<u>**Sustainable Developments in Knitting**</u>

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<u>Abstract</u>

The global community is aware that policies and practices regarding human consumption of resources need to change. Sustainability is now a dominant factor within government policies worldwide. A recent report compiled on behalf of the European Union identified clothing and textiles as key industries in terms of reducing environmental impact. In response to this report the UK government devised the clothing roadmap to investigate sustainable developments within these industries. Sustainable design was identified as one area for improvement. This paper acknowledges that the clothing supply chains are not transparent. Consumers can purchase garments produced from organic and eco fibres since labelling indentifies the raw material sources. However, it is less straightforward to purchase garments produced using sustainable technologies since processing information is not displayed at the point of sale. This paper investigates sustainability within the knitwear industry and challenges the view that the textile manufacturing industries are significant contributors to energy consumption.

<u>Keywords</u>

Clothing, energy consumption, production efficiency, fabric construction, garment production, global fashion industry, knitting, knitwear, manufacturing, seamless, sustainability, sustainable design, textiles, waste,

<u>1.0 Introduction</u>

Sustainable is defined as 'capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage' (Makins ed, 1995, p.1358). In recent history sustainability has become associated with human consumption of resources. The Brundland report (1987) contains one of the most quoted definitions of sustainable development '... meeting the needs of the present without compromising the ability of future generations to meet their own needs' and has become the guiding principle for much of the UN and national government policies. The report called upon all EU member states to move towards sustainability by considering policies, programmes and budgets which encouraged sustainable development. Of course in the 21st century there is an increased global awareness regarding climate issues and sustainability. However, it is widely acknowledged that climate change poses a serious challenge for all countries (CCC, 2009) and every industry (particularly manufacturing). 2005 saw the UK government launch its new strategy for sustainable development based on the discussions of the 2002 world summit in Johannesburg (DEFRA, 2005). More recently the world summit in 2005 referred to reinforcing pillars of sustainable development which are more commonly referred to as the three pillars of sustainability: social development, economic development and environmental protection, which are now built into most EU countries internal policies for sustainability (UNGA, 2005). During 2006 the European Commission launched a project aimed to identify products which had the highest environmental impact (EIPRO, 2006). The project highlighted four product groupings (food, transport, building and clothing) which accounted for 70-80% of all environmental impacts and 60% of consumer expenditure. DEFRA furthered this work by indentifying a selection of products within the four EIPRO groupings and devised 10 product roadmaps as part of its Sustainable Consumption and Production (SCP) initiative. In 2007 DEFRA launched the Sustainable Clothing Roadmap, one of the challenges acknowledged within the early discussions was the implementation of sustainable design which included the consideration of the use of energy, water, raw materials and waste within clothing and the textiles from which they were constructed. Throughout history modern technological developments have consumed a vast amount of energy, to power their manufacturing industries and released large amounts of CO^2 emissions without much consideration regarding the environmental impacts. Whilst the landscape of manufacturing has changed dramatically in many developed economies the environmental impact of manufacturing globally has continued to rise.

2.0 The clothing industry

The global clothing and textile industries are worth over £500 billion and employ somewhere in the region of 26 million people (Allwood et al, Nov 2006a; DEFRA, 2010). In the UK alone approximately 2 million tonnes of clothing is purchased every year which amounts to a market value of £23 billion. Since the majority of UK clothing and textiles are imported (90%) it is difficult for the consumer to know exactly how clothing is being manufactured with regards to environmental impact. Quite often a product can be identified as being constructed from a sustainable raw material from the label. However, it is less straightforward to purchase garments produced using sustainable technologies since processing information is not displayed at the point of sale and supply chains are complex. Supply chains or pipelines are organised interconnected activities and networks which result in the delivery of a product to a customer. Apparel pipelines have an extensively rich heritage which began during the industrial revolution in Britain. The textile industry is accredited to have provided the first examples of a factory system worldwide. Of course the modern supply chains are far removed from the early $18^{th/}19^{th}$ century models. They are complex in construction and vary greatly between product and retailer. Three factors have contributed significantly to the changes in the stages of apparel supply chains. Firstly globalisation has enabled a wide variety of processes to be accessed relatively easily in low cost labour countries. Secondly technological advances have blurred the stages of production, in some cases completely combining the later processes in garment manufacture; and finally consumer demand for newer cheaper fashion and highly innovative functional clothing. In the last decade supply chain management has become flexible and fast responding to these external factors, enabling individual organisations to gain and maintain competitive edge. This has involved removing any unnecessary cost during production, reducing the processing times and employing new innovative strategies and technologies within the product development stages. Technology has and will continue to play a key role within this radicalised industry. Providing faster, cleaner more automatic machinery with advanced technical functions and programming capabilities to enable new innovations to prevail. New technological developments have enhanced production over the decades in four key areas; improving the quality of the product; increased productivity therefore reducing cost, providing opportunities for new and modified products and techniques through innovation; and finally reducing environmental impact of industrialised production.

There is an increasing business case for improving sustainability both socially and economically within the clothing industries. Consumers have increased awareness of the environmental impacts associated with clothing and textile production through media investigations; and are demanding more accountability from the retailers in terms of their supply chains. In addition as energy prices continue to rise globally near to market solutions using energy efficient manufacturing technologies are becoming more desirable, thus reducing the cost of transportation. Competition in all textile manufacturing sectors is high due to low cost labour countries and increasing globalisation. Successful mills are those which produce quality fabrics, delivered on time at a reasonable price; thus optimising output, quality and production planning. Various studies (ITMF, 2006; Koc & Cincik, 2010) have shown that the main costs in woven fabric production are the price of the raw materials; the depreciation and interest owed in relation to the machinery; followed by labour, energy, auxiliary material and waste costs, which is similar across all textile fabric sectors including knitting. Of course the figures for each of the identified categories vary significantly depending on the country selected for research; since labour and energy costs are less expensive in undeveloped economics than in the West. However, energy costs are forever increasing worldwide and reduction in energy consumption is high on the political agenda for all governments concerned with climate change and sustainability issues; which has resulted in increasing environmental legislation. Therefore, monitoring energy consumption and creating policies for energy reduction has become a key factor in the management of all profitable businesses worldwide.

3.0 Sustainability in clothing

Generally there are two views regarding sustainability in clothing; the first being to produce garments more efficiently and the second involves changing consumer and manufacturers opinions by creating alternatives in relation to what is currently produced (Fletcher, 2008). The challenge is to combine innovative technologies to secure the employment of millions whilst dramatically reducing resources and waste. Web searches revealed that generally in the knitting industry sustainability is considered from the materials view point rather than the manufacturing. Creating products or garments that use renewable resources, eco-friendly production methods and recycle or reclaim raw materials such as; organic cotton, bamboo, hemp, PET, PTT, recyclon and biodegradable fibres PLA, Lyocell, is a growing business. There are many manufacturers, brands (Hounslea, (2010) suggest that there are more than 80 worldwide) and retailers that are using this approach including; Figleaves, Greenknickers, Chantelle, Enamore and C-IN2's (Curtis, May 2008). What appears to be in limited supply in the public domain is reliable information relating to energy consumption and material savings (in relation to reducing waste) during the production process; although Fletcher (2008) states this is the most common approach to increasing sustainability used generally within the clothing production sector. When considering sustainable design the term eco is a regular feature. The consumer can purchase organic or eco friendly garments in terms of the raw materials from which they are constructed; but much less information is provided regarding the process of producing the fabric from which the garment is manufactured. Fabric construction processes such as knitting and weaving are considered by many to be high contributors to environmental pollution in terms of energy and waste materials, (Allwood et al, 2006 ; Fletcher, 2008; Johnson, 2009; Sivaramakrishnan et al, Aug 2009). But in reality how true are these claims given the limited information in the public domain regarding the fabric production processes. This paper examines secondary data from a variety of sources to determine if the knitwear manufacturing industries are key polluters in terms of environmental impact.

4.0 Sustainability in the knitting industry

Despite there being significant savings made in energy consumption and reduced manufacturing waste through new innovative technologies the majority of knitting machine manufacturers do not make key reference to the environmental and sustainable benefits of these innovations in recent advertising campaigns. The notable exceptions is Shima Seiki the Japanese flatbed manufacturer who claim in their marketing that their complete garment machinery (known as whole garment technology) can be classified as environmentally friendly due to only the required amount of yarn being used in each garment; and a few lesser known manufacturers who claim low energy consumption, but fail to quantify this in real terms. To simplify the investigation the knitting industry sector has been split into its two main sectors of warp and weft knitting. Since most fashion knitwear, sportswear and lingerie are produced using the weft knitted technique (similar to hand knitting) the remainder of this report will focus on this sector. However, it must be acknowledged that innovations in warp knitting technology such as 3-D knitting are associated with reducing the carbon footprint through a combination of the removal of post knitting operations, reducing material waste and lowering transport emissions, thus, providing a cost effective, near to market, production opportunity (specifically in the hosiery industry) within developed nations globally (Curtis, June 2010a). The weft knitting sector which is the largest sector of knitting can be further divided into three segments based on the machinery from which the product was obtained; flat-bed knitting, circular knitting and the older type of weft fully fashioned knitting which uses the straight bar frame (often referred to as the cotton's patent machine).

4.1 Reducing waste

It is claimed that reducing the waste in knitted garments will have a significant impact on the sustainability of textiles both in terms of raw materials and landfill. A recent report by Allwood et al (2006) investigated the waste of a typical weft knitted cotton T-shirt in relation to UK consumption for the total market. It was estimated that 460,000,000 units or 115,000 tonnes are required to satisfy the UK consumption for T-shirts and from that 35,880 tonnes of waste textile materials are produced annually. This represents a significant waste factor of 31.2% and is representative of only a small amount of the total knitted goods markets. The report suggests that by introducing new technology (seamless technology) and changing the location of the production, waste could be reduced to 20.4%. However, the report fails to recognise that the selected new technology scenario is based on utilising a circular weft knitted technology, which in reality would still require some element of cut and sew to join the sleeves (hence it is not completely seamless and waste would still be produced, a factor which is overlooked in the report). In addition the labour and manufacturing costs are significantly underestimated in terms of knitting time since the figures used are based on men's briefs which are significantly shorter in terms of length and do not require extra tubes for the sleeves. Never-the-less this paper represents the difficulties encountered when attempting to calculate waste savings on a theoretical level. Realistically products need to be compared on a like for like basis with physical samples to fully appreciate the manufacturing savings in terms of sustainability. True seamless knitwear is the technology referred to as complete weft knitted manufacture (of the flat-bed technology type) the two leaders in this field are Shima Seiki with *wholegarment* and Stoll with *knit and wear*. The technologies however are limited in gauge (fineness of the material obtained) and speed if compared to general circular weft knitted cut and sew T-shirts material (single jersey). Using complete knitting technology (true seamless) will assist in the reduction of the energy consumption used in garment manufacture by shortening knitting times, and reducing CO^2 emissions from transportation; it will benefit the environment by eliminating post knitting processes (seaming) and reducing waste in terms of raw materials within a garment (since there is no armhole, sleeve and neck cut to be made) (Scrimshaw, 2003; Mowbray, 2004; Curtis, Aug 2009; Textile Outlook International, April 2010). Some authors report a reduction of production time to between 30-40% (if compared to cut and sew manufacture), of course the saving is dependant on the gauge, yarn, style amongst other factors. In addition reclaiming production waste from more conventional methods of knitwear production methods such as cut and sew and fully fashioned garment manufacture should not be overlooked. This is common practice in the manufacture of garments from cashmere and merino wools where the small fabric cut offs are broken down into individual fibres and reprocessed.

4.2 Reducing the carbon Footprint

This is an area that requires significantly more clarification in relation to textile manufacturing, since it is reported in different units by various authors. Allwood et al (2006) claimed that by changing the manufacturing location of products globally (T-shirts) combined with introducing new production technology, CO^2 emissions could be reduced to 3 million CO^2 equivalents. A separate report by Johnson (2009) estimates total energy consumption of a T-shirt to be 109MJ (mega joules) per unit of this 24MJ is related to production costs, but the source of this study is omitted. This figure however was listed in Allwood et al (2006a) publication. When attempting to compile comparative energy consumption for knitting machinery it is ambiguous since general technical data only lists maximum connection values in Kilowatts which generally range from 1-3 for modern flat-bed technology (which is relatively low for industrial machinery). However, the actual consumption during knitting will fluctuate depending on operating speed, which is strongly related to the actual knitting area and patterning within the knitwear (complex shaped knitted panels generally are produced at lower than maximum operating speeds). It is therefore unrealistic to compare energy consumption using the energy labelling used in domestic appliances since you would need to compare every knitting machine using the same base factors (fibre, yarn, speed, gauge, garment style and size, and method of garment production), since knitting is extremely versatile offering many gauges and methods of production this would be near impossible, more often in knitting machinery, efficiency is used for marketing purposes. Efficiency is often expressed in circular types of knitting machines as rpm and even this is dependent on yarn, structure type, gauge and the size of the dial (diameter of machine), more often a range is provided (Tait, May 2008). Alternatively flat-bed knitting machinery expresses efficiency as the linear speed in metres per second (I.6 m/sec on the most productive machines), again this figure will change depending of yarn, structure, and bed-width amongst other factors. The industry has seen a recent trend for ultra fine gauge knitwear the main markets being sportswear and underwear (Steele, May 2008). By very definition fine gauge is less eco friendly than the coarse gauge alternatives since more energy and yarn will be required to produce a garment of similar dimensions. The productivity declines by around 14% when using finer gauges (Curtis, March 2010), gauges of 60 needles per diametric inch are now attainable in circular machines (Steele, May 2008) and up to 18 needles per inch in flat-bed technologies including complete garment machinery.

Two major breakthroughs in reducing the carbon footprint of knitted garments can be reported with some degree of confidence. The first is to optimise energy by efficiency (Johnson, 2009). A UK hosiery manufacturer reported a reduction in energy consumption from 21 kilowatt hours/dozen to 8.5 was achieved by simply reducing idle machine time (Curtis, Dec 2009); in addition the same company reported a year on year reduction in manufacturing costs of 18% had been achieved through the automating of post knitting operations. The second break through is technology based, this began in the late 80s for flat-bed knitting with the advent of variable stroke (Hunter, Aug 2004 & Oct 2004; Power, 2007; Power, 2008), the ability of the carriage to change direction mid way across the needle bed and individual needle control, this had a significant impact on knitting speeds (Brackenbury, 1992). Nowadays this has been further improved by reducing the time taken for the carriage to change direction known as rapid response which has been reported to improve efficiency by up to 8% (Curtis, March 2010; Curtis, June 2010). The mid 90s brought the introduction of complete garment to the world stage (Hunter, Feb 2004; Power, 2008). Originally this was marketed to bring new innovation into the markets rather than for product efficiency. But the change in economic conditions combined with environmental issues of lower carbon emissions and fears of climate change have provided opportunities for this technology to be used to reduce the carbon footprint created during transportation by providing a close to the market production facility. It has been reported that in the UK, Europe and US there has been significant investment in advanced flat-bed machinery during 2009 (Mowbray, Feb 2004; Hunter, Feb 2004; Siddons, Oct 2009). However, one UK company Quantum knitwear (whose machinery plant consists of all complete garment machines) suffered in this fragile market for a variety of reasons. Santoni has done the same for circular knitting that complete garment has done for flat-bed. Although not seamless in entirety it eliminates up to 90% of seams by knitting on a circular machine with a circumference of similar dimensions to the human form (Tait, May 2008). These machines have the benefit of high speeds and fine gauge and claim to offer knitting sweaters 3 times faster than conventional flat-bed machines (Tait, May 2008), they have gained a large market share in lingerie.

4.3 Associated factors

Other energy saving initiatives included the use of oils to lubricate the mechanical parts during the knitting action and new developments in needle technology. Groz-beckert one of the world leaders in needle production has recently introduced *litespeed,* this needle has been developed to promote environmental protection and sustainability. The design has changed by reducing the size and weight of the needle component thus reducing friction during the knitting process. It claims to reduce energy consumption in a circular knitting machine by up to 20% and significantly reduce CO^2 emission by 1,500kg per machine (needles lifetime based on 5,000 hours or 208 days). If compared to CO^2 emissions produced by a plane this equates to a distance of approximately 3,800 km. It also reports benefits in terms of less wear on parts thus increasing service life and reduction in the amount of lubricants required during the knitting action (Groz-Beckert, Jan 2010). Knitting Industry reported (May 2010) that this multi patented technology was awarded the Kyocera Environmental prize in April 2010 for its contribution to sustainability. It is estimated that circular knitting accounts for 1/5th of the worlds textiles (most of the T-shirt market), if this innovation was used in all high speed circular knitting machines globally it would account for a reduction of approximately 457 tonnes of CO^2 emissions over 12 months (Knitting Industry, May 2010). Fukuhara (circular fine gauge knitting machine) incorporates the patented technology E-needle which makes similar claims of reducing energy consumption (atb, 2010). Further to this there have been many developments in environmentally friendly synthetic knitting oil which have been specifically designed for the lubrication of high speed knitting machines to provide long life and extremely low friction performance which claim to increase productivity and lower power consumption. Synol part of the Mavani group is one chemical brand operating in this area, its Ecoknit lubricant is eco-friendly and claims to reduce power-consumption by reducing friction, Kluber lubrication presented similar claims at the recent Asia ITMA event, however there are no figures to quantify this in real terms (Wilson, A, 2008).

4.4 Knitting the sustainable way

It is clear that the knitting industry can make a significant contribution globally to savings in terms of energy consumption and waste through a number of avenues including tightening internal efficiency (reducing downtime), using indirect technology (needles and oils), using new innovations to change the manufacturing process (less waste, reduced post knitting operations) and reduced transport costs (complete garment for warp knitting, flatbed knitting and circular weft knitting). One final technology that will have a significant impact on the knitting sector is to completely re-think the process of forming a stitch, thus producing an eco stitch. Japanese engineers have made significant developments in using rotors to form stitches (instead of needles), this offers great potential for all knitting sectors. It has been trialled on circular knitting machines with some success and it is predicted that the resultant knitting machines will be lighter in weight, smaller in size and use significantly less energy (Hirano, March 2010). Since T-shirts sales in the UK industry alone amounted to £1,248 million (Allwood et al, Nov 2006), this technology can be predicted to make significant environmental savings. Knitted garments (both T-shirts and pullovers) were reported to be in the top three clothing products in terms of sales in the UK in 2004 (Allwood et al, Nov 2006). With the trend for causal dressing and sportswear continuing knitted garment should be leading greener production since there is no doubt that the future of clothing is energy efficient, reduced waste production, using eco friendly self cleaning biodegradable raw materials.

5.0 Summary

The research conducted in this paper found that despite the knitting machine builders introducing new energy efficient technologies, general advertising and marketing campaigns did not put a key emphasis on promoting this. In addition it was acknowledged though research that weft knitted technologies exist that completely eliminate cutting waste. However, it was highlighted that there is general confusion regarding the different types of weft knitting technology and the capabilities (seamless or less seams). Data utilised in some research make claims regarding commercial benefits that are based on figures that significantly underestimate the waste factor and the length of time taken to produce a garment. This paper clarified two types of knitting technologies that are commonly confused due to misrepresentation regarding the terminology used to describe them. True seamless is complete garment production, however the term seamless may be used to mean “less seams”. The paper acknowledges that whilst both technologies produce weft knitted goods they are not in direct competition since they operate in different product markets. Flat-bed technology (complete garment) has not obtained the productivity (nor the fine gauges) of circular knitting; and circular knitting does not have the patterning and shaping capability offered by flat-bed. Of course this may change in future years as finer gauges of complete garment become more widely used. It is important that reports claiming sustainable benefits are based on accurate information and like for like products to ensure they are able to contribute to effective business plans. It can be concluded from this investigation into knitting sustainability that energy consumption within this sector requires more investigation with indepth primary studies being conducted into technology benefits, productivity, waste production, labour and transportation savings. It is fair to say that knitting is a complex process of converting yarn into fabric and any sustainable studies should seek expert advice regarding comparable technologies. The two factors that can be reported with some degree of confidence from the findings of this study, are that energy consumption within the knitting industry is much less than in other domains of manufacturing and therefore the reports that claim textile manufacturing are key contributors to environmental pollution in terms of energy and waste materials are clearly misguided. This study clearly demonstrates energy and waste materials in knitwear production are relative moderate. However, energy efficiency savings should be a primary concern for any business globally since studies highlighted in this paper clearly demonstrate that substantial savings can be made in terms of reducing downtime and energy consumption when there has been consideration of secondary factors (Lubricants and new needle technology).

6.0 The way forward for sustainability

It is worth noting that no one section of the textile pipeline will make a product truly sustainable. Textiles is reported to be one of the two most polluting sectors in China (NRDC, 2010). Sustainability need to take a multi-phase approach including raw materials, processing technologies, chemicals, transport, energy saving, waste reduction, consumer laundering and disposal which involves many diverse divisions and sub industries within the textile pipeline. Energy consumption and carbon emissions now dominate the sustainability debate. However, the marketing of energy efficient garments will only be useful if the consumer understands the labelling. Energy saving categories have been established for a number of years for domestic appliances such as washing machines, fridges and freezers. However, this research has demonstrated that it is not going to be easy to achieve this level of simplicity in the knitwear industry due to the diversity of the machinery and range of products available. To achieve total sustainability you need to embrace economy, environment, and society simultaneously. Of course energy consumption accounts for a large proportion of the environmental impact in textiles and clothing, but it is near impossible to determine if a product is manufactured sustainably unless you have input into all aspects of the supply chain (in most cases the pipeline is not this transparent). In contrast it is relatively easy to determine if the source of the raw material is eco-friendly which is why clothing products are marketed using the eco friendly raw materials story. Various standards exist to guide consumers including, Oeko-tex, GOTS, made in green, to name a few. One of the most interesting organisations in terms of monitoring and accrediting textile manufacturing including energy consumption and CO^2 omissions is Blue Sign a swiss-based company (Hounslea, 2009; Hounslea, 2010) they encompass all aspects of the supply chain and members include Pategonia (the US pioneer of truly sustainable clothing).

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