CARBON NEUTRAL MINE SITE VILLAGES: MYTH OR REALITY?

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Abstract: This paper focuses on the calculation of the carbon footprint of a typical West Australian mine site village and the ways by which it can be reduced to a point where the village can be legitimately described as ‘carbon neutral.’ The study contributes to a broader ARC joint research program by Murdoch and Curtin Universities entitled ‘Decarbonising Cities and Regions.’

The term carbon neutral has a far from uniform definition. For the purpose of the carbon accounting that follows carbon neutrality is achieved when there is a net zero carbon footprint across the full life cycle or when total emissions are balanced by total offsets. As much of the full life cycle of the village as is practical is included in the process and acknowledges any omissions made. The paper will show how the carbon footprint of a mine site village in Western Australia’s mid-west has been measured, calculated and reduced effectively to a point where carbon neutrality can be claimed. This will commence with calculation of the embodied and operational energy in constructing and operating the village, followed by methods towards achieving carbon neutrality. The latter includes energy efficiency opportunities; an environmental and economic sustainability assessment of renewable energy and construction materials; design modification of the infrastructure; and assessment of accredited biomass offset mechanisms. The whole process has been termed LEVI©: Low Energy Village Infrastructure.

An economic assessment of the carbon neutral strategy is the key to implementation. Mining companies are particularly drawn to the ‘bottom line’ when making investment decisions and only sound financial analysis will facilitate substantial carbon neutral expenditure. LEVI© significantly includes a net present cost (NPC) analysis of all such investment and belies the myth that carbon neutral mine site accommodation cannot be achieved. The paper then presents a carbon accounting methodology of the case study mine site village and set out the results and overall carbon emissions the village is responsible for. This life cycle analysis (LCA) is done from cradle to gate in terms of LCA terminology and represents the manufacture, construction, installation and operation. Energy efficiencies and behavioural changes are then applied and estimated as to their carbon reductive effect on the total carbon, followed by verifiable renewable energy offsets. These offsets are substantiated by a vigorous renewable energy analysis and selection supported by an NPC analysis. An optimum renewable energy system (RE) is then selected (best value for money) and its carbon reducing effect over the current power system calculated. This amount, together with that produced by energy efficiencies and behavioural changes, makes a total carbon reduction and is annualised.

The paper clearly shows that the projected life of the mine, and therefore the village, is a critical factor in the overall carbon analysis and that the optimum time period within which carbon neutrality of such a mine site village can be claimed lays somewhere between 7 and 10 years. Another key finding was that the capital expenditure (CAPEX) savings by developing such a village as a standalone facility produces clear advantages over connection to a mine power generation system as is the case study example. The optimum standalone RE system for introduction from 2014 was found to be 110kW fixed amorphous photovoltaic array and two 100 kW wind turbines with one 150kW and one 100 kW low-cycle diesel generators as backup. The projected cost was approximately $2 million.

It is contended that the metrics produced from the results can provide a pro-rata basis with which to model future carbon neutral villages of similar construction. The model accommodates dependencies such as life of mine, size of village, number of workers and location. The paper will describe some innovative solutions and outcomes from this research that may be applied to the built environment on a broader scale.

Keywords: Carbon neutral, carbon reduction, mine site villages, LCA, NPC.
1. INTRODUCTION

Access to a typical mine site village was essential for the research and determination of the carbon footprint during its lifecycle from manufacture to operation. Black Cat Camp (MMG) in Mt. Magnet, Western Australia, owned by Ramelius Resources Ltd (RMS) was agreed to be the site of this study. Flights and access over the research period was made available by RMS for installation of an extensive online monitoring system and information gathering from the staff operating the camp. Data has been collected for 20 months from 44 power circuits and 7 water meters the analysis of which has been completed. MMG is typical of many throughout the nation, if not the world, in that it is made up of lightweight transportable accommodation and amenities buildings shipped to site by road, accessible by road and air.

Five main research questions form the essence of this paper:

1. What is the carbon footprint of a typical mine site village?
2. In the context of mine site village development what does the term “carbon neutral” mean?
3. What are the constituents of this footprint and how are they calculated?
4. How can the footprint be sustainably reduced to a point of carbon neutrality?
5. Is the Carbon Neutral mine site village a viable proposition or merely a desirable objective in the context of sustainable development of the built environment?

Following sections will answer these research questions and include: a methodology and conceptual model of the carbon accounting process with emphasis on the boundaries of such an LCA, limitations of the study, the tools used and understanding of carbon neutrality in the context of this research; a results section of the carbon emissions of MMG over village lifespans of 5, 10, 15 and 20 years; conclusions and recommendations to achieve carbon neutrality in future mine site villages and application to the built environment more generally. For the purpose of comparison of the results with per capita carbon emissions attributed in the literature the overall emissions calculated in this research is divided by 162 which is the individual capacity of MMG. This highlights the magnitude of how dramatically a fly-in fly-out working regime can increase a person’s annual carbon footprint just by going to work. Once established the carbon account needs to be offset by considering energy efficiency and behaviour change measures followed by renewable energy offsets. A final mechanism to achieve carbon neutrality is not considered here, that is the purchase of permits emanating from accredited forestry or alternative biomass.

A definition of the term ‘Carbon Neutral’ answers Q 2 above. The term has been defined largely by popular usage in the past (Murray and Dey, 2007). Even within scientific literature the academic definitions are few and varied, despite a raft of papers on life cycle analysis, input and output methods and tools for carbon accounting, especially when considering which emissions of the built form life cycle are actually to be included (Wiedmann and Minx, 2008). Murray and Dey (2007) discuss the terms ‘carbon neutral’ and ‘carbon footprint’ with several references on the subject (Goodfield et al 2011). In the context of this paper the calculation of the carbon footprint is regarded as comprising of the carbon emissions from the life cycle of the mine site village that can reasonably be calculated, from a clear site for development through to the end of life estimated to be between 5 and 20 years.

2. METHODS

Previous research has developed a conceptual model (Figure 1 below) to organise calculation of the carbon emissions MMG is responsible for (Goodfield et al, 2011). The areas of emission accounting are set out in Figure 2 below.

2.1 Embodied energy - Three methods were used to calculate the embodied energy of MMG: carbon inventory analysis of scope 1 and 2 emissions, as defined by the Commonwealth Government (DCCEE, 2010); life cycle analysis (LCA), a method supported by the International Energy Association outlined in AS/NZS ISO standard 14040:2006 which states that the assessment is conducted for impacts throughout a product's life, in this case from “cradle to gate’; and finally, carbon profiling, a modification of LCA to include the emissions associated with land development itself according to the fuel consumed and its emissions factor when applied to a specific location (Hamilton et al, 2007). The carbon account requires the system boundaries of where the responsibility for the emissions lay to be defined.

Once the overall footprint of the village is calculated, following the National Carbon Offset Standard guidelines (NCOS, 2009) then process of offsetting begins. This included: reduction of the embodied energy of construction; implementation of operational energy efficiency measures; renewable energy system offsets to achieve carbon neutrality within a defined period achieved, each process measured by the mass of carbon they are reduced by. The energy efficiency measures and behavioural changes, in terms of carbon reduction, could only be estimated at this stage using personal experience across the building industry. The results are tabulated in section 3 along with quantification of table 1.
Table 1: Areas covered in carbon account with short description of process and applied tools

<table>
<thead>
<tr>
<th>Facility/Operation</th>
<th>Process</th>
<th>Tool or method of calculation of carbon emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Operational Energy</td>
<td>81% LNG and 19% Diesel power generation at mine</td>
<td>Data from RMS &amp; mentoring. National Greenhouse Account Factors.</td>
</tr>
<tr>
<td>5. Fly In – Fly Out transport</td>
<td>Air travel – 8 days on/ 4 off roster</td>
<td>Gov. Victoria and South Australia worksheets (GHG Protocol 1&lt;sup&gt;y&lt;/sup&gt; source)</td>
</tr>
<tr>
<td>7. Solid Waste</td>
<td>Mixed waste to landfill</td>
<td>National Greenhouse Account Factors.</td>
</tr>
</tbody>
</table>

2.2 Explanation of Table 1

2.2.1 Accommodation & General Buildings – the embodied energy of buildings, and the infrastructure to service them, consumes up to 40% of global energy consumption and produces 30% of the world’s carbon emissions (UNEPE, 2009). It, therefore, can provide a large proportion of the carbon footprint of MMG. Freeware known as eTool™ has been used to calculate this embodied energy and the results certified as correct by the software developers. The tool applies internationally recognised life cycle inventory database methodology and algorithms specific to Australia and complies with ISO 14040 to 14044:2006.

2.2.2 Transport of Buildings – the buildings were constructed in a Perth southern suburb and transported on single trailer to transfer station north of Perth where twin trailers would take over for the 600km journey to Mt. Magnet. Average fuel consumption figures per tonne x km were provided by peer reviewed paper Gaballa (2007) supported by the Australian Bureau of Statistics. Fuel combustion emission factors for fuels used for transport energy purposes were provided by the National Greenhouse Account (NGA) Factors (DCCEE, 2010 at 17).

2.2.3 Operational energy – discussion with Engen Ltd, lessors of the power plant to RMS at the mine head, confirmed that fuel for the energy production was in the ratio of 81.19 liquid natural gas (LNG) to diesel. The NGA Factors (DCCEE, 2010 at 15) details the fuel combustion emission factors for liquid fuels and certain petroleum based products for stationary energy purposes.

2.2.4 Transport of Supplies – as per item 2 for the calculation based on truck delivery from Perth.
2.2.5 Fly In – Fly Out transport - Carbon emissions per km per person for medium haul flight (<500km) verified by South Australia local government worksheet, following the GHG Protocol. It was assumed that all MMG staff fly from Perth, although many access Perth Airport from considerable distances away and some travel to MMG from other areas.

2.2.6 Water Supply & Waste Water Treatment – bore water is supplied, pumped and stored at MMG. Energy is required to desalinate this groundwater, distribute it for camp use, return the waste to the waste water treatment plant, treat the waste, and finally pump out to secondary treatment ponds outside the camp. Data monitoring and meter reading provided the information required to determine the energy required for all these processes. The NGA Factors provided detail of greenhouse emissions from waste water treatment (DCCEE, 2010 at 70).

2.2.7 Solid Waste – detail of the amounts of solid mixed waste sent to RMS’ private landfill were provided by MMG. The NGA Factors gave detail of greenhouse emissions from landfill (DCCEE, 2010 at 46).

2.3 Renewable energy selection
The process of selection of an optimum renewable energy system to offset the balance of carbon emissions left after energy efficiency and behavioural change measures have been subtracted from the gross figure, is a complex process and subject of previous research, as yet unpublished. However, a précis follows herein.

2.3.1 Energy demand – the predicted annual demand was little over 1GWh and maximum demand at 300kW. Monitoring for an extensive period confirmed this figure was accurate. A load profile can be seen in figure 2 below.

Figure 2: MMG village electricity use forecast from June 2011 to November 2013 (BEC engineering, 2011)

2.3.2 Current power system - the most significant complication to assessing renewable energy (RE) penetration at MMG is that the village is connected to the mine generating system and the primary software, HOMER (HOMER, 2010), models only standalone systems.

2.3.3 Technology identification and selection – as well as essentially being designed for assessing standalone RE HOMER is not designed to model generators meeting 80% of demand and another 20% of the load at the same time as here where the generation is by using LNG and diesel fuels in these proportions respectively. A new Excel spreadsheet was developed to accommodate this situation referred to as REMAX and based similar principles to HOMER and single source systems as well as hybrid systems were analysed. No battery backup was required as the MMG village power system behaves as a small grid connected system using the mine’s power system as backup when required.

HOMER was, however, used to assess the potential of appropriate RE systems while treating MMG as a standalone facility in order that this possibility could also be considered. A variety of diesel generator manufacturers were researched and low load diesel generators were found to be the most suitable in this situation. These can run at 5% of maximum capacity and provide significant financial savings and increased RE penetration in the system. Batteries tend to lower the overall efficiency of such systems and were not considered except.

In both standalone and grid connected configurations PV an wind were the optimum RE systems selected although the hybrid mix varied according to the following economic assessment.

2.3.4 Economic assessment - each configuration was investigated for project lives from 1 to 20 years). Various PV array and wind turbine were analysed and selected dependant on the resource as well as the capital and ongoing costs. The configuration with the lowest Net Present Cost (NPC) could then be identified with the lowest NPC as the most economically viable, both in standalone and mine generation plant connected formats. The results of this analysis can be seen in section 3 below.

3. RESULTS
The research questions set out in section 1 above can now be answered.
3.1 What is the carbon footprint of a typical mine site village?
The embodied energy of the village has been calculated at 1022 tonnes CO$_2$e for the case study village with a projected lifespan of 5 years although they are frequently reused elsewhere. The lifespan is significant as the embodied energy of manufacture and installation is a one-off total and the longer the village is in operation the smaller each annual proportion becomes. See Table 2 below.

<table>
<thead>
<tr>
<th>Facility/Operation</th>
<th>Emissions p.a. (tonnes CO$_2$e)</th>
<th>Proportion of Total</th>
<th>Lifespan</th>
<th>Emissions per annum over lifespan</th>
<th>Emissions per worker per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation &amp; General Buildings (5 yr lifespan)</td>
<td>1022</td>
<td>39.3%</td>
<td>20 years</td>
<td>1826 (Tonnes CO$_2$e)</td>
<td>11 (Tonnes CO$_2$e)</td>
</tr>
<tr>
<td>Transport of buildings to MMG</td>
<td>11</td>
<td>0.4%</td>
<td>15 years</td>
<td>1912</td>
<td>12</td>
</tr>
<tr>
<td>Operational Energy</td>
<td>490</td>
<td>18.8%</td>
<td>10 years</td>
<td>2083</td>
<td>13</td>
</tr>
<tr>
<td>Transport of MMG supplies</td>
<td>91</td>
<td>3.6%</td>
<td>5 years</td>
<td>2600</td>
<td>16</td>
</tr>
<tr>
<td>FI-FO</td>
<td>653</td>
<td>25.1%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste Water Treatment &amp; Desalination</td>
<td>50</td>
<td>1.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid Waste</td>
<td>283</td>
<td>10.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>2600</td>
<td>100%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Left side - Carbon account summary of Black Cat Camp with lifespan of 5 years. Right side – Comparison of total emissions over various lifespans.

3.2 In the context of mine site village development what does the term “carbon neutral” mean?
The term has been defined largely by popular usage in the past (Murray and Dey, 2007). Even within scientific literature the academic definitions are few and varied, despite a raft of papers on life cycle analysis, input and output methods and tools for carbon accounting, especially when considering which emissions of the built form life cycle are actually to be included (Wiedmann and Minx, 2008). Murray and Dev (2007) discuss the terms ‘carbon neutral’ and ‘carbon footprint’ with several references on the subject (Goodfield et al 2011). In the context of this paper the calculation of the carbon footprint is regarded as comprising of the carbon emissions from the life cycle of the mine site village that can reasonably be calculated, from a clear site for development through to the end of life estimated to be between 5 and 20 years.

3.3 What are the constituents of this footprint and how were they calculated?
The carbon footprint is calculated from the aggregate of the carbon emissions from the following (as in Table 1 above): the embedded energy from the materials comprising the accommodation & general buildings; emissions from the transport of the buildings to site; the energy required to operate the village; the energy for transport of supplies to the village; FI-FO emissions; the energy required to desalinate stored bore water and pump distribution; the energy required to pump waste water to the WWTP; from anaerobic digestion of waste water and pump out to settling ponds; and fugitive emissions from mixed waste sent to landfill.

3.4 How can the footprint be sustainably reduced to a point of carbon neutrality?
3.4.1 Energy efficiencies can be applied in many ways, from simple technological solutions, such as increasing insulation and modifying lighting, adding more effective shade to the more complex smart systems to monitor and control a building’s thermal comfort. It has been estimated that energy savings of between 30 to 50% can be made in the built environment without substantial expenditure (UNEP, 2009).
3.4.2 Programs to achieve behaviour change in communities are now commonly practiced by utilities and governments typically using a community based social marketing methodology for best results (McKenzie-Mohr, 1999). Discussion and development of a methodology to introduce staff to new technologies and systems that might affect their amenity needs to follow the introduction of any technology or operational system change.
Removal of any barriers to change is essential, not only to implement the change but to maintain it in a cost-effective and socially acceptable way (McKenzie-Mohr and Smith, 1999: 19). The significance of social acceptance is woven into the technology development (Osislo, 2010: 2).

Table 3 below includes a selection of energy efficiency measures and behavioral change possibilities together with estimated carbon emission reduction effect. The potential to increase these ‘low hanging fruit’ measures depends on several factors, primarily commitment to ecologically sustainable development and village ownership (see head of figure 1 above).

Two renewable energy systems were assessed and found appropriate for consideration at MMG: solar photovoltaic (PV) and wind with low-cycle diesel generation backup. A Net Present Cost analysis follows in section 3.5.1 below.

<table>
<thead>
<tr>
<th>Reduction Method</th>
<th>Detail</th>
<th>Carbon Reduction/annum across whole village</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Energy efficiency:</strong></td>
<td>Village design, improved insulation, shade structures, water heating.</td>
<td>- 12.5% (estimate) = - 13 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td>i. Modified building construction design.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. Smart control</td>
<td>Integrated BMS.</td>
<td>- 12.5% (estimate) = 13 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td>iii. Laundry modification</td>
<td>Energy efficient appliances</td>
<td>= - 1 tonne CO$_{2e}$</td>
</tr>
<tr>
<td>iv. Roster change (flight reduction)</td>
<td>From 8 ON 4 OFF to 10 ON 5 OFF</td>
<td>56 flights 48 = - 93 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td>v. Grey water reuse of residential waste water</td>
<td>Reduces ½ vol. water to WWTP</td>
<td>= - 25 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td><strong>2. Behaviour Change:</strong></td>
<td>Efficiencies</td>
<td>- 10% (estimate) = - 5 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td>i. Water use - desalination</td>
<td>Overall awareness to reduce operational energy.</td>
<td>- 10% (estimate) = - 10 tonnes CO$_{2e}$</td>
</tr>
<tr>
<td>ii. Waste water - treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. General awareness</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>- 160 tonnes CO$_{2e}$ (Complete village)</td>
</tr>
</tbody>
</table>

Table 3: Energy efficiency and behaviour change examples with carbon emission resultant reduction.

3.5 Is the Carbon Neutral mine site village a viable proposition or merely a desirable objective in the context of sustainable development of the built environment?

The essence of the question points to the question in title of the paper – ‘myth or reality?’ Is there evidence to show that the lifetime carbon emission responsibility of a typical mine site village can be sustainably offset to a point where carbon neutrality can be legitimately claimed and to the satisfaction of all stakeholders and avoid contravention of Australian Consumer Law under the Competition and Consumer Act, 2010 wherein carbon related claims must not ‘mislead or deceive’ those relying on the information (ACCC, 2011: 3) and is relevant to this research if a future developer of similar villages makes the claim to be carbon neutral.

<table>
<thead>
<tr>
<th>Lifespan of Village</th>
<th>Emissions per annum over lifespan of village (Tonnes CO$_{2e}$)</th>
<th>Estimated emission reduction per annum (Tonnes CO$_{2e}$)</th>
<th>Overall reduction % p.a.</th>
<th>Annual balance of carbon to offset (Tonnes CO$_{2e}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 years</td>
<td>1826</td>
<td>160</td>
<td>8.7</td>
<td>1666</td>
</tr>
<tr>
<td>15 years</td>
<td>1912</td>
<td>160</td>
<td>8.4</td>
<td>1752</td>
</tr>
<tr>
<td>10 years</td>
<td>2083</td>
<td>160</td>
<td>7.7</td>
<td>1923</td>
</tr>
<tr>
<td>5 years</td>
<td>2600</td>
<td>160</td>
<td>6.2</td>
<td>2440</td>
</tr>
</tbody>
</table>

Table 4: Deduction of energy efficiency and behaviour change measures from gross carbon emissions.
Having established the quantity of carbon that the selected RE system is required to offset (see Table 4) an economic assessment now needs to be made to justify the expenditure. This was done using the NPC method and the results can be seen in the following graphs using an annual discount rate of 8%. Note the detail of both standalone and grid connected analyses.

3.5.1 NPC analysis of RE systems – the accelerated reduction of the cost of PV installations has far exceeded the International Energy Agency’s 2010 prediction of 40% by 2015 and 50% by 2020 (Hearps et al. 2011). Similarly with wind the predicted reduction of 17% by 2030 has been significantly exceeded. Current costs of both through NPC analysis fully justify the investment.

Graph 1: NPC Projects commencing 2013 and 2018 connected to mine power plant.

Graph 2: NPC Current power system of various lengths and standalone systems compared.

3.5.2 Interpretation of the Graphs 1, 2 and 3:

**Graph 1** – 2013 cost of PV and wind indicate a financial advantage of approximately $1 million for the optimum RE system to offset MMG’s carbon account to a point of neutrality (see table 5 below). 2018 projected cost of PV and wind indicate a financial advantage of approximately $1.75 million. The financial advantage appears at year 6 of the life of the village.

**Graph 2** – indicates a financial advantage of between $1 million and $2 million if the supply line from the mine site generation plant is not constructed and the village exists as a standalone facility. Estimates vary per km of supply line but the figure of $80k has been used here, that is, for the ‘non-construction’ of a 9km power line the CAPEX
saving would be $240,000 and pay for approximately a 100kW fixed PV array. The financial advantage appears at year 6 of the life of the village by removing a 9 km supply line but only from year 9 with a 6km line or less.

Graph 3 - indicates the financial advantage of standalone RE with low-cycle generator backup, on a zero discount (simple payback) accounting basis, is up to $2.75 million cheaper than the current system up to 9 km in length.

Clearly the longer the lifespan of the village the greater the financial advantage of RE with low-cycle generator backup.

### Table 5: Offset of carbon emissions by standalone RE and grid connected systems compared against life of mine.

<table>
<thead>
<tr>
<th>Village Lifespan (years)</th>
<th>Balance of carbon for RE to offset per annum (Tonnes CO(_2)e)</th>
<th>Carbon emission reduction p.a. 2014 (Tonnes CO(_2)e)</th>
<th>Carbon emission reduction p.a. 2018 (Tonnes CO(_2)e)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standalone RE (years)</td>
<td>Grid connected RE (years)</td>
<td>Standalone RE (years)</td>
</tr>
<tr>
<td>20</td>
<td>1666</td>
<td>3.7</td>
<td>3.6</td>
</tr>
<tr>
<td>15</td>
<td>1752</td>
<td>5.2</td>
<td>4.5</td>
</tr>
<tr>
<td>10</td>
<td>1923</td>
<td>6.7</td>
<td>11.7</td>
</tr>
<tr>
<td>5</td>
<td>2440</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 5: Offset of carbon emissions by standalone RE and grid connected systems compared against life of mine.

The optimum standalone RE system for introduction from 2014 was found to be 110kW fixed amorphous photovoltaic array and two 100 kW wind turbines plus two low-cycle generators as backup (1 x 150 kW to meet peak load and 1 x 100 kW backup). The projected cost was approximately $2 million in 2014 reducing in time.
4. CONCLUSIONS

There were several aims for the research behind this paper to which the research questions in the paper refer, namely:

1. Calculation of the carbon footprint of a typical West Australian mine site village.
2. Assess the carbon footprint reduction by employing energy efficiency and behaviour change measures.
3. Assess optimum RE offsets of the selected village for mine site grid connection and standalone configurations.
4. Determine the time taken for economically viable RE systems to offset the balance of carbon emissions remaining following the deduction of estimated emission reduction of energy efficiency and behaviour change measures from the gross village account.
5. Consider the financial and technical implications of removing the power supply line and severing the mine site village from the mine generating plant several kilometres away, and calculate any advantages of applying this process to a variety of distances.
6. Investigate the applicability of metrics produced by the overall results to model future carbon neutral villages of similar construction based on dependencies such as life of the enterprise, size of village, number of workers and location.
7. Determine the broader implications of the overall findings to Decarbonising Cities and Regions ARC of which this research is part.

4.1 Research Conclusions (corresponding with paragraphs 1- 7 in section 4)

1. The carbon footprint of MMG village varied according to the life of the village and was assessed to be a minimum of 1826 tonnes CO$_2$-e for a 20 year lifespan and 2600 tonnes CO$_2$-e for 5 years. For convenience of calculation it was assumed that the village buildings would not be recycled for use elsewhere. These figures divided by the number of village residents equates to between 11 and 16 tonnes CO$_2$-e per person per annum. When compared to equivalent published per capita carbon emissions per annum of 15 tonnes CO$_2$-e in a West Australian report (Govt. of W.A, 2008) and the broad Garnaut Review 2008 where Australian’s individual responsibilities for carbon emissions is set at 28.5 tonnes CO$_2$-e, referring to the World Development Report 2010 (World Bank, 2010).

2. The application of energy efficiency and behaviour change measures, although effective, are likely to reduce the annual carbon footprint by only an estimated 6% at 160 tonnes CO$_2$-e. The balance can be offset by the introduction of RE systems provided that they are financially acceptable in budgetary terms to the mining company.

3 & 4. Table 5 sets out both the optimum standalone and grid connected RE system over village lifespans of 5 to 20 years. The RE carbon reduction has been calculated to account for the full balance of emissions at 3.7 to 6.7 years as a standalone system and 3.6 to 11.7 years as a grid connected system if the system is purchased and installed at 2013 rates. With purchase and installation cost projected to 2018 the standalone coverage of carbon can be offset between 3.9 and 7.1 years and for grid connected between 3.4 and 20.4 years.

As the sun doesn’t shine and the wind blow 24/7 two low-cycle diesel generators would be attached to all RE configurations to meet the necessary peak load in the village.

5. The current power system is the generating plant adjacent to the mine itself. A spur line runs approximately 8 km to the village. Analysis has been carried to determine if there is any financial gain to set up the village as a standalone facility as if the spur was not constructed and the CAPEX of so doing saved.

The analysis of creating the village as a standalone facility appears in Graphs 2 and 3 above, the former a NPC analysis based on discount rate of 8% and a simple payback based on 0% discount. Graph 2 shows a
financial advantage of RE installation of between $1 million and $2 million by not constructing a 3 km and 9 km spur respectively. Graph 3 indicates a higher return.

Furthermore, both graphs indicate that the minimum lifespan of the village for this scenario is 5 years.

6. There is clear applicability of the metrics produced in this research to future mine site village development. The dependencies have been mentioned above and are: life of mine – and therefore village; size of village and number of residents; location for RE resources and access to fuels other than diesel, such as LNG via the Dampier pipeline in Western Australia.

7. This research contributes to the Decarbonising Cities and Regions ARC awarded jointly to Murdoch and Curtin Universities. A cornerstone of the decarbonising research is carbon neutrality of the built environment and it is this that this paper addresses directly. Global miners, Rio Tinto, BHP and Xtrata, all significantly represented in Australia, accept their responsibility to tackle climate change (Rio Tinto, 2011; BHP, 2010; Xtrata, 2011). Environmental consultants Sinclair Knight Merz indicate that mining companies are now giving serious consideration to ecological sustainability in mine site accommodation development, as well as mining per se, and report on one such investigation (SKM, 2008), however, to date little more has been published by others. The award-winning report reveals no quantification of the overall carbon footprint other than indicating a reduction in water use of 50 per cent and energy use of 30 per cent per head (Goodfield, 2011).

This paper details a practical carbon accounting method which can be applied on a wider scale to similar construction in Australia and, with appropriate modification, internationally. The global thirst for resources is likely to continue and if resource companies can adopt an approach to carbon emission reduction as detailed in this paper there is little reason why it cannot be applied on a wider scale to mining itself. The emissions mitigated would certainly reinforce an ethical corporate responsibility espousing global warming reduction.

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References


DCCEE (2010). Commonwealth Govt. of Australia, Department of Climate Change & Energy Efficiency, National Greenhouse Accounts (NGA) Factors, Canberra, ACT.


