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ENERGY CONSERVATION MEASURES FOR THE TEXTILE AND ALLIED INDUSTRIES IN NIGERIA

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Abstract
The textile industry has been an important segment of the Nigerian economy, accounting for about 15% of output and 37% of employment in manufacturing at its peak in 1994. Thus, the industry has an important economic development role in Nigeria as both an employment and output generator. However, recent events in the last two decades present substantial challenges for the industry. Today, there are less than 25 textile manufacturing companies in the country. This represents an 80% reduction from the 124 companies that were in existence in 1994. Since Nigeria lacks sufficient self-produced energy, increasing energy efficiency and energy savings are therefore crucial and essential to the Nigeria textile manufacture and market. This study summarizes energy-saving measures for energy users in the Textile industry, in addition, it identifies the areas in the textile firm where energy can be saved and also provide an energy efficiency baseline for adoption.
Keyword: Nigeria, textile, industry, energy, and efficiency.

Introduction
In homes across Nigeria, energy is wasted prolifically. In the winter, heat wafts out of poorly ventilated windows, under doors, and through un-insulated garret. In the summer time, sunlight rays shine into the house, causing air conditioners to work harder. House lightings and television screens are left on all night and sometimes even in the afternoon. These attitude leads to inefficient use of energy, and though individually small, add up to serious money and waste of resources when bills are to be settled.

Numerous analytical studies in different countries have been undertaken on energy auditing or energy conservation for different industries, such as the iron and steel industry (Mohsen and Akash, 1998; Ross, 1987; Thollander *et al*., 2005; Chan *et al*., 2010), cement industry (Hasanbeigi *et al*., 2010), textile industry (Palanichamy and Babu, 2005), petroleum industry (Pollio and Uchida, 1999), small and medium scale industries (Gruber and Brand, 1991; Priambodo and Kumar, 2001; Thollander *et al*., 2007), manufacturing industry (Chan *et al*.,2007; Fromme, 1996; Harris *et al*., 2000; Mukherjee, 2008; Worrell *et al*., 2009) and industrial/commercial/residential sectors (Anderson and Newell, 2004; Ibrik and Mahmoud, 2005; Sardianou, 2007; Steg, 2008). There are additional studies that recommend improving energy efficiency with the help of energy conservation techniques (Blok *et al*., 1993; Lang and Huang, 1993), by heavy investment in infrastructure (Lin, 2007) or through energy management (Christoffersen *et al*., 2006; Thollander and Ottosson, 2010).

Increasing energy efficiency is the most direct means of reducing capital expenditure (Mohsen and Akash, 1998). Little or no investment is needed to achieve a 10–30% reduction in cost (Ghaddar and Mezher, 1999; IPCC, 1996). If energy users are willing to adopt improved technology, or government incentives are implemented, cost of energy can be further reduced (Priambodo and Kumar, 2001). This work aims to describe the possible ways in which energy can be conserved in the Nigeria textile industry.

The Textile Industry: The textile industry is one of the oldest in the world. The oldest known textiles, which date back to about 5,000 B.C., are scraps of linen cloth found in Egyptian caves. The industry was primarily a family and domestic one until the early part of the 1500s when the first factory system was established. It wasn't until the Industrial Revolution in England, in the 18th century, that power machines for spinning and weaving were invented. In 1769 when Richard Arkwright's spinning frame with variable speed rollers was patented, water power replaced manual power (Neefus, 1982). The Nigerian Textile Industry is approximately 57 years old. The first textile firm in Nigeria was Kaduna Textile Mills which was established in 1956. United Nigeria Textiles and Arewa Textiles were established in the early 1960's. By the late 1960's Afprint, Asaba Textiles, Enpee Plc, Aswani Textiles and Five Star came on stream. During this period, the demand for textiles was relatively high-grey cloth and printed fabrics were produced for both urban and rural markets. The textile industry is characterized by product specialization. Most mills only engage in one process or raw material. For example, a mill may be engaged in either broadloom weaving of cotton or broadloom weaving of wool. Similarly, many mills specialize in either spinning or weaving operations, although larger integrated mills may combine the two operations. These large mills normally do not conduct their own dyeing and finishing operations. Weaving, spinning, and knitting mills usually send out their fabrics to one of the approximately 16 dyeing and finishing plants in Nigeria.

The textile industry is comprised of a diverse, fragmented group of establishments that produce and/or process textile-related products (fiber, yarn, fabric) for further processing into apparel, home furnishings, and industrial goods. Textile establishments receive and prepare fibers; transform fibers into yarn, thread, or webbing; convert the yarn into fabric or related products; and dye and finish these materials at various stages of production. The process of converting raw fibers into finished apparel and non apparel textile products is complex; thus, most textile mills specialize. Little overlap occurs between knitting and weaving, or among production of manmade, cotton, and wool fabrics. The production of cotton yarns and fabrics involves the following general processes: (a) cotton ginning, (b) spinning, weaving and knitting of yarns and fabrics and (c) Wet processing which includes scouring, de-sizing, washing, mercerizing, bleaching, dyeing, printing and finishing of yarns and fabrics. These stages are highlighted in the process flow chart shown in Figure 1.

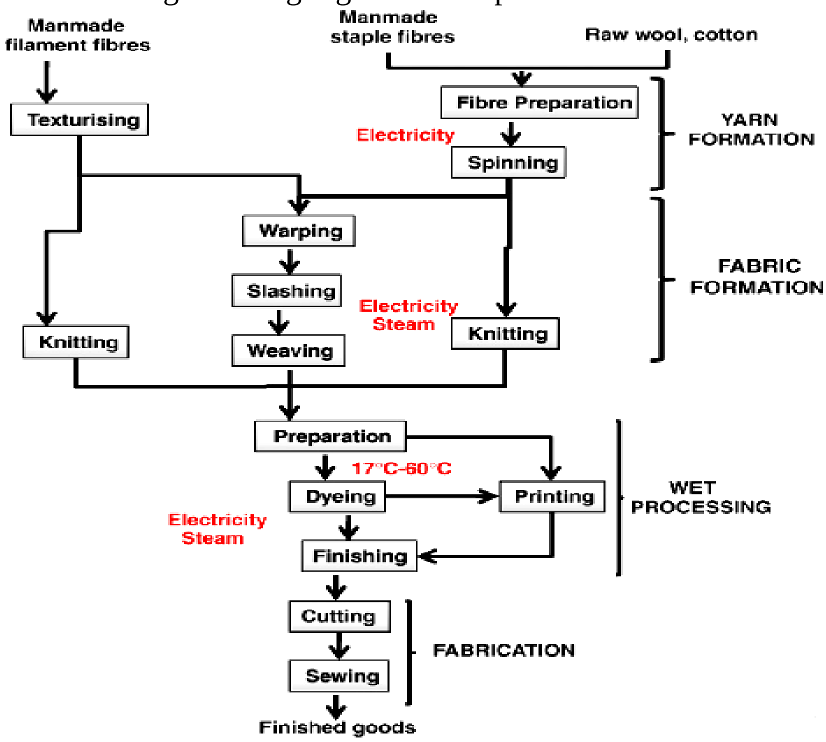

Figure 1: A typical process flow chart of a textile industry

Energy use in main textile operations: Within the textile industry, different sources of energy are used for different purposes: electricity is mostly used as a power source for machinery, cooling and temperature control systems, lighting, office equipment, etc., and natural gas as a fuel for boilers. Table 1 depict the average percentage of energy consumption for selected operations in a major textile industry.

Table 1: Average percentage of energy consumption for selected operations in the textile industry

Product	Process	Energy consumption (%)	Energy use
Spinning mill	Mixing/opening	7.5	Electricity
	Carding	8	
	Combing	5	
	Drawing/roving	4	
	Ring spinning	30	
	Finishing	6.5	
	Air conditioning	39	
Weaving shed	Woven fabric	32	Electricity and steam
	Denim	7	
	Woven towel	30	
	Knitted	30	Electricity
Dyeing, Printing and Finishing	Filling and heating of the bath water	9	Electricity and steam
	Bleaching	22	Electricity
	Washing	41	Electricity and steam
	Dyeing	16	
	Printing	13	Electricity and steam
	Softening	12	

Source: BLU *et al*. 2000, Intelligent Energy Europe 2006 and interviews with members of the Textile Associations.

In general, the amount of electricity consumed in each piece of equipment varies according to the type of machinery and the factory scale and therefore cannot be treated in a standardised manner. As one report suggests (UNIDO, 1992), the generally accepted average values are 3.5 kWh/kg for a single heater system, 5.0 kWh/kg for a double-heater system and boiling temperatures around 90°C in Soft flow/Jet dyeing/Jigger. Dyeing may be carried out at any temperature between 60 and 130°C depending upon the type of fabric to be dyed and the machine to be used (BLU, 2000, IEE, 2006; WBG, 2007). A brief description of textile processes, indicating where energy is used, is given below:

Spinning (includes opening, carding, combing/drawing, roving, spinning, and winding)**:** The fibre is first opened and cleaned. The trash is removed, and a lap or sheet of fibre is produced. Carding converts the lap to a parallel sliver, removing more of the trash and some lint. The fibres collected at the end of the card in the form of a filmy web are condensed into a card sliver of about 25 mm in diameter (BTTG, 1999). The sliver is then delivered into a tall can. In drawing, the card sliver is drafted down to an intermediate roving. In ring spinning, a fine sliver of fibres is fed downwards from a roving bobbin through a drafting zone, which drafts out the strand of fibres to the correct thickness; the electricity is consumed in driving the spindles, packaging, spinning, drafting, and operating the lifting and cleaning mechanisms. This process requires air conditioning since in an ideal working environment the temperature must be less than 30°C (UNIDO, 1992; BLU *et al*., 2000).

Weaving (includes beaming, warp sizing, fabric/carpet weaving, and others)**:** At this stage, cotton and some manmade warp yarns are sized to improve their strength and to minimise breakage. The size is squeezed into the threads as they pass between rollers, and drying is achieved by large steam-heated cylinders. Typical weave structures are calico or plain weave; twill weaves, which produces diagonal lines in the fabric; satin weave, which is predominantly weft-faced with a smooth surface; and figured patterns made on a Jacquard loom. A carpet is essentially a heavy pile fabric with vertical tufts or loops held in place with a backing material (EPA, 1997). The amount of energy consumed by each loom during its weaving operation can be estimated from the motor capacity and weaving speed.

Knitting (includes texturing, winding, warping, and knitting): Manmade yarn is textured by twisting the yarn and by heat, setting it into place before cooling and untwisting. Knitting machines are either circular or flat bed. The use of electricity depends on the type of machinery and capacity.

***Dyeing (includes atmospheric, pressure, and pad dyeing systems*):** There is a wide range of machines and processes available for dyeing fibre, yarns, staple, tow, fabric, and garments. Dyeing can be done continuously or batch-wise, at pressure or in open vessels. The process chosen depends on the nature of the textile, the type of dyestuff, and the end use. Heat is applied via a steam coil, and the dye liquor is forced through the package in a two-way flow pattern until the correct shade has been achieved at temperatures of between 120 and 130°C (BTTG, 1999). The consumption of energy is linked to the dye bath ratio, which depends on the type of dye, the dyeing system, and the affinity of the dyes for the fibres.

The finishing process consists of many interwoven unit operations, and it is a well-known fact that the process generally goes through repeated wet stages. The heat balance of a unit operation can mainly be considered as the difference between the total supplied heat on one hand and the sum of the heat required by the system and various forms of heat losses on the other.

***Energy efficiency analysi*s:** The main electricity energy use equipment includes: dynamic facilities, air compressors, spinning frames and refrigerators, which are responsible for 57.0%, 17.0%, 5.4% and 1.0%, respectively, of total energy use (Chan *et al*., 2007). The main thermal energy use equipments are steam boilers, thermal oil boilers and dyeing machines.

(a) **Air compressor:** Three types in common used are: reciprocal type, screw type and centrifugal type. For most applications, flow and pressure considerations will restrict the choice of compressor, with cost (and hopefully efficiency) being the determining factors (Falkner, 2009). During the air compressor operation process, only 60% of the total energy input is applied to the manufacturing process, 30% energy consumption is surge and leakage and the other 10% wasted is caused by poor control. In general, the compressor has to work more than it ought to, in order to maintain pressure in the compressed air line, which leads to a higher electricity consumption than is necessary. Therefore, system controls are one of the most important elements of a compressed air system, and also a central factor in air compressor system efficiency.

(b) **Spinning frames:** The yarn manufacturing process includes: mowing, carding, combing, ironing, roving, spinning and vending. In the steps of yarn production, the staple fibers are fed to the spinning frames, after passing through the blow room (opening and cleaning) and the carding frame, drawing frame and flyer (separation of individual fibers, parallelization and formation of a fiber tape). The finished yarn is produced by drawing and rotating operations. The spinning step accounts for 55.6% of total energy use in the yarn manufacturing process. Energy use of spinning frames is high due to conventional drive systems in different sections of the machine. High-speed spinning frames with modified system, including: motor drive system, transmission of motion and spindle drive system provide significant improvement in energy conservation along with reduction in noise level and vibration (Basu *et al*., 2003).

(c) **Refrigerators:** There are a wide range of refrigerators available, depending on style and use. Energy use per unit product is significantly influenced by the efficiency of the refrigerators. The efficiency of the old equipment is around 0.8–1.1 kWh/RT (Refrigeration Ton) with appropriate chiller capacity. If old equipment is replaced with a high efficiency type (0.6–0.65 kWh/RT), the energy conservation potential should be over 25%.

(d) **Dyeing machines:** Nowadays, overflow dyeing machines are still being widely used in the knitted fabrics segment. The conventional over-flow machines consume a large amount of water, electricity, steam and chemicals, which lead to high cost of wastewater treatment, as well as serious environmental pollution. If old equipment was replaced with new type (high-speed dyeing machine), heating steam energy would be saved by a small dye bath rate realized by circulating the cloth at a high speed, and increasing its contact with the dyestuff. Therefore, with a high-speed dyeing machine equipped with an inverter type variable-speed pump, which generates a power consumption variable in function of the torque of the motor, the energy saving potential could reach 20–40%.

(e) **False twist machine:** For the false twist machine, the energy efficiency depends on operating schedules, maintenance, machine vintage and other factors with negligible impact on energy efficiency. In general, the energy efficiency of the false twist machine is between 646 and 2152 kWh (kilowatt per hour) per metric tons for 75 denier 5 product, 557–924 kWh per metric tons for 150 denier product and 469–1400 kWh per metric tons for 300 denier product.

(f) **Stenter setting machine:** A stenter setting machine provides fabric stability, preventing it from shrinking. The machine is mainly used in the stenting and heat setting of pure cotton, polyester cotton and other blended fabrics, as well as various knitted fabrics. Each processing station comprises several regulating units and a winding device. Energy use of the stenter setting machine is usually determined by the efficiency of the thermal oil boiler.
At present, the energy efficiency of the stenter setting machine is around 85.6 LOE per thousand yard textile product. In general, the discharge temperature of the stenter setting machine is around 1701C and the operating temperature setting is about 2001C. This will cause 90% heat loss into the atmosphere. However, for the newest type stenter setting machine, the energy efficiency will be reduced to 60 LOE per thousand yard textile product, if the operating temperature setting is under 1801C.Fig. 6shows the energy efficiency distribution of the stenter setting machine.

Energy conservation technologies in textile industry

The energy conservation technology and potential for the textile industry can be categorized according to the support and production process based on the article by Trygg and Karlsson (2005). The production processes produce products, while the support processes support production.

(1) Support process

(a) Air conditioning system: Reduce the use of cooling water under low load and increase the cold water outlet temperature setting.

(b) Air compressor system: A well-known problem with air compressor systems is leakage. Leakage means that the compressor has to work more than it ought to in order to maintain pressure in the compressed air line, which leads to a higher electricity consumption than is necessary (Trygg and Karlsson, 2005). If an air compressor system is converted to a system with electrically powered tools, an air-free chiller is installed and a screw type air compressor is used to replace the centrifugal type, the coefficient of utilization would be raised.

(c) Lighting system: If daylight is used as an alternative light source, lighting energy consumption would be reduced (Kim and Kim, 2007). Moreover when traditional fluorescent lighting is replaced with high frequency (HF) fluorescent lighting, or mercury lighting is changed to high-pressure sodium or ceramic metal lamp; this should also save lighting energy.

(d) Fans, pumps and motors: Electricity use should be saved if the motor is switched to an energy-efficient motor-driven system. Moreover variable frequency drives are an excellent choice for adjustable-speed drive users, because they allow operators to fine-tune processes, while reducing costs for energy and equipment maintenance in the heating, ventilating and air-conditioning of buildings (Jayamaha, 2006; Teitel *et al*., 2008). The electricity usage could be reduced if motors are combined with frequency control.

(2) Production process

(a) Process control system: Fuel oils and electricity should be saved if high-speed dyeing machines and high-speed spinning frames are used. If idle machines are monitored or operating hours reduced, this also could reduce energy use. By the way, old equipment should be upgraded or replaced as this is a cost effective method in terms of energy saved and lower costs.

(b) Electrical system: The total capacity could be decreased and still meet the demands of production, since the capacities of energy users were over-dimensioned. Furthermore, the power factor can be improved on the low-voltage side. Energy-saving measures are adopted for the power converter.

(c) Boiler system: Adding inverters to blowers of the boiler could save electricity. Other energy conservation measures such as controlling the discharge oxygen concentration and minimizing excess air, recycling the cooling water and waste heat, and lowering the discharge temperature to below the original design setting, are effective.

Conclusion

This paper presented an analysis of the Nigeria textile industries in terms of energy consumption and energy efficiency. This paper presented a set of guidelines and strategies for the textile industry that could reduce the expenditure on power generation or use. These strategies question the current industrial system and open views to new efficient energy conservation possibilities inside this industry.

Recommendation

Increasing energy efficiency is an important strategy for reducing capital. Consequently, energy research institutes and governmental energy departments in various states in the nation should be committed to developing methods for assessing energy efficiency; these can be used as references for policy-making. Additionally, energy utilization status can be compared among different states to achieve the common aim of reducing expenditure on power generation.

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