USING ECO-EFFICIENCY TO IMPROVE SUSTAINABILITY IN THE LARGE-SCALE MINING INDUSTRY

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ABSTRACT

Eco-efficiency is used to analyze the convenience of installing a solar-based water heating system for a large-scale mining operation in Chile. The solar-based system will be used as primary source of heat, complemented with the currently in-use diesel-based system. Eco-efficiency is defined as the ratio between comparative savings from business as usual and GWP 100. Use scenarios are fixed to 25 years, with variations depending on annual energy demand and technology used. Eco-efficiency increases when the solar-based system is used for both energy scenarios. We find that incorporating the solar-based system makes the heating process more resilient, hence improving the overall performance of the whole system.

INTRODUCTION

Eco-efficiency first appeared as a concept in 1991 (WBCSD, 2000) and due to increased popularity and application it earned its own ISO norm in 2012. In the norm, eco-efficiency is defined as a relation between the environmental value of a product and the value of the product system (ISO 14045, 2012). Being a flexible indicator, eco-efficiency must comply with two basic rules: i) To equal product system value and better environmental performance, the eco-efficiency indicator must be greater; ii) To equal environmental performance and higher product system value, the eco-efficiency indicator must be greater (ISO 14045, 2012). A typical eco-indicator can be defined as: Eco-efficiency = value / impact.

Eco-efficiency has been increasingly used by companies, which have developed their own methods, tools, certifications and even labels for calculating this quantity (BASF, 2012). In the mining sector this concept has been used for over a decade, but its use has not been massive (Guerin, 2009; van Berkel, 2007). Zaldivar Mining (ZM) is a large-scale mining industry that produces 133,500 ton/y of copper cathodes. Its production process includes electro-winning (EW), for which large amounts of hot water are needed. The current technology used for water heating is diesel-powered water heaters. ZM looks forward to reducing the cost of heating water while improving its relationship with the environment. For that, a solar-powered alternative has been considered to serve as the primary heating system, leaving the older diesel-based technology as a back-up system. ZM also wants to reduce its hot water consumption in the long run (25 years horizon). But, how to aid decision making in economic and environmental terms?

We propose eco-efficiency as a suitable indicator to aid the decision-making process to meet the requirements defined by ZM. This work aims to provide relevant information and to show how eco-efficiency can be used to guide sustainability for a large-scale electro-winning copper refining process in Chile.

METHODS

We use eco-efficiency as defined in ISO 14045, and frame our study following the consequential approach. Four scenarios are analyzed for a period of 25 years, namely:

- Constant energy requirement with diesel heating;
- Constant energy requirement with solar heating complemented with diesel heating;
- Decreasing energy requirement with diesel heating;
- Decreasing energy requirement with solar heating complemented with diesel heating.

Diesel heaters are the business as usual case, and are used as the base line for comparison in the two energy demand cases studied (constant and decreasing energy demand in the next 25 years). The product system value indicator is defined as the savings arising from the use of the “solar with diesel” heating system versus the “diesel-only” system for a particular energy demand case. The environmental value is defined as the carbon footprint of the heating system in the energy demand case defined. Hence, the eco-indicator is defined as savings divided by carbon footprint for each scenario. For both energy demand cases (constant and decreasing), it is assumed that “diesel only” scenarios caused no savings (base line case). In order to calculate costs and savings for each case, the cost of diesel, solar system installation and maintenance are calculated using data provided by ZM. All costs are corrected to present value and aggregated for comparison.

The energy demand of year 2011 is taken as base for the calculation. In the “constant energy” cases, it is assumed that the annual energy demand for all years would be equal to that of 2011. In the case of “decreasing energy” scenarios, it is assumed that the energy demand of the first 10 years would equal to that of 2011 and that for the following 15 years energy demand decreased in approximately 1% per year.

The carbon footprint is calculated using SimaPro with the GWP100 method. Use of diesel as well as the construction and maintenance of the solar-based system are considered. The construction of the diesel-based heaters is not taken into account because they will continue operating, though at a lower rate.

RESULTS

Results are unambiguous both for savings and carbon footprint, showing that for all cases, the addition of the solar-based heating system increases savings in the long run while reducing the carbon footprint of water heating. These results can be seen in Table 1.

Table 1. Economic and environmental values and eco-efficiency scores for the four scenarios analysed.

Value	At constant energy demand		At decreasing energy demand	
	Diesel	**Diesel & Solar**	**Diesel**	**Diesel & Solar**
Savings [US$]	0	15,219,108.33	0	14,278,671.61
GWP 100 [ton CO_{2eq}]	237.803,69	117.645,59	186.822,86	93.955,90
Eco-efficiency	**0**	**129.36**	**0**	**151.97**

From the table it can be seen that for both economic and environmental values, the process choice with solar complementation is better, resulting in higher eco-efficiency results.

For both constant and decreasing energy demand in the next 25 years, the addition of the solar-based system resulted in a reduction of approximately 30.5% in costs and 50% in the life cycle carbon footprint. This makes it very clear that incorporating the solar technology is convenient for business and also for the environment.

DISCUSSION

This study offers some limitations. The effect of transport of the solar system was not taken into account, and neither was the effect of maintenance of the diesel system. The authors cannot estimate the effect of shipping the solar panels over a 25 year period, but we assume it is small compared to the savings in diesel combustion. Regarding maintenance, ZM estimates that the maintenance and part replacement for the diesel boilers will be reduced when the solar system starts operating, so we understand the effect over the eco-efficiency indicator should be positive. Additionally, maintenance of the solar system is minimal.

This work makes a good example for eco-efficiency at the process design level (van Berkel et al., 2007), but it does not respond to the principle of resource efficiency, since it brings in more materials and, instead of substituting a system, it complements it with a renewables-based one. Moreover, it also presents a good example of how eco-efficiency can aid into making systems more resilient. The addition of the solar-based heaters complemented by the older diesel-based heaters makes the water heating process more resilient as in the definition of Korhonen (2008). The system will be more *diverse* since it has two energy sources, which brings in greater *adaptability* of the system to accidents, changes in climate and reparations. As well, it becomes more *flexible* to changes in the copper process conditions, and finally, increases the *reserve* capacity of heat. In addition, the system becomes more independent of fossil fuels, decreasing supply risks caused by political, infrastructural or production issues and freeing resources for investment in other areas of the mining industry.

Overall, results do not show compromise between the economic benefit of the solar system and the environmental performance of this heating process. The authors strongly believe that case studies like the one presented here will aid in introducing eco-efficiency as an everyday tool for use in decision making and process design in industry.

CONCLUSIONS

We conclude that the addition of a solar-based heating system is convenient for the water heating process for electro-winning at ZM. The addition of this system will result in both an increase of savings and a decrease of the carbon footprint, thus leading to a two-way increase of the eco-efficiency of the process. In addition, the implementation of the solar heater may increase the resilience of the process by making it more adaptable, diverse and flexible. Therefore, it is recommended the implementation of the solar heater for Zaldivar Mining.

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