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Chapter

The Cost of Energy Independence

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Abstract

To reduce potential exposure to economic fluctuations and dependence on extra-territorial energy sources, some European Union (EU) member states are exploring energy diversification as a path to energy independence, economic vitality and national security. Nuclear power is a leading alternative energy source which may enable the EU to weather and potentially avert energy insecurity crises, including ones arising out of or related to political crises, collective action by oil-producing nations, global oil demand, and oil price fluctuations. Although nuclear power may be a long-term energy solution, the risks and cost trajectories deter many EU member states from nuclear power plant construction due to operation, maintenance and security costs. This chapter considers some key costs and potential options to reduce costs.

Keywords: cost, discount rate, price, supply, production, coal, gas, uranium, EU, OPEC, IMF, Euratom Treaty, Nord Stream, power plant, power generation, renewables, reactor

1. Introduction

Although global energy markets began tightening in 2021 as economies emerging from the COVID-19 pandemic unleashed pent-up demand in manufacturing, transportation, and travel and as consumers gradually resumed pre-pandemic activities, [1] the global energy market contraction accelerated in 2022 with the disruption of supply chains and the rise in energy prices caused by uncertainty over energy supplies [2] and weather-related factors [3].

Due in large part to the cuts in oil supplies by Russia [4] after its invasion of Ukraine on February 24, 2022, [5] and lowered production targets by the Organization of Petroleum Exporting Countries [6] (OPEC), this contraction in global energy supply fueled rising inflation rates worldwide. The emerging energy crisis deepened in September 2022 after Russia cut off oil supplies to Europe from the Nord Stream 1 pipeline [7]. In November 2022, OPEC further cut production in response to the weakening global economy, rising interest rates and growing fear of a potential global recession [8].

Against this backdrop, the International Monetary Fund (IMF) cut projected global growth rate to 3.2% for 2022 and to 2.7% for 2023, a significant decrease from the 6% achieved in 2021 [9]. The IMF identified energy as a key driver of global inflation in Figure 1 in its October 2022 World Economic Outlook report, as illustrated below ([9], at 4).

In response to unprecedented high fossil fuel costs which “account [ed] for 90% of the rise in the average costs of electricity generation worldwide (natural gas alone
Exacerbating the energy crisis, EU member states imposed sanctions on Russia, including cessation of coal imports. As of August 2022, coal “deliveries from Europe’s largest external supplier fell to zero.” Prior to Nord Stream 1 pipeline supply cut-off, Russian energy deliveries to the EU were down by 80% by September 2022. As the war in Ukraine continues and constricted access to energy resources continues to drive inflationary costs and pricing, EU members states continue to grapple with measures to alleviate the economic impact of Russia’s cutting gas deliveries and the EU’s ban on Russian coal importation.

2. Price vs. cost

2.1 Definitions

As the price and cost of energy resources influence decisions about energy resources, it is important to understand the terms are not an interchangeable. For purposes of this chapter, the term “price” is defined as

“a: the amount of money given or set as consideration for the sale of a specified thing
b: the quantity of one thing that is exchanged or demanded in barter or sale for another” [11].

and the term “cost” is defined as

“a: the amount or equivalent paid or charged for something
b: the outlay or expenditure (as of effort or sacrifice) made to achieve an object” [12].
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2.2 Price

With respect to the price of uranium ore, the per pound price was $48.15 on December 16, 2022 [13]. In comparison, the price of crude oil on December 17, 2022 ranged from $74.29 (WTI crude) to $80.47 (OPEC basket) [14]. While the price of uranium ore is relatively low compared to that of crude oil, the price of uranium's fuel form increases once processed and enriched due to the costs of processing and enrichment. In its 2021 Uranium Marketing Annual Report, the U.S. Energy Information Administration (USEIA) noted civilian nuclear power reactor owners and operators (collectively, COOs) purchased a total of 46.7 million pounds of uranium (equivalent) at a weighted-average price of $33.91 per pound [15]. In comparison, as natural gas prices skyrocketed in 2021, the global demand for coal power generation increased 9% to “10,350 terawatt-hours (TWh)” ([16], pp. 8, 10). Although EU coal consumption was projected 45 metric tonnes (MT) in 2021, the price of coal quadrupled to $170/MT in September 2021 [16] and soared to an “all-time high of around $450 per tonne” while the price of uranium was $48.10 [17].

3. Cost

3.1 Processing and enrichment

In addition, COOs purchased 14 million separative work units (SWU) under enrichment services contracts from 11 sellers at an average price of $99.54 per SWU [18]. According to the WNA, the $1663 front-end fuel cycle costs of 1 kg of uranium as of September 2021 were significantly higher than for raw uranium ore ($842 for 8.9 kg U3O8×$94.6/kg) due to the cost of conversion ($120 for 7.5 kg U×$16), enrichment ($402 for 7.3 SWU×$55) and fuel fabrication ($300) ([18, 19], p. 62).

In 2011, the World Nuclear Association (“WNA”) concluded “about half of the cost [of nuclear power] is due to enrichment and fabrication” [17]. Although those costs are significant, the WNA concluded nuclear power is “cost competitive with other forms of electricity generation, except where there is direct access to low-cost fossil fuels” [emphasis added] [19]. However, the WNA also acknowledged “nuclear technologies are capital intensive relative to natural gas or coal, [and] the cost of nuclear rises relatively quickly as the discount rate is raised”, [18] seemingly undercutting its 2022 assertion of nuclear power’s cost competitiveness. However, after applying a 7% discount rate, “the median value of nuclear is close to the median value for coal ...,” and at a 10% discount rate the median value for nuclear is higher than that of either CCGTs or coal” [18].

3.2 Old vs. new nuclear plants

While nuclear power generated by existing older plants may be competitive with fossil fueled plants, the unit cost of nuclear energy by new nuclear power plants which must amortize the costs of new construction are higher than for older nuclear and new fossil fuel power plants. In large part, the higher cost of power generated by new nuclear plants is due to finance costs and construction cost overruns [20]. Specifically, the high capital costs for plant construction, lengthy construction time, interest fees on capital used to finance construction and lengthy time period before
a power plant begins generating for new nuclear power plant construction [21]. In addition, the cost of nuclear accidents is also a factor. If such costs were “allocated to the aggregate output of nuclear power plants . . . [in 2011, they] would [have led] to a price increase of 2.3 euro cent per kWh” [22]. EDF Group, one of the world’s largest power companies, estimated the minimum construction cost of a new nuclear power plant in France will be €950 million (approximately €5700 per kW) before 2030 [23]. Consequently, nuclear plant construction typically requires some form of government subsidization/support ([24], p. 17).

While the cost to bring a new nuclear power plant online (e.g., fuel, construction, safety, accident liability, environmental impact, etc.) may be daunting, the levelized cost of electricity (LCOE) for “nuclear energy plants coming online in 2020 was $95.2/megawatt hour (MWh), comparable to conventional coal ($95.1/MWh), above conventional combined cycle natural gas-fired plants ($75.2/MWh) but below conventional combustion turbine natural gas fired plants ($141.5/MWh)” [24, 25]. In a 2020 joint study by the International Energy Agency (IEA), Nuclear Energy Agency (NEA) and Organization for Economic Co-Operation and Development (OECD), estimated the LCOE in U.S. dollars per MWh for nuclear plants built 2020–2025 based on specific discount rates and an assumed 85% capacity factor [26]. Depending on the discount rate applied and the country in which construction occurs, the projected LCOE per MWh of a new nuclear plant will vary. Accordingly, while the LCOE of new nuclear plant in France is estimated at $45.3 (3% discount rate), $71.1 (7% discount rate) and $96.9 (10% discount rate), the LCOE of a similar new plant in Slovakia is estimated at $57.6 (3% discount rate), $101.8 (7% discount rate) and $146.0 (10% discount rate) [27].

3.3 Cost effectiveness

Historically, the 1957 Treaty on the European Atomic Energy Community (Euratom Treaty), as amended, [27] was created in part to enable EU member states to develop civilian nuclear power as an inexpensive, plentiful source of power generation [28]. By 2019, the Euratom Treaty contributed to the EU receiving “25% of electricity ... from nuclear, 46% ... from fossil fuels and biomass, and 29% ... from renewables (including 11% from hydro)” [29]. As France is one of the EU’s leading producers of nuclear energy, assuming its socio-economic approach of applying “standardized hypotheses (on GDP, demographics, public policies in other European countries, and electricity consumption)” is applicable to other EU member states, and assuming the majority of those states’ respective “existing nuclear units were the most affordable ones” [emphasis added], nuclear power may be an economically tempting alternative to fossil fuels ([30], pp. 163–167).

In comparison to other renewable energy resources, the 2021 report commissioned by European Conservatives and Reformists (ECR) Group and Renew Europe concluded “nuclear energy is more cost-effective than [other] renewables ... and would remain the cheaper option in 2050.” [30]. That conclusion may not hold true if uranium ore costs $100/kg (or more) as the resulting fuel cost is €5.50/MWh [30]. For example, after uranium prices peaked at $125–150/kg in 2008, they subsequently decreased to $100/kg by 2019 [31]. As the lion’s share of nuclear power costs occur early on, its cost advantage over other renewables decreases if the weighted average cost of capital [31] increases. Accordingly, unless the direct and indirect costs of new construction can be lowered and the lengthy timeline from construction to power generation can be offset, fossil fuels may remain an economically attractive option.
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As the EU’s electricity generation is dependent on fossil fuel plants which rely heavily on fuel imports from Russia, ([32], pp. 206, 209) it makes economic sense for the EU to increase investment in alternative or supplementary energy sources and technologies such as nuclear power. Indeed, as early as 2018, the EU’s use of renewable energy resources surpassed that of solid fossil fuels and accelerated in 2020 [33]. The EU’s need to utilize renewables to provide a reliable and cost-effective supply of energy for civilian uses is underscored by its wide deployment and development in Russia and the People’s Republic of China (PRC). In 2019, Russia and the PRC were at forefront of the “5.5 GW of new nuclear capacity” installed worldwide [34]. In the third quarter of 2022 EU energy product imports reached €70 billion, reflecting an 11.3% increase in petroleum imports and a 13.2% increase in natural gas imports from 2021 [35]. Although this increase may be attributed mainly to surging prices after Russia cutting off its exports of those commodities to the EU, the strain of filing the supply void of the 14.4% Russia supplied to the EU [36] until its late September 2022 cut-off underscores its sensitivity to global oil demand and oil price fluctuations – and the need for a stable, reliable and cost-effective energy supply within the EU.

4. Cost-reduction options

In November 2021, the French secretary of state for the digital sector, Cedric O, nuclear energy “is not an ideological question, it is a mathematical question.” [37]. For EU member states to overcome cost hurdles posed by new construction and other related costs (e.g., regulatory oversight, waste water storage, spent fuel disposal, political opposition, public acceptance, insurance, environmental concerns, accident clean up, etc.), cost-reduction options are critical. As Europe imports 90% of its natural gas and 97% of its oil supplies, [38] technologies, techniques and design solutions may be the keys to efficient lower cost construction and decreased time to power generation in ways which do not compromise safety will be the drivers.

4.1 Cooperation

One seemingly straight-forward option is to increase cooperation within the EU on energy construction projects. Although this option may seem simple, multistate coordination among numerous government agencies is a complex process. Updates to the Euratom Treaty such as Council Directive 2014/87 [39] and the European Instrument for International Nuclear Safety Cooperation (effective on June 14, 2021, [40]), provide guidance and a framework for cooperation. Although the practical aspects of multistate cooperation such as equitable allocation of projects, fairness and open competition during the bid process, project management, regulatory oversight, national security, budgeting and cost management are harder nuts to crack, energy security is vital to EU economies and of paramount interest in light of the on-going hardships occasioned by the Nord Stream 1 pipeline cut-off, cessation of coal imports from Russia and production decrease by OPEC.

4.2 Plant size and design

In this winter of energy discontent, if the EU considers construction of new nuclear plants within its member states as a potential longer term solution to its energy woes, plant size and design must be factored in the planning and budgeting
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stages. Although smaller plants should require less materials and less time for construction than larger plants, small modular nuclear reactors (SMRs), “[d]ue to the loss of economies of scale, the decommissioning and waste management unit costs of SMR [is actually two to three times] higher than those of a large reactor” [41]. Such plants cost may cost over 30% “more than the traditional nuclear power plants by 2030s... [as] each kWh of electricity would cost between 15 and 70% more ... due to economies of scale” [42]. While larger scale plants are more cost-effective from a power generation standpoint as the reactor typically produces 1000 MW compared to the 300 MW typically produced by a smaller reactor, [42], the “capital start-up costs are much lower.. [with fewer construction] cost risks”, place less of a load strain on electricity grids, “can be manufactured and assembled at a central factory and then sent to the site of installation”, [42]... “greater simplicity of design, economy of series production ... , short construction times, and reduced siting costs”, potential for below ground level installation, “high level of passive or inherent safety in the event of malfunction” [43]. As there are multiple SMR manufacturers (e.g., GE Hitachi Nuclear Energy, NuScale Power, China National Nuclear Corporation, CAREM, SMART, Holtec International, Rosatom, etc.), [43] the EU may be able to drive better bargains on construction costs if it hosts open bids.

4.3 Management practices

According to a 2018 study by the Massachusetts Institute of Technology (MIT), mismanagement (i.e., poor construction management practices) is behind the large cost of nuclear plant construction [44]. As in any industry, benchmarking and utilizing best practices are tools to increase efficiency. In the case of nuclear power, MIT concluded mismanagement is the real reason why “cost [in the East] is $3000–$4000 per kilowatt, whereas in the West the cost is north of $8000 per kilowatt” when it benchmarked “failed projects and the successful projects” [45]. The study determined “indirect costs—those external to hardware—caused 72% of the cost increase ... Examples include rising expenditures on engineering services, on-site job supervision, and temporary construction facilities.” [46]. Based on its review, the MIT study made the following cost management recommendations:

“Make[s]ure that the design is complete, ... that you have fabricators and constructors on your design team early so that you know that what you design can be built.”

To minimize construction delays and cost over-runs, ensure "everyone has skin in the game, making sure the process can deal with and adapt quickly to change ...”

To prevent supply chain gaps and/or delays, take steps to ensure the project has a “reliable supply of spare parts and trained workers” prior to starting construction.” [47].

Reduce materials used and "automate some construction tasks” [48].

5. Conclusion

To achieve an economically acceptable and feasible level of independence from economic fluctuations and dependence on extra-territorial energy sources, the EU will need make a long-term investment in nuclear power to mitigate economic and
national security risks of fossil fuel supply fluctuations. As the KWh cost of nuclear power is competitive with fossil fuel, safely reducing construction costs and the timeline to power generation are critical to widening development, deployment and utilization of nuclear power within the EU. By using benchmarking and best practices to drive efficiencies in indirect costs, the intensive capital costs of nuclear power construction may be reduced considerably and construction timelines decreased without adversely impacting safety.

Conflict of interest

The author declares no conflict of interest.

Notes/thanks/other declarations

The views expressed in this Article are the author’s and do not necessarily represent the views of the BIED Society, the BIED Global Leadership Academy or the United States.

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