MANAGING THE EFFICIENT USE OF ENERGY ON CONSTRUCTION SITES AND COST REDUCTION

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Abstract

South Africa is a high energy intensity country by world standards; it has the highest emission of greenhouse gases per capita in Africa whose energy production processes rely on coal powered stations. The construction sector consumes approximately 40% of all energy consumed in the economy; previous studies have focused mostly on energy usage in building operation which is well accounted and profiled. However, a significant amount of energy is consumed by the construction processes but its efficiency level is not understood. The paper explores factors that influence inefficient use and conservation of energy in construction processes to determine measures that can be used conserve energy in the construction process. A questionnaire was randomly administered to site managers, foremen, and machine operators on site. A likert Scale was used to measure opinions of respondents on scale of 1 to 5 and was subjected to a multi-attribute method of analysis. The study shows that inefficient site management is a major constraint to conservation of energy in the construction processes. Efficient utilization and conservation of energy on site can lead to 10-20% cost savings on energy usage. The construction activities that consume most energy are transportation, hoisting and concreting. Effective site management, maintenance of plant and equipment and the choice of machines intended for the activities for which they have been designed are the most important factors for improving energy efficiency in the construction processes. These findings are be useful to those managing construction sites to improve energy efficiency and reduce energy costs and overall cost of construction. It is also useful for global warming mitigation strategy and policy formulation.

Keywords: Climate Change, Construction, Site Management, Energy Efficiency

INTRODUCTION

Energy efficiency is increasingly becoming an important subject worldwide due to the link between the rising energy demand, the greenhouse gas emissions and global warming (Watson, 2003). The subject is also of importance to South Africa due to unstable power supply. The main electricity producing body-Eskom, reported that the production reserve was lower than the world's recommended level which is between 15% to 18% (Eskom 2007), this ultimately leads to the common phenomenon of load shedding during interruption of generation schedules (for example during repairs, maintenance or excessive peak demand). The situation is compounded by the fact that the South Africa's energy sector is largely dependent on coal as the primary source.

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The US Department of Energy, Energy Administration Office (2007) observed that in the year 2004, energy related Carbon Dioxide (CO_2) emissions was 430 million metric tons with contributions by source as follows; Coal (82%), Oil (17%) and Natural Gas (1%). The 2007/2008 United Nations Development Programme (UNDP, 2008), the human development report observed that by international standards South Africa's economy is extremely high energy intensive in terms of energy consumption in relation to its Gross National Product. Studies in energy efficiency are of great importance to South Africa. This is underscored in the government's energy strategy paper (Department of Minerals and Energy (DME), 2005) which sets the target for demand reduction through energy efficiency at 12% by the year 2014.

United Nations Environmental Programme (UNEP) reports that the amount of energy used in buildings is 30-40% of all primary energy worldwide (UNEP, 2007). In South Africa, this figure has been calculated as 27% (Department of Minerals and Energy, 2003). Consequently, energy efficiency in buildings has been identified as one of the key mitigating factors in climate change. However, studies on energy efficiency in buildings have concentrated on building design and operations (Mathews *et al.*, 1999, Wentzel 2006 and Jaini *et al.,* 2013). There is limited information regarding energy utilization on construction sites. This paper highlights the main issues that contribute to energy efficiency on the construction site.

Energy in construction processes

Although energy is used in the project life cycle at different levels, it is during building operation that the bulk of energy is consumed (Jones, 1998). However, it is important to account for energy usage at all levels of the building life cycle. Construction operations consume huge amounts of energy in various forms but have never been sufficiently accounted for. A significant portion of energy utilization on construction site is associated with the mechanical plant used for transportation, levelling, earthworks, lifting, compacting and mixing, including the embodied energy in materials extraction (Fog, *et al,* 1983). The major forms of energy used in construction production processes on site include diesel, electricity, petrol and gas. To illustrate this point reference is made of the U.S. statistics on energy use as an example. As stated by the U.S. Environmental Protection Agency (2006), construction equipment consumed 5.968 million gallons of diesel, equivalent to 827.8 trillion Btu at 138,700 Btu / Gal, and 688 million gallons of gasoline, equivalent to 86.04 trillion Btu at 138,700 Btu/gal. As total construction industry use in 2006 was 913.85 trillion Btu, the construction process alone represented 1.2% of total US energy consumption.

The different forms of energy are used for different purposes in the construction process. For instance, diesel fuel is an important petroleum product and offers a wide range of performance, efficiency and safety features. It also offers a greater power density than other fuels, and contains between 18% and 30% more energy per litre compared to petrol (gasoline as used in the US) (US Energy Information Administration, 2007). According to Energy Information Administration (2004), diesel is a safer fuel compared to petrol and other alternatives because it is less flammable. The major disadvantage of diesel fuel is its high emissions of CO_2.

Electricity on the other hand is a derived energy and is one of the most widely used forms of energy. Electricity is used for the operation of almost all the power tools or equipment on site. Fused distribution boards are used to enable easy pluging of power tools to the electrical source (McMullan, 2002; Foster and Harrington, 1998). In South Africa, the building Industry accounts for 27% of electricity use and 12% of the final energy use (DME, Eskom and ERI, 2002).

Petrol is also in used construction processes and is used for powering small petrol engines especially power tools, such as hammers and small compressors. Natural gas on the other hand, burns more cleanly than other fossil fuels. It has lower emissions of sulphur, carbon, and nitrogen than coal or oil, and when it is burned, it leaves almost no ash particles. Like other fossil fuels, burning of natural gas produces CO_2.

In dollar terms, as reported by Department of Commerce (DOC) (2005a), the construction industry spent $15 billion on energy of which $ 11 billion was spent on gasoline and diesel fuel, $ 1.1 billion on natural gas and $ 2.6 x 10^9 on electricity. With the above statistics, it is important that there is a crucial need for energy efficiency with relation to cost in the construction industry.

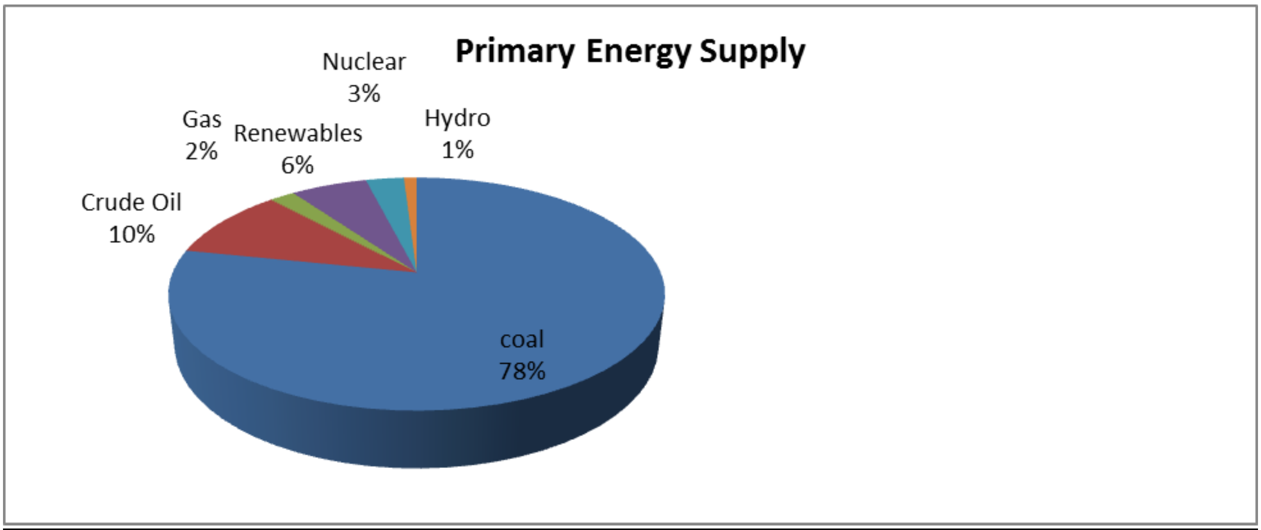

Figure 1: Energy usage by form in South Africa (Source: DME, 2005)

Activities that utilize energy in construction processes

The knowledge of the activities or processes that consume the most energy is an important step towards determining how energy is utilized in the construction processes. Demolition, transportation (including concreting), excavation, and hoisting are some of the processes that consume huge amounts of energy in the construction process.

The demolition process can be either manual or mechanical through use of large hydraulic breakers, elevated work platforms, cranes, excavators or bulldozers. Large buildings may require the use of a wrecking ball, a heavy weight on a cable that is swung by a crane into the side of the buildings. Wrecking balls are especially effective against masonry, but are less easily controlled and often less efficient than other methods. Other methods may use rotational hydraulic shears and silenced rock breakers attached to excavators to cut or break through wood, steel, and concrete. The use of shears is especially common when flame cutting would be dangerous. Large buildings, tall chimneys, smokestacks, and increasingly some smaller structures may be destroyed by building implosion using explosives and this is preferred in dense urban areas to minimize damage to neighbouring structures. In a nutshell, demolition involves the use of large plant that consumes high levels of diesel and electricity.

The excavating processes include both surface and deep excavation of soil and often involve the movement of excavated soil from one place to another. The machines used in this process are divided into two; excavators (such as face shovel, skimmer, dragline, crane and grab, pile driving and drilling and tractors (trench digger, scraper, bulldozer, grader, trenching machine, and mechanical auger) and mostly powered by diesel (Foster and Harrington, 1998). Dippers are used for exportation of excavated materials.

Table 1: Categorises the plant, tool or epuipment according to the type of energy used and the construction processes they perform

Plant,tool or equipment	**Energy used**	**Contruction Processes**
placers rebators and routers	Electricity	Grooving ,moulding other joinery
Saws,	Electricity,comprassed air,pertol engine	Cutting,grinding,
rotary drill,rock drill ,picks and breakers	Electricity,comprassed air,pertol engine	Drilling,driving screws,
Hammers	Electricity, comprassed air,pertol engine	Hummering,
poker vibrater,tempers	Electricity, comprassed air,pertol engine	Vibrating concrete,consolidation of concrete
Power foat	Electricity or pertol engine	Trowelling screeds
Sanders	Electricity,comprassed air,pertol engine	Foor surfacer
Conveyors	Electricity	Transporting soil ,concrete or other light materials
Forklift,dumpers,	Diesel	Transporting concrete
Mobile	diesel and electricity	hoisting and transportation
Elevators	Petrol or disel engine	Hoisting
cranes(stationary)	Electricity	Hoisting
Plant,tool or equipment	Energy used	Contruction Processes
Mechanical auger	Diesel	Boring
Trenching machine, grader, buldoser and angle dozer, scraper, skimmer, dradline	Diesel	Excavation
Pumps	Electric motor,petrol or diesel engine	Keep surfaces free from water
Compressers	Electric motor or diesel engine	Supply compressed air

Hoisting may be done using manually, electrically or pneumatically operated machinery. These include cranes, elevators and hoists which sometimes carry materials. Cranes are electrically and or diesel engine powered while hoists are powered by petrol or diesel engines. Elevators are used to raise bags of cement, bricks and tiles and are also powered by small engines and amounted on two wheels so that they can be moved around the site (Foster and Harrington, 1998). A telescopic handler is used for hoisting and is powered by diesel.

According to UNEP (2003), transportation of construction materials consume more energy than all the construction processes. This activity involves the largest percentages of diesel as a form of energy. The transportation also includes the movement of concrete from one place to another (from trucks or point of mixing to the point of placing). The heavy trucks are used to transport materials such as sand and stones and are powered by diesel. Concrete is transported by trucks and are powered by petrol or diesel. Small petrol engines in conveyors, concrete pumps and placers are also used and these are mechanically or pneumatically operated (Foster and Harrington, 1998).

Concreting processes require a significant amount of energy. The machines used in this process are; mixers, concrete pumps, placers, vibrators and conveyors and are either mechanically or pneumatically operated (Foster and Harrington, 1998). Concreting and the type of equipment used have a large embodied energy in the ingredients used and the transportation process. It can be observed that, at different levels of construction process, energy is used. Knowing the construction method statement, an opportunity arises on how energy can be used efficiently on site. Table 1 below summarises the plant, tool or epuipment with the corresponding type of energy used and the construction processes they perform.

METHODOLOGY

The study was carried out in Gauteng and as reported by the Sustainable Energy Africa (SEA) (2009), Gauteng province is the economic hub of South Africa. Many significant industries and business sector bodies are situated in the province. Therefore the province provides opportunities for economic development and competitiveness of its industries through the establishment of a low carbon economy to ensure sufficient energy supply to support sustainable development and cleaner production. This justified the need for study for the study area. For the purpose of this research, a survey was undertaken to obtain practice based opinions. This was via investigative structured scheduled interviews from a sample of five randomly selected construction sites. The interviews targeted managers, foremen, machine operators on sites in Gauteng. Questionnaires were also used and administered to corroborate the findings from the interviews. Fifty questionnaires were randomly distributed to people who work on construction sites (that included managers, foremen, and machine operators). In total 42 questionnaires were received. This accounted for 38% of foremen, 32% of machine operators and 30% of site managers. The mix was on the basis of the willingness of the respondents to complete the questionnaire. The analysis involved the computation of the mean rating (MR) for every aspect within a specified divide. This was calculated using 5 point rating system. Ranking of each factor: From Very High Influence (VHI) = 5, High Influence (HI) = 4, Neutral (N) = 3, Low Influence (LI) = 2, Very Low Influence (VLI) = 1, Rankings also included total response (TR), mean rating (MR) which indicates whether a factor has an influence or not, and relativity index (RI) which indicates the comparative influence in percentages.The total number of respondents (TR) involved in rating every aspect was attained within every computation, and the number of the respondents that relate to a rating of the particular aspect / variable was calculated as a percentage.

RESEARCH FINDINGS

Summarised research findings are discussed in the following sections.

Factors influencing inefficient use and conservation of energy on construction processes

The study highlighted the extent to which pre-identified key factors influenced inefficient use and conservation of energy in construction sites. Respondents were asked to rank from their informed opinion the extent to which these factors influenced inefficient energy use trends and conservation. The rankings results are as outlined in Table 2. It can be seen that lack of efficient site management and ignorance are the main causes of inefficient use of energy on site. This corroborates the findings in studies undertaken by Harlow (1992) and Davis (1982).

Table 2: Factors influencing inefficient use and conservation of energy

Factor	VHI (5)(%)	HI(4) (%)	N(3) (%)	LI(2) (%)	VLI(1) (%)	TR	MR	RI	RI %
Lack of site management	52.4	35.7	11.9	0.0	0.0	42	4.41	0.286	28.6
Lack of skilled operators	14.2	23.3	33.3	16.7	11.9	42	3.11	0.202	20.2
Ignorance	50.0	28.6	16.7	4.8	0.0	42	4.24	0.275	27.5
Plant	21.4	28.6	23.8	16.7	9.5	42	3.65	0.237	23.7
Sum ($\sum$)							15.41	1.00	100

The scale of cost reduction

Proper efficiency mechanisms can impact on the reduction of costs on energy costs. The results from the survey indicate that between 10 -20% reduction can be achieved by carefully implementing energy efficiency and conservation strategies. It is evident from the respondents that efficient energy utilisation and conservation has a positive impact on the reduction of energy costs on construction sites.

Table 3: Cost Reduction and Responses in percentages

	Responses	
Cost reduction in Percentage	**(%)**	**Number**
Less than 10%	28.6	12
Greater 10 but less than 20%	35.7	15
Greater 20 but less than 30%	16.6	7
Greater 30 but less than 40%	9.5	4
Greater 40 but less than 50%	7.2	3
Greater 50 %	2.4	1
Total	100.0	42

Construction areas/activities which consume more energy in construction processes

Table 4 shows key activities that consume more energy in construction processes. It can be seen that transportation, hoisting and concreting, in that order of merit would need more attention and effort towards conserving energy on site. This supports the findings by UNEP (2007)

Table 4: Construction areas/activities with high energy consumption

Activity	VHC (5)	HC(4)	MC(3)	LC(2)	VLC(1)	TR	MR	RI	RI%
Demolition	23.81	30.95	38.10	7.14	0.00	42	3.71	0.183	18.3
Excavations	26.19	28.57	45.24	0.00	0.00	42	3.81	0.188	18.8
Concreting	35.71	42.86	14.29	7.14	0.00	42	4.07	0.201	20.1
Hoisting	50	28.57	16.67	4.76	0.00	42	4.24	0.209	20.9
Transportation	50.00	42.86	7.14	0.00	0.00	42	4.43	0.219	21.9
Sum (∑)							20.26	1.00	100

Various types of energy used on sites

Figure 2 shows the percentage in Rand value of energy used on construction sites. It can be seen that diesel is the most used form of energy in construction processes, followed by electricity, petrol and gas. Diesel is associated with transportation activities. This makes it the most consumed form of energy. This is an indication that more attention must be given to consumption of diesel fuel as revealed in the literature that it is the most CO_2 emitter (DME, 2005).

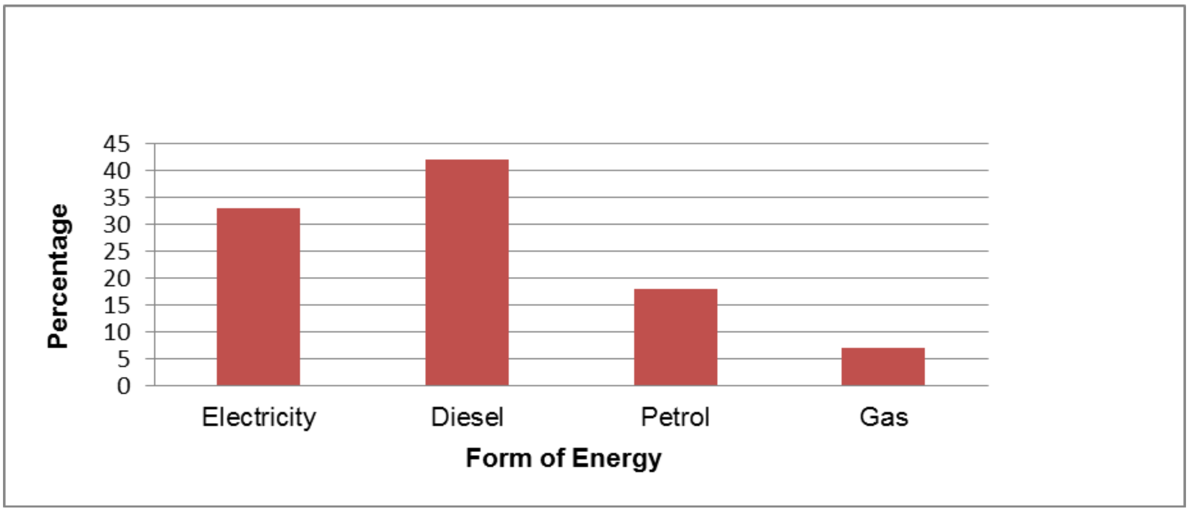

Figure 2: The types of Energy used in Construction Processes

Other Findings

Other findings were obtained through open ended questions on how energy conservation on site can be improved. Among them is the use of machines and equipment. It was found that it is common amongst subcontractors to tender and win projects for which they have no capacity. They end up using machines inefficiently. In addition they use machines for which are not designed for the task, others use equipment that are not sanctioned or are not maintained. In adition safety rules and best practices of management of equipment were not followed. For instance it was common to observe equipment in operation but was not doing any task. It was also clear that staff were not trained on maintenance of equipment in order to conserve energy.

CONCLUSIONS

The paper has highlighted the extent to which certain factors influence inefficient use of energy in construction processes, and how proper energy utilisation and conservation can reduce costs. Areas that comparatively consume more energy have been identified. Transportation, hoisting and concreting are some of the processes that demand more energy usage. It can be seen that for energy efficiency to be achieved on site, a lot more effort will be required to improve site management and training of workers to be more conscious of the use of energy. The future of the efficient energy use on construction site will rely on a number of things. One among them is efficient site management practices, which include efficient site layout; the use equipment for which it has been designed, and its maintenance according to the manufacturers' instructions; and the training of staff to be conscious of energy conservation. Transport as a major consumer of energy, it is necessary that a proper logistical transport system be in place that synchronizes the delivery of materials and removal of waste on site.

REFERENCES

Davis, W.H. (1982) *Construction Site Production 4 Checkbook.* London: Butterworth & CO (Publishers) Ltd.

Department of Minerals and Energy (2005) Energy Strategy of the Republic of South Africa, Republic of South Africa, Pretoria.

Department of Minerals and Energy (2003) White Paper on the Renewable Energy Policy of the Republic of South Africa, Republic of South Africa, Pretoria.

Department of Minerals and Energy, ESKOM and Energy Research Institute (2002) Energy Outlook for South Africa [online]. Available from:
http://www.dme.gov.za/pdfs/energy/planning. pp 1-41.

Department of Commerce (DOC) (2005) (2002) Economic census, industry summary. Çonstruction subject series, EC02-235G-1 Economics & statistics Administration, U.S Census Bureau Washington, DC.

ESKOM (2007) Annual Report, Partnering for growth, Eskom Holdings [online]. Available from:
http://financialresults.co.za/2007/eskomar2007_fin/downloads/eskom_ar2007.pdf [Accessed 19 August 2013]

Fog, M.H. and Nadkarni, K.L. (1983) Energy Efficiency and Fuel Substitution in the Cement Industry with Emphasis on Developing Countries. United State of America.

Foster, J.S. and Harrington, R. (1998) *Mitchell's, Structure & Fabric Part2, 5th Edition*, London, Macmillan.

Harlow, P.A. (1992) *The Practice of Site Management Volume 4.* Berkshire, UK: Chartered Institute of Building.

Jaini, S., Bhadouria, A.S. and Khare, A. (2013) 'Sustainability in building design: integrating architecture with technology to achieve energy *efficiency'' Special Issue of International Journal of Sustainable Development and Green Economics* (IJSDGE), Vol. 2(1), 2.

Jones, D.L. (1998) *Architecture and the Environment*. London, Laurence King Publishing.

Mathew, E.H., Kleingeld, M. and Tailor, P. (1999) Estimating the Electricity Savings Effect of Ceiling Insulation, *Building and Environment*, Vol. 34(2), 505-514.

McMullan, R. (2002) *Environmental Science in Building, Fifth Edition*, New York: Palgrave Macmillan.

Sustainable Energy Africa (SEA) (2009) Draft Integrated Energy Strategy, Cape Town, .pp-11

UNDP (2008) Human Development Report 2007/2008, Fighting Climate change: Human solidarity in a divided World [online]. Available from: http://hdr.undp.org/en/media/HDR_20072008_EN_Complete.pdf [Accessed 19 August 2013]

UNEP (2007) Annual Report [online]. Available from:
http://www.unep.org/annual report2003 [Accessed 16 September 2013]

UNEP (2003) Annual Report [online].
http://www.unep.org/annual report2007 [Accessed 16 September 2013]

US Energy Information Administration (2007) Report on Independent Statistics and Analysis of energy for South Africa [online]. Available from:
http://www.eia.gv/countries/analysisbriefs/south_africa/south_africa.pdf [Accessed 12 September 2013]

US Energy Information Administration (2004) Report on Independent Statistics and Analysis of energy for South Africa [online]. Available from:
http://www.eia.gv/countries/analysisbriefs/south_africa/south_africa.pdf [Accessed 12 September 2013]

U.S. Environmental Protection Agency (2006) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006 [online]. Available from: http://epa.gov/climatechange/emissions/usgginv_archive.html [Accessed 12 September 2013]

Watson, D. (2003) *Energy Conservation through Building Design*. New York:
McGraw Hill Book Company.

Wentzel, M. (2006) Quantifying benefits of energy efficient house design through monitoring of specified air quality and household energy activity. *Journal of Energy in Southern Africa*, Vol. 17(2).