Energy Management Practices In Ugandan SME Foundries

John Baptist Kirabira, Angella Nalweyiso, Thomas Makumbi

Abstract: Foundry is one of the most energy intensive metallurgical industries. In Uganda, foundries are associated with large energy consumption necessitating the need to seek for ways to minimize their energy consumption. This study sought to establish the energy efficiency of the SMEs in Uganda with the view of devising means to reduce on their energy consumption. This was accomplished by studying the energy consumption trends in the industry using primary and secondary data obtained from a number of SME foundry operators in Uganda and basing on this data, energy efficiency and conservation measures have been devised. The major energy sources used in these foundries include used oil at a consumption rate of 72%, biomass (charcoal and firewood) at 21%, diesel at 6%, and electricity at 1%. The specific energy consumptions (SEC) of the firms studied range from 7.35 MJ/kg to 14.61 MJ/kg which is considerably on the higher side. The melting process consumes the biggest part of the total energy consumed, at 70% in the foundries. This necessitates the employment of more energy efficient melting technologies. Implementation of energy management programs in order to reduce energy requirements per unit of output is thus recommended. Different energy saving measures that can be employed in this sector were identified. Some of these can be implemented by adopting simple courses of action while others require high capital investment. It is thus recommended that these firms start by implementing the low cost solutions and progressively move to the capital intensive solutions.

Key Words: Casting, Crucible Furnace, Energy Consumption Pattern, Energy Management, Foundry, SMEs, Uganda, Used Oil Minimum.

1. INTRODUCTION

SMALL and Medium Enterprises (SMEs) account for a sizeable share of the Ugandan industry and contribute a lot to its economic development. They are a vehicle through which the rural poor and informally employed Ugandans can transform themselves into the middle and the industrial class of tomorrow. The sector has potential for long-term growth and accounts for approximately 90% of the private sector, contributes 75% of Gross Domestic Product (GDP), 30% of employment and 80% of the manufacturing sector in Uganda. Over 80% of the sector is located in urban areas. The employment growth is estimated at 25% per annum and therefore the SME sector is a prime source of new jobs [1]. SMEs in Uganda face a number of challenges which impede their competitiveness and growth, and among the most important ones is energy management. Improving energy efficiency can be an important strategy for enhancing competitiveness, particularly for energy intensive SMEs like foundries. Similar to many others worldwide, SMEs in Uganda are generally considered less efficient in material and energy use compared to larger enterprises and enterprises of similar scale in the developed world.

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However, the SME is a continuously growing sector of the Ugandan economy in terms of number of enterprises as well as production, and an important feature of SME development is technology advancement and modernization process involving substitution of labor-intensive technologies by capital-intensive technologies [2,3,4]. Energy management is the judicious and effective use of energy to maximize profits and to enhance competitive positions through organizational measures and optimization of energy efficiency in the process. Foundry is one of the most energy intensive metallurgical industries in the SME sector, and was the focus of this work. At the firm level, energy intensity reduction due to efficiency improvement should reduce the cost of production of individual SMEs and at the aggregate level it will bring down or curtail the growth of industrial demand for energy. The former will contribute to the cost competitiveness of SMEs, whereas the latter will call for less energy-related investments at the national level [5]. In a manufacturing facility, for instance, energy efficiency can be achieved by using more efficient equipment, providing advanced systems to control energy use and improving operation and maintenance practices [4,6,7]. These objectives can be obtained by identifying the most suitable energy type and maximizing the efficiency of the energy type used. This study attempts to determine energy utilization efficiency of small and medium scale foundries in Uganda and the ways in which productivity can be improved through proper energy utilization. Similar studies have been carried out elsewhere [8,9,10,11].

2. METHODS

2.1 COLLECTION OF DATA

Since there is no systematic list of SMEs operating foundries in Uganda, the research took advantage of snowball sampling technique. Two foundries known to the researchers which were visited first facilitated in generating the list of other foundry workshops. Focus was put on foundries in the Central region. Data was collected from seven SME foundries. The technology, energy sources and major products of the foundries under the study are given in

Table 1. Data were collected through personal interviews with the help of a structured questionnaire for each SME that was selected. While the questionnaire gave “structure” to the interview, additional discussions were held with the respondent to capture as much qualitative information as possible. Additionally, observations coupled with photographs taken, were used to supplement in collection of related data. Preliminary visits to all the SMEs were done enabled familiarization SME operations and develop sector-specific schedules. Each schedule comprised six sections: A. Unit profile, B. Production, C. Technology used (inventory), and D. Human resource inventory. As a result, data were gathered on variables such as enterprise characteristics, type and quantity of energy used, employment, technology in use, entrepreneurial background, etc. The data collection exercise was performed during the last half of 2012. The energy consumption pattern was analyzed in terms of energy cost per unit of enterprise. Energy intensity was calculated as energy cost per unit of value of output.

3. Results and Discussion

3.1 Technology used

Ugandan SME foundries are characterized by basic technology consisting of mainly used-oil crucible and tilt furnaces. The main source of fuel is used-oil, electric energy is used to run the blower and also sparingly for machining and seldom for lighting the workshop. Biomass (firewood and charcoal) is commonly used for baking/drying moulds. The pattern making and mould construction are generally manual. Fig 1 – 3 illustrate in pictorial the kind of technology used. The main source of raw material is cast iron and non-ferrous alloys scrap bought from scrap scavengers and collectors. Table 1 summarizes the technology, energy source and the major products profiling the foundries visited.

Table 1: Technology, Energy Source and major Products of individual SMEs

Foundry	Technology	Source of Energy	No. of Employees	Major Products
1	Tilt furnace Pit furnace	Used Oil Electricity Biomass (firewood)	24 (8)	Brake shoes, fire bars, manhole covers, different spare parts.
2	Pit furnace	Used Oil Electricity Biomass (firewood)	20(10)	Gears, bearing houses, bushes, fun housings, pipe benders and other products as may be required by the customer.
3	Tilt furnace	Used Oil Electricity Biomass (firewood)	5	gears, bearing houses, bushes, weights, fun housings and other products as required by the customer
4	Tilt furnace	Used Oil Electricity Biomass (firewood)	6	Railway spacers, weights, gears, bearing houses, bushes, and other products as required by the customer
5	Crucible furnace Rotary furnace	Used Oil Diesel Electricity	10	Sugar factory spare parts like rollers, bushes, pulleys, fans, gears, etc.
6	Tilt furnace	Used Oil Diesel Electricity	8	Weights, housings, machines bases, rollers, manhole covers, various spare parts.

Fig 1: An aerial view of a typical tilt furnace used by SME foundries in Uganda

Fig 2: A tilt furnace in operation at one of the foundries visited

Fig 3: Moulds baked using charcoal at one of the foundries

3.2 General Processes Followed

The major manufacturing processes in foundry industry include pattern making, sand preparation and moulding, melting, pouring/casting, fettling and machining to finish. The processes used by the Ugandan SME foundries in Uganda are not any different from the general processes used in casting elsewhere in the world, Fig 4. The energy intensive process is shown by the arrow as melting.

3.3 Energy Balance Sheet

The data collected on energy use were used to prepare an energy balance sheet. The energy balance sheet itemizes all relevant input and output energy forms and shows the breakdown of energy used in various processes. The energy balance sheet was then used to identify the energy centers, which were then analyzed to identify areas of energy saving potential. To prepare the energy balance sheet, a continuous on-site study was conducted at the production unit, and a process and energy flow diagram was developed as shown in Fig 4.

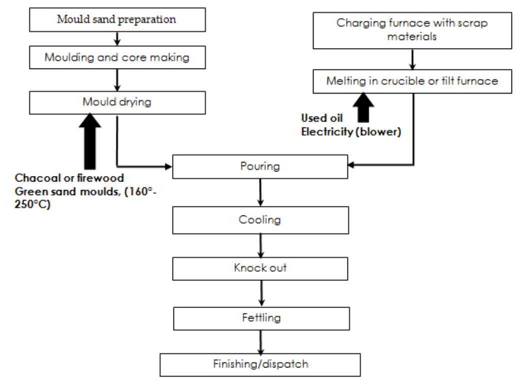


Fig. 4. General production processes followed in the foundries.

3.5 Specific Energy Consumption

Specific energy consumption was estimated in terms of kWh per kg of finished product.

3.5.1 Energy Consumption per Source per Casting

Specific energy consumption was used to evaluate the firms' efficiency and the results show that foundry 3 consumes the least energy per kg with 7.35 MJ/kg while foundry 5 consumes the most energy with 14.61MJ/kg. These values were compared with benchmarks from Canadian iron foundries [12]. The benchmarks were adapted for this study since there are no standards established for the Ugandan Foundry Industry. The specific energy consumption of all the firms under study are generally acceptable with the benchmark (8,622 MJ/ton or 8.62 MJ/kg)), except for foundries 1 and 5. The likely cause of this big difference is the technology used. Most foundries in Canada employ electric furnaces which are much more efficient as compared to the crucible furnaces employed by small and medium scale foundries in Uganda.

Table 2: Estimated specific energy consumption and cost for the different SME foundries

FOUNDRY	NET METAL MELTED PER CASTING (kg)	ENERGY CONSUMPTION PER SOURCE PER CASTING				Total Consumption (MJ)	Energy Consumption (MJ/kg)	Specific Energy Cost (UGX/kg)
		Used oil per casting (Litres)	Diesel per casting (Litres)	Biomass per casting (kg)	Electricity per casting (kWh)			
1	350	300	0	60	11.19	11,521	10.97	1,151
2	550	280	10.0	120	0	12,918	7.83	745
3	520	240	5.0	120	0	11,459	7.35	655
4	280	200	0	50	33.57	8,263	9.84	1,018
5	190	200	0	60	12.00	8,330	14.61	1,438
6	225	87.5	87.5	0	33.57	6,295	9.33	1,898

*Note that $1≈ 2,540 UGX

3.6 Energy Consumption Patterns and Content of the Different Energy Sources

The percentage annual energy consumption per source is shown in Fig 5. The most widely used source is used oil with 72%, followed by biomass with 21%, followed by diesel with 6% and electricity is the least used source with 1%.

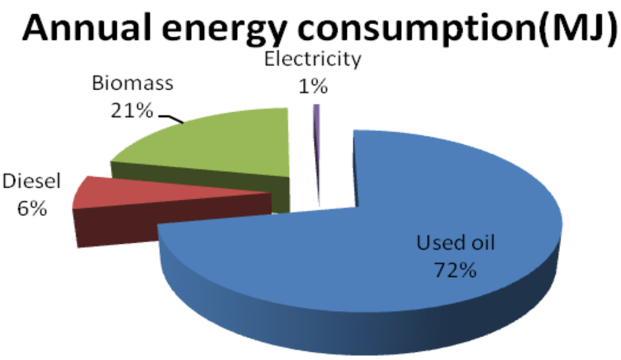


Fig 5: Pie chart showing the percentage usage per source

Since used oil is the most used source of energy covering more than 70%, there is need to improve its utilization efficiency for productivity optimization. Another source that needs serious consideration is biomass since its usage is also relatively high. The cost implications of these energy sources were also calculated in the next section in order to further justify the need for improvement, Table 2.

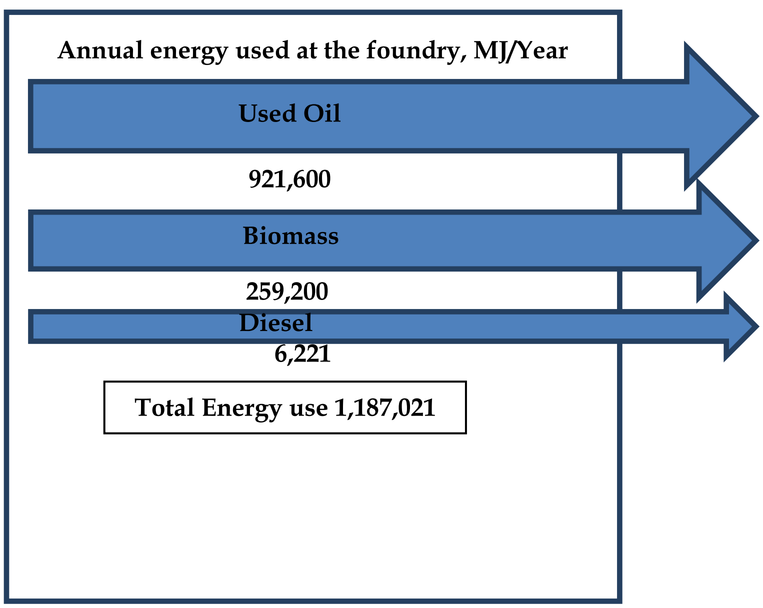
3.7 Identification of Energy Saving Measures

3.7.1 Technical

From the energy balance sheet, areas of high energy consumption “energy centers” were considered as potential areas for energy saving. However, other areas could also be considered to improve the overall energy utilization. There may be many options to reduce energy consumption. For example, better housekeeping, behavioral changes, preventive maintenance, installation of energy efficient equipment etc. are a few of the options available.

3.7.2 Energy Saving Measures

The specific energy consumption of the foundries ranged from 7.35 – 14.61 MJ/kg, with an average of 10 MJ/kg which is above the benchmark of 8.62 MJ/kg. Therefore there is potential to save energy especially in the melting process. This is a high energy consumption process where potential energy savings were identified. This is illustrated in the Energy balance sheet of say, foundry 5,c Fig 6. Some housekeeping practices should be encouraged to reduce energy consumption.



Processes	Cost
Melting	921,600
Mould baking	259,200
Drives	6,221
Moulding	0
Laddle heating	0
Office processes	0
Fettling	0

Fig 6: Annual energy balance for the foundry under study

From the energy balance sheet, the area of high energy consumption that is melting was considered as potential area for energy saving, (Fig 1 and Fig 2. However, other areas like molding, mold drying, and drives were also considered to improve the overall energy utilization. This is supported by the results of the relative energy efficiency analysis that showed that foundry B can reduce its diesel usage by around 45% if it benchmarked its peers like foundry C and foundry D. The largest energy-saving measures are found in the melting process followed by the mold baking process. The opportunities for energy savings in melting include; preheating of the charge, proper selection and adjustments of oil burners, furnace insulation and maintenance, monitoring and control and proper choice of melting technology.

3.7.3 Causes of Energy Inefficiencies (high losses)

Findings from field survey visits indicated that the main causes of energy inefficiency are as follows:

A) Insufficient Metering of the Energy Consumption of Main Production Processes

It was observed during the study that most firms lacked meters to monitor their energy utilization for the main production systems, such as motor systems, pump systems, and process heat system. This is more evident in firms that use electricity to run their blowers. These foundries do not have equipment to measure the amount of energy during the process. The electricity usage used is this study was estimated by using the rating of the motors and the amount of time taken to accomplish the activity. Furthermore, the biomass energy input into the processes is not measured by these firms. Monitoring energy use in a foundry shop is an important element that helps in reducing on the specific energy consumption. Measuring equipment like meters installed before the furnace input helps to show how much of the total energy used in the foundry is actually used to melt the metal. If the operator is aware of the energy consumption of each activity, high energy consumption areas can be identified and measures to improve the same devised. Installing such equipment can be cost effective in the long run.

B) Design flaws, Insufficient Insulation and Poor Maintenance

Foundries in Uganda mostly use crucible furnaces for the melting process. The designs are poor and the insulators used are insufficient and in sometimes not well fitted. This leads to considerable heat losses in the melting process. This was mainly due to the inexperienced artisans who neither have experience in building furnace insulations nor maintaining them. Poor maintenance leads to breakdowns of furnaces, Fig 7, shows examples of furnace cover and wall linings used by most firms under study. The losses can be high if the enclosure is not properly maintained. Heat loss can occur because of deficiencies such as: damaged or missing insulation; damaged, warped or loose-fitting furnace doors and missing sampling covers and other openings in the furnace enclosure that allow ingress of air to cool the inside furnace temperature; and excessive heat transmission through the furnace structure. Heat losses due to radiation and convection from a furnace must be minimized. Lining material, thickness and its sintering play important role in energy saving. Thick lining reduces furnace volume and hence the metal output resulting in high specific energy consumption. Thin lining, though improves the power density and promotes heat loss from the side wall has a drawback of more heat loss if the lining is made of material with a high thermal conductivity. Lining material with long sintering cycle time consumes much energy for the first heat to get ready. Improper lining causes premature failure. Therefore it is important to fit furnaces with the proper linings and where possible do the lining as prescribed by the furnace manufacture to get optimum result for energy consumption.

Fig 7: Left is a worn furnace cover lining and on the right a worn wall lining as evidenced concerning poor maintenance weaknesses in Ugandan foundries

C) Poor Quality Furnace Inputs

All firms visited during data collection use scrap as their main raw material. Scrap is got from around the country and it is of differing contents. This scrap is normally charged with no proper sorting in relation to size and cleanliness. Very large pieces create gaps and spaces within the crucible and affect heat conduction and distribution tremendously. Some of it has alloys that have high melting points. This increases the amount of energy required to melt the charge and hence the specific energy consumption. The size of the furnace input also tends not to be uniform and in most cases made up of big metal pieces. This reduces the efficiency of the furnace. **Error! Reference source not found.**A heap of scrap with varying sizes, sometimes of varying alloys too, stacked in a crucible were a common feature during the survey visits. The quality and size of scrap charged into a furnace need to be properly sorted to improve the charge quality and hence minimize energy usage. It is judicious to charge small pieces of scrap to get optimum results. Weighing of scrap in every heat to maintain proportion of charge mix is required for consistency in quality as well as energy consumption. Use clean scrap – one kilo charged means two kilos of iron not melted and increases the slag generated [4,7,11,13,14].

D) Employing Energy Inefficient Technology

The production processes of foundry industry are very similar in all the units. The utilities vary depending upon the requirement. All the foundries visited employ crucible furnaces for the melting process except one that has both a crucible and a rotary furnace installed. The foundry uses the rotary furnace only twice a year as compared to the crucible furnace that is used on a daily basis. Crucible furnaces are not as efficient as rotary furnaces because the heat must be transferred through the walls of a crucible to the metal. The efficiency of crucible furnaces range from a low of 3.5% to a high of 28% the common commercial average being around 15% [8,9]. Crucible furnaces are generally common in small scale foundry shops due to their low capital outlay and their ability to melt small volumes of metal. Besides, many motor driven systems are mostly installed with oversized motors.

Fig 8: A crucible furnace in operation with fire coming from the bottom

E) Operational and Maintenance Practices

In additional to the inefficient technology employed in these small scale foundries, operational practices in majority of the units are generally poor and need serious enhancement. There are no specific procedures followed for any particular operation and maintenance of equipment/machines. For instance, Fig 8, shows a crucible furnace in operation at one of the foundries visited. Fire is coming out from the bottom of the furnace shell which is an indicator of poor furnace operation. In a similar manner, Fig 9 is an illustration of foundry workers pouring molten metal into the mold. It can be seen that a significant amount of metal spills on the sides of the mold. This is not a good foundry practice as it leads to considerable energy losses and productivity. In addition, instruments to monitor and regulate important process parameters such as temperature and energy usage were absent. These units do not maintain proper records of process data – such as amounts of fuel and charge loaded, numbers of castings produced and rejected, causes for rejection, yet such data are vital to ensure operational control and efficiency. Ways of saving energy can be found from the use of equipment and on the other hand from melting operation procedures. The more delays there are in melting and pouring operations the higher the energy losses. Once the molten metal is ready for tapping there should not be a single minute delay in it. Metal carrying ladles should be absolutely ready and preheated. After the tapping there should not be any obstruction in movement of ladle. It is to be ensured that transfer ladle is adequately preheated. It is better to use a big ladle to minimize heat losses that occur during pouring. It is also important to ensure that the molten metal is poured directly into the mold and not splashed on the outside. Furthermore, as the furnace is full with molten metal and has attained the required temperature, de-slagging should be done. Prior to it slag removing tools should be brought near to the furnace and kept ready. Complete removal of slag is necessary to avoid slag deposition on lining with time reducing furnace volume and hence the metal output. Foundries will also benefit from having up-to-date operating procedures and work instructions to ensure consistency and standardization of operations. Better still is putting process documentation in flowchart form.

Fig 9: Foundry workers pouring molten metal from the ladle to the moulds while it spills on the sides

There are many ways through which foundry shops can improve their energy utilization efficiency including better housekeeping, behavioral changes, preventive maintenance, installation of energy efficient equipment and others. Investing in more energy efficient technology is another way that SME foundries can reduce on their energy consumption. There is a plethora of technological options available to industrial energy users, but in general the principle of using technology to increase energy efficiency involves upgrading existing equipment, replacing existing equipment, or installing/developing completely new technology/processes. Melting is the most intensive energy consuming operation in these foundries. It represents about 69% of all energy use. Electric melting is considered to be the best practice method having an energy efficiency of up to 70% however; this may not be a viable solution Ugandan case since electricity is very expensive and intermittent. Cupola melting has the advantage of cheap fuel prices. However, coke is not readily available in Uganda. Rotary furnaces have a lower energy efficiency of only 20 - 35% as compared to the electric furnace and the cupola but higher than that of crucible furnaces. The efficiency of crucible furnaces range from a low 3.5% to a high of 28% the common commercial average being around 15% [9,15,17]. This is much lower as compared to the efficiency of the direct fired rotary furnace. If SME foundry shops in Uganda adopted the direct-fired rotary furnace, their energy utilization efficiency would improve tremendously since it is an efficient, fast melting, high volume unit as compared the crucible furnaces. But depending on the financial status of these firms and small batches of metal processed, this may not be an immediate option. In addition, these foundries need to replace the oversized motors with the right sizes so that they run as near fully loaded as possible. Speed control is another energy efficient method for varying motor driven systems. It is useful to invest in variable speed drives (VSD) and turn off the motor systems when they are not needed. Higher efficiency motors represent an improvement in the systems' electricity efficiency

4 CONCLUSION

There are mainly four sources of energy used in small and medium scale foundry shops and these include used oil, diesel, electricity and biomass. The furnaces employed are fuel fired and used/burnt furnace is used for melting the scrap metal. Biomass in the form of charcoal is used for baking the molds and diesel/electricity is used to run the blower motors. Used oil has the highest usage with 51%, followed by diesel with 32, followed by biomass with 14% and lastly electricity with 3%. The melting process consumes the biggest part of the energy used in foundry shops. It consumes about 69% of the total energy consumed in the foundries and this necessitates the foundry to employ more energy efficient melting technologies. The specific energy consumption (SEC) of the small and medium scale foundries ranges from 22.9MJ/kg to 32.7 MJ/kg. Comparing this to the Canadian benchmark of 8622MJ/ton (8.62MJ/kg), it is clear that the Ugandan SME foundries are relatively inefficient and have a lot of work to do in order to reduce on their energy consumption. The major cause of this difference is the technology employed. Most Canadian foundries employ electric furnaces which are much more efficient as compared to those of their Ugandan counterparts. Other causes of high energy consumption in small scale foundries include insufficient insulation and poor maintenance, unsorted furnace materials inputs, lack of energy management skills, poor communication systems, and poor working conditions. Therefore it can be concluded that there is potential for reducing the energy consumption and increasing the productivity. Melting and pouring processes have been identified as key factors influencing energy consumption and hence the need to devise ways in which they can be streamlined. Several measures can be employed to reduce on energy use including installation of energy metering, monitoring and control systems, monitoring the quality and size of scrap charged into the furnaces, investment in energy efficient technology, fitting furnaces with sufficient insulation and proper maintenance, implementation of an effective communication system, seeking external help on technical issues and motivation of workers.

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