7. CONCLUSION

The main focus of this study was to assess the embedded energy contained in wall tiles produced by using the technology of fast and conventional firing in Sri Lanka. In addition to that other facts of energy conservation techniques, advantages and disadvantage of two technologies, energy efficient output levels were discussed.

The contribution of embedded energy to the cost of production is 30% to 40% which is in increasing trend due to increase of fuel prices. Considering this hindrance, energy conservation techniques and new innovations have been considered for reducing embedded energy in ceramic industry. Process improvements and machinery improvements are the two major factors which can significantly reduce embedded energy in the manufacturing process.

Double firing method has been used in the process to manufacture wall tiles in Sri Lanka which consume massive quantity of energy. The latest method of single firing has been considered in most of the other countries which has remarkable reduction in energy consumption and the identified adverse effect is reduction of output yields. However the single firing method is being used to manufacture floor tiles in Sri Lanka, because of its low energy consumption when compared to the double firing method, even though the output yield is low. Therefore the conversion of double firing to single firing is one method which is a solution for the reduction of embedded energy substantially.

The latest innovations launched for ceramic machinery such as double layer kilns, regulating conveyer speeds by variable speed drives, utilization of waste heat recovery methods for drying tiles, improving of kiln furniture with high emissive refractory to economize heat wastage, using of soft starters to rotate ball mills, using of energy efficient motors for driving of machinery, using of high velocity high efficient burners for the kilns heating purpose and using the technology of gas and air modulation in kiln firings could too significantly contributed to reduce embedded energy of the system.

By caring out proper energy audits in the existing ceramic plants one could identify the real potential which could be addressed to economize the energy consumption. Further the alternative energy sources such as solar, coal and biomass can be considered to use for heating spray dryer and

biscuit kilns. Already coal and wood gasification have been used in ceramic industry by many countries such as India, Indonesia for the operation of spray dryer and biscuit kilns.

Implementation of basic energy conservation techniques to the plants exist can be saved 5 to 10 percent electrical energy and 2 to 3 percent of thermal energy. Improving of combustion air is a no cost project which can be implemented through a controlling of combustion air according to the air fuel ratio. Introduction of variable speed drives to the compressed air system and blowers of the spray dryer are the other potential available which can be implemented.

As for the overall conclusion, the fast firing technology is the best energy efficient technology for manufacture wall tiles in Sri Lanka on the basis of final results. Embedded energy in fast and conventional firing technology is 9 GJ/MT and 16 GJ/MT respectively.

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Appendix A

LEVEL 1 ENERGY ANALYSIS.

Specimen calculation of level 1 energy of conventional firing technology.

(i) Direct Energy in Conventional Firing Technology

Density of Kerosene oil	=	800 kg/ m^3
Heating value of Kerosene oil	=	45 MJ / kg.
Density of Furnace oil	=	910 kg/m^3
Heating value of furnace oil	=	44 MJ
Density of LPG	=	550 kg/m^3
Heating value of LPG	=	46 kg/m^3

a.	The average kerosene oil consumptions per month	=	323.23 m^3
	Energy in kerosene oil	=	323.23 x 800 x 45
		=	11,636,280 MJ
b	The average electricity consumption per month	=	320,171 kwh.
	Energy in electricity	=	320,171 x 3.6
		=	1,156,615 MJ
c.	. The average furnace oil consumption per month	=	11,910 Lt.
	Energy in furnace oil	=	11,910 x 910 x 44 kg/m^3
		=	476,872 MJ.
	Total direct energy consumption per month	=	a + b + c
		=	13,269,767 MJ
d.	Average nos. of square meters produced per month	=	86,276 Sqm.
e.	Average direct energy per square meter	=	13,269,767 / 86,276
		=	153.86 MJ / Sqm

Table A1, Level 1 Energy in Fast Firing Technology

No	Energy source	Direct energy in fast firing (MJ) per month
1	Kerosene oil	2,576,520
2	Electrical	1,579,721
3	Furnace oil	-
4	LPG	7,795,252
	Total energy	11,951,495

Appendix B

LEVEL 2 ENERGY ANALYSES.

(i) Fast Firing Technology.

No of wheel loaders in the plant.	=	01 Nos.
Average fuel consumption per months.	=	1300 Lt.
Average hydraulic consumption per month.	=	70 Lt
Average oil consumption per month	=	50 Lt.
Average man days per month	=	78 Nos.
Average energy consumed by a labour per day	=	2500 kcal or 10.4 MJ
Density of diesel fuel	=	850 kg/m^3
Heating value of diesel fuel	=	45 MJ /kg

Assumptions

Embedded energy of spare parts was not considered for the calculations.

Embedded energy of oil was not considered.

(a.) Energy consumption for raw materials loading.

Loading of raw materials to the loading point at the start of the process is done by a wheel loader.

Bucket capacity of the loader is one cubic meter.

i. Energy consumed by the loader per month $\;=\;$ 1.3 x 850 x 45 MJ

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad = \;$ 49,725 MJ

ii. Energy on transportation of oil $\qquad = \;$ 20ltr.x 4 /1000 x 850 x 45 + 8 x 10.4

$\qquad\qquad\qquad\qquad$ Per month $\qquad = \;$ 3143 MJ

iii. Energy of labour per month $\qquad\quad = \;$ 10.4 X 78

$\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad = \;$ 811.2 MJ

$\qquad$ Total monthly energy consumption $\quad = \;$ 53,679 MJ.

(b.) Energy consumed by the fork lifts operations

Nos. of fork lift available in the plant	=	3 Nos.
Average fuel consumption per months	=	4500 Lt.
Average hydraulic consumption per month	=	50 Lt
Average oil consumption per month	=	70 Lt.
Average man days per month	=	150 Nos.

i.	Energy of fuel per month	=	4.5 x 850 x 45 MJ
		=	172,125 MJ

ii.	Energy of labour per month	=	10.4 X 150
		=	1560 MJ
	Monthly energy consumption	=	173,685 MJ.

(c.) Energy consumption for the generator operation and services.
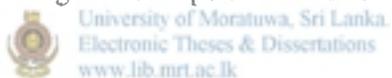
Nos. of generators available in the plant	=	2 Nos.
Labour requirement per service	=	6 Nos.
Gear oil requirement per service	=	400 Lt.
Nos. of service per year	=	10 Nos.

i.	Energy of labour on services per year	=	10.4 X 6 x 10
		=	624 MJ.

ii.	Energy on transportation of gear oil	=	80 x 850 x 45 /1000
		=	3060 MJ
	Monthly energy consumption	=	3684 MJ.

(d.) Energy consumed by hydraulic oil used for the press machines.

1. Nos. of press machine in the plant	=	02 Nos.
2. Hydraulic oil consumption per year	=	2000 Lt.

i. Energy on transportation of hydraulic oil 　　= (4 x 20 x 850 x 45 /1000 +10.40 x 4)/12

　　(Labour + transportation) 　　　　　　　= 258 MJ.

(e.) Energy consumed for servicing of compressors.

Nos. of compressors in the plant	=	03 Nos.
Gear oil consumption per year	=	225 Lt.
Operating hours	=	24 hr.

i. Energy on servicing of compressors per month = 3 x 10.4 x 4 + 0.02 x 4x 850 x 45

　　　　　　　　　　　　　　　　　　　　= 257 MJ.

(f.) Energy of labour and administration of fast firing technology.

The section of milling, spray dryer, press, biscuit, and glost kilns are operated through out the day and other sections of glazing and inspection are operated two shifts per day. In addition to that administration section is operated in general shift.

Specimen calculation of energy in administration

No of workers in crushing and weighing section	- 03
No of shifts operates	- 02
No of 8 hr. shifts per months	- 3 x 6 x 4
Energy consumed per month	- 72 x 10.4 MJ
	- 748.8 MJ

No of workers in slip preparation section	- 11
No of shifts operates	- 03
No of 8 hr. shifts per months	- 11 x 6 x 4
Energy consumed per month	- 264 x 10.4 MJ
	- 2,745.6 MJ

Table B1, Level 2 Energy of conventional Firing Technology

No	Work Description	Monthly energy consumption in MJ.
1	Energy consumed by the loader per month	45,411
2	Energy consumed by the fork lifts	149,540
3	Energy on generator operation and services	2833
4	Energy on hydraulic oil used for the press machines	10,421
5	Energy on servicing of compressors	3257
	Total energy consumed	211,462

Appendix C

LEVEL 3 ENERGY ANALYSES

(i) Energy in Raw material transportation

Fast firing technology.

Quantity of material per trip	=	12 -15 tons
Bowser capacity per trip	=	13,000 Lt.
Bowser capacity of LPG per trip	=	8 tons
Fuel consumption of a vehicle per trip	=	5 Lt.

C.1 Details of raw material transportation of fast firing technology

No	Material	Units	Average consumption per month	Nos. of trips
1	Ball clay	kg	643,441	43
2	Keoline	kg	572,252	47
3	Calcite	kg	153,381	13
4	Phyrophilite	kg	22,867	2
5	Feldspar	kg	69,398	6
6	Frit and englobe	kg	111,628	8
7	Colour stain	kg	722	1
8	Sodium silicate	kg	34,286	3
9	Ball stone	kg	4000	1
10	Silica sand	kg	297,856	20
11	LP Gas	kg	169,461	21
12	Diesel	Ltr.	13,079	1
13	Kerosene oil	Ltr.	71,573	6

(a.) Ball clay

Distance of travel to the plant	- 40 km
Required fuel volume	-10 Lt
Energy on transportation per trip	- 10/1000 x 850 x 45
	- 382 MJ.
Energy per month	- 382 x 43
	- 16,447 MJ

(b) Keoline

Distance of travel to the plant	- 110 km
Required fuel volume	- 22 Lt
Energy on transportation per trip	- 22/1000 x 850 x 45
	- 841 MJ.
Energy per month	- 841 x 47
	- 39,550 MJ

(c) Calcite

Distance of travel to the plant	- 110 km
Required fuel volume	- 22 Lt.
Energy on transportation per trip	- 22/1000 x 850 x 45
	- 841 MJ.
Energy per month	- 841 x 13
	- 10,939 MJ

(d) Phyrophilite

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 2
	- 459 MJ

(e) Feldspar

Distance of travel to the plant	- 110 km
Required fuel volume	- 22 Lt.
Energy on transpotation	- 22/1000 x 850 x 45
	- 841 MJ.

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| Energy per month | - 841 x 6 |
| | - 5046 MJ |

(f) Frit & Englob

Distance of travel to the plant	- 30 km
Required volume of fuel	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 8
	- 1836 MJ

(g) Colour stain

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 1
	- 229 MJ

(h) Sodium silicate

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 3
	- 687 MJ

(i) Ball Stone

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 1
	- 229 MJ

(j) Silica Sand

Distance of travel to the plant	- 250 km
Required fuel volume	- 50 Lt.
Energy on transportation	- 50/1000 x 850 x 45
	- 1912 MJ.
Energy per month	- 1912 x 20
	- 38,250 MJ

(k) LPG

Distance of travel to the plant	- 50 km
Required fuel volume	- 10 Lt.
Energy on transportation	- 10/1000 x 850 x 45
	- 382 MJ.
Energy per month	- 382 x 21
	- 8032 MJ

(l) Diesel

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 1
	- 229 MJ

(m) Kerosene oil

Distance of travel to the plant	- 30 km
Required fuel volume	- 6 Lt.
Energy on transportation	- 6/1000 x 850 x 45
	- 229 MJ.
Energy per month	- 229 x 6
	- 1374 MJ

Total energy in raw material transportation	- 123,307 MJ. -

(ii) Energy in Raw material transportation.
Conventional firing technology.

Average consumption of raw materials per month is shown in the following table.

Quantity of raw materials per trip	– 12 -15 tons
Quantity of fuel transport per trip	– 13,000 Lt.
Quantity of LPG transport per trip	– 8 tons
Average fuel consumption of a vehicle	– 5 km/ Lt.

C.2 Details of raw material transportation in conventional firing.

No	Material	Units	Average consumption per month	Nos. of trips
1	Ball clay	kg.	462,026	35
2	Keoline	kg.	120,842	10
3	Calcite	kg.	126,242	10
4	Phyrophilite	kg.	145,609	12
5	Feldspar	kg.	3,865	1
6	Quartz	kg.	31,125	3
7	Colour stain	kg.	692	1
8	Sodium silicate	kg.	3,819	1
9	Ball stone	kg.	1000	1
10	Silica sand	kg.	239,805	20
11	LP Gas	kg.		
12	Diesel	Lt.	8,013	1
13	Kerosene oil	Lt.	323,225	25

(a) Ball clay

Distance of travel to the plant	-150 km
Required fuel volume	-30 Lt
Energy on transportation per trip	- 30/1000 x 850 x 45
	- 1147 MJ.
Energy per month	- 1147 x 35
	- 40,145 MJ

(b) Kaolin

Distance of travel to the plant	- 10 km
Required fuel volume	- 2 Lt
Energy on transportation per trip	- 2/1000 x 850 x 45
	- 76 MJ.
Energy per month	- 76 x 10
	- 760 MJ

(c) Calcite

Distance of travel to the plant	- 10 km
Fuel consumption per trip	- 2 Lt.
Energy on transportation per trip	- 2/1000 x 850 x 45
	- 76 MJ.
Energy per month	- 76 x 10
	- 760 MJ

(d) Phyrophilite

Distance of travel to the plant	- 150 km
Fuel consumption per trip	- 30 Lt
Energy on transportation	- 30/1000 x 850 x 45
	- 1147 MJ.
Energy per month	- 1147 x 12
	- 13,764 MJ

(e) Feldspar

Distance of travel to the plant	- 10 km
Fuel consumption per trip	- 2 Lt.
Energy on transportation	- 2/1000 x 850 x 45
	- 76 MJ.
Energy per month	- 76MJ

(f) Quartz

Distance of travel to the plant	-10 km
Fuel consumption per trip	- 2 Lt.
Energy on transportation	- 2/1000 x 850 x 45
	- 76 MJ.
Energy per month	- 76x 3
	- 228 MJ

(g) Colour stain

Distance of travel to the plant	- 150 km
Fuel consumption per trip	- 30 Lt.
Energy on transportation	- 30/1000 x 850 x 45
	- 1147 MJ.
Energy per month	- 1147 x 1
	- 1147 MJ

(h) Sodium silicate

Distance of travel to the plant	- 160 km
Fuel consumption per trip	- 32 Lt.
Energy on transportation	- 32/1000 x 850 x 45
	- 1224 MJ.
Energy per month	- 1224 x 1
	- 1224 MJ

(i) Ball Stone

Distance of travel to the plant	- 150 km
Fuel consumption per trip	- 30 Lt.
Energy on transportation	- 30/1000 x 880 x 44.5
	- 1147 MJ.
Energy per month	- 1147 MJ

(j) Silica Sand
Distance of travel to the plant   - 360 km

Fuel consumption per trip   - 72 Lt.

Energy on transportation   - 72/1000 x 850 x 45

         - 2754 MJ.

Energy per month   - 2754 x 20

         - 55,80 MJ

(k) Diesel
Distance of travel to the plant   - 140 km

Fuel consumption per trip   - 28 Lt.

Energy on transportation   - 28/1000 x 850 x 45

         - 1071 MJ.

Energy per month   - 1071x 1

         - 1071 MJ

(l) Kerosene oil
Distance of travel to the plant   - 140 km

Fuel consumption per trip   - 28 Lt.

Energy on transportation   - 28/1000 x 850 x 45

         - 1071 MJ.

Energy per month   - 1071 x 20

         - 21,420 MJ

Total energy in raw material transportation   - 136,822 MJ.