Energy Policy xx (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Energy Policy

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

Short communication

Apples and oranges: Comparing nuclear construction costs across nations, time periods, and technologies

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ARTICLE INFO

Keywords:
Nuclear construction costs
Experience curves
International comparison

ABSTRACT

The literature on energy technology costs, diffusion, and learning has been characterized by data limitations, partial or arbitrary data sets, apples to oranges comparisons, and imprecision in the use of key concepts and terminology. Two responses to our paper, Lovering et al. (2016), by Koomey et al. and Gilbert et al. reflect many of these problems, conflating learning curves with experience curves, trends in actual costs with the relationship between cost estimates and final construction costs, and component costs with total installed costs. The respondents use inconsistent definitions of demonstration, first-of-a-kind, and commercial deployment across different energy technologies. They also propose to compare final installed costs for nuclear power plants, encompassing construction and finance costs, across different national economies and time periods encompassing a wide range of macro-economic circumstances and finance arrangements that overwhelm any signal from trends associated with the actual construction costs of the plants in question. In this response, we address the specific issues raised in these papers and suggest better practices for comparing energy technology costs, trends, and technological learning.

1. Introduction

Koomey et al. and Gilbert et al. offer a range of criticisms of our data and analysis. Some relate to the quality of our data, the choices we made about what data to include, and how we treat the data that we collect. Other criticisms relate to our analysis, how we compare costs across different economies and time periods, how we treat construction and finance costs, how we define technological learning versus cost trends and demonstration versus commercial technologies. Finally, some criticisms take issue with our conclusions, whether or not there is evidence for intrinsic negative learning associated with the growth of national and/or global nuclear capacity and what can be said about costs of nuclear plants cross-nationally.

We find many of the specific criticisms in these responses to be without merit, reflecting either basic misunderstandings of the nature and extent of the data collected, misapplication of key concepts and terminology, or misapprehension of the analytical claims that we have made. Many of these criticisms, however, do point to broader problems that have been endemic to the energy technology literature generally and assessments of costs, cost trends, and technological learning associated with nuclear power plants more specifically. These include significant data limitations, partial or arbitrary data sets, apples-to-oranges comparisons, and imprecision in the use of key concepts and terminology.

We agree with Gilbert et al. that better data might allow for stronger conclusions as to the drivers of nuclear costs. However, better methods and more consistent and precise use of key concepts will be necessary to draw clearer conclusions as long as the available data on the cost of the global nuclear fleet remains limited.

In the sections that follow, we address all of the criticisms specifically, while also placing our methods and analysis in the context of broader challenges for the field. We suggest better practices for addressing those challenges and directions for future research.

2. Data availability, quality, and novelty

Koomey et al. claim that our data has not been made public. This is not the case. The data set is publicly available on our website and also has been shared with dozens of scholars who have requested access since the publication of our analysis in these pages earlier this year. We have also included it as an Appendix to this article.

The data set used is by far the largest collection of verified final construction costs for global nuclear power plants ever compiled, over twice the size of that compiled in Sovacool et al. (2014). Our standards

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http://dx.doi.org/10.1016/j.enpol.2016.11.004
Received 13 May 2016; Received in revised form 12 September 2016; Accepted 2 November 2016
Available online xxxx
0301-4215/

for including data were simple and straightforward, only real costs for completed reactors (no cost estimates or projections) that were operated commercially (no experimental or research reactors). We also constrained our data presentation to those countries where we could get data for the entire commercial nuclear history. As an example, we were able to find reliable OCC data for 24 commercial reactors in the UK, but we did not include them in the study because we could not get costs for the full commercial history (45 reactors total) in the UK.

We do not find merit in Gilbert et al. suggestion that our data set is less reliable than that cited in Sovacool et al. (2014). Much of it is drawn from the same sources. In fact, Sovacool et al. (2014) acknowledge that they acquired cost data by taking “estimates at face value from a variety of sources, including government reports, peer-reviewed academic articles, project documents, industry assessments, electric utility annual reports, and public utility commission briefings. Each of these sources may define costs and construction periods differently.” By contrast, we only cited costs where we could find consistent final costs across multiple sources. The Sovacool data set is not only significantly smaller but also fails to compile the full commercial history for any of the nations that it covers, encompassing only 57% of commercial reactors in the US, 82% in France, 55% in Japan, 16% in Canada, 17% in Switzerland, and 2% in Britain.

Koomey et al. question the accuracy of data collected for South Korean plants, possibly based on their recent history with fraudulent parts certificates in their plants. We acquired the South Korean cost data from the national utility, but we corroborated and checked this data against figures from two independent bodies: the National Assembly Budget Office and the Korean Power Exchange. Additionally, we can corroborate the Korean cost trend by looking at construction duration, which is monitored by the IAEA, an independent and international organization focused on safety and security. Their data on construction time in Korean shows a parallel trend of declining construction duration over time (IAEA, 2016).

There was some inconsistency in the number of South Korea reactors cited in our analysis, as noted by Gilbert et al. Our analysis includes costs for 25 completed reactors in South Korea. Table 1 refers to 19 reactors in the second wave of Korean reactor deployment, but three of those are still under construction and thus were not included in our cost trends.

More generally, the issues raised by Koomey et al. and Gilbert et al. do speak to a broader set of challenges associated with assessing nuclear cost trends and learning. Nuclear power deployment globally has entailed hundreds of large, complicated, and costly public works projects undertaken in a wide variety of economic circumstances and institutional arrangements (i.e public entities, regulated private utilities, and private contractors). Reliable data on actual construction costs is scant in some major nuclear countries, such as Russia, China and, surprisingly, the United Kingdom. Given the partial nature of the current data and the wide range of contexts in which nuclear plants have been deployed, it is critical that researchers use consistent criteria for selecting plants to include in their analysis and precise terminology to define both selection criteria and analytical scope. We will return to this question in the following sections. Undertaking further efforts to find reliable costs from China and Russia, would be particularly important, as much anecdotal evidence suggests that these nations may have quite different cost experiences than that encompassed in the nuclear cost literature to date.

3. Comparing costs across widely varied national, temporal, and macro-economic contexts

Gilbert et al. (2016) and Koomey et al. (2016) both criticize our use of Overnight Construction Cost as our metric for comparison and our exclusion of Interest During Construction (IDC), suggesting that doing so understates the final installed cost of nuclear power. The criticism both misapprehends the purpose of our analysis and argues for introducing a factor -interest costs- across a wide range of macroeconomic conditions, institutional arrangements, and financing methods that would make any comparison of construction costs cross-nationally and temporally functionally impossible.

The sixty-year history of nuclear construction encompasses periods in which private capital has been extremely costly and extremely cheap. Plants have been constructed by private utilities and private contractors raising capital on private markets and by public utilities, government agencies, and state-owned enterprises with public bonding authority and access to much cheaper capital. Depending on the finance arrangement and the cost at which capital has been acquired, construction duration and delays have dramatically different implications for the final cost of the plant. For any analysis attempting to ascertain how the cost of building a nuclear plant across multiple national economies and time periods has evolved, attempting to include IDC introduces a range of highly variable factors that obscure any trend associated with the evolution of the technology, learning by doing, economies of scale, labor and materials costs, or other factors associated with the actual construction of the plant.

OCC costs are lower than costs after financing. But our paper makes no specific claims about how much nuclear plants cost either cross-nationally or in comparison to other energy technologies but simply seeks to compare construction cost trends in different countries and across different time periods in order to ascertain what evidence there is for technological learning and what contexts and institutional arrangements appear to be correlated with positive or negative cost trends.

IDC can be a somewhat accurate proxy for construction time and delays, but there is no need for a proxy. Construction time is much better documented than construction cost and is available for every commercial reactor through IAEA. Studying trends in construction time and delays directly, and the relationship of those factors to total costs, is a much more useful analysis than aggregating both time and interest in IDC. See Davis (2011) for an estimation of the effect of both cost of capital and construction duration on the total cost of a nuclear power plant. See Moreira et al. (2013) or Berthélemy & Rangel (2015) for a study of trends in construction duration.

Lastly, Overnight Construction Cost is more useful as a base cost in both energy systems models and estimates for policymakers. Total cost can be estimated through a combination of assumptions about overnight cost, interest rates, and construction duration, all of which follow different trends in different countries.

Gilbert et al. and Koomey et al. also argue that it can be inappropriate to compare costs across countries without properly converting between currencies. We agree. For this reason, we chose to present OCC in local currencies in Figures 2–11. We did present costs for all countries in Fig 12, but the motivation was to compare the difference in cost trends across these countries, not to compare absolute costs.

By contrast, it has been common in the peer reviewed literature to cite trends in global nuclear costs (Trancik, 2006) when what is in fact being cited are cost trends in the United States, a country where, until recently, no new construction had been initiated for over three decades. One purpose of our study was to examine global trends in nuclear construction costs beyond the United States (and France) and encompassing recent decades. Given both the globalization of the market for nuclear and other non-fossil based energy technologies and the reality that most energy consumption and carbon emissions in the 21st century occur beyond the borders of OECD economies, it will be all the more important that the literature more closely examine energy technology learning, cost trends, and institutional arrangements in non-OECD contexts.

4. Comparing learning rates for different technologies

Koomey et al. (2016) criticize our use of solar PV cost data and