Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Energy 32 (2007) 1996–2005
ENERGY
www.elsevier.com/locate/energy

A centurial history of technological change and learning curves for pulverized coal-fired utility boilers

Sonia Yeh[a,*], Edward S. Rubin[b]

[a]Carolina Transportation Program, Campus Box #3140, New East, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3140, USA
[b]Department of Engineering and Public Policy, Baker Hall 128A, Carnegie Mellon University, Pittsburgh, PA 15213, USA

Received 30 November 2006

Abstract

Recent study of the history of technological change has provided better understanding of the driving forces for technological innovation, as well as quantitative estimates of historical rates of technical change. Although such results are widely used in long-term energy models to estimate future costs over time periods of up to a century, most studies of technological learning for major energy technologies are based on historical trends over time periods not longer than 20–30 years (often because of data limitations). Relatively few studies quantify longer-term (century-scale) trends. This study helps fill that gap by reviewing the history of pulverized-coal (PC) power plants, with a specific focus on the technological progress of PC boiler technology over the last century. Historical data for U.S. plants are used to develop long-term experience curves for the overall thermal efficiency of PC power plants, as well as the capital cost of PC boilers and non-fuel operating and maintenance (O&M) costs of PC plants. Despite a technology plateau experienced by PC power plants two decades ago, recent developments indicate that such plants will continue to improve and remain a competitive and important part of power generation technology portfolios.

Keywords: Pulverized-coal boilers; Experience curve; Thermal efficiency; Coal-fired power plant; Learning-by-doing; Technological change; Steam plant; Steam turbine; Electricity

1. Introduction

The importance of technological innovation and its contributions to increased productivity, lower production costs, and economic growth are widely recognized [1–3]. Studies have characterized the historical pattern of cost reductions associated with increased level of production in a variety of industries—a phenomenon commonly called learning-by-doing [3–5]. In most cases, cumulative output or capacity is used as a measure of experience to quantify overall cost reductions resulting from economies of scale, learning-by-doing, capital deepening [6], and expenditures for research and development [7], as well as other factors that influence cost trends (e.g., changes in market structure, organizational forgetting, variations in knowledge transferability, and government regulations) [8–11]. Endogenous models of technical change are increasingly used in large-scale integrated assessment models, typically in the form of an ‘‘experience curve’’ (also called a learning curve) that relates changes in specific investment cost to the cumulative installed capacity of the technology. While there are substantial uncertainties in the use of experience curves to project future technology costs and implications [12,13], the growing use of experience curves in large-scale energy models represents a significant methodological advance over the more common assumption of an exogenously specified cost reduction that is independent of other factors.

For energy technologies, most experience curves used in large-scale models are based on technologies with observed time scales of not longer than about 30 years [14–16]; yet, such curves are commonly used to project energy technology cost reductions over periods of 50–100 years [17–21]. Because relatively few of today’s technologies have been in use for longer than half a century, and because

*Corresponding author. Tel.: +1 919 962 3512; fax: +1 919 962 5206.
E-mail address: sonia_yeh@unc.edu (S. Yeh).

0360-5442/$ - see front matter
doi:10.1016/j.energy.2007.03.004