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Market Mechanisms and Electricity Export Pricing: A Comparative Study of Wholesale and Bilateral Trade Models

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ABSTRACT

The price of electricity exports affects global energy markets because of the increase of grid interconnections and decarbonization requirement. The model of wholesale (PJM Interconnection), bilateral (Iran cross-border trade), and hybrid (EU market coupling) will be compared in the study to determine the efficiency of pricing, market transparency, integrating renewables and cross-border trade in totality. The mixed-methodology approach is the combination of the qualitative analysis of policy and the quantitative indicators which are based on both primary and secondary sources. Although the model of PJM (wholesale strategy) ensures competent pricing, it lacks integration of renewable and is highly volatile. Bilateral model of Iran offers non-transparent non-renewable non-flexible pricing. Despite the existence of legislative fragmentation, the hybrid approach of the EU has reached equal pricing, reduced volatility, and high integration of renewable. The hybrid strategies allow maximising the export price and sustainability under the support of joint governance, institutional reform and transition-oriented policies. The suggested policies include the dynamic pricing mechanisms of PJM, transparent reporting of the contracts of Iran and the EU-style regional integration of emerging markets. Future research may consider blockchain-based trade to enhance the transparency and carbon pricing to enhance renewable shares as scalable solutions to world energy transitions, while addressing environmental and economic challenges.

Keywords: Electricity Export Price, Pricing Efficiency, Market Transparency, Integration of Renewable, Energy Efficiency
JEL Classifications: L94, D40, F13, Q41, L51

1. INTRODUCTION

As trade dynamics are altered by interconnected grids, the use of renewable energy, and decarbonization goals, makes the price of electricity exports crucial to global energy markets (MacIver et al., 2021; IEA, 2022). The centralized auctions and locational marginal pricing (LMP) in the wholesale markets such as PJM Interconnection encourage competition (Kyrylenko et al., 2019), whereas the bilateral models such as the exports of Iran, Iraq and Turkey (Dehghan and Amin-Naseri, 2022) rely on stability associated with negotiated contracts. These models vary in pricing effectiveness, disclosure, and integrability of renewables which have an impact on the trade across borders (Ambec and Yang, 2024). This paper juxtaposes three scenarios, PJM (wholesale), Iran (bilateral), and EU market coupling (hybrid) to answer the question:

How do the models maximize export prices, integrate renewables, and trade?

Using both qualitative analysis of policy and quantitative measures, it applies both the market design theory and regulatory economics to provide policy-makers with actionable information (Dehghan and Amin-Naseri, 2022; Zhang et al., 2022). In contrast to earlier research that concentrated on established markets (Newbery et al., 2016; Joskow, 2019), the study addresses export pricing in emerging markets (Iran) and renewable integration in bilateral systems (Peng, 2022), thereby addressing important gaps in the field. It offers scalable policy solutions for sustainable energy trade by comparing various market models in developed and emerging contexts (Atmo et al., 2022). In order to navigate the economic and environmental problems of global energy transitions, stakeholders can benefit from this analysis (Norris, 2025).

This paper will examine the price of energy export in relation to different market models based on institutional economics, multi-level governance (MLG), and social-technical transitions (STT) (North, 1990; Hooghe and Marks, 2003; Geels, 2002). The institutional economics considers regulative and geopolitical institutions to have a role in price efficiency (Makholm, 2023), and the MLG focuses on the significance of governance coordination of trade and integration of renewable energy (Stojčevski et al., 2023). Gaugl et al. (2023) state that in STT, market mechanisms are presented as tools of energy transitions, which are necessary in decarbonization. These models facilitate the comparison of PJM, Iran, and the EU, and give interdisciplinary information regarding the maximization of export markets, and define the sustainable policy alternatives to resolve global issues in energy (Ambec and Yang, 2024).

The fast-changing geopolitical and economic powers are strongly affecting the global energy market, and trading in electricity export prices is very essential for the whole process of succeeding in both trade efficiency and sustainability goals (Makholm, 2023; Peng, 2022). The growing number of interconnections resulting from such undertakings as the EU Energy Union and China's Belt and Road energy projects (Zhang et al., 2022; IEA, 2022) make the demand for the development of market models that would be able to support different economic and regulatory environments (Norris, 2025). Unlike the interconnected grids of developed areas (IEA, 2024), the power exchange of emerging markets such as the Middle East and Southeast Asia is often obstructed by political disputes, underdeveloped infrastructure, and a gradual shift to renewable sources of energy (Nguyen and Wongsurawat, 2017; Atmo et al., 2022). The comparative assessment of these differences in the context of PJM, Iran, and the EU in this study, will give an insight into how the power market structures can lead to both the decarbonization and pricing efficiency objectives (Woo et al., 2017; Gaugl et al., 2023). Considering both developed and developing markets, it bridges a knowledge gap of relevance on how scalable trade systems can be used to facilitate energy transitions in the world (Ambec and Yang, 2024; Xu et al., 2025). It can make policymakers know how to enhance cross-border collaboration and introduce renewables into various regulatory frameworks (Stojčevski et al., 2023).

2. LITERATURE REVIEW

The evolution of the electricity markets is attributed to, deregulation, the merging of renewable energy sources, and international commerce, with the market structures affecting the prices for exports. The review gives an overview of the literature concerning the bilateral and wholesale models, emphasizing their merits, demerits and gaps to facilitate comparative analysis.

Wholesale markets such as PJM Interconnection apply centralized auctions and LMP to indicate transmission constraints and supply-demand interactions to offer effective resource allocation (Schmalensee, 2016). Even though LMP considers some marginal costs such as congestion and losses, non-convexity such as the cost of start-up of generators causes the so-called missing money problem, which is further worsened by zero-marginal-cost of renewables such as solar and wind (Hogan, 2017). Since such renewables lower expenses, there is a need to have capacity remuneration mechanisms (CRM), which ensure reliability (Joskow, 2019). The electricity market target model (EMTM) applied in Europe is a market coupling approach linking national markets to eradicate border price gap, but faces constraints in its ability to do so because of regulatory fragmentation and insufficient capacity of interconnectors (Newbery et al., 2016). Common bilateral arrangements in developing countries like Iran are negotiated contracts to keep hydro-generated and thermal generation of relatively low cost exported to Turkey and Iraq (Churkin et al., 2021). However, these arrangements are often not transparent, have geopolitical-affected clauses, and unchangeable pricing regimes that limit the ability to integrate variable renewables (Sioshansi, 2013). Wholesale markets are characterized by great competitiveness and volatility unlike bilateral models that appreciate predictability but hamper innovativeness.

Despite the abundance of research efforts, comparative analysis of export pricing within the framework of different market models, particularly in a developing economy, still has gaps. Though Joskow (2019) addresses the issue of wholesale models and Newbery et al. (2016) focus on European hybrid systems, little research has been conducted to understand the renewable integration of bilateral systems or the dynamics of emerging markets (Churkin et al., 2021). The paper closes these gaps by making comparisons of PJM, Iran and the EU and by bringing an insight into the effectiveness of pricing, transparency and sustainable trade in the developed as well as in the emerging economies. The major findings and gaps are discussed in Table 1 below.

Hooghe and Marks (2003) observe that multi-level governance (MLG) provides a critical insight to understanding the role played by layered governance structures on export price of energy. Through ENTSO-E, supranational coordination assists in market coupling and harmonizing national policies to minimize price discrepancies and enable renewable incorporation, helping achieve 40 per cent renewable in the EU (ENTSO-E, 2024). Conversely, the wholesale market operated by PJM is operated in a federal-state system, where the state-level regulation offers inconsistencies (FERC, 2023). Iran cannot scale its bilateral trade and incorporate renewable energy, as geopolitical tensions and sanctions do not provide regional control (Churkin et al., 2021). MLG stresses on the fragmented or lacking regional structures such as in Iran hinder market development, and effective coordination of various levels of governance enhances trade efficiency as seen in the EU (Börzel, 2010).

Table 1: Market model comparison

Model	Key studies	Strengths	Weaknesses	Gaps
Wholesale	Schmalensee (2016), Joskow (2019)	Efficient pricing, transparency	Volatility, renewable integration	Export pricing in emerging markets
Bilateral	Churkin et al. (2021), World Bank (2022)	Stability, geopolitical alignment	Low transparency, rigid pricing	Renewable integration, scalability
Hybrid	Newbery et al. (2016), ACER (2024)	Balances efficiency, stability	Regulatory fragmentation	Non-European applications

3. THEORETICAL FRAMEWORK

The paper relates the models of the wholesale and bilateral trade based on the market design and regulatory economics (Kyrylenko et al., 2019). Wholesale markets are based on neoclassical economics and the efficient market hypothesis, and include centralized auctions and LMP to factor in marginal costs such as losses and congestion (Hogan, 2017). Though the presence of the non-convexities which include start-up expenses and zero-marginal-cost bids complicate the integration of the renewables, such marketplaces promote competitiveness (Woo et al., 2017). Bilateral agreements such as Iran have been based on stability through negotiated contracts, depending on geopolitical factors or the cost of production, aligning with the contract theory (Churkin et al., 2021; Dehghan and Amin-Naseri, 2022). Such contracts are often not flexible and transparent to intermittent renewable generation. The comparative framework classifies models according to four criteria, such as the pricing efficiency (cost reflectivity, low volatility), transparency (public access to data), integration of renewable (accommodating intermittency) and the international trade (infrastructure, regulatory alignment). To produce scalable global energy market policy solutions, PJM, Iran, and the EU models will be examined within the framework relying on the market design theory (Wilson, 2002).

The importance of institutional economics places emphasis on the role of formal and informal institutions in influencing the electricity export prices, and supplements the principles of market design (Makholm, 2023). Wholesale markets and hybrid markets also have transparent prices and regulatory supervision by formal institutions, as in the case of FERC in the PJM and ACER in the EU (North, 1990). On the other hand, Iran's bilateral approach, which is impacted by unofficial geopolitical conventions, limits price efficiency and market scalability due to opaque discussions and high transaction costs (Williamson, 2000; Peng, 2022). In contrast to competitive marketplaces, these institutional impediments impede cross-border trade and the integration of renewable energy in bilateral systems (Stojčevski et al., 2023). The framework assesses the effect of institutional structures on efficiency and transparency to help solve the global energy market policies.

4. METHODOLOGY

The paper uses a mixed-method comparative analysis to assess the impact of wholesale, bilateral and hybrid trade models on electricity export pricing, in the areas of pricing efficiency, transparency, integration of renewables as well as cross-border trade (Dehghan and Amin-Naseri, 2022). Three cases of PJM Interconnection (wholesale, United States), Iran's cross-border trade (bilateral, Middle East), and EU market coupling (hybrid, Europe), are used to answer the research issue of how these models maximize price and assist energy transitions. Because of their varied market structures, legal systems, and geographical settings, these cases were chosen to fill in the gaps in the literature on emerging markets and bilateral renewable integration (Atmo et al., 2022).

Models are compared on four criteria, which are: pricing efficiency, transparency, renewable integration, and cross-border trade, on the analytical framework that is based on the market design and regulatory economics (Wilson, 2002; Hogan, 2017). Qualitative analysis reviews policy and institutional structures by analysing the contents of regulatory documents and scholarly literature regarding the topic through content analysis (Gaugl et al., 2023). The quantitative analysis employs descriptive statistics (mean export prices, volatility standard deviation, trade volumes, renewable shares) of the years 2018-2024, as it is justified due to the recent growth of renewable and market reform (IEA, 2022). Descriptive comparisons ensured robust cross-case analysis, whereas statistical tests (such as t-tests for price differences) were taken into consideration although constrained by the availability of data.

Primary data from PJM, FERC, ACER, ENTSO-E and secondary data from World Bank reports were used as summarized in Table 2 (MacIver et al., 2021). Triangulating regional energy assessments and proxy indicators (such as regional price benchmarks) helps to reduce the opacity of Iran's data (Nguyen and Wongsurawat, 2017). Limitations include limited generalizability because of geographical variances, which are explained in case analyses, and possible biases in secondary sources for Iran, which are addressed through cross-referencing.

5. CASE STUDIES

Based on qualitative and quantitative data, this section analyses three scenarios in order to assess how market processes impact export pricing (20182024) Table 3 below.

5.1. PJM Interconnection (Wholesale)

PJM offers LMP to establish the export rate between 30 and 50/MWh, considering transmission congestion and supply-demand dynamics with a capacity of 185 GW and 65 million customers (PJM, 2024; Kyrylenko et al., 2019). Non-convexity causes such as the cost of starting up generators make exporters pay more, particularly to Canada, when the volatility is high (20-30 standard deviation) (FERC, 2023; Woo et al., 2017). Transparency is one of the strong points of the regulatory system as FERC's supervision makes it accountable. On the other hand, intricate LMP calculations are a reason for misunderstanding the likes of IESO in Ontario. The 10% of generation (80 Twh) that is subject to the zero-marginal-cost bids of wind and solar is limited to the extent that it not only lowers the market prices but also jeopardizes the stability of the grid (Woo et al., 2017). The Reliability Pricing Model (RPM) of PJM is a type of capacity payment used to enhance reliability but increases the expenditures of the exporters (Joskow, 2019). Low interconnector capacity (50% usage) limits cross-border trade to Canada at 2 TWh per year, highlighting the necessity of infrastructure investment to increase exports (MacIver et al., 2021).

5.2. Iran's Cross-Border Trade (Bilateral)

Iran, which has 90 GW capacity, sells 10 Twh every year to Iraq, Turkey, and its neighbors at 5070/MWh under bilateral agreement (Dehghan and Amin-Naseri, 2022). Such fixed prices guarantee predictability to the importers but do not capture the dynamics of the real-time market, which is likely to cause inefficiency or under-pricing (Churkin et al., 2021). There is low levels of transparency since the terms of contracts are not disclosed because of geopolitical negotiations, which limits accountability and integration of the markets in the region (World Bank, 2022; Peng, 2022). The integration of renewable is also low, as 5% of generation (15 TWh) is solar and wind, where the fixed-price contracts prefer thermal generation and do not encourage investment in variable renewables (Dehghan and Amin-Naseri, 2022).

5.3. EU Market Coupling (Hybrid)

The electricity market target model (EMTM) of the EU is a market integration model that employs market coupling in order to permit 400 TWh of cross-border trade at the price of €50-100/MWh without high volatility with a combination of 27 national markets (ACER, 2024; Stojčevski et al., 2023). Though congestion sometimes leads to price spikes, the process lowers price disparity across borders (Newbery et al., 2016). Although access for smaller stakeholders is complicated by multi-country coordination, transparency is high and comprehensive data is available on the ACER and ENTSO-E platforms. With 40% of generation (1,000 TWh) coming from wind and solar, renewable integration is strong and is bolstered by cross-border balancing markets and zero-cost bids (Gaugl et al., 2023).

Table 2: Energy market case sources

Case	Primary sources	Secondary sources
PJM	PJM website, FERC reports	Joskow (2019), Hogan (2017)
Iran	World Bank (2022), Churkin et al. (2021)	IEA, regional energy analyses
EU	ACER, ENTSO-E	Newbery et al. (2016), Eurelectric (2023)

Table 3: Energy market comparison metrics

Case	Price (USD/MWh)	Volatility (% SD)	Trade volume (TWh)	Renewable share (%)
PJM	30-50	20-30	2	10
Iran	50-70	Low (estimated)	10	5
EU	50-100	15	400	40

However, the need for storage technologies is highlighted by negative pricing during renewable surpluses (ENTSO-E, 2024). High interconnector utilization (85%) maximizes cross-border trade, however regulatory heterogeneity among member states continues, necessitating additional harmonization to improve energy efficiency (Ambec and Yang, 2024). Table 4 below summarize the different trade-offs and performance profiles found in the comparison analysis.

5.4. Socio-Technical Transitions in Electricity Markets

Socio-technical transitions (STT) framework is a framework that helps understand the interactions of technological niches, socio-technical regimes, and landscape pressures to explain how market structures characterise renewable energy transitions (Geels, 2002). In this subsection, STT is applied to PJM, Iran, and the EU in evaluating their effects on the renewable integration and trade scalability.

5.4.1. PJM interconnection

The wholesale market structure of PJM discourages the use of renewable niche innovations because it depends on locational marginal pricing (LMP) and capacity remuneration framework, which values the stability of thermal generation (Woo et al., 2017). Prices are suppressed by zero-marginal-cost bids from solar and wind (10% share, 80 TWh), which results in capacity factor losses for solar of 5-7% because of grid restrictions (PJM, 2024; Joskow, 2019). Due to market regulations favouring dispatchable production over intermittent renewables, this solidifies the regime based on fossil fuels (Geels, 2002). The low interconnectors capacity also limits the exports of renewable to Canada (2 TWh), preventing the niche scaling (MacIver et al., 2021). To undermine the regime and promote the integration of renewable energy sources, policy changes are required, such as the growth of demand response.

5.4.2. Iran's cross-border trade

Despite a potential of 10 GW by 2030, Iran's bilateral trade model strengthens a thermal regime lock-in, restricting solar scalability (World Bank, 2022; Dehghan and Amin-Naseri, 2022). Fixed-price contracts for exports to Turkey and Iraq (10 TWh) marginalize renewables (5% share, 15 TWh) in favour of low-cost thermal and hydro generation (Churkin et al., 2021). Special breakthroughs such as solar are stifled by the stability of this regime that is provided by the sanctions and geopolitical priorities due to strict pricing and outmoded grid infrastructures (Geels, 2002). Transition will require 200m grid upgrades and flexible contracting to meet the needs of the landscape (Peng, 2022).

Table 4: Performance comparative analysis

Criterion	PJM (Wholesale)	Iran (Bilateral)	EU (Hybrid)
Average export price (USD/MWh)	40	60	80
Price volatility (Standard deviation)	High (12)	Low (6)	Medium (9)
Market transparency	High	Very Low	High
Renewable share in exports	10%	5%	40%
Cross-border volume (TWh/year)	2	10	400

5.4.3. EU market coupling

The hybrid model by EU provides market coupling of renewable transitions by aligning policy and technology across 27 countries (Gaugl et al., 2023). The presence of cross-border balancing markets and extensive use of interconnectors, which makes it possible to have a 40% renewable share decimates curtailment by 20% (ENTSO-E, 2024). Market coupling fosters the niche development by integrating wind and solar using collaborative governance and disrupting fossil fuel regimes (Geels, 2002). However, the regulatory fragmentation and negative pricing during surplus emphasize the need to spend on storage (Ambec and Yang, 2024). By working together at the regional level, this approach gives emerging markets a blueprint on how to expedite the socio-technical changes.

6. DISCUSSION

Unlike Iran, which has stable yet less dynamic prices, the LMP in PJM is ensuring efficient pricing (3050/MWh), however, the volatility (20-30/SD) is impeding scaling of exports (PJM, 2024; Churkin et al., 2021). By market coupling, the EU provides a balance between efficiency and a lower level of volatility (ACER, 2024). FERC enhances transparency using publicly accessible data on PJM. This outweighs the concealment of Iran, where the lack of transparency and responsibility is supported by secret contracts. The reporting regulations by the EU make a balance between the intricacy and transparency. The EU leads in renewable integration due to the zero-cost bids and Iran cannot flexibly generate variable generation and PJM encounters price suppression problems. Despite infrastructure limitations in all situations, the EU's 400 TWh trade volume surpasses that of PJM (2 TWh) and Iran (10 TWh), mostly due to high interconnector use (MacIver et al., 2021).

Pricing efficiency differs greatly: PJM's LMP is responsive to real-time but subject to volatility due to non-convexities, Iran's fixed prices are stable but risk under-pricing, and the EU's market coupling reduces differentials but for occasional spikes (Stojčevski et al., 2023). PJM has the highest level of transparency, the EU has a moderate level because of coordination issues, and Iran has the lowest level because of geopolitical secrecy. Renewable integration in the EU is the best with cross-border balancing facilitating high shares, while PJM and Iran are lacks behind because of market rigidities and contract inflexibility respectively. The EU trade is the most efficient cross-border trade, then the Iranian exports, which is geopolitically inclined and PJM trade which is limited. Table 3 validates these results, and they show the extent to which hybrid model balances sustainability, efficiency, and transparency in international energy markets.

According to Kyrylenko et al. (2019), the comparative study reveals minor trade-offs in pricing effectiveness that are impacted by structural differences among market models. Cost reflectivity with PJM locational marginal pricing (LMP) is provided using real-time supply-demand interactions and transmission capacity, but is highly volatile as a result of market inefficiencies due to non-convexities, including the start-up costs of generators and the inability to ramp rapidly (PJM, 2024; Hogan, 2017). Further quantitative analysis reveals that PJM is more volatile than the EU, which is 15% above the risk premium in export contracts than the EU where market coupling makes the market volatility 15% standard deviation due to convergence of prices across borders (ACER, 2024).

Iran's bilateral pricing strategy, which maintains prices between \$50 and \$70/MWh, prevents volatility but at the expense of efficiency because fixed contracts are unable to adapt to changes in demand, which could result in export prices that are 10-15% higher than their marginal costs (Churkin et al., 2021; Dehghan and Amin-Naseri, 2022). In contrast to Iran's opaque negotiations, the EU's hybrid model uses auction theory to reduce the winner's curse, which occurs when bidders overpay because of knowledge asymmetry, through transparent day-ahead auctions. These results indicate that pricing efficiency is achieved in the maximum when the mechanisms of competition are combined with regulatory frameworks that internalize such externalities as congestion, and providing a scalable model for emerging markets transitioning to hybrid systems.

Another distinction between the models is renewable integration, which has an implication on the scalability of cross-border trade (Gaugl et al., 2023). The market coupling of the 40% renewable share (1,000 TWh) of the EU allows wind and solar intermittency to be addressed by balancing across borders, instead of just 10% of the 40% renewable share (80 TWh) in PJM (ENTSO-E, 2024; PJM, 2024). PJM price suppression at zero-marginal-cost bids deters renewable investment and capacity factor losses of 5-7% to solar in the grid constraint (Joskow, 2019; Woo et al., 2017). The 5% renewable quota (15 TWh) of Iran is limited by fixed-price contracts, which favour thermal generation and do not allow a greater solar contribution, even though the potential solar capacity could reach 10 GW by 2030 (World Bank, 2022). According to game theory, the EU has an advantage over PJM's isolated grid since its 27 member states work together to maximize renewable dispatch and reduce negative pricing events by 30% (Newbery et al., 2016). The bilateral model of Iran, which does not have such coordination, has Nash equilibrium where the individual export agreements waken the regional renewable growth. These factors highlight the necessity for hybrid markets to incorporate regional interconnectors and flexible pricing, allowing emerging nations to mimic the cross-border benefits of the EU while mitigating the volatility of PJM and the rigidity of Iran.

The multi-level governance (MLG) model explains the performance of EU regarding renewable integration relative to PJM and restrictions in Iran (Hooghe and Marks, 2003; Stojčevski et al., 2023). The supranational structure of the EU through ENTSO-E facilitates balancing markets across borders, which facilitates high use of interconnections (85) and reduces renewable curtailment at by 20% (ENTSO-E, 2024). Conversely, the federal-state PJM governance introduces incompatibility, where state-level policies restrict the integration of renewable and increase the price volatility because of the lack of coordination (PJM, 2024). The geopolitical isolation of Iran prohibits the scalability of renewables because bilateral contracts prioritize thermal production and act counterproductively to cooperative systems (Churkin et al., 2021; Makholm, 2023). MLG emphasizes that efficient multi-level coordination, such that seen in the EU, maximizes the deployment of renewable energy sources and trade efficiency (400 TWh). It provides emerging countries with a model for overcoming the regulatory fragmentation in PJM and the governance deficiencies in Iran, thereby promoting sustainable energy transitions.

7. CONCLUSION AND POLICY IMPLICATIONS

The paper exposes trade-offs in global energy transition since it is the first to examine the electricity export pricing in the wholesale (PJM), bilateral (Iran), and hybrid (EU) regimes in both established and emerging markets. Even though PJM ensures efficiency through its locational marginal price, exports cannot be close to transmission constraints because it is tremendously volatile and inefficiently integrated with renewables. Bilateral approach will give geopolitical alignment and stable price, however, it lacks transparency and renewable flexibility. The hybrid model in the EU despite the barriers of legislation contributes to 400Twh of trade and is very successful in terms of efficiency, reduced volatility, and integration of renewables. The socio-technical transitions (STT) model, contrasting sharply with thermal locked systems of Iran or the volatility constrained ones in PJM, highlights the role of hybrid systems in facilitating renewable transitions through a proper alignment of market structures with the decarbonization goal since they are characterized by contractual stability and competitive auctions. The grid investments of $1-2 billion, dynamic capacity systems and public reporting, optimise their export markets. The research on blockchain-based trade should explore future methods of enhancing transparency, destabilizing fossil fuel regimes, and scaling specialized breakthroughs such as solar energy systems. These findings provide scalable alternatives to policymakers, where STT will be used to enhance sustainable trade to overcome the twenty first century economic and environmental challenges.

In order to maximize markets for power exports and facilitate energy transitions, this research provides specific policy proposals (Ambec and Yang, 2024). In the case of PJM, volatility can be minimized by using dynamic capacity remuneration mechanisms (CRM), for example scarcity pricing auctions and competitive signals can be retained (Joskow, 2019). Improving the calculation of LMPs and offering importers transparent pricing guidelines, such as the IESO of Canada will increase transparency (Hogan, 2017). In the case of Iran, indexed contracts based on regional benchmarks, for example gulf cooperation council prices will enhance the energy efficiency of prices without compromising stability (Churkin et al., 2021; Dehghan and Amin-Naseri, 2022). Disclosure of the terms of contracts by a regional energy authority based on the ACER of the EU will enhance responsibility in spite of geopolitical limitations. In the case of EU, the harmonization of capacity remuneration mechanisms between the member states and the streamlined access to data on the ENTSO-E platforms will minimize the fragmentation of regulations (ACER, 2024).

To increase the penetration of renewables, PJM ought to encourage battery storage and scale demand response initiatives to handle zero-marginal-cost bids and increasing the proportion of the renewable beyond 10% (PJM, 2024; Woo et al., 2017). The flexible contracts with variable-price provisions should be introduced in Iran to promote solar exports as it has a 5% renewable potential (World Bank, 2022). According to ENTSO-E (2024) and Gaugl et al. (2023), the EU should preserve its 40% renewable part and boost investments and anticipation tools in storage to combat negative pricing. In the case of cross-border trade, PJM will need upgrading interconnectors bilateral requirements with Canada. To overcome sanctions, Iran must spend $500 million on the modernization of its grid and enter into free trade agreements through the Economic Cooperation Organization (Makholm, 2023). With the help of regional compacts, emerging countries should be guided by the EU's 15% interconnector capacity target by 2030.

Hybrid models with a combined competitive auctions and bilateral contracts are recommended in emerging markets like the Middle East (Atmo et al., 2022). Iran could pilot auction based renewable exports and keep the bilateral thermal contracts, which were experimented with IEA-funded projects.

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