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A review of the technologies, economics and policy instruments for decarbonising energy-intensive manufacturing industries

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ABSTRACT

Industrial processes account for one-third of global energy demand. The iron and steel, cement and refining sectors are particularly energy-intensive, together making up over 30% of total industrial energy consumption and producing millions of tonnes of CO_2 per year. The aim of this paper is to provide a comprehensive overview of the technologies for reducing emissions from industrial processes by collating information from a wide range of sources. The paper begins with a summary of energy consumption and emissions in the industrial sector. This is followed by a detailed description of process improvements in the three sectors mentioned above, as well as cross-cutting technologies that are relevant to many industries. Lastly, a discussion of the effectiveness of government policies to facilitate the adoption of those technologies is presented. Whilst there has been significant improvement in energy efficiency in recent years, cost-effective energy efficient options still remain. Key energy efficiency measures include upgrading process units to Best Practice, installing new electrical equipment such as pumps and even replacing the process completely. However, these are insufficient to achieve the deep carbon reductions required if we are to avoid dangerous climate change. The paper concludes with recommendations for action to achieve further decarbonisation.

Contents

Abbreviations: BAT, best available technology; BF, blast furnace; BOF, basic oxygen furnace; BP, best practise; CCA, climate change agreement; CCL, climate change levy; CCS, carbon capture and storage; CDM, clean development mechanism; CDQ, coke dry quenching; CDU, crude distillation unit; CHP, combined heat and power; DRI, direct reduced iron; EAF, electric arc furnace; ETS, emissions trading system; FCC, fluid catalytic cracker; ISIC, International Standard Industrial Classification; OHF, open hearth furnace; SMR, steam methane reforming; TGR, top gas recycling; TRT, top-pressure recovery turbine; VDU, vacuum distillation unit; VSD, variable speed drive

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1. Introduction

Industrial processes are highly energy intensive and currently account for one-third of global energy use [1]. Around 70% of this energy is supplied by fossil fuels. CO_2 emissions from industry make up 40% of total CO_2 emissions worldwide. If emissions from the industrial sector remain unchecked, total emissions are projected to increase by 74–91% by 2050 compared to 2007 [2]. The UN IPCC recommends that global CO_2 emissions should be reduced by at least 50% compared to 1990 levels by 2050, so as to confine the rise in global mean temperature to below 2 °C and to limit the possibility of dangerous climate change [3]. In order to realistically meet this target, the International Energy Agency (IEA) [2] recommends that by 2050, direct emissions from industry must be 24% lower than those in 2007. However, demand for manufactured goods is expected to be double or even greater by 2050 [4]. The majority of this growth will occur in developing or newly industrialised countries such as China, India, the Middle East and Africa to follow [2]. These countries are currently heavily dependent on fossil fuels, and coal in particular. Although newly built equipment in these countries is often state-of-the-art, a significant proportion of the capital stock is inefficient and outdated.

Since the 1990s, the energy consumption of industry per unit of value added in the IEA19 countries has decreased by ~1.3% per year on average (once adjusted for structural changes) [5]. This is less than in earlier decades. The 1970s and 1980s saw an average reduction in energy intensity of 2.8% per year. However, potential for improvement still remains, particularly in the non energy-intensive sectors. To date, energy costs for these industries have made up a smaller share of their costs, so they have had less incentive to improve their energy efficiency compared to energy-intensive industries. A headline conclusion of the World Energy Outlook 2012 [6] is that 'energy efficiency can keep the door to 2 °C open for just a bit longer'. The IEA suggests that if energy efficiency is made a priority (as in their Efficient World Scenario), savings in the industrial sector alone could amount to around 23 EJ (550 Mtoe), compared to their New Policy Scenario [6]. Total industrial energy use in the New Policy Scenario is 146 EJ (3497 Mtoe), hence energy efficiency can save around 15.7% of energy consumed.

This paper reviews the energy efficient and low carbon technologies for achieving energy and CO_2 savings in the industrial sector, focussing on three main sectors: (1) iron and steel, (2) cement and (3) refineries, as well as (4) crosscutting options (e.g. motor and steam systems and combined heat and power). The paper begins by defining the industrial sector and then gives an overview of past and present activity, energy consumption and CO_2 emissions from the industrial sector as well as the recent literature in this field (Section 2). The next Sections (3–5) look in detail at the energy efficiency technologies. These cover process-specific options in three sectors as well as crosscutting options. In each case, the overall production process is described and the sector is placed in context in terms of current production, energy consumption and emissions trends. The full range of energy efficiency technologies is discussed, including the energy savings potential and costs. In Section 9, the paper looks beyond energy efficiency and considers a range of other technologies for further decarbonising industry. Finally, in Section 10 the various policy mechanisms for encouraging the uptake of these technologies are introduced and discussed.

2. An overview of the industrial sector

2.1. Classification of industrial activity

The term 'industry' is often used very loosely in the context of both energy and CO_2 emissions. In some publications it is used to refer only to manufacturing and in others includes the power, mining and construction sectors. It is important to clarify exactly what is meant before making any assumptions. There are a