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THE PURE THEORY OF CONTRACTS AND THE DOCTRINE OF CONTRACTUAL INCOMPLETENESS: COMPARING IMPACTS OF LONG-TERM ENERGY CONTRACTS ON SUSTAINABLE ENERGY DEPLOYMENT

Danna Daniel Gashion*
Rabiatu Musa**
Moses Garba Yusuph***

ABSTRACT

This study investigates the applicability of the Pure Theory of Contracts and the Principle of Incomplete Contracts to long-term Power Purchase Agreements (PPAs) in fostering sustainable renewable energy deployment. The central research question explores how contractual design, specifically addressing incompleteness and power imbalances, influences the effectiveness of PPAs in achieving renewable energy targets. Objectives include analysing the theoretical frameworks, evaluating existing PPA structures, and proposing improvements for enhanced sustainability outcomes. Employing a mixed-methods approach, this research combines doctrinal legal analysis of contractual principles with qualitative case studies of renewable energy PPAs in diverse contexts. Legal analysis highlights the limitations of assuming complete contracts and emphasises the importance of incorporating flexibility into long-term agreements. Case studies provide empirical insights into how incomplete contracts and power asymmetries impact project implementation, risk allocation, and long-term viability. Key findings reveal that traditional PPA structures often fail to adequately address unforeseen contingencies and power imbalances, hindering sustainable renewable energy deployment. Incomplete contracts necessitate robust renegotiation mechanisms and adaptive governance structures. Furthermore, the study highlights the importance of incorporating social and environmental externalities into contractual frameworks. Recommendations include adopting a dynamic PPA structure that promotes collaborative risk sharing, incorporating clear dispute resolution processes, and implementing mechanisms for periodic contract review. This research concludes that integrating the insights of the Pure Theory of Contracts and the Principle of Incomplete Contracts into PPA design is crucial for fostering resilient and sustainable renewable energy ecosystems. Jointly addressing key principles of contractual incompleteness and power asymmetries can provide leverage for PPAs to be more effective in driving energy transition to a low-carbon future.

Keywords: Sustainable Energy Deployment, Incomplete Contracts, Power Purchase Contracts, Risk Mitigation, Renewable Energy, Long-term Energy Contracts.

1. INTRODUCTION

The global imperative to transition towards sustainable energy systems has propelled renewable energy (RE) sources to the forefront of energy policy[1]. Power Purchase Agreements (PPAs), long-term contracts between energy producers and consumers, play a pivotal role in facilitating this transition[2]. However, the inherent complexities of long-term energy projects, coupled with the dynamic nature of the RE sector, necessitate a nuanced understanding of contractual design[3]. This paper delves into the intersection of the Pure Theory of Contracts and the Principle of Incomplete Contracts with long-term PPAs, aiming to explore how these theoretical frameworks can enhance the effectiveness of PPAs in achieving sustainable RE deployment[4]. The central research question focuses on how effective contractual design, specifically regarding incompleteness and power imbalances, influences the long-term viability and sustainability outcomes of renewable energy power purchase agreements (RE-PPAs). This study aims to analyse the theoretical underpinnings of the Pure Theory of Contracts and the Principle of Incomplete Contracts, evaluating their applicability to the specific context of long-term RE-PPAs with the objectives of examining existing PPA structures, identifying common contractual challenges, and proposing improvements to enhance sustainability outcomes. The methodology employs a mixed-methods approach, combining doctrinal legal analysis of contractual principles with qualitative case studies of renewable energy PPAs across diverse geographical and regulatory contexts[5]. This approach allows for a comprehensive understanding of both the theoretical and practical dimensions of PPA design. A thorough literature review will examine existing scholarship on contract theory, renewable energy policy (REP), and PPA structures. This review synthesises the existing knowledge regarding the limitations of complete contract assumptions in long-term agreements, the role of flexibility and renegotiation mechanisms, and the impact of energy price imbalances on PPA implementation. Furthermore, it will

* PhD (UK), Lecturer, Department of Private Law, Faculty of Law, University of Jos. Nigeria. Email: dannag@unijos.edu.ng;

** PhD, Lecturer, Department of Public Law, Faculty of Law, University of Jos. Nigeria. Email: Abdullahir@unijos.edu.ng;

***, LL.M, Lecturer, Department of Public Law, Faculty of Law, University of Jos. Nigeria. Email: Yusuphm@unijos.edu.ng.

1 Hassan, Q., Viktor, P., J. Al-Musawi, T., Mahmood Ali, B., Algburi, S., Alzoubi, H. M., Khudhair Al-Jiboory, A., Zuhair Sameen, A., Salman, H. M., & Jaszczur, M. (2024). The Renewable Energy Role in the Global Energy Transformations. *Renewable Energy Focus*, *48*, 100545. Available at: https://doi.org/10.1016/j.ref.2024.100545. Accessed on 10/11/2024.

2 Yang, H., Xu, S., Gao, W., Wang, Y., Li, Y., & Wei, X. (2024). Mitigating long-term financial risk for large customers via a hybrid procurement strategy considering power purchase agreements. *Energy*, *295*, 131038. Available at: https://doi.org/10.1016/j.energy.2024.131038. Accessed 21/1/2025.

3 Kumar, R., Rangan, U. S., & Rufín, C. (2005). Negotiating complexity and legitimacy in independent power project development. *Journal of World Business*, *40*(3), 302-320. Available at: https://doi.org/10.1016/j.jwb.2005.05.006. Accessed on 30/4/2024.

4 Cheng, L., Huang, P., Zhang, M., Yang, R., & Wang, Y. (2025). Optimizing Electricity Markets Through Game-Theoretical Methods: Strategic and Policy Implications for Power Purchasing and Generation Enterprises. *Mathematics*, *13*(3), 373. Available at: https://doi.org/10.3390/math13030373. Accessed on 20/1/2025.

5 Lu, Y., Yi, F., Yu, S., Feng, Y., & Wang, Y. (2022). Pathways to Sustainable Deployment of Solar Photovoltaic Policies in 20 Leading Countries Using a Qualitative Comparative Analysis. *Sustainability*, *14*(10), 5858. Available at: https://doi.org/10.3390/su14105858. Accessed on 21/2/2025.

explore the growing body of literature on the integration of environmental and social considerations into contractual frameworks, highlighting the importance of incorporating sustainability principles into PPA design. This review will provide the foundation for analysing the empirical findings and formulating informed recommendations.

The anticipated findings of this research will highlight the limitations of traditional PPA structures in addressing the inherent uncertainties and power asymmetries associated with long-term renewable energy projects. It is expected that the study will reveal the importance of incorporating robust renegotiation mechanisms, adaptive governance structures, and clear dispute-resolution processes to ensure the long-term viability of PPAs. Furthermore, the findings are expected to underscore the need for incorporating social and environmental externalities into contractual frameworks, promoting a comprehensive approach to sustainable renewable energy deployment[6]. Based on the analysis of the theoretical frameworks and empirical findings, this study will conclude by offering recommendations for improving PPA design to enhance its effectiveness in fostering sustainable renewable energy deployment. These recommendations will focus on promoting collaborative risk sharing, incorporating flexibility and adaptability into contractual agreements, and addressing power imbalances between energy producers and consumers[7]. Ultimately, this research aims to contribute to the development of more resilient and sustainable renewable energy ecosystems by providing insights into the crucial role of contractual design in facilitating the transition to a low-carbon future.

2. THE FRAMEWORKS IN CONTRACT THEORY AND THE DOCTRINE OF INCOMPLETE CONTRACT

The traditional "complete contract" model assumes that all possible future contingencies can be perfectly anticipated and incorporated into a legally binding agreement. This framework, while conceptually neat, falters significantly when applied to long-term, complex projects, particularly within the inherently uncertain renewable energy sector. Factors like technological advancements, fluctuating market conditions, and evolving regulatory landscapes render it impossible to foresee every potential scenario[8]. Consequently, rigid contracts often become ill-equipped to handle unforeseen events, leading to disputes, and inefficiencies, and ultimately, hindering the intended project goals. This foundational limitation necessitates a shift towards a more realistic and adaptable approach to contractual design. The Principle of Incomplete Contracts acknowledges the inherent limitations of foresight, recognising that contracts cannot possibly account for every future eventuality[9].

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6 Santoyo-Castelazo, E., & Azapagic, A. (2014). Sustainability assessment of energy systems: Integrating environmental, economic and social aspects. *Journal of Cleaner Production*, *80*, 119-138. Available at https://doi.org/10.1016/j.jclepro.2014.05.061. Accessed 19/11/2024.

7 Zhou, Y., & Lund, P. D. (2023). Peer-to-peer energy sharing and trading of renewable energy in smart communities ─ trading pricing models, decision-making and agent-based collaboration. *Renewable Energy*, *207*, 177-193. Available at: https://doi.org/10.1016/j.renene.2023.02.125. Accessed on 10/11/2024.

8 Wiertsema, A. (2024). *Collective Action in Smart Energy Hubs: Examining How Stakeholders Address Common-Pool Resource Challenges Through Collaboration* (Master's thesis, University of Twente). Available at: https://essay.utwente.nl/102830/1/Wiertsema_MA_BMS.pdf. Accessed 23/2/2025.

9 Hart, O. (2003). Incomplete contracts and public ownership: Remarks, and an application to public-private partnerships. *The economic journal*, *113*(486), C69-C76. Available at: https://academic.oup.com/ej/article-abstract/113/486/C69/5060959#. Accessed 26/12/2024.

This theory emphasises the importance of incorporating flexibility, renegotiation mechanisms, and adaptive governance structures into long-term agreements. Embracing incompleteness, contracts can better accommodate unforeseen circumstances, allowing parties to adjust their obligations and collaborate in finding mutually beneficial solutions. This approach is especially crucial in the context of PPAs for RE, where long-term viability depends on the ability to navigate uncertainty and adapt to changing conditions. Implementing clear procedures for renegotiation, establishing robust dispute resolution processes, and fostering ongoing communication is essential for ensuring that PPAs remain effective and contribute to the sustainable deployment of RE[10].

The economic theory of contracts centres on designing agreements to maximise the shared value, or surplus, generated. This surplus arises when parties value what they receive more than what they give. Contracts facilitate future performance for reasons like geographical distance, credit, risk sharing, and, crucially, investments that boost exchange value. The theory particularly emphasises the tension between shared and individual incentives related to these investments. Contracts encourage specific investments, where resources gain more value within the relationship. Optimising these investments, ex-ante efficiency can clash with ex-post efficiency, ensuring exchanges are valuable when they occur. Uncertainty in future costs and values can force wasteful performance. Ideally, contracts should ensure exchanges happen only when they create value, balancing investment protection with flexibility. A complete, contingent contract, specifying obligations for every scenario, would resolve this tension. However, transaction costs, especially information-related ones, prevent such contracts[11]. These costs include ex-ante costs of anticipating contingencies and ex-post costs of enforcing agreements. Both contribute to incomplete contracts.

Economists define contract incompleteness as the failure to provide efficient obligations in every scenario, not simply the absence of obligations[12]. This informational incompleteness occurs when contracts don't account for situations where performance becomes inefficient. This is due to the cost and unavailability of information, either at the time of contracting (front-end costs) or enforcement (back-end costs). Notably, unverifiable information to a court has driven many theoretical propositions. Mechanism design, including tools like auctions and option contracts, attempts to address back-end information problems by eliciting private information. While mechanisms can resolve information obstacles, many are unrealistic or parameter-specific, failing to provide general solutions. Renegotiation is a critical aspect of contract theory, influencing ex-ante and ex-post efficiency. While renegotiation can correct inefficient outcomes, it can also deter initial investments due to the hold-up problem, where one party captures a larger share of the surplus after investments are made.

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[10] Hart, O., & Moore, J. (1988). Incomplete Contracts and Renegotiation on JSTOR. *Econometrica*, 755. Available at: https://doi.org/1912698. Accessed on 3/11/2024.

[11] Harju, A., Schaëfer, K., Hallikas, J., & Kähkönen, A. (2024). The role of risk management practices in IT service procurement: A case study from the financial services industry. *Journal of Purchasing and Supply Management*, *30*(2), 100899. Available at: https://doi.org/10.1016/j.pursup.2024.100899. Accessed 1/2/2024.

[12] Frydlinger, D., & Hart, O. (2024). Overcoming contractual incompleteness: The role of guiding principles. *The Journal of Law, Economics, and Organization*, *40*(3), 625-647. https://doi.org/10.1093/jleo/ewac027

Instead of preventing renegotiation, contracts can regulate the process to predetermine surplus sharing. This can be achieved through property rights allocation, payment deposits, or quantity term design. Contract theory now considers renegotiation as a key factor, analysing performance, breach, and renegotiation options[13]. This approach highlights how initial contract terms influence future renegotiation, emphasising the importance of strategic behaviour and the need to design contracts that balance ex-ante and ex-post efficiency. The economic approach views a contract as a framework for future renegotiations after uncertainties are resolved. Parties designing contracts face the challenge of predetermining or constraining these renegotiations to achieve both ex-ante and ex-post efficiency. This modern analysis emphasises that even with perfect renegotiation, the initial assignment of rights significantly influences investment incentives, particularly for unverifiable investments. It also acknowledges that the initial agreement can determine who must incentivise whom, impacting efficient breach. This approach extends to analysing strategic behaviour in other areas, like litigation, by working backwards from predicted outcomes to optimal contract design.

Implications of the principles of Contract Theory and Incomplete Contracts in Long-Term Power Procurement Agreements.

The application of contract theory, particularly the doctrine of incomplete contracts, is highly relevant in long-term power procurement agreements. These agreements, often spanning decades, are inherently susceptible to unforeseen changes, making complete contractual coverage impossible. Therefore, understanding and managing contractual incompleteness is crucial for their success[14].

Long-term power procurement contracts face numerous uncertainties, including fluctuating fuel prices, technological advancements, regulatory changes, and shifts in energy demand. Attempting to specify every potential scenario in advance is impractical and costly. The doctrine of incomplete contracts acknowledges this reality, emphasising that contracts will inevitably have gaps. This recognition is vital in the power sector, where massive infrastructure investments and long-term commitments necessitate adaptable agreements[15].

The hold-up problem, a key concept in incomplete contract theory, is particularly pertinent in power procurement. This problem arises when one party makes significant relationship-specific investments, becoming vulnerable to opportunistic renegotiation by the other party. For example, a power producer investing in a plant based on a long-term contract could be held up if the buyer later demands lower prices. Mitigating this risk through careful allocation of control rights and renegotiation mechanisms is essential.

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[13] Johnson, J.S., Sohi, R.S. Understanding and resolving major contractual breaches in buyer–seller relationships: a grounded theory approach. *J. of the Acad. Mark. Sci.* **44**, 185–205 (2016). Available at: https://doi.org/10.1007/s11747-015-0427-8. Accessed 24/11/2024.

[14] Frydlinger, D., & Hart, O. (2024). Overcoming contractual incompleteness: The role of guiding principles. *The Journal of Law, Economics, and Organization*, *40*(3), 625-647. Available at: https://doi.org/10.1093/jleo/ewac027. Accessed 2/2/2023.

[15] Gardner, George K. "An Inquiry into the Principles of the Law of Contracts." *Harv. L. Rev.* 46 (1932): 1. Available at: https://heinonline.org/HOL/LandingPage?handle=hein.journals/hlr46&div=11&id=&page= Accessed 23/2/2025.

Effective management of incomplete power procurement contracts requires balancing contractual rigidity and flexibility. This involves:

a. *Clear allocation of residual control rights*: Defining who makes decisions in unforeseen circumstances.
b. *Robust renegotiation clauses*: Establishing procedures for adapting to changing conditions.
c. *Dispute resolution mechanisms*: Providing frameworks for resolving conflicts.

Applying these contract theory principles empowers stakeholders to design more resilient and adaptable power procurement agreements[16], fostering long-term stability and efficiency in the energy sector.

3. PERSPECTIVES OF POWER PURCHASE AGREEMENTS

Long-term energy contracts in the form of PPAs are the cornerstone of modern electricity markets, serving as complex contractual frameworks that govern the sale and purchase of power between generators and buyers[17]. Given the diverse nature of energy sources and market participants, PPAs have evolved into various structures, each tailored to specific needs and risk appetites[18]. This analysis will examine the common PPA structures and their contractual provisions, focusing on risk allocation and price management mechanisms, to illuminate the critical factors that underpin successful power procurement in today's dynamic energy landscape. PPAs are complex contracts designed to facilitate the sale of electricity between a power generator and a buyer[19]. These agreements vary significantly in structure, each with distinct approaches to risk allocation, pricing, and dispute resolution. Common structures include physical PPAs, synthetic (or virtual) PPAs, and private wire PPAs. Physical PPAs involve the direct, physical delivery of electricity from the generator to the buyer through the grid[20]. These agreements necessitate careful risk allocation regarding grid availability, transmission losses, and balancing responsibilities. Pricing mechanisms in physical PPAs can range from fixed prices, providing long-term price certainty, to variable

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16 Maddahinasab, M. (2023). The application of contractual tools to the adjustment of fiscal regime in renewable energy projects: within a framework of energy justice centered on transactional justice. Available at: https://www.researchgate.net/profile/Mostapha-Maddahinasab/publication/383822773_The_application_of_contractual_tools_to_the_adjustment_of_fiscal_regime_in_renewable_energy_projects_within_a_framework_of_energy_justice_centered_on_transactional_justice/links/66db7f2a2390e50b2c701a03/The-application-of-contractual-tools-to-the-adjustment-of-fiscal-regime-in-renewable-energy-projects-within-a-framework-of-energy-justice-centered-on-transactional-justice.pdf?__cf_chl_tk=Su4JEf.iOB_2I6cGsFwEf60C72hTVjYPNiq9GfitW5c-1740467189-1.0.1.1-hNttzfrtJcOqzgZ5UKs72C2hw4SwBtNJfdHVWsa6Bgs Accessed on 23/9/2024.

17 Castro, R. (2024). Emerging Energy Markets. In: Engineering of Power Systems Economics. Springer, Cham. Available at: https://doi.org/10.1007/978-3-031-55251-9_8. Accessed 3/9/2024.

18 Falchetta, G., Michoud, B., Hafner, M., & Rother, M. (2022). Harnessing finance for a new era of decentralised electricity access: A review of private investment patterns and emerging business models. *Energy Research & Social Science*, *90*, 102587. Available at: < https://www.sciencedirect.com/science/article/pii/S2214629622000925> Accessed 22 March 2025.

19 Słotwiński, S. (2022). The Significance of the "Power Purchase Agreement" for the Development of Local Energy Markets in the Theoretical Perspective of Polish Legal Conditions. *Energies*, *15*(18), 6691. Available at < https://doi.org/10.3390/en15186691> Accessed 12 March 2025.

20 Mohseni Taheri, D., Nadarajah, S., & Trivella, A. (2023). Physical vs Virtual Corporate Power Purchase Agreements: Meeting Renewable Targets Amid Demand and Price Uncertainty. *Available at: < https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4520684> Accessed 3 April 2025.*

prices indexed to market rates, exposing buyers to market fluctuations[21]. Dispute resolution typically involves contractual clauses specifying arbitration or litigation, often addressing issues related to delivery obligations and performance guarantees.

Synthetic PPAs or virtual PPAs, are financial contracts where the generator and buyer agree on a contract for differences (CFD). The generator sells electricity into the wholesale market, and the PPA settles the financial difference between the agreed strike price and the market price. This structure shifts market risk to the buyer, while the generator secures a stable revenue stream. Dispute resolution in synthetic PPAs often focuses on financial settlements and market price calculations, requiring clear contractual definitions and audit trails.

Private wire PPAs involve direct, on-site electricity delivery, bypassing the public grid. These agreements are common for co-located generation and consumption. Risk allocation centres on the reliability of the private connection and on-site generation capacity. Pricing is often negotiated based on the avoided costs of grid transmission and distribution. Dispute resolution may involve technical assessments of on-site performance and liability for outages. In all PPA structures, detailed contractual provisions defining force majeure events, termination rights, and liability limitations are crucial for managing potential disputes.

I. Contractual Challenges and Power Imbalances in Long-term Power Purchase Agreement Management

Power Purchase Agreements (PPAs), particularly those spanning long durations, are inherently vulnerable to a multitude of contractual challenges. One of the most significant is the rapid pace of technological advancement within the energy sector. Innovations in renewable energy generation, energy storage, and grid management can render existing contractual assumptions obsolete[22]. For instance, dramatic reductions in solar panel costs or the emergence of more efficient battery technologies may necessitate renegotiation of pricing structures or performance guarantees. Similarly, the evolution of smart grid technologies and distributed energy resources can challenge established grid connections and balancing responsibilities, requiring contractual adaptation to maintain operational efficiency and equitable risk allocation. Beyond technological shifts, regulatory changes and market volatility present substantial contractual hurdles. The energy sector is subject to frequent policy adjustments related to environmental regulations, renewable energy mandates, and market liberalization[23]. These changes can significantly impact the economic viability of PPAs, requiring parties to navigate complex legal and regulatory landscapes. Furthermore,

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[21] Hollmén, S., Levihn, F., & Martinsson, G. (2022, September). When markets don't deliver:–bilateral hedging by means of PPAs in managing intertemporal price risks in power generation investments. In *2022 18th International Conference on the European Energy Market (EEM)* (pp. 1-6). IEEE. Available at: https://ieeexplore.ieee.org/abstract/document/9921036. Accessed on 24/2/2025.

[22] Smith, A., Contreras, G. A. T., Brisbois, M., Lacey-Barnacle, M., & Sovacool, B. K. (2023). Inclusive innovation in just transitions: The case of smart local energy systems in the UK. *Environmental Innovation and Societal Transitions*, *47*, 100719. Available at: https://doi.org/10.1016/j.eist.2023.100719. Accessed on 22/2/2023.

[23] Cheah, S. K. A., & Low, B. (2022). The impact of public policy marketing, institutional narratives and discourses on renewable energy consumption in a developing economy. *Asia Pacific Journal of Marketing and Logistics*, *34*(5), 944-962. Available at: https://www.emerald.com/insight/content/doi/10.1108/apjml-11-2020-0835/full/html. Accessed 12/2/2024.

the inherent volatility of energy markets, driven by factors such as fuel price fluctuations and demand variability, can lead to significant discrepancies between contracted and actual market prices. This necessitates robust contractual mechanisms for price adjustments, risk sharing, and dispute resolution to ensure the long-term stability and enforceability of PPA agreements[24].

Power imbalances between energy producers and consumers significantly influence the negotiation, implementation, and outcomes of Power Purchase Agreements (PPAs). In markets where a few large energy producers dominate, they often possess greater bargaining power, enabling them to dictate unfavourable terms to smaller consumers or utilities. This imbalance can manifest in pricing structures that heavily favour producers, stringent performance guarantees that place undue risk on consumers, and limited consumer recourse in dispute resolution. Conversely, in regions with abundant renewable energy sources and a competitive market for power generation[25], consumers may wield more influence, securing more favourable pricing and risk-sharing arrangements.

The impact of power imbalances is particularly evident in long-term PPAs, where the potential for unforeseen market shifts can amplify the effects of unequal bargaining power. For example, a dominant producer may leverage its market position to resist renegotiations due to declining technology costs or changing regulatory landscapes, effectively trapping consumers in unfavourable contracts. This can stifle innovation and hinder the adoption of more efficient or sustainable energy solutions. Conversely, consumers with significant purchasing power may exert undue pressure on producers to accept unsustainable pricing or operational demands, potentially jeopardising the long-term viability of energy projects.

Furthermore, power imbalances can distort the allocation of risks inherent in PPA agreements. In markets with limited competition, producers may shift a disproportionate share of regulatory, technological, and market risks onto consumers, leaving them vulnerable to financial losses and operational disruptions. This can discourage investment in new energy infrastructure and hinder the development of a balanced and resilient energy market. Conversely, in consumer-driven markets, producers may face excessive risk exposure, leading to underinvestment or a reluctance to engage in long-term agreements[26]. Addressing power imbalances in PPAs requires a multi-faceted approach, including fostering market competition, promoting transparency in contract negotiations, and establishing robust regulatory oversight. Measures such as standardised PPA templates, independent market monitoring, and dispute resolution mechanisms can help level the playing field and ensure

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[24] Ragosa, G., Watson, J., & Grubb, M. (2024). The political economy of electricity system resource adequacy and renewable energy integration: A comparative study of Britain, Italy and California. *Energy Research & Social Science*, *107*, 103335. Available at: https://doi.org/10.1016/j.erss.2023.103335. Accessed on 16/1/2025.

[25] Grgic, I. (2024). *Unfair Trading Practices in Contract Farming-Ensuring Commercial Justice and Contract Enforcement* (Doctoral dissertation, University of Pittsburgh). Available at: https://d-scholarship.pitt.edu/46945/.

[26] Al Janabi, M. A. (2024). Crises to Opportunities: Derivatives Trading, Liquidity Management, and Risk Mitigation Strategies in Emerging Markets. In *Liquidity Dynamics and Risk Modeling* (pp. 169-256). Palgrave Macmillan, Cham. Available at: https://link.springer.com/chapter/10.1007/978-3-031-71503-7_3.

that PPA agreements are fair and equitable[27]. Ultimately, a balanced and competitive energy market is essential for fostering sustainable energy development and ensuring that the benefits of PPAs are shared equitably between producers and consumers.

II. Fundamentals of Price Risk Management Strategies in Long-term Power Procurement Agreements

Electricity pricing in Power Purchase Agreements (PPAs) for intermittent renewable energy (RE) presents a significant challenge to the energy transition. The inherent volatility of RE generation, influenced by weather and market fluctuations[28], creates price risks that deter investment and hinder the development of stable, long-term energy contracts. Price risk management strategies are therefore crucial to provide certainty and guarantee for both producers and off takers, ensuring the financial viability of RE projects. The fluctuations in electricity prices, particularly with the rise of intermittent RE sources, raise concerns about financing costs and project bankability. Energy transition has further complicated this volatility, as RE generation depends on unpredictable factors like weather and seasonal changes. Consequently, the price paid by the off taker is subject to significant variability[29]. This uncertainty necessitates mechanisms that stabilise energy pricing, enabling parties to make informed short- and long-term decisions based on predictable financial outcomes.

Price risk arises from the sale of energy into wholesale markets, where prices fluctuate based on various sources and locations[30]. The profitability of energy transactions depends on the difference between the contracted PPA price and the wholesale market price. While fixed PPA prices can protect offtakes from long-term price increases, they can also lead to losses if wholesale prices fall below the contracted rate. PPAs have evolved as a tool to manage these uncertainties, stabilising electricity pricing and mitigating the price volatility associated with RE generation. Parties to PPA contracts seek pricing structures that ensure certainty and confidence in future energy costs[31]. Long-term pricing provisions are key to attracting contracting parties, defining responsibilities and rights related to RE generation pricing. Fixed power pricing structures offer advantages to both generators and off takers, providing a reliable income source and stable energy supply. However, each PPA has a unique risk profile, requiring careful consideration during contract negotiations to determine a fair premium based on various variables.

Mitigating energy price uncertainty is essential for long-term energy contracts, influencing investment planning and decisions. Pricing in PPAs often involves the differential

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27 Barat, D. (2023). 'Virtual'Power Purchase Agreements: Legal Status and Regulatory Framework in India. *J. on Governance*, *6*, 27. Available at: https://heinonline.org/HOL/LandingPage?handle=hein.journals/jnlogvane6&div=7&id=&page=.

28 Algarvio, H. (2023). Risk-Sharing Contracts and risk management of bilateral contracting in electricity markets. *International Journal of Electrical Power & Energy Systems*, *144*, 108579. Available at: https://doi.org/10.1016/j.ijepes.2022.108579

29 Tokarski, S., Magdziarczyk, M., & Smoliński, A. (2021). Risk Management Scenarios for Investment Program Delays in the Polish Power Industry. *Energies*, *14*(16), 5210. Available at: https://doi.org/10.3390/en14165210

30 Fabra, N., & Imelda. (2023). Market power and price exposure: learning from changes in renewable energy regulation. *American Economic Journal: Economic Policy*, *15*(4), 323-358. Available at: https://www.aeaweb.org/articles?id=10.1257/pol.20210221.

payment between wholesale market reference prices and negotiated strike prices, along with components like inflation indexation and RE certification costs. The pricing structure is a critical risk factor, impacting investor confidence and project bankability. Effective PPA design, focused on revenue guarantees, is crucial for attracting investment in the transition to clean RE generation. Given the importance of price provisions in RE contracts, parties incorporate compensation and pricing terms to provide certainty and protect their interests. As the energy system transitions towards a higher percentage of intermittent RE, investors require risk management tools beyond government support. Bilateral PPAs have emerged as a solution to hedge against electricity market price volatility[32], reducing risk and increasing investments in RE generation. Comparative reviews of PPA contracts across jurisdictions are conducted to identify key pricing structures and develop hybrid models for uniform application, while also considering the need for contractual flexibility and renegotiation to adapt to unforeseen contingencies.

III. Common Strategies for Price Risk Management in Power Purchase Agreements

Price volatility in spot electricity markets poses significant challenges for investors and energy suppliers, particularly with the rise of intermittent RE sources. To mitigate these risks, PPAs have evolved, incorporating long-term pricing provisions to provide certainty and stability[33]. These provisions often include inflation indexation and fees for RE certification, ensuring a balance between cost and benefit for both generators and offtakes. The PPA market has seen increasing participation from corporate entities, particularly in developed markets like the USA. The success of PPAs hinges on mutually negotiated terms, where risk allocation and pricing strategies are crucial[34]. Developers and buyers must carefully consider the trade-offs between risk transfer and price, with pricing playing a pivotal role in project feasibility.

Fixed and floating (variable) pricing are the two primary PPA strategies. Fixed pricing, where the electricity price is set or escalates predictably, offers price certainty and is favoured by developers. However, buyers may face concerns about value for money if market prices fall below the PPA strike price. Conversely, the collar and floor strategy allow price adjustments within agreed bands, mitigating extreme price fluctuations for both parties[35]. Fixed PPA pricing structures can be fully fixed, adjusted based on predetermined patterns or renegotiations, or indexed to inflation. These structures provide long-term price certainty, simplifying project financing and offering protection against energy price fluctuations. Fixed

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32 Kröger, M., Neuhoff, K., & Richstein, J. C. (2022). Contracts for difference support the expansion of renewable energy sources while reducing electricity price risks. *DIW Weekly Report*, *12*(35/36), 205-213. Available at: https://www.econstor.eu/handle/10419/264921

33 Prokhorov, O., & Dreisbach, D. (2022). The impact of renewables on the incidents of negative prices in the energy spot markets. *Energy Policy*, *167*, 113073. Available at: https://doi.org/10.1016/j.enpol.2022.113073.

34 Solana Martínez, S. (2024). Analysis of the future impact of renewable energy in electricity markets. Available at: https://repositorio.comillas.edu/xmlui/bitstream/handle/11531/91932/Annex%20A%20Severiano%20Solana.pdf?sequence=2.

35 Engdahl, M., GODINET, S., & Lawyer, T. (2023). Can the hedging activities managed by commodity trading companies be freely moved and shifted for tax purposes within the legal and tolerated Transfer Pricing guidelines?

PPAs with escalation or inflation indexation allow for price adjustments based on market changes, ensuring alignment with anticipated wholesale rates and mitigating cost variances.

Floors and collars are employed to protect against significant price volatility in long-term PPAs. These strategies involve setting upper and lower price bounds, ensuring stable revenue for generators and minimising risks during market uncertainty[36]. Discount-to-market structures with floors or collars allow buyers to secure lower prices while providing generators with a minimum price guarantee, enhancing project bankability. Hybrid pricing structures, such as output percentage splits or phased pricing models, offer a balance between fixed and variable rates. These approaches allow for shared risk allocation, catering to offtakers seeking to avoid complete price lock-ins while ensuring revenue certainty for producers. Clawback PPA pricing structures provide a mechanism for offtakers to benefit from market price fluctuations while ensuring a minimum level of revenue for generators[37].

The choice of PPA pricing structure depends on various factors, including risk appetite, market conditions, and project specifics. Fixed pricing provides stability, while variable and hybrid structures offer flexibility and risk sharing. Clawback structures allow for market participation with downside protection. Ultimately, effective PPA design requires careful consideration of these factors to ensure long-term viability and mutual benefit.

PRICING RISK STRUCTURE	**SUMMARY OF RISK**	**GENERATORS/SUPPLIER'S POSITION**	**OFFTAKER/BUYERS' POSITION**
FIXED PRICING	A fixed PPA pricing structure is a typical and straightforward arrangement understood by all stakeholders. It provides long-term visibility but may not suit all buyers.[38]	It provides a high level of revenue visibility over the PPA term. This is a preferred outcome for many power producers and allows a low cost of capital to be raised from equity and debt holders who perceive less risk.	Long-term cost visibility is advantageous, but being locked into an unfavourable long-term price can pose a significant risk to competitive industries.
FIXED PRICING WITH INDEX AND ESCALAT	Offtakers and generators can mitigate inflation risk through contractual revenue escalation in high-inflation	Generators prefer inflation-linked financing for satisfaction, but equity capital is increasingly popular for long-term	PPA off-takers prefer low upfront cash flow outflow. Escalating structures are gaining interest due to low wholesale prices, but can

[36] Kapral, K. (2023). *Off-site PPA as a tool to protect against electricity price spikes: Developing a framework for risk assessment and mitigation* (Master's thesis, Universitat Politècnica de Catalunya). Available at: https://upcommons.upc.edu/handle/2117/397525

[37] Mohseni Taheri, D., Nadarajah, S., & Trivella, A. (2023). Physical vs Virtual Corporate Power Purchase Agreements: Meeting Renewable Targets Amid Demand and Price Uncertainty. *Available at SSRN 4520684*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4520684

[38] Stanitsas, M., & Kirytopoulos, K. (2023). Sustainable Energy Strategies for PPAs (PPAs). *Sustainability*, *15*(8), 6638.

ION	markets. This provides long-term visibility and is more competitive than fixed-price structures, which may not be suitable for all buyers.[39]	investors seeking an inflation hedge. Fixed prices with inflation uplifts are preferable for high revenue visibility, but some generators may opt for a fixed-price nominal structure for greater upfront cash flow.[40]	be a disadvantage if the PPA cost exceeds the wholesale price. Growing power prices are reasonable for off-takers dealing with inflationary pressure and looking for a soft start with low prices.
FLOORS AND COLLARS PRICING	Offtakers may not commit to long-term pricing but want to support RE production and improve wholesale electricity prices. The floor price is crucial for revenue security. Offtakers take risks beyond the collar, while generators take risks within. The placement of the cap and floor prices is vital.	Indexed price arrangements offer less security than fixed-price arrangements, require more equity financing, and limit project upside. However, they can benefit power producers with bullish views on the wholesale price. The cap placed on such arrangements reduces upside potential, but the floor included enhances bankability and provides minimum revenue certainty.[41]	Discount-to-market arrangements help high-energy-intensity companies improve their electricity supply without committing to a fixed cost. Caps and floors require specialist support and knowledge, especially in increasing RE penetration and price volatility. These arrangements are best suited for companies with high energy intensity and a deep understanding of energy markets.
HYBRID PRICING, OVERTIME/PERCENTAGE OUTPUT	In electricity purchase agreements, the buyer (Offtaker) and the seller (generator) take on price risk. A company typically assumes the risk of selling at a fixed price, while the producer	Power generators can opt for a fixed-price PPA output, which is more secure, or a floating-price PPA, which could capture higher prices but is less safe. The latter provides long-term bullish views	This option suits companies that consume much energy but only want to commit to a fixed price for part of the project output. It provides a price hedge on the fixed production and a possible discount on

[39] Dobrotkova, Z., Surana, K., & Audinet, P. (2018). The price of solar energy: Comparing competitive auctions for utility-scale solar PV in developing countries. *Energy Policy*, *118*, 133-148.Available at: https://doi.org/10.1016/j.enpol.2018.03.036

[40] Shrestha, R. B., & Ogunlan, S. (2006). Comparative study of PPAs in the Nepalese environment. *Journal of Financial Management of Property and Construction*, *11*(3), 133-148.

[41] Fell, H., Burtraw, D., Morgenstern, R. D., & Palmer, K. L. (2012). Soft and hard price collars in a cap-and-trade system: A comparative analysis. *Journal of Environmental Economics and Management*, *64*(2), 183-198. https://doi.org/10.1016/j.jeem.2011.11.004 .

	assumes the risk of selling at a variable cost. The structure provides financial security and risk sharing. Over time, a portion of the risk can be transferred back to the producer. Different structures exist for managing price risk.	and some upside on the wholesale price, but there is lower visibility over revenue. The fixed-price PPA is considered bankable, while the floating-price PPA is less so.	the floating portion. This is ideal for companies with a short-term view of power prices or those who prefer to avoid locking in long-term prices.
CLAWBACK PRICING	Threshold placement and generator loss caps should be carefully considered for new projects. This can provide revenue certainty and make the project more bankable[42]. Lower prices may also help overcome internal stakeholder barriers.	Not all power producers may be familiar with the structure, and larger power producers will generally be more open to bespoke structures. The PPA strike price will typically increase to reflect the initial downside risk borne by the power producer.	The ability of prices to reduce before the loss cap is hit may provide specific. Corporate buyers with comfort if they are. Unsure about locking in a long-term price.

Table Comparing the Impacts of Different Pricing Structures on PPA Stakeholders[43]

The table above outlines various pricing structures within PPAs, each with distinct implications for risk allocation between generators/suppliers and off-takers/buyers. Fixed pricing, the most straightforward, offers revenue visibility to generators and cost certainty to off-takers, but locks both parties into a set price, potentially leading to losses if market conditions shift. Fixed pricing with index and escalation mitigates inflation risk, appealing to generators seeking inflation-linked financing and off-takers desiring a soft start with lower initial costs. Floors and collar pricing introduces price bands, balancing revenue security for generators with flexibility for off-takers but demands specialised market knowledge[44]. Hybrid

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42 Jha, A. (2022). Regulatory Induced Risk Aversion in Coal Contracting at US Power Plants: Implications for Environmental Policy. *Journal of the Association of Environmental and Resource Economists*. Available at: https://doi.org/10.1086/715885

43 World Business Council for Sustainable Development (WBCSD)), Pricing structures for corporate RE power procurement agreements available at < Pricing structures for corporate renewable PPAs – WBCSD> Accessed on 22/09/2023.

44 Ondraczek, J. (2024). *Two-way Contracts for Difference for Renewable Energy Projects in the EU: An Economic and Legal Analysis* (Master's thesis, by Medien-und Informationszentrum, Leuphana Universität Lüneburg Files in This Item: File Description Size Format Ondraczek_Two-way_Contracts_for_Difference_for_Renewable_Energy_Projects_MA. pdf MD5: ea5c5e644165a6defe3253e1a49901d5 License: Nutzung nach Urheberrecht open-access 1 MB Adobe PDF View/Open Items in PubData are protected by copyright, with all rights reserved, unless otherwise indicated. Views Show full item record).

pricing allows for a mix of fixed and floating prices, catering to off-takers with fluctuating energy needs and generators seeking potential upside while managing risk[45]. Clawback pricing, particularly for new projects, shifts initial downside risk to the generator, potentially increasing the PPA strike price but offering off-takers price reduction comfort. The table effectively illustrates the trade-offs inherent in each pricing structure. Generators prioritise revenue certainty and bankability, often favouring fixed or escalated pricing, while off-takers seek cost control and flexibility, leading them to explore indexed hybrid, or floor/collar arrangements[46]. Power imbalances can manifest in the selection of a pricing structure, with larger, more sophisticated players having greater leverage to negotiate complex arrangements like clawback or hybrid models. Ultimately, the optimal pricing structure depends on the risk tolerance, market outlook, and strategic objectives of both generators and off-takers[47], highlighting the importance of thorough negotiation and a deep understanding of energy market dynamics.

VI. *Comparative analysis of price risk mitigation strategies in PPAs across California, Germany, and the UK*

a. Price Stability and Market Responsiveness

California's PPA market prioritises price stability through fixed pricing structures, often supplemented with index-based adjustments. The California Sample Contract illustrates this by setting fixed rates for different energy categories (start-up, delivered, and excess), providing revenue certainty for generators and cost predictability for off-takers. Index-linked pricing, using benchmarks like SP-15 or the CPI, further mitigates inflation and market volatility risks[48]. Renegotiation is strictly controlled, requiring mutual consent and regulatory oversight, ensuring long-term contract integrity. This approach fosters investor confidence and supports the state's ambitious renewable energy goals by minimising price uncertainty.

In contrast, Germany's PPA market incorporates greater flexibility to adapt to dynamic market conditions. German PPAs often feature price adjustment clauses, allowing for rate modifications based on cost and market developments. This responsiveness is crucial in a market characterised by evolving energy policies and fluctuating costs. The distinction between unilateral performance determination rights and price escalation clauses reflects the legal complexities of price adjustments. While fixed pricing exists, German contracts often

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[45] Gavriil, E. (2025). *The risks in Power Purchase Agreements (PPAs) for utilities & corporate offtakers* (Master's thesis) Available at: https://dione.lib.unipi.gr/xmlui/handle/unipi/17434

[46] Acharya, A. (2022). Advent of renewable energy market–understanding critical success factors in PPA model. *Energy and Environment Research*, *11*(1), 1-1. Available at: https://www.researchgate.net/profile/Abhijeet-Acharya/publication/349427618_Advent_of_Renewable_Energy_Market-Understanding_Critical_Success_Factors_in_PPA_Model/links/602f80204585158939b494a6/Advent-of-Renewable-Energy-Market-Understanding-Critical-Success-Factors-in-PPA-Model.pdf

[47] Derré, J. E. (2024). Valuation Methodology for Baseload Power Purchase Agreements including risks borne by the Seller: Application to Spain's market. Available at: https://www.diva-portal.org/smash/get/diva2:1904044/FULLTEXT01.pdf.

[48] Supriyanto, E., Sentanuhady, J., Hasan, W. H., Nugraha, A. D., & Muflikhun, M. A. (2022). Policy and Strategies of Tariff Incentives Related to Renewable Energy: Comparison between Indonesia and Other Developing and Developed Countries. *Sustainability*, *14*(20), 13442. Available at: https://doi.org/10.3390/su142013442.

embed mechanisms to reflect changes in indices or cost components, balancing stability with market adaptability[49]. The shift towards shorter, market-oriented procurements also indicates a preference for flexibility over rigid long-term contracts.

The UK's approach to price risk mitigation in PPAs blends elements of both California and Germany. Contracts for Difference (CfDs) play a pivotal role, providing a guaranteed strike price and thus revenue stability for renewable energy generators[50]. This mechanism reduces price volatility risk and encourages investment, similar to California's fixed pricing. However, the UK also promotes corporate PPAs, which often incorporate market-linked pricing, allowing for greater flexibility and direct procurement of renewable energy by businesses. This dual approach balances the need for long-term stability with the benefits of market responsiveness, reflecting the UK's competitive energy market.

b. Comparing Fixed Pricing Index-Based and Pricing Adjustment Strategies

All three regions utilise fixed pricing, but with distinct nuances. California employs straightforward fixed rates, often with index-based escalations for long-term predictability. Germany uses fixed prices as a starting point, but with embedded price adjustment clauses to reflect changing market conditions[51]. The UK primarily uses CfDs to provide a guaranteed price, which functions as a form of fixed pricing for revenue certainty. This reflects differing regulatory and market priorities: California's focus on long-term stability, Germany's adaptability to market fluctuations, and the UK's blend of guaranteed revenue and market responsiveness.

Index-based pricing is a common tool for mitigating inflation and market risks in California, using established indices like CPI or market-specific benchmarks[52]. Germany employs broader price adjustment clauses, often tied to cost components or market indices, allowing for more dynamic responses to changing conditions. The UK's CfDs, while providing a fixed strike price, implicitly incorporate market dynamics through the difference payments. This highlights a spectrum of flexibility: California's focused index adjustments, Germany's comprehensive adjustment clauses, and the UK's indirect market integration.

Comparative Analysis of Renegotiation and Market Influence

California strictly regulates contract amendments, emphasising mutual consent and regulatory oversight to maintain long-term stability. Germany allows for greater flexibility through price

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49 Newbery, D. (2023). Efficient Renewable Electricity Support: Designing an Incentive-compatible Support Scheme. *The Energy Journal*. Available at: https://doi.org/10.5547/01956574.44.3.dnew

50 Huber, C., Resch, G., Haas, R., & Everts, M. (2021). Value Factors, Capture Prices and Cannibalism: Nightmares for Renewable Energy Decision-makers. *The Journal of World Energy Law & Business*, *14*(4), 231-247. Available at: https://doi.org/10.1093/jwelb/jwab027.

51 Supriyanto, E., Sentanuhady, J., Hasan, W. H., Nugraha, A. D., & Muflikhun, M. A. (2022). Policy and Strategies of Tariff Incentives Related to Renewable Energy: Comparison between Indonesia and Other Developing and Developed Countries. *Sustainability*, *14*(20), 13442. Available at: https://doi.org/10.3390/su142013442

52 Tong, M. J. (2021). Corporate Hedging, Executive Compensation and Commodity Price Prediction. Available at: https://yorkspace.library.yorku.ca/items/ba904db0-d6d1-4be1-ad24-24ea73a0562b.

adjustment clauses and market-oriented procurements, indicating a more dynamic approach[53]. The UK's CfDs and corporate PPAs demonstrate a market-driven approach, where CfDs provide stability and corporate PPAs allow for direct market engagement. This reflects distinct regulatory philosophies: California's emphasis on contractual certainty, Germany's responsiveness to market signals, and the UK's balanced approach combining regulatory support with market mechanisms.

c. Summary Representation of Price Risk Mitigation Strategies

Needless to reiterate, the pricing structure of long-term PPAs plays a crucial role in mitigating electricity risks and determining investment decisions[54]. Essentially, PPAs are contracts between power generators and Offtakers, typically utility companies, which outline the terms of electricity sales. Establishing a long-term PPA provides stability to both parties by securing a fixed or flexible electricity price for a period typically ranging from 10-20 years. For power generators, long-term PPAs provide certainty regarding future revenue streams, which can be instrumental in securing financing for energy projects. This encourages investment in new energy infrastructure, like RE projects, and reduces reliance on fossil fuels while lowering greenhouse gas emissions[55]. For off-takers, long-term PPAs help manage the risk of electricity price volatility by setting the cost of electricity for a predetermined period. This is particularly beneficial in markets where electricity prices are unpredictable. By locking in a fixed price, off-takers can avoid the risk of price spikes and budget more effectively for their energy needs.

Energy procurement is a complex field that involves various pricing strategies across different jurisdictions. PPAs are designed to manage price volatility and ensure energy procurement is done efficiently and effectively. To enhance energy procurement, it's essential to understand these pricing strategies and how they work. Each jurisdiction has its own unique set of pricing strategies that are incorporated into PPAs, as already discussed in detail. These strategies include fixed pricing, fixed pricing with indexation, fixed pricing with escalations, and hybrid pricing structures as outlined and streamlined to jurisdiction in the table below. In a nutshell, Fixed pricing is a strategy where the energy price is fixed for a certain period, which provides price certainty and predictability. Index pricing is a strategy linking energy prices to a public index that tracks energy prices. A hybrid pricing structure combines both fixed and index pricing strategies. Fixed pricing with escalations permits the buyer to purchase a fixed amount of energy from the generator at a fixed price for a certain for the entire contract period. However, this fixed price may not account for changes that may occur in the future, such as inflation or changes in market prices. To address this, the PPA

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53 Lohse, A. (2024). Comparative Analysis: Assessing the Institutional Impact of Disruptions. In: Higher Education in an Age of Disruption. Palgrave Macmillan, Cham. Available at: https://doi.org/10.1007/978-3-031-57912-7_8

54 Davies, L. L., Crossley, P., Connor, P., Park, S., & Shaw-Hughes, S. (2016). Climate Regulation of the Electricity Industry: A Comparative View from Australia, Great Britain, South Korea, and the United States. *SCJ Int'l L. & Bus.*, *13*, 109. Available at: https://heinonline.org/HOL/Page?handle=hein.journals/scjilb13&div=11&id=&page=&collection=journals

55 Brinker, L., & Satchwell, A. J. (2020). A comparative review of municipal energy business models in Germany, California, and Great Britain: Institutional context and forms of energy decentralization. *Renewable and Sustainable Energy Reviews*, *119*, 109521. Available at < https://doi.org/10.1016/j.rser.2019.109521> accessed on 12/8/2023.

may incorporate escalations, which are predetermined increases in the price of RE over time. These escalations are often tied to a specific index, such as the Consumer Price Index (CPI)[56], which tracks inflation.

When developing a pricing framework for a PPA, it is imperative to achieve a balanced and equitable structure. Nevertheless, this may pose challenges as specific frameworks may appear to favour one party over the other, and what may be advantageous at the onset of the contract may not be suitable in the future. As such, both parties must collaborate to make necessary adjustments to keep the agreement current and adaptable to new developments. In the long run, a PPA should be viewed as a dynamic and living document that evolves and is never truly finished.[57]

For a fair PPA pricing framework, both parties must work collaboratively to make necessary adjustments and keep the agreement current. A PPA is an evolving document that requires continuous changes, and both parties should understand these pricing strategies to make informed procurement decisions.

S/N	GENERAL PRICING RISK STRUCTURE	CALIFORNIA PRICING RISK STRUCTURE	GERMANY PRICING RISK STRUCTURE	UNITED KINGDOM PRICING STRUCTURE
1	Fixed Pricing	Fixed Pricing	Fixed Pricing	Fixed Pricing
2	Floating/Variable Pricing	Variable Pricing	Fixed Pricing with Escalation	Feed-in Tariff with Contract for Difference
3	Indexed Pricing	Indexed Pricing		
4	Floors and Collars Pricing	Floors and Collars		Floors and Collars
5	Hybrid Pricing Structure			Hybrid Pricing Structure
6	Fixed Pricing with Escalations	Fixed Price with Escalations		
7	Clawback Pricing			

Table 2 Pricing Management Structures in PPAs Associated with Case Study Jurisdictions

d. Assessment of Pricing Structures Based on Advantages and Disadvantages

RE PPAs offer parties in different jurisdictions an opportunity to mitigate the risk of price fluctuations through various pricing structures. While each structure has advantages and disadvantages, carefully considering options is crucial before deciding. Assessing and comparing the pricing structures is imperative to determine the most suitable choice. Fixed pricing offers a stable rate for the duration of the agreement, providing price certainty but

[56] Poudineh, R. (2024). *Can UK green hydrogen contract for difference (CfD) match the cost-saving success of renewable electricity?* (No. 39). OIES Paper: ET. Available at: https://www.econstor.eu/handle/10419/306631.

[57] Gabrielli, P., Aboutalebi, R., & Sansavini, G. (2022). Mitigating financial risk of corporate PPAs via portfolio optimization. *Energy Economics*, *109*, 105980.

limiting opportunities for savings if prices decrease. Floating pricing offers flexibility, allowing for a price change based on market trends. Floor and collar pricing balances the stability of fixed pricing and the flexibility of floating pricing. Variable pricing allows for adjustments based on market conditions, while hybrid pricing structures combine the benefits of two or more pricing structures. Choosing the proper pricing structure for a RE PPA requires a thorough understanding of the advantages and disadvantages of each option.[58] Parties must carefully consider their risk tolerance, market trends, and forecasted energy needs before deciding.

California has fixed pricing, variable pricing, and consumer price index pricing. In Germany, two pricing structures are used: fixed pricing and fixed pricing with escalation. These pricing structures provide stability and predictability for both the offtaker and the producer. Fixed pricing ensures that the energy price remains constant throughout the contract, while fixed pricing with escalation allows for incremental price increases over time[59]. Similarly, RE PPA has two pricing structures in the United Kingdom - fixed and flexible pricing with the CfD. Fixed pricing offers constant energy prices, while flexible pricing with CfD allows for price adjustments depending on market conditions. Using both pricing structures, the UK can provide stability and predictability for both the energy producer and the offtaker while allowing flexibility to adjust to changing market conditions.

The decision to choose a particular pricing structure is taken by the offtaker or the producer, depending on their business interests. The selection of pricing structure is critical as it can affect the project's profitability and the venture's overall success. Therefore, evaluating each option carefully and determining which pricing structure aligns best with the specific business needs of a party is essential. Consequently, critically analysing the advantages and the disadvantages of each pricing structure helps either of the parties to choose from the pricing options. The table below represents the advantages and disadvantages of each pricing option.[60]

S/N	*Pricing Structure*	*Advantages*	*Disadvantages*
1	**Fixed Pricing**	• Simplicity for Project	• Risk of locking in at a

[58] NICULESCU, E., HRISTESCU, C., & TANȚĂU, A. (2022). Key Barriers that Prevent the Development and Implementation of PPA in the Transition Process to a Zero Carbon Economy. *Fostering Recovery through Metaverse Business Modelling*, 114. Available at: https://d1wqtxts1xzle7.cloudfront.net/92700831/9788367405072-011-libre.pdf?1666183027=&response-content-disposition=inline%3B+filename%3DKey_Barriers_that_Prevent_the_Developmen.pdf&Expires=1737073344&Signature=TaPpO229DLhK3pa8pEAZXdXPBAgU74Cn616uIdps-zLleqkWUZuo-DWrWPnZKPoqg99ZlZVcfPK4aOEypNd4qQdfS24QqewYCCXMuaq5En0kGKfg11cDAFtXTtAlTWYFfCPYNaygKx2fAWx4HEGXJhnJUEo0VoQc9-NuMrbHBqzYy8MjcQ7RNvxE-lfQvL2mvyJDPSfBCTMLWg8SyO5t4JUJrWd9z4FSc~mt6Df5WVt6rB-VJDvnojjmgsJ6g0CfszQw6MvtYhsqOApS4JUtzJTM4Xlxz0Lc0TCXhP~95JssiZcsxC7TPfNFRUaHpvb8FjMcmJD5ZbQ1XepIWtDWFQ__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

[59] Talus, K. (2011). Long-term natural gas contracts and antitrust law in the European Union and the United States. *Journal of World Energy Law and Business*, *4*(3), 260-315i. Available at https://doi.org/10.1093/jwelb/jwr015 Accessed on 3/7/2024.

[60] Gwasanaeth Ynni Energy Service, Power Offtaker Options, Available at < https://www.gov.wales/sites/default/files/publications/2023-02/power-purchase-agreements-guidance.pdf> Accessed on the November 2023

		Financing • Stringer price hedge offers budget certainty • Predictable Cash flows • Potential to lock in at a price below future market	price that could be above market rate in the future
2	**Fixed Price with Escalation**	• Simplicity for Project Financing • Stronger price hedge; offers budget certainty • Predictable Cash flows • Potential to lock in at a price below future market • Alignment to inflation cost	• Risk of locking in at a price that could be above market rate in the future • Annual price increase
3	**Floors, Caps and Collars**	• Tracks market prices • Protection against the risk of price spikes in the market • Guarantees a price range	• It can be complicated for project financing • It is challenging to get buy-in for such a pricing structure • Doesn't form such a defined hedge • Less predictable cash flow compared to a fixed structure
4	**Floating/Variable**	• Allows tracking of market prices • Offers a discount on the market price	• It can be complicated for project financing • It is challenging to get buy-in for such a pricing structure • Doesn't for such a defined hedge • Less predictable cash flow compared to fixed pricing

Table 3 The Advantages and Disadvantages of Different Types of Pricing Structures in Long-term RE PPA

The table presents a summary and an overview of the advantages and disadvantages of various price risk management structures in PPAs[61]. Fixed pricing and fixed pricing with escalation offer simplicity, budget certainty, and predictable cash flows, making them

[61] Mittler, C., Bucksteeg, M., & Staudt, P. (2023). Review of renewable power purchasing agreement types and classification through morphological analysis. *Available at SSRN 4626108*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4626108.

attractive for project financing. These structures provide a strong price hedge and the potential to lock in prices below future market rates, which is advantageous in volatile markets. However, a significant drawback is the risk of locking in at a price above future market rates, potentially leading to financial losses. Fixed pricing with escalation also introduces annual price increases, which can be a concern for off-takers. These structures are most effective in jurisdictions where long-term price stability is prioritised and market volatility is anticipated. Floors, caps, and collars, as well as floating/variable pricing, offer the advantage of tracking market prices and providing protection against price spikes. These structures allow for flexibility and potential discounts compared to fixed rates[62]. However, they introduce complexity in project financing and can be challenging to implement due to their less-defined hedge and less predictable cash flows. These methods require a deeper understanding of market dynamics and are better suited for off-takers with higher risk tolerance and sophisticated financial capabilities. They are less ideal for projects requiring stable, long-term financing, as they introduce greater uncertainty. The choice between these structures depends heavily on the specific market conditions, the risk appetite of the parties involved, and the regulatory environment.

4. SUSTAINABILITY CONSIDERATIONS IN POWER PROCUREMENT AGREEMENT DESIGN

Recognising the interconnectedness of environmental, social, and economic factors, contemporary PPA designs must integrate comprehensive sustainability considerations. This necessitates a shift from traditional models that often overlook environmental externalities, such as carbon emissions and land use, to frameworks that mandate rigorous impact assessments and mitigation strategies. Furthermore, addressing the social impacts of renewable energy projects, including community engagement and equitable benefit sharing, is crucial for fostering social acceptance and long-term project viability[63]. Embedding the sustainability principles throughout the PPA lifecycle, and aligning with supportive legal and regulatory frameworks can empower stakeholders to ensure that renewable energy projects not only contribute to a cleaner energy future but also deliver tangible benefits to communities and the environment.

a. *Environmental Externalities*

Incorporating environmental considerations into PPA frameworks is paramount for achieving sustainable energy transitions. Traditional PPAs primarily focused on economic factors, often neglecting the broader environmental impact of energy generation. Modern PPAs, however, must explicitly address environmental externalities, such as carbon emissions and land use. For instance, PPAs supporting solar or wind projects should quantify

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62 Bovera, F., Zapparoli, L., & Zatti, M. A New Approach to Long-Term Contracts to Hit Renewables and Storage Deployment Targets While Balancing Private and Public Risks. *Available at SSRN 5130804*. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=5130804.

63 Pouikli, K. (2021, January). Towards mandatory Green Public Procurement (GPP) requirements under the EU Green Deal: reconsidering the role of public procurement as an environmental policy tool. In *Era Forum* (Vol. 21, No. 4, pp. 699-721). Berlin/Heidelberg: Springer Berlin Heidelberg. Available at: https://link.springer.com/article/10.1007/s12027-020-00635-5.

and report the avoided greenhouse gas emissions compared to conventional fossil fuel-based generation. This requires robust methodologies for calculating carbon offsets and ensuring transparency in reporting[64]. Furthermore, land use impacts, particularly for large-scale renewable projects, need careful assessment. PPAs should mandate environmental impact assessments and implement mitigation measures to minimise habitat disruption, soil erosion, and water pollution. Provisions for decommissioning and site restoration at the end of the project's lifespan are also crucial to ensure long-term environmental sustainability. Additionally, PPAs can incentivize the adoption of environmentally friendly technologies and practices, such as the use of biodegradable materials, rainwater harvesting, and biodiversity conservation measures.

b. Social Impacts

Renewable energy projects, while environmentally beneficial, can have significant social impacts that must be addressed within PPA frameworks. Analysing these social impacts involves examining issues like community engagement and equitable benefit sharing. Effective community engagement requires early and continuous consultation with local stakeholders throughout the project lifecycle[65]. PPAs should mandate participatory processes that allow communities to express their concerns, provide input on project design, and negotiate benefit-sharing agreements. This ensures that projects are aligned with local needs and priorities, fostering social acceptance and minimising conflicts. Equitable benefit sharing involves ensuring that the economic and social benefits of renewable energy projects are distributed fairly among affected communities. PPAs can incorporate mechanisms such as community ownership, local employment opportunities, and revenue-sharing agreements. For example, a portion of the project's revenue could be allocated to community development funds, supporting local infrastructure, education, and healthcare initiatives. Furthermore, PPAs should address potential negative social impacts, such as displacement of communities, loss of livelihoods, and cultural disruption. This requires robust social impact assessments and mitigation plans, including compensation mechanisms for affected individuals and communities.

c. Integration of Sustainability Principles

Designing PPAs to promote a holistic approach to sustainability requires balancing economic, environmental, and social factors. This involves integrating sustainability principles throughout the PPA lifecycle, from project development and financing to operation and decommissioning. PPAs should incorporate sustainability criteria into project selection and evaluation processes, prioritising projects that demonstrate a strong commitment to

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[64] Kristensen, H. S., Mosgaard, M. A., & Remmen, A. (2021). Circular public procurement practices in Danish municipalities. *Journal of Cleaner Production*, *281*, 124962. https://doi.org/10.1016/j.jclepro.2020.124962

[65] Anthony Jr, B. (2024). The role of community engagement in urban innovation towards the co-creation of smart sustainable cities. *Journal of the Knowledge Economy*, *15*(1), 1592-1624. https://link.springer.com/article/10.1007/s13132-023-01176-1.

environmental protection and social responsibility[66]. This can be achieved through the use of sustainability rating systems and certification schemes, such as LEED or B Corp, which assess projects based on their environmental and social performance. Economic sustainability can be enhanced by incorporating innovative financing mechanisms, such as green bonds and impact investments, which attract capital from socially responsible investors. Environmental sustainability can be promoted by mandating the use of best available technologies and practices for energy generation and environmental management. PPAs should also include provisions for continuous improvement and adaptation to changing environmental and social conditions. Social sustainability can be fostered by promoting local ownership, employment, and capacity building. PPAs should mandate the development of local supply chains and the provision of training and education programs for local communities.

d. Legal and Regulatory Frameworks

Current legal and regulatory frameworks play a crucial role in either facilitating or hindering the use of PPAs for sustainable development. Supportive frameworks provide clear and consistent rules for renewable energy development, grid connection, and PPA implementation. For instance, feed-in tariffs, renewable portfolio standards, and carbon pricing mechanisms can incentivise the adoption of renewable energy and create a level playing field for sustainable PPAs[67]. Conversely, ambiguous or restrictive regulations, such as complex permitting processes, grid access barriers, and discriminatory tax policies, can impede the development of sustainable PPAs. Legal frameworks should also address the environmental and social aspects of renewable energy projects, ensuring that they comply with international standards and best practices[68]. This includes regulations on environmental impact assessments, land use planning, and community engagement. Furthermore, legal frameworks should promote transparency and accountability in PPA implementation, requiring developers to disclose information on project impacts, performance, and compliance with sustainability criteria. Effective enforcement mechanisms are also essential to ensure that developers adhere to legal and regulatory requirements. Finally, legal frameworks should be adaptable to changing technological, economic, and social conditions, allowing for the continuous improvement and innovation of sustainable PPA practices.

The Impacts of Long-term Energy Contracts on Sustainable Energy Deployment

Long-term energy contracts are foundational instruments in the global shift towards sustainable energy systems. These agreements, which often extend over decades, provide the necessary framework for the development and deployment of renewable energy

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66 Romianingsih, N. P. W., Utomo, S. W., & Hamzah, U. S. (2023). A Comparative Study Of Different Practices In Environmental Impact Assessment. *Journal of Environmental Science and Sustainable Development*, *6*(1), 50-69. https://scholarhub.ui.ac.id/jessd/vol6/iss1/5/.

67 Aziz, S. (2024). *Effects of Regulatory Framework on Investment in Renewable Energy* (Doctoral dissertation, © University of Dhaka). http://reposit.library.du.ac.bd:8080/xmlui/handle/123456789/3437.

68 Ukoba, K., Olatunji, K. O., Adeoye, E., Jen, C., & Madyira, D. M. (2024). Optimizing renewable energy systems through artificial intelligence: Review and future prospects. *Energy & Environment*. Available at: https://doi.org/10.1177/0958305X241256293

technologies[69]. Beyond simply facilitating the sale of electricity, they exert a profound influence on the energy landscape, shaping investment patterns, market structures, and the very sustainability of energy production. This section discusses the five key impacts of long-term energy contracts, revealing their crucial role in accelerating the transition to a cleaner and more sustainable energy future. Here's a breakdown of five major impacts:

(a) *Providing Financial Stability and Attracting Investment:* Long-term contracts offer a predictable revenue stream for renewable energy projects, which are characterised by high upfront capital costs. This stability is crucial for securing financing from investors and lenders who require assurance of long-term returns. By mitigating financial risks, these contracts make renewable energy projects more bankable, thereby attracting essential private investment. This injection of capital is vital for scaling up sustainable energy infrastructure.

(b) *Enabling Project Development and Expansion:* The security provided by long-term contracts allows developers to plan and execute large-scale renewable energy projects. With guaranteed offtake, they can invest in advanced technologies and expand their operations, driving down costs and increasing efficiency. This fosters innovation and accelerates the deployment of sustainable energy solutions across diverse geographical locations.

(c) *Driving Energy Market Liberalisation:* Long-term contracts, especially PPAs, contribute to the liberalisation of energy markets by enabling the participation of independent power producers (IPPs)[70]. This breaks the monopoly of traditional utilities, fostering competition and diversifying the energy mix. By creating a level playing field, these contracts encourage innovation and drive the adoption of cleaner energy sources.

(d) *Facilitating Grid Stability and Integration:* Long-term contracts can be structured to incorporate grid stability services, such as frequency regulation and voltage control, which are essential for integrating intermittent renewable energy sources into the grid[71]. This helps to ensure a reliable and resilient energy supply, minimising disruptions and maximising the utilisation of sustainable energy. Moreover, they can help to finance energy storage systems that are very important to grid stability.

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69 Del Río, P., & Burguillo, M. (2009). An empirical analysis of the impact of renewable energy deployment on local sustainability. *Renewable and Sustainable Energy Reviews*, *13*(6-7), 1314-1325. <https://doi.org/10.1016/j.rser.2008.08.001> Accessed 3 April 2025

70 Twesigye, P. R. (2021). Understanding Structural, Governance and Regulatory Incentives for Improved Utility Performance: A Comparative Analysis of Electricity Utilities in Tanzania, Kenya and Uganda. Available at <https://open.uct.ac.za/server/api/core/bitstreams/2a45d3b1-13e8-4edc-8377-96fa0e929fa6/content> Accessed 3 April 2025.

71 Das, P., Mathur, J., Bhakar, R., & Kanudia, A. (2018). Implications of short-term renewable energy resource intermittency in long-term power system planning. *Energy Strategy Reviews*, *22*, 1-15. <https://doi.org/10.1016/j.esr.2018.06.005> Accessed 3 April 2025.

(e) *Promoting Socio-Economic Development:* The development of renewable energy projects through long-term contracts creates numerous socio-economic benefits, including job creation, local economic development, and improved energy access. This is particularly significant in developing economies, where sustainable energy can drive economic growth and improve living standards. Furthermore, these projects can empower local communities through ownership and participation, fostering social equity and sustainable development.

5. CONCLUSION AND RECOMMENDATIONS FOR IMPROVED POWER PURCHASE AGREEMENT DESIGN

This study addressed the central research question of how contractual design, particularly regarding incompleteness and power imbalances, influences the effectiveness of long-term PPAs in achieving sustainable renewable energy targets. To ensure effective price risk mitigation in long-term PPAs, a shift towards dynamic models is essential. Traditional PPAs, often rigid and inflexible, struggle to adapt to the volatile nature of renewable energy markets. Alternative models that promote collaborative risk sharing, flexibility, and adaptability are crucial. These models should incorporate mechanisms for dynamic pricing, allowing for adjustments based on real-time market conditions and technological advancements. This approach fosters a more equitable distribution of risk, incentivising both generators and offtakers to participate in the long-term sustainability of the project. Robust renegotiation mechanisms are equally vital. Long-term PPAs are inherently susceptible to unforeseen contingencies, such as regulatory changes, technological disruptions, and economic downturns. Clear and effective processes for renegotiating contracts are necessary to address these challenges. These mechanisms should define triggers for renegotiation, establish transparent negotiation protocols, and provide for independent dispute resolution. By facilitating timely and equitable renegotiations, stakeholders can ensure that PPAs remain relevant and effective throughout their lifespan.

Adaptive governance structures are critical for fostering ongoing communication, collaboration, and dispute resolution. These structures should establish clear lines of communication between generators, offtakers, and other stakeholders, enabling timely information sharing and collaborative decision-making. Regular stakeholder meetings, joint working groups, and independent oversight committees can facilitate effective governance. Furthermore, robust dispute resolution mechanisms, such as arbitration and mediation, should be incorporated into PPA frameworks to address conflicts promptly and efficiently. Addressing power imbalances is crucial for promoting equitable risk allocation in long-term PPAs. In markets where a few large players dominate, smaller generators and offtakers may face unfavourable contract terms. Strategies for mitigating these imbalances include promoting market transparency, fostering competition, and establishing regulatory oversight. Standardised PPA templates, independent market monitoring, and dispute resolution mechanisms can help level the playing field, ensuring that all stakeholders have a fair chance to participate in the renewable energy market. Mechanisms for periodic review are essential to ensure that PPAs remain relevant and effective over their long duration. Regular contract reviews, conducted by independent experts, can assess the performance of the PPA, identify

areas for improvement, and recommend necessary adjustments. This allows stakeholders to adapt to changing market conditions, technological advancements, and regulatory requirements. By implementing regular reviews, stakeholders can ensure that PPAs continue to deliver value and contribute to the long-term sustainability of renewable energy projects. Finally, this study has found that effective price risk mitigation in long-term PPAs requires a holistic approach that integrates dynamic models, robust renegotiation mechanisms, adaptive governance structures, equitable risk allocation, and regular reviews. By adopting these strategies, stakeholders can create more resilient and sustainable PPAs that promote the long-term viability of renewable energy projects and contribute to a cleaner, more secure energy future.