US-UK Comparison: Technologies, Attitudes and Barriers in Industrial Energy Efficiency

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ABSTRACT: The adoption of best available technology (BAT) within industry could reduce energy demand by 20-30% globally. The energy efficiency of a number of energy intense industries (cement, iron and steel and pulp and paper) from the US and UK have compared to assess technologies, attitudes and barriers with respect to the uptake of energy efficiency. Each industry has specific barriers to the uptake of BAT and no one single transfer of technology or knowledge between the US and UK which can address the barriers faced by each individual industry has been identified. One of the primary drivers of energy efficiency identified within the UK has been the introduction of legislation taxing energy usage (e.g. CCL), which can be attributed to accelerating market forces and efficiency particularly within the cement industry.

Key words: Industrial energy efficiency, energy efficiency barriers, energy intense industries

1 INTRODUCTION

Industrial energy efficiency has become a priority within the both the US and the UK for a number of mutual factors; economic, political and environmental. The UK has a less energy intense economy, as a whole, than the US (OECD, 2010). The IEA/OECD (2009) predicts that globally industry energy usage could be reduced by between 20-30% through the implementation of best available technology (BAT).

This study has been proposed by AEA, a multidisciplinary consultancy and through a recent acquisition has gained increased exposure in the North American market.

The purpose of this study is to assess the energy efficiency of a variety of industrial sectors within the US and UK and investigate the relative efficiencies of established processes and practices, understand and highlight barriers to the adoption BAT and draw conclusions about knowledge and technological transfer between the two countries.

2 ENERGY EFFICIENCY

2.1 *Energy Efficiency Drivers and Potential*

Industrial energy efficiency has become a priority in both countries for a number of mutual and exclusive factors. Economically, energy efficiency allows industries to remain competitive within increasingly globalised markets. Politically both countries wish to reduce reliance on imported energy. In addition there are environmental concerns in the control of GHG emissions.

The potential savings from industrial energy efficiency have been widely recognised and publicised. The IEA/OECD (2009) predicts that global energy usage by industry could be cut by between 20-30% through the implementation of BAT. A recent report supported by the DoE and the EPA, the Mckinsey Report (2009), highlighted the economic potential of energy efficiency measures, within the US, and projected cost savings could total $1.2 trillion by 2020 (from 2010) and reduce annual energy consumption by 23% compared to "business as usual".

2.2 *Identification of Industry Sectors*

The industries focussed on within this report (see Figure 1) have been considered for a number of reasons; the high energy intensity of the process and the high embodied energy of the product (cement manufacturing), the economic significance (iron and steel industry) and the total energy consumption of the industry (paper and pulp).

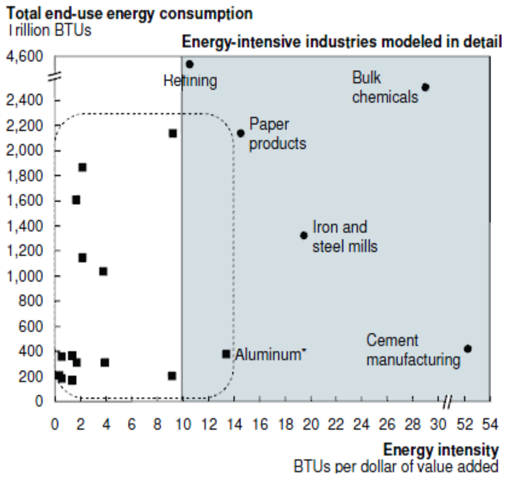

Figure 1. Energy intensity and total energy consumption of a variety of energy intense industries within the US (McKinsey, 2009)

3 GENERAL INDUSRTY

Some barriers to unlocking potential energy efficiency savings within US and UK industry transcend one individual industry sector or are relevant to more than one. This section will explore national macro economic and political barriers.

3.1 *Identified Barriers*

- Disjointed political power and responsibility (US specific): Different levels of US government (federal, state and local) have varying powers over environmental and energy regulation, policy and taxation.
- Education (US/UK): A lack of education about energy efficiency is a broad barrier and has a number of drivers, some of which are dependent on the scale of industry facility or company. A number of the most important are: companies or facilities were not large enough to warrant energy management roles, reliance on external consultants, mistrust of claims and potential savings and a lack of information regarding support schemes, information or available financial schemes
- Investment Culture: This is a wide ranging barrier some of the main issues being: typically a return on

investment was expected within three years for energy efficiency measures, thus limits the range of investments possible, the benchmark return on investment is set much higher than the cost of finance borrowed to fund improvements (DeCanio, 1993) and a lack of finance or a lack of affordable finance to invest in energy efficient technologies

3.2 *Technology and Knowledge Transfer*

There is significant scope for the transfer of knowledge from the UK to the US regarding energy efficiency within industry and in addition at governmental level both in federal and state legislatures;

- Guidance and consultation on various alternative mechanisms for regulating energy usage/GHG emissions e.g. CCL, ETS etc. An upcoming opportunity being Californian legislation (Global Warming Solutions Act, AB 32), which includes 'cap and trade' from 2012.
- Advice and support to industries and businesses in complying with legislation on GHG emissions, from experience with UK industry regarding accounting, monitoring, investment plans etc.
- Energy management policies and practices for business to set up internal energy management structures.

4 CEMENT INDUSTRY

4.1 *Process and Industry Overview*

4.1.1 *Process Energy Usage*

The cement industry is the most energy intense industry considered within this report, with over 40% of the final cost being related to the input energy (IEA, 2009)

There are two main processes used in the cement industry, the wet kiln (historically the dominant method) and the dry kiln process. A wet kiln process has a feed stock with high moisture content (~36%), typically as a result of onsite input natural resources (Ernest Orlando Lawrence Berkeley National Laboratory, 2005) having high moisture contents and the ease of transporting wet feed. The moisture content of dry kiln feed is much lower (~0.5%). Modernisation of the industry and improvements in manufacturing equipment (particularly blending) has allowed the transition to dry kilns. Dry kilns represent a significant energy saving compared to wet kilns, this is due to the energy required to evaporate the water in the wet kiln feed.

An additional process is the semi-wet or semi-dry process these consist of a preliminary stage (compared to the wet process) before entry into the kiln to reduce the water content of the mixture. A semi-wet kiln utilises a slurry press filter where as a semi-dry kiln utilises waste heat from the kiln in a gas slurry drier. A slurry drier can reduce net energy demand (compared to the wet process) by ~0.95 MBtu/ton.

BAT of cement production is considered a six stage pre-heater with pre-calciner as outlined in the BREF (EC, 2010) guidance; this is assumed to be approaching the upper limits of energy efficiency (2.9 GJ/t clinker) with the current process, any further improvement on this would require a 'step change' in the cement production process.

4.1.2 *Industry Overview*

The UK cement industry is highly consolidated with over 93% of production being controlled by three large multi-national corporations. Production is split approximately 90%-10% between the dry and wet kiln process respectively (BSG, 2008). The average energy intensity of the UK cement industry is estimated to be 4010 MJ/t (CSI, 2008).

The US cement industry in contrast is less consolidated with 90% of production being controlled by the ten largest companies (USGS, 2010), a mix of multi-nationals (CEMEX, LaFarge etc) and regional operators, the remaining production capacity is controlled by smaller regional companies and independent owner-operator mills. Production is split approximately 80%-20% between the dry and wet kiln process respectively (USGS, 2010). The average energy intensity of the US cement industry is estimated to be 4240 MJ/t (CSI, 2008).

The energy savings potentials within the US and UK, through the adoption of BAT, is estimated at 1.5GJ/t and 0.8 GJ/t respectively (IEA, 2009)

4.2 *Identified Barriers*

In addition to the macro barriers to uptake, faced by all industry (see Section 3.1), the cement industry faces some sector specific barriers to uptake;

- Identifying and implementing energy efficiency measures - Given the lowest ranking of importance within management of facilities
- Limited Capital- Small owner-operator cement plants have insufficient capital or affordable finance to implement necessary upgrades.
- Production Concerns- Cement works operate most efficiently at continuous operation at near capacity. Significant disruption to production during upgrades likely.
- Expense of retrofit vs. New build – Investment in BAT and other energy efficiency measures are most financially viable and most effective when incorporated in a new build plant rather than a retrofit of an existing facility (IEA, 2009)

4.3 *Technology and Knowledge Transfer*

Due to the nature of the cement industry, i.e. being dominated by large multi-national corporations, BAT is widely understood. The drivers for energy efficiency within the UK are observed in the US, primarily increasing consolidation and rationalisation of production are trends occurring currently and US energy efficiency is likely to improve in the near future and therefore the scope for technology and knowledge transfer between the two countries is limited.

5 IRON AND STEEL INDUSTRY

5.1 *Process and Industry Overview*

5.1.1 *Process Energy Usage*

The steel industry can be split into two separate sub-sectors, primary and secondary steel making. Primary steel, or integrated steel production, is generally made from feedstock from an onsite blast furnace from "new" iron. Secondary steel is that primarily made from scrap metal in an electric arc furnace (EAF).

The production of primary steel, by blast furnace/basic oxygen furnace (BF/BOF), is energy intensive due to the processes of reducing iron ore to iron, ore preparation, coke-making and iron making. Secondary steel production uses EAFs to melt scrap steel, which is subsequently rolled and shaped, this offers significant energy and cost savings. In addition an alternative, but growing production technique is the use of direct reduced iron (DRI) and EAFs. Typical energy consumption per ton of steel output for BF/BOF and EAFs are 13-14 GJ/t and 4-6 GJ/t respectively (IEA, 2009)

5.1.2 *Industry Overview*

The US is the third largest steel producer in the world, with integrated steel mills primarily being located in the Northeast of the country. Production is split 43%-57% between integrated and secondary steel making respectively (USGS, 2010), the average energy intensity in the US steel industry is 12.8 GJ/t (AISI, 2006).

The UK steel industry is the eighteenth largest in the world. Production is dominated by TATA steel primarily in South Wales and Northeast England. Production is split 80%-20% between integrated steel making and secondary steel making respectively. The average energy intensity in the UK steel industry is 19.2 GJ/t (EEF, 2010)

The energy savings potentials within the US and UK, through the adoption of BAT, is estimated at 2.4GJ/t and 2.1 GJ/t respectively (IEA, 2009), primarily in the integrated steel making process.

5.2 *Identified Barriers*

In addition to the macro barriers to uptake, faced by all industry (see Section 3.1), the iron and steel industry faces some sector specific barriers to uptake;

- Increasing global production capacity - Throughout the recent financial crisis and recession (both in Europe and US) global production capacity has increased ~7% per annum throughout '07-'09, the result being a suppression of global steel prices. Import market share (in the US) has grown throughout the recessionary period, and the trade balance, in steel within the US, has further deteriorated (OECD, 2009). In addition global steel production capacity exceeds consumption, demonstrated by recent (Q1-Q2 2009) global capacity utilisation rates of ~74% (Steel Grips, 2009)
- Investment culture within the US- The US integrated steel industry is considered to be in terminal decline since the mid part of the 20th century. The impact being that it is considered unattractive as an investment option (Stubbles, 2000).
- Recent investment activity of US steel manufacturers - Nucor, the US' largest mini-mill operator (Nucor, 2010) has recently been investing in the production of DRI and alternative iron sources (2.5Mt) all of which are in foreign territories (Brazil, Australia and Trinidad), for a number of reasons, location to raw material (iron ore) or inexpensive and abundant energy (e.g. natural gas in Trinidad) (Metal Strategies, 2007). The development in Trinidad has seen the relocation of a DRI facility from Convent, LA to the island and potential expansion to boost production to 2.4Mt

5.3 *Technology and Knowledge Transfer*

The steel industry is highly globalised and steel products, both finished steel products and crude steel, are widely traded; the US and UK industry is highly exposed to global steel corporations and BAT and practice are well understood. Current best practice in integrated steel making has reached the limits of the production process and a radical new process is needed to reduce energy intensity further (EC, 2001)

In addition to those outline in Section 3.2, specific knowledge transfer regarding the steel industry include;

- The recent development of the micro mill in the US (Nucor, 2011) and the Castrip method of ultra thin slab casting. This offers significant energy saving potentials of up to 80% (~0.8 GJ/t) in the casting process compared to mini-mills. Examples plants at Crawfordsville, Indiana and Blytheville, Arkansas. (US transfer to UK)

6 PULP AND PAPER INDUSRTY

6.1 *Process and Industry Overview*

6.1.1 *Process Energy Usage*

The production of paper is split into two distinct processes, the production of virgin pulp, particularly from wood, though other substitute materials can be used e.g. rice etc., the production of pulp from recovered fibres (e.g post consumer waste) and paper and paperboard mills, which produce the finished paper products from pulp. Energy costs represent ~20% of the production cost per ton of completed paper product (Ernest Orlando Lawrence Berkeley National Laboratory, 2009).

The stages of the paper manufacturing processes, both pulp and paper making uses varying amounts of energy, the most significant stages being, the pulping processes (chemical pulping 14.25 GJ/t and mechanical pulping 7.5 GJ/t) and drying in the paper making process (IEA, 2009). Integrated pulp and paper mills have the greatest energy saving potential due to the possibilities of recycling and reusing waste heat from either process in the other.

6.1.2 *Industry Overview*

The US paper and pulp industry has experienced considerable consolidation in terms of ownership, with over 50% of production being controlled by 4 companies in all aspects of the industry (pulp production, paper mills and paperboard mills). The United States is the largest global producer of both paper and paperboard and pulp production (2006 Figures; IEA, 2009). The US has one of the oldest age distributions of paper and pulp mills (IEA, 2009), and therefore the energy saving potential is one of the greatest in the world.

The UK paper and pulp industry is small in comparison, to the US, with the vast majority of pulp demand being met through imports. There are 2 remaining integrated mills in the UK (CPI, 2009a), exclusively supplied by UK grown softwood and sawmill waste. The UK pulp industry has been in continuous decline with the industry halving in size since 1996 (Department of the Environment, 1996).

The energy savings potentials within the US and UK, through the adoption of BAT, is estimated at 5.2GJ/t and 2.0 GJ/t respectively (IEA, 2009).

6.2 *Identified Barriers*

In addition to the macro barriers to uptake, faced by all industry (see Section 3.1), the pulp and paper industry faces some sector specific barriers to uptake;

- Geographic split in US pulp and paper production- The greatest energy efficiency potential (EC, 2001; IEA, 2009) is through the development of new integrated pulp and paper mills, due to the utilisation of waste heat gases at various stages. There is a geographic split in the production of pulp (centered in the Southeast) and production of paper products (centered in the Northeast. Though the exported orientated production in Northern Europe, specifically Finland and Sweden, has shown the potential competitive benefits of integrated production (US specific).
- Expense of retrofit vs. New build – Investment in BAT and other energy efficiency measures are most financially viable and most effective when incorporated in a new build plant rather than a retrofit of an existing facility. The incorporation of CHP units requires complex integration of infrastructure into the pulp and paper mill, as the steam and heat are the primary benefits of installation and electricity secondary. (Ernest Orlando Lawrence Berkeley National Laboratory, 2009)
- Technical limits of paper recovery - The upper technical limits of paper recovery is 81% (CEPI, 2006), however US and UK recovered paper

utilisation rate is less than total recovered paper, both countries are exporters of recovered paper to China and other emerging nations (FAO, 2011; CPI, 2009b), therefore potential energy efficiency gains from increasing recovery rates is limited.

6.3 *Technology and Knowledge Transfer*

In addition to those outline in Section 3.2, specific technology transfer regarding the paper and pulp industry;

- European BAT – Recent investment in the pulp and paper industry in Northern Europe (Finland and Sweden), have produced industry leading energy efficiency performance. Significant investment expected with the US industry replacing and/or upgrading the existing aging capital stock.

7 CONCLUSIONS

It is clear that no one energy efficiency technology or knowledge transfer between the UK and the UK or vice versa, is a single solution to overcoming barriers of investment. Policies and strategies will have to be sector specific and to some extent different from business to business. One of the single most important differences however has been the effect of UK environmental policy e.g. the Climate Change Levy, which has directly taxed energy usage, this has been one of the primary drivers for increasing energy efficiency especially in the cement sector.

8 FURTHER RESEARCH

A significant amount of further research has been highlighted as a result of this study; primarily a more detailed study of the individual sectors considered is required. This future research should highlight potential technologies, particularly breakthrough technologies that could significantly reduce energy consumption and investigate the policies and conditions for them to be successfully adopted.

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