ASSESSMENT OF EMBEDDED ENERGY OF FLOOR TILES MANUFACTURED IN SRI LANKA

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DECLARATION

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ABSTRACT

Floor tile manufacturing is one of the highest energy intensive industries in the world. Basically, the thermal energy is the most prominent energy component in the value. Embedded energy is a fairly a new concept which will be used to estimate how much energy had been used to produce one unit of material.

The embedded energy concept will be used to check the energy efficiency of the manufacturing.

The embedded energy comprises four components as level 01,02 03 and 04. Level 01 energy is the direct energy used in the manufacturing process. Level 02 is the labour component and the ancillary services. The transport and mining energy is considered as level 03 energy. The level 04 is the energy being used for manufacturing of the capital equipment or the machineries which are being used in the manufacturing process. Accessing of level 04 energy is very difficult and that energy is not considered in this research.

The fossil fuel is a limited resource to the world and in the countries like Sri Lanka, all most all the fuels are being imported. If it is strived to reduce the embedded energy or at least trying to reach the lowest values achieved by other countries will serve the world by saving energy.

The embedded energy of a typical factory in Sri Lanka is 12.58 MJ/Kg for Level 01, 0.14 MJ/Kg for the level 02 and 0.84 MJ/Kg for Level 03. Which gives the embedded energy as 13.56 MJ/Kg. According to the literature revived the internationally accepted embedded energy value is 11MJ/Kg for the floor tiles as per Inventory of Carbon and Energy.

To achieve the imbedded energy value 11 MJ/Kg is not an unrealistic task. For this the manufactures of the country have to rearrange their manufacturing processes in such a way that the wastages are minimized and the thermal energy is efficiently used.

By rearranging the production process to have the energy efficient manner will serve two purposes.

It will help to produce low embedded energy tile and lesser embedded energy means low fuel consumption in the manufacturing process. It will help to reduce the global energy demand and the unit cost of the product will be lower making it high profitable

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	**Description**
BTU	British Thermal Unit
CEB	Ceylon Electricity Board
CPC	Ceylon Petroleum Corporation
GWh	Giga watt hour
Kcal	kilo calorie
kWh	kilo watt hour
LKR	Sri Lankan Rupee
LNG	Liquefied Natural Gas
LOLP	Loss of Load Probability
LPG	Liquefied Petroleum Gas
LTGEP	Long Term Generation Expansion Plan
MJ	Mega joule
MW	Mega watt
NCRE	Non-Conventional Renewable Energy
NCV	Net Calorific Value
NG	Natural Gas
O&M	Operation and Maintenance
MT	Metric tonne (1,000 kg)
USD	United States Dollar
RPL	Royal Porcelain Factory
RCL	Royal Ceramics Lanka Factory
LTL	Lanka Tiles Limited Factory

1 INTRODUCTION

1.1 Background

Sustainable development is the key concern these days. In the manufacturing process of any item there has to be a balance between the profit and environment impact.

Countries with different levels of technological development can achieve the sustainability with their technology advancement.

Tile industry uses massive amount of energy to the process and also the waste is very high. Wastage occurs at different stages of the production process.

World floor tile demand is averagely 2540 Million Square meters. China is producing 23% of the demand and Italy 14%, Spain 14% respectively.

Use of more energy means use of more and more fossil fuels, which emits more and more CO2. Those gasses act as greenhouse gases and many environmental problems are created.

In Sri Lankan electricity generation, a larger share is from coal [1].

Floor tile is an energy intensive product. Normally 40-50 % of the production cost comprises the energy cost. Electricity, Kerosene and LPG is being used as the sources of energy for manufacturing of floor tiles.

Electricity generation in Sri Lanka is largely based on thermal power.

Therefore, whatever the form of energy used for manufacturing of floor tiles, it causes addition of CO2 to the environment.

Long term energy sector planning is essential for a country to acquire sustainable development in all its social, economic and environmental dimensions. Further it will ensure the energy supply security of the country. Energy supply side needs to deal with technical, economic and environmental assessments of all energy supply options such as natural resources, energy imports, energy exports, etc. Also, the energy supply side should follow policy directives of the government and should take all other related constraints in to account. Similarly, the demand side too has to deal with the assessment of future energy needs of various consumption sectors, policy directives, etc.

Embedded energy of the tile indicates the total energy being used to produce a tile. Earlier everybody was considering the operational energy of the factory or a building. Embedded energy includes the direct energy used in the factory as well all other energies involved to produce the product.

If the embedded energy of all the building material are known and the quantity of the material to a building is known we can calculate the amount of energy used to build the particular building in Sri Lanka.

1.2 Motivation

The outcome of this project is to find the embedded energy of floor tiles manufactured in the country in MJ/Sqm. From that we can judge how efficient our manufacturing processes are. The local manufacturers can adopt measures to energy efficient process in order to reach the world standards.

Energy efficient manufacturing process will use less energy and save more energy. There by those manufacturing plants consume less fossil fuel. The adverse impact to environment is minimized.

The cost incurred on energy is reduced due to the low energy consumption. The production cost will be lower. The overall tile price will be reduced.

1.3 Aim

To access imbedded energy of floor tiles manufactured in Sri Lanka and thereby set bench mark values for the local manufactures.

1.4 Objectives of the study

- Access the embedded energy of floor tiles Manufactured in Sri Lanka
- Propose Bench mark value for the local tile industry

1.5 Methodology

For the timely completion of the research, the work flow was arranged in the manner given below.

i. **Literature Survey**

Under the literature survey, literatures in relation to embedded energy were referred. Some of the papers contained embedded energy of the building materials done locally and in other countries. The findings of the literature survey and other related information are discussed in section 2.

ii. **Collection of manufacturing and production data**

Production and energy data were collected from three tile factories in the country. Department wise energy meters had been installed and all the data of two years were collected from the three manufacturing plants.

iii. **Calculation and data analysis**

All the 24 months Energy, LPG usage, Kerosene usage, labour usage and the raw material consumptions were tabulated. Using the above values and the specific energy for the different processes were calculated. The embedded energy is the sum of four types of energy. Department wise energy is calculated in three levels. Namely level 01 level 02, level 03 and level 04. Output of one department is the input to the other department also the energy to the complete product is the sum of the department wise value addition.

iv. **Sensitivity analysis**

The sensitivity analysis is done with changing the different parameters to check the international accepted energy level is achieved

v. **Compare with the internationally accepted values**

The results obtained in this research were validated by comparing them with other published reports in relation to embedded energy.

1.6 Contributions

Even though few researches have been done to find the embedded energy of the raw materials use in the construction, it is very much limited to few basic materials like cement and roofing tiles.

No sufficient studies being carried out to find the energy used in other materials like floor tiles, bricks, ceiling material ..etc.

This research will be an eye opener to do the studies to find the energy values of other building materials as well. Eventually the people and the economy of the country will be benefited through implementation of the results of this study.

Further implementation of the cost reduction plans discussed at the end of this project will help the manufactures to implement measures to reduce their manufacturing cost and to reduce the embedded energy.

1.7 Organization of the report

Rest of this dissertation is organized as follows.

- Section 2 summarizes the literature survey.
- Section 3 explains the theory and the concept of the embedded energy.
- Section 4 Shows how the data collection was done and the collected data in tables
- Section 5 Shows the data analysis
- Sections 6 sensitivity analysis to check different combinations of energy reduction to achieve the international bench mark.
- Sections 7 discusses on the conclusions of the research.

2 LITERATURE REVIEW

A thorough literature review was done at the outset of this research to identify the principle of embedded energy and the theory of calculating the embedded energy. The use of calculating the embedded energy and what is its actual value to the country and for the manufactures were identified. This section summarizes the information gathered through the literature review and the key findings of it.

2.1 Production Process of a ceramic floor tile manufacturing plant

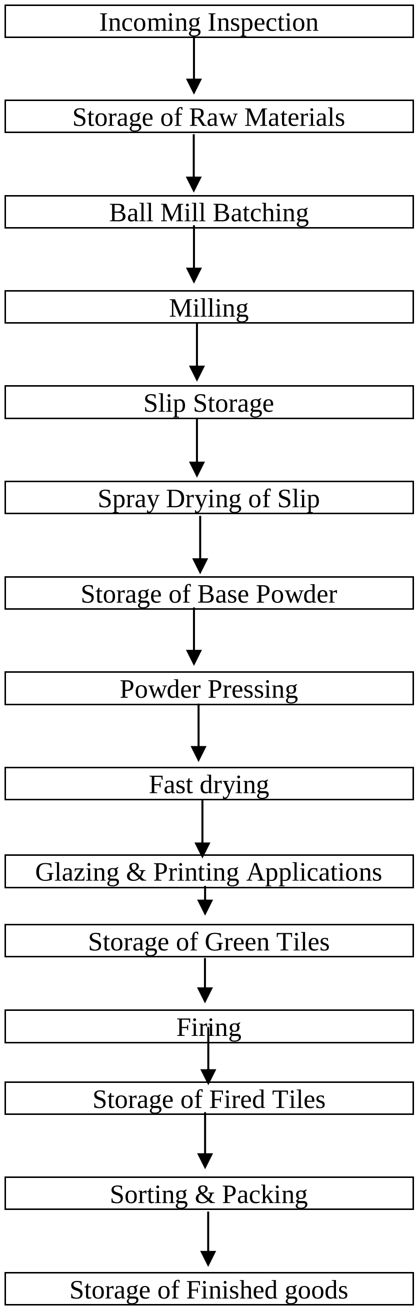

Figure 2-1: Flow chart of the production process

2.2 Body raw materials

Consider a batch sheet (product data), Each ball mill batch contains 23Ton of raw material and its composition is as below.

Feldspar	46%
Dolomite	05%
Ball Clay	31%
Silica Sand	14%
Green Damage reuse	05%

Feldspar

Feldspar is used as fluxing agent to form a glassy phase at low temperature and as a source of alkalis and alumina in glazes. It improves the strength, toughness and durability of the ceramic body and cements the crystalline phase of other ingredients.

Ball clay

Ball clay is used in ceramic bodies because of their plastic nature combined with high firing temperature (Used as a plasticizing binder). Ball clays have very high dry shrinkage combined with high green strength and slow drying.

Silica

Silica use to improve structural integrity, regulate drying and shrinkage and modify thermal expansion. This material acts as a filer in ceramic body.

Dolomite

Dolomite acts as a catalyst. It can facilitate the melting of silica and feldspar. Dolomite improves some special body properties such as open porosity, firing shrinkage, firing strength and water absorption in manufacturing process. There are some disadvantages associate with dolomite too. Such as evolving CO_2 gas; which may cause development of porosity with in ceramic body, which may cause to evolve pin whole defect.

2.3 Storage of Raw Materials

Ceramic raw materials are usually heterogeneous mixtures rather than pure substances. Variations in composition are likely to occur in the materials are received at the plant both within the individual carloads and between successive carloads of the same material. Such variations often course trouble in plants making vitreous porcelain. Therefore, raw materials are stored in bin yards for aging purposes. That is to make the raw material as nearly homogeneous mixture specially for Ball clay.

2.4 Ball Mill Batching

For many ceramic products, including tiles, the body composition is determined by the amount and type of raw materials. The color of the tile body is also determined by the raw materials. Therefore, it is important to mix the right amounts together to achieve the desired properties. It is necessary to consider both physical properties and chemical compositions of the raw materials. Once the appropriate weight of each raw material is determined, the raw materials must be mixed together.

Raw materials loaded into weighing machine batch wise. There are specific quantities for raw materials separately for each batch. The major body raw materials are ball clay, feldspar, dolomite and silica sand. Other than these body raw materials, deflocculates (STPP, $Na_2SIO_{3)}$ and water are added. There was no specific order of raw materials for loading. But to minimize the flocculation of ball clay lumps, it can be added feldspar or silica sand before and after the addition of ball clay.

The large lumps of ball clay should be broken by workers to have appropriate size to penetrate through the net which is above the weighing machine. Then all these raw materials are transported to the ball mill for milling process by using conveyer belts.

All these raw materials with deflocculates and water were added to the mill through the lid.

2.5 Raw material Grinding

Grinding reduces the dimensions of solid raw materials. Sometimes it is necessary to add water to improve the mixing of a multiple-ingredient batch as well as to achieve fine grinding. This process is called **wet milling** and is often performed using a ball mill. Grinding causes for high degree of homogeneity and result more complete, faster chemical reaction during firing.

In ball mill there are two processes taken place such as crushing and grinding. To success this process, it is arranged "lift a bar" at the inner surface of the mill lining. Lift a bar is necessary to maintain this pathway for better grinding of raw materials.

The rate of the grinding process can be basically depending on several factors.

a) **rpm of the ball mill**
b) **Density of the grinding media**
c) **Hardness of raw materials**
d) **Grinding media**
e) **Mill lining**
f) **Audit quality**
g) **Viscosity of the raw materials**
h) **The composition of the raw materials**

The grinding media is the Alubit balls. Alubits can be basically consisting with several diameter sizes such as 50mm, 40mm, 30mm, 25mm and 20mm.Usually for each batch 12.5kg of 50mm and 12.5kg of 30mm Alubit Balls are added. The resulting water filled mixture is called a **slip.** Usually a batch should be ground approximately 11hours and then the slip was checked for density, viscosity and residue.

Figure 2-2: Ball mill used for raw material grinding

2.6 Slip storage

The out- put of the ball mill is a thick liquid which is called slip, is stored in underground slip tanks with agitating materials.

Then slips in different tanks are mixed to make a homogeneous mixture. After that the mixed slip is passed through a series of mesh, with mesh numbers 40#, 120# and then 80# mesh. Finally, that slip is passed through a ferro filter to remove iron particles and then finally send into service tank. These filtered slip is pumped into spray dryer to produce the base powder.

2.7 Ceramic powder preparation from Spray dryer

The excess water is usually removed via spray drying. This involves pumping the slip to an atomizer consisting of nozzles at the perimeter of the spray dryer. Droplets of the slip are dried as they are heated by a rising hot air column, forming small, free flowing granules that result in a powder suitable for forming.

The Advantages of Spray Drying in Ceramic Industry

- Continuous and easy to control process
- Applicable to both heat-sensitive and heat resistant materials
- Applicable to corrosive, abrasive, toxic and explosive materials
- Satisfies aseptic/hygienic drying conditions
- Powders can be produced
- Different sizes and different capacities
- High installation cost
- Lower thermal efficiency

Components of Spray Drying System

A conventional spray drying process consists of the following four stages:

1. Atomization of feed into droplets
2. Heating of hot drying medium
3. Spray-air contact and drying of droplets
4. Product recovery and final air treatment

Limitations:

- Higher energy consumption compared to pressure nozzles
- More expensive
- Broad spray pattern requires large drying chamber diameter

There were two piston pumps to supply slip onto the spray dryer under hydraulic pressure. These two pistons were connected together and continuously pumped slip at a uniform velocity. The pressure level was approximately 16-20 bar. If the slip pressure is high at spray dryer, it is pumped high quantity of slip to the nozzles because the slip velocity is high. The nozzle diameter is also important for the quantity of slip which is coming out of the nozzle. If the nozzle diameter is large, high quantity of slip is ejected from the nozzles. The height of the nozzle is also very important to the "v" shape of the ejected slip from nozzles.

There were 13 nozzles in spray dryer on 08 lanes. Diameter of these nozzles varies such as 3.0mm, 2.9mm, 2.8mm, 2.7mm, 2.6mm and 2.5mm. This is done to increase the total diameter size of all 13 nozzles. As a result of that total quantity of slip which was ejected from nozzle can be increased and the overlapping of two droplets can be minimized.

Nozzle changing is done at least per week time to increase the efficiency of spray drying process.

Figure 2-2: spray dryer used for powder preparation

2.8 Storage of Ceramic Powder

The base powder is stored in silos for aging purpose. There are 14 silos in RPL factory.

Figure 2-3: Silos used for storage of base powder

2.9 Formation of a Ceramic tile by Powder Pressing

The pressing process basically consists with three steps such as **filling, pressing** and **ejection**. The powder should be fed in to hoppers after sieving from vibrating sieve and from magnetic safety sieve. Powders from hoppers are then filled into mobile hoppers and then into moving cells and into dies. During first pressing, pistons with upper plunger press the powder once. As a result of that, the air trapped in cavity is removed. During the second pressing, powder is compacted tightly and a tile is formed. Next the green tile is ejected from the pressing machine. tiles are transported into dryers to dry. The powder pressing process is fully automated

Figure 2-4: A pressing machine

2.10 Fast drying

This process is necessary to remove moisture from pressed green tiles by evaporation to increase the strength of tile. The moisture content of the green tile is about 5% to 6%, after drying it can be reduced up to 0.5%.

They use vertical or horizontal dryers. Vertical dryers cause less green tile damages than the horizontal dryer in which tiles are moving on rollers and cause damages to tile due to vibrations and collision with each other.

2.11 Glazing & Printing Applications

It is a layer of coating of a vitreous substance which fuses to the ceramic body at the stage of firing. A uniform layer of englobe is applied under the glaze to prevent the glaze penetration into the body.

There are three glaze lines in two factories and two glazing lines in one factory. After the pressing machine green tiles are transported to dryers through conveyer belts. Each glazing line starts with a dryer. That is because the tile should have sufficient strength to travel along the glazing line at which the tiles are subjected to all printing applications.

Green tiles are usually dried up to 60-65 ^{0}C (depending on the tile size) to assure surface moisture of green tiles less than < 0.5.

There are surface cleaning brushers fixed to remove dust from tile surfaces. The spacer is another device to establish an equal gap between tiles. The gap between the tiles has to be consistent at the tile printers.

The water spray (for mat tiles) and clay spray (for glossy tiles) are applied on tile surface before apply the englobe on tile surface. The englobe is applied on tile surface using bell machine by water fall system. The glaze is applied after the englobe by using water fall system.

The major glaze application devices are;

- **Bell unit**
- **Vela machine and**
- **Double disk**

Bell unit

When the glaze runs on its surface it forms a constant, uniform **waterfall** like curtain. The glaze flows out of the apex of the bell with feed parameters being adjusted to suit the characteristics of the glaze being applied.

Bell unit is the most widely adopted continuous application solution allowing manufactures to obtain very smooth surfaces. Mainly englobe is applied by using bell machine.

Figure 2-5: A bell machine

Glaze application Vela machine

lazes can also be applied using the vela machine. It used pressurized injection through newly designed water fall units. Vela machine can be used to apply glaze more homogeneously across the width.

Figure 2-6: A vela machine

Double disc machine

This is used to apply the englobe by centrifugal force through packs of discs of varying diameter, which rotates at high speed. Characterized by excellent flexibility, this system can apply glazes with higher densities and viscosities as well. The glazes with coarser particle also provide very good flexibility in terms of applied quantity with this machine.

Figure 2-7: A double disk machine

Printing

After glazing, tiles are transported for printing. There are basically two types of printing systems used in tile manufacturing factories. That is digital and **rotocolor** printing. These two systems are fully automated. It is necessary to synchronize the rotocolor machine before using it. After backwashing the lower surface of the green tile, it is transported into box dryers to remove moisture and for further drying. Next green tiles are fed into kilns for firing.

Rotocolor printing

There is a screen wrapped around to form a cylinder which rotates over the tile passing under it. Rotocolor machines consist with constant printing speed and decorative pattern are also possible with speed changes of the drum or the cylinder.

Figure 2-8: A Rotocolor machine

Digital printing

There are two renown brand names in the ceramic industry; **Creta** digital printing and **Durst** digital printing. In digital printing, more intense colors and viscous inks can be used. It is enable to print with ink drops of different volumes which provide sharper images.

Figure 2-9: A digital Tile printer

2.12 Storage of Green Tiles

The glaze applied tiles are fed to kiln loading area by loading into boxes. These boxes are store in box dryer for about one hour to decrease the moisture content of the green tiles. After that green tiles are fed to the kilns for firing.

2.13 Firing the tiles in the kilns

Firing is the most important stage of the entire production process as it actually creates the ceramic materials by transforming the raw materials in the body into new crystalline and vitreous compositions. Firing also causes the vitreous coating to melt and form a continuous layer that is solidly anchored and interlocked with the tile body.

Heating increases the vibration amplitude of the atoms in the material. It causes the material to expand. In the firing progresses, certain compounds in the materials disappear and new ones are created. These changes can be observed as expansion or shrinkage.

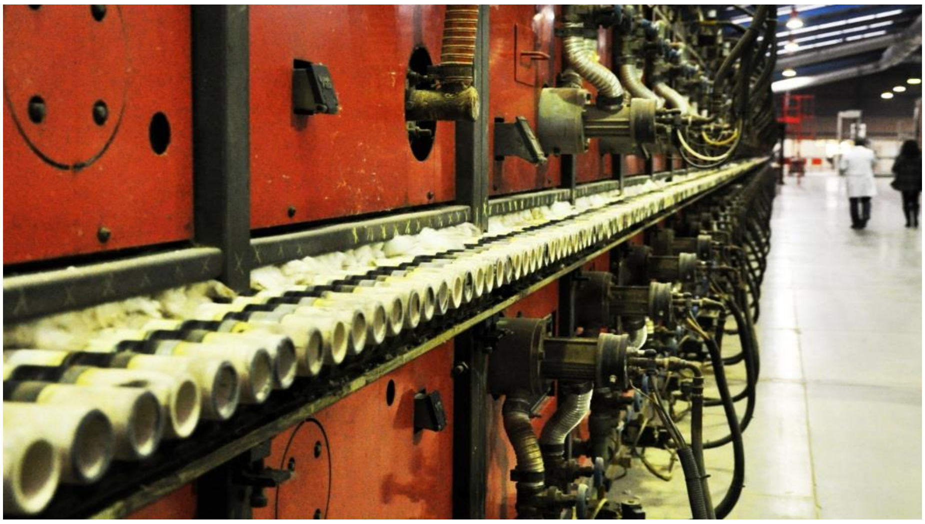

Figure 2-10: A Roller Kiln

There are three SACMI Branded roller kilns for firing of tiles in RPL factory Horana, two kilns in RCL factory Eheliyagoda and four kilns in LTL factory Homagma. The box loaded green tiles are kept in box dryer to remove residue moisture. In box dryers, the tiles are heated up to $100^{o}c$. After that the boxes are unloaded and tiles are loaded into kilns. Then the tiles are passed through a set of rollers. The length of the kiln is corresponding to the required firing time. Tiles usually pass through the kiln at constant speed. Kerosene or liquid petroleum gas is used as the fuel. The liquid fuel is atomized by pumping it into a duct which ends in a nozzle of a burner. The burners are fitted on the walls of the firing chamber.

The capacity of one kiln is 4,000 m^2 /day. The basic purpose of the kiln is to maintain the size and the flatness of a tile. By increasing the cycle time and peak temperature tile size can be minimized. In the kiln, as firing progresses the kiln temperature increases. According to the temperature the kiln is divided into several thermal zones. Several chemical reactions take place in the tile body when it passes through different thermal zones. Basically, kiln consist with six zones.

1st Zone - Pre kiln zone

2nd Zone - Pre heating Zone

3rd Zone - firing zone

4th Zone - rapid cooling Zone

5th Zone - Slow Cooling Zone

6th Zone - Final cooling zone

Pre kiln zone

-This is the kiln inlet zone.

- Tiles drive only on rollers.

-There are no burners.

- Heat energy is supplied by the hot air fumes from the downstream firing zones.

-The temperature range is between 50^{o}C – 450^{o}C.

Pre-heating zone

-The main event is degassing of the ceramic body and reducing the surface porosity.

of the tile.

-Temperature of this zone is between 350^{0}C - 880^{0}C.

-Organic materials are decomposed and remove from green tiles.

-The α-β transition of green tiles is taken place at 573^0C.

-The firing process is stared.

Firing zone

-The entire firing zone is equipped with wall- mounted burners both above and below the rollers.

-The temperature range of this zone is 1140^0C- 1150^0C.

-The firing zone consists with the maximum temperature at 1215^0C.

- In this zone, the tiles are fired and make the ceramic body.

-The tiles are fired in this zone and all the final size, flatness, metrifications, glaze characteristics of the tiles are established in the zone

Rapid cooling Zone

-This stage involves a sharp drop in temperature and the return of both body and glaze to a solid state.

-Rapid cooling is achieved by blowing cold air through pipes mounted on the walls both above and below the rollers.

- The temperature range of this rapid cooling zone is 1200 ^{0}C – 580 ^{0}C.

-The expanded tile was shrunk due to the β to α transition at 573 ^{0}C.

-For the cooling process it can be used rapid cooling fans.

Slow cooling zone

-This zone is used to absorb the heat of tiles and to lower the tile temperature.

Final cooling zone

-The temperature of this zone is decreased up to about 480^0C.

- Turbine fans are used to suck fresh air from outside and pump them into the inside of the kiln and cool the tile surface.

2.14 Storage of Fired Tiles

Fired tiles coming out from the kilns are loaded to steel pallets. Automated machines are used for loading and unloading purposes. Tiles are unloaded to steel pallets by the automated machine. Those pallets are transferred to the squaring and polishing department using fork lifts.

2.15 Polishing and Squaring

In the squaring machines, tiles with small size changes are being squared using grinding wheels. The output from the squaring machine is of perfect straight edges. There are two main brands of squaring machines used in Sri Lanka. One is from Italy and other one is from China.

Some varieties of tiles are being polished. The polishing of the tile is done using abrasive heads. The tile is under the polishing head and the head is being rotated with the help of an induction motor.

The pressing pressure can be adjusted using the pneumatic cylinder attached to the polishing head. Polishing is an additional process which uses to increase the flatness quality of the tile surface. For some codes of the tiles, polishing is not required.

As the cutting and polishing is a wet process the tile surface is wet after this process. There is a LPG fired tile dryer at the end of the polishing plant. The output of this section enters the sorting and packing section.

Finally, tiles are further sorted in to different grades according to the surface quality and packed separately in cartoon boxes with a print on it relevant to its grading.

Figure 2-11: A Tile Polishing and Squaring Machine

2.16 Sorting & Packing

Sorting

The sorting department allows the product to be sub divided and pack on the basis of both objectively and subjectively set parameters according to the ceramic company's quality parameters.

Kiln output and some of the squaring output are sent into the sorting department. There are three tile sorting machines in every plant to sort the output of the kiln.

- Some tiles are from the Squaring Plant
- Some tiles are directly from the kilns

Major components of the sorting line

- Loading machine -consist with suction planes to suck and transport the tiles
- Roller bed -unload tiles from suction plane to roller beds
- Sorting table -visual inspection of tiles by **Sorter** and **Checker**
- Planar machine -use laser beam cameras for inspection
- Stacker -consist with several stacks to segregate the tiles according to the grade assigned

- Packing machine - use to wrap sorted tiles by using cartoons. Consist with printing and strapping machines too.
- Pelletizing - pelletize the sorted tiles using robot machine

Visual inspection

Good illumination is required to visualize the defects by the checker. At this stage, main aim is to identify the defects caused by production errors such as cracks, particles on the surface etc...

After checking the surface quality of the tiles by the checker, the second operator marks on the tile surface with a fluorescent ink pen according to the quality class.

The fluorescent ink marks are read by the ultra violet photocell and that signal is transmitted to the micro controller processor to sort the tiles.

Automatic inspection

The tiles are then sent to automatic inspection zone consisting of two different sections. There is a flatness control device and a device for geometric measurements as well. The flatness control device is called as the planner. In the planner, laser cameras are being used to measure the tile flatness.

Stacking

Tiles are next classified according to the quality classes. The device for the control of size and geometric defects is called as the caliber. It measures the linear measurements of tiles in both longitudinally and transversely and classify into standard groups called calibers and damage groups.

The classified tiles are conveyed to the stacking zone by two feed belts. Here the tiles are sub divided according to the quality classes.

Palletizing

After printing the information, (includes a description of the product, its class size, shade and quality, date and codes of checker and sorter) the boxes are sent to the palletizing zone.

The automatic action is done by using a palletizing robot which picks up the packs and arranges them on pallets. The palletizer picks the tile boxes according to the relevant codes and place on the pallet

Packaging

The final product is packed automatically or semi automatically. The packing included the wrapping with polythene sheets and steel straps. The Polythene stretch wrapping is done automatically by the machine and the steel straps are fixed manually.

The purpose of the packaging process is to enclose stacks of the same class of tiles in a pallet. This stretch wrapping will help to hold all the tile boxes together and it will help to transport the tile pallets without having tile damages

2.17 Storage of Finished goods

Final products are stored in Finished Good Store until they are distributed for local market or exported for other countries.

2.18 Product Classification

There are two types of floor tiles manufactured in Sri Lanka Those are;

1. Glazed vitrified tiles.
2. Glazed ceramic tiles.

Product classification is based on the method of forming and water absorption of tiles.

Table 2.1: Classification of tiles based on method of formation

Forming method	**Class**
Extrusion	Group A
Dry pressing	Group B
Casting	Group C

Dry pressing is the tile forming method carried out in the three manufacturing plants in Sri Lanka. All the tiles manufactured in Sri Lanka falls in to the Dry pressed type. That is Group B, according to ISO classification.

Table 2.2: Classification based on water absorption.

Tile type	Amount of water absorption (E_b) (%)	Class
Porcelain	$E_b \leq 0.5$	Ia
Vitrified	$0.5 < E_b \leq 3.0$	Ib
Ceramic	$3.0 < E_b \leq 6.0$	IIa
Wall tile	$6.0 < E_b \leq 10.0$	IIb

Water absorption of tiles manufactured in Sri Lanka is in between 0.5-6.0%. And also tiles with water abortion below 0.5% too are being manufactured in the same factories.

There are some standards according to the ISO 13006 for those two type of tiles which maintained by the Factory.

The standards are;

For vitrified tiles- **ISO 13006 Group B Ib**

For ceramic tiles- **ISO 13006 Group B IIa**

2.19 Product portfolio of the local manufactures

Table 2.3: The major tile sizes and types in RPL factory

Parameter	Tile Size							
Tile size cmXcm	30X30	40X40	45X45	50X50	60X30	60X40	60X60	45X90
Area Of a tile/m2	0.09	0.16		0.25	0.18	0.24	0.36	0.405
Pressing Pressure Kg/cm^2	280-300	280-330	280-330	280-330	330-340	330-340	330-340	330-340
Green Tile Weight g	1550	3150	4200	5650	4200	5650	8350	10400
Green Tile Thickness mm	8.4	9.2	9.7	10	10	10.4	10.8	11.5
Fired Tile Weight g	1470	2950	3950	5250	2900	5250	8000	9750
Fired Tile Thickness mm	8.1	8,9	9.6	9.6	9.6	10	10.2	10.8

Table 2.4: The major tile sizes and types in RCL factory

Parameter	Tile Size							
Tile size cm x cm	30X30	40X40	45X45	50X50	60X30	60X40	60X60	45X90
Area Of a tile/m2	0.09	0.16	0.22	0.25	0.18	0.24	0.36	0.405
Pressing Pressure Kg/cm^2	330-340	330-340	330-340	340-360	340-360	340-360	400-460	400-460
Green Tile Weight g	1580	3200	4250	5690	4280	5685	8400	10550
Green Tile Thickness mm	8.4	9.2	9.7	10	10	10.4	10.8	11.5
Fired Tile Weight g	1480	2975	3980	5270	2930	5260	8025	9770
Fired Tile Thickness mm	8.1	8,9	9.6	9.6	9.6	10	10.2	10.8

2.20 Energy Consumption in Ceramic Industry

The magnitude of energy consumption has always been taken as an indicator of development status of economy. However, a country requires not only energy but also the services that energy provides. A nation can increase the services by keeping the same inefficient devices and machinery and using more energy. More energy will positively not accelerate the economic growth as long as the energy intensities the high. In the globalize economy, countries with high energy intensities may become uncompetitive due to high energy costs. Therefore, energy cost reduction must become one of the important benchmarks for economic success. Efficiency in consumption of energy and its conservation would be one of the most important in terms of energy cost reduction and for meeting future energy demand. Indentation of energy saving potential in the local industries and domestic sector are being carried out by various institutions. Efficient use of energy provides the least cost and environmentally friendly option for capacity creation in the shortest time frame. Energy efficiency is also assumed further importance as "one unit of energy saved at consumer end, avoids 3 units of fresh capacity addition" [3]

Fossil fuels are the main energy sources that are being used for heating up kilns and furnaces in most of the industries.85% of energy requirement of the world is supplied by the fossil fuels. Fossil fuels are energy source such as coal, oil and nature gas. With this rate the world virtually depends on supply of fossil fuels. But the common issue presented is that depletion of fossil fuels in the world hence fossil fuels are identified as nonrenewable sources of energy. In fact, some oil companies have estimated that petroleum resources will be depleted within 100 years. Conservation of energy helps to conservation of energy helps to conserve the resource by which energy is being created. Renewable energy has come in as a resolution for this globe issue. Renewable energy is any natural source that can replenish itself naturally over a short period of time [6].

The energy source of coal, fossil fuels and nuclear power are used to generate electricity in the world most commonly. Further the fossil fuels are used for the vehicles operations too. Carbon dioxide (CO_2) and other molecules, some harmful to human health and to the environment are emitted by the vehicles. Burning of wood, leaves, and other items for warmth or disposal also involves harmful emissions to the environment. Nuclear power is the most efficient energy out of the all renewable and non-renewable energy sources which has the highest risk of handling and disposing of waste. Nuclear power is generated from radioactive uranium.

Some of the adverse effects of consuming nonrenewable energy source are described as follows.

i. Uranium and coal mining are hazardous to miners and to the environment Navajo and African uranium miners have extremely high cancer death rates. Uranium, coal mining and oil drilling be harmful to the environment and agricultural lands.
ii. Local air is polluted by the auto emission, cool power generation and wood leaf burning kilns. As per past data about 55,000 Americans were died year due to suffering of asthma, emphysema, etc. The main reasons of this kind of deceases are microscopic small particulate matters which are very dangerous and penetrates deeper into the lungs.
iii. Sulfur dioxide(SO_x) and Nitrous oxide (NO_x) are emitted by the coal power plants and vehicles. There oxides are traveled beyond the local area and harmful to the health of people in the region. SO_X/NO_X and mixed under certain conditions and formed sulfuric acid and nitric acid which is known as acid rain. Acid rains are very harmful to the lungs.

Depletion of energy sources is the main contributor to the scarcity of non-renewable energy and as a result of that frequent price escalations are been occurred in the world market. Accordingly, the fuel prices of the local market are get increased. These frequent price escalations are seriously affected to the heavy energy consumers such as ceramic industry, steel industry etc. As to compensate the price increase of energy, energy consumers are compelled to increase the prices of their commodity, thereby the demand to the commodity will be reduced. Further the cost of transportation, costs of raw materials are indirectly to the cost of production due to increase of cost of fuels. Therefore, energy has become as a crucial factor to the ceramic industry at presently [12].

The ceramic industry is one of the energy intensive industries in Sri Lanka which consumes thermal energy as well as electrical energy. The total rated output of the floor tile industry is about 34,000 m^2 per day which is about one million m^2 per month. The wall tile production in the country is 9000 m^2 pay day which is about 270,000 m^2 per month. There are two wall tiles manufactures in Sri Lanka. Comparing the above production capacity with the other countries like India, Indonesia, Malaysia and the “pioneer of ceramic” Italy, it is fairly a smaller quantity. With the rapid rate of increase of cost of energy in Sri Lanka due to various reasons such as increase of international fuel prices, country current economic situation, it increases the manufacturing cost for energy. Apart from the increase of cost of energy, all other manufacturing factors such as raw material transportation, labor are becoming expensive. Hence energy becomes an important topic for a manufacturing companies and it contributes directly and indirectly to the company growth as well. The specific energy of ceramic tiles manufacturing plants is very high due to the wastages. Since there is a huge competition in the market due to the incoming imported floor tiles it is essential to have high quality product at low price in order to be competitive at market [12].

Availability of raw materials within the country is an advantage for the ceramic industry today. It is the reason for ceramic industry to become as a traditional industry in Sri Lanka. Raw material scarcity is one of the major issue for most Sri Lanka industries to carry out their production smoothly. Ceramic industry has no barriers with raw material issues at present. Energy is the main expensive resource to the ceramic industry which has now become critical to all the ceramic manufacturing industries in Sri Lanka. Quality is the dominant factor to the sustainability of market in local and foreign which depend on quality of raw materials and fuel used to fire the kilns.

There are several kinds of ceramic products are in existence in the country such as tiles, porcelain ware, and ornamental ware. As per the preliminary energy audit carried out by ceramic cluster in Sri Lanka in years 2001 December to 2002 April under “Energy Efficiency in Ceramic Industry” [12] the monthly average cost is about Rs.8.7 to 10 million in porcelain ware, Rs.14 to 20 million in tile manufactures and Rs.2 to 3 million in ornamental ware. The specific electrical energy of porcelain product is about 1233 to 2072 kWh/ MT, tile industry 228 to 240 kWh/MT, ornamental ware 690 to 1165 kWh/MT and sanitary ware 1300 KWh/MT respectively. This data indicates only the direct energy consumption. In addition to that more elements on energy consumption such as energy consumed by human activities, energy of raw material and transportation are hidden factors to be considered for overall energy analysis. The embedded energy of a product includes all the energy consumption that consumed during its manufacturing process. Therefore, it is easy to identify and implement the possible energy activities to all the areas which directly contributed to the process.

2.21 Non-Plastic Raw materials

Non-plastic raw materials such as calcite, pyrophyllite, feldspar is crushed until it becomes powder form and then the raw materials are loaded to the ball mills using a long conveyer. Averagely 21 tons of raw materials are mixed with 5000 liters of water. Balls stones or alumina balls are used as grinding media in the ball mill. It consumes eight to ten hours to complete a milling cycle where a massive quantity of energy is consumed for body slip preparations. Milling of raw materials is completed when achieving the desired slip density of the slurry. Properly ground batch of materials appeared as molten liquid are unloaded to the storage tanks through vibration sieves which is used to remove ungrounded and dirty particles. Milling is a heavy energy consuming area which consumed 40% of electrical energy out of all electrical energy of the plant.

Properly ground slip batches are stored in the storage tanks under agitation for few hours for the purpose of homogenizing. Homogenized slip is pumped to a service tank prior to spray drying. Construction of the spray dryer consist with a large chamber and hot air generator which converts body slip into powder form. Hot air is supplied by the hot air generator to the main chamber burning kerosene oil or Liquid petrol gas. Homogenized slip is sprayed by the plunger pumps at the middle of the chamber of the spray dryer. Dried powder with 5 to 6 percent moisture is collected from the bottom of the chamber and is stored in the storage silos. The evaporated moisture from the slip is removed by the main blowers to outside thorough a wet scrubber. A negative pressure is maintained inside the chamber of the spray dryer. The inside temperature of the chamber is maintained at a certain level in order to control the moisture of the powder. The average temperature inside of the chamber is around 500 to 600 C. Moisture content of the finals power affects the tile quality at pressing process.

Usually LPG or kerosene is used as fuel to the spray dryer and in some countries like china coal power for the heat generation is used. Both thermal and electrical energy is used for the operation of spray dryer, electrical energy is used for driving all blower fans, pumps and all auxiliary operations. Thermal energy is used to supply hot air to evaporate moisture of the slip. The total energy consumption is about 25% out of total embedded energy of the process. Hot air generator is with a single high velocity burner where compressed air is used for the atomization of kerosene oil. The heat capacity of the burner is 3 to 4 million kcal / Hrs. Primary air is being supplied by a separate blower and secondary air is sucked due to negative pressure inside the chamber.

Pressing is the first step of the forming a tile using dried powder as per sizes such as 20x20, 20x30, 45x45, 60x60 cm. The average force applied by the press on to the powder is approximately 275 kilograms per square centimeter. All the function of the press is activated hydraulically and operations are controlled with a programmable logic controller. Steel moulids are used to obtain the correct tile sizes. Isostatic and normal pressing are the two main technologies that are used in ceramic industry. Elimination of powder sticking on the dies a rubber coating has been used on surfaces of the dies. Many properties such as hardness, correct thickness and smooth finish on the surface are being maintained as quality standard after pressing of tiles. Press is fully electro hydraulic operation which is fully automated machine and electrical energy is highly used for the operations. The main important parameters that required in the pressing a ceramic tile are packing density, green size of the tile and smooth surface finish.

i. **Drying of tiles**

   After pressing all the ceramic tiles are fed in to a dryer to remove all the moisture in the body. Drying is an important process to a ceramic process which has to be tightly monitored in the process. The length of the dryer is averagely 18 to 20 meters and the maximum temperature of the dryer is about 150 centigrade. Many kinds of dryers such as vertical and horizontal are used for the drying of ceramic products. LPG and Kerosene oil are the main fuels used to heat the dryers. Most occasions waste heat of the kilns are used to heat dryers which is to economize the energy**.**

Drying can be done by using a basic air drying or sophisticated electronic drying which is required to remove water of the surface of the ceramics at a given rate. The real requirement for drying is to remove the water inside the ceramics as fast as possible so that the surface water is evaporated. To accomplish this process, it is required to understand the factors that control how quickly the water can leave the surface, and the factors that control how quickly the water can move from the inside of the piece to the surface. Identification of these requirements are facilitated to designing a dryer for a process.

ii. Drying Principles

Water from the surface of a piece of ceramic cannot move into the surrounding air faster than it would from a pool of standing water. Fortunately, that speed was determined at about the turn of the last century by Willis Carrier, the man who invented air conditioning. The heating, ventilating, and air conditioning (HVAC) industry uses the following equation derived from Carrier's work to establish the maximum rate of evaporation from pool of water.

$$\text{LB water /sq.ft. of surface area /hr} = k\,(1+200/V)\,(W_{0}\text{-}W_{RH})$$

Where k is a constant for the particular situation (often taken as 0.192) and V is the perpendicular air velocity in feet per minute. Omega saturated (W_0) is the partial pressure of water vapor in fully

2.22 Power Generation and Distribution in Sri Lanka

Analysis published by the Ministry of Power and energy on local power generation that importance of energy conservation due to lack energy sources.25% of the demand supplied by the hydro power which is identified as renewable energy source and other 75% is supplied by the thermal power which is categorized under nonrenewable energy source. As to cater the required demand private generation plants have been rented by Ceylon Electricity Board which is operated by fossil fuels.

Summary of local power generation

CEB Major Hydro Plants	1380MW
CEB Norochcholai Coal Plant	900MW
CEB Wind Power Plants	3MW
CEB Thermal Plants	567MW
Private Mini-Hydro Plants	342MW
Private thermal	611MW
Private wind	128MW

The Hydro Power Stations contributed 3481 GWh or 24.6% of energy during the year 2016. Hydro Power is generated mainly from Mahaweli complex, Laxapana complex, Samanalawewa Power Stations, Kukuleganga Power Station and three Mini Hydro Power Stations at Inginiygala, Udawalawe and Nilambe. The Kukule Ganga Hydro Power Plant with an installed capacity of 70 MW was commissioned and ceremoniously opened on 19th September 2003. This is particularly a significant achievement which enhanced the hydro generation capacity of Ceylon Electricity Board and is the first Hydro Power Plant commissioned after commissioning of samanalavewa power plant in 1992.

ii.16.2% of the country power requirement is supplied from CEB thermal oil energy in 2016. 35.7% of the country power requirement is supplied from CEB thermal coal energy in 2016.

3x300 MW Coal Fired Thermal Power Plant commissioned in 2011/2014 at Norochcholai in the west coast of Sri Lanka. The CEB had sought a soft loan from donor agencies for this power plant. Project cost is about US Dollars 465 Million and construction period was few years.
The forecast made by the CEB on the growth of electricity demand in the country project a growth between 7 to 8 percent in the next decade. Due to rapid growth in some sectors of industry and the accelerated efforts in electrification, the rate of growth in a particular year may increase but it is likely to remains as predicted over a longer period of time [8].

3 EMBEDDED ENERGY.

Embedded Energy is the quantity of energy required to manufacture, supply to the point of use, a product, material or service. Embedded energy is an accounting methodology which aims to find the total energy necessary to complete a product. The elements inclusive in embedded energy are raw marital extraction, transportation, manufacturing, assembly, installation and other energy of a specific material, to complete a product.

3.1 Elements of the Embedded Energy

The elements inclusive in embedded energy are raw material extraction, transportation, manufacturing, assembly, installation and other energy of a specific material, to produce a service or application and the type of energy embedded. Some methodologies are interested in accounting for the energy embedded in terms of oil that support economic processes. Other types of methodologies are concerned to account for the energy economic processes. Other types of methodologies are concerned to account for the energy embedded in terms of sunlight that support ecological processes. And other like system ecology is concerned about the support of the ecological- economic process as a whole. Embedded energy as a concept used in systems ecology seeks to measure the "true" energy of an item, and the extended this to the concept of "true" value.

i. Importance of embedded energy

   Embedded energy indicates the true energy consumption of a product or item which is not varying with other environmental changes. Technology is one of main contributing factor for increase or decrease embedded energy of a product or an item. Embedded energy is an important scale to measure the real value of energy of a product or an item and make comparisons with other products or with other technologies which would help to take business decisions on manufacturing industries or in-service industries. Embedded energy content varies greatly with different manufacturing types. In many cases a higher embedded level can be justified if it contributes to lower operating energy. For example, large amounts of thermal mass, high in embedded energy, can significantly reduce heating and cooling needs in well designed and insulated passive solar houses.

   The energy efficiency in a manufacturing process is an important aspect that to be considered in designing and operational stage of a process. Embedded energy has included all the energy levels of energy consumption of a product or material. Therefore, embedded energy is the most suitable parameter that gives the ways and means to identifications and implementation to improve energy efficiency of the process. Improving of energy efficiency of a process, directly contributes to conserve the energy which is most important in these days.

ii. Assessing embedded energy

Whereas the energy used in operations of a manufacturing process can be readily measured, the embedded energy contained in the machinery is difficult to assess. The energy used for manufacture machinery is often hidden and can only be fully quantified through a complete life cycle analysis. It also depends on where 'boundaries' are drawn in the assessment process. Energy analysis was the starting point for life cycle analysis. It is the process by which the energy implications of a products are considered from the product's cradle to grave. The life cycle energy analysis is carried out in four different levels as described below.

Level one - is analysis of direct energy consumed by the product such as fuels and electricity.

Level two – is an energy analysis of the material input to the final production process, the analysis also include transportation to the input and energy in auxiliary inputs

Level three – is energy of the raw materials consumed by the final process, their processing and the machines employed the final product.

Level four – is an energy analysis of the capital equipment use to make the machines used throughout the system. It is rarely utilized in reality.

Embedded energy in building materials has been studied for the past several decades by researches interested in the relationship between building materials, construction processes, and their environment impacts. Basically, this research has been performed in the way of categorizing embedded energy in two sections such as initial embedded energy and recurring embedded energy. Initial embedded energy in a building represent nonrenewable energy consumed in the acquisition of raw materials, their processing manufacturing transportation to site and construction. Recurring embedded energy in a building represent the non-renewable energy consumed to maintain, repair restore, refurbish or replace materials, components or systems during the life of the building. The amount of embedded energy in building varies considerably. Embedded energy consumption depends on the nature of the building, the materials used and the source of these materials (this is why data for a building, material in one country may differ significantly from the same material manufactured in another country). The recurring embedded energy is related to the durability of the building materials, components and systems installed in the building, how well these are maintained, and the life of the building (the longer the building survives, the greater the expected recurring energy consumption).

Research carried out by Cole and Kernan [7] using a model based on Canadian construction of a generic 4620 m^2 (50,000 ft2) three- story office building with underground parking, considered three different construction systems (wood, steel and concrete), and has yielded the following results for average total initial embedded energy (Note: Data were averaged for the three construction systems as the overall differences between the building types were not significant.

The building envelope, structure and services contribute fairly equally and account for about three – quarters of total initial embedded energy. The finishes, which represent only 13% of embedded energy initially, typically account for the highest increase in recurring embedded energy. Embedded energy may not be significantly different between building systems (e.g. wood, versus steel versus concrete), the environmental impacts associated with one material versus another can be dramatically different.

3.2 Assessing of energy in a manufacturing process

Assessing of energy in a manufacturing process, product or services can be handled in two ways. Life cycle analysis over a period and analysis of embedded energy are the two methods that can be used to assess energy in product. Life cycle consist four levels covering as described in above energy of product’s cradle to grave which is called as Gross energy requirement (GER). Assessment of energy in level four is the energy embedded in machinery which is the difficult part to asses in life cycle energy analysis. Gross process energy and Process energy requirement are the two basic aspects of the embedded energy analysis. Process Energy Requirement (PER) is a measure of the energy directly related to the manufacture of the product. This is simpler to quantify. Consequently, most figures quoted for embedded energy re based on the PER. This would include the energy used in transporting the raw materials to the factory but not energy used to transport the final product. In general process energy requirement is 50% to 80% of gross energy requirement. Further simplifying process energy requirement, it can be divided in to three groups such as level one all direct energy, level two analysis, energy in auxiliary services and level three analysis, energy in raw material transportation.

As above simplification all the data was collected and the study was driven to find out embedded energy of wall tiles. Even within this narrower definition, arriving at a single figure for a material is impractical as it depends on:

- **Efficiency of the individual manufacturing process.**
- **The fuels in manufacturing of the materials.**
- **The distance materials are transported.**
- **The amount of recycle product used, etc.**

Each of these factors varies according to product, process, manufacturer and application. Further it varies depending on how the embedded energy has been assessed. Estimates of embedded energy can vary by a factor of up to 10. As a result, figures quoted for embedded energy are guidelines only and should not be taken as ‘correct’. Important is to consider the relative relationships and try to use materials that have the lower embedded energy. Therefore, in order to have accurate figure a boundary condition was introduced.

3.3 Boundary conditions

The study findings were confined to a certain hypothetical boundary condition in order to achieve precious final objective in terms of theoretical and practical and aspect. All the information was gathered assuming the hypothetical boundary condition for all the level of energy analysis. It was analyzed the life cycle energy of level 1, level 2, level 3 during this study for both manufacturing process. The manufacturing technologies of both plants are identical and similar machinery was used more or less. The main objective of the study is to compare the embedded energy of these two technologies.

The demographic locations of the plants which were taken in to consideration in this study are in three locations with similar environments. The distance between three plants is about fifty kilometers. They are situated in Kaluthara, Rathnapura and Colombo districts. The life cycle of the plants was considered as ten years for the study due to rapid change of ceramic technology in the world. The location of the plants is also contributed to increase and decrease the embedded energy with effect of energy consumption in raw material transportation.

Hypothetical boundary was defined for all the raw materials transportation with in the country area from the mine or from the local suppliers, since most of the raw materials are available within the country. Some of the raw materials such as pyrophyllite and frits are imported from Spain and Italy. The energy consumed on transportation of all the imported raw materials was considered from Colombo to the relevant factories.

The subject area considered under this study is manufacturing of floor tiles roller kilns. The study consists of transportation of raw materials from the mines to the factories, unloading of raw materials in the factory, loading of raw materials to the process start up and all plants operations. The plants with fast firing technology operates throughout the day and week.

The direct energy is used for energizing of all machinery. Energy consumed by the machinery was taken in to account for the energy assessment. All types of fuel transportations and consumptions were also taken in to consideration. The level 4 energy which of capital energy embedded in the machinery was not considered under this study due to unavailability of real values. Energy consumed for manufacturing tile machinery is a large process therefore it was ignored in this energy assessment. Further the energy in recurring items or events such as replacing of spare parts and machine maintenance were neglected due to negligible amount of energy consumption. The unit of final production is taken in square meter in both plants therefore the final solution of the project would be in unit of mega joule per square meter. As to observer is usual notations of heat working mega joule per kilogram the final solution was converted.

4. DATA COLLECTION

Data collection from the three manufacturing plants in the country

- **Royal Ceramics Lanka Ltd**
- **Royal Porcelain (PVT) Ltd**
- **Lanka tiles Ltd**

The royal Ceramics Lanka ltd is situated in Eheliyagoda and Rathnapura District. Royal Porcelain is situated in the Horana, Kalutara District., Lanka tile is situated in Homagama, Colombo District.

All the three factories are using the same material and the suppliers for the all the three factories same.

The raw material mines are common for all the three factories and only the distance from the mines are slightly varying due to the geographical situation.

The time frame for the study is two years, 2015 and 2016. Monthly data considered. All the department wise data were considered.

[1] Electricity consumption department wise

[2] Diesel consumption department wise

[3] LPG consumption department wise

[4] Labour usage department wise

[5] Fuel for the transportation of the raw materials from the Mines

4.1 Level 01 Energy

The data collected from Royal porcelain factory (RPL) situated in Horana, Kaluthara District

Table 4-1: Level 01 energy Milling department

Year	MONTH	Milling (Ball Mill+ SD)			
		Production MT	Electricity KWh	Fuel Energy KWh	Total Energy KWh
2014	January	6,007.15	436,498.16	2,232,717.06	2,669,215.22
	February	5,322.51	377,292.84	1,990,613.20	2,367,906.04
	March	6,334.75	449,257.38	2,373,457.58	2,822,714.96
	April	2,531.56	215,788.83	1,032,110.67	1,247,899.51
	May	4,691.86	359,402.47	1,871,317.99	2,230,720.46
	June	3,607.35	307,213.98	1,441,840.48	1,749,054.46
	July	4,089.41	325,854.33	1,482,766.99	1,808,621.32
	August	4,288.46	324,853.76	1,656,004.69	1,980,858.46
	September	4,545.02	375,466.93	1,780,642.91	2,156,109.83
	October	6,453.85	459,790.50	2,411,016.83	2,870,807.34
	November	6,435.51	453,079.88	2,448,854.15	2,901,934.03
	December	6,065.71	429,449.08	2,419,383.36	2,848,832.44
2015	January	6,718.92	487,387.44	2,586,258.44	3,073,645.88
	February	5,122.11	371,941.72	1,938,141.48	2,310,083.19
	March	5,408.80	330,897.74	2,085,672.38	2,416,570.12
	April	2,568.62	211,133.97	1,006,479.71	1,217,613.68
	May	5,247.53	367,761.32	2,157,272.87	2,525,034.20
	June	6,125.80	410,555.51	2,203,502.56	2,614,058.06
	July	6,397.06	412,978.26	2,357,370.91	2,770,349.18
	August	6,170.92	445,634.53	2,281,554.84	2,727,189.37
	September	5,410.39	390,541.71	2,006,578.71	2,397,120.42
	October	5,439.93	371,171.62	1,983,428.72	2,354,600.34
	November	6,877.62	415,166.46	2,251,757.69	2,666,924.15
	December	6,540.08	447,060.30	2,329,945.03	2,777,005.33

Table 4-2: Level 01 energy Pressing department

Year	MONTH	Pressing			
		Production MT	Electricity KWh	Fuel Energy KWh	Total Energy KWh
2014	January	5,821.02	188,522.41	0.00	188,522.41
	February	5,156.32	177,750.74	0.00	141,072.01
	March	6,139.08	208,219.09	0.00	165,253.24
	April	2,446.66	93,831.43	0.00	74,469.39
	May	4,544.04	158,228.04	0.00	125,577.81
	June	3,491.12	139,204.99	0.00	110,480.15
	July	3,959.14	156,699.39	0.00	124,364.60
	August	4,152.39	138,056.44	0.00	109,568.60
	September	4,401.48	151,933.98	0.00	120,582.52
	October	6,254.71	215,838.50	0.00	171,300.39
	November	6,236.91	207,331.00	0.00	164,548.41
	December	5,877.88	217,232.98	0.00	172,407.12
2015	January	6,512.06	217,540.41	0.00	172,651.12
	February	4,961.76	140,035.79	0.00	111,139.52
	March	5,240.10	182,175.52	0.00	144,583.75
	April	2,482.64	69,085.93	0.00	54,830.11
	May	5,083.52	192,907.37	0.00	153,101.09
	June	5,936.21	203,017.56	0.00	161,125.05
	July	6,199.57	181,397.78	0.00	143,966.49
	August	5,980.02	152,065.30	0.00	120,686.75
	September	5,241.64	150,716.58	0.00	119,616.33
	October	5,270.32	148,123.77	0.00	117,558.55
	November	6,666.13	171,432.80	0.00	136,057.78
	December	6,338.42	174,271.24	0.00	138,310.51

Table 4-3: Level 01 energy Glazing department

Year	MONTH	Glasing Line			
		Production MT	Electricity KWh	Fuel Energy KWh	Total Energy KWh
2014	January	5,442.51	183,329.44	1,409,076.55	1,592,405.99
	February	4,820.89	173,810.05	1,471,476.84	1,645,286.89
	March	5,739.95	204,563.43	1,752,174.08	1,956,737.52
	April	2,286.85	107,462.45	619,238.29	726,700.73
	May	4,248.29	150,339.65	973,797.90	1,124,137.55
	June	3,263.62	137,684.50	1,073,239.07	1,210,923.57
	July	3,701.31	148,399.66	847,639.59	996,039.25
	August	3,882.03	140,783.90	1,275,069.00	1,415,852.90
	September	4,114.98	152,765.00	1,313,651.74	1,466,416.74
	October	5,848.09	200,647.26	1,846,426.47	2,047,073.73
	November	5,831.44	201,814.29	1,623,129.77	1,824,944.06
	December	5,495.68	205,384.45	1,694,286.84	1,899,671.29
2015	January	6,088.76	209,762.45	1,691,921.25	1,901,683.70
	February	4,638.94	167,604.12	1,400,103.73	1,567,707.86
	March	4,899.24	189,863.57	1,589,544.52	1,779,408.09
	April	2,320.50	76,000.54	577,235.69	653,236.22
	May	4,752.81	174,063.44	1,576,829.07	1,750,892.50
	June	5,550.24	195,897.28	1,590,150.34	1,786,047.62
	July	5,796.53	180,645.13	1,272,001.71	1,452,646.84
	August	5,591.21	139,195.55	626,719.77	765,915.32
	September	4,900.68	141,083.73	614,137.91	755,221.64
	October	4,927.51	142,273.21	742,953.05	885,226.27
	November	6,232.85	181,765.13	1,608,175.71	1,789,940.84
	December	5,926.38	192,836.05	1,605,110.87	1,797,946.91

Table 4-4: Level 01 energy Kiln department

Year	MONTH	Kiln			
		Production MT	Electricity KWh	Fuel Energy KWh	Total Energy KWh
2014	January	5,378.72	264,744.08	4,280,258.02	4,545,002.10
	February	4,763.26	257,656.86	4,120,042.93	4,377,699.80
	March	5,673.22	293,197.82	4,735,976.72	5,029,174.54
	April	2,254.31	167,707.57	2,040,745.19	2,208,452.76
	May	4,196.33	221,261.18	3,307,785.87	3,529,047.05
	June	3,221.40	209,761.47	2,869,618.75	3,079,380.23
	July	3,654.76	230,023.25	3,137,086.71	3,367,109.96
	August	3,833.69	229,596.41	3,226,131.22	3,455,727.62
	September	4,064.33	245,519.93	3,226,131.22	3,471,651.15
	October	5,780.28	289,807.68	4,598,891.34	4,888,699.02
	November	5,763.80	291,021.73	4,573,329.47	4,864,351.20
	December	5,431.37	313,305.15	4,527,907.37	4,841,212.53
2015	January	6,018.57	301,350.47	4,921,990.21	5,223,340.68
	February	4,583.11	258,827.68	3,839,855.04	4,098,682.72
	March	4,840.83	280,566.25	4,298,369.73	4,578,935.97
	April	2,287.63	139,313.91	1,507,163.01	1,646,476.92
	May	4,695.85	267,370.29	4,364,486.58	4,631,856.88
	June	5,485.38	268,839.65	4,700,167.32	4,969,006.97
	July	5,729.24	269,341.63	4,660,430.95	4,929,772.58
	August	5,525.95	270,920.46	4,720,314.21	4,991,234.67
	September	4,842.26	262,486.36	4,420,276.76	4,682,763.12
	October	4,868.82	249,407.90	4,578,250.72	4,827,658.62
	November	6,161.23	242,637.27	4,833,582.77	5,076,220.04
	December	5,857.80	253,861.74	5,091,956.76	5,345,818.49

Table 4-5: Level 01 energy Sorting department

Year	MONTH	Sorting			
		Production MT	Electricity KWh	Total Fuel KWh	Total Energy KWh
2014	January	5,378.72	178,944.21	216,025.69	394,969.90
	February	4,763.26	123,311.78	178,662.36	301,974.14
	March	5,673.22	185,952.07	235,535.53	421,487.60
	April	2,254.31	111,589.76	248,738.52	360,328.27
	May	4,196.33	135,770.44	213,334.13	349,104.57
	June	3,221.40	132,022.70	299,910.04	431,932.74
	July	3,654.76	145,143.22	236,188.51	381,331.74
	August	3,833.69	192,443.07	251,860.09	444,303.16
	September	4,064.33	195,066.03	233,576.58	428,642.61
	October	5,780.28	132,715.77	240,488.64	373,204.41
	November	5,763.80	157,228.03	244,406.53	401,634.56
	December	5,431.37	147,184.91	217,474.99	364,659.90
2015	January	6,018.57	181,685.28	232,190.99	413,876.26
	February	4,583.11	160,666.54	171,718.44	332,384.99
	March	4,840.83	153,045.71	225,957.71	379,003.42
	April	2,287.63	105,411.73	157,958.04	263,369.76
	May	4,695.00	134,607.40	228,910.15	363,517.55
	June	5,485.38	128,960.55	223,160.72	352,121.27
	July	5,729.24	140,145.23	177,187.57	317,332.80
	August	5,525.95	117,743.72	321,410.68	439,154.40
	September	4,842.26	127,795.98	306,662.83	434,458.81
	October	4,868.82	161,675.62	224,259.64	385,935.26
	November	6,161.23	163,954.09	301,470.83	465,424.92
	December	5,857.80	124,002.43	335,776.29	459,778.72

4.2 Level 02 Energy

In this category, Energy for the human to work and the energy for the ancillary works is included.

Table 4-6: Level 02 energy for ancillary activities

Year	MONTH	Milling		Press		Glasing		Kiln		Sorting		Sq/Pol	
		MT	kWh	MT	kWh	MT	kWh	MT	kWh	MT	kWh	MT	kWh
2014	January	6007.15	35002.01	5821.02	1520.06	5442.51	3546.82	5378.72	8117.14	4419.45	9556.14	959.27	10944.46
	February	5322.51	30636.25	5156.32	1567.59	4820.89	3126.64	4763.26	7240.46	2100.69	4449.17	2662.57	7554.91
	March	6334.75	36462.66	6139.08	1866.36	5739.95	3722.71	5673.22	8623.66	1763.22	3734.43	3909.99	11094.42
	April	2531.56	14571.57	2446.66	743.81	2286.85	1483.16	2254.31	3426.70	756.77	1602.80	1497.55	4249.21
	May	4691.86	27006.22	4544.04	1381.45	4248.29	2755.28	4196.33	6378.69	1867.73	3955.77	2328.60	6607.29
	June	3607.35	20763.82	3491.12	1061.34	3263.62	2116.65	3221.40	4896.74	1166.90	2471.45	2054.50	5829.55
	July	4089.41	23538.56	3959.14	1203.63	3701.31	2400.52	3654.76	5555.47	360.56	763.65	3294.20	9347.14
	August	4288.46	24684.26	4152.39	1262.38	3882.03	2517.73	3833.69	5827.45	1293.60	2739.80	2540.09	7207.38
	September	4545.02	26161.04	4401.48	1338.11	4114.98	2668.81	4064.33	6178.05	732.13	1550.62	3332.20	9454.96
	October	6453.85	37148.19	6254.71	1901.51	5848.09	3792.84	5780.28	8786.40	3473.03	7355.72	2307.26	6546.73
	November	6435.51	37042.66	6236.91	1896.10	5831.44	3782.04	5763.80	8761.35	1930.69	4089.11	3833.11	10876.28
	December	6065.71	34914.10	5877.88	1786.95	5495.68	3564.28	5431.37	8256.03	2498.76	5292.26	2932.61	8321.14
2015	January	6718.92	38673.94	6512.06	1979.75	6088.76	3948.93	6018.57	9148.62	3040.72	6440.12	2977.85	8449.51
	February	5122.11	29482.75	4961.76	1508.44	4638.94	3008.64	4583.11	6966.62	3015.64	6386.99	1567.47	4447.63
	March	5408.80	31132.91	5240.10	1593.06	4899.24	3177.45	4840.83	7358.37	3212.01	6802.90	1628.82	4621.69
	April	2568.62	14784.89	2482.64	754.75	2320.50	1504.99	2287.63	3477.34	515.27	1091.32	1772.36	5028.98
	May	5247.53	30204.64	5083.52	1545.46	4752.81	3082.49	4695.85	7138.00	3250.00	6883.36	1445.00	4100.12
	June	6125.80	35259.95	5936.21	1804.68	5550.24	3599.66	5485.38	8338.13	3445.50	7297.42	2039.88	5788.07
	July	6397.06	36821.33	6199.57	1884.75	5796.53	3759.40	5729.24	8708.80	3040.72	6440.12	2688.51	7628.53
	August	6170.92	35519.68	5980.02	1818.00	5591.21	3626.24	5525.95	8399.79	3043.78	6446.60	2482.16	7043.02
	September	5410.39	31142.06	5241.64	1593.53	4900.68	3178.39	4842.26	7360.54	3015.64	6386.99	1826.62	5182.94
	October	5439.93	31312.12	5270.32	1602.25	4927.51	3195.79	4868.82	7400.91	2885.43	6111.21	1983.39	5627.77
	November	6877.62	39587.39	6666.13	2026.59	6232.85	4042.38	6161.23	9365.47	2229.12	4721.17	3932.12	11157.19
	December	6540.08	37644.52	6338.42	1926.96	5926.38	3843.62	5857.80	8904.23	3212.01	6802.90	2645.79	7507.30

Table 4 -7: Level 02 energy for labour activities

Year	MONTH	Milling	Pressing	Glazing	Kiln	Sorting	Squaring/Pol
		kWh	kWh	kWh	kWh	kWh	kWh
2014	January	2103.11	1352.00	3397.33	2912.00	2903.33	3640.00
	February	2022.22	1305.78	3345.33	2946.67	2883.11	3466.67
	March	1964.44	1331.78	3408.89	2940.89	2903.33	3512.89
	April	1978.89	1357.78	3380.00	2914.89	2868.67	2914.89
	May	1993.33	1323.11	3374.22	2883.11	2614.44	3348.22
	June	2022.22	1343.33	3411.78	2880.22	2611.56	3221.11
	July	2108.89	1314.44	3120.00	2903.33	2597.11	3484.00
	August	2080.00	1334.67	3235.56	2894.67	2582.67	3489.78
	September	1993.33	1357.78	3374.22	2877.33	2891.78	2914.89
	October	2022.22	1224.89	3382.89	2906.22	2857.11	3221.11
	November	2028.00	1334.67	3394.44	2891.78	2761.78	3484.00
	December	2056.89	1297.11	3365.56	2883.11	2894.67	3495.56
2015	January	2007.78	1305.78	3348.22	2886.00	2888.89	3463.78
	February	1964.44	1326.00	3354.00	2906.22	2787.78	3345.33
	March	1990.44	1360.67	3319.33	2903.33	2906.22	3481.11
	April	2082.89	1297.11	3377.11	2900.44	2894.67	3495.56
	May	2016.44	1326.00	3408.89	2891.78	2857.11	3536.00
	June	2051.11	1343.33	3403.11	2883.11	2894.67	3423.33
	July	2065.56	1328.89	3385.78	2874.44	2914.89	3460.89
	August	2054.00	1314.44	3406.00	2917.78	2888.89	3472.44
	September	2007.78	1326.00	3374.22	2906.22	2883.11	3492.67
	October	1987.56	1354.89	3377.11	2917.78	2582.67	3466.67
	November	1990.44	1357.78	3380.00	2883.11	2894.67	3460.89
	December	2028.00	1326.00	3385.78	2920.67	2923.56	3423.33

Table 4-8: Level 02 Total Energy

Year	Month	Milling		Pressing		Glazing		Kiln		Sorting	
		MT	KWh	MT	KWh	MT	KWh	MT	KWh	MT	KWh
2015	January	6,007.15	46,752.45	5,821.02	3,618.80	3,397.33	11,057.83	5,378.72	13,896.72	5,378.72	34,075.35
	February	5,322.51	41,149.68	5,156.32	3,620.44	3,345.33	10,216.83	4,763.26	12,835.78	4,763.26	23,125.87
	March	6,334.75	48,418.15	6,139.08	4,029.65	3,408.89	11,443.46	5,673.22	14,571.33	5,673.22	26,768.80
	April	2,531.56	20,853.58	2,446.66	2,648.01	3,380.00	7,099.23	2,254.31	7,990.40	2,254.31	14,660.81
	May	4,691.86	36,539.44	4,544.04	3,407.74	3,374.22	9,538.90	4,196.33	11,669.87	4,196.33	20,822.42
	June	3,607.35	28,710.41	3,491.12	3,029.89	3,411.78	8,357.81	3,221.40	9,798.97	3,221.40	17,808.42
	July	4,089.41	32,315.79	3,959.14	3,172.77	3,120.00	8,536.20	3,654.76	10,658.09	3,654.76	20,401.79
	August	4,288.46	33,722.96	4,152.39	3,272.28	3,235.56	8,907.25	3,833.69	10,989.87	3,833.69	20,184.72
	September	4,545.02	35,474.52	4,401.48	3,396.81	3,374.22	9,372.58	4,064.33	11,409.78	4,064.33	21,183.44
	October	6,453.85	49,354.72	6,254.71	3,939.26	3,382.89	11,545.60	5,780.28	14,732.70	5,780.28	25,175.65
	November	6,435.51	49,229.03	6,236.91	4,070.77	3,394.44	11,539.39	5,763.80	14,682.94	5,763.80	26,726.07
	December	6,065.71	46,583.45	5,877.88	3,885.92	3,365.56	11,084.12	5,431.37	14,035.31	5,431.37	25,204.57
2016	January	6,718.92	51,258.97	6,512.06	4,139.76	3,348.22	11,802.16	6,018.57	15,163.62	6,018.57	26,765.29
	February	5,122.11	39,623.47	4,961.76	3,571.39	3,354.00	10,000.76	4,583.11	12,439.78	4,583.11	21,379.34
	March	5,408.80	41,735.43	5,240.10	3,721.69	3,319.33	10,281.80	4,840.83	12,929.75	4,840.83	22,443.02
	April	2,568.62	21,253.40	2,482.64	2,585.35	3,377.11	7,137.57	2,287.63	8,036.01	2,287.63	15,763.25
	May	5,247.53	40,598.56	5,083.52	3,618.03	3,408.89	10,211.97	4,695.85	12,637.52	4,695.00	21,894.50
	June	6,125.80	47,011.94	5,936.21	3,966.50	3,403.11	11,199.50	5,485.38	14,138.77	5,485.38	24,448.39
	July	6,397.06	48,997.48	6,199.57	4,049.18	3,385.78	11,484.92	5,729.24	14,594.89	5,729.24	25,759.97
	August	6,170.92	47,342.84	5,980.02	3,946.88	3,406.00	11,254.25	5,525.95	14,260.14	5,525.95	25,012.20
	September	5,410.39	41,768.79	5,241.64	3,678.60	3,374.22	10,352.76	4,842.26	12,936.12	4,842.26	22,611.60
	October	5,439.93	41,957.59	5,270.32	3,725.99	3,377.11	10,389.87	4,868.82	13,001.55	4,868.82	22,413.28
	November	6,877.62	52,388.07	6,666.13	4,264.30	3,380.00	12,021.95	6,161.23	15,433.21	6,161.23	28,014.74
	December	6,540.08	49,987.38	6,338.42	4,098.73	3,385.78	11,646.91	5,857.80	14,899.37	5,857.80	26,027.93

4.3 Level 03 Energy

This is the energy used for transportation of the raw materials from the mines to the factory. The factory is situated in Horana.

Feldspar is from Balangoda, Dolamite from Mathale, Ball clay Kaluthara. Silica sand from Naththandiya.

The data were collected from the running charts, record books and various documents maintained by the trucks.

Table 4-9: Level 03 Total Energy for transportation

Year	Milling (Ball Mill+ SD)										
	Feldspar		Dolamite		Ball Clay		Silica Sand			Total Diesel Lts	Total Energy kWh
	No of trips 15 Ton/Trip	Diesel	No of trips 15 Ton/Trip	Diesel Lts	No of trips 15 Ton/Trip	Diesel Lts	64.71 14.00	No of trips 15 Ton/Trip	Diesel		
2015	187.98	5153.93	20.43	2195.79	143.03	4453.10	858.16	57.21	4664.38	16467.20	
	166.55	4566.53	18.10	1945.53	126.73	3945.58	760.36	50.69	894.18	11351.82	115036.66
	198.23	5435.00	21.55	2315.53	150.83	4695.95	904.96	60.33	65235.08	77681.56	787206.26
	79.22	2171.99	8.61	925.36	60.28	1876.64	361.65	24.11	23098.69	28072.68	284481.75
	146.82	4025.45	15.96	1715.01	111.71	3478.07	670.27	44.68	50951.55	60170.08	609749.20
	112.88	3094.98	12.27	1318.59	85.89	2674.13	515.34	34.36	15655.21	22742.91	230471.22
	127.97	3508.58	13.91	1494.80	97.37	3031.48	584.20	38.95	32891.91	40926.76	414741.99
	134.20	3679.35	14.59	1567.55	102.11	3179.03	612.64	40.84	26519.94	34945.88	354133.15
	142.23	3899.47	15.46	1661.34	108.21	3369.23	649.29	43.29	31862.54	40792.57	413382.13
	201.96	5537.18	21.95	2359.07	153.66	4784.24	921.98	61.47	47446.37	60126.85	609311.05
	201.38	5521.45	21.89	2352.36	153.23	4770.65	919.36	61.29	50142.10	62786.56	636263.95
	189.81	5204.17	20.63	2217.19	144.42	4496.51	866.53	57.77	67109.47	79027.35	800844.22
2016	210.25	5764.60	22.85	2455.96	159.97	4980.74	959.85	63.99	74125.21	87326.50	884945.83
	160.28	4394.60	17.42	1872.28	121.96	3797.02	731.73	48.78	53261.61	63325.50	641725.46
	169.25	4640.56	18.40	1977.07	128.78	4009.54	772.69	51.51	62299.34	72926.52	739019.83
	80.38	2203.78	8.74	938.90	61.16	1904.11	366.95	24.46	22554.40	27601.20	279703.98
	164.21	4502.20	17.85	1918.12	124.94	3889.99	749.65	49.98	48656.25	58966.56	597552.96
	191.69	5255.73	20.84	2239.15	145.85	4541.06	875.11	58.34	26973.98	39009.91	395317.10
	200.18	5488.46	21.76	2338.31	152.31	4742.14	913.87	60.92	57546.43	70115.34	710532.04
	193.10	5294.44	20.99	2255.65	146.93	4574.51	881.56	58.77	64803.15	76927.75	779567.31
	169.30	4641.93	18.40	1977.65	128.82	4010.72	772.91	51.53	59332.42	69962.72	708985.44
	170.23	4667.28	18.50	1988.45	129.52	4032.62	777.13	51.81	57547.55	68235.90	691486.22
	215.22	5900.76	23.39	2513.97	163.75	5098.38	982.52	65.50	63789.54	77302.64	783366.41
	204.66	5611.16	22.25	2390.58	155.72	4848.16	934.30	62.29	60990.13	73840.03	748277.19

5 ANALYSIS OF DATA

The energy demand to the factory is proportional to the production output of the plant in all three manufacturing plants

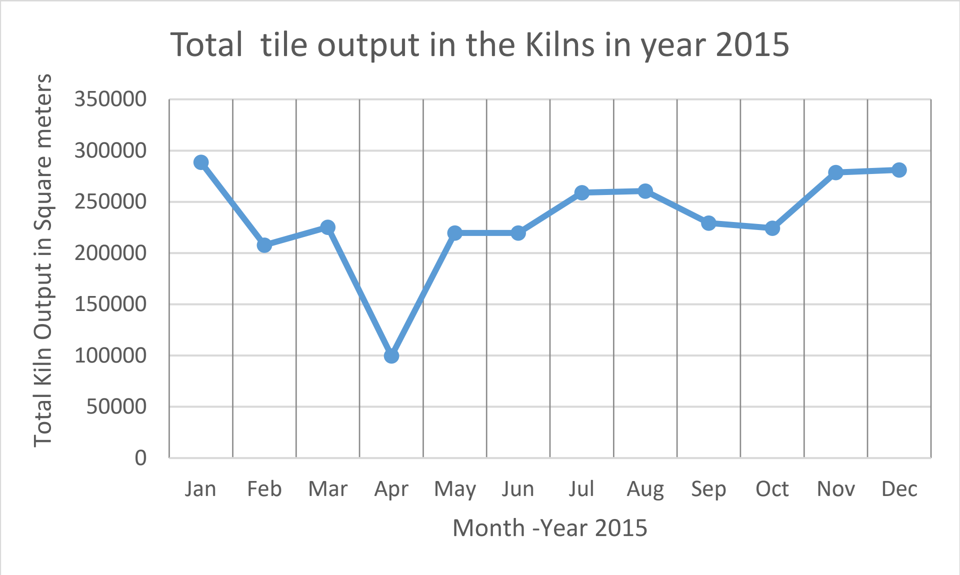

Figure 5-1: Tile production in RPL plant in the year 2015

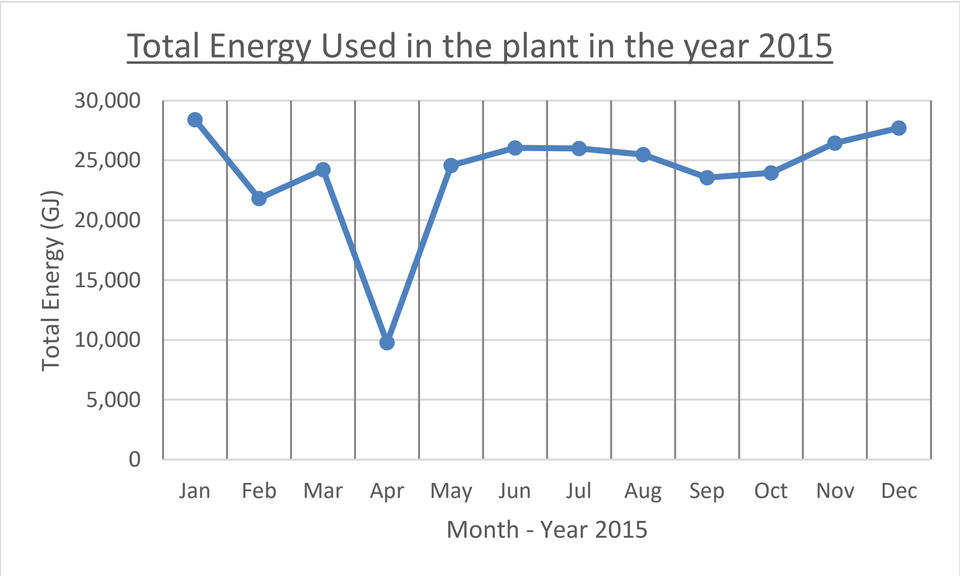

Figure 5-2: Energy Demand for the RPL Factory in the year 2015

Figure 5-1 and Fig 5-2 shows the production in Square meters of floor tiles and the total Energy consumed in RPL factory in the year 2015. The energy demand curve shows the same pattern as that of the production curve.

5.1 Average monthly energy level 01

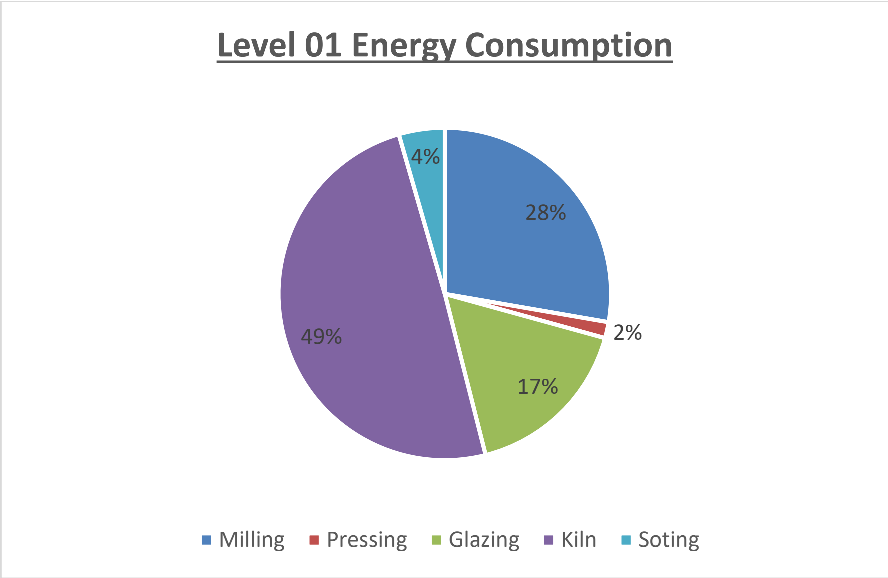

Figure 5-3: Level 01 Energy consumption

The Kiln department consumes 49% of Leve 01 energy of the embedded energy as per the pie chart shown in the Figure 5-3. The main source of energy for this process is LPG

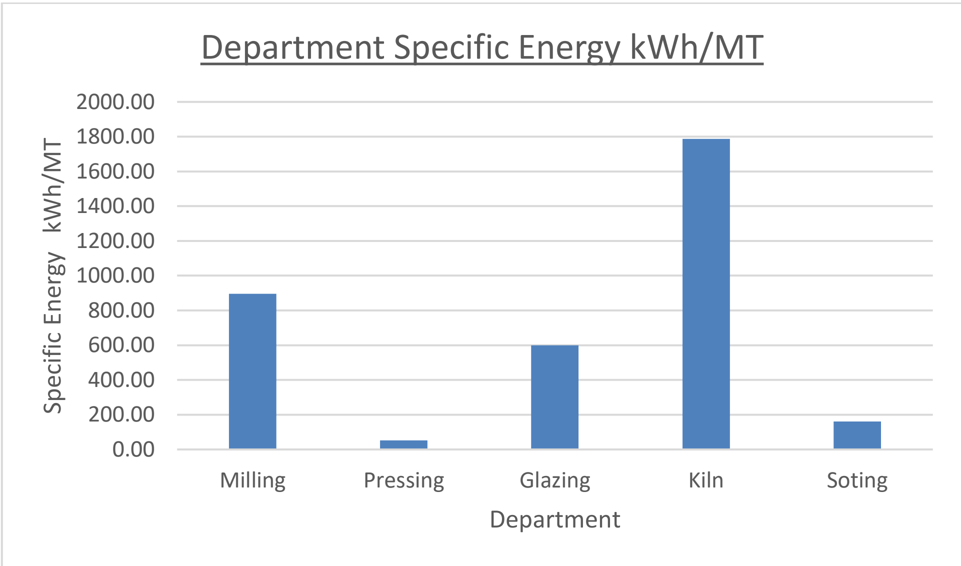

Figure 5-4: Department wise Specific Energy

The highest specific energy is recorded in the kiln department. According to the Figure 5-4 the specific energy is highest in the kiln and lowest in the pressing section.

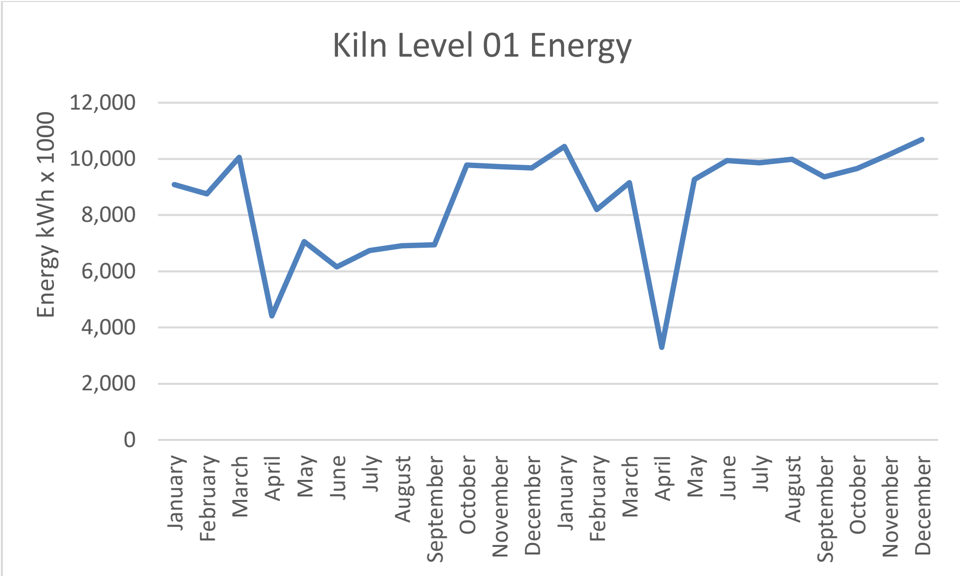

Figure 5-5: Level 01 energy for the Kiln

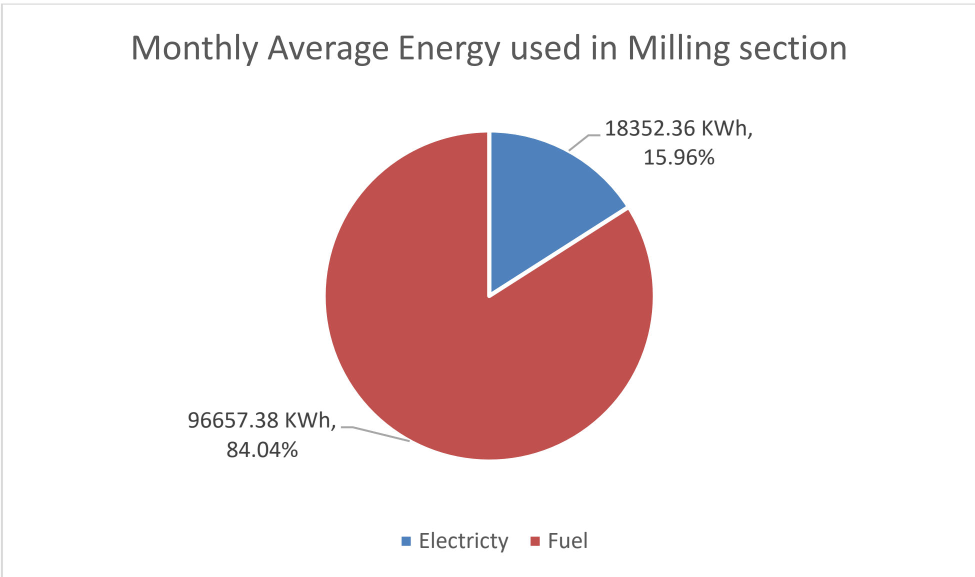

Figure 5-6: Monthly Average energy for the Milling

Figure 5-6 shows the composition of Level 01 energy in the Milling department. 84% of Level 01 energy is from LPG and kerosene while 16% balance is in the form of electricity.

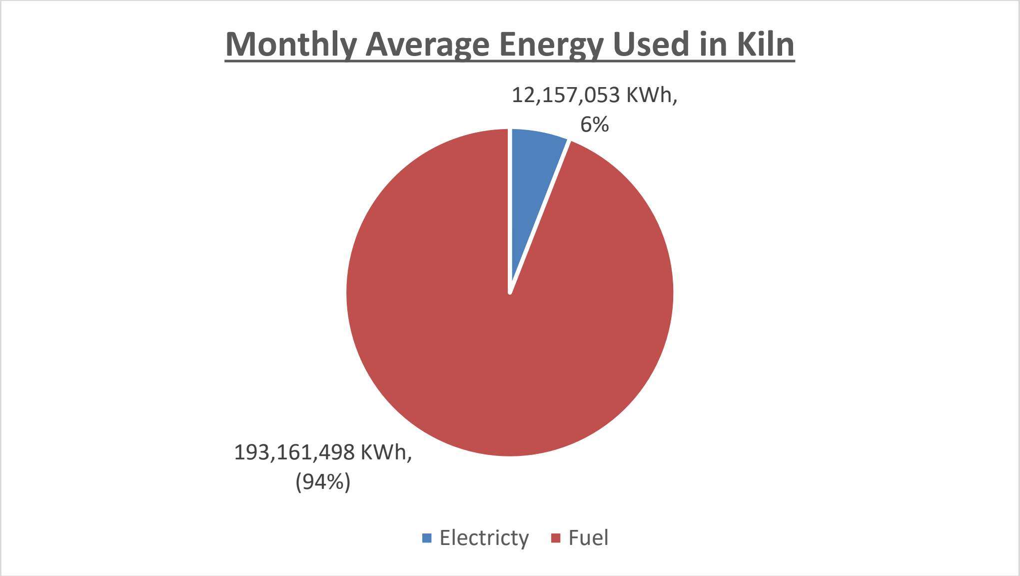

Figure 5-7: Monthly Average energy for the Kiln

Figure 5-7 shows the composition of Level 01 energy in the kiln department. 94% of Level 01 energy is from LPG and kerosene while 6% balance is in the form of electricity.

5.2 Level 01 Energy as embedded energy

Table 5-1: Department wise embedded specific level 01 energy

Department	Specific Energy (KWh/MT)	Monthly Average Energy (MWh)
Milling	895.71	4792.00
Pressing	52.12	270.00
Glazing	598.31	2899.00
Kiln	1786.74	8555.00
Sorting	161.17	772.00

Table 5-2: Department wise embedded specific level 02

Department	Specific Energy (kWh/MT)	Monthly Average Energy (MWh)
Milling	15.47	82752.34
Pressing	1.41	7288.23
Glazing Line	6.11	20540.30
Kiln	5.36	25645.21
Sorting	9.72	46555.95

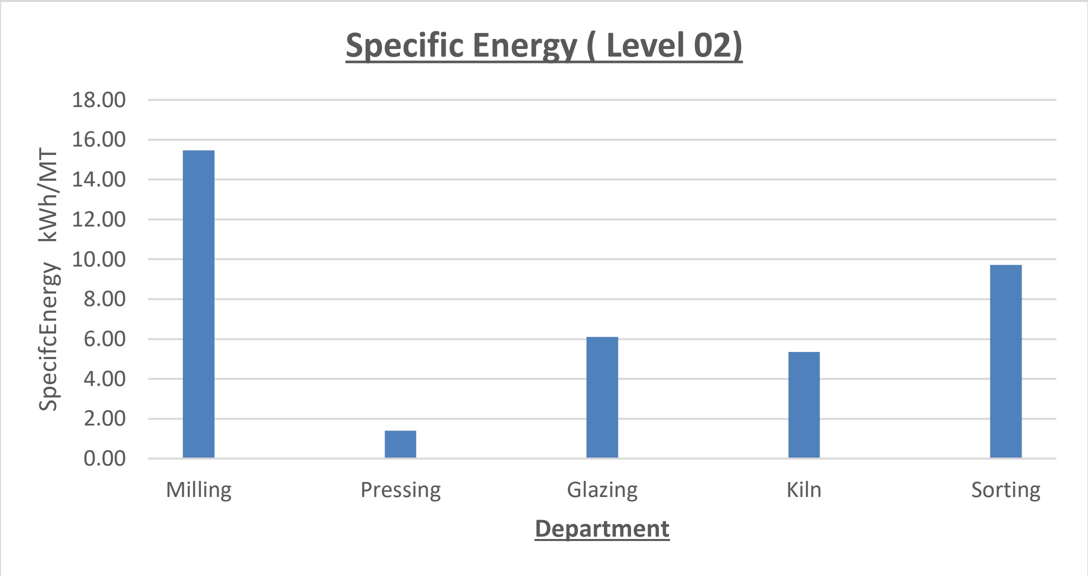

Figure 5-8: Level 02 Specific Energy

Figure 5-8 shows the Level 02 specific energy. The highest specific level 02 energy is recorded in the milling department. This is because the amount of manual work in this department is higher than other departments. Some processes cannot be automated as they need more people involvement.

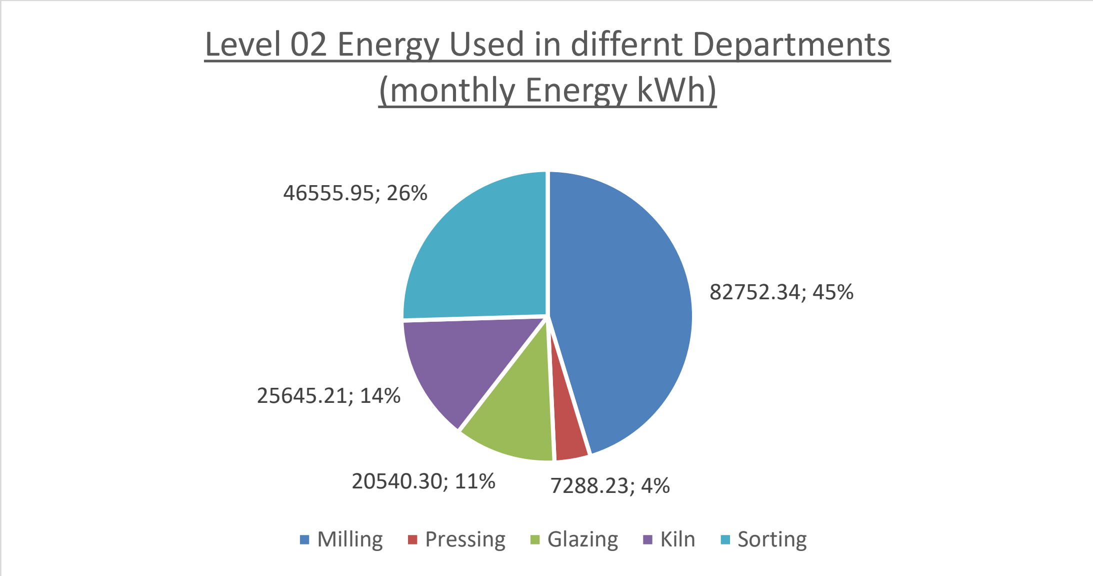

Figure 5-9: Level 02 average monthly energy for different departments

Figure 5-9 shows the average monthly Level 02 Energy demand for different departments. The highest level 2 energy demand is recorded in the Milling department. The second highest is Sorting department. Labour involvement for the activities in these two particular departments are high.

<u>Level 03 Energy</u>

Monthly Average Energy for raw Material Transport

=26,765,951.92 kWh/24

=1,115,248 kWh

Specific Energy for transport =26,765,951.92 kWh/114,911.30 MT

=232.93 kWh/MT

5.3 Calculation of Embedded Energy

The embedded Energy is expressed in MJ /kg for the material.

Embedded Energy = Level 01 Energy + Level 02 Energy + Level 03 Energy

Level 01 embedded Energy =Milling + Pressing +Glazing+ Kiln +Sorting

	=895.7 + 52.12 +598.3+1786.74+161.16 kWh/MT
	=3494.02 kWh/MT
	=12.58 MJ/Kg
Level 02 embedded Energy	=Milling + Pressing +Glazing+ Kiln +Sorting
	=15.46+1.4+6.1+5.36+9.72 kWh/MT
	=38.08 kWh/MT
	=0.14 MJ/Kg
Level 03 Embedded Energy	=232.92 kWh/MT
	=0.84 MJ/Kg

Table 5-3 Embedded Energy Level 01,02 and 03 of the Three factories

	Specific Energy MJ/kg		
	RPL Factory	**RCL Factory**	**LTL Factory**
Level 01	**12.58**	**14.00**	**13.4**
Level 02	**0.14**	**0.20**	**0.16**
Level 03	**0.84**	**0.94**	**0.90**

Embedded Energy	= Level 01 + Level 02 + Level 03
	=12.58+0.14+0.84 MJ/kg
	=13.56 MJ/kg

5.4 Benchmark embedded energy for local tile factories

In this approach to arrive at a figure for a benchmark value for the energy embedded in floor tile, a substantial amount of literature had been reviewed. Referring to past research literature, decided to accept the figure 11 MJ/kg as the benchmark and proceed with further analysis on

Sri Lankan context. [Geoff Hammond "Inventory of Carbon and Energy", Department of Mechanical Engineering, University of Bath, UK]

Table 5-4: Embedded Energy Bench mark value and the local Values

	Embedded Energy MJ/kg
Bench mark Value	11.00
RPL	13.56
RCL	15.14
LTL	14.46

5.5 Reasons for the Variations

When the derived figures are tabulated in above table, it is easily visible that there is a substantial variation in actual figures among each factory as well as against the set benchmark value.

There are multitudes of reasons for the variations between plants. Royal Ceramic Lanka Limited (RCL) factory is 20 years old. Whereas Lanka tile factory LTL is more than 25 years old.

RPL factory situated in Horan is about 15 years old. So, the RPL factory is fairly new in comparison to others.

RPL factory is having automated most of the activities in the sorting area. For example, the tile sorting machine is coupled to an automatic palatizing machine, which acts as a robot.

But in the other factories the same activity is done by manual work. So, the Level 01 energy of the embedded energy is increased.

Similarly, the main raw material clay is being supplied from Kaluthara Area.

The distance from Kaluthara to Eheliyagodea is higher than Kaluthara to Horana.

That leads to higher Level 03 energy to the embedded energy of the tiles manufactured in Eheliyagoda factory.

Even though the Lanka tile factory (LTL) is more than 35 Years old, it has been undergone few renovations and upgrading.

6 SENSITIVITY ANALYSIS

Sensitivity analysis is an essential part to see the different percentages and combinations. The objective of doing a sensitivity analysis is to cover the various sources of uncertainty resulting from mathematical simplification (for instance linearization of various parameters), adopted assumptions and estimations made to prepare some input data.

The results of sensitivity analysis are very useful for policy formulation of energy sector as it helps in identifying the weight of different economic, technical, financial and environmental dimensions and their implications.

Table 6-1: Level 01 Specific Energy for different Energy Sources

Department	Energy Type		MJ/Kg
Milling	Fuel	MF-1	2.91
Milling	Electricity	ME-1	0.55
Pressing	Fuel	PF-1	0.00
Pressing	Electricity	PE-1	0.24
Glazing	Fuel	GF-1	1.85
Glazing	Electricity	GE-1	0.24
Kiln	Fuel	KF-1	5.86
Kiln	Electricity	KE-1	0.37
Sorting	Fuel	SF-1	0.34
Sorting	Electricity	SE-1	0.21

Table 6-2: Level 02 Specific Energy for different Energy Sources

Department	Energy Type		MJ/Kg
Milling	Labour	ML--2	0.00
Milling	Ancillary	MA-2	0.06
Pressing	Labour	PL-2	0.00
Pressing	Ancillary	PA-2	0.00
Glazing	Labour	GL-2	0.01
Glazing	Ancillary	GA-2	0.01
Kiln	Labour	KL-2	0.01
Kiln	Ancillary	KA-2	0.01
Sorting	Labour	SL-2	0.01
Sorting	Ancillary	SA-2	0.02

To achieve internationally accepted embedded energy of 11 MJ/kg, the local tile manufacturing plants need some changes to be undergone in their machineries and the practicing processes to minimize department wise wastages.

The embedded energy of locally manufactured tiles is found as 13.56 MJ/kg,15.14MJ/kg, and 14.46 MJ/kg for RPL, RCL and LTL factories respectively. Different options and combinations of energy sources are used at Level 01, Level 02 and Level 03 to run the production process. As an example, the energy at Level 01 is supplied by Thermal power and from Electricity while the same at level 02 is achieved majorly through the labor. In addition, the energy from ancillary services are counted.

An approach had been taken to find out different combinations of energy sources and their volumes used for supplying of energy at each level so that to identify the possibilities of reaching the set benchmark figure of 11 MJ/kg for the embedded energy in floor tiles under the sensitivity analysis. This analysis will lay the foundation to prepare the plan and road map to improve the energy efficiency in floor tile manufacturing.

According to the table 5-3, it is obvious that the contribution to the embedded energy from the level 01 energy is significant.

From that also the thermal energy portion is contributing to the embedded energy immensely.

Table 6-3: Different combinations and percentage reduction

Parameter	Percentage Reduction	Expected Embedded Energy MJ/Kg
Kiln Fuel	10%	13.12
Kiln Fuel	15%	12.68
Spray Dryer Fuel	10%	13.26
Spray Dryer Fuel	15%	13.12
Kiln fuel+Spray dryer fuel	10%	12.68
Kiln fuel+Spray dryer fuel	15%	12.24
Glsing line Fuel	10%	13.37
Glsing line Fuel	15%	13.28
Kiln+Glasizing+Spry Dryer	10%	10.26
Kiln+Glasizing+Spry Dryer	15%	11.96
Kiln+Glasizing+Spry Dryer	20%	11.42

The table summarizes the embedded energy for different options for the level 01 energy changes. If the thermal energy consumption for the Kiln, Glazing line and spray dryer is reduced by 20 %, the total embedded energy will be 11.42 MJ/Kg

7 CONCLUSIONS AND RECOMENDATIONS

The embedded energy of floor tiles manufactured in the country is higher than that of the internationally accepted value. Out of the three floor tile manufacturing plants, Royal Porcelain limited (RPL) records the lowest embedded energy value of 13.56 MJ/Kg

Approaching the bench mark value of embedded energy of 11 MJ/Kg has many advantages. In a way the reduced embedded energy means that the manufacturing process is very energy efficient.

So, the wastages are very less. Such a production process uses the fossil fuel very carefully and helps to save the fossil fuel reserves.

On the other hand, less wastage means saving money to the manufactures. The profitability will be high. So, the manufactures profit will be high.

Similarly, when the production cost is less the selling price too will be lowered. Then the consumers will receive the goods at a lesser price.

Achieving the world standard bench has many advantages as listed below.

Save the fossil fuel reserves

Manufactures profitability Increases

Customer will get a price reduction

A considerable investment is required to do the modifications or purchasing of new energy efficient machines

- By installing new machines
- By install new thermal insulations
- Adopt Heat recovery system to use waste heat

7.1 Replacement of less efficient machines with new machines

The present machines are with weak thermal insulations. Thermal losses due to conductive losses. And also, the firing efficiencies of the burners are low due to the deteriorations of the burners.

Figure 7-1: Weak thermal insulations

The thermal efficiency of the spray dryer is 2.1 MJ/Kg and 4.8 MJ/Kg in the kiln. New machines are more efficient, thermal efficiency of a new spray dryer is 1.4 MJ/Kg and that of a new kiln is 2.5MJ/kg.

Table 7-1: Thermal Consumption comparison

	CIF Value/Euro	**Thermal Consumption MJ/Kg**	
		New Machine	**Existing Machine**
Spray dryer	**178,700.00**	**1.4**	**2.1**
Kiln	**750,000.00**	**2.5**	**4.8**

Annual Saving due to reduction in Fuel =15 Million Rs

Pay Back period = Investment/Saving

=9 Years.

Investment payback period is higher than the investment policy of the company.

7.2 Heat recovery System

Exhaust chimney carries lots of energy as the kiln flue gases. Because of the sulfur contents in the flue gas, it is not being used.

With the use of a heat exchanger that exhaust gas can be reused. The stack temperature is in the range of 200 Celsius. The hot air from the heat exchanger can be used as the secondary air in the kiln burners as well as the burners in the spray dryers and horizontal dryers. This will save substantial amount of fuel. The investment for this kind of heat recovery system can be recovered with in less than three years.

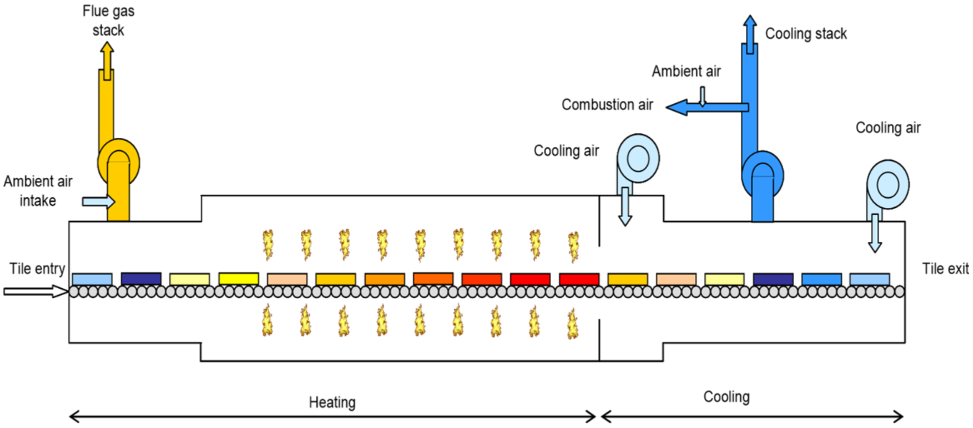

Figure 7-2: Exhaust flue gas system in a LPG fired Kiln

7.3 Heat recovery System calculation

Heat recovery H	$= m\,C\,\Delta T$
Stack temperature t_1	=211 C
End process temperature t_2	=60 C
Heat	=3.540 x 0.266 x (211-60)
	=142 kCal/s
LPG Saving	=46 kg/h
Annual saving	=46kg/hx350daysx 24x 124 Rs/kg
	=47,913,600.00 Rs/year
Estimated cost for the Electricity	=2,735,436.00 Rs/Year
Net Annual Saving	=45,178,164.00 Rs

7.4 Investment for the Heat recovery system

This installation comprises two components as local and foreign components.

Foreign component includes the total technical design, SCADA system, Main control components including al the servo controllers, Motors, Dampers.. etc.

The local component includes supplying of insulated air ducts and labour for the complete project.

Investment for the foreign component	=46,334,400 Rs
Investment for the Local component	=23,000,000 Rs
Payback period	=1.5 Years
Average LPG consumption of a Plant	=298.5 kg
Saving per Hour	=46.0 kg
Percentage reduction in LPG usage	= 46.0/298.5
	= 15.5 %

According to sensitivity analysis 15% reduction in the thermal energy leads to achieve the imbedded energy of 11kg/MJ

7.5 Overall conclusion

The Heat recovery system for the plant is the best option recommended in order to reach the embedded energy 9 MJ/kg. Other countries have achieved this value because of their high thermal efficiency and also the economies of scale effect due to their mass scale production compared to Sri Lanka.

To achieve the low embedded energy value the small-scale manufacturers, have to consider a high thermal efficient manufacturing process. The heat recovery system is the most suitable option that the local manufactures have to adopt.

Reduction of the embedded energy has in many aspects

- **Save the environment due to less consumption of petroleum products**
- **Low priced product to the customers**
- **Increase in profit to the manufactures**

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