AN END-USE ENERGY CONSUMPTION ON BANGLADESHI TEXTILE INDUSTRY

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We tried our best to finish this thesis flawlessly. However, if any faults are there, we seek apology for our mistakes.

-The Authors.

DECLERATION:

This is to declare that the project "***AN END-USE ENERGY CONSUMPTION IN BANGLADESHI TEXTILE INDUSTRY*** " and related audit was carried out by the authors under the supervision of Dr. Mohammad Ahsan Habib, Assistant Professor, MCE Department, IUT.

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ABSTRACT:

In industrial sector the overall demand of electricity is increasing by about 5% per year in industrial sector. An energy consumption audit was conducted in Kojima Lyric Garments, Gazipur to determine the total electrical energy consumption. Different energy saving measures were discussed and suitable ones for garments industry were applied. It was found that, about 1,294,589 kWh electric energy was consumed annually in a year. Among this, the motor or motor driven system consumes 9,13,350 kWh. If we installed energy efficient motors we could save 47,761.6 kWh for full load, which is 5.23% of total energy used my motors. If we used variable speed drive the saving would be up to 37% of total energy consumed by motors. The payback period for these cases was found to be economically viable. The emission reduction due to these energy saving measures are also calculated.

AN END-USE ENERGY CONSUMPTION IN BANGLADESHI TEXTILE INDUSTRY

INTRODUCTION:

The growth of an economy is closely related with growth in its energy consumption, particularly in the case of developing countries [1]. The energy intensity of production sectors is a function of technological progress and varies from sector to sector. Electricity, by virtue of being a relatively clean, efficient and convenient form of energy has a vital role to play in the socio-economic development of the country [1]. On the other hand non-availability of energy as an obstacle of economic growth is recognized universally. Energy demand in industrial sector is growing 5% each year [2].

Energy use in commercial and residential buildings has steadily increased by between 20% and 40% in developed countries for the last decade [3]. The building sub-sector consumed approximately 8-50% of total energy for few selected countries [4]. Bujak [5] reported that about 40% of total energy is consumed by residential and public buildings in the EU (European Union). Yang et al. [6] reported that energy usage in office buildings is about 70-300 kWh/m^2 per annum, 10-20 times that of residential buildings. The commercial sector accounts for approximately 32% of total energy consumption in Malaysia as reported by Saidur [4].

Rahman Mohamed and Lee (2006) investigated that the energy demands in Malaysia is increasing rapidly. The energy demand increased almost 20% within 3 years (from 1999 to 2002). The energy demand was further expected to increase almost 60% within 8 years (from 2002 to 2010) [7].

As the demand is increasing for electricity in various sectors, we have to focus on the reduction of energy use and efficient use of energy below.

The advanced technologies discussed below promise significant reductions in energy use, and implementing these may be less costly compared to generating electricity through supply expansions, taking into consideration the environmental costs associated with new installations [8].

a) Proper maintenance of electric motors in textile industries brings down energy consumption considerably; about 3% of power consumption can be saved by improved maintenance. This also reduced repairs as shown by the fact that burnout of motors varies in frequency from one in three months/10,000 spindles to 8-20 in three months/10,000 spindles. The increase is 8-20 folds in the second case. Similarly, burn out frequency varies from l-7 to 60 for six months for 25,000 spindles.

b) Waste heat recovery in boilers can reduce energy use by about 10%. It is shown that the payback period is a few months.

c) Use of polyester cotton tapes, etc. in textile mills will reduce consumption by about 10%.

d) Replacement of old boilers with high efficiency boilers and introduction of turbines and generators can reduce total energy requirements by more than 20&30%.

e) Spindle speed is an important factor in energy consumption in textile industries. Proper speed can reduce energy use. In the survey, energy consumption varies from 60 to 165% (with the base of 100 chosen for one mill). This shows that proper speeds can reduce consumption.

f) Advanced processes in the steel industry are mostly major process changes that could revolutionalise the iron and steel sector. The plassmelt method [9] involves smelting partially reduced iron powder with pulverized coal by using heat supplied by a plasma system. Ore to powder steel making could reduce the energy consumed by 40%. Direct steel making could double or triple production rates compared to the blast furnace and offer a 30% reduction in energy use. The energy required to produce steel from scrap is less than one-half that required to produce steel from raw materials. However, scrap contains residual elements that have adverse effects on the properties of the steel. The electric arc furnace is a well-established technology, and because of its increasing market share, improvements such as scrap preheating, DC arc furnace, induction melting, heat and dust recovery and ladle refining are to be researched.

g) Conventional chemical pulping in the paper industry is dominated by the very energy intensive kraft process. The energy required to recycle paper is about one-half that required by the kraft process. Desired improvements in the recycling process concentrate on improving the process to remove color and filler. Improvements in the paper making process focus on improved process control, process physics and improved materials. These improvements would have a substantial effect on decreasing energy consumption. Bio-pulping, chemical pulping with fermentation, and ethanol organ sol pulping are the most recent promising advanced processes involving integration of at least one fermentation process with a conventional pulping process.

h) Carbothermic reduction of aluminium ore or alumina has the potential for substantial energy savings. Aluminium trichloride electrolysis allows for more production per unit cell volume, The permanent anode design would decrease the frequency of anode replacements and the wetted cathode might enable a reduction in the distance between the electrodes associated with a high voltage loss without a loss in current efficiency.

i) Catalysts are used in many industries to produce chemical reactions at a lower pressure and temperature, thereby using the less energy. Better understanding of the basic mechanisms of catalysts may lead to new classes of catalysts. These could be beneficial in the areas of one-step conversion of methane to methanol, photocatalytic reduction of water, combustion enhancement, and pollution control [10].

j) Recovery and reuse of water heat offers significant opportunities for energy conservation. The development of cost effective heat exchanger and thermal storage units is needed for the recovery of high temperature reject heat. The development of high lift heat pumps could greatly enhance the utility of low grade waste heat.

k) Cogeneration is the simultaneous production of process heat and electric power. Providing moderate or low temperature heat as a byproduct of the work from a heat engine is much more efficient than providing heat directly by burning fuel. Most typical cogeneration industries convert only l0-15% of the energy into electricity [11]. The intercooled steam injected gas turbine[12] a new technology, is being developed which incorporates a modern aircraft engine and can accommodate variable amounts of steam returned to the turbine combustor and, therefore, has a flexible electricity-heat ratio. Steam not returned to the turbine is used for process heat. With full steam injection, 40% of the energy can be converted into electricity.

l) Variable speed controls for motors are currently available for application on existing and new equipment to adjust the speed control so that the motor and driven equipment can match the requirement of the process. Motors account for about 55% of the electric energy consumed in Karnataka State. The potential for conserving energy by applying high temperature superconductors [13] in place of conventional conductors in industrial motors is very large. The advantages include reduced volume and mass, higher power density, enhanced performance and improved operating efficiency.

m) Industrial separation processes involving separation of the components in a mixture are highly energy intensive. Advancement of alternative processes, such as membrane separation, solvent extraction, critical fluid extraction and advanced drying concepts, promise less energy intensity. This could be beneficial to applications like black liquor concentration in the paper and pulp industry, hot food processing waste water concentration, dilute soluble food process stream concentration and drying of products, such as textiles and paper [14].

The majority of the equipment in an industry is operated by motors or a motor-driven system. In the literature, it was reported that approximately 31-75% of total energy is consumed by electrical motors for a few selected countries around the world [15]. There-fore, electrical motors are targeted in this study to reduce their energy consumption along with emission reduction associated with energy savings.

In industrially developed and large developing nations, electric motors account for a considerable proportion of total national energy consumption [16]. Electric motors and motor driven systems use major share of energy in an industry, and so the cost of energy to operate motors and motor driven systems has become a real concern for industries [17].Energy use, savings, energy efficiencies of machines used in industrial sectors were studied by many authors in different parts of the world [18]. Percentages of electric motor energy use for few selected countries are given below.

TABLE 1:

Percentage of electric motor energy use for few selected countries

Country	Motor Energy Usage (%)	Reference
US	75	16,17
UK	50	18
EU	65	19
Jordan	31	20
Malaysia	48	21
Turkey	65	22
Slovenia	52	23
Canada	80	24
India	70	25
China	60	26
Korea	40	27
Brazil	49	28
Australia	30	29
South Africa	60	30

Use of energy-efficient motors and variable speed drives to match the load requirements has been found to be an economically viable solution to reduce motor energy consumption [19]. Teitel et al. [20] carried out an experiment using a variable frequency drive and found that about 64% of energy can be saved by matching the load.

It may be mentioned that energy can be saved using capacitor banks to improve the power factor, by regular maintenance of electric motors and implementing energy efficiency regulations. Electric motor energy can also be saved by avoiding over sizing as mentioned by Nadel et al. [21]. Almeida et al. [22], Garcia et al.[23]. Saidur [24], Saidur et al. [25] estimated energy savings for industrial motors based on a walk through energy audit data.

A comprehensive study on electric motors energy savings, policy, and technology is presented by Nadel et al [21].A comprehensive review on the electric motor energy use and savings was presented by Saidur [24].

However, very few works were done in Bangladesh, especially on Bangladeshi Textile industries. So, this report analyzed energy audit data to estimate the energy and bill saving as well as emission reduction of harmful gas by implementing various changes in a Bangladeshi Textile industry. Here we shall use Variable speed drive (VSD) and will replace standard motors by energy efficient motors.

In a Bangladeshi textile industry (Kojima Lyric Garments) an energy audit along with detail study was conducted and found out that, about 12.61% of total energy in that industry is utilized in lighting. Here in this industry still now the standard tube lights are used. We can replace these lights with energy saving bulbs, which in turn, reduce the total electricity consumption and annual bill.

The worldwide concern for the emission of greenhouse gases and other pollutants has prompted the regulators of utility companies to enforce alternative measures to meet the load growth [17]'.

Marland et al. (1999) investigated the global, regional and national CO2emissions in the year 1996 and estimated that 77.5% of CO2 emissions are emitted from liquid and solid fuels whereas, 18.3% of CO2 emissions are emitted from gaseous fuels burning [26]

The accumulation of carbon dioxide and other greenhouse gases (GHG) due to anthropogenic action is seen to be an important reason for recent environmental problems, such as global warming and climate change. Marland et al[27].note that liquid and solid fuels accounted for 77.5% of CO_2 emissions from global fossil fuel burning in 1996, while the combustion of gaseous fuels accounted for 18.3% of the total emissions from fossil fuel. Fuel consumption in industries contributes significantly to global CO_2 emissions. It is estimated that in 1990 the global industrial sector consumed about 91 EJ of end use energy (including biomass) which resulted in emissions of an estimated 1.80 Gt.C. When electricity consumption in the industries is included, the total primary energy consumed by the global industrial sector rises to 161 EJ, increasing the emissions to 2.8 Gt.C, or about 47% of the global CO_2 emitted [28]. Of the total GHG emission, CO_2 contributes about 67%, while methen contributes about 18% [29]. Table 1 presents the CO_2 emissions from fossil fuel burning and cement manufacturing in the world in 1995 [30]. The major contributors of CO_2 emissions are the developed and industrialized countries, notably Europe and North America. The whole Asia contributes about 36.4% of which China and Japan contribute about 14% and 5% respectively.

TABLE 2:

CO_2 emission from fossil fuel burning and cement manufacturing in 1995 [30]

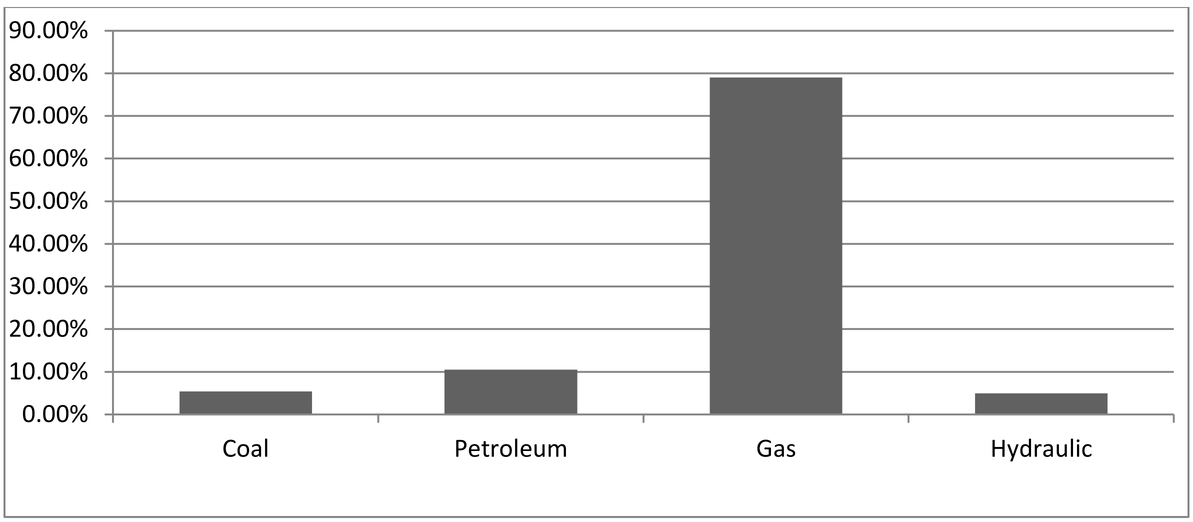
Region	CO_2 emission (000 metric ton)	Share of CO_2 emission (%)
Africa	745,595	3.3
Europe	6,247,094	27.5
North America	5,904,312	26
Central America	477,045	2.1
South America	747,332	3.3
Asia	8,270,648	36.4
Oceania	322,535	1.4
Total (World)	22,714,561	100

To minimize the risks of the GHG effect and to consider options for reducing GHG emissions, the United Nations Framework Convention on Climate Change (UNFCCC) initiated efforts in Reo de Janeiro in 1992. In the third conference of parties of the UNFCCC in Kyoto in December, 1997, the developed countries committed themselves to reducing the emissions of CO_2, CH_4 and N_2O by 6-8% in the period 2008-2012. As compared to the 1990 emission levels [31] though increased GHG emissions are from the developed countries, due to increased industrialization and growing energy demand, the GHG emissions from developing countries will also be significant if there are no mitigation actions. GHG emissions and their mitigation also become important in the context of the clean development mechanism being considered for implementation. Obviously, the major contributor to GHG emissions is primarily due to large scale commercial consumption.

Because of rapid industrialization of the South East Asian developing countries, their GHG emission is expected to increase in the future.

In Bangladesh the main fossil fuel used for the production of electricity is natural gas. About 79% of electricity is produced using natural gas. (Here we have not considered the quick rental power plants) The percentage of various fossil fuels used in the production of electricity is given below:-

FIGURE 1



A textile industry requires massive utilization of energy, resulting in the generation of a considerable amount of carbon dioxide emission as an undesirable byproduct.

By using the energy efficient motors and VSD, as well as replacing the standard tube lights with energy saving bulbs we can reduce the total electric power consumed in the textile industry. Thus we can save a considerable amount of money and reduce the emission of CO_2 and other greenhouse gases.

METHODOLOGY:

In methodology, the brief description of the audit process, the approach used in data collection, and the mathematical equations and formula to calculate the total energy consumption, electric bill, energy and bill saving by using VSD and energy efficient motor is given. Payback period for the energy strategies are also estimated.

A walk through energy audit was conducted in Kojima Lyric Garments. Lyric Group is a renowned name in Bangladesh garments sector. Lyric Group Started its operation in the year 1993 as the name of LYRIC GARMENTS ltd. Being a manufacturer and exporter of readymade garments Lyric established it's footage in the world market specially USA, JAPAN, CANADA, EUROPE, ENGLAND.

Later Lyric started a joint venture project with a renowned suit manufacturing company in JAPAN called KOJIMA and Established a ladies suit manufacturing factory in Bangladesh as the name of KOJIMA. Kojima Lyric garments ltd is exporting garments to Japan only and later have plans to spread its operation to USA and EUROPE.

An energy consumption audit in Kojima Lyric Garments was conducted on last week of June.

A walk through energy audit was conducted .A detailed preparation of the audit was made. A meeting was held with the appropriate personnel and a specific set of questioners were made. Then a floor by floor visit under the supervision of authority was conducted.

The Garments is a seven storied building with an underground level. Level one contains Accounts and Administrative office, Child care room, medical center, cutting section, quick-checking section and some essential electrical equipment like boiler, generator and pump. The second floor contains spot removing room, quality control room, processing and packing section. Third floor contains work station for both usual clothing as well as raincoats. The production of raincoat runs only for a few months of the year. Level four, five and six are similar and they contain gaze pattern room, sewing floor, and store room. Level seven consists of sample and CAD room, water treatment plant, cafeteria and kitchen, prayer room and store room. Underground level is used for fabric checking and lot packing.

After the audit a list of all the electrical equipment were made.

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A high efficiency motor uses low-loss materials to reduce core and copper losses. Therefore, it generates less heat and requires a smaller and more energy-efficient cooling fan. The most popular approach is demand-side management, one aspect of which is to improve efficiency to offset load growth. These facts led electric motor manufacturers to seek methods for improving the motor efficiency, which resulted

in a new generation of electric motors that are known as energy-efficient electric motors. Several leading electric motor manufacturers in the USA and Europe have developed energy-efficient electric motors [32]. High efficiency motors typically cost 10-25% more than standard motors [33].

Formulation for Energy Consumption

Annual energy consumption by electric equipment,

AES= W× hr × L×0.001……………. [Eqn. 1]

Here, W= rated power, kW

hr= usage hour

L=Load factor

Annual energy savings by replacing standard efficient motors with energy efficiency motors,

AES= W × L× hr × $[\frac{1}{E_{std}} - \frac{1}{E_{ee}}]$ × 100……… [Eqn. 2]

Here, W= rated power, kW

L= load factor (50%, 75% or full load)

hr= usage hour

E_{std}=efficiency of standard motor, %

E_{ee}=efficiency of energy efficient motor, %

Now, the efficiency of various standard motors and energy efficient motors are given below:

TABLE 3

The efficiency of various standard motors and energy efficient motors

Power (Watt)	Load (50%)		Load (75%)		Load (100%)	
	E_{std}	E_{ee}	E_{std}	E_{ee}	E_{std}	E_{ee}
1120	76.04	80.06	78.03	82.28	78.5	82.55
1500	77.2	80.02	79.29	83.07	81	83.55
2000	77.66	82.29	79.71	84.44	81.33	85
3000	81.07	83.69	82.39	85.25	82.9	85.96
3240	81.07	83.93	83.53	85.86	83.57	86.38
4000	81.09	84.26	84.12	86.07	84.67	87.6
4103	81.15	84.35	84.73	86.5	85.3	87.75
7460	84.32	86.9	86.3	88.87	85.2	90.1
12000	84.97	88.61	86.45	89.85	87.94	90.56

Energy savings by using variable speed drives:

Electric motors are over 90% efficient when running at their rated loads. However, they are very inefficient when running on part loads. Normally, motors operate more efficiently at 75% of rated load and above. However, motors are very inefficient when they are operated at lower than 50% of rated load. Due to the reactive current increase, power factors are also decreased [34]. In such cases, variable speed drive can be used to match load requirements so that energy can be saved. The study carried out by Ref.[35]found that variable speed drives are good candidates to match the load requirements and consequently will save a huge amount of energy, lower utility bills and protect the environment from harmful pollutants. Energy savings with the application of variable speed drive can be estimated as:

$ES_{VSD}=W \times H_{avg\_usage} \times S_{SR}$………… [Eqn. 3]

Here, H_{avg_usage}= average usage hour

S_{SR}= percentage energy savings using speed reduction

Percentage energy savings using speed reduction S_{SR} is given in the table below:

TABLE 4

Percentage energy savings using speed reduction

Average speed reduction (%)	Potential energy saving, S_{SR} (%)
20	15
40	35
60	55

Mathematical formulations of bill savings

Bill saving for using VSD or energy efficient motor is given by

Bill saving=AES× c ………… [Eqn. 4]

Where, c = average energy cost (BDT/kWh)

Mathematical formulations of payback period (years)

Simple payback period $= \frac{Increamental\ cost}{Annual\ bill\ Saving}$, years………….. [Eqn. 5]

Formulations of emission reductions associated with energy savings

Emission reductions associated with the use of high efficiency motors and variable speed drives can be estimated based on the emission factor per unit energy use taken from the table below:

TABLE 5

The emission factor per unit energy use for various fuels

Fuels	Emission factors(kg/kWh)		
	CO_2	SO_2	CO
Coal	1.18	0.0139	0.002
Petroleum	0.85	0.0164	0.002
Natural Gas	0.53	0.0005	0.005
Hydro	0	0	0

Emission reduction, $EM_i = EP_i\,(PEi1 \times Em_p^{1} + PE_i^{2} \times Em_p^{2} + PE_i^{3} \times Em_p^{3} + \ldots\ldots\ldots$

$PE_i^{n} \times Em_p^{n})$………… [Eqn. 6]

Here, EM_i= total amount of emission (ton)

EP_i= electricity production in the year i

$PE_i^{n=}$ percentage of electricity generation in a year I of fuel type n recommended

Em_p^{n} =fossil fuel emission for a unit of electricity generation of fuel type n (ton)

Calculation and discussion:

Energy consumption and annual bills:

Annual energy consumption for *"Kojima Lyric Garments"* the year 2014 are presented in *"Table 6(a) (b) (c)"*.Although it is an average calculation for whole year but it is pretty obvious that, In summer season for running the air-conditioning systems there will be an increment of bill but in winter season it is low because of not using air-conditioning systems in the industry.

Table 6 (a): Annual energy consumption & Bill for lights in 2014.

Type	Quantity	Power (W)	Usage (hour/yr)	Consumption (kWh)	Bill (BDT)
Tube light (single)	2272	20	3000	136320	1011494.4
Tube light (double)	177	40	3000	21240	157600.8
Energy saving bulb	96	20	3000	5760	42739.2
Total				163320	1211834.4

Table 6 (b): Annual energy consumption & Bill for electrical motors in 2014.

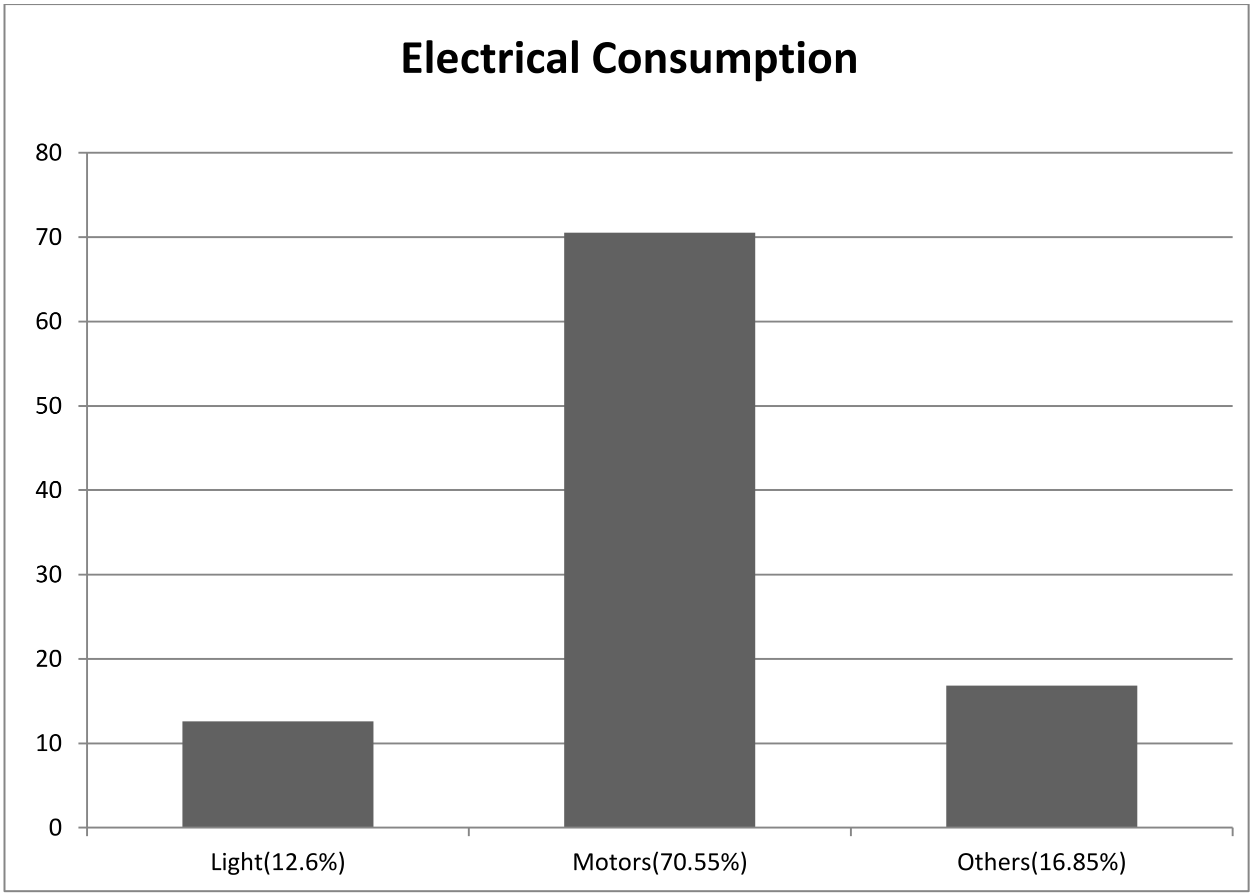
Machine	Power(W)	Quantity	Usage (hour/year)	Consumption (kWh)	Bill (BDT)
Repeat Button	400	1	112.5	45	333.9
Tonton	550	3	225	371.25	2754.675
Double needle (fixed bar)	550	19	1875	19593.75	145385.6
Double needle (angular)	550	5	1875	5156.25	38259.38
Button stitch	550	3	1875	3093.75	22955.63
Eyelet hole	550	7	1875	7218.75	53563.13
APW	350	7	1875	4593.75	34085.63
Hydarulic	2000	1	600	1200	8904
Hydraulic	3000	1	600	1800	13356
Button hole	300	5	1875	2812.5	20868.75
ABLE sleeve joint	550	14	1875	14437.5	107126.3
ABLE pad joint	550	8	1875	8250	61215
Fladlock loop	550	3	1875	3093.75	22955.63

Cintel	3240	5	600	9720	72122.4
Stopper	500	7	600	2100	15582
Blind Stitch	550	18	1875	18562.5	137733.8
Vertical Plane	550	14	1875	14437.5	107126.3
ABLE vertical	550	8	1875	8250	61215
Hand Stitch	400	3	225	270	2003.4
Vortex	550	11	1750	10587.5	78559.25
Hook and Bar	150	2	1875	562.5	4173.75
Zigzac	450	1	1875	843.75	6260.625
Saddle stitch	550	1	1875	1031.25	7651.875
Heat Transfer	150	3	1500	675	5008.5
Bend Knife	1120	7	1750	13720	101802.4
Lay	90	4	2250	810	6010.2
Fusion	12000	6	1750	126000	934920
Fusion	4000	2	1750	14000	103880
Pintap	400	4	1875	3000	22260
Auto Plain	500	380	1875	356250	2643375
Overload	400	66	1875	49500	367290
CAD	400	3	1875	2250	16695
Shearing	500	15	1875	14062.5	104343.8
WinDa	1000	1	1000	1000	7420
Needle Detector	150	1	1500	225	1669.5
Iron Table	550	217	1250	149187.5	1106971
Fabric Inspection	1020	1	1000	1020	7568.4
Sponging	35000	1	1000	35000	259700
PP belt	150	1	2250	337.5	2504.25
Spot Remover	1000	1	1000	1000	7420
Spot Remover	1500	1	1000	1500	11130
Pump (sub-mersible)	4103	1	500	2051.5	15222.13
Pump	7460	1	500	3730	27676.6
Total		863	Total	913350.3	6777059

Table 6 (c): Annual energy consumption & Bill for Other appliances in 2014.

Machine	Power(W)	Quantity	Usage (hour/year)	Consumption (kWh)	Bill (BDT)
Air Compressor	11000	1	1500	16500	127380
Boiler	536	2	1750	1876	14482.72
Lift(goods)	11000	1	250	2750	21230
Lift(passenger)	5500	1	500	2750	21230
Fridge(8.5 cft)	330	1	2920	963.6	7438.992
Fridge(10 cft)	610	1	2920	1781.2	13750.86
Fan	70	520	2640	96096	741861.1
Exhaust Fan(big)	210	26	3000	16380	126453.6
Exhaust Fan(small)	90	5	3000	1350	10422
Stand fan	350	8	1560	4368	33720.96
Computer	200	28	3000	16800	129696
Laptop	150	12	2000	3600	27792
A/C 4.5 Ton	5200	3	1080	16848	130066.6
A/C 2 Ton	2100	14	1080	31752	245125.4
Window A/C	1900	2	1080	4104	31682.88
Total				217918.8	1682333

Electrical consumption of total building has been shown below in graph:



Electricity use in different sectors:

According to the study, it is seen that the total electrical energy consuming area is divided into three sectors:lighting,motor-based and others equipments sections.In the pie chart, it is shown that lighting section consumes about 12.6%,motor-based section cosumes about 70.55% and other electrical equipments consume about 16.85% .Her main focus will be on motor-based equipments and ligting section will be included too.But in other electrical equipments there are some equipments which can not be changed because it will not be economicaly lucrative.aso this section has tobe remained as it now.

TABLE 7:

Energy and bill saving using variable speed drive at certain speed reduction.

Motor (w)	Annual energy saving(kwh) for speed reduction			Annual bill saving (BDT) for speed reduction		
	20%	40%	60%	20%	40%	60%
90	121.5	283.5	445.5	901.53	2103.57	3305.61
150	236.25	551.25	866.25	1752.975	4090.275	6427.575
300	421.875	984.375	1546.875	3130.313	7304.063	11477.81
350	689.0625	1607.813	2526.563	5112.844	11929.97	18747.09
400	8212.5	19162.5	30112.5	60936.75	142185.8	223434.8
400	6.75	15.75	24.75	50.085	116.865	183.645
400	40.5	94.5	148.5	300.51	701.19	1101.87
450	126.5625	295.3125	464.0625	939.0938	2191.219	3443.344
500	55546.88	129609.4	203671.9	412157.8	961701.6	1511245
500	315	735	1155	2337.3	5453.7	8570.1
550	15468.75	36093.75	56718.75	114778.1	267815.6	420853.1
550	55.6875	129.9375	204.1875	413.2013	964.1363	1515.071
550	1588.125	3705.625	5823.125	11783.89	27495.74	43207.59
550	22378.13	52215.63	82053.13	166045.7	387439.9	608834.2
1000	300	700	1100	2226	5194	8162
1020	153	357	561	1135.26	2648.94	4162.62
1120	2058	4802	7546	15270.36	35630.84	55991.32
1500	225	525	825	1669.5	3895.5	6121.5
2000	180	420	660	1335.6	3116.4	4897.2
3000	270	630	990	2003.4	4674.6	7345.8
3240	1458	3402	5346	10818.36	25242.84	39667.32
4000	2100	4900	7700	15582	36358	57134
4103	307.725	718.025	1128.325	2283.32	5327.746	8372.172
7460	559.5	1305.5	2051.5	4151.49	9686.81	15222.13
12000	18900	44100	69300	140238	327222	514206
Total	131718.8	307343.8	482968.9	977353.4	2280491	3583629

Energy savings, bill savings and payback period by using variable speed drive:

Energy savings, bill savings and payback period has been calculated by using Equations (2), (3), (4) and the results are presented in Tables 6 and 7 for the factory.It was found that 131718.8kwh,307343.8kwh and 482968.9kwh of energy can be saved for a 20%, 40% and 60% speed reduction by using a variable speed drive respectively. This will translate into bill savings of BDT 977,353, BDT 2,280,491and BDT 3,583,629 for 20%, 40% and 60%, respectively. It was observed that payback periods are shorter for a higher percentage of speed reduction (for example 60% speed reduction). It was also found that payback periods are shorter for larger motors (i.e.10 HP and above). Saidur et al. [35] found that the payback periods for using a variable speed drive for larger motors are reasonable (i.e. within 1-3 years).

TABLE 8:

Payback periods (year) by using a variable speed drive at a certain speed reduction.

Motor (w)	Incremental cost(BDT)	Payback period for speed reduction		
		20%	40%	60%
90	568.8	0.63	0.27	0.17
150	948	0.54	0.23	0.15
300	1896	0.6	0.25	0.16
350	2212	0.43	0.18	0.11
400	2528	0.04	0.01	0.01
400	2528	8.41	3.6	2.29
450	2844	3.02	1.29	0.82
500	3160	0.007	0.003	0.002
500	3160	1.35	0.57	0.37
550	3476	0.03	0.012	0.008
550	3476	8.41	3.6	2.29
550	3476	0.29	0.12	0.08
550	3476	0.02	0.008	0.005
1000	6320	2.83	1.21	0.77
1020	6446.4	5.67	2.43	1.54
1120	7078.4	0.46	0.19	0.12
1500	9480	5.67	2.43	1.54
2000	12640	9.46	4.05	2.58
3000	18960	9.46	4.05	2.58
3240	20476.8	1.89	0.81	0.51
4000	25280	1.62	0.69	0.44
4103	25930.96	11.35	4.86	3.09
7460	47147.2	11.35	4.86	3.09
12000	75840	0.54	0.23	0.14

Energy savings, bill savings and payback period by using a high

Efficiency motor:

Energy savings, bill savings and payback periods for both the buildings have been calculated by using Equations (3)-(5) and the results are presented in Tables 9 and 11.It was estimated that 4253.8 kWh, 5650.9 kWh and 6436.8 kWh of energy can be saved for motor loadings of 50%, 75% and 100%, respectively. This will translate into bill savings of BDT315, 564 BDT41, 929 and BDT47, 762 for motor loadings of 50%, 75% and 100% respectively. Almeida et al. [36] analyzed cost-effectiveness based on the cost of saved energy and showed that it is cost-effective to apply an energy-efficient motor in all capacities of motor. Saidur [24] found the cost for high efficiency motors ranged from 10% to 30%, but since a motor may use 75% of its initial cost in electric energy over its lifetime, the savings potential is great. Saidur et al. [37] found that the payback period for using energy-efficient motors ranges from 0.59 to 7.89 years for different percentages of motor loadings. These payback periods indicate the implementation of energy-efficient motors seems very cost-effective as their payback periods are less than one-third of the motor life (if an average motor life of 20 year is considered) particularly for large motors.

TABLE 9:

Payback period for replacing by Energy efficient motor in year.

Power (W)	Incremental cost(BDT)	Payback period for Energy efficient motor in year		
		50% Load	75% Load	100% Load
1120	5400	1.6	1.07	0.85
3240	8450	5.57	4.81	3.01
4000	8660	3.59	4.12	2.11
7460	12300	25.24	17.68	6.96
12000	13100	0.58	0.42	0.42

TABLE 10:

Energy and bill savings by using energy-efficient motors at different loadings.

Power (W)	Quantity	For 50% load		For 75% load		For 100% load	
		Energy saving kWh	Bill saving BDT	Energy saving kWh	Bill saving BDT	Energy saving kWh	Bill saving BDT
1120	7	452.994	3361.21	681.1588677	5054.199	857.4768	6362.478
1500	1	34.23691	254.037	64.56270145	479.0552	56.51972	419.3763
2000	1	43.46982	322.546	63.24739117	469.2956	63.7056	472.6956
3000	1	34.75442	257.877	54.97065491	407.8823	77.2935	573.5178
3240	5	204.2796	1515.75	236.8372904	1757.333	378.3633	2807.456
4000	2	324.7645	2409.75	282.7957273	2098.344	553.0469	4103.608
4103	1	47.95323	355.813	37.1580348	275.7126	67.14929	498.2478
7460	1	65.66715	487.250	93.74265351	695.5705	238.0897	1766.625
12000	6	3045.745	22599.4	4136.448737	30692.45	4145.233	30757.63
Total	25	4253.865	31563.6	5650.922058	41929.84	6436.878	47761.63

Energy saving And Bill saving by introducing energy saving bulb:

Kojima Lyric Garments was established in 1990, so most of the lighting system here is not so modernized. A few amount of energy efficient bulb are being used over there. That is why the lighting system here is consuming a large amount of power of electricity. It has been found out that using energy efficient bulb about 42,045kwh energy can be saved and so as BDT 324587 well.

TABLE 11:

Energy saving And Bill saving by using energy saving bulb.

Type	Power	Quantity	Energy Saving(kwh)	Bill Saving(BDT)
Single	15	2272	34080	263097.6
Double	25	177	7965	61489.8
Total			42045	324587.4

Emission reduction:

By introducing high efficiency motors, variable speed drives and energy efficient light, only energy consumption cannot be saved, emission of various gaseous pollutants can also be saved. Using the equation (6) and data from Table 5. Emission results are then presented in Tables 12, 13 and 14 for variable speed drive and high efficiency motors respectively. It was estimated that about 100,304.91kg, 175,677.73kg and 276,065kg of CO_2 emissions can be reduced by using a variable speed drive for 20%, 40% and 60% of motor speed reductions respectively. Similarly about 2,431.5kg, 3,230.06kg and 3,679.31kg of CO_2 emissions can be reduced by using energy-efficient motors at 50%, 75% and 100% loadings respectively. About 24033kg CO_2 emission can be reduced changing lighting systems. Besides, SO_2, CO this kind of gaseous pollutants emission also can be saved.

TABLE 12:

Emission reduction in kg at a certain speed reduction for using a variable speed drive.

Motor (w)	20% speed reduction			40% speed reduction			60% speed reduction		
	CO_2	SO_2	CO	CO_2	SO_2	CO	CO_2	SO_2	CO
90	92.523	0.778	0.051	162.05	1.814	0.119	254.65	2.851	0.187
150	179.91	1.512	0.099	315.09	3.528	0.232	495.15	5.544	0.364
300	321.26	2.7	0.177	562.67	6.3	0.413	884.19	9.9	0.65
350	524.73	4.41	0.289	919.03	10.29	0.675	1444.2	16.17	1.061
400	6253.9	52.56	3.449	10953	122.6	8.048	17212	192.7	12.65
400	5.1402	0.043	0.003	9.0027	0.101	0.007	14.147	0.158	0.01
400	30.841	0.259	0.017	54.016	0.605	0.04	84.883	0.95	0.062
450	96.378	0.81	0.053	168.8	1.89	0.124	265.26	2.97	0.195
500	42299	355.5	23.33	74085	829.5	54.44	116419	1304	85.54
500	239.88	2.016	0.132	420.13	4.704	0.309	660.2	7.392	0.485
550	11780	99	6.497	20631	231	15.16	32420	363	23.82
550	42.406	0.356	0.023	74.272	0.832	0.055	116.71	1.307	0.086
550	1209.4	10.16	0.667	2118.1	23.72	1.556	3328.5	37.27	2.446
550	17041	143.2	9.399	29846	334.2	21.93	46902	525.1	34.46
1000	228.45	1.92	0.126	400.12	4.48	0.294	628.76	7.04	0.462
1020	116.51	0.979	0.064	204.06	2.285	0.15	320.67	3.59	0.236
1120	1567.2	13.17	0.864	2744.8	30.73	2.017	4313.3	48.29	3.169
1500	171.34	1.44	0.095	300.09	3.36	0.221	471.57	5.28	0.347
2000	137.07	1.152	0.076	240.07	2.688	0.176	377.26	4.224	0.277
3000	205.61	1.728	0.113	360.11	4.032	0.265	565.88	6.336	0.416
3240	1110.3	9.331	0.612	1944.6	21.77	1.429	3055.8	34.21	2.245
4000	1599.2	13.44	0.882	2800.8	31.36	2.058	4401.3	49.28	3.234
4103	234.34	1.969	0.129	410.42	4.595	0.302	644.95	7.221	0.474
7460	426.06	3.581	0.235	746.22	8.355	0.548	1172.6	13.13	0.862
12000	14393	121	7.938	25208	282.2	18.52	39612	443.5	29.11
TOTAL	100305	843	55.32	175678	1967	129.1	276065	3091	202.8

TABLE 13:

Emission reduction in kg at a certain loading by using a high efficient motor.

Motor (w)	50% Load			75% Load			100% Load		
	CO_2	SO_2	CO	CO_2	SO_2	CO	CO_2	SO_2	CO
1120	258.93	2.899	0.19	389	4.359	0.29	490.13	5.488	0.365
1500	19.57	0.219	0.01	36.9	0.413	0.028	32.307	0.362	0.024
2000	24.847	0.278	0.02	36.2	0.405	0.027	36.414	0.408	0.027
3000	19.866	0.222	0.01	31.4	0.352	0.023	44.181	0.495	0.033
3240	116.77	1.307	0.09	135	1.516	0.101	216.27	2.422	0.161
4000	185.64	2.078	0.14	162	1.81	0.12	316.12	3.54	0.236
4103	27.41	0.307	0.02	21.2	0.238	0.016	38.383	0.43	0.029
7460	37.535	0.42	0.03	53.6	0.6	0.04	136.09	1.524	0.101
12000	1740.9	19.49	1.3	2364	26.47	1.762	2369.4	26.53	1.766
Total	2431.5	27.22	1.81	3230	36.17	2.407	3679.3	41.2	2.742

TABLE 14:

Emission reduction in kg by introducing energy efficient bulb.

Type of Bulb	Energy Saving (kWh)	Emission reduction (kg)		
		CO_2	SO_2	CO
Single	34080	19480	218.112	14.5181
Double	7965	4552.8	50.976	3.39309
Total		24033	269.088	17.9112

CONCLUSION:

The following conclusions can be drawn from this study:

Based on end-use energy breakdown, it was estimated that 131718.8kwh, 307343.8kwh and 482968.9kwh of energy can be saved for a 20%, 40% and 60% speed reduction by using a variable speed drive respectively. This will translate into bill savings of BDT 977,353, BDT 2,280,491and BDT 3,583,629 for 20%, 40% and 60%, respectively. About 4253.8 kWh, 5650.9 kWh and 6436.8 kWh of energy can be saved for motor loadings of 50%, 75% and 100%, respectively. This will translate into bill savings of BDT315,564 BDT41,929 and BDT47,762 for motor loadings of 50%, 75% and 100% respectively. The highest amount of energy of about482,968.9 kWh can be saved for 60% speed reduction using a variable speed drive. The corresponding bill savings for this amount of energy saving is found to be BDT 3,583,629. Payback periods are shorter for larger motors (i.e. 10 HP and above) when variable speed drives are used. Energy efficient bulb saves a large amount of energy. Using energy efficient bulb about 42,045kwh energy can be saved and BDT 324587 as well. At the same time high efficiency motor, variable speed drive and energy efficient light play a vital role in global warming by emission reduction.

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