Low Carbon Technologies for Energy-Intensive Industries

Energy-intensive industries such as chemicals, paper, ceramics, cement, iron and steel are responsible for 45% of carbon emissions from businesses and the public sector in the UK. This briefing discusses carbon dioxide (CO$_2$) abatement technologies for these industries and policies to support their adoption.

Background

Energy-intensive industries (EIls, see Box 1) employ around 620,000 people in the UK, contributing over £49 billion in goods and services to the economy (2008). There is debate over how to ensure that production of these goods in the UK is compatible with achieving greenhouse gas emission targets. The Climate Change Act 2008 requires a 34% reduction by 2020 and an 80% reduction by 2050 compared with 1990 levels. Several policies are being used to penalise emissions and so encourage a shift to low carbon technologies. However, such technological change involves significant time and investment by EIls, which could lead to “carbon leakage” (Box 2) – the movement of operations or investment outside the UK. To achieve a balance between reducing emissions and keeping industry in the UK, the government also provides commercial incentives to develop and implement abatement technologies.

Policy

The Climate Change Levy

The Climate Change Levy (CCL) came into effect in 2001 in the UK. It taxes the following commodities to try and encourage efficiency: electricity; coal; coke; natural gas; and other hydrocarbon gases in a liquid state. Electricity from renewable sources or electricity to be used in electrolysis (e.g. aluminium smelting) is not taxable under the levy. Also commodities that are used for non-fuel or for dual-use purposes, such as coal used in integrated steel plants, are exempt. Fuel used by “good quality” combined heat and power schemes is also not covered.

Overview

- Government has to balance two competing goals: reducing CO$_2$ emissions and keeping industry in the UK. It does this by penalising emissions while incentivising investment in low carbon technologies.
- Over the next decade, existing technologies will be used to continue emissions reduction.
- Beyond 2020, transformative technologies, such as carbon capture and storage, will be needed to make significant improvements. Development and demonstration of such technologies requires considerable time and investment.
- Alongside this, where electricity use is essential to make a product, it will be important to use a low CO$_2$ electricity supply.

Box 1. Energy-Intensive Industries (EIls)

EIls use large amounts of electricity, fuel or heat and may also release CO$_2$ from raw materials (process emissions) e.g. in cement manufacture. The major EIl sectors are iron and steel, aluminium, cement, ceramics, chemicals, food & drink, foundries, lime, glass, non-ferrous metals, paper and industrial gases.

EU Emissions Trading System (EU ETS)

The EU ETS is a “cap and trade” system for electricity generation and heavy industry implemented in 2005 to reduce greenhouse gas emissions (see POSTnote 354). EIls covered by the system include iron and steel, cement, glass and ceramics and other industries involving combustion plants, for example oil refining. It is currently in Phase II, which runs from 2008-2012 and covers 45% of EU emissions. Each member state agrees with the European Commission the level of emissions allowable for the industries covered as a portion of an EU-wide cap. Allowances can then be traded between over-emitters and under-emitters. This creates a price for carbon dioxide (CO$_2$), and provides an incentive for low carbon manufacturing. In Phase III (2013-2020), aluminium, bulk organic chemicals, non-ferrous metals, and gypsum will be
Green Investment Bank is an important consideration and so the government's availability and cost of capital in the EU and in developing countries. Allowances could be spent to tackle climate change both in the sector's energy cost and in return for meeting negotiated CO2 emissions under Climate Change Agreements (CCAs).

To incentivise investment in energy efficiency and low carbon technologies, 65% discounts on the CCL are available under Climate Change Agreements (CCAs) for EIIs, in return for meeting negotiated CO2 reduction targets. These will rise to 90% in 2013 for electricity as part of the mitigation package for the carbon price floor. To qualify for CCAs the sector's energy costs per unit of production value must be more than 3%. This rises to greater than 10% if a threshold 'import penetration ratio', which assesses the risk of carbon leakage, is not met (2006 Energy Products Directive). Also, under a non-legally binding commitment, at least half of the revenues from the auctioning of EU ETS allowances could be spent to tackle climate change both in the EU and in developing countries.

The availability and cost of capital for low carbon technology is an important consideration and so the government's Green Investment Bank, which is designed to accelerate private sector investment in the UK's transition to a "green economy" over the coming years, may play a role.

Existing Low Carbon Technologies

Energy costs are considerable for EIIs and so have driven improvements in energy efficiency. These improvements resulted in an average yearly reduction of 1.1% in energy related carbon emissions between 1990 and 2007. The prevailing message from EIIs is that they will spend the next decade implementing best available technologies (BAT) to further increase energy efficiency, without changing how their core processes operate. There are several potential energy efficiency measures that have short payback periods. These range from good practices, such as maintenance and adding lagging to pipes, to more advanced technologies including better monitoring and process control. However, the consensus is that many of the easy abatement options have already been implemented.

Achieving further efficiency savings will require major investments, such as replacing steam boilers or updating onsite power plants. With these assets lasting several decades, replacement or retrofitting with energy efficient alternatives will make financial sense only if the existing equipment is at the end of its natural life. Thus it can take time for the most energy efficient technology and practices to become standard through an industry, and feasibility might also be limited as a result of the original design of the plant. Investments in low carbon technology for the UK also need to compete with other international opportunities within multinational companies, such as building a brand new plant outside the UK. The following are some examples from a range of industries describing continuing energy efficiency measures.

Iron and Steel

The UK's three integrated iron and steel plants make up the bulk of this industry's 20.4 Mt of CO2 emissions - the largest outside the power sector. Most emissions come from coke use in the blast furnace reaction. Modern furnaces operate close to the theoretical minimum amount of coke needed, meaning continued use of BAT in peripheral activities is required to realise industry expectations of a 20% CO2 reduction by 2020 compared with 1990 levels. Improving on-site electricity generation can yield major reductions. For example, at the Tata steelworks in Port Talbot, a £60m investment enabled the recycling of exhaust gases to produce 10% of the plant's electricity needs. This also led to a 60% reduction in the amount of natural gas needed, and a reduction in CO2 emissions of 0.3 MtCO2/year.

Brick

The UK brick industry emits ~1 MtCO2/year. Ibstock, the largest manufacturer in the UK, has implemented a number of energy efficiency measures to date through investments totalling £50m in new kiln and dryer technology. For example, a new £12m kiln has yielded fuel savings of around 25%.
Cement

The UK’s 14 cement plants accounted for 5.7 MtCO₂ emissions in 2010 (9.6 MtCO₂ in 2007). In cement production, 40% of the emissions come from heating the kiln and 60% from the chemical reaction that produces the clinker, which is the main component of cement used in concrete. Advancements in energy efficiencies in the UK and the impact of the recession saw CO₂ emissions fall 57% between 1990 and 2010. A common abatement measure uses surplus heat from the kiln to dry the input material. Alternatives to fossil fuels, such as tyres and waste packaging, are also increasingly used. The UK cement industry replaces 38% of the kiln energy with waste-derived alternatives (nearly 17% from biomass), less than some EU countries with better waste recovery and greater public acceptance. However, such measures do not address the 60% of emissions coming from the chemical reaction itself, which requires new technologies (Box 3).

Transformativeness Technologies

The government’s Carbon Plan predicts that total industrial emissions may have to be reduced by 70% by 2050 to meet its national targets. However, an energy consultancy firm has estimated that, assuming no significant carbon leakage occurs and best available technology is implemented, UK emissions will fall just 13% by 2050. This suggests that new technologies will be needed.

Some potential transformative technologies are specific to a given industry; Box 3 outlines the potential of novel cements. Others may have applications across a range of sectors. For example, as an alternative to fossil fuels, biomass can be used to create syngas, a mix of carbon monoxide and hydrogen, which as a fuel has the potential to reduce emissions in the brick and other kiln-based sectors (Box 4). This syngas, along with other industrial biotechnologies, can also form the basis for the manufacture of a wide range of low carbon chemicals (Box 5). Future biomass availability is critical to the success of these technologies. For instance, it is vital that the source of biomass does not compete with food production. An example source is municipal solid waste, from which a company called Graphite Resources can recover up to 55% as useful biomass. Finally, carbon capture and storage could be applied to plants with very large CO₂ emissions.

Carbon Capture and Storage (CCS)

Carbon Capture and Storage (CCS, see POSTnote 335), captures CO₂ released by a process and then stores it permanently underground to stop it entering the environment. Alternatively this CO₂ could be used as a raw material (Box 6). So far CCS development in the UK has focused on power generation, but sectors it could be applied to include iron and steel, ammonia production and cement manufacture. It has been reported that if CCS was implemented outside power generation that it would be feasible to abate ~38 Mt of CO₂, increasing the previously quoted 13% reduction between 2008 and 2050 to a 42% reduction. There are three main points to consider when applying CCS to industry as opposed to power generation:

- sector-specific capture technologies are needed;
- the costs of CCS across sectors is different;
- cost effective CCS needs CO₂ transport clusters.

Sector-Specific Capture Technologies

The CCS technologies needed to capture industrial emissions differ from those needed to capture power sector emissions because the processes and the way in which the CO₂ is generated are different. They will also vary between industries meaning CCS will be available on varying timescales. For example, each novel steelmaking technology may require a unique CCS technology (Box 7).
real economies of scale in this infrastructure: doubling investment in a pipeline provides 10 times the capacity. Thus, cost effective industrial CCS will require cooperation with the very large CO₂ emitters of the power sector to create CO₂ transport clusters. For example creating pipework suitable for a future cluster would add 10% to the first power station project but could reduce future CO₂ transport costs by 40%. The location of Erills in the UK lends itself to transport clusters, as much heavy industry is geographically compact within short distances to oil fields and saline formations, which have massive storage potential. A proposed cluster which involves a project applying for European funding through DECC is described in Box 7. The forthcoming DECC CCS delivery programme will consider industrial CCS and the importance of clustering to achieve cost-effective CCS for the mid-2020s.

Box 7. Combining Coke-Free Steelmaking with CCS
The ultra-low carbon dioxide steelmaking consortium of EU steel companies and research institutions identifies these four steelmaking technologies as part of their goal to more than halve emissions.

- **Top Gas Recycling with CCS (post-2020).** This emits CO₂ in a way that is compatible with subsequent CCS and could be retrofitted to existing UK plants, reducing total CO₂ emissions by up to 60%. A full scale demonstration project is expected in France by 2015.

Further reductions would require new designs to replace coke.

- **Hisarna Smelting,** a total redesign yielding a 20% CO₂ reduction (80% if combined with CCS). The first pilot plant is in the Netherlands.

- **the ULCORED process.** This uses gas (instead of coke) and electricity to create steel and could also be used with CCS.

- **ULCOWIN (Alkaline Electrolysis).** This uses electricity to create steel. It is unlikely to be commercialised before 2040 and requires cheap, decarbonised, electricity.

**CO₂ Transport Clusters.**
Pipeline infrastructure to transfer captured CO₂ to storage facilities will require significant capital investment. There are