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ENERGY EFFICIENCY FOR SUSTAINABLE DEVELOPMENT OF SMALL INDUSTRY CLUSTERS: WHAT FACTORS INFLUENCE IT?

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ABSTRACT

Small Scale Industries (SSIs) are a crucial component of the Indian economy and the majority of them exist in clusters. Survival and growth of such clusters in the current globalized era hinges on three vital dimensions of sustainability viz. Economic, Environmental, and Social. In energy intensive SSIs, the first two dimensions depend on effective utilization of energy, a key input in their operations. The improved Energy-Efficiency (EE) helps not only in enhancing competitiveness through cost reduction, but also in minimizing environmental degradation. But, a good understanding of factors influencing EE is essential for its improvement. This paper attempts to probe these factors in an energy intensive Brick and Tile cluster in India. Based on the primary data from 44 SSIs, the importance of energy input is established using a Cobb-Douglas production function. The energy consumption pattern and associated environmental pollution are also studied. The variables influencing EE are classified *a priori* under four categories viz. Technical Factor (TF), Economic Factor (EF), Human Resource Factor (HRF) and Organizational and Behaviour Factor (OBF). While the TF comprises variables like age of plant and machinery, quality of energy used, and process specific variables, the EF includes plant capacity utilization, resource use efficiency, and production volume. Similarly, the HRF involves labour skill level, owner/supervisor education, and business experience of the owner, with OBF encompassing variables such as work-practices, layout and housekeeping, importance attached to energy, and the external interaction level. Regression analysis is adopted while assessing the significance of these factors in explaining the variation in EE. The production function revealed energy as the most important contributor to the value of output amongst all inputs. Though all the hypothesized factors are found significant, EF and OBF obtained the top two ranks. These results have useful policy implications for ensuring Sustainable growth of the SSI sector.

Key words: *Energy-Efficiency, Sustainable Development, SSI Clusters, Brick and Tile, Factors.*
JEL Classification: Q 49

ENERGY EFFICIENCY FOR SUSTAINABLE DEVELOPMENT OF SMALL INDUSTRY CLUSTERS: WHAT FACTORS INFLUENCE IT?

1. INTRODUCTION

Energy, Environment and Sustainable Development are closely interconnected subjects receiving growing attention in research and policy-making circles of the contemporary world. Energy, the capacity to do work, is the "life blood of modern economy" as every human being uses it in one form or the other each day, and energy use lies at the core of modern industrial society. Environment comprises the bio-sphere, the thin skin on the earth's surface on which life exists, the atmosphere, the geo-sphere and all flora and fauna. Sustainable Development (SD) is "a development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (UNIDO, 1998). The concept of SD involves three important dimensions viz., environmental, economic and social. In other words, a development, which is environmentally, economically and socially sustainable, becomes a SD.

There is interaction among energy, environment and SD in an economy. As most of the environmental problems are associated with energy use and economic development without energy use is difficult, there is an "energy trilemma" involving energy consumption, economic development and environmental impact (Khan, 1992). It is very difficult to come out of this vicious circle especially for developing countries with their expanding economic activities causing amplified energy consumption. Demand for energy in a growing economy stems from diverse sectors such as agriculture, industry, commerce, transport, and residential. Of these major sectors, the industrial sector is the largest energy consumer in most developing countries (Ross, 1997). At the global level, the industrial sector is the largest energy-consumer accounting for about 32% of total energy use (IEA, 2004).

Industry has emerged as the major energy-consuming sector in India as well, with a share of about 42% of the total energy consumption (Reddy and Balachandra, 2003). Even though India's industrial sector comprises both small and large-scale enterprises, the former accounts for a lion's share of total industrial units. As per the prevailing definition in India, an industrial undertaking is called SSI unit, if original investment in fixed assets i.e. plant and machinery is up to Rs.10 million (in case of hosiery and hand-tool categories upto Rs.50 million) (DCSSI, 2002). The Small Scale Industry (SSI) sector is of strategic importance in the Indian economy in view of its contribution to employment generation, production, GDP and exports. In 2004-05, the SSI sector comprised 11.85 million units, employed more than 28 million persons and generated Rs.3,990 billion worth of production (MoF, 2005). The export by this sector stood at Rs.860 billion during 2002-03. The SSI sector has a diversified and prominent presence in the Indian economy by producing over 7500 products and accounts for about 7% of GDP, 40% of industrial production and 34% of national exports (MoSSI, 2004).

SSI growth in India is characterized, among others, by its concentration in different parts of the country in the form of clusters (Hussain, 1997; UNIDO, 2001). In fact, over 400 modern small industry clusters and 2000 rural and artisan clusters exist in the country. These clusters contribute about 60% of manufactured national exports and account for a significantly high share in employment generation (SIDO, 2004). SSI sector, being a vital component of Indian economy is also a major consumer of energy input. Even if the energy use by an individual unit is trivial, the total consumption by the SSI clusters and the sector as a whole is likely to be of sizable quantum in view of the large number of SSI units and clusters operating in the country. However, SSIs are found wanting in energy utilization efficiency and environmental aspects like pollution control (LUS, 1997). Highly energy-intensive SSIs belonging to steel, paper and pulp, textile, cement, sugar etc., cause both global and local pollution due to their inefficient energy use. Studies have shown that SSI firms not only produce more waste per unit of output, but also, at an aggregate level, account for at least equal if not more pollution than their large-scale counterparts (UNEP, 1998; SIDBI, 2002; Visvanathan and Kumar, 2002; Kathuria and Gundimeda, 2002).

In the current liberalized Indian economy, the SSIs are under unprecedented pressure to improve their competitiveness apart from reducing environmental pollution for their survival and growth. Though energy use and associated pollution from an individual SSI firm is trivial, it assumes significant proportion at the cluster level, especially in a growing cluster, meriting serious attention. Moreover, energy efficiency improvement in such clusters helps not only in enhancing their competitiveness through cost reduction but also in reducing energy related environmental pollution, thus contributing towards their SD. In this context, this paper analyzes energy consumption and its associated environmental pollution in an energy intensive brick and tile SSI cluster in South India.

2. REVIEW OF LITERATURE

The available literature indicates that energy and environment related aspects of Indian SSIs have not attracted researchers and policy makers in the past to the desired extent. Probably, the maiden study related to energy aspects of SSIs in India was conducted in the “grain mill sector” of Karnataka State. Analyzing the energy utilization, it estimated a potential energy saving of 23-38% by better capacity utilization (Ramachandra and Subramanian, 1993). Studies conducted by Development Commissioner of Small Scale Industries (DCSSI) on ceramic tableware units and glass production firms in different parts of the country revealed energy saving potential of up to 40% and 30% respectively (DCSSI, 1997a and1997b). The Energy and Resources Institute (TERI) study at Noida identified plastic and rubber, fabrication and machining, and textile as three of the most energy-intensive sub-sectors. Despite the potential scope for energy saving, it was felt that SSIs may not consider energy saving options purely on economic benefits but it must be promoted along with other concerned issues (TERI, 1998). In its ‘Action Research’ programme on foundry clusters at Agra and Howrah, TERI improved the cupola design for further energy saving of up to 40% with reduced pollution levels (TERI, 1999a). Though afore mentioned studies are primarily concerned with Energy Efficiency (EE) improvement, their outcome has direct implications on environmental performance and sustainability as energy linked environmental pollution is predominant in these industries.

A recent study of environmental pollution by SSI clusters in Karnataka has identified labour skill levels, owner qualifications, and technology levels as important factors in explaining the energy consumption and environmental impact of SSIs (Subrahmanya and Balachandra, 2002). But, noting that most of the initiatives to improve EE and environmental performance in Indian SSIs have adopted a technocratic approach and achieved little, Dasgupta (1999) argues that these initiatives suffer from narrow perspectives and inappropriate methodology. Combustion related pollution is closely related to several factors such as inefficient resource use, absence of waste management, poor work practices and housekeeping. Such factors must be addressed first to prepare the ground for technological change and any energy-led initiative must necessarily afford them due consideration（Dasgupta, 1999）.

Thus, it is essential that initiatives to improve EE and environmental performance in SSIs must view the problem with a holistic perspective for comprehensively addressing the problem. According to Weber (1997), energy consumption belongs to the realm of technology but energy conservation to the realm of society. Since EE improvement is a part of energy conservation strategy, a whole lot of social factors are relevant, in addition to manufacturing technology, in the EE analysis. Baranzi and Giovannini (1996) link energy consumption to four major factors viz. technological, economic and financial, institutional, and cultural. Another study conducted by Kiel University (UoK, 1998) on Small and Medium-sized Enterprises (SME) of certain European countries stresses organizational and behavioural aspects of SMEs in achieving EE. Further, it underlines the paramount importance of external actors to trigger energy related activity in SMEs and to foster a lasting implementation of efficiency measures, which points at promising domains for policy intervention. Dasgupta (1999), after analyzing some initiatives of EE and environmental improvements in Indian SSIs, is of the opinion that a technocratic top-down approach for EE improvement is not comprehensive. Advocating a bottom-up participatory approach, she emphasizes the need to address other non-technical factors associated with EE such as resource use efficiency, waste management, poor work practices, layout and housekeeping, etc.

Subrahmanya and Balachandra (2002 and 2003) have analyzed energy consumption and environmental pollution of a few SSI clusters in Karnataka from a managerial perspective. They have identified labour skill levels, owner qualifications, and technology levels as the important factors in explaining energy use and environmental pollution. Further, they advocated the promotion of EE in SSIs through a 'cost cutting' or 'profit maximizing' strategy. Recently, Subrahmanya (2006a and

2006b) has analyzed how EE makes a difference to economic performance and how labour efficiency matters for EE and economic performance. These empirical studies give sufficient indication that non-technical factors do have a critical role in EE analysis. It is with this backdrop that we have proposed a hypothetical framework for analyzing various factors influencing EE.

3. OBJECTIVES, SCOPE, SAMPLING AND DATA

The objective of this paper is to establish the importance of energy amongst the inputs and study the prevailing energy consumption pattern in an energy intensive brick and tile SSI cluster. Further, the environmental implications of current energy use patterns are estimated so as to substantiate the environmental benefits associated with EE improvement. The factors affecting EE and hence environmental pollution are analyzed in order to facilitate fine-tuning the policies and help improve the performance of SSIs on the dual fronts of energy and environment. The scope of the study is limited to a brick and tile SSI cluster, which is highly energy intensive. The cluster is located at Malur near Bangalore in the State of Karnataka, South India. The study is based on the primary data pertaining to 44 SSIs in the cluster selected on a “Random Sampling” basis. The required sample size for the study is computed using the equation (Kothari, 2001)

$$n = \{Z^2 . N . \sigma_p{}^2\} / \{(N-1) . e^2 + Z^2 . \sigma_p{}^2\} \qquad (1)$$

where: n = Size of the sample required for a given precision and confidence level; N = Finite population size; Z = Standardized variate at a given confidence level (1.96 for 95% and 2.57 for 99% confidence level); e = Acceptable error or the precision required (About 5% of mean value); and σ_p = Standard deviation of the population (estimated through pilot study). Energy-Efficiency (EE) indicated by Specific Energy Consumption (SEC: Energy used in Million Joules (MJ) per brick/tile produced) is adopted as the criterion variable for estimating the sample size. Table 1 gives the details of sample size calculation.

Table 1: Sample Size Estimation in the Brick and Tile Cluster

Population Size	Specific Energy Consumption (SEC) Estimated Through Pilot Study			Required/ Executed Sample Size
	Mean	e	σ_p	
200	9.82 MJ/Unit	0.49 MJ/Unit	1.81 MJ/Unit	(42; Required) (44; Executed)

Considering the uncertainty of exact population size and the limitations of field survey, a slightly higher sample size (44) than required (42) is executed (i.e. 44 SSI units are selected at random out of 200 Units). The primary data required for the study was gathered through canvassing a structured questionnaire. The questionnaire covered various aspects pertaining to brick and tile enterprises like:

unit profile; material input; production details; energy consumption; output; wastage; technology details; investment and human resource aspects.

4. INDUSTRY AND CLUSTER BACKGROUND

Brick/Tile making is a traditional but important building material industry in India and other developing countries. Though demand for roofing tiles is dwindling due to development of alternative roofing materials, the brick industry is thriving because of large demand owing to rising construction activity, especially in urban areas. It is one of the largest employment-generating industries, providing about 1.5 millions jobs in the country. More than 90% of brick industries are in the small-industry sector in India (AIT, 2002). They are energy-intensive with energy cost accounting for 30-40% of production cost and also deserve attention from the environmental point of view as they cause substantial land and air pollution. It is estimated that in India, more than 0.1 million kilns operate and produce about 140 billion bricks yearly with an annual turnover of more than Rs.140 billion. This constitutes the second largest production in the world after that of China (Maithel and Uma, 2000). As clay bricks are widely used basic building material in the country, brick-making firms are seen in various States of the country including Karnataka.

Malur, located about 50 kms from Bangalore in the State of Karnataka has abundant amounts of suitable clay required for the brick and tile industry. The clay extracted from irrigated tank beds in the area has excellent properties such as good plasticity, low burning temperature and low moisture content with sustaining capability of severe weather conditions. Out of around 200 SSI firms in the cluster, the majority of them produce only bricks. But, there are a considerable number of firms producing tiles only or both bricks and tiles.

Clay is the major raw material in brick/tile manufacture besides sand and water. The clay extracted from locations such as tank beds is brought to the backyard of the SSI firms and for a few months kept for seasoning. The seasoned clay is tempered before being thoroughly mixed with water and sand. The next process is to compress the clay slabs into tiles or mould the clay mixture into rectangular bricks. The green brick/tile thus produced is air-dried for about a week and then they are ready for burning in kilns. Usually the burning duration for brick is about a day and twice of this for tiles. Burnt brick/tile is then unloaded from the kiln and graded for stocking or selling as the case may be.

It may be noted that the burning of brick/tile is the most energy-consuming stage in its entire production cycle and is carried out using brick-kilns. Depending on the heat/smoke flow direction and continuity of operation, kilns are classified into three groups (GATE, 2000) viz.

- Intermittent Up-draught Kilns (IUK) without chimney (e.g. Rural Clamps and Vertical Shaft Brick Kilns (VSBK))

- Intermittent Downdraught Kilns (IDK) with chimney (e.g.: Scotch, Round, Annular, and Zigzag kilns)
- Continuous Horizontal-draught Kilns (CHK) with chimney (e.g. Hoffmann, Bull's Trench, and Tunnel Kilns).

All the kilns in Malur cluster belong to IDK type except a very few SSI firms belonging to CHK variety. The relative EE levels of these kilns are considerably lower than better designs like VSBK. However, the cluster is still dominated by energy-inefficient kilns and technology up-gradation is an urgent need, among others, to improve EE. Out of around 200 SSI enterprises in the cluster (Table 2), the majority of them produce only bricks even though considerable number of firms produced only tiles or both bricks and tiles.

Table 2: Characteristics of Sampled SSI Firms in the Brick and Tile Cluster

Cluster size	About 200 firms
Main products	Table moulded bricks and roofing tiles
Sample	Randomly selected 44 SSI firms
Entrepreneurship	10% Partnership; 90% Proprietorship
Marketing	Direct sales: 70%; Sales through agent: 30%
Age of the units	Less than10 years: 45%; More than 20 years: 30% Between 10 - 20 years: 25%
Employment	Up to 25: 64% firms; 26 to 75: 34% firms; Above 75: 2% firms.
Total production	44.10 Million (brick + tiles) annually
Energy consumption	Annual - Biomass (wood, leaves & twigs): 39,500 Tonnes; Diesel: 15,700 litres; Electricity: 56,000 kWh.
Energy-Efficiency	Specific energy consumption: 8.75MJ/ Product
Technology	Intermittent down draught kiln for brick/tile firing
Energy cost	40 % of total variable cost
Quality system	None of the unit is ISO 9000 certified

Proprietorship is the dominant ownership type and the owners are moderately educated ranging from primary schooling to graduation with very few owners having professional qualifications. Burning of green brick/tile alone accounts for 99% of total energy consumed and is met by the biomass. The average specific energy consumption (SEC) in the cluster is found to be 8.75 MJ/Unit of product, which is much higher than the best reported SEC of 2.25 MJ/Unit with efficient kiln designs (TERI, 1999b). This clearly implies the scope for energy conservation and hence pollution reduction through EE improvement in the cluster.

5. HOW IMPORTANT IS ENERGY? THE PRODUCTION FUNCTION ANALYSIS

The "production function" is essentially an engineering concept that relates the various input factors in production to the output from it. Traditionally, standard production models considered capital, land and labour as the fundamental factors of production. However, most of the applied economic theories recognize energy as an independent factor of production and advocates a KLME (Capital, Labour, Material and Energy) model for economic analyses.

The production function analysis in this brick and tile cluster is aimed at answering the question "How important is energy amongst all the inputs in explaining variation in the value of output?" This is indicated by the beta coefficients in the multiple regression representing the production function in the cluster. As energy constitutes about 42% of Total Variable Cost (TVC) in this industry, it fully deserves to be considered an explanatory factor in production functions. Though a variety of functional forms are used in economics to describe production, the Cobb-Douglas or multiplicative form is most generally used, because, it accurately characterizes many production processes (Petersen and Lewis, 2002). Besides, earlier empirical studies in clay industries have also adopted Cobb-Douglas form (Moroney, 1967) to good effect. Hence, we have decided to use Cobb-Douglas production function in the following form to establish the importance of energy.

$$Y=A\,K^{\alpha}\,L^{\beta}\,E^{\gamma}\,M^{\delta} \quad (2)$$

where: Y = Value of output of a SSI firm in the cluster; K = Value of capital (Current value of Plant and Machinery); L = Labour cost; E = Energy cost; M = Raw material and other miscellaneous costs (excluding energy); A, α, β, γ, and δ = Parameters that when estimated describe the quantitative relationship between the inputs and the output.

Taking logarithms on both sides of equation (2), Cobb-Douglas production function reduces to a log-linear relationship between output of production and factors of production. Therefore, it essentially takes the form of a multiple regression equation. If all inputs and the output are expressed in monetary terms, the coefficients of independent variables may be used for interpreting the importance of the independent variables in explaining the variation in the dependent variable. Hence, from an economic point of view the coefficient of energy input indicates the importance of energy in explaining the variation in value of production in the presence of other inputs. The output expressed in terms of its monetary value assists nullifying minor variation, if any, in the quality of goods produced by different SSIs in the cluster. We have used the current value of plant and machinery to represent capital. The current value of plant and machinery in SSIs is obtained from the respective entrepreneurs and it was subsequently confirmed after discussions with experts in the field.

Economists prefer to express labour in terms of total man-hours or man-days with adjustments for non-production workers. However, labour input in the form of man-hours or man-days is extremely difficult to get from SSI firms and is also less reliable than labour cost data. This is for the reason that most SSIs do not have any formal payroll and owners are more concerned about labour costs than man-hours. In addition, experts observe that SSIs operate under highly competitive conditions, particularly those which are in the same industry in a cluster. In theory, competitive environment leads to equality between marginal productivity and wage rate. Thus, we have used labour cost in place of man-hours or man-days in the analysis. This also suited the statistical requirement of expressing all inputs in the same measuring units to make better comparison of coefficients of independent variables in regression. The energy cost and material cost are separated out for the obvious reason of finding their exclusive role in explaining the variation in value of output.

Table 3 gives the result of multiple regression analysis. Stepwise regression method with Statistical Package for Social Sciences (SPSS) is employed for this purpose. The relevant assumptions of regression analysis are validated by performing appropriate statistical tests. From the table, it can be noted that the regression model in the cluster is appropriate as it has significant 'F' value. The independent variables included appear to explain a large amount of variation in the value of output as reflected in the high values of adjusted R^2. But more importantly, energy is found to contribute most significantly towards explaining the variation in output in the cluster. Interestingly, the proportion of variation in the value of output explained by energy input (beta coefficient) in the cluster appears to be much higher than the share of energy in the value of output (which is about 28%). Further, capital represented by current values of plant and machinery is found statistically insignificant in explaining the variation of the value of output. Perhaps this can be attributed to the fact that SSI firms employ relatively less capital compared to their large-scale counterparts and the labour costs override the capital in this cluster. Additionally, it is the annualized capital cost or 'depreciation' which is more relevant from the standpoint of annual value of production and quantitatively its value is likely to be less significant. Although material consumed (clay, sand and water) has a direct relationship with physical output, it did not turn out to be significant in explaining the variation in value of output possibly due to relatively low economic value associated with it. Thus, energy and labour are the only two significant inputs, in that order, found useful for explaining the variations in output value. Since energy is the most important input in this cluster, it is meaningful to probe its consumption pattern and the factors influencing its efficient utilization.

Table 3: Production Function (Regression) Analysis

Ln {Energy}	0.641 (6.857) [0.000]
Ln {Labour}	0.388 (4.197) [0.000]
Ln {Material}	-
Ln {Capital}	-
Ln {A} - Const	1.022 (2.574) [0.014]
Adjusted R^2	0.962
F	539.821 [0.000]
N	44
Values within the parentheses and square brackets indicate the ‘t’ values and the significance levels respectively	

6. PREVAILING ENERGY CONSUMPTION PATTERN

The brick and tile cluster of Malur predominantly uses biomass for the production of brick and/or tiles as shown in Table 4. The other energy carriers like diesel and electricity account for a meager share in total energy use. Though electricity is mainly used for lighting purposes and running water pumping motors, tile producing firms need it for operating their pug mills, mixers, etc. Diesel consumption is only by enterprises which have captive Diesel Generator (DG) sets for use when power from the Electricity Board is unavailable. Based on our field survey data the total energy use in the sample units is computed and is then projected to the entire cluster considering average production volume.

Table 4: Energy Consumption Pattern in the Brick and Tile Cluster

Sl. No	Type of Energy Carrier	Total Annual Consumption in Sampled SSIs (TJ)	Projected Annual Consumption in the Cluster (TJ)	% Share in Total Energy Consumption
1	Biomass: Firewood	175	796	
	Eucalyptus leaves	280	1273	99.46
2	Electricity	2	9	0.44
3	Diesel	0.45	2	0.1
	Total	457.45	2080	100

The biomass used in the cluster includes firewood and eucalyptus leaves and twigs. The former is used mostly by tile manufacturers while the latter by brick producers. As the baking time is higher for tiles than bricks, tile producers use firewood in view of its longer flame retaining capacity. The eucalyptus leaves and twigs used in brick kilns need to be frequently fed during firing due to its faster burning rate. The energy consumption pattern in the brick and tile cluster clearly suggests that efficiency improvement must focus on the brick/tile kilns to bring about any appreciable change in energy use. The presently employed Intermittent Downdraught Kiln (IDK) design in this cluster is energy-inefficient, thus consuming large quantities of biomass resulting in considerable environmental pollution.

7. ENVIRONMENTAL IMPACT ASSOCIATED WITH ENERGY USE

The energy consumption in this energy-intensive industrial cluster is also associated with negative environmental implications. The major environmental contamination is in the form of "air pollution". The land pollution caused in this industrial cluster is not attributable to energy use *per se*. However, air pollution caused is mostly associated with their energy use. Accordingly, we estimated air pollution in a detailed and systematic way while other kinds of pollution which are not directly linked to energy use are broadly obtained from survey data.

Air pollution due to energy use is expressed in terms of generation of Green House Gases (GHGs) and other pollutants. They include Carbon Dioxide (CO_2), Methane (CH_4), Sulphur Dioxide (SO_2), Nitrous Oxide (N_2O), Carbon Monoxide (CO), Nitrogen Oxides (NO_X), Non Methane Volatile Organic Compounds (NMVOC) and Total Suspended Particulate matters (TSP). These emissions due to energy use are estimated using Intergovernmental Panel on Climate Change (IPCC) guidelines. Basically, these emissions depend on the type of energy carrier and the fuel combustion technology adopted. Emission factors are compiled referring IPCC (1996) and International Institute for Applied Systems Analysis (IIASA, 2001) estimates. Table 5 gives the emission factors for the cluster, where firewood is separated from eucalyptus leaves as they have different heating values.

Table 5: Emission Factors in Brick and Tile Clusters

Sl. No	Pollutant	Emission Factor for Biomass in kg/tonne		Emission Factor for Diesel in kg/tonne
		Firewood	Eucalyptus leaves/twigs	
1	CO_2	1562.25	1062.33	3177.22
2	CH_4	0.45	0.31	0.13
3	SO_2	9.54	6.48	6
4	N_2O	0.06	0.04	0.03
5	CO	15	10.2	0.65
6	NO_X	1.5	1.02	8.67
7	NMVOC	0.75	0.51	0.22
8	TSP	7.8	5.3	0.09

Source: IPCC, 1996; IIASA, 2001

The firewood used has a better calorific value than the partially dried eucalyptus leaves, though the latter has better energy content in the fully dried condition. We have noticed that the eucalyptus leaves and twigs supplied to the SSI firms in this cluster are only dried to an extent of about 60%, while the firewood used was almost fully dried, thus calling for separation of the two emission factors.

The World Business Council for Sustainable Development and World Resources Institute (WBCSD/WRI, 2004) have recommended a corporate accounting and reporting standard for GHG emissions. As per this, three "scopes" are defined for GHG accounting and reporting purposes. Scope-1 (Direct GHG emissions) and Scope- 2 (Electricity - indirect GHG emissions) are carefully defined in this standard to ensure that two or more companies will not account for emissions in the same scope. Companies shall separately account for and report on scopes 1 and 2 at a minimum. Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Companies may further subdivide emissions data within scopes where this aids transparency or facilitates comparability over time. Together, the three scopes provide a comprehensive accounting framework for managing and reducing direct and indirect emissions. Even without any policy drivers, accounting for GHG emissions along the value-chain may reveal potential for greater efficiency and lower costs (WBCSD/WRI, 2004).

Initially, we computed typical intensities of air pollution levels due to energy use in manufacturing each product. The average values of pollution levels computed from the sample SSI firms is taken as the emission intensity and specified for 1000 bricks and tiles (Table 6). Then, estimated total production volume in the cluster facilitated projecting pollution to the entire cluster including not only the sampled SSI firms but also others (Table 7). The annual production volume of the cluster is an important input in arriving at cluster level emissions. We have estimated the annual production volumes of the cluster based on our field study and secondary source and considered the minimum of the two values to make the estimated GHGs emissions more dependable.

Table 6: Air Pollution Intensity in Brick and Tile Production

Boundary	**Emissions in kg Per 1000 Bricks/Tiles (Based on Data obtained from 44 Brick & Tile Firms)**							
Scope 1 Emissions due to Fuel combustion	CO_2	CH_4	SO_2	N_2O	CO	NO_X	NMVOC	TSP
	1075	0.31	6.57	0.04	10.34	1.04	0.52	5.37
Scope 2	CO_2 Emissions due to Purchased Electricity = 13.50 kg/1000 Bricks or Tiles				**Total CO_2 Emission** (Scope 1 & 2) 1088.5 kg/1000 Bricks/Tiles			

With 200 SSI brick and tile firms in Malur, an average annual production volume of 1.0 million brick/tiles per SSI enterprise is considered, based on our field survey. The data pertaining to national brick production, mostly by SSIs, puts the average at about 1.4 million bricks per enterprise (Maithel and Uma, 2000). The estimated annual GHG emissions (Table 7) indicate the minimum air pollution level in the cluster, as we have considered lower bound production volumes.

Table 7: Annual GHGs and Other Emissions from the Brick and Tile Cluster

Scope	Annual Emissions in kilo tonnes							
Scope 1	CO_2	CH_4	SO_2	N_2O	CO	NO_X	NMVOC	TSP
Emissions due to Fuel combustion	215	0.06	1.31	0.008	2.07	0.21	0.1	1.07
Scope 2 CO_2 Emissions due to Purchased Electricity= 2.70 kilo tonnes				**Total CO_2 Emission** (Scope 1 & 2) 217.70 kilo tonnes				

Yet, looking at the projected annual air pollution figures, one can say that the SSI enterprises collectively cause substantial pollution at the cluster level, if not at the individual level. Apart from this estimated air pollution, the brick and tile cluster is a source of considerable land pollution due to scrapping of the wastes generated in nearby land areas. As our study is concerned with energy consumption and its associated environmental pollution, a detailed study of other kinds of pollution is beyond the scope of this research. However, our own field study and data from secondary sources enabled us to compile Table 8, which shows the extent of these pollutions in the cluster.

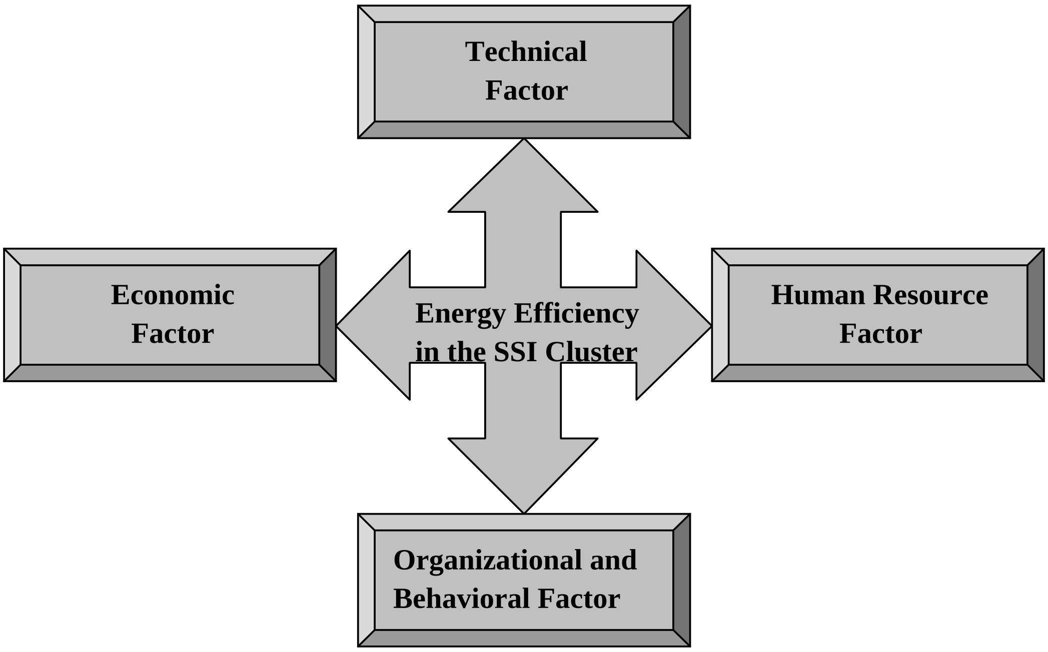
Table 8: Other Kinds of Environmental Pollution in the Brick and Tile Cluster

Product Cluster (Location)	Nature and Extent of Other kinds of Pollution (Annually)
Brick & Tile Cluster (Malur in the Karnataka State, South India)	Predominantly Land pollution due to dumping of waste products, ash and charcoal * Estimated waste bricks & tiles of 15.5 million (@85/1000) constitute 46.50 kilo tonnes of solid waste. * Estimated ash generated = 2.0 kilo tones. * Estimated charcoal generated = 0.5 kilo tones.

8. FACTORS INFLUENCING ENERGY EFFICIENCY

One of the noticeable features of Energy Efficiency (EE) as indicated by Specific Energy Consumption (SEC - which is a measure of EE) in Indian SSI clusters is its wide variation among the SSI firms within a given industry (Ramachandra and Subramanian, 1993; TERI, 1998 and 1999a; Subrahmanya and Balachandra, 2002 and 2003). This is true even in the present case, though energy use technology adopted for brick/tile burning remained similar to a large extent in the cluster. Thus, the variation in EE in the cluster cannot be attributed to production technology adopted *per se*. This prompted us to interpret the variation in EE involving non-technology factors. In this context, we developed a hypothetical framework of factors influencing EE as shown in Figure 1.

Figure 1: Factors Influencing Energy Efficiency



Technical Factor
* Age of plant and machinery
* Quality of energy used
* Process specific variables

Economic Factor
* Plant capacity utilization
* Resource use efficiency
* Production volume

Organizational and Behavioral Factor
* Work practices, Layout and Housekeeping
* Importance attached to Energy
* External interaction level

Human Resource Factor
* Owner/Supervisor education
* Experience of the owner
* Labour skill level

This is formulated on the basis of the literature on hand followed by discussion with the experts. The interactions with some progressive entrepreneurs in the cluster and also with officials of SSI development institutions have assisted in this endeavour. We arrived at four factors *a priori* which are likely to influence EE in the clusters, viz. Technical Factor (TF), Economic Factor (EF), Human Resource Factor (HRF), and Organizational and Behavoiural factor (OBF). It is hypothesized that the variation in EE may be explained by a combination of these factors. The variables coming under the factors are also shown in Figure 1. As each variable under a given factor is likely to capture a particular dimension, the cumulative values of all the included variables are worked-out to represent a factor. However, a variable is included under the respective factor, only if it meets the basic requirement of showing some significant association with EE.

Subsequently, assuming a linear relationship between EE in a SSI unit and the hypothesised factors, a multiple regression model is developed in the following form:

$$\eta = f\ (TF, EF, HRF, OBF) \tag{3}$$

$$\eta = b_0 + b_1\ (TF) + b_2\ (EF) + b_3\ (HRF) + b_4\ (OBF) + u \tag{4}$$

where: η = Energy-Efficiency (EE) (As indicated by SEC – Specific Energy Consumption, i.e. Amount of energy consumed to produce a unit of product); TF = Technical Factor score; EF = Economic Factor score; HRF = Human Resource Factor score; OBF = Organizational and Behavioural Factor score; u = Random component; b_0 = Constant (intercept); b_1, b_2, b_3 and b_4 = Coefficients of the above factors.

In multiple regression analyses, it is assumed that the dependent variable is a quantitative measure with normal distribution and equal variance for all combinations of independent variables. It is not assumed that the independent variables are normally distributed or even that they are quantitative measurements (Overall and Klett, 1972). It is perfectly acceptable to use qualitative or categorical variables as independent variates, provided they are logically or empirically derived ordinal scale measurements (Overall and Klett, 1972). Considering this, application of multiple regression analysis in the present case appears to be justified from a statistics standpoint. If the overall model explains a considerable amount of variation in the EE (SEC), we consider that our hypothesis of these four factors influencing SEC is acceptable. Then, we assess the ability of the individual factors in explaining variation in EE through their standardized beta coefficients in the multiple regression models.

We identified around 15 variables and classified them under four categories. Further, three levels are created for each variable, considering their 'central tendency' and 'dispersion' within the cluster. In other words, variable values are derived on a 1-3 scale. Level-3 (with a score of 3) indicates the most favourable situation for EE and is represented by group 3. Similarly, level-1 is the least preferred state (with a score of 1) and comes under group 1. The level-2 is the intermediate level indicated by group 2. Then, each of the sampled SSI firms is classified appropriately in any of these 3 groups under every variable. By expressing all the variables in a common scale of 1-3, an equal weightage is assumed for each of the variables within a factor. However, a variable gets included in the respective factor group, only if it shows significant correlation with EE, otherwise it is omitted. As a result, there is no uniformity among the four factors in terms of the number of variables used to arrive at their factor scores. Table 9 gives the variable grouping used in the cluster.

Following the grouping criteria in the cluster, values are assigned on a 1-3 scale under each variable, for all the sampled SSI firms. Then, correlation analysis is performed between each of the variables and EE (SEC) to ascertain their usefulness in explaining the variation in SEC. Eventually, only those variables which have significant correlation with EE (SEC) are included in a particular factor group. Then, the cumulative variable scores are obtained to arrive at the respective factor scores to be used in the multiple regression models. Accordingly, one variable in HRF, two variables each in TF and EF, and all the three variables in OBF are found useful for explaining variation in EE in this cluster.

Table 9: Variable Grouping for Obtaining Factor Scores in the Brick and Tile Cluster

Factor	Variable	Group-3	Group-2	Group-1
Technical Factor (TF)	Age of plant & machinery	Upto 5 years	Between 6 -11 years	Above 11 years
	Quality of energy (Proxy: Cost of energy per kg of biomass)	Above Rs.0.42	Between Rs.0.36 - 0.42	Below Rs.0.36
	Process specific variable (Based on duration of baking)	Firms producing only bricks	Firms producing bricks & tiles	Firms producing only tiles
Economic Factor (EF)	Plant capacity utilization	Above 60%	Between 35 - 60 %	Below 35%
	Resource use efficiency (Proxy: Rejection rate)	Below 6%	Between 6 - 10 %	Above 10%
	Annual production volume (Bricks/Tiles)	Above 1.0 million	Between 0.5 - 1.0 million	Below 0.5 million
Human Resource Factor(HRF)	Owner/Supervisor qualifications	Professional/ Master degree	College education	School education
	Business experience of the owner	Previous work experience	Family occupation	No previous experience
	Labour skill level (Skilled/Unskilled)	Above 0.6	Between 0.35 - 0.60	Below 0.35
Organizational & Behavioural Factor (OBF)	Work practices, Layout & Housekeeping	Very Good	Good	Average
	Interaction level of the organization	High	Medium	Low
	Importance attached to energy aspects	Very important	Important	Moderately important

In HRF, labour skill alone is found useful in explaining the variations in EE (SEC). The other prospective variables ‘owner/supervisor education’ and ‘business experience of the owner’ did not exhibit any significant association with EE. This is quite reasonable considering the relatively low level of technology, capital and knowledge base required for a brick/tile industry. The TF involved only ‘age of plant and machinery’ and ‘baking duration’, as ‘energy cost’ taken as a proxy of ‘quality of energy’ proved insignificant in explaining variations in EE. This is attributable to the fact that not much of a difference in the biomass quality existed within the cluster warranting its inclusion. In the EF category ‘plant capacity utilization’ and ‘resource use efficiency’ merited inclusion, while ‘production volume’ turned out to be an insignificant variable. This is perhaps due to the fact that SSI firms in the cluster have small production volumes (average of about 1.00 million brick/tile per annum) which is insufficient to bring about any noticeable "economies of scale", which may require still larger production volumes. Since all the variables under OBF are found to contribute in explaining the variation of EE, all of them are included. Thus, HRF scores varied from 1 to 3, TF and EF scores from 2 to 6, and OBF scores from 3 to 9 in the regression analysis. The multiple regression result for the cluster is presented in Table 10.

Table 10: Multiple Regression Results in the Brick and Tile Cluster

TF	EF	HRF	OBF	Constant	Adj. R2	F	N
-0.468 (-3.967) [- 0.273]	-0.615 (-4.349) [- 0.345]	-0.699 (-2.897) [- 0.217]	-0.464 (-4.159) [- 0.317]	19.593 -32.86	0.871	73.426	44
Entries within the parentheses and square brackets indicate the 't' value and 'standardized beta coefficient' respectively. All 't' and 'F' value are significant at 0 level							

All the coefficients of independent variables have negative signs indicating that with the increase in factor scores the SEC is going to reduce, in other words, the EE is going to increase (as SEC is an inverse measure of EE). Additionally, adjusted R^2 is high (about 87%) along with statistically significant 'F' value. This suggests that the considered set of four factors does possess a linear relationship with EE (SEC) in the brick and tile cluster. The relevant assumptions of regression analysis are validated by performing the appropriate statistical tests.

The next pertinent issue is to probe the relative impact of each factor on EE. For this purpose, we considered the 'standardized beta coefficient' obtained in the regression analysis. Standardized beta coefficients are amenable for comparison, though they do not in any absolute sense reflect the importance of the various independent variables. Since all of the variables used in building up the factor scores are expressed on a common 1-3 scale, comparison of beta coefficients are also not likely to be influenced by differences in measurement units. On this basis, it appears that EF is the most important factor influencing EE (SEC) followed by OBF, TF and HRF respectively. The significance of EF, TF and HRF factors are quite understandable and well-known in the context of small enterprises. The importance of HRF has been recently analyzed in greater detail with reference to the same cluster by Bala Subrahmanya (2006b). But, it is worth noting that OBF is found quite influential in achieving better EE in the cluster. As this industry does not demand a high level of technical knowledge, with given technology, the variables under OBF such as importance attached to EE, attitude towards energy, housekeeping, and organizational interaction are the variables affecting the efficiency levels.

9. SUMMARY

Succinctly, the current research studied the energy consumption pattern in a brick and tile SSI cluster and assessed the environmental pollution associated with the energy use. The importance of energy as an input was established through production function analysis. A hypothetical framework of factors influencing EE levels in a SSI cluster was proposed and subsequently validated by the empirical data obtained through field-study. The findings of this study imply that while the need for technology upgradation to enhance EE and hence sustainability of SSI clusters is undisputable, this alone cannot succeed in meeting the goal either. But, human resource, economic, organizational and behaviour issues of SSIs also need to be properly addressed for fruitful results.

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