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Research Paper

Industrial decarbonisation of the pulp and paper sector: A UK perspective

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ABSTRACT

The potential for reducing industrial energy demand and 'greenhouse gas' (GHG) emissions in the *Pulp and Paper* sector (hereinafter denoted as the *paper* industry) has been evaluated within a United Kingdom (UK) context, although the lessons learned are applicable across much of the industrialised world. This sector gives rise to about 6% of UK industrial GHG emissions resulting principally from fuel use (including that indirectly emitted because of electricity use). It can be characterised as being heterogeneous with a diverse range of product outputs (including banknotes, books, magazines, newspapers and packaging, such as corrugated paper and board), and sits roughly on the boundary between *energy-intensive* (EI) and *non-energy-intensive* (NEI) industrial sectors. This novel assessment was conducted in the context of the historical development of the *paper* sector, as well as its contemporary industrial structure. Some 70% of recovered or recycled fibre is employed to make *paper* products in the UK. Fuel use in *combined heat and power* (CHP) plant has been modelled in terms of so-called 'auto-generation'. Special care was taken not to 'double count' auto-generation and grid decarbonisation; so that the relative contributions of each have been accounted for separately. Most of the electricity generated via steam boilers or CHP is used within the sector, with only a small amount exported. Currently-available technologies will lead to further, short-term energy and GHG emissions savings in *paper* mills, but the prospects for the commercial exploitation of innovative technologies by mid-21st century is speculative. The possible role of bioenergy as a fuel resource going forward has also been appraised. Finally, a set of low-carbon UK 'technology roadmaps' for the *paper* sector out to 2050 have been developed and evaluated, based on various alternative scenarios. These yield transition pathways that represent forward projections which match short-term and long-term (2050) targets with specific technological solutions to help meet the key energy saving and decarbonisation goals. The content of these roadmaps were built up on the basis of the improvement potentials associated with different processes employed in the *paper* industry. Under a *Reasonable Action* scenario, the total GHG emissions from the sector are likely to fall over the period 1990–2050 by almost exactly an 80%; coincidentally matching GHG reduction targets established for the UK economy as a whole. However, the findings of this study indicate that the attainment of a significant decline in GHG emissions over the long-term will depends critically on the adoption of a small number of key technologies [e.g., energy efficiency and heat recovery techniques, bioenergy (with and without CHP), and the electrification of heat], alongside a decarbonisation of the electricity supply. The present roadmaps help identify the steps needed to be undertaken by developers, policy makers and other stakeholders in order to ensure the decarbonisation of the UK *paper* sector.

1. Introduction

1.1. Background

The industrial sector in the *United Kingdom of Great Britain and Northern Ireland* (UK) accounts for 17% of total final energy consumption [1] and a corresponding 20% of carbon emissions [2] in 2015. There are large differences between industrial sub-sectors in the end-use applications of energy, especially in terms of products manufactured, processes undertaken and technologies employed (see Fig. 1 [3]). It is clear that the pulp and paper subsector (hereinafter denoted as the *paper* industry) as seen in Fig. 1 gives rise to the sixth highest industrial energy consumption in the UK; caused by a combination of drying/separation processes (40%), low temperature heating processes (28%), compressed air requirements (10%), space heating (8%) and electrical motors (6%) [3]. UK industry overall has been found to

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Nomenclature

Abbreviations

BAT	Best Available Technology
BCE	before the 'Common Era'
BGS	British Geological Survey
BPT	Best Practice Technology
CCA	Climate Change Agreements
CCL	Climate Change Levy
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CE	(in the) 'Common Era'
CEPI	Confederation of European Paper Industries
CHP	Combined Heat and Power
CPI	Confederation of Paper Industries (in the UK)
CT	(the UK) Carbon Trust
DECC	(the former UK) Department of Energy and Climate Change
DNO	Distribution Network Operator
DSF	Demand-Side Flexibility
DSP	Demand Side Participation
DSR	Demand Side Response
DUKES	Digest of United Kingdom Energy Statistics (annual)
ECN	Energy research Centre of the Netherlands
ECUK	Energy Consumption in the UK (DECC annual statistical publication)
EI	energy-intensive
EU	European Union
EU-ETS	EU Emissions Trading Scheme
GB	Great Britain
GHG	'greenhouse' gas
GOS	(the UK) Government Office of Science
H:P	heat-to-power ratio
I&C	industrial and commercial
ICT	information and communications technology
IEA	International Energy Agency
IOP	Index of Production (ONS statistical bulletin)
IPPC	Integrated Pollution Prevention and Control (EU regulatory data)
LA	Low Action (scenario)
NEI	non-energy-intensive
NG	natural gas
NP RES	'non-programmable' renewable energy sources
ONS	Office of National Statistics (for the UK)
ORC	organic Rankine cycle
PRODCOM	'Production Communautaire' (Community Production – EU statistical database)
PV	(solar) photovoltaic (power generators)
RA	Reasonable Action (scenario)
RA-CCS	Reasonable Action together with Carbon Capture & Storage (scenario)
RCUK	Research Councils UK
RT	Radical Transition (scenario)
SEC	specific energy consumption
SIC	(UK) Standard Industrial Classification
SRF	solid recovered fuel
UED	(the industrial) Usable Energy Database
UK	United Kingdom of Great Britain and Northern Ireland
UKERC	UK Energy Research Centre

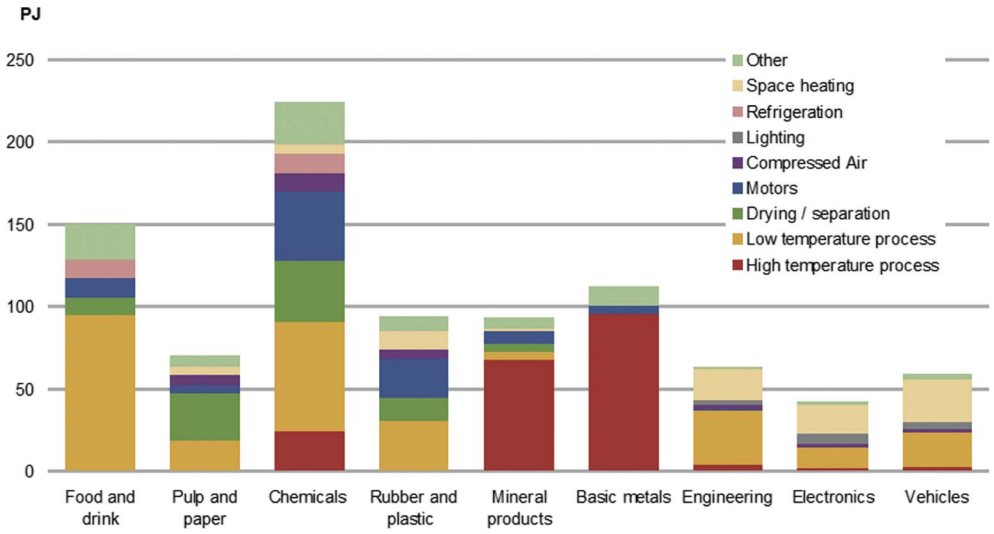

Fig. 1. Final UK energy demand by industrial subsector and end-use. *Source:* Norman [3].

consist of some 350 separate combinations of sub-sectors, devices and technologies [4,5]. Nevertheless, it is the only end-use energy demand sector in the UK that has experienced a significant fall of roughly 60% in final energy consumption over the period 1970–2015 [1]. This was in spite of a rise of over 40% in industrial output in value added terms. However, the aggregate reduction in energy intensity (MJ/£ of gross value added) fell by 38 per cent during 1990–2015 [1], but this masks several different underlying causes: *end-use efficiency* {accounting for around 80% of the fall in industrial energy intensity; largely induced by the price mechanism [4,5]); *structural changes in industry* [a move away from *energy-intensive* (EI) industries towards *non-energy-intensive* (NEI) ones, including services [4,5]}; and *fuel switching* (from coal and oil to natural gas and electricity that are cleaner, more readily controllable, and arguably cheaper for the businesses concerned).

1.2. The issues considered

The present study builds on work by Dyer et al. [4], commissioned by the UK *Government Office of Science* (GOS), Hammond and Norman [6], and on a recent 'Advanced Review' by Griffin et al. [7]. In each case, a variety of assessment techniques for determining potential energy use and 'greenhouse gas' (GHG) reductions were discussed. Griffin et al. [7] then evaluated the wider UK industrial landscape with the aid of decomposition analysis [8] in order to identify the factors that have led to energy and carbon savings over recent decades. They consequently assessed the improvement potential in two sectors: 'Cement'