Prediction of Greenhouse Gas Emissions for the Olympic Dam Mega-Expansion

Technical Paper

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Overview

This briefing paper presents a broad analysis of the potential greenhouse gas emissions (GHG) for the next Olympic Dam expansion – whereby the current underground mine and on-site metallurgical complex is converted to a massive open cut mine with approximately half of the product processed at a new on-site metallurgical complex and half of the uranium (U) rich copper (Cu) concentrate is exported to China for a total of 730,000 t Cu/year and 19,000 t U_3O_8/year. In addition, the potential expansion to a 1,000,000 t Cu/year and 23,000 t U_3O_8/year is also analysed. The history to date of Olympic Dam operations is reviewed, followed by a brief description of the proposed expansion (as known from the public record), and finishing with a detailed analysis of the major components contributing to energy consumption and therefore greenhouse gas emissions.

Production and Greenhouse Performance 1991 to 2006/07

The Olympic Dam deposit was first discovered in 1975 by Western Mining Corporation (later to be WMC Ltd) and, after extended project difficulties and political controversies, production began in August 1988. The current configuration can be simply described as involving underground mining, ore grinding, flotation to produce a U-enriched Cu concentrate and uranium-rich tailings, acid leaching of the Cu concentrate, which is then processed in a conventional smelter and then refinery, while the flotation tailings are also acid leached and the metal-rich solutions sent to a hydrometallurgical plant for processing to extract the majority of U (as 'U_3O_8') plus a small amount of Cu. Although there is more complexity to the total Olympic Dam process flow sheet for treating the ore and producing the four metals, the above description is reasonable, and is shown in Figure 1.

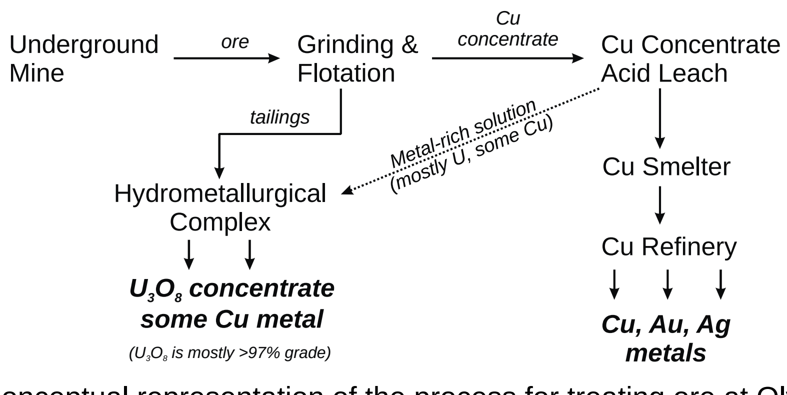

Figure 1: Conceptual representation of the process for treating ore at Olympic Dam (adapted from Kinhill, 1997)

By December 2008 the project had treated some 113.54 million tonnes (Mt) of ore, with average grades of 2.46% Cu, 0.070% U_3O_8 and about 5.8 g/t silver (Ag) and 0.55 g/t gold (Au), to produce some 2.516 Mt of Cu, 52,586 t U_3O_8, 332.9 t Ag and 33.9 t Au (about 1.1 million ounces of gold). This gives an average extraction efficiency of 90.0% for Cu, 65.8% for U_3O_8, and about 50% each for Ag and Au[1].

[1] Since the takeover of WMC Ltd by BHP Billiton Ltd in 2005, gold and silver grades in ore processed are no longer reported, hence Ag-Au ore grade and extraction efficiency estimates are long-term averages from 1988 to mid-2005.

Quarterly production data over time is shown in Figure 2, showing a gradual decline over time for all ore grades (except gold) and the relative difference in production scale between the first and second decades of the Olympic Dam project. The discrepancies in Cu production >100% are most likely a result of the timing of production between the mine, mill, smelter and refinery (but this remains unexplained). The annual proportional economic value for each metal is shown in Figure 3. The long-term average proportional economic value of production has been as 75.23% copper, 19.30% uranium, 4.76% gold and 0.71% silver.

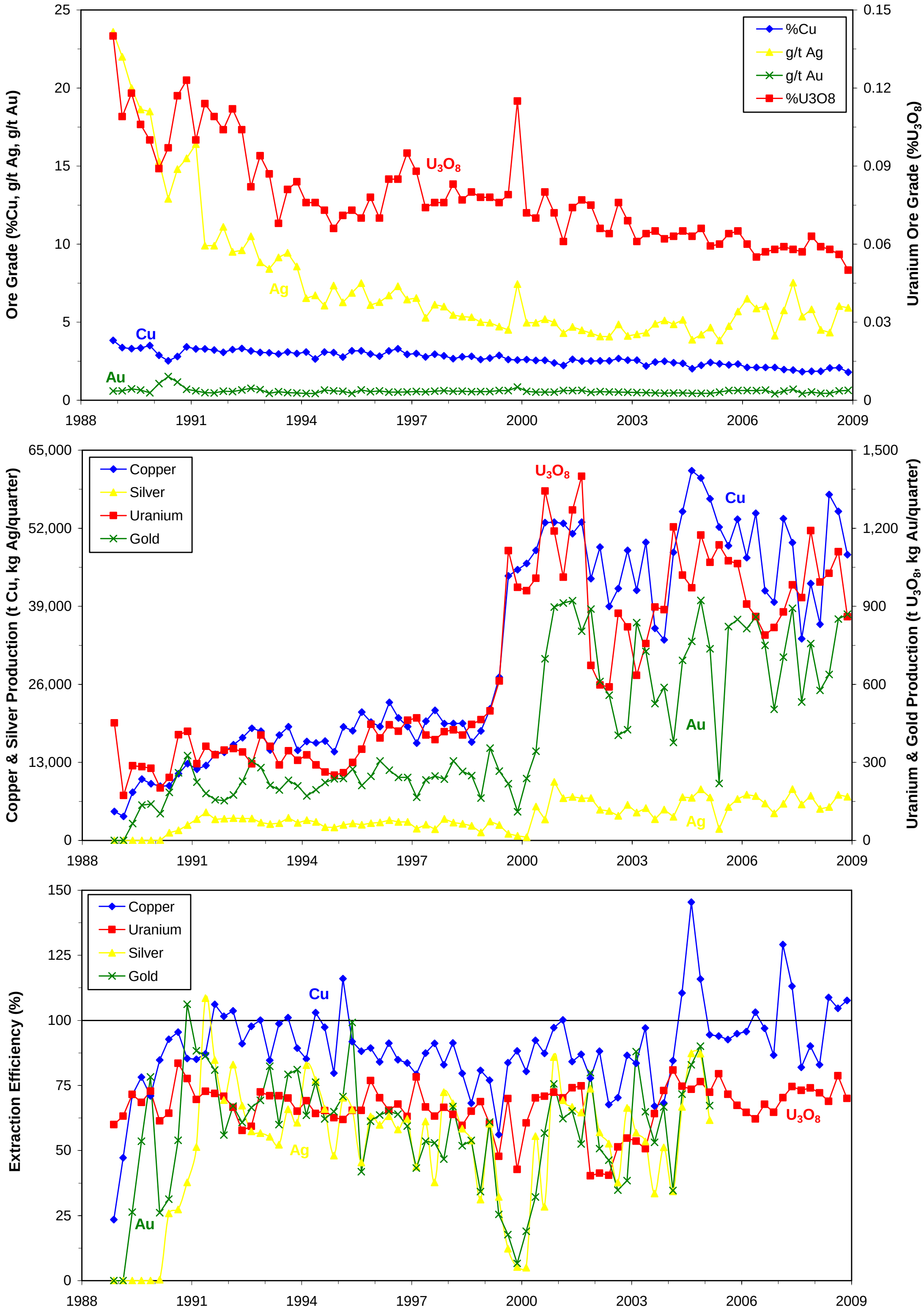

Figure 2: Production data for Olympic Dam (1988-2008) (data from Mudd, 2009a)

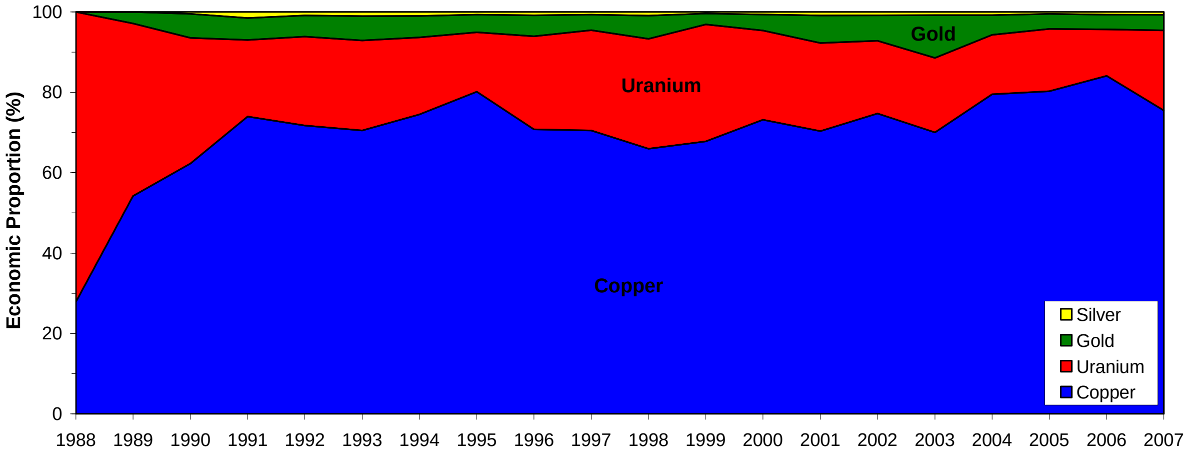

Figure 3: Proportional economic value of metals for Olympic Dam (Mudd, 2009a)

Historical Energy Consumption and Greenhouse Gas Emissions

WMC was the amongst the first mining companies in the world to begin annual reporting on their environmental performance, releasing their first such report in 1995 (WMC, 1995). The report covered all of their individual mines, and included data for major inputs such as energy and water, pollutants such as sulfur dioxide and greenhouse emissions, waste volumes as well as a review of the environmental progress being made at each site. This reporting was continued, changing name to 'sustainability reports' in 2001, until WMC was taken over by mining giant BHP Billiton Ltd (BHPB) in August 2005. This means WMC data is available from 1991 to 2004 for Olympic Dam. Although BHPB also release a sustainability report, they commonly do not release individual mine site reports (though a small number of sites do, and this practice seems to be increasing in recent years). Further data on greenhouse emissions and water and energy consumption is available from the annual environmental management report for Olympic Dam (eg. BHPB, 2007), submitted to the South Australian Government and available online through the Department of Primary Industries & Resources (or 'PIRSA'). All greenhouse gas emissions are presented as carbon dioxide equivalents, or '$CO_{2\text{-}e}$'.

Over time the level of environmental data reported by WMC grew, although some gaps still remained (such as waste rock). An example of an 'input-output' diagram for Olympic Dam is shown in Figure 4.

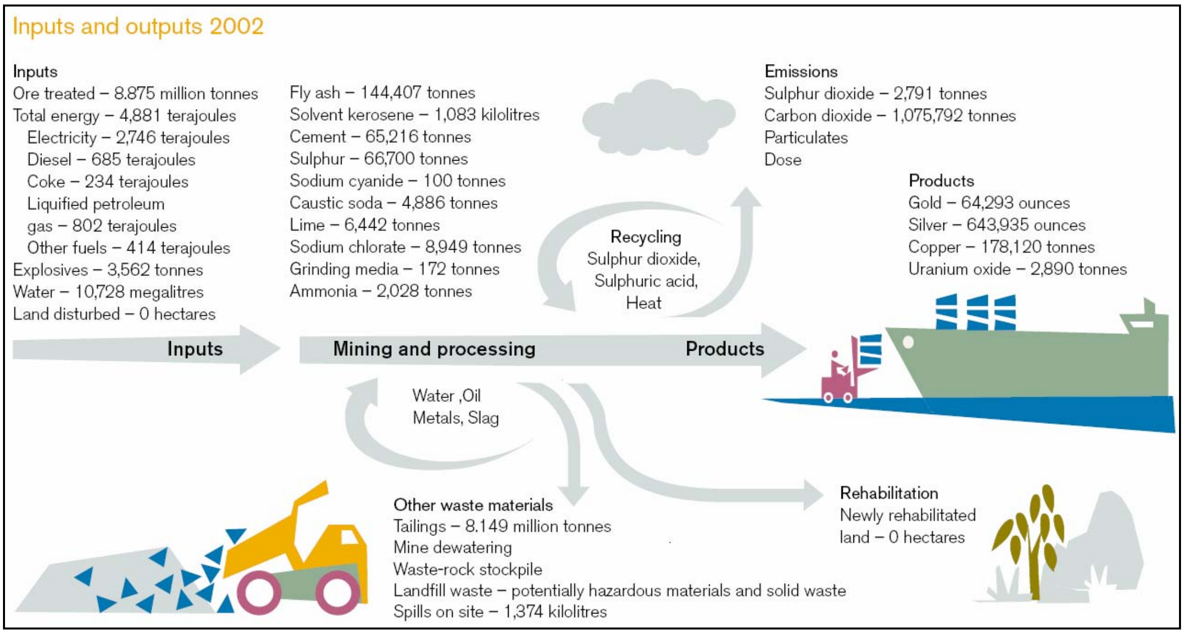

Figure 4: Major inputs and outputs for Olympic Dam (2002) (WMC, 2002)

It can be seen in Figure 4 that the inputs are totals for the entire project, and it is not easy to ascertain the fractions of inputs attributable to individual components. For example, electricity would be used throughout the complex in the mine, mill, smelter and refinery. Some aspects are only used in certain operations, such as coke in the smelter or diesel and explosives in the mine, but overall, for energy and greenhouse emissions, it is not possible based on the reported data to attribute the inputs-outputs to specific process stages of the Olympic Dam project and assign it to final production accordingly.

To address this problem, it is conventional to attribute inputs-outputs on the basis of economic value. Therefore, all data will be presented in three ways – with 100% allocated to copper production only, or 75.2% to copper and 19.3% to uranium production. The principal focus is energy and greenhouse emissions, with other key environmental aspects such as water consumption included in less detail, while other pollutant emissions (eg. sulfur dioxide) are excluded to keep this paper concise.

Total energy and water consumption and greenhouse gas emissions is shown in Figure 5, with attributable consumption over time to copper and uranium shown in Figure 6. Total greenhouse emissions include those derived from the import of electricity (ie. emissions from the South Australian electricity grid). Given the significance of ore grade in the energy costs of metal production, the unit energy costs are graphed against ore grades in Figure 7.

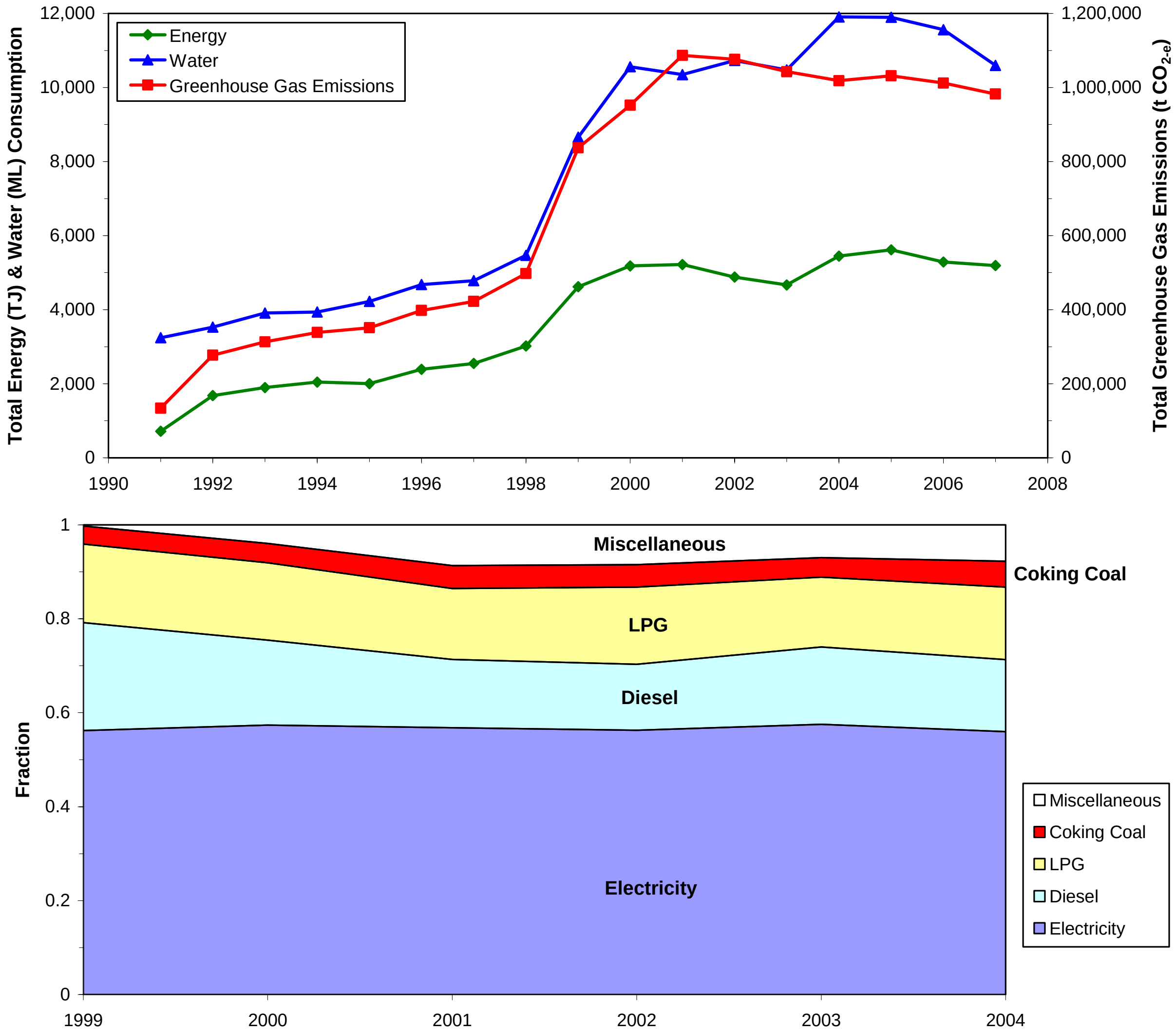

Figure 5: Annual energy consumption and greenhouse gas emissions for Olympic Dam (top) and energy source by fraction (1999-2004; bottom)

(1991 to 2007; with years 1998 to 2004 being calendar year, all others are financial year)

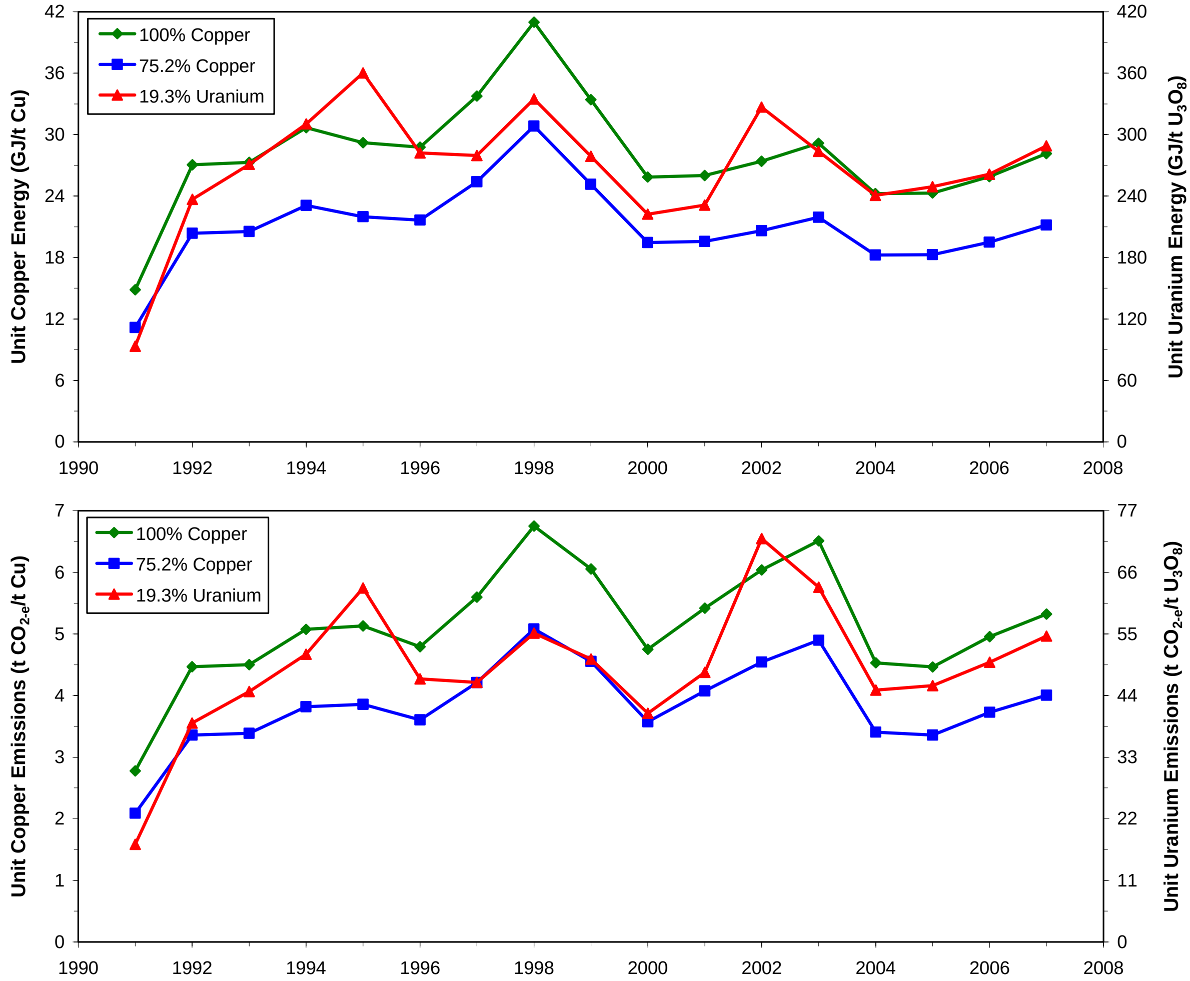

Figure 6: Attributable unit energy consumption (top) and greenhouse gas emissions (bottom)

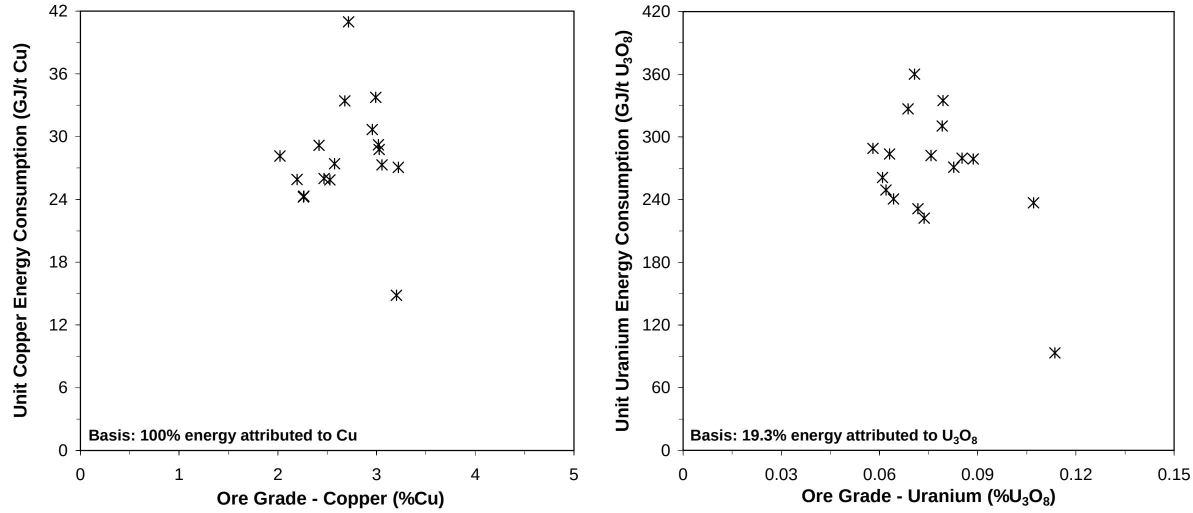

Figure 7: Unit energy consumption versus ore grades – copper (left) and uranium (right)

Overall, Figure 5 again shows the significant effect of the late 1990's expansion with respect to total energy consumption and total greenhouse emissions. However, Figure 6 clearly shows that there has been no substantive or sustained long-term improvement in efficiency since, in unit terms, the energy or emissions costs have stayed in a similar range. That is, on a 100% basis for copper, the unit energy and emissions costs have stayed within 24.2-33.8 GJ/t Cu and 4.50-6.75 t CO_2/t Cu, respectively (excluding 1991).

The data in Figure 7 shows that copper ore grade shows a partially scattered relationship with respect to unit energy consumption but overall suggests an increasing risk of elevated unit energy costs as ore grade declines. An overall increasing trend for unit energy consumption is evident as uranium ore grade declines. For the next 'mega-expansion', ore grades for copper and uranium are expected to decline by about half – thereby leading to the expectation that unit costs would increase even further.

Current Ore Resources

In June 2008, the total ore resources identified at Olympic Dam were 8,340 Mt of ore (ie. ~8 billion tonnes) with an average grade of 0.88% Cu, 0.028% U_3O_8, 0.31 g/t Au and 1.51 g/t Ag (BHPB, 2008a) – representing a contained metal resource of some 73 Mt Cu, 2.3 Mt U_3O_8 and 2,584 t Au. For comparison, this is nearly four times Australia's total copper production since 1842 (19.59 Mt Cu) and more than thirteen times Australia's uranium production since 1954 (174,175 t U_3O_8) (see Mudd, 2009b). The contained gold is more than Victoria's entire gold production of 2,384 t Au, and is higher than every state except Western Australia (which has produced 6,177 t Au) (Australia has produced 11,570 t Au by 2007) (see Mudd, 2009b).

Future Olympic Dam Expansion Greenhouse Gas Emissions Scenarios

At present, precise proposals for the next expansion at Olympic Dam are not publicly documented. Some aspects are confirmed, such as the move from underground to open cut mining, but critical aspects such as energy needs and sources remain unclear. Furthermore, it is not clear whether a similar project configuration will be adopted, following essentially the same processing system, or whether a radically different approach will be built. Based on recent media reports and the original referral for Commonwealth environmental assessment (Ryan and Green, 2005), a further critical issue is the extent of copper processing on-site – that is, whether all copper concentrate is smelted and refined at Olympic Dam or whether a portion is exported (eg. half to China). A major briefing on the Olympic Dam expansion project was given by BHP Billiton in late October 2008 (BHPB, 2008b), and this indicates that a gradual, staged development approach is being planned, but no exact details with regards to energy needs or sources was provided. Full details are expected in the impending environmental impact statement (due 1 May 2009).

Given the overall uncertainty in the exact project configuration, three full production scenarios are assumed for the next Olympic Dam expansion:

(i) complete processing on-site at either 730,000 t Cu/year or 1,000,000 t Cu/year;

(ii) processing half of the Cu on-site and half of the Cu concentrate is exported to China.

The target annual production stated by BHPB in October 2008 was 730,000 t Cu, 19,000 t U_3O_8 and 25 t Au (or 800,000 oz Au) (BHPB, 2008b). An approximate ore throughput totalling 72 Mt/year was suggested (slide 54), however, this is not consistent with resource ore grades and historical production efficiency. Based on extraction efficiencies to date (90% Cu, 65.8% U_3O_8 and about 50% Au) and the June 2008 ore grades of 0.88% Cu, 0.028% U_3O_8 and 0.31 g/t Au, this means that a target ore throughput of some 92 to 103 Mt/year would be required (depending on whether one uses Cu or U_3O_8 for the estimate). A comparison of the production estimates is given in Table 1.

Table 1: Comparisons of annual production rates for Olympic Dam

	Mt ore/year	%Cu	%U_3O_8	g/t Au	g/t Ag	t Cu	t U_3O_8	t Au	t Ag
Current[§]	9,335,000	2.11	0.060	~0.53	5.25	199,000	4,013	2.83	25.56
BHP Billiton *(Oct. 2008)*	72,000,000	***1.13***[#] 0.88[#]	***0.040***[#] 0.028[#]	***0.69***[#] 0.31[#]	- 1.51	730,000[#] 570,000[#]	19,000[#] 13,250[#]	24.9[#] 11.2[#]	-
Expansion(s) *(my estimate)*	100,000,000 *126,000,000*	0.88	0.028	0.31	1.51	730,000 *1,000,000*	19,000 *23,000*	15.5 *19.5*	75.5 *95.1*

[§] Based on average of past five years annual production (2004-2008).

[#] Based on the proposed ore throughput and using the average resource ore grade of 0.88% Cu, the BHP production targets are clearly unrealistic. Either BHP are assuming a higher average grade as mined in the early years of production, as shown in ***bold-italics***, or perhaps a higher throughput, though this is not clarified in BHPB (2008b).

However, in order to inform the various factors involved in either scenario, a range of general energy consumption factors have been derived from sustainability reporting for a wide variety of large Cu, Au or Cu-Au mines around the world. In this manner, energy intensity factors have been estimated from actual energy data for specific aspects such as explosives and diesel consumption in open cut mining per tonne of rock mined, electricity consumption in grinding-flotation mills (very common for Cu and Cu-Au projects), coke inputs to Cu smelters, and the like. These factors are then used to build a conceptual model of the energy and greenhouse costs for the three Olympic Dam expansion scenarios analysed. Each section or project stage is now reviewed in detail.

Future Olympic Dam Expansion : Open Cut Mining

The October 2008 presentation (BHPB, 2008b) gave a plan view of the potential ultimate size of the Olympic Dam open cut mine after 100 years – with a main length of 6.5 km northwest-southeast and width of 2.5 km, plus an extra section on the southwest corner of approximately 2 by 2 km. The depth ranged from 1,055 to 1,220 m. After allowing for angled walls, it is possible to estimate a total open pit volume of some 20 km^3. Given that the ore at Olympic Dam has a density of some 3.2 to 3.6 t/m^3 (Johnson, 1990; Ring *et al.*, 1998; Waggitt, 1994), the 8,340 Mt of ore has a volume of about 2.5 km^3 – leaving some 17.5 km^3 as waste rock. The cover rocks overlying the Olympic Dam deposit are limestone, sandstone and shale, and total about 400 m in thickness (Kinhill, 1997). Typical in-situ densities for these rocks are of the order of 2.5 t/m^3, meaning that some 43,750 Mt of waste rock will be mined in conjunction with the ore. This gives an overall life-of-mine waste:ore ratio of 5.25. Assuming this value gives an annual mining rate of 100 Mt ore plus 525 Mt waste rock – a massive total of 625 Mt rock mined per year. If a target production of 1 Mt Cu/year is used, this means some 126 Mt ore plus 662 Mt waste rock mined per year – ie. approximately 788 Mt rock/year.

There is no single mine in the world known to the author which excavates rock at these potential rates – with some of the biggest copper mines such as Escondida, Codelco Norte or Freeport-Grasberg all mining of the order of 300-400 Mt per year. The actual rate and mix of mining for the Olympic Dam pit will clearly vary over time, with the first several years being the initial excavation of the 400 m sedimentary rock cover to expose the underlying orebody. After this time, the waste:ore ratio will gradually decline as ore availability improves from the pit. However, even if an ore throughput of 100 Mt/year is achieved, the average ratio of 5.25 has to be maintained over the life-of-mine and so waste rock generation will remain in the order of some 525 Mt/year. If one assumes the BHPB throughput rate of 72 Mt/year and the waste:ore ratio of 5.25, this gives some 450 Mt/year mined – a figure closer to but still higher than the actual mining range of known Cu or Cu-Au mines.

The dominant source of energy consumption and greenhouse gas emissions in open cut mining is the diesel consumed by mine trucks. Although there is also a contribution from electricity, petrol, propane or other sources, in comparison these are very minor. To ascertain the likely consumption rate for the Olympic Dam pit, the available diesel data was compiled from large Cu, Au or Cu-Au mines around the world to derive a representative figure of diesel consumed per tonne of rock mined ('L/t rock'). Only mines where the diesel consumption was clearly from open cut mining were included, since some mines also use diesel for on-site electricity generation.

From this data, an average figure for diesel energy and greenhouse emissions can be estimated based on diesel consumption per tonne of rock mined per year. There are only very minor differences around the world in the energy content of diesel, with greenhouse emissions then estimated based on diesel consumption (eg. DCC, 2008). The average data for all mines analysed is given in Table 2.

The average energy content of diesel is 38.6 MJ/L with a unit greenhouse gas emissions factor of 69.5 g $CO_{2\text{-}e}$/MJ (DCC, 2008). Using the average figure of 0.68 L/t rock for the expansion and either 450, 625 or 788 Mt/year gives total diesel consumption of 306, 425 or 536 million litres (ML) and total direct emissions of 0.821, 1.14 to 1.44 Mt $CO_{2\text{-}e}$/year, respectively.

Table 2: Average diesel consumption in open large cut mines around the world

	Years of Data	Mt rock/year			L diesel/t rock		
		average	min.	max.	average	min.	max.
Gold mines[§]	62	56.7	13.0	199.3	0.68	0.33	1.18
Copper mines[‡]	3	393.7	321.1	431.6	0.88	0.81	1.00
Copper-Gold mines[#]	15	201.7	40.0	359.5	0.64	0.38	1.18
Overall Average	**80**	**96.6**	**13.0**	**431.6**	**0.68**	**0.33**	**1.18**

[§] Includes the Goldstrike, Cortez, Yanacocha, Newmont-Nevada, Porgera, Dome, Granny Smith, Kalgoorlie West, St Ives, Agnew, SuperPit, Jundee, Tarkwa, Damang, Inti Raymi, Bald Mountain, Misima and Kidston Au mines.

[‡] Only includes Codelco Norte (most large Cu mines are Cu-Au; or alternately underground mines only, eg. Mt Isa, El Teniente). Other large Cu only mines, such as those in Arizona, do not report site specific data (eg. formerly Phelps Dodge, now part of Freeport-McMoRan Copper and Gold Inc).

[#] Includes the Freeport-Grasberg, Escondida, Alumbrera, Batu Hijau and Highland Valley Cu-Au mines.

Indirect energy and emissions costs are those required to make the explosives used in open cut mining. There is very little data known on the unit energy costs for explosives, such as ammonium nitrate fuel oil ('ANFO'), the most extensively used explosive in mining due to its safety and low unit cost (eg. O'Malley, 1988). For some the Cu and Cu-Au mines used in Table 2 plus the Tintaya Cu-Au mine, approximately 0.17 kg of ANFO explosives are required per tonne of rock mined (ie. kg ANFO/t rock; 7 data points). Conversely, based on many of the Au mines analysed in Table 2, a higher figure of 0.27 kg ANFO/t rock can be derived (87 points).

The only data known to the author for unit ANFO energy costs is that reported by Dyno Nobel in their 2006 sustainability report (DN, 2006). The average energy cost for ANFO is 7.81 GJ/t ANFO (production-weighted basis). For the Olympic Dam expansion, with mining rates of some 450, 625 or 788 Mt/year, this leads to an ANFO demand of about 76,500, 106,000 to 134,000 t ANFO, respectively – a magnitude consistent with available data (eg. Escondida or Freepoprt-Grasberg). The manufacture of this quantity of ANFO therefore requires some 603,000, 836,500 to 1,046,000 GJ/year external to the mine site. This compares to diesel energy consumption of 11,800,000, 16,400,000 to 20,700,000 GJ/year, respectively.

The use of explosives leads to the direct release of greenhouse gases, with the factor estimated at 0.167 t $CO_{2\text{-}e}$/t ANFO (DCC, 2006). At the potential mining rates of 450, 625 or 788 Mt/year, this gives rise to direct emissions at the mine of 12,800, 17,700 to 22,400 t $CO_{2\text{-}e}$/year, respectively. In addition, some 134,000, 186,000 to 234,000 t $CO_{2\text{-}e}$/year, respectively, are released during the manufacture of the explosives (using Dyno Nobel's factor of 1.75 t $CO_{2\text{-}e}$/t ANFO; DN, 2006).

It would be possible to analyse further the emissions associated with other aspects of open cut mining, such as those during manufacture of large mining trucks, although this would be a time consuming task and is beyond the scope of the current paper. A major source of upstream energy consumption and emissions is, of course, the manufacture of the diesel, though this has been excluded at present.

The actual energy inputs and greenhouse gas emissions would evolve over time, as the pit deepens, haul roads increase in length, mine plans change, waste rock dumps are further away, haul trucks are upgraded and soon. Based on the available data, it is not possible to quantify the impacts of these factors on diesel consumption, with annual variation of the mines analysed in Table 2 showing significant differences and no clear trend or relationship.

Based on the data compiled and analysed in this section, it is clear that diesel remains the dominant energy input into open cut mining. For a mining rate of 450, 625 or 788 Mt/year, diesel energy inputs could be expected to be between 11,800,000, 16,400,000 to 20,700,000 GJ/year, representing a source of 0.821, 1.14 to 1.44 Mt $CO_{2\text{-}e}$/year of greenhouse gas emissions.

Future Olympic Dam Expansion : Ore Grinding and Flotation

The first primary stage in treating Olympic Dam ore is grinding to a fine powder – a very energy intensive process. The fine ore powder is then mixed with water to form a slurry. Reagents are then added to facilitate the process of flotation, whereby air bubbles are blown through the slurry to separate and concentrate fractions of the ore which contain the metal-bearing minerals (eg. copper minerals such as chalcopyrite). The output of this process is then divided into two streams – (i) the copper concentrate, typically grading about 30% Cu, and (ii) the tailings, or solid waste remaining after extraction of the copper concentrate. At Olympic Dam, the uranium has, *historically*, split about 20% into the Cu concentrate and about 80% into the flotation tailings (see Figure 10-7; Kinhill, 1997).

The dominant energy input into grinding and flotation is electricity, with minor indirect energy required to manufacture reagents, steel grinding balls and other consumables. Given that all operational stages at Olympic Dam require electricity, and that only total electricity is reported, it is not possible to estimate a site-specific unit energy intensity for the grinding and flotation stage. Furthermore, given that the expansion will involve a completely new processing mill to allow for the significantly higher ore throughput, as well as the different processing characteristics of the ore, the current process plant is not necessarily the best basis for preparing such an estimate.

In this manner, as done for open cut mining, a compilation of Cu or Cu-Au mills has been analysed in order to derive a reasonable range which might be expected for the Olympic Dam expansion. Due to the manner in which energy data is reported by various companies, it has only been possible to find 19 data points which are clearly the electricity used in mills involving grinding and flotation only. Based on this data, an average of 88.6 MJ/t ore milled has been derived, ranging from 66.3 to 146.6 MJ/t ore milled. This is slightly higher than the 76 MJ/t ore milled reported by Lund et al. (2008), showing that the methodology is giving results consistent with other studies.

As a check, if we assume that the electricity data reported from 1999 to 2004 is all consumed in grinding and flotation, this would give a unit electricity consumption of about 335 MJ/t ore milled – considerably higher than the previous data.

For the next Olympic Dam expansion, annual ore throughput rates are estimated to range from some 72, 100 to 126 Mt/year. Based on 88.6 MJ/t ore milled, this leads to a total of 6,380,000, 8,860,000 to 11,160,000 GJ/year, respectively, or, in terms of electricity consumed, represents 1,770,000, 2,460,000 to 3,100,000 MWh/year, respectively. If we assume this is derived from a power station operating at 85% availability per year, this gives a capacity of 240, 330 to 415 MW of electrical power, respectively.

The unit greenhouse gas emissions factor for electricity generation in all states is given by DCC (2008), with the latest estimate for South Australia being 0.98 t $CO_{2\text{-}e}$/MWh or 0.272 t $CO_{2\text{-}e}$/GJ (year unstated but presumably 2007). The greenhouse gas emissions derived from the above electricity consumption, assuming this intensity remains constant, would therefore be 1.74, 2.41 to 3.04 Mt $CO_{2\text{-}e}$/year, respectively.

Future Olympic Dam Expansion : Cu Concentrate Smelter

The main directly attributable energy inputs and greenhouse outputs for smelting at Olympic Dam are coking coal (or coke) and electricity. Historically, annual coke use was reported by WMC from 1999 to 2004 (ranging from 177,000 to 300,000 GJ/year; or 5,900 to 10,000 t using 30 GJ/t from DCC, 2008). If we assume that all coke is used only in the smelter (a reasonable proposition based on the current project configuration), then this leads to 1.25 GJ coke/t Cu produced (or 41.7 kg coke/t Cu). For Cu smelting in Australia, Lund *et al.* (2008) reported a typical average of 3.37 GJ coke/t Cu (or 101 kg coke/t Cu).

According to Lund *et al.* (2008), typical unit electricity consumption in Cu smelters is 1.55 GJ/t Cu, with natural gas at 3.0 GJ/t Cu and oil at ~0.1 GJ/t Cu. Based on unit emissions factors from DCC (2008), the unit greenhouse emissions from coke, electricity (SA), natural gas and oil can therefore be estimated as 0.113, 0.422, 0.154 and 0.007 t $CO_{2\text{-}e}$/t Cu, respectively – a total of 0.696 t $CO_{2\text{-}e}$/t Cu (compared to 0.882 t $CO_{2\text{-}e}$/t Cu from Lund *et al.*, 2008; the lower derived figure due to apparently lower unit coke consumption at Olympic Dam).

Overall, at the current average production of some 200,000 t Cu/year, this would mean the smelting stage contributes about 139,200 t $CO_{2\text{-}e}$/year, or about 14% of Olympic Dam's present total of 1 Mt $CO_{2\text{-}e}$/year.

With respect to the expansion, on-site smelting is being proposed to expand to either 350,000 t Cu/year or the full 730,000 t Cu/year. Assuming the new smelter would be marginally more efficient at say 0.6 t $CO_{2\text{-}e}$/t Cu would mean that smelter emissions alone would be of the order of 210,000 to 438,000 t $CO_{2\text{-}e}$/year, respectively, for these two production levels. If the full production of 1 Mt Cu/year was processed all on-site, smelter emissions would be some 600,000 t $CO_{2\text{-}e}$/year.

Future Olympic Dam Expansion : Cu Refinery

Since there is no direct data available for Olympic Dam's Cu refinery, values from Lund *et al.* (2008) will be used as approximate values. The refining of Cu to pure, market grade metal (eg. >99% Cu) requires significant electricity (1.08 GJ/t Cu) and natural gas (0.78 GJ/t Cu). The associated emissions are 0.29 and 0.04 t $CO_{2\text{-}e}$/t Cu, respectively. For Cu production capacities of 350,000 to 730,000 t Cu/year, this gives Cu refinery emissions of 116,000 to 241,000 t $CO_{2\text{-}e}$/year, respectively. If the full production of 1 Mt Cu/year was processed all on-site, smelter emissions would be some 330,000 t $CO_{2\text{-}e}$/year.

Future Olympic Dam Expansion : Miscellaneous Costs

The analysis presented herein covers the most obvious and easily identifiable aspects of energy input and greenhouse gas emissions outputs, including diesel, explosives and electricity – assuming the current configuration will be effectively replicated in the mega-expansion. However, a range of key areas of possibly significant energy or emissions costs remain unaccounted for :

- ***Cement*** – like explosives, cement production leads to significant unit greenhouse emissions. In 2002 Olympic Dam used 65,216 t of cement, which, at 0.544 t $CO_{2\text{-}e}$/t cement (DCC, 2008), would lead to 35,500 t $CO_{2\text{-}e}$/year.
- ***Uranium, gold & silver production*** – the current Olympic Dam complex includes significant facilities for the hydrometallurgical processing and refining of U, Au and Ag. This would add significant electricity consumption, as well as high cost reagents such as kerosene and ammonia (see Figure 4).
- ***Desalination plant*** – the current expansion proposal includes a very large desalination plant and long distance pipeline (~300 km), which combined will be incredibly energy intensive – and arguably a much more energy intensive water supply than the present borefields in the Great Artesian Basin.
- ***Chemicals*** – there are a variety of chemicals required to operate a complex project such as Olympic Dam (see Figure 4) – all of which originally required energy and led to emissions in their manufacture. A detailed audit would add significant indirect energy and emissions costs.
- ***Transport*** – the transport requirements for a project such as Olympic Dam would be very substantive, including workers travelling to and from Adelaide, hauling of all fuels, chemicals and other inputs to the site, haulage of saleable products away from the site, and so on.

Future Olympic Dam Expansion : Water Costs

A fundamental input to any large mining and metal processing project is water – it is needed for dust suppression in the open cut, to create the slurry for the flotation stage, pollution control, drinking and so on. Water consumption is one area where the Olympic Dam project has shown small gains since the start of operations – with unit water consumption per tonne of ore declining since 1988, shown in Figure 8. With respect to production, however, unit water costs have remained similar (see Figure 8).

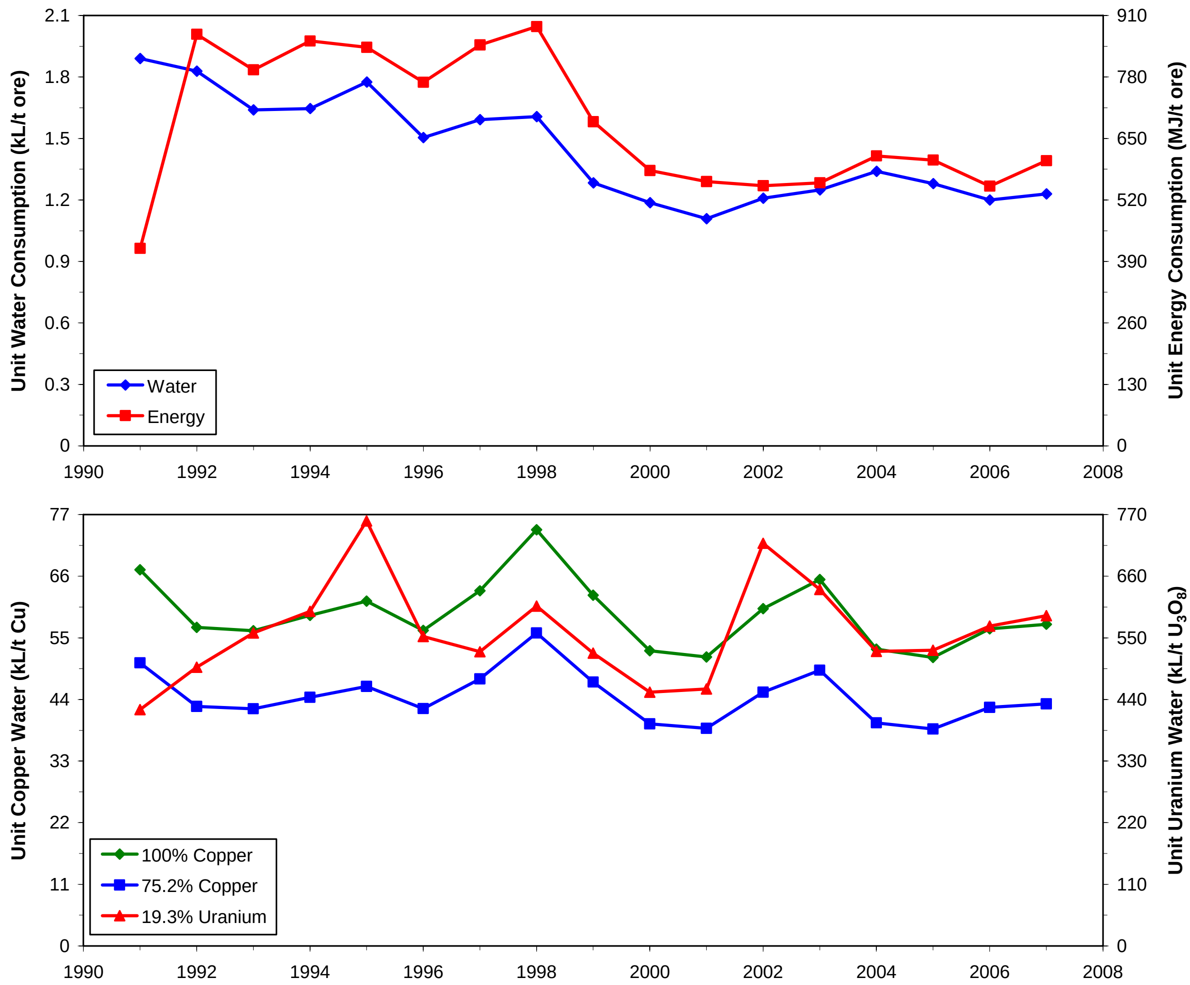

Figure 8: Water and energy costs in processing ore at Olympic Dam

At present, Olympic Dam imports approximately 31 million litres (ML) per day of groundwater from the Great Artesian Basin (some 200 km to the north), averaging about 11.3 billion litres (GL) per year over the past five years. This leads to a current consumption of 1,260 litres per tonne of ore processed, a figure similar to other Cu mining-milling-smelter-refinery projects around the world (see Mudd, 2008). No comments or detail on water requirements for the expansion were given by BHP Billiton in October 2008 (see BHPB, 2008b).

If we assume that the new processing mill will be more slightly more efficient then we could adopt a value of 1,000 litres (kL) per tonne of ore processed (ie. 1 kL/t ore). For processing throughputs of 72, 100 or 126 Mt ore/year, this leads to a water demand of 197, 274 to 345 ML/day (or total water demands of 72, 100 to 126 GL/year).

At present, detailed water requirements for the expansion have not been stated, nor the critical issue of what water quality is required to ensure that all of the process stages where water is used work effectively. It is clear, however, that the expansion will require a substantial increase in total water consumption to facilitate the full production rates being achieved.

SUMMARY

Based on extensive surveys of available data, the next expansion at Olympic Dam is likely to lead, directly and indirectly, to a major overall increase in greenhouse gas emissions. This technical paper has presented a detailed breakdown of the potential emissions associated with each of the major stages of the proposed expansion. It is expected that a more sophisticated analysis can be undertaken upon release of the EIS – with the data in this paper providing a realistic comparison to the EIS. Therefore, the total greenhouse gas emissions ***in South Australia*** for the three major production scenarios are summarised in Table 3 below.

For BHP Billiton's current expected eventual production rate of 730,000 t Cu, 19,000 t U_3O_8 and 25 t Au, it can be expected that the total greenhouse gas emissions will rise to 5 Mt $CO_{2\text{-}e}$/year – a value some five times higher than the present 1 Mt $CO_{2\text{-}e}$/year. If the full scale expansion to 1 Mt Cu/year proceeds and includes complete on-site processing of Cu, total emissions will rise nearly seven-fold to some 6.6 Mt $CO_{2\text{-}e}$/year.

Table 3: Estimated total greenhouse emissions **in South Australia** for the three Olympic Dam expansion scenarios (all Mt $CO_{2\text{-}e}$/year)

Project Stage	**Sources**	**730 kt Cu/year**		**1 Mt Cu/year**
		half on-site / -half China	**100% on-site**	**100% on-site**
Open Cut	diesel	1.14	1.14	1.44
Mining	ANFO	0.204	0.204	0.257
Grinding-Flotation	electricity	2.41	2.41	3.04
Cu Smelter	electricity & fossil fuels	0.21	0.44	0.60
Cu Refinery	electricity & fossil fuels	0.12	0.24	0.33
Miscellaneous	desalination, transport, etc.	~0.4	~0.6	~0.9
GRAND TOTAL (Mt $CO_{2\text{-}e}$/year)		***4.48***	***5.03***	***6.57***

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