Energy Policy 52 (2013) 264–276

Contents lists available at SciVerse ScienceDirect

Energy Policy

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

Reviving manufacturing with a federal cogeneration policy

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HIGHLIGHTS

- ► Industrial cogeneration could meet 18% of US electricity demand by 2035, vs. 8.9% today.
- ► The policy would be highly favorable to manufacturers and the public.
- ► Traditional electric utilities would likely lose revenues.
- ► Deadweight loss would be introduced by tax incentives.
- ► The policy's net social benefits would be much larger.

ARTICLE INFO

Article history:
Received 31 October 2011
Accepted 29 August 2012
Available online 22 October 2012

Keywords:
Cogeneration
Industrial energy efficiency
Cost–benefit analysis

ABSTRACT

Improving the energy economics of manufacturing is essential to revitalizing the industrial base of advanced economies. This paper evaluates ex-ante a federal policy option aimed at promoting industrial cogeneration—the production of heat and electricity in a single energy-efficient process. Detailed analysis using the National Energy Modeling System (NEMS) and spreadsheet calculations suggest that industrial cogeneration could meet 18% of U.S. electricity requirements by 2035, compared with its current 8.9% market share. Substituting less efficient utility-scale power plants with cogeneration systems would produce numerous economic and environmental benefits, but would also create an assortment of losers and winners. Multiple perspectives to benefit/cost analysis are therefore valuable. Our results indicate that the federal cogeneration policy would be highly favorable to manufacturers and the public sector, cutting energy bills, generating billions of dollars in electricity sales, making producers more competitive, and reducing pollution. Most traditional utilities, on the other hand, would lose revenues unless their rate recovery procedures are adjusted to prevent the loss of profits due to customer owned generation and the erosion of utility sales. From a public policy perspective, deadweight losses would be introduced by market-distorting federal incentives (ranging annually from $30 to $150 million), but these losses are much smaller than the estimated net social benefits of the federal cogeneration policy.

1. Introduction

The ability of the United States to manufacture goods and sell them to world markets has propelled the nation into its current position as a world superpower. Despite this historic strength, global competition for export markets, foreign investments and raw materials is intensifying, and U.S. manufacturing is now struggling to remain competitive. Since 1957, manufacturing has declined from 27% of U.S. GDP to only 11% today (PCAST, 2011, p. 2). Over the past decade, China has become the world's largest producer of steel, aluminum, and cement (IPCC, 2007), and in 2010, it surpassed the U.S. as the world's leading producer of manufactured goods (PCAST, 2011). Starting with furniture, clothing and textiles, and now extending to information technology and other high-tech commodities, production facilities are moving offshore. Some contend that developing countries naturally transition from agriculture to manufacturing and finally, services; however, when manufacturing migrates offshore, so do many of the capabilities that spur innovation and help to create new industries (Pisano and Shih, 2009), suggesting it can be a perilous transformation. Furthermore, expanding industries overseas have the opportunity to use the most modern and high-efficiency technologies, while older U.S. industries frequently have inefficient legacy technologies that can be expensive to upgrade.

A recent report by the President's Council on Science and Technology (PCAST, 2011) on *Ensuring American Leadership in Advanced Manufacturing*, and President Obama's announcement of the Advanced Manufacturing Program both underscored the

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0301-4215/$ - see front matter Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.enpol.2012.08.070

link between manufacturing and innovation. As Pisano and Shih (2009) explain it, product and process innovation are intertwined, making essential the co-location of manufacturing and process design. When manufacturing is exported, subsequent generations of U.S. inventions and innovations may also be compromised. Without process engineering, companies find it difficult to develop the next generation of process technologies, which in turn makes it difficult to create new products. The outsourcing of manufacturing thus creates a downward spiraling chain reaction.

One way to make U.S. manufacturing more competitive is to cut its energy costs by improving the energy efficiency of its operations, as noted by PCAST (2011). An additional way is for manufacturers to create a new revenue stream by generating electricity from "opportunity fuels" that would otherwise be waste products at their manufacturing plant, including thermal heat, high pressure steam, black liquor, and hot exhaust gases. Industry currently purchases 25% of the electricity generated by utilities in the U.S. (EIA, 2011a, Table A8). If manufacturers could instead cogenerate enough power to meet their own needs, and possibly sell excess power back to the grid or to other consumers, their profitability could grow considerably. Additional revenues streams can result from other services that CHP can provide, such as district heat and biofuels, which can rival the value of the manufacturer's "principal" commodity, as it does in the pulp and paper industry in Scandinavia.

Industry accounts for nearly one-third of total U.S. energy use, including the direct combustion and conversion of petroleum products, natural gas, and coal (EIA, 2011a, Table A2). Large firms with more than 250 employees are responsible for about two-thirds of industry's energy use and many of them are also excellent candidates for cogeneration—the production of electricity and heat in a single process. Also called combined heat and power (CHP), cogeneration uses about 40% less energy than conventional production of heat and electricity (assuming that there is a heat sink or demand for utilizing the heat from the condenser). A traditional system separately producing heat and power operates at 45–49% efficiency, while a CHP system meeting the same heat and power demand can be 75– 80% efficient (EPA, 2011; Shipley et al., 2008). Such figures may be higher or lower depending on the specific industrial context, the efficiency of the boiler and electric power production for the traditional system, and the efficiency of the CHP system, as shown by Trygg and Karlsson (2005).

Approximately two-thirds of industrial CHP systems in the U.S. are fueled by natural gas (ICF International, 2009; Shipley, et al., 2008). Prominent among the remaining fuel types are other fossil fuels (principally oil and coal), as well as wood. Waste gases from landfills, methane from anaerobic digesters, solid waste, wood waste and agricultural by-products can also be exploited by CHP systems, and these resource recovery markets are expanding (SENTECH, 2010). The primary CHP technologies used in U.S. industries today are gas turbines, reciprocating engines, and steam turbines. These "prime movers" are combined with a generator, heat recovery unit, and electrical interconnections into systems that are optimized based on available fuels, the "spark-spread" between fuel and electricity prices, and the need for power versus thermal energy. For example, recuperated gas turbine systems use exhaust heat to preheat combustion air, which significantly increases electrical efficiency and is important for applications with higher power to thermal ratios. Steam turbines are usually used where low-cost solid waste fuels are available for boiler use. In combined systems, a gas turbine is coupled with a heat recovery steam generator to drive a steam turbine generator, achieving power generation efficiencies as high as 60%. Large CHP installations often use this combined cycle design, and it has become the most common design worldwide for new central power stations fueled with natural gas (SENTECH, 2010).

Based on U.S. technology assessments and comparisons with CHP markets in other countries such as Japan, Denmark and Germany, there is a large potential for expanded CHP usage in this country (Brown et al., 2012; Shipley et al., 2008; Granade et al., 2009). Despite the apparent economic attractiveness of CHP, the technology is penetrating the market slowly.

2. Barriers and drivers

The broader application of high-efficiency industrial technologies is impeded by a range of technical, corporate, regulatory, and workforce barriers. While chemical manufacturing, petroleum refining, pulp and paper production, iron and steel, and cement manufacturing dominate industrial energy use, the sector is diverse in terms of products, manufacturing processes, and business practices. This diversity promotes competition and innovation, but also complicates the process of transformation and modernization. In addition to the difficulty of sharing lessons across industries, numerous other financial, regulatory, and workforce barriers stall the market penetration of combined heat and power systems (CCCSTI, 2009; Brown et al, 2010). CHP suffers generally from high upfront cost and inexpensive electricity (Chittum and Kaufman, 2011). Financial barriers including lack of access to credit and project competition within firms are also key issues blocking the diffusion and implementation of new technologies like CHP across firms and industries (Canepa and Stoneman, 2005; Rohdin et al., 2006; Worrell et al., 2001). Broadly defined, regulatory barriers impose significantly on CHP—these include input-based emissions standards, the Sarbanes–Oxley Act of 2002, utility monopoly power, and grid access difficulties that require interconnection standards and net metering rules (Shirley, 2005; Brooks et al., 2006; Brown and Chandler, 2008). Lastly, adopting a new technology like CHP without a trained workforce and adequate engineering know-how increases the perceived risk to managers, lessening technology transfer and deployment (Bozeman, 2000; Worrell et al., 2001).

Of particular note is the fact that electric utilities typically do not support industrial cogeneration because they can experience a loss of profits from the erosion of utility sales. Thus, this promising source of clean electricity and industrial competitiveness will likely not flourish in the absence of federal regulations and subsidies. While CHP represents 9% of power generation in the U.S., it represents more than 50% of the power generation in Denmark, the world leader, and nearly 40% in the Netherlands (Casten and Ayres, 2007, p. 210). Cogeneration has been a priority for the supply of power in these countries, partly because of the high price of electricity in European markets and the denser populations. Government programs in Europe have promoted CHP with supporting regulations and RD&D programs.

Drivers that could motivate greater industrial CHP usage are also numerous and illuminate the choice of effective policy interventions. While the uncertainty of future energy costs is a deterrent to capital-intensive energy upgrades, firms can achieve greater financial stability through energy efficiency and on-site power generation. Energy efficiency will help meet energy needs. In combination with peak load pricing for electricity, energy efficiency and demand response can be a lucrative enterprise for industrial customers, especially when an additional revenue stream from the sale of electricity and other byproducts can be created. Several state and federal programs have made significant contributions to strengthening the CHP market, notably the U.S. Department of Energy's Regional Clean Energy Application Centers and the federal CHP investment tax credit (Chittum and Kaufman, 2011). In addition, pressure from shareholders, consumers, regulators, and internal actors to set and attain