation system whereas undertaking the project could destroy approximately 70% of it (4-5 ktpa) by flaring.

5 ALTERNATIVES FOR UTILISATION OF COAL SEAM GAS

The need to assess energy production alternatives to coal mine methane flaring has been recently stressed by the Methane to Markets Partnership of which Australia is an active member. The Methane to Markets Coal Subcommittee recently addressed the issue of coal mine methane flaring in its Draft Policy White Paper entitled *Flaring Coal Mine Methane: When Does it Contribute to Sustainable Development* (2006). The Subcommittee maintains that flaring-only contributes substantially less to sustainability than does energy capture, and therefore that flaring should never be the only option considered when planning methane emission abatement. It advises that project developers should consider the costs and benefits of all technologically viable mitigation operations and clearly demonstrate that flaring on balance constitutes the solution of choice in terms of maximising sustainability while achieving acceptable project economics.

The Methane to Markets Coal Subcommittee however recognises that not all energy projects will prove economically attractive, even with revenues from energy and carbon emission reduction sales, with some options clearly being infeasible for power generation. Steps in assessing the viability of methane utilisation are given as:

- Firstly, determining whether energy production is *technically feasible*, and
- Subsequently, considering the *economics and marketability* of the project.

If energy production is technically feasible but project economics can be demonstrated to be unacceptable for energy utilization, flaring methane with no energy capture can be considered an acceptable alternative.

Options for the utilisation of coal seam methane generally include electrical power generation, on-site use in boilers, coal drying and space heating, local low pressure pipeline supply to industry or domestic consumers and injection into high pressure national distribution pipelines. The development of a CSG utilisation scheme generally depends on several factors with market conditions and end use options influenced by (Creedy *et al*. 2001):

- rates of gas production
- gas reserves
- direct or indirect market for gas
- contract conditions in terms of length of supply, gas availability, back up fuel source
- capital and operating costs
- availability and cost of alternative fuels
- existing energy distribution infrastructure
- environmental, planning and regulations

To be commercially feasible such utilisation projects must have a reliable gas supply and a market for gas use or electrical power generation. Furthermore, the cost of supplying the coal seam methane must be competitive with other fuels in the local energy market, particularly with clean fuels such as natural gas and renewables. Irrespective of the end use, most utilisation schemes require gas to be delivered within specified flow rates and purities, with long term supplies generally more desirable particularly in cases where high capital costs are likely to be incurred.

Taking local circumstances at West Cliff Mine into account, the following potential options could be considered for alternative use of the goaf gas extracted by the proposed Surface Goaf Gas Drainage Project:

- Generation and sale of electricity (new power generation facility)

- Piping of gas to the existing Appin Power Station or WestVAMP facility
- Construction of a pipeline to a nearby consumers

An overview of each of these alternative utilisation schemes is given in subsequent subsections and the potential viability of such options briefly considered taking into account the availability, quality and rates of gas production due to the proposed Surface Gas Drainage Project. The aim of this assessment is not to undertake a comprehensive, quantitative technical feasibility study or cost-benefit analysis but rather to determine, qualitatively, whether alternatives hold sufficient potential to warrant additional, in-depth investigation.

5.1 Power Generation (New)

Options for coal seam methane use to generate electrical power typically include the installation of reciprocating engines or gas turbines. Reciprocating engines are, for example, used at the Appin Power Plant. Two power generation configurations have been considered by BHPIC within the current context, namely:

- ~5MW facility, exporting power at 11kV
- >5MW facility, exporting power at 66 kV

The installation of either power generation facility would require back-up flaring capability, installation of a gas capture and reticulation network and power distribution network. It would also require the availability of alternative fuels in the event that shortfalls in the mine gas arise. (E.g. natural gas is added at the Appin power station to ensure consistent quality and quantity when necessary; coal seam methane from the gas drainage plant is utilised at the WestVAMP facility when mine ventilation air qualities are inadequate.)

The power generation facility would not be relocatable and would therefore have implications in terms of local landowners and its criteria pollutant emissions would need to be assessed in terms of the potential for cumulative contributions to the Greater Sydney Airshed.

An advantage of exporting power at 11 kV, rather than 66 kV, would be the reduced electrical infrastructure required to control and protect the broader distribution network. The >5MW option would also require a larger footprint due to the increased number of generating units needed and would be associated with higher costs and complexity, particularly with regard to electrical components.

5.2 Power Generation (Supplement Existing Power Generation Facilities)

The routing of the goaf gas to the Appin Power Station, situated >7km away, would require the installation of a gas compression station and a new high-pressure distribution pipe network. Equipment and software to meter and control gas quality and flow would also be required including power supplies to operate the gas compression equipment.

In consideration of transport and utilisation of the extracted goaf gas at West Cliff as an option, the WestVAMP project is designed to utilise low purity methane in air mixtures (1%) and is not designed to handle the very much higher purities (70 to 80% methane) associated with goaf gases and therefore could not be utilised.

In both cases, the Company does not own land or have right of way to install overland pipelines or the necessary support infrastructure in this regard.

Another aspect considered for utilisation of the goaf gas at the Appin Power Plant is in relation to connection and drawing on the goaf wells via the underground methane extraction infrastructure. The barrier to this is that the Appin and West Cliff underground methane extraction systems are presently not interconnected and are not in a position to (in a mining area and proximity sense) within the life of this project.

5.3 Pipeline Transport for Direct Use of Gas

Significant surface infrastructure would be required to meet the supply quality requirements for pipeline quality gas, including construction of a surface pipeline gas collection network, gas compression station, dewatering facility, pipe network and gas monitoring, quality control and metering system.

Given that the West Cliff Mine is relatively remote in terms of proximity to potential direct industrial or commercial users, the pipeline construction required is also likely to be extensive. Issues associated with land access for pipe network and the potential for environmental impacts associated with this alternative are considerable.

5.4 Gas Reserve, Quality and Flow

A critical factor affecting the technical viability of utilising the goaf gas extracted by the Project for any of the above-mentioned alternatives is the availability, quality and rate of gas production.

All of the potential utilisation schemes identified will require the gas to be delivered within specified flow rates and purities. Given the relatively high capital costs associated with the infrastructure required for these options, it is obvious that longer term supplies would be more desirable to justify expanding the project to incorporate alternative gas utilisation options.

During BHPIC's Surface Goaf Well Trial Program, considerable production variations were noted between the various trial wells (as illustrated in **Section 2.3**), with the causes for such variations still being investigated.

Well flow rates and their influence on longwall gas concentrations are due to a complex interaction between geological and geomechanical factors (Meyer, 2006). More detailed analysis of the effect of goaf wells on longwall gas levels is given as being required to fully evaluate the benefit provided by the wells in terms of improving longwall production and for efficient extraction of coal mine methane for destruction or potential utilisation.

Based on information gathered to date from the surface gas well trials, the following can be concluded with regard to the availability, quality and rate of gas production:

- **Gas Quality** - Although the methane concentration in the goaf gas was noted to vary between ~75% and ~95% during the trial period, the methane content is sufficiently high (i.e. >25%) to support pipeline sales or power generation.
- **Gas Flow** - Considerable temporal variability in the gas flow was noted to occur at individual trial wells, ranging from 0 to 900 L/s, with peaks of 700-900 L/s occurring during week 1 and average flows of 200 L/s during subsequent weeks, reducing to <150 L/s after week 8. Significant variability in gas flow trends also occurred between the various trial wells with the reasons for such variability still under investigation (**Section 2.3.5**).
- **Reserve Extent and Duration** - The duration of the project is given as being restricted to three years, with indications that it may be cut shorter if shown to be ineffective or uneconomical. Considerable uncertainty (factor of 2.6) also exists regarding the exact quantities of methane which will be extracted during the three year period. It is estimated that the methane to be captured over the three year period will be in the range of 8.8 kt to 22.8 kt, with a best estimate of 15.2 kt (**Section 3.1, Table 4**).

Considerable scope still exists for improving the design, practise and management of the goaf gas extraction system to obtain consistently higher methane recovery. Given that investigations in this regard are still underway, and considering available information regarding gas flows, reserve extent and supply duration, it appears impractical at this stage to consider the utilisation of the goaf gas extracted during the proposed project for any of the energy utilisation alternatives identified.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Potential for Alternatives

The need to assess energy production alternatives to coal mine methane flaring/venting is recognised. Based on the projected goaf gas flows, reserve and supply duration for the proposed Surface Gas Drainage Project, and considering the costs and environmental implications associated with infrastructure requirements for the utilisation options identified, such options are not viable at this time.

It is also noted that the goaf gas extraction system at West Cliff Mine is currently still under investigation and that considerable scope exists for improvements in the design, practise and management of the system to obtain consistently higher methane recovery rates.

It is therefore recommended that the Surface Goaf Gas Drainage Project, comprising goaf gas flaring, be permitted as proposed.

Information collected during the project will support improved understanding of goaf gas properties and well behaviour leading to improved designs in extraction systems. This information would be necessary for assessing the feasibility of future gas utilisation systems as West Cliff mining operations continue in the longer term.

6.2 Environmental Implications of the Project

Although the energy content of the flared methane will not be fully exploited given implementation of the project, its global warming potential will be substantially reduced through partial combustion and conversion to carbon dioxide and water.

The proposed Surface Gas Drainage Project is predicted to result in a reduction in greenhouse gas emissions in the range 90 kt to 231 kt (best estimate of 154 kt) CO_2-e during the project period (financial years 2008-2010). This constitutes a 4.6% to 8.0% (best estimate of 6.5%) reduction in West Cliff Mine greenhouse gas emissions during this period.

6.3 Flare Capacity

The greenhouse gas assessment considered the preferred flaring configuration proposed by BHPIC, viz. partial flaring of goaf gas from a single well, comprising two existing flaring units(5) with a combined capacity of 250 L/s.

Based on the gas flow profile for the **initial set of trial wells**, the flare capacity was exceeded for almost 40% of the time, with the flow rate only dropping to <80% of the flare capacity (i.e. <200 L/s) for ~15% of the time. The theoretical flare potential was calculated to be in the range of 75% assuming that flaring would be initiated within a day of the well becoming operational and would be available 100% of the time during the 6-8 week period during which the well was operational. Given these observations it could be concluded that the environmental benefits of the proposed project could be enhanced through improvements in the flare capacity.

Gas flow data obtained for the **latter set of trial wells** however indicates that significant increments in the flare capacity may not be justified. Based on this dataset, the flare capacity was only noted to be exceeded for ~24% of the time, with the flow rate below 80% of the flare capacity for ~50% of the time. The theoretical flare potential was calculated to be of the order of 90%, assuming initiation of flaring within a day of well commissioning and 100% availability of the flaring units.

5 The two enclosed gas flare units are hired from Landfill Management Services.

The above factors indicate that there is potential to improve on the current flare configuration and design.

In the interim, the current flare units should be operated so as to maximise the flaring of extracted goaf gas within the constraints of the flare capacity (e.g. by initiating flaring as soon as possible following wells coming on-line and ensuring flare availability until wells are sealed.)

6.4 Recommended measures for greenhouse gas minimisation and management

It is recommended that the project routinely meter and record the volumes of goaf gas extracted, destroyed by flaring or directly emitted to atmosphere.

The constituent elements of the goaf gas should continue to be analysed at a frequency that provides sufficient data to determine the projects variability in operations and performance and to accurately quantify its impacts and benefits.

Diesel fuel usage should be logged.

It is recommended that if the project is to run beyond the proposed project time frame, then:

- use of gas engine / generator units to provide the necessary project site power should be considered to replace the present diesel engine powered generator units.
- longer term interconnection of the underground methane drainage extraction systems of Appin and West Cliff be considered to increase West Cliff's present underground methane drainage system extraction capacities and to increase the amount of mine drainage gas reticulated to the Appin Power Plant as a consequence.
- improved flaring capacity units be designed.

7 REFERENCES

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8 ABBREVIATIONS AND ACRONYMS

ADO	Automotive Diesel Oil
AGO	Australian Greenhouse Office
BHPIC	BHP Illawarra Coal
CH_4	Methane
CO_2	Carbon dioxide
CO_2-e	Carbon dioxide equivalent emissions
CSG	Coal Seam Gas
EDL	Energy Developments Limited
GWP	Global Warming Potential
Ktpa	kilotonnes per annum
L/s	Litres per second
m^3	Cubic metre
MW	Megawatt
MJ	MegaJoule (joules x 10^6)
NGA	National Greenhouse Accounts
NSW DECC	NSW Department of Environment and Climate Change
SGE	Specific gas emissions
SGW	Surface goaf well
tpa	tonnes per annum
WestVAMP	West Cliff Ventilation Air Methane Project

1. The Greenhouse Gas Protocol Initiative

The Greenhouse Gas Protocol Initiative (hereafter, “the GHG Protocol”) is a multi-stakeholder partnership of businesses, non-governmental organizations (NGOs), governments, and others convened by the World Resources Institute (WRI), a U.S.-based environmental NGO, and the World Business Council for Sustainable Development (WBCSD), a Geneva-based coalition of 170 international companies. Launched in 1998, the Initiative’s mission is to develop internationally accepted greenhouse gas (GHG) accounting and reporting standards for business and to promote their broad adoption. (WBCSD, 2005)

The GHG Protocol comprises two separate but linked standards:

- *GHG Protocol Corporate Accounting and Reporting Standard* (this document, which provides a step-by-step guide for companies to use in quantifying and reporting their greenhouse gas emissions).
- *GHG Protocol Project Quantification Standard* (forthcoming; a guide for quantifying reductions from greenhouse gas mitigation projects).

There are three scopes of emissions that are established for greenhouse gas accounting and reporting purposes, defined as follows.

1.1 Scope 1 Emissions – Direct GHG Emissions

The GHG Protocol defines Scope 1 emissions as those which result from activities under the company’s control or from sources which they own. They are principally a result of the following activities:

- generation of electricity, heat or steam. These emissions result from the combustion of fuels in stationary sources, e.g. boilers, furnaces or turbines;
- physical or chemical processing. The majority of these emissions result from the manufacture or processing of chemicals and materials e.g. the manufacture of cement, aluminium, adipic acid and ammonia, or waste processing;
- transportation of materials, products, waste, and employees. These emissions result from the combustion of fuels in company owned/controlled mobile combustion sources (e.g., trucks, trains, ships, airplanes, buses, and cars)
- fugitive emissions. These emissions result from intentional or unintentional releases, e.g., equipment leaks from joints, seals, packing, and gaskets; methane emissions from coal mines and venting; hydrofluorocarbon (HFC) emissions during the use of refrigeration and air conditioning equipment; and methane leakages from gas transport.

1.2 Scope 2 Emissions – Electricity indirect GHG Emissions

Scope 2 emissions are those which relate to the generation of purchased electricity consumed in its owned or controlled equipment or operations. For many companies, purchased electricity represents one of the largest sources of GHG emissions and the most significant opportunity to reduce these emissions.

1.3 Scope 3 Emissions – Other indirect GHG Emissions

The GHG protocol states that Scope 3 reporting is optional and covers all other indirect GHG emissions. Scope 3 emissions are defined as those which do not result from the activities of a company although arise from sources not owned or controlled by the company. Examples of

Scope 3 emissions include the extraction and production of purchased materials, transportation of purchased fuels and the use of sold products and services.

In the case of the coal mining industry, Scope 3 emissions may include the transportation of sold coal and the use of this coal, either at home or overseas.

The GHG protocol flags the issue that the reporting of Scope 3 emissions may result in the double counting of emissions. A second problem is that as their reporting is optional, comparisons between countries and / or projects may become difficult. The GHG protocol also states that compliance regimes are more likely to focus on the "point of release" of emissions (direct emissions) and / or indirect emissions from the use of electricity. However, for GHG risk management and voluntary reporting, double counting is less important.

2. National Greenhouse Accounts (NGA) Factors

The National Greenhouse Accounts (NGA) Factors document, issued by the Department of Climate Change (DCC) in January 2008 and revised in February 2008, updates and replaces the the Australian Greenhouse Office (AGO) Factors and Methods Workbook published in December 2006.

The NGA Factors are generally taken from the *Technical Guidelines for the Estimation of Greenhouse Emissions and Energy at Facility Level*, published by the DCC in December 2007. The NGA Factors have bee designed to support reporting under the *National Greenhouse and Energy Reporting Act 2007*, once the first reporting period under the Act commences on 1 July 2008.

The NGA Factors however have a general application to a broader range of greenhouse emissions inventories, and their use is not intended to be restricted to reporting under the Act. Further information on the emission estimation methods employed in the National Greenhouse Accounts is available in the *Australian Methodology for the Estimation of Greenhouse Gas Emissions and Sinks* series.

NGA Factors are consistent with international guidelines and are to be subject to international expert review each year.

2.1 Direct Emissions

Direct emissions are defined in the NGA Workbook as those which are produced from sources within the boundary of an organisation and as a direct result of that organisation's activities and arise from the following activities:

- generation of energy, heat steam and electricity, including carbon dioxide (CO_2) and the products of incomplete combustion (methane and nitrous oxide);
- manufacturing processes, which produce emissions (for example, cement, aluminium and ammonia production);
- transportation of materials, products, waste and people; for example, use of vehicles owned and operated by the reporting organisation;
- fugitive emissions – intentional or unintentional GHG releases (such as methane emissions from coal mines, natural gas leaks from joints and seals); and
- on-site waste management, such as emissions from company owned and operated landfill sites.

The NGA 2008 document gives several examples of direct emissions; a company with a vehicle fleet would report the GHG emissions from the combustion of petrol or diesel in these vehicles as direct emissions. A mining company would report methane escaping from a coal seam during mining (fugitive emissions) as direct emissions and a cement manufacturer would report carbon dioxide released during cement production as direct emissions.

2.2 Indirect Emissions

Indirect emissions as those which are defined as being generated in the wider economy as a consequence of an organisation's activities (particularly from its demand for goods and services), but which are physically produced by the activities of another organisation. The most important category of indirect emissions is from the consumption of electricity. Other examples of indirect emissions from an organisation's activities include upstream emissions generated in the extraction and production of fossil fuels, downstream emissions from transport of an organisation's product to customers, and emissions from contracted / outsourced activities. The appropriate emissions factor for these activities depends on the parts of the upstream production and downstream use considered in calculating emissions associated with the activity.

For purposes of harmonisation, the NGA emission factors for indirect emissions have been subdivided into Scope 2 and Scope 3 emissions (adopted by the GHG Protocol).

Broadly, the NGA Workbook defines Scope 3 emissions as including:

- disposal of waste generated (e.g. if the waste is transported outside the organisation and disposed of);
- use of products manufactured and sold;
- disposal (end of life) of products sold;
- employee business travel (in vehicles or aircraft not owned or operated by the reporting organisation);
- employees commuting to and from work;
- extraction, production and transport of purchased fuels consumed;
- extraction, production and transport of other purchased good and materials;
- purchase of electricity that is sold to an end user (reported by electricity retailer);
- generation of electricity that is consumed in a transport and distribution system (reported by end user);
- out-sourced activities; and
- transportation of products, materials and waste.

3. Draft Guidelines for Energy and Greenhouse in EIA

The Draft NSW EIA Guidelines were prepared in August 2002 by the NSW Sustainable Energy Development Authority (SEDA) and Planning NSW (now the Department of Planning (DOP)). The guidelines state that they are an advisory document and should principally be applied to projects which require an EIS under Part 4 and Part 5 of the Environmental Planning and Assessment Act 1979 (NSW) but can also be used for the assessment of other projects.

The Draft NSW EIA Guidelines define four scopes of emissions, the first three being adopted along the lines of the GHG Protocol with the fourth relating to emission abatement.

3.1 Scope 1: Direct Energy Use or GHG Emissions

Scope 1 considers energy use and GHG emissions that occur on site or are under a proponent's direct and immediate control. Scope 1 emissions broadly consist of the energy use and GHG emissions produced by the following activities:

- production of electricity, heat or steam;
- combustion of fossil fuels for any other purpose;
- physical or chemical processing on site;
- transportation of materials, products, waste and employees by proponent controlled vehicles;
- fugitive emissions occurring on site;
- on site landfill wastes or wastewater treatment;
- animal husbandry; and
- on site vegetation or soil disturbance.

3.2 Scope 2: Indirect Energy Use or GHG Emissions from Imports and Exports of Electricity, Heat or Steam

Scope 2 broadly focuses on the indirect emissions associated with the generation of purchased and imported electricity, heat or steam.

3.3 Scope 3: Other Indirect Energy Use or GHG Emissions

Scope 3 considers the indirect energy use or GHG emissions that are a consequence of the Project but do not occur on site or those emissions which are removed from the proponent's direct control. Examples of Scope 3 emissions as described in the Draft NSW EIA Guidelines include the following:

- off site waste management (e.g. land filled waste or waste water treatment);
- transportation of products, materials and waste by vehicles not controlled by the proponent;
- employee related business or commuter travel;
- outsourced activities;
- production of imported materials, plant and equipment; and
- use of products or services produced by the Project (and end of life phases of products).

3.4 Scope 4: GHG Emission Abatement from Offset Opportunities

Scope 4 reporting under the Draft NSW EIA Guidelines allows the reporting of any carbon offsets which have occurred as a direct result of the Project. Proponents may report the following if applicable:

- carbon sequestration performed by the proponents;
- community based energy use or emissions reduction initiatives;
- the use of government endorsed Kyoto Protocol flexibility mechanisms such as Clean Development Mechanism (CDM) and Joint Implementation (JI) (refer **Section 3.4.1** below).

3.4.1 Kyoto Protocol Flexibility Mechanisms

Although Australia has not currently ratified the Kyoto Protocol (KP) and is therefore not bound by its commitments, the GHG offset mechanisms contained within the KP can be used as instruments for carbon reduction and can be reported in Scope 4 of the Draft NSW EIA Guidelines. The following mechanisms are relevant for reporting under Scope 4:

- Clean Development Mechanism (CDM) – Developed countries can invest in greenhouse gas emission reduction projects in developing countries;
- Joint Implementation (JI) – Developed countries can invest in greenhouse gas reduction projects in other developed countries.

4. Policy Instruments

4.1 The NSW Greenhouse Plan

Published in November 2005, the NSW Greenhouse Plan is a strategic document which sets out the NSW Government's aims and initiatives in terms of greenhouse gas emissions abatement over the next 20 to 45 years. The NSW Government state that it would like to meet the following criteria:

- a 60% reduction in greenhouse gas emissions by 2050; and
- cutting greenhouse gas emissions to year 2000 levels by 2025.

The NSW Greenhouse Plan does not set out a methodology for reporting greenhouse gas emissions, rather seeks to:

- increase awareness among those expected to be most affected by the impacts of climate change;
- begin to develop adaptation strategies to those unavoidable climate change impacts; and
- put NSW on track to meeting the targets set out above.

5. References

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1. Baseline Coal Seam Methane Emissions Based on Mine Ventilation Data

Site-specific data, in the form of mine ventilation air volumes and measured methane concentrations, are available for the quantification of current coal seam methane emissions from the West Cliff Mine. Baseline methane emissions estimated based on current mine ventilation air volumes are given in Table 1. The current mine ventilation air volume was given by BHPIC as being on average 340 m^3/s with the methane content ranging between 0.7% and 1.1% and on average 0.9% for 11 months of the year reducing to ~0.2% due to longwall change out during one month a year. Uncontrolled methane emissions were therefore estimated to be in the range 47 ktpa to 73 ktpa (average of 60 ktpa), assuming a methane density of 0.662 kg/m^3 (at temperature of 25°C). With the methane in the 250,000 m^3/hour coal mine ventilation air being converted to 6 MW of electricity at WestVAMP, an estimated 10 ktpa to 15 ktpa (average 12 ktpa) of methane is likely to be removed. Current methane emissions, remaining following the WestVAMP utilisation of 20% of the mine ventilation air, are calculated to be in the range 37 ktpa to 58 ktpa (average of 48 ktpa CH_4).

Table 1 Baseline methane and CO_2-equivalent emissions within mine ventilation air at West Cliff Mine

	Methane Emissions within Mine Ventilation Air		
	Minimum (based on 0.7% CH_4)	**Average (based on 0.9% CH_4)**	**Maximum (based on 1.1% CH_4)**
Total methane emissions within mine ventilation air (uncontrolled)	46.7 ktpa CH_4	59.7 ktpa CH_4	72.8 ktpa CH_4
Reduction in methane emissions due to WestVAMP	(9.5 ktpa CH_4)	(12.2 ktpa CH_4)	(14.9 ktpa CH_4)
Total methane emissions (controlled)	**37.2 ktpa CH_4**	**47.5 ktpa CH_4**	**57.9 ktpa CH_4**
Baseline CO_2-equivalent emissions	**780.8 ktpa CO_2-e**	**998.3 ktpa CO_2-e**	**1,215.8 ktpa CO_2-e**

2. Baseline Coal Seam Methane Emission Estimation Based on AGO Workbook Factors

Greenhouse gas emissions due to venting of coal seam gas from baseline West Cliff Mine operations were calculated based on AGO Workbook emission factors for the production of coal in gassy underground mines in NSW (**Table 2**) for comparison with estimates made on the basis of site-specific information.

Table 2 AGO Workbook (2006) Emission factors for coal production (fugitive)

	AGO Workbook 2006 Emission factor for Scope 1 (Direct source Emission Factor) (kg/tonne raw coal)		
	CO_2	**CH_4**	**CO_2-e**
Gassy underground coal mines – NSW	NA	14.54	305.3

Given raw coal extraction of the order of 3 Mtpa, total CO_2 equivalent emissions are estimated to be 916 ktpa.