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Reviewing electricity production cost assessments

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ABSTRACT

A thorough review of twelve recent studies of production costs from different power generating technologies was conducted and a wide range in cost estimates was found. The reviewed studies show differences in their methodologies and assumptions, making the stated cost figures not directly comparable and unsuitable to be generalized to represent the costs for entire technologies. Moreover, current levelized costs of electricity methodologies focus only on the producer's costs, while additional costs viewed from a consumer perspective and on external costs with impact on society should be included if these results are to be used for planning. Although this type of electricity production cost assessments can be useful, the habit of generalizing electricity production cost figures for entire technologies is problematic. Cost escalations tend to occur rapidly with time, the impact of economies of scale is significant, costs are in many cases site-specific, and country-specific circumstances affect production costs. Assumptions on the cost-influencing factors such as discount rates, fuel prices and heat credits fluctuate considerably and have a significant impact on production cost results. Electricity production costs assessments similar to the studies reviewed in this work disregard many important cost factors, making them inadequate for decision and policy making, and should only be used to provide rough ballpark estimates with respect to a given system boundary. Caution when using electricity production cost estimates are recommended, and further studies investigating cost under different circumstances, both for producers and society as a whole are called for. Also, policy makers should be aware of the potentially widely different results coming from electricity production cost estimates under different assumptions.

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Abbreviations: CASES, cost assessments for sustainable energy systems; CC, coal condensing; CCGT, combined cycle gas turbine; CHP, combined heat and power; CHP-B, combined heat and power biomass; CHP-W, combined heat and power waste; DECC, Department of Energy and Climate Change; DR, discount rate; EIA, U.S. Energy Information Administration; EU, European Union; EUR, Euro; EUSUSTEL, European Sustainable Electricity; EWEA, European Wind Energy Association; GBP, British Pound; GDP, Gross Domestic Product; HC, heat credit; HP, hydropower; IDC, interest during construction; IEA, International Energy Agency; IHS, Information Handling Services; IMF, International Monetary Fund; kW_e, kiloWatt electrical; MIT, Massachusetts Institute of Technology; MW_e, megaWatt electrical; MWh_e, megaWatt-hour electrical; NEA, Nuclear Energy Agency; NEEDS, New Energy Externalities Development for Sustainability; NP, Nuclear Power; OCGT, open cycle gas turbine; PB, Parsons Brinckerhoff; PV, Photovoltaics; PwC, PricewaterhouseCoopers; PWR, pressurized water reactor; R&D, research and development; SKGS, Skogen, Kemin, Gruvorna och Stålet (Swedish); USD, United States Dollar; VGB, VGB PowerTech e.V.; WP, Wind power

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1. Introduction

The last decade has witnessed an increased number of studies examining electricity generation or production costs[1] from alternative power generating technologies, and references to such studies can often be heard in the public debate. In the European Union (EU), electricity production costs assessments have been used to justify various forms of economic support schemes for renewable power generating technologies [1,2], and to estimate necessary levels of CO_2 emission fees, such as those used within the EU Emission Trading System, needed to narrow the gap between fossil fueled technologies and other low-carbon alternatives [3]. Recent literature in this field includes the works by NEEDS [4], IEA and NEA [5], EIA [6], VGB [7], Elforsk [8], and DECC [9].

It is common to find the cost figures reported in these studies to vary greatly. This is problematic since electricity generation cost assessments are typically used to rank different power generating technologies based on the expected generation cost and to estimate economic subsidies or penalty charges needed. As such, generation cost assessments are important in energy decision and policy making.

This paper focuses on costs for producers, i.e. costs that that can be directly attributed to the investment and operation of power plants. Such costs will be named *production costs of electricity* in this paper. However, power plants also cause socio-environmental damages during their construction, operation and dismantling, for instance, due to the emission of environmentally unfriendly and hazardous gases, particles and greenhouse gases. Such costs are called *external costs*, since they are costs not incurred by the power plant owners.[2] External costs are discussed in this paper, but in a more qualitative way. Whenever they are discussed and/or added to production costs, the wording *electricity generation costs* will be used.

This paper[3] reviews several electricity production cost assessments with the purpose to identify the differences in the methodologies and in the underlying assumptions that can explain the often diverging cost figures reported in the literature. These differences are discussed with special attention to some major factors influencing the stated electricity production costs. Moreover, issues regarding the current methodologies are also highlighted and discussed from a perspective of energy policy making.

A thorough analysis of twelve studies of electricity production costs published in the year 2007 or later, is carried out. Some of these studies were conducted or commissioned by government departments [10–12]; others were performed by energy agencies [5], by research and development companies [8], consulting firms [13], and by European Commission funded projects [4,14,15]. The study by Förnybart.nu [16] is a compilation of different studies [17–20] and was also analyzed in this study. A recent review by Branker et al. [21] about solar photovoltaic levelized cost of electricity production was also included.

The review about low-carbon baseload generating technologies by Nicholson et al. [22] was not considered since the electricity production costs presented appear too generalized and it was not deemed possible to distinguish different cost components (for example, external costs are not separated from electricity production costs and the discount rates used are not presented). Freeman [23] provided an overview of the environmental costs of electricity, while Damen et al. [24] compared electricity and hydrogen production systems with CO_2 capture and storage, but none of them are included since they appear quite outdated. Finally, we remark that Khatib [25] provided an overview of the joint report by the IEA and the OECD Nuclear Energy Agency [5], which is one of the 12 studies included in our review.

The paper is structured as follows: Section 2 presents an overview of the electricity production cost estimates from different studies. Section 3 highlights some factors that have a major influence on the stated costs, and which can explain the wide range of published estimates. Section 4 is devoted to the implications of using these electricity production cost estimates for policy making. Finally, Section 5 provides a concluding discussion of the main findings.

2. Overview of current electricity production cost estimates

The main focus of this study is on current cost figures of commercial power generating technologies: to avoid outdated cost figures, no study published earlier than the year 2007 was included in this review (see Table 1).

External costs, due to the potential impact of power plants on, for example, human health, ecosystems, crops, buildings and climate change are not considered. Costs induced by taxes and subsidies are also excluded, despite the fact that such costs can be significant, since they vary among different countries and are decided by governments. However, external costs, subsidies, taxes and differences in technical characteristics have to be considered in decision and policy making. The electricity system is simply affected in different ways depending on the technology with some power plants in more need of balancing power, back-up capacity and transmission investments than others. Therefore, these will be discussed in Section 4 which considers the policy implications of assessments for electricity generation costs. Estimates of future electricity production costs that might change in the future due to, for example, learning curves are also outside the scope of this review.

From an investor's perspective, the future assumptions about the income coming from produced electricity are crucial for investment decisions. In liberalized electricity markets, investors face greater risk as future electricity price levels are uncertain [26]. Moreover, current electricity production cost methodologies generally fail to account for the fact that dispatchable power generating technologies have an economic and technical advantage over non-dispatchable alternatives, since the latter only produce electrical energy during favorable weather conditions. However, our

[1] A more suitable name would be *electrical energy* production or generation costs. The use of *electricity* as an equivalent of electrical energy is commonly accepted and it will therefore be retained in this paper.

[2] See the report by the European Commission [28] for more details.

[3] This paper is based on the work conducted by Larsson [29] on behalf of the Energy Committee at the Royal Swedish Academy of Sciences. For details and further information related to the topics discussed in this paper, please see Larsson [29].

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