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A Study on a Korea-Specific Nuclear PPA Model Based on the Analysis of Overseas Nuclear PPA Cases

Youngwoo Lee*, Joo Hyung Moon, Jai Oan Cho, Gisol Nam, Young Joon Lee
Korea Atomic Energy Research Institute
111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, 34057, Republic of Korea
**Corresponding author: leeyoungwoo@kaeri.re.kr*

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1. Introduction

Power Purchase Agreements (PPAs) have increasingly emerged as a key instrument for corporate electricity procurement in response to global decarbonization initiatives such as RE100. In Korea, however, the PPA framework has been designed primarily around renewable energy sources, and its practical utilization remains limited due to cost uncertainty, complex settlement mechanisms, and grid bottlenecks [1]. As electricity demands from energy-intensive industries and AI data centers expand, renewable energy-based PPAs (renewable PPAs) alone may be insufficient to ensure stable and high-quality carbon-free power supply [2].

Nuclear power, as a large-scale carbon-free baseload source, has recently gained renewed attention in global markets as a PPA resource. This study analyzes overseas nuclear PPA cases and proposes Korea-specific nuclear PPA model options that reflect domestic market conditions, with a focus on institutional feasibility and policy implications. In particular, this study seeks to identify how nuclear PPAs can be institutionally designed to complement existing renewable PPA schemes in Korea.

2. Overview of the Domestic PPA Framework in Korea

A PPA refers to a contractual arrangement in which electricity is supplied directly to end-users through a generator, bypassing the wholesale electricity market. This section reviews the current status of PPA implementation in Korea and examines recent domestic discussions regarding the potential application of PPAs to nuclear power.

2.1 Korea's PPA Scheme

Korea introduced the PPA scheme in 2021 as a new electricity procurement mechanism for renewable energy, departing from the conventional wholesale market structure in response to global carbon neutrality commitments and the expansion of RE100 participation [3]. The institutional framework formally defines two types of PPAs: (1) direct PPAs, in which electricity is supplied directly from generators to end-users, and (2) third-party PPAs, in which Korea Electric Power Corporation (KEPCO) intermediates the transaction [1]. In third-party PPAs, electricity may be delivered physically through the grid or transacted virtually. In virtual arrangements, transactions are settled financially based on differences between contract prices and wholesale market prices.

Under the current regulatory framework, PPAs are allowed only when they do not undermine power supply stability or public interest. Power generators with capacities above 1 MW are allowed to sell electricity directly to consumers with demand exceeding 300 kW, subject to regulatory conditions. Facilities below 1 MW are eligible only in cases of direct supply arrangements that do not involve the use of the transmission and distribution network [4]. Generators are required to supply at least the annual contracted volume, while consumers must purchase the full amount of electricity supplied on an hourly basis. Eligible energy sources are limited to six categories of renewable energy: solar, wind, hydro, marine, geothermal, and bioenergy. While direct PPAs allow multiple generators and multiple consumers to participate, third-party PPAs restrict participation to a single consumer, with KEPCO acting as the intermediary.

Importantly, Korea's PPA framework is governed by fundamental principles that emphasize compliance with relevant laws and market rules, including the Electric Utility Act and the Rules on Operating the Electricity Market. The framework explicitly seeks to prevent instability in the power system and to avoid situations in which excessive benefits accrue to participating firms at the expense of non-participating electricity consumers [4].

2.2 Drivers of Nuclear PPAs in Korea

Although nuclear power is currently excluded from Korea's PPA scheme, there is growing recognition of its potential role as a direct power supply option for advanced industries, given its ability to provide stable electricity on a 24/7 basis. Rising industrial electricity prices and growing demand for stable carbon-free power from energy-intensive industries and data centers have increased corporate interest in nuclear PPAs. Under these conditions, renewable PPAs alone are increasingly viewed as insufficient to meet continuous 24/7 electricity demand, prompting discussions on expanding the scope of PPAs to include nuclear power [5]. At the same time, the feasibility of nuclear PPAs—particularly those centered on small modular reactors (SMRs)—has begun to attract attention. Korea Hydro & Nuclear Power Co., LTD (KHNP) has signed memoranda of understanding with LS Electric and the city of Daegu to develop direct power supply models utilizing innovative SMR (i-SMR) [6,7].

Despite the growing consensus on the necessity of nuclear PPAs, concerns regarding public interest and fairness have also been raised. While nuclear power's low generation cost could deliver substantial benefits—such as stable carbon-free electricity supply—to both corporations and the national economy, there is a risk that such benefits could become concentrated among a limited number of large firms. This could, in turn, lead to higher electricity tariffs for the general public and other consumers [8]. Accordingly, the successful introduction of nuclear PPAs in Korea requires careful institutional design to ensure that they function not merely as a corporate benefit mechanism, but as a system that does not impose undue burdens on society as a whole.

3. Analysis of Overseas Nuclear PPA Cases

Several major countries, including the United States, have introduced nuclear PPAs primarily as a means to support continued operation of existing nuclear plants and to prevent premature retirements. More recently, growing voluntary demand from corporations seeking carbon-free electricity has accelerated the use of nuclear PPAs as a mainstream procurement option for decarbonization. This section reviews overseas nuclear PPA cases and summarizes key implications drawn from international practice.

3.1 Classification of Overseas Nuclear PPA Cases by Asset Type

Recent nuclear PPA contracts can be classified by nuclear asset type into three categories: restart of previously shut-down plants, operating nuclear plants, and new nuclear builds. As summarized in Table I, restart-related PPAs have emerged as a third option beyond new construction and life extension, while PPAs

Table I: Overseas Nuclear PPA Cases Classified by Asset Type and Contract Characteristics

Asset Type	Country	Nuclear Asset	Buyer Type	Contract Scope*	Transaction Structure	Contractual Objective	Ann. Year
Restarted Plant	U.S.	Three Mile Island Unit 1 (Constellation)	Big Tech (Microsoft)	Elec.	Physical delivery via grid (market-based PPA)	Long-term carbon-free electricity supply	2024
	U.S.	Duane Arnold (NextEra)	Big Tech (Google)	Elec.	Physical delivery via grid (market-based PPA)	Carbon-free electricity + price hedging	2025
Operating Plant	U.S.	Constellation Nuclear Fleet	Big Tech (Microsoft)	Attr.	Virtual settlement (financial)	Carbon-free attributes procurement	2023
	U.S.	Clinton (Constellation)	Big Tech (Meta)	Elec., Attr.	Physical delivery via grid (long-term corporate PPA)	Firm carbon-free electricity supply	2025
	U.S.	Constellation Nuclear Fleet	Federal Government	Elec.	Physical delivery via grid (government offtake)	Long-term baseload electricity supply	2025
	U.S.	Susquehanna (Talen Energy)	Big Tech (Amazon)	Elec., Attr.	Physical delivery (near-site)	Firm carbon-free electricity (proximity to demand)	2025
	U.S.	Point Beach (NextEra)	Public Utilities (WPPI)	Elec., Attr.	Physical delivery via grid (utility-mediated PPA)	Long-term carbon-free electricity procurement	2025
	FR	EDF Nuclear Fleet	Data Center (Data4)	Elec.	Physical delivery via grid (corporate PPA)	Stable carbon-free electricity supply	2025
	SE	SE3 Nuclear Fleet (Fortum)	Industrial (Vargön Alloys)	Elec., Attr.	Physical delivery via grid (industrial PPA)	Carbon-free baseload supply + cost stabilization	2024
New Nuclear Build	U.S.	Hermes 2 (Kairos Power)	Utility / Big Tech (TVA–Google)	Elec., Attr.	Physical delivery (near-site)	Early access to firm carbon-free electricity	2024–2025
	U.K.	Hinkley Point C	Government	Elec.	CfD-based long-term offtake	Long-term carbon-free electricity supply	2016
	U.K.	Sizewell C	Government	Elec.	RAB-based financing and offtake	Future baseload electricity supply	2025
	CZ	Dukovany (EDU II)	Government-owned SPV	Elec.	Long-term offtake via SPV	Long-term electricity supply security	2024

* *Elec. denotes electricity delivery, and Attr. denotes carbon-free attributes.*

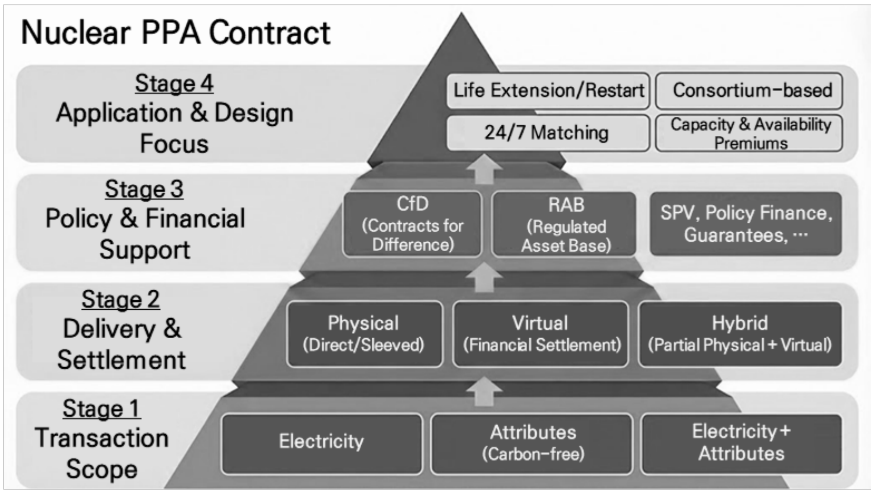

Fig. 1. Stepwise Framework for Designing Nuclear PPAs

for operating plants primarily focus on securing continued operation through the delivery of electricity and associated carbon-free attributes. In contrast, PPAs investment risks associated with capital-intensive projects.

3.2 Key Implications

The reviewed cases indicate that nuclear PPAs have evolved beyond simple physical electricity supply arrangements and can be characterized by three key dimensions of expansion: (i) diversification of transmission and delivery structures, (ii) expansion of transaction scope, and (iii) policy intervention where necessary.

With respect to delivery structures, overseas nuclear PPAs employ both behind the meter or near-site delivery configurations that directly supply electricity near demand centers and grid-connected configurations that allocate electricity through existing transmission networks. In addition, some arrangements provide conventional electricity through the market while settling the difference between contract prices and market prices, thereby functioning as virtual PPAs in which electricity is financially settled without physical delivery.

In terms of transaction scope, overseas practices increasingly allow for the trading of nuclear power's carbon-free attributes either in conjunction with electricity delivery or as a standalone product. This contrasts with the current Korean regulatory framework, under which carbon-free attributes associated with nuclear electricity are not explicitly unbundled or traded independently from physical electricity supply.

Finally, to mitigate investment risks associated with continued operation and new nuclear construction, governments have employed various price and revenue stabilization mechanisms, including Contracts for Difference (CfD) and Regulated Asset Base (RAB) models. In some cases, such as the Czech Republic, governments directly enter into long-term contracts as counterparties. By comparison, in Korea's renewable energy sector, policy support mechanisms have served similar functions, including feed-in tariffs (FIT) that were previously used and CfD to stabilize prices, as well as long-term fixed-price auctions and centralized procurement schemes to secure long-term revenue and demand.

4. Proposed Korea-Specific Nuclear PPA Model

This section proposes nuclear PPA models suitable for the Korean context, drawing on the analysis of the current domestic PPA framework and the overseas nuclear PPA cases reviewed in the previous sections.

4.1 Stepwise Framework

Based on the key implications identified from overseas nuclear PPA cases (Section 3.2), a stepwise framework for designing nuclear PPAs in Korea can be developed by sequentially incorporating the three dimensions of expansion observed in practice, as illustrated in Fig. 1.

In the first stage (transaction scope), the object of the contract may include electricity, carbon-free attributes, or a combination of both. The second stage (delivery and settlement) encompasses physical delivery, virtual settlement, or hybrid arrangements that combine partial physical delivery with partial virtual settlement. The third stage (policy & financial support) includes instruments such as Contracts for Difference (CfD), Regulated Asset Base (RAB) schemes, Special Purpose Vehicles (SPVs), as well as other forms of policy finance, guarantees, and tax incentives. Finally, the fourth stage (application & design focus) allows for tailored configurations depending on specific objectives, including support for plant restarts or life extensions, consortium-based procurement, 24/7 matching, and capacity or availability premiums.

4.2 Representative Model Types

Using the stepwise framework proposed in Section 4.1, this study identifies representative nuclear PPA model

Table II: Representative Nuclear PPA Model Types for Korea based on the Stepwise Framework

Model Type	Transaction Scope (Stage 1)	Delivery & Settlement (Stage 2)	Policy & Financial Support (Stage 3)	Application & Design Focus (Stage 4)	Intended Role in Korea
New Nuclear Investment Model	Electricity + Carbon-Free Attributes	Virtual PPA (financial settlement)	CfD-based revenue stabilization	Consortium-based procurement for large-scale projects (e.g., SMRs)	Mitigate investment risk and facilitate private participation in new nuclear projects
Life Extension / Restart Support Model	Electricity	Physical or sleeved PPA using existing grid	SPV-based financing	Life extension and restart of existing nuclear plants	Secure cost-competitive baseload electricity for energy-intensive industries
High-Tech 24/7 CFE Model	Electricity + Carbon-Free Attributes	Hybrid (partial physical delivery + virtual settlement)	Certification guarantees	Hourly 24/7 matching with capacity and availability premiums	Meet continuous carbon-free electricity demand of data centers and advanced manufacturing

types that are compatible with Korea's electricity market characteristics. Table II presents representative nuclear PPA model types derived by applying the proposed stepwise framework to Korea's electricity market conditions, illustrating how different combinations of transaction scope, settlement structure, policy support and application focus can be configured. The New Nuclear Investment Model is designed to mitigate the substantial upfront costs and long investment recovery periods associated with new nuclear projects. By combining virtual settlement with revenue stabilization mechanisms, this model can facilitate private participation while limiting exposure to market price volatility. The Life Extension and Restart Support Model links investment in existing nuclear facilities with stable electricity demand from nearby industrial complexes. This model enables the procurement of cost-competitive baseload electricity within shorter timeframes compared to new nuclear construction. The High-Tech 24/7 CFE Model combines electricity supply with associated carbon-free attributes to meet continuous
electricity demand from data centers and advanced manufacturing facilities. By incorporating electricity into the contractual scope, this model enables hourly matching rather than annual volume matching, thereby supporting a more robust definition of 24/7 carbon-free electricity supply.

4.3 Institutional, Technical and Fairness Considerations

For the proposed nuclear PPA models to be implemented in practice, both institutional reforms and technological advancements are required. From an institutional perspective, priority should be given to establishing a predictable contractual and settlement framework that enables PPA activation while maintaining power system stability. In addition, certification frameworks consistent with global trade and decarbonization initiatives—such as RE100 and CFE—should be proactively developed and standardized.

From a technical standpoint, the commercialization of load-following operation technologies for nuclear power plants is essential to enable flexible responses to real-time fluctuations in electricity demand and the intermittency of renewable energy. Furthermore, the expansion of advanced metering infrastructure (AMI) and the integration of energy storage system (ESS)-related technologies are necessary to ensure accurate real-time measurement, settlement, and balancing.

Most importantly, it is critical to ensure that nuclear PPAs do not disproportionately benefit specific market participants. Concerns regarding "cherry-picking," whereby the benefits of low-cost nuclear generation accrue primarily to large corporations, must be addressed through appropriate institutional design. Rather than permitting PPAs at generation-cost-level prices alone, mechanisms could be considered to return a portion of the price differential between contract prices and market prices to society, for example through energy welfare funds or grid modernization contributions. Such approaches would help ensure that the enhanced corporate competitiveness resulting from nuclear PPAs is clearly translated into broader social benefits.

5. Conclusions

This study examined the applicability of nuclear PPAs in Korea by reviewing the current domestic PPA framework and analyzing overseas nuclear PPA cases. The analysis showed that, in several countries, nuclear PPAs have been utilized not only to support the continued operation and restart of existing nuclear plants, but also to mitigate investment risks associated with new nuclear projects through institutional arrangements.

Based on these findings, this study proposed a stepwise framework for designing nuclear PPAs and identified representative model types that could be adapted to Korea's electricity market conditions. The results suggest that nuclear PPAs may provide a complementary option for supplying carbon-free electricity to energy-intensive industries, particularly in contexts where renewable PPAs face structural limitations.

At the same time, the introduction of nuclear PPAs in Korea would require careful institutional design to ensure consistency with existing market rules and to address concerns related to public interest and fairness. Further research is needed to quantitatively assess the impacts of nuclear PPAs on electricity prices and to examine legal and market design issues associated with their implementation.

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