MODELLING OF ENERGY EFFICIENCY IN COPPER MINING INDUSTRY

Bernard Tembo, UCL Energy Institute, +44 72381887, bernard.tembo.12@ucl.ac.uk

Overview

In 2007, global total final energy consumption was 347 PJ; with the industrial sector consuming 37%. Energy demand in the industrial sector is projected to increase by at least 50% by 2050 compared to the 2006 consumption (Saygin et al., 2011). Given that most sub-sectors in the industry are energy intensive and significant contributors to CO_2 emissions, effort around the world have focused on how energy consumption can be reduced to mitigate the climate and environmental impacts of the industrial sector without affecting its output and profitability.

Mining and mineral processing sub-sectors are some of the major energy consumers in the industrial sector (Gielen and Taylor, 2007); under which the copper industry falls. The copper industry is energy intensive and significant emitter of CO_2 and SO_2 gasses (Alvarado et al., 1999). Furthermore, the theoretical minimum energy required in primary copper production (for sulphide ore) is calculated to be between 1.4 to 2.2 GJ per tonne of metal. However, the actual specific energy consumption (SEC) for ore from an open pit mine at ore grade of 1.32% is between 25 - 30 GJ per tonne of metal (Alvarado et al., 1999; Alvarado et al., 2002; Norgate and Jahanshahi, 2010). The actual SEC is largely influenced by the type of mining method, grade of ore and type of ore being processed (oxide or sulphide ore). For instance, the energy requirements for processing oxide and sulphide ores (ore grade of 0.5% from an open pit mine) is 30 and 60 GJ per tonne of metal respectively (Marsden, 2008).

Apart from the physical factors that influence energy consumption, there are also other factors such as an organisation's investment policy in capital equipment, both energy consuming and production equipment. In studying the energy efficiency gap, Jaffe and Stavins (1994) observes that one of the major challenges in resolving the energy efficiency gap, is the lack of a holistic approach when tackling this problem. For instance, most industrial energy studies (Garcia et al., 2007; Saidur et al., 2009) have focused on the energy costs, and overlooking the impacts that other costs such as labour cost would have on decision making. With mining organisation focusing on profit maximisation (Haglund, 2010), it is important that energy costs savings opportunities are put in context of other cost saving opportunities available to an organisation. Most organisations make capital investment decisions relative to other factors (not just energy) and policies.

Past studies that have looked at energy efficiency lacked a holistic view of an organisation's system and only focused on the energy system. This study therefore focuses on understanding how different organisation decision making policies would impact on the organisation's profitability. It considers two decision making policies: an expansive and an energy efficiency policies. The expansive policy puts stronger emphasis on increasing the organisation's production capacity (that is increasing output) while the energy efficiency policy favours investment in more energy efficient technologies over expansion of production capacity. A case study of Zambia's copper industry is used. Zambia's industry accounts for approximately 6% of the total global copper cathode production and consumes about 54% and 32% of the total final electricity and petroleum consumption of the country's supply respectively (IEA, 2012).

Methods

Energy models are used to study how organisations use energy and also how the demand will change over time. Of the two main modelling approaches: top-down and bottom-up approaches (Fleiter et al., 2011); this study uses a bottom-up approach. A simulation model that accounts for all the major costs and investment options of the industry is developed. The model also captures the materials process flows of the industry in order to be able to account for how changes say of ore grade would impact on the quantity of energy consumed and on the organisation's profitability.

The model is developed following a systems dynamic methodology, on a Vensim systems dynamic platform. Systems dynamics (SD) is an approach that is used to study the dynamic behaviour of various systems. This is achieved by including feedback loops in the cause-and-effect analysis. This (SD) approach is suitable because it helps capture and mimic behaviour as that of a real decision maker, a heuristic decision making behaviour as opposed to an optimisation methodology (Wilson and Dowlatabadi, 2007). System dynamics also helps in modelling sequential decision making processes and the impacts that this sequential process has on the whole system. It was important that sequential processes are captured because decision makers do not have the full knowledge of key decision variables in moments that decisions are supposed to be made.

Using an SD model, the change that occurs over time can be modelled by using a similar approach of system of differential equations, where the state of the system (x) at time t is always dependent on the history of x, the system policies (r) and exogenous factors (ε), such as copper price, that might be acting on the system. The focus of the modelling study will be on how an organisation’s profitability is impacted by past decisions, fluctuating copper prices and reducing copper ore grade. Different scenarios are developed to simulate either an expansive or an energy efficiency investment policy and how organisations would respond to these stimuli, assuming all other things are kept constant.

Results and Discussion

The tentative results from the model, in the short term, found that copper prices have the largest impact while in the long term, an organisation’s profitability is greatly impacted by the copper ore grade. During times of good copper prices, organisations tend to invest more in production capacity in order to maximise on the profits, but this would lead to technology lock-in when the prices drop and production operations become unprofitable.

However, when organisations implement an energy efficiency investment policy, their revenue growth is generally reduced but the organisation becomes less susceptible to copper price shocks. Further such organisations tend to be more profitable (relative those that implement an expansive investment policy) as ore grade continues to reduce. This is because energy consumption increases at an exponential rate relative to ore grade. It is, thus, intuitive that an organisation that implements an energy efficiency policy will not only be robust but also prolong its operational life.

Concluding Remarks

The model that has been developed captures an organisation’s system holistically: the engineering part and the financial part. Decision rules, the investment policies, are also modelled to guide how the model responds to different stimuli. However, further analysis still needs to be done on the model so that the impacts of both copper price and copper ore grade can be quantified.

References

Alvarado, S., Maldonado, P. & Jaques, I., 1999. Energy and environmental implications of copper production. Energy, 24(4), pp.307–316.

Alvarado, S. Maldonado, P., Barrios, A. & Jaques, I., 2002. Long term energy-related environmental issues of copper production. Energy, 27(2), pp.183–196.

Fleiter, T., Worrell, E. & Eichhammer, W., 2011. Barriers to energy efficiency in industrial bottom-up energy demand models—A review. Renewable and Sustainable Energy Reviews, 15(6), pp.3099–3111.

Garcia, A.G.P. et al., 2007. Energy-efficiency standards for electric motors in Brazilian industry. Energy Policy, 35(6), pp.3424–3439.

Gielen, D. & Taylor, M., 2007. Modelling industrial energy use: The IEAs Energy Technology Perspectives. Energy Economics, 29(4), pp.889–912.

Haglund, D., 2010. Policy evolution and organisational learning in Zambia’s. University of Bath.

IEA, 2012. Energy Statistics of Non-OECD Countries: 2012 Edition. , 1(September). Available at: http://www.esds.ac.uk/international/doipages/ieaesnon.asp.

Jaffe, A.B. & Stavins, R.N., 1994. The Energy Efficiency Gap: What does it mean? , 22(10), pp.804–810.

Marsden, J.O., 2008. Energy Efficiency & Copper Hydrometallurgy. Presentation.

Norgate, T. & Jahanshahi, S., 2010. Low grade ores – Smelt, leach or concentrate? Minerals Engineering, 23(2), pp.65–73.

Saidur, R. et al., 2009. End-use energy analysis in the Malaysian industrial sector. Energy, 34(2), pp.153–158.

Saygin, D. et al., 2011. Benchmarking the energy use of energy-intensive industries in industrialized and in developing countries. Energy, 36(11), pp.6661–6673.

Wilson, C. & Dowlatabadi, H., 2007. Models of Decision Making and Residential Energy Use. Annual Review of Environment and Resources, 32(1), pp.169–203.