Environmental Innovation and Societal Transitions 10 (2014) 42–58

Contents lists available at ScienceDirect

Environmental Innovation and Societal Transitions

journal homepage: www.elsevier.com/locate/eist

Do lead markets for clean coal technology follow market demand? A case study for China, Germany, Japan and the US

Jens Horbach[a,*], Qian Chen[b], Klaus Rennings[c], Stefan Vögele[d]

[a] Augsburg University of Applied Sciences, Augsburg, Germany
[b] Chinese Academy of Science (CAS), Institute for Policy and Management (IPM), Beijing, China
[c] Centre for European Economic Research (ZEW), Mannheim, Germany
[d] Forschungszentrum Jülich (FZJ), Jülich, Germany

ARTICLE INFO

Article history:
Received 6 December 2012
Received in revised form 19 August 2013
Accepted 19 August 2013

JEL classification:
Q31
Q37
Q43

Keywords:
Coal power plants
Energy technology
Energy policy
Lead markets

ABSTRACT

Despite high CO_2 emissions released by coal-fired energy production, coal will remain an important source of energy in coming decades. This case study explores the lead market status of China, Germany, Japan and the US for clean coal technologies. We concentrate on two existing technological standards: supercritical (SC) and ultra-supercritical (USC) pulverized coal technologies. In 1960s and 1970s, the US was a lead market for SC und USC technologies. During these decades, Japan was a lag market, but it surpassed the US in the early 1980s. Recently price and demand advantages began to shift to China. We conclude that lead market status may switch over time to markets with high growth rates, although first mover advantages may exist in non-lead markets for some R&D-intensive products, such as turbines. Less R&D-intensive products, such as boilers, are attractive as a basis for leapfrogging strategies, which many emerging countries have been successfully employing.

1. Introduction

Despite the high CO_2 emission intensity of fossil and especially coal-fired energy production, these energy carriers will play an important role during the coming decades. In Germany, nuclear energy

* Corresponding author.
E-mail address: jens.horbach@hs-augsburg.de (J. Horbach).

2210-4224/$ – see front matter
http://dx.doi.org/10.1016/j.eist.2013.08.002

is in the process of being phased out, and in countries such as China and India, energy demand is still growing at a rapid pace, requiring the further expansion of coal consumption. With known coal deposits of over 14,800 billion tons, coal can power us well into the next century (Löschel, 2009). Some 44% of hard coal resources are located in the US, 28% in China and 18% in Russia. The reserves of lignite (brown coal) are also considerable: 4200 billion tons remain in the ground, with 33% in the US, 31% in Russia, 15% in China and 1% in Germany. Aside from its abundance, an additional argument in favor of coal is that in most countries, it is cheaper than natural gas.

In Germany, hard coal (22.8%) and brown coal (25.5%) were responsible for nearly half of overall electricity production in 2007. According to IEA projections (2007), the share of coal in electricity generation will not shrink until 2030. In the EU 27, coal will continue to make up 30% of electricity production in 2030, while in China it will be responsible for 80% of electricity production by this year. Even if we factor in the expansion of efficiency improvements, China will produce more than 60% of its electricity using coal in 2030 (Löschel, 2009).

Against this backdrop, cleaner and more efficient coal-fired power plants will have an important role to play in global energy production and in climate policy in the future. This study examines the lead market status of four major countries (China, Germany, Japan and the US) with regard to innovation in clean coal technology. Japan, Germany and the US are the leading countries for developing and producing coal technologies, whereas China is the country with the highest demand for coal-based electricity production (see Section 3). The lead market approach for environmental innovation developed by Beise and Rennings (2005) identifies six success factors for lead markets: comparative price and demand advantages, a high reputation in environmental technology (transfer advantage), similar market conditions (export advantage), a competitive market structure and ambitious environmental regulation. In addition, we also take supply side aspects into account (Rennings and Cleff, 2011; Tiwari and Herstatt, 2011). Our ex-post analysis identifies the existence of lead markets for the most important clean coal technologies.

The dominant technological trajectory in fossil fuel power plants is pulverized combustion, which is used in 90% of coal-fired production worldwide (WCI, 2005; Rennings and Smidt, 2010). Accordingly, we focus on this technology in our study. Another reason for this focus is that we want to concentrate on technologies that have already left the demonstration phase. This is the case for subcritical, super and ultra-supercritical pulverized coal technologies. By contrast, for Carbon Capture Storage (CCS), no diffusion curves can be derived, as this technology is still fairly new.

This paper is organized as follows: Section 2 describes clean coal technologies and their diffusion curves for Germany, China, Japan and the US. Section 3 applies the lead market approach to the case of clean coal technologies by developing and quantifying indicators of lead market factors. Section 4 takes additional supply side factors into account. In Section 5, we validate our results with expert interviews with German firms. Section 6 summarizes the results and concludes.

2. Coal power plant technology and diffusion curves

In general terms, a clean coal technology may be defined as a "technology that, when implemented, improves the environmental performance and efficiency as compared to the current state-of-the art in coal-fired power plants" (Buchan and Cao, 2004). Coal-fired power stations using pulverized bed combustion are categorized based on steam conditions when entering the turbine, condenser pressure or, alternatively, turbine efficiency (RWE Power AG, 2011; IEA, 2010a). Steam conditions are categorized as subcritical, supercritical or ultra-supercritical. Steam is called supercritical when the steam parameters exceed its critical point. The higher the temperature and pressure of the steam, the higher is the efficiency of the power plant. A subcritical power plant works with a steam temperature of about 540 °C or less and a pressure of about 160 bar, which lies under the critical point. This technology is out-of-date and has been superseded by supercritical power plants, where the steam temperature lies between 540 °C and 600 °C and pressure between 230 bar and 270 bar. Temperatures of 600 °C with a pressure of 270 bar are state of the art and are called ultra-supercritical. Using this technology, an efficiency rating of 40–43% can be achieved. We shall call technologies characterized by temperatures