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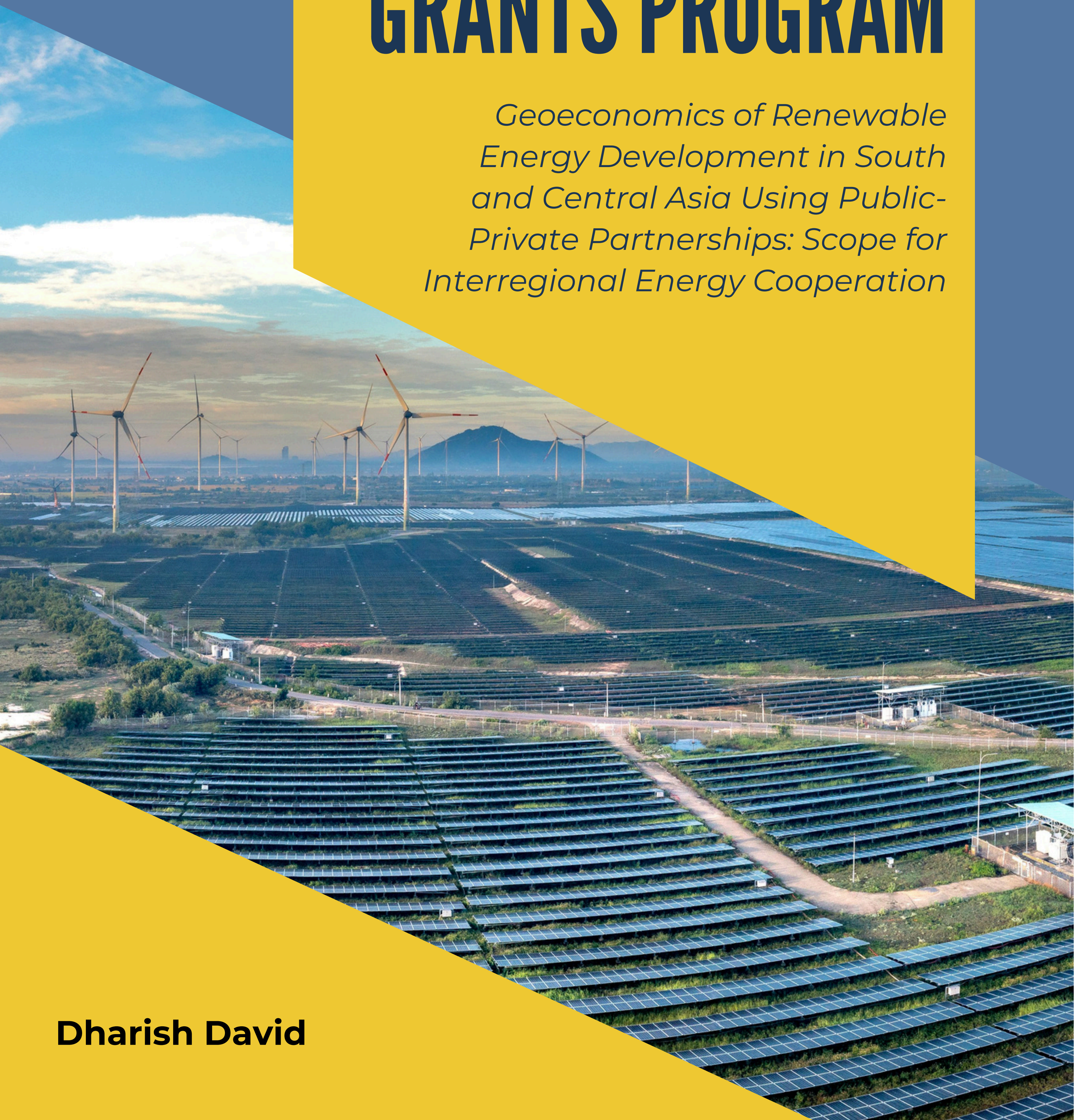
Geoeconomics of Renewable Energy Development in South and Central Asia Using Public-Private Partnerships: Scope for Interregional Energy Cooperation



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Disclaimer

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Abstract

This explorative study examines the renewable energy cooperation potential between South Asia's rapidly expanding energy demand and Central Asia's abundant renewable resources. It analyzes how complementary energy profiles can accelerate regional decarbonization through innovative financing mechanisms. Employing a mixed-methods approach that combines quantitative analysis of World Bank Private Participation in Infrastructure data (2003–2023) with policy document analysis, the study evaluates USD 193.9B in cumulative energy public–private partnership (PPP) investments across both regions to identify successful cooperation models and financing frameworks. Key findings reveal (i) a marked shift in investment patterns from coal-dominated portfolios toward renewable energy, with solar and wind projects attracting USD 17.6B in recent commitments; (ii) effective blended finance mechanisms, exemplified by Uzbekistan's renewable energy auctions achieving a USD 0.027/kWh tariff in 2019; and (iii) emerging cross-border initiatives, including Central Asia-South Asia power project (CASA-1000) and proposed Central Asia–South Asia energy corridors, which demonstrate institutional frameworks capable of enabling regional market integration. The analysis identifies persistent governance gaps (e.g., regulatory fragmentation, political economy constraints, and insufficient risk mitigation mechanisms) that limit optimal resource allocation despite strong economic complementarity. The study contributes by providing the first comprehensive PPP investment analysis across both regions while offering policy insights on harmonized regulatory frameworks, advanced risk-sharing mechanisms, and institutional innovations necessary to unlock clean energy investment opportunities and achieve sustainable regional and interregional energy security.

Keywords

Central Asia, South Asia, renewable energy financing, cross-border electricity trade, public-private partnerships (PPP), energy geoeconomics, solar energy investment, wind energy infrastructure, hydroelectric projects, inter-regional cooperation,

JEL Codes

Q42, Q48, F59, P48, O22, L94

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1. Introduction

Global energy investment surpassed USD 3T for the first time in 2024, with USD 2T directed toward clean energy technologies and infrastructure, marking a decisive shift away from fossil fuels and reflecting the sector's growing appeal to both investors and governments worldwide (International Energy Agency, 2024). This transformation has fundamentally reshaped power infrastructure development, particularly in emerging economies, where energy security, economic growth, and environmental sustainability intersect in complex ways. South Asia, which hosts nearly one-fourth of the global population, and Central Asia, endowed with vast wind and solar resources, occupy pivotal positions in this transition (BloombergNEF, 2025). However, these regions exhibit contrasting energy realities: Bangladesh and Pakistan continue to face chronic energy deficits, while Tajikistan and Kyrgyzstan experience seasonal surpluses due to robust hydropower assets (ESCAP, 2018). These disparities underscore both the urgency and the potential for interregional energy cooperation, highlighting how complementary resources can be leveraged through innovative financing mechanisms.

Investment momentum is reinforced by clear evidence that renewables are now viewed as an attractive and resilient asset class in global capital markets. BloombergNEF reports that total energy transition investment, including renewables, electrified transport, and grid modernization, reached a record USD 2.1T in 2024, with USD 728B allocated to renewable sources (BloombergNEF, 2025). The Asia-Pacific region, led by China's USD 940B in clean energy investment, continues to set the global pace, while the Belt and Road Initiative has supported 12.6 GW of non-hydro renewables across both regions (Carbon Brief, 2025; Eco-Business, 2024). Pakistan has emerged as the largest recipient of Belt and Road Initiative (BRI) renewable investments, with 1.7 GW installed via Chinese equity, while India achieved some of the world's lowest renewable energy costs in the late 2010s through competitive policy instruments, providing critical models for interregional cooperation (PWC, 2019; UNDP, 2018).

The strategic imperative for enhanced cooperation extends beyond commercial considerations to address substantial investment needs and climate vulnerabilities. The Asian Development Bank estimated that Central Asia alone requires approximately USD 400B in energy sector investment through 2030, while South Asia faces similarly large capital demands driven by population growth and industrialization (Asian Development Bank (ADB), 2019). As traditional government-led financing proves insufficient to meet ambitious renewable targets, hybrid financing approaches that combine public oversight with private-sector efficiency have become essential. The complementarity between Central

Asia's renewable generation potential and South Asia's demand creates clear opportunities for mutually beneficial cooperation that can enhance energy security while advancing decarbonization objectives.

This analysis is particularly timely given evolving renewable energy financing paradigms, with emphasis on public–private Partnership (PPP) models and cross-border cooperation between these regions. The Central Asia Regional Economic Cooperation (CAREC) program's vision of integrated energy markets, combined with South Asia's growing demand, creates unprecedented opportunities for interregional collaboration that require sophisticated approaches to risk allocation, revenue sharing, and institutional coordination across jurisdictions (ADB, 2019). Through analysis of major initiatives (i.e., including the Central Asia–South Asia Electricity Transmission and Trade Project (CASA-1000), the Turkmenistan–Afghanistan–Pakistan–India (TAPI) pipeline, and emerging solar cooperation frameworks) this study examines how PPP models have adapted to the challenges of cross-border renewable energy projects.

The renewable energy investment landscape linking South and Central Asia (Table 1) is being reshaped by market forces, policy incentives, and strategic partnerships. This paper revisits the geoeconomics of regional complementarities, drawing on multilateral, institutional, and comparative South–South cooperation evidence to clarify how financing mechanisms have evolved to address complex cross-border infrastructure demands. By grounding the analysis in recent empirical trends and evaluating both successes and constraints, the study aims to inform policymakers, development finance institutions, and private-sector stakeholders navigating the next decade of sustainable energy development in emerging markets.

Table 1: Estimated infrastructure investment needs by region, 45 development member countries (2016–2030, Climate-Adjusted and USD billion in 2015 prices)

Sector	Baseline est. (USD billion 2015 prices)	Climate-adjusted est. (USD billion 2015 prices)
Central Asia	492	565
East Asia	13,781	16,062
South Asia	5,477	6,347

Southeast Asia	2,751	3,147
The Pacific	50	45
Total	**22,551**	**26,166**

Sector	Baseline est. (USD billion 2015 prices)	Climate-adjusted est. (USD billion 2015 prices)
Power	11,689	14,731
Transport	7,796	8,353
Telecommunications	2,279	2,279
Water and Sanitation	787	802
Total	22,551	26,166

Source: Asian Development Bank 2017.

Notes:

* Pakistan and Afghanistan are included in South Asia.

** Climate change adjusted figures include climate mitigation and climate proofing costs

1.1. Justification for Interregional Energy Cooperation

The case for deeper interregional energy cooperation between South Asia and Central Asia is rooted in asymmetries and complementarities in their energy resource bases, consumption profiles, and economic structures. South Asia, comprising the South Asian Association for Regional Cooperation (SAARC) member states—India, Pakistan, Bangladesh, Sri Lanka, Afghanistan, Nepal, Bhutan, and Maldives—presents a paradox of substantial demographic weight and persistent energy deficits. Despite accounting for roughly 24% of the global population, the region contributes only 4% to world gross domestic product (GDP), highlighting how poverty and uneven development constrain energy access and consumption (CRISIL, 2018). Economic dynamism, led by India and Bangladesh, drives rapid growth in energy demand, yet continued import dependence exposes these economies to external shocks, trade imbalances, and rising indebtedness (ADB, 2019; REN21, 2019).

Central Asia, meanwhile, exhibits sharp contrasts between hydrocarbon-rich economies such as Kazakhstan, Turkmenistan, and Uzbekistan and hydro-dependent, energy-poor states such as the Kyrgyz Republic and Tajikistan. Although the former have begun diversifying through renewable projects—often supported by private and foreign investment—hydro-dominated countries face social and environmental constraints associated with large-scale dams, complicating access to green finance and international support (Eurasian Development Bank (EDB), 2022; Shadrina, 2019). However, the decline in wind and solar generation costs—by up to 85% since 2010—has made these technologies increasingly viable, even for countries historically reliant on fossil fuels (REN21, 2019; World Bank, 2023).

The rationale for interregional cooperation is further reinforced by structural complementarities. South Asia's rapid demand growth and dependence on imported electricity and gas position it to benefit from Central Asia's surplus hydropower capacity and untapped solar and wind resources (Table 2). Conversely, Central Asia's need to diversify away from carbon-intensive exports and stabilize development trajectories aligns with South Asia's demand for cleaner, more affordable energy (ADB, 2019; Aminjonov, 2019). Afghanistan, despite its current economic and political instability, could serve as a critical physical and transactional bridge linking the two regional power systems (Economic and Social Commission for Asia and the Pacific (ESCAP), 2018).

Multilateral frameworks such as the CAREC program provide the institutional foundation for these ambitions. As of 2019, CAREC had invested nearly USD 8.6B across 50 regional projects, focusing on expanding electricity trade, strengthening grid connectivity, and integrating sustainable energy resources (ADB, 2019; EDB, 2022). The CAREC Energy Strategy 2030 (ADB, 2019) further emphasized regional interconnections, market reform, and green energy development as core pillars.

Importantly, the transition from fossil fuels to renewables in Central Asia is projected to proceed through three phases: a high-carbon pathway through 2020, a gas-dominated intermediate stage until 2030, and a low-carbon transformation between 2040 and 2050 (REN21, 2019; Sulaimanova et al., 2023). As wind and solar costs continue to decline, investment in cross-border grid infrastructure, harmonized regulatory frameworks, and inclusive financing models becomes essential not only for sustainable growth but also for reducing energy poverty, particularly in lower-income countries.

Table 2: Regional electricity production and consumption (2021)

South Asia (2021)	Production (kWhM)	Exports (kWhM)	Imports (kWhM)	Consumption (kWhM)	Energy Surplus (kWhM)	Imports (% Consumption)
Afghanistan	1,298	0	5,315	3,890	–2,592	136.63%
Bangladesh	72,320	0	8,103	71,488	832	11.33%
Bhutan	10,822	8,074	25	2,711	8,111	0.92%
India	1,484,463	9,249	7,974	1,316,765	167,698	0.61%
Maldives	596	0	N/A	355	241	n/a
Nepal	6,045	44	2,806	7,313	–1,268	38.37%
Pakistan	143,704	0	498	116,816	26,888	0.43%
Sri Lanka	16,716	0	N/A	15,214	1,502	n/a

Central Asia (2021)	Production (kWhM)	Exports (kWhM)	Imports (kWhM)	Consumption (kWhM)	Energy Surplus (kWhM)	Exports (% of Production)
Kazakhstan	115,079	2,663	2,120	114,536	543	2.31%
Kyrgyz Republic	15,138	548	1,683	13,535	1,603	3.62%

Tajikistan	20,624	3,303	883	13,800	6,824	16.02%
Turkmenistan	22,500	3,200	0	14,700	7,800	14.22%
Uzbekistan	71,363	2,644	6,232	74,952	–3,589	3.71%

Source: ADB Key Indicators 2024

The table above illustrates electricity consumption, production, energy surplus, access gaps, and import and export shares relative to consumption and production for each country in South and Central Asia, highlighting the scale of both challenges and opportunities across the regions.

India's cross-border electricity trade (CBET Table 3) has shifted from a net importer in 2013–16 to a consistent net exporter since 2016–17, reflecting its expanding role in South Asia's energy market. Exports to Nepal, Bangladesh, and Myanmar have grown steadily, peaking before the pandemic, while imports from Bhutan remain significant but have declined in recent years. By 2023–24, India exported 8,576 million units (MUs) compared with 3,862.78 MUs of imports, reinforcing its position as a regional electricity hub with a net surplus of 4,713.29 MUs.

Table 3: CBET between India and neighboring countries from 2013/14 to 2023/24 (MUs)**

Year	Bhutan (import)	Nepal (export)	Bangladesh (export)	Myanmar (export)	Net export/import by India
2013/14	5,555.18	840.37	1,448.19	–	3,266.62
2014/15	5,109.48	997.17	3,271.89	–	840.42
2015/16	5,555.07	1,469.59	3,654.40	–	431.08
2016/17	5,863.58	2,021.21	4,419.61	3.23	–580.47
2017/18	5,611.14	2,388.96	4,808.83	5.07	–1,591.72
2018/19	4,657.07	2,798.84	5,690.31	6.67	–3,838.75

2019/20	6,310.73	2,373.06	6,987.94	8.61	−3,058.88
2020/21	9,318.17	1,865.05	7,551.99	9.24	−108.11
2021/22	7,670.34	1,921.09	7,301.74	8.80	−1,561.29
2022/23	6,379.95	158.05	8,622.14	9.80	−2,410.04
2023/24	3,862.78	154.08	8,413.52	8.47	−4,713.29

Source: (REGlobal, 2025)

The urgency for joint action is underscored by mounting climate risks, demographic pressures, and the risk of widening economic divides in the absence of inclusive energy transitions. As both regions stand at the crossroads of energy transformation, only robust interregional cooperation, facilitated by platforms such as CAREC, competitive PPPs, and sustained multilateral engagement, can deliver resilient, affordable, and sustainable power systems suited to the challenges of the coming decades (ADB, 2019; Shadrina, 2019; CRISIL, 2018; EDB, 2022).

1.2. Hypothesis

Recent evidence suggests that South Asia's energy demand is projected to more than double by 2050, and that its chronic deficits can be strategically addressed through imports from Central Asia, which maintains persistent surplus capacity, particularly in renewables (ERIA, 2023; World Bank, 2022b). This mutually beneficial dynamic positions interregional cooperation not only as a mechanism to optimize resource utilization but also to reduce costs and accelerate large-scale renewable deployment, as supported by both academic and multilateral assessments (CAREC, 2024; EDB, 2022; UNECE, 2024).

Therefore, the working hypothesis is that deeper market integration and coordinated transmission infrastructure between the two regions will accelerate the transition toward a resilient, low-carbon power system while unlocking significant socioeconomic and environmental benefits. Critically, the interregional boundaries separating Central and South Asia, despite traversing zones of political and security complexity, also constitute corridors of strategic infrastructure opportunity: shared energy networks can foster positive-sum economic interdependence, generate mutual revenue flows, and create incentives for sustained diplomatic engagement and cross-border stability. Achieving this vision, however, will require overcoming persistent barriers in policy harmonization, technical standardization, and financing innovation, best addressed through institutionalized regional collaboration anchored in multilateral frameworks such as CAREC, South Asia Subregional Economic Cooperation (SASEC), and the evolving Central Asia–South Asia power trade architecture.

1.3. Methodology

This study employs a mixed-methods approach to analyze the evolving dynamics of renewable energy investment, electricity demand, and the operational feasibility of PPPs across South and Central Asia. Quantitative analysis is primarily based on the World Bank Group's Private Participation in Infrastructure (PPI) database, the ADB, and regionally focused think-tank datasets—including Economic Research Institute for the Association of Southeast Asian Nations (ASEAN) and East Asia (ERIA), EDB, and relevant publications from CAREC and other multilateral organizations. This triangulation provides a robust empirical foundation for assessing electricity demand, financing flows, subsector investment preferences, and the commercial viability of large-scale renewable projects across both regions.

Desk research involved the systematic review and cross-validation of over 25 scholarly articles, policy briefs, and multilateral reports published between 2020 and 2025. Official data on installed capacity, transmission infrastructure, and investment volumes were verified using government gazettes, energy ministry communiqués, and recent infrastructure-focused league tables (CRISIL, 2018; PWC, 2019; REN21, 2019; EDB, 2022). To support comparative analysis, project-level documentation from interregional initiatives, including CASA-1000, TAPI, and regional solar installations, was examined to evaluate transmission requirements, demand projections, revenue-sharing models, and key parameters influencing PPP adoption.

Overall, the methodology is designed to capture both the demand–supply complementarity between Central and South Asia and the practical determinants of sustainable cross-border cooperation. Particular attention is given to assessing commercial viability under PPP models, including investment risk allocation, tariff structures, and multi-country regulatory requirements, drawing on lessons from completed and ongoing interregional projects.

2. South Asia: Economic and Energy Profile

2.1. Economic and Electrification Data

South Asia presents a distinctive demographic and economic landscape that drives substantial growth in energy demand. With a population of approximately 1.97B and a regional GDP per capita (PPP) of USD 10,176, the region sustained annual economic growth of around 7% prior to the COVID-19 pandemic (World Bank Group, 2024; ERIA, 2023). Table 4 below presents key data for South Asia.

Table 4: South Asia profile of economy, electrification, and energy source

Country	Population (million) 2024	GDP per capita, PPP (current international USD) 2023	Electric power consumption (kWh/capita) 2022	Electrification Rate (% of population) 2023	Fossil fuel (% of total) 2021	Hydro (% of total) 2021	Renewables (% of total) 2021
Afghanistan	42.6	2,201.7	-	85	21.8	71.7	6.6
Bangladesh	173.6	9,147.8	603	100	98.6	0.7	0.8
Bhutan	0.8	16,254.0	-	100	0.0	100.0	0.0
India	1,450.9	10,323.5	1,075	100	75.6	9.9	9.2
Maldives	0.5	24,735.1	-	100	94.2	0.0	5.8
Nepal	29.7	5,395.2	321	94	0.0	99.1	–15.3
Pakistan	251.3	6,036.6	606	96	63.6	20.5	7.8
Sri Lanka	21.9	14,455.7	684	100	51.1	41.5	7.8
South Asia	**1,971.3**	**10,176.4**	**1,007**	**99**	**75.7**	**10.8**	**8.5**

Source: World Bank Group 2025

The region has made substantial progress in electricity access, reaching electrification rates of approximately 99% across most countries, although rural access remains incomplete in some areas (World Bank, 2023). However, this progress has been accompanied by rapidly rising energy demand—electricity demand has increased by over 50% since 2000 and is projected to more than double by 2050 (ERIA, 2023). India dominates regional consumption with 1,075 kWh per capita, while countries such as Nepal and Afghanistan lag significantly behind.

The energy mix reveals persistent structural dependencies: 75.7% of regional electricity generation still relies on fossil fuels, with only 8.5% derived from non-hydro renewables as of 2021 (World Bank Group, 2025b). Coal remains dominant, particularly in India (75.6% fossil share), Bangladesh (98.6%), and Pakistan (63.6%), while Bhutan and Nepal depend almost entirely on hydropower (World Bank Group, 2025c).

2.2. Renewable Energy Challenges for South Asia

South Asia faces multifaceted challenges in transitioning to renewable energy despite abundant natural endowments. Underutilization remains a critical constraint: although the region possesses significant solar, wind, and hydropower potential, these resources are not fully developed relative to capacity (ERIA, 2023; World Bank, 2025). Similarly, domestic gas reserves in Pakistan and Bangladesh—historically central to power generation—are declining, increasing fuel security risks and dependence on liquid natural gas (LNG) and other imports.

Limited fuel diversification characterizes most countries. India remains heavily coal-dependent, Bangladesh and Pakistan rely largely on gas and imported LNG, and Bhutan and Nepal lack diversification beyond large-scale hydropower (ADB, 2023). This concentration heightens vulnerability to supply shocks and price volatility.

Despite strong renewable potential, penetration remains limited across the region, except for hydropower in Bhutan and Nepal (ERIA, 2023). While India has accelerated solar and wind deployment through policy instruments such as feed-in tariffs and power purchase agreements, adoption in Bangladesh, Pakistan, and Sri Lanka remains constrained by regulatory gaps and financing limitations. Private sector participation is further hindered by inconsistent incentives and regulatory uncertainty, although progress is evident in India’s renewable sector (ADB, 2023; ERIA, 2023).

Infrastructure limitations and import dependence further compound these challenges. Most South Asian economies rely heavily on imported energy, particularly oil and petroleum. Afghanistan, despite possessing crude oil reserves, meets nearly all domestic demand through imports due to limited processing capacity (World Bank, 2025). Refining capacity remains insufficient outside India, with Bangladesh, Nepal, and the Maldives relying almost entirely on imports.

2.3. Regional Cooperation in Energy and Prospects for Renewables—South Asia

Regional Energy Cooperation in South Asia:

Energy cooperation in South Asia has evolved beyond traditional impediments such as political tensions and resource nationalism, although structural challenges remain. While India–Pakistan tensions continue to constrain direct energy trade, multilateral arrangements have emerged that bypass bilateral limitations.

Recent Breakthroughs in Cross-Border Trade:

The region witnessed significant developments in 2024 with the signing of a tripartite agreement in October 2024, which came into effect in November with an initial transaction of 40 MW, followed by regular seasonal exports beginning in June 2025 (MEA, 2024). Nepal exported 40 MW of hydroelectricity to Bangladesh via the Indian grid, formally opening electricity trade between the two countries (World Bank, 2025). This represents a shift from bilateral arrangements toward more integrated regional energy markets.

Cross-border electricity transmission capacity has expanded markedly—from approximately 4,700 MW in 2024 to a projected 43.7 GW by 2036—driven by renewable energy development and improved regional coordination (REGlobal, 2025). As of 2024, electricity exchanges through cross-border links total approximately 4,100 MW across multiple projects.

Enhanced Institutional Framework:

The SASEC program has prioritized regional energy cooperation, with technical assistance focused on power and gas interconnections, indigenous hydropower development, and renewable energy alternatives (ADB, 2024). The program emphasizes coordinated bilateral and regional mechanisms to support the development of a regional power trading market.

Private Sector Engagement:

In Bhutan, Druk Green Power Corporation Limited has signed agreements with Tata Power to develop 5,000 MW of clean energy, highlighting growing private sector participation in regional energy cooperation (World Bank, 2025). This reflects a shift from predominantly government-led arrangements toward commercial partnerships.

Expanding Market Access:

Nepal began importing electricity from India's power exchange in April 2021, followed by Bhutan in 2022, with Bangladesh expected to join (SARPF, 2024). This transition from case-by-case negotiations to market-based mechanisms marks a significant step toward regional energy integration.

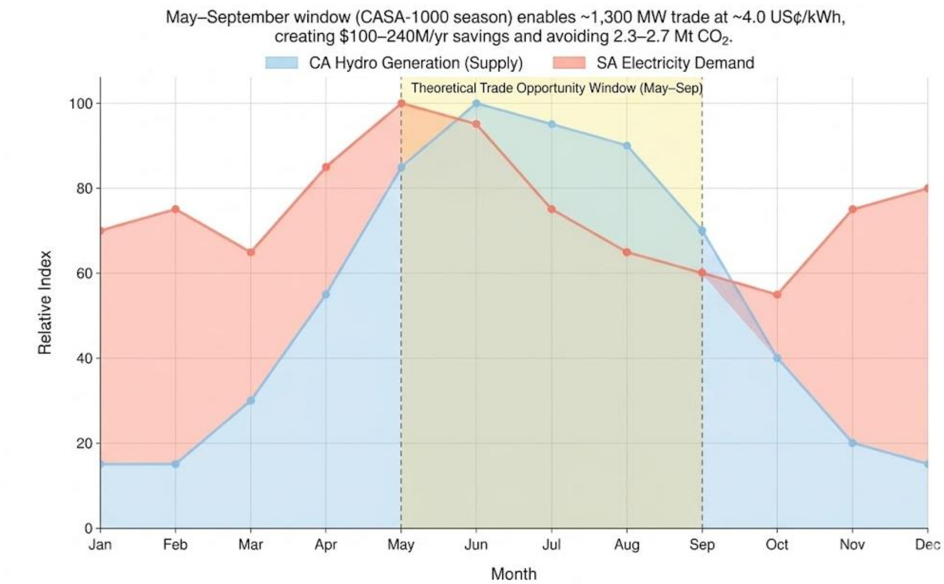
Future Prospects and Renewable Energy Integration:

South Asia possesses substantial untapped renewable potential: 350 GW of hydropower (of which only 20% is developed), 940 GW of solar, and 1,290 GW of wind capacity (REGlobal, 2025). The One Sun One World One Grid initiative, co-launched by India and the U.K. under the International Solar Alliance at COP26 (2021), proposes linking national and regional grids through a shared transmission platform. This framework leverages differences in solar availability and demand peaks across time zones to enable continuous cross-border clean energy flows (ISA, 2021).

2.4. Seasonal Demand–-Supply Complementarities and Interregional Trade Potential

The geoeconomic case for interregional energy cooperation rests on complementary temporal patterns of energy generation and demand across Central and South Asia (Figure 1).

Figure 1: Seasonal Energy Complementarity: Central Asia (CA) Surplus vs South Asia (SA) Demand



Source: Author's visualization (using AI capabilities)

The core geoeconomic logic is straightforward: Central Asia's hydropower generation peaks when South Asia faces its highest electricity costs and lowest domestic renewable availability. The May–September window, during which CASA-1000's 1,300 MW exportable surplus is available, creates a generation-cost arbitrage of USD 0.04–0.08/kWh at source—translating into USD 25–60M in net annual regional savings at current trade volumes of 2,500–3,000 GWh, and 2.3–2.7M t of CO_2 avoided through displacement of South Asian coal generation (Table 5).

Table 5 Seasonal Demand Supply Complementarity: Central-South Asia Trade Window

Dimension	Jan–Apr	May–Sep (Trade Window)	Oct–Dec
CA Hydro Generation	Low–building (snowmelt begins)	**Peak surplus** (glacial/snowmelt runoff)	Declining
SA Electricity Demand	Moderate–rising	**Peak** (cooling + monsoon uncertainty)	Moderate–high (industrial/heating)

SA Domestic Hydro	Limited	Constrained (Nepal/Bhutan monsoon variability)	Recovering
SA Coal Reliance	High	**High, costly** (USD~0.095/kWh)	High
CA Exportable Surplus	Minimal	~1,300 MW via CASA-1000	Minimal
Trade Price (CA hydro)	—	USD~0.04/kWh at source	—
Price Arbitrage	—	USD 0.04–0.08/kWh (generation-cost spread)	—
Estimated Annual Savings	—	USD 25–60M/yr (2,500–3,000 GWh, net of transmission)	—
CO_2 Avoided	—	2.3–2.7 Mt/yr	—

Source: Author's calculation from various sources, including ESCAP 2024

3. Central Asia: Economic and Energy Profile

3.1. Economic and Electrification Data

Central Asia encompasses a diverse set of economies (as highlighted in Table 6) with a combined population of 82.3M and a regional GDP per capita (PPP) of USD 13,220, reflecting substantial variation from Kazakhstan's USD 38,515 to Tajikistan's USD 4,964 (World Bank Group, 2025; CAREC, 2024). The region has achieved near-universal electrification (99.9% access) and relatively high-power consumption, averaging 2,795 kWh/capita—well above South Asia's regional average.

Table 6: Central Asia profile of economy, electrification, and sources

Country	Population (million) 2024	GDP per capita, PPP (current international USD) 2023	Power Consumption (kWh/capita, 2022)	Electrification rate (%) 2023	Fossil fuel (%) 2021	Hydro share (%) 2021	Renewables share (%) 2021
Kazakhstan	20.6	38,515.2	5,322	100	88.2	8.1	3.0
Kyrgyz Republic	7.2	7,298.1	1,975	100	14.1	85.9	0.0
Tajikistan	10.6	4,963.6	1,427	100	7.3	92.7	3.3
Turkmenistan	7.5	19,828.9	2,659	100	100.0	0.0	0.0
Uzbekistan	36.4	11,107.0	2,119	100	90.7	8.7	0.1
Central Asia	**82.3**	**13,220.0**	**2,795**	**99.9**	**75**	**22**	**3**

Source: World Bank Group 2025

Kazakhstan leads in power consumption at 5,322 kWh/capita, followed by Turkmenistan and Uzbekistan, while the Kyrgyz Republic and Tajikistan exhibit lower consumption levels reflecting differences in economic structures and energy resource endowments. This disparity underscores the region's dual character: energy-rich fossil fuel exporters alongside hydropower-dependent mountainous economies.

The energy generation profile indicates a 75% regional dependence on fossil fuels, with 22% from hydropower and only 3% from other renewables (World Bank Group, 2025c; CAREC, 2024). Kazakhstan and Turkmenistan exhibit near-complete reliance on fossil fuels (88.2% and 100%, respectively), hereas the Kyrgyz Republic and Tajikistan depend predominantly on hydropower (85.9% and 92.7%, respectively).

3.2. Renewable Energy Challenges for Central Asia

Central Asia faces distinct renewable energy transition challenges shaped by its Soviet legacy and resource endowments. Limited energy diversification persists despite significant solar, wind, and hydropower potential, with most countries relying on dominant single sources: Kazakhstan (coal), Uzbekistan and Turkmenistan (gas), and Tajikistan and the Kyrgyz Republic (hydropower) (CAREC, 2024; World Bank, 2020).

Financial and technical constraints continue to impede renewable deployment. Lower-income countries lack sufficient financing and technical capacity to scale renewable energy, while state-owned utilities in several cases discourage foreign investment (ADB, 2023; CAREC, 2024). Private sector and PPP participation remain limited outside successful solar PPPs in Kazakhstan and recent wind developments in Uzbekistan.

Obsolete infrastructure represents a major constraint, as the energy sector relies heavily on Soviet-era equipment from the 1960s–1970s, leading to maintenance challenges and operational inefficiencies since the 2000s (CAREC, 2024). Grid bottlenecks further restrict the integration of new renewable projects and CBET, necessitating substantial modernization investment.

Fragmented regional cooperation compounds these challenges. The breakdown of the Central Asian Power System (CAPS) following Turkmenistan's exit in 2003 and Uzbekistan's withdrawal in 2009 disrupted power exchange and coordinated development (CAREC, 2024). Although resource-rich countries maintain energy self-sufficiency, coordination gaps persist that could otherwise support more balanced regional development.

Recent progress is notable. Uzbekistan has emerged as a regional leader in renewable PPPs, with significant solar and wind projects underway, while Kazakhstan continues to expand wind energy programs (World Bank, 2025; CAREC, 2024). However, unlocking Central Asia's renewable potential will require coordinated investment in grid modernization, sector reform, and renewed regional power market integration.

3.3. Regional Energy Cooperation in Central Asia

Central Asia's energy cooperation landscape has undergone significant transformations since the collapse of the Soviet-era CAPS, with renewed integration efforts producing mixed but promising results.

Historical Context and Recent Developments

The legacy of CAPS dissolution continues to shape regional dynamics. Following Turkmenistan's exit in 2003 and Uzbekistan's withdrawal in 2009, countries pursued energy self-sufficiency, resulting in higher costs and supply inefficiencies (Krasnopolsky, 2024). However, recent political shifts—particularly Uzbekistan's reform agenda since 2016—have revived prospects for regional cooperation.

Tajikistan Reconnection Efforts:

Tajikistan's planned reconnection to CAPS represents a major recent development. The ADB approved a USD 35M grant in 2018 to reconnect Tajikistan's system via Uzbekistan, although implementation has faced technical delays beyond the original 2022 target (Krasnopolsky, 2024; The Diplomat, 2024). As of mid-2024, completion was expected by July 2024, though delays persist.

CASA-1000 Progress:

The ASA-1000 project has achieved substantial construction milestones. The 500 kV alternating-current (AC) Datka–Sugd transmission line (~480 km), connecting the Kyrgyz Republic and Tajikistan, was commissioned on March 31, 2025, along with associated substations. Pakistan's infrastructure components are largely complete, but full system activation depends on completion of the Afghanistan segment, now expected by the end of 2026, with operations commencing in 2027 (World Bank, 2025).

Regional Institutional Framework

The CAREC Energy Strategy 2030 emphasizes regional market development and renewable energy integration. CAREC's Energy Work Plan (2013–2015) targeted development of the Central Asia–South Asia energy corridor, although implementation has largely focused on national-level projects rather than regional integration (Aminjonov, 2019).

Contemporary Challenges and Opportunities

Political and Technical Constraints:

Despite multilateral institutional support, bilateral cooperation often prevails over coordinated regional approaches (Aminjonov, 2019). Capacity constraints also persist, as fossil fuel export ambitions may exceed the existing infrastructure's ability to meet both domestic and external demand.

Infrastructure Modernization:

Aging Soviet-era infrastructure requires extensive rehabilitation across Central Asia, constraining rapid integration. Restoring a unified power system will require coordinated strategies addressing timing, operational frameworks, and investment terms.

External Partnership Role:

External actors remain central to regional cooperation dynamics. Russia continues to play a strategic role, while Chinese BRI investments shape energy development trajectories. The ADB provides key financial support for CAPS reconnection and CASA-1000 infrastructure.

Future Integration Prospects:

Momentum for deeper regional cooperation gained institutional traction in 2024, when ESCAP and the ECO Secretariat convened a coordination meeting on the Economic Cooperation Organization (ECO) Regional Electricity Market (ECO-REM), marking a shift from ad hoc engagement to a more structured integration agenda (ESCAP, 2024; The Diplomat, 2024). Discussions addressed both short-term grid coordination challenges and long-term renewable integration, including expansion toward Iran, Afghanistan, and South Asia. However, translating political commitments into operational market structures requires addressing aging infrastructure, regulatory fragmentation, and risks of policy reversal (U.N. ECE, 2024; ESCAP, 2024).

A major institutional development occurred in January 2026, when the World Bank approved the Regional Electricity Market Interconnectivity and Trade (REMIT) program—a 10-year, three-phase initiative with indicative financing of USD 1.018B. The initial phase allocates USD 143.2M in International Development Association (IDA) and Central Asia Water and Energy Program grants to the Kyrgyz Republic, Tajikistan, Uzbekistan, and the Central Dispatch Center Energia to establish the regulatory, technical, and institutional foundations of a multilateral electricity market (World Bank, 2026). REMIT operationalizes longstanding policy recommendations from UN ESCAP and UN Economic Commission for Europe (UNECE), aligning financing with regional integration objectives.

REMIT aims to triple regional transmission capacity to 16 GW, increase annual electricity trade to at least 15,000 GWh, and enable up to 9 GW of new clean energy capacity. Phase one alone is expected to unlock approximately 900 MW and catalyze USD 700M in private investment. By 2050, enhanced regional connectivity could generate up to USD 15B in cumulative economic benefits, highlighting the transformative potential of multilateral market integration relative to the current bilateral framework (World Bank, 2026).

4. Financing PPI: Global Energy Sector Dominance and Regional Patterns in South and Central Asia

4.1. Global PPP Investment Patterns in Energy Infrastructure

PPI has emerged as a key mechanism for addressing global infrastructure deficits, with the energy sector consistently dominating across regions. From 2003 to 2023 (Table 7), energy infrastructure attracted the largest share of global PPP investment, accounting for approximately 59% of total PPI investment across all sectors—energy, transport, water, and information and communication technologies (World Bank, 2023).

Table 7: Worldwide PPP trends in infrastructure: 2000–2023 (USD Million)

Infrastructure Category	Number of Projects	Total Investment (USD Million)
Energy	577	140,817
Electricity	525	124,374
Electricity, Water Utility	2	-
Natural gas	50	16,443
Information and communication technology (ICT)	11	12,524

ICT	11	12,524
Municipal solid waste	66	4,723
Collection and transport	40	2,664
Integrated MSW	4	241
Treatment/ disposal	22	1,818
Transport	113	100,702
Airports	41	51,446
E-vehicle charging station	2	193
Ports	32	7,211
Railways	11	5,494
Roads	27	36,358
Water and sewerage	44	4,132
Treatment plant	5	694
Treatment plant, Water Utility	1	25
Water utility	38	3,414
Total	811	262,899

Source: World Bank PPI Database 2025

The energy sector's predominance reflects both the capital-intensive nature of power generation projects and the growing recognition of private sector efficiency in delivering complex infrastructure. In 2023, investment in energy increased threefold compared to 2022, with most growth concentrated in the East Asia and Pacific region, reaching USD 86.0B across 322 projects globally (World Bank, 2023).

Technology-Specific Investment Evolution:

Global PPP investment patterns reveal distinct technological preferences that have evolved over the past two decades. Large-scale hydropower has historically dominated renewable energy PPPs, attracting USD 121.4B globally between 2000 and 2023, particularly in Latin America, South Asia, and East Asia Pacific.

However, the most significant transformation has occurred in non-hydro renewables. Solar photovoltaic technology has expanded rapidly, accounting for 41% of total power generation capacity in low- and middle-income countries as of 2023, followed by wind at 29% and hydropower at 17% (World Bank, 2023). Notably, 97% of electricity generation projects were renewable in 2023, up from 93% during 2018–2022 (Table 8).

Table 8: Investment flows for renewable technology across regions

Technology Type	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	South Asia	Sub-Saharan Africa	Total
Biogas	97	111	296			24	528
Biomass	5,442	416	5,343		533	1,093	12,827
Coal	63,512	25,595	4,238	4,035	100,790	830	199,000
Coal, Diesel		9,270					9,270
Coal, Diesel, Natural Gas	1,210						1,210
Coal, Natural Gas		4,374			2,996		7,370
Diesel	114	3	2,623	1,178	1,792	1,921	7,630

Diesel, Geothermal, Hydro, Large (>50 MW), Wind						109	109
Diesel, Natural Gas	197		538	120	412		1,267
Diesel, Natural Gas, Other						196	196
Diesel, Waste			44				44
Geothermal	7,359	2,134	1,409			417	11,319
Hydro, Large (>50 MW)	30,176	13,878	55,780		17,504	4,105	121,443
Hydro, Large (>50 MW), Diesel, N/A						-	-
Hydro, Small (<50 MW)	3,232	1,689	9,671		1,111	1,597	17,299
N/A	19,039	3,831	28,466	1,719	4,454	7,478	64,986
N/A, N/A		-					-
Natural Gas	22,916	20,255	22,092	6,932	13,987	7,483	93,665
Natural Gas, Diesel	250			180			430
Natural Gas, Hydro, Large (>50 MW), Wind		2,539					2,539
Natural Gas, Other						172	172
Natural Gas, Steam	103	233	225				561
Natural Gas, Steam, Solar, CSP				315			315

Natural Gas, Steam, Solar, PV				158			158
Not Applicable	12,526	30,894	36,330	104	9,742	869	90,464
Not Applicable, Diesel, Wind			38				38
Not Applicable, N/A					-		-
Nuclear		-			559		559
Other	5,631	60	1,273	2,109	940	1,747	11,760
Solar, CPV		157	1,334	930	60		2,481
Solar, CSP	377			3,276	950	4,566	9,169
Solar, PV	19,664	9,531	21,403	4,684	14,829	11,799	81,910
Solar, PV, Biogas	17						17
Solar, PV, N/A				-		324	324
Solar, PV, Not Applicable			13				13
Solar, PV, Other	1,011						1,011
Solar, PV, Solar, PV						77	77
Solar, PV, Wind	190		260				450
Solar, PV, Wind, N/A						92	92

Steam			135				135
Waste	4,079	28	2,341	120	95	451	7,114
Wind	19,006	15,818	52,840	4,557	12,553	11,397	116,170
Wind, N/A	42						42
Wind, Not Applicable			378				378
Wind, Other	644						644
Wind, Solar, PV					280		280
Total	216,834	140,817	247,069	30,416	183,585	56,746	875,468

Source: World Bank PPI Database 2025

Coal-fired power plants, while still significant in cumulative terms due to historical investments—particularly in South Asia, have attracted minimal new PPP investment in recent years. This shift reflects global climate commitments and the declining cost competitiveness of renewable technologies relative to fossil fuel alternatives.

4.2. South Asia: PPP Investment Trends by Country and Technology

PPP Trends by Country:

South Asia has emerged as the leading global destination for renewable energy PPPs, attracting USD 183.6B in cumulative energy investment from 2003–2023. India dominates the region, accounting for USD 148.3B (81%) of total investment, followed by Pakistan at USD 23.1B (13%) and Bangladesh at USD 7.0B (4%), as seen in

Table 9 below.

Table 9: South Asia energy public–private partnership project, by technology and country: 2003–2023 (USD Million)

Tech	Afghanistan	Bangladesh	Bhutan	India	Maldives	Nepal	Pakistan	Sri Lanka	Total
Biomass		9		107			334	83	533
Coal		579		92,628			7,059	525	100,790
Coal, Natural Gas				2,996					2,996
Diesel	2	572					1,097	122	1,792
Diesel, Natural Gas		412							412
Hydro, Large (> 50MW)			403	9,936		2,541	4,625		17,504
Hydro, Small (< 50MW)				328		476	38	269	1,111
N/A				3,122			1,332		4,454
Natural Gas	172	4,476		7,352			1,987		13,987
Not Applicable		62		7,472			2,208		9,742
Not Applicable, N/A				-					-
Nuclear							559		559
Other		481		20			439		940
Solar, CPV				60					60
Solar, CSP				950					950

Solar, PV	38	416		13,931	-	17	414	12	14,829
Waste				88			8		95
Wind				9,357			3,009	186	12,553
Wind, Solar, PV								280	280
Total	211	7,007	403	148,346	-	3,034	23,108	1,478	183,585

Source: World Bank PPI Database 2025

India’s investment profile highlights the region’s coal dependency and ongoing transition. Coal projects alone attracted USD 92.6B, representing the largest technology category, although this reflects historical investment patterns rather than current trends. Natural gas projects accounted for USD 7.4B, while large hydropower attracted USD 9.9B.

The renewable energy transition is most evident in India’s recent investment patterns. Solar PV projects totaled USD 13.9B, wind projects USD 9.4B, and solar CSP USD 950M. Pakistan’s portfolio shows greater diversification, with substantial investments in large hydropower (USD 4.6B), natural gas (USD 2.0B), and emerging renewable projects.

PPP Trends by Time:

Temporal analysis indicates a marked shift toward renewable energy PPPs in South Asia since 2015, with acceleration occurring thereafter. Solar PV investment exhibited consistent growth from 2016 to 2023, reaching annual commitments of USD 1.8B in 2021 and USD 4.4B in 2023. Wind investment followed a similar trajectory, with a notable peak of USD 3.2B in 2012 and sustained expansion in subsequent years.

Natural gas projects exhibited volatility, with major investment peaks in 2011 (USD 3.4B) and 2020 (USD 3.2B), often driven by specific LNG terminal and distribution projects rather than sustained sectoral growth (Table 10)

Table 10: South Asia energy public–private partnership project, by tech and year: 2003–2023 (Time series, USD Million)

Tech	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total (USD M)
Biomass				9	13	41	6	10	4	49	97	14			200						91	533
Coal		473	581	6,032	9,578	10,494	23,329	27,641	12,425	3,080	525		75	1,108	1,940	1,080	520	1,912	-			100,790
Coal, Natural Gas		2,996																				2,996
Diesel	2	62	60	32	225		839	108	43	176	40	115			26			64				1,792
Diesel, Natural Gas															412							412
Hydro, Large (> 50MW)	408	269		2,490	3,969	1,186	1,135	462	509	1,402	229		368		3,588		647			842		17,504
Hydro, Small (< 50MW)	65	79	92	26	43	109	15	210	101	9		164		26	151	21						1,111
N/A	41	30	1,302	22	2,510	234	221														94	4,454
Natural Gas	336	1,530	59	170	392	860	534	858	3,394	761		402	300	170		269	172	3,167		613		13,987
Not Applicable				18		87	406	910	493	2,429	58	875		994	147	186	1,658	275	23	1,148	37	9,742
Not Applicable, N/A	-																					-
Nuclear			559																			559
Other						439	51	40	183									207			20	940
Solar, CPV															60							60

Solar, CSP									186	652			113									950
Solar, PV								134	1,229	476	172	388	752	797	854	1,053	933	1,717	1,848	118	4,357	14,829
Waste	23		21	13	18	21																95
Wind		26		14	68	283	66	637	981	3,208	1,293	475	1,663	476	640	503	776			1,320	124	12,553
Wind, Solar, PV										280												280
Total	874	5,465	2,673	8,825	16,817	13,753	26,601	31,009	19,547	12,521	2,414	2,431	3,270	3,571	8,017	3,112	4,706	7,342	1,871	4,041	4,723	183,585

Source: World Bank PPI Database 2025

The data indicate a fundamental structural shift: although cumulative coal investments dominate historical totals, new financial closures since 2018 are predominantly renewable energy projects, signaling an irreversible transformation in South Asia’s energy investment landscape.

4.3. Central Asia: PPP Investment Trends by Country and Technology

Central Asia’s PPP investment profile totals USD 10.3B for 2003–2023, reflecting rapid growth in renewable energy investment despite the region’s fossil fuel abundance. Uzbekistan leads with USD 5.8B (56%), followed by Georgia at USD 1.6B (15%) and Kazakhstan at USD 1.1B (11%) (Table 11).

Table 11: Central Asia energy public–private partnership, by country and technology (USD Million)

Tech	Azerbaijan	Georgia	Kazakhstan	Kyrgyz Republic	Tajikistan	Uzbekistan	Total
Biogas							-
Biomass							-
Coal							-

Coal, Diesel							-
Coal, Natural Gas							-
Diesel							-
Geothermal							-
Hydro, Large (> 50MW)		1,175		118	940		2,233
Hydro, Small (< 50MW)		102					102
N/A		233					233
N/A, N/A							-
Natural Gas						2,084	2,084
Natural Gas, Hydro, Large (> 50MW), Wind							-
Natural Gas, Steam							-
Not Applicable		50		40			90
Nuclear							-
Other							-
Solar, CPV							-
Solar, PV	450		751			1,626	2,827
Waste							-
Wind	348	14	343			2,064	2,769
Total	798	1,575	1,094	158	940	5,773	10,338

Source: World Bank PPI Database 2025

Uzbekistan's portfolio exemplifies the region's renewable energy transition. Solar PV projects attracted USD 1.6B and wind projects USD 2.1B, making these technologies the primary recipients of PPP investment. Natural gas projects totaled USD 2.1B, reflecting a dual strategy of leveraging domestic gas reserves while diversifying into renewables.

Kazakhstan's investments are concentrated in solar photovoltaic (PV) (USD 751M) and wind (USD 343M), reflecting active renewable energy policy implementation. Georgia's hydropower dominance is evident, with USD 1.2B in large-scale hydro projects, while Azerbaijan shows smaller but steadily increasing renewable investment.

PPP Trends by Time:

Central Asia's investment patterns reveal distinct phases of development and policy evolution. The early period (2003–2008) was dominated by large hydropower investments, particularly in Georgia and Tajikistan, totaling approximately USD 720M in 2006 and USD 276M in 2007, reflecting initial private sector engagement in hydropower resources.

A prolonged investment hiatus occurred from 2009 to 2017, with minimal PPP activity due to political transitions, regulatory uncertainty, and constrained market access. A transformative phase began in 2018–2019, coinciding with Uzbekistan's policy reforms under President Mirziyoyev.

Renewable energy investment accelerated significantly thereafter. In 2019, solar and wind commitments reached USD 580M annually, followed by rapid expansion from 2021 to 2023, with investments of USD 1.2B in 2021, USD 2.2B in 2022, and USD 3.4B in 2023.

Natural gas investment remained episodic, with major peaks in 2020 (USD 1.0B) and 2022 (USD 1.1B), typically associated with discrete infrastructure projects rather than sustained sectoral growth (Table 12).

Table 12: Central Asia energy public–private partnership, by technology (time series, USD Million)

Tech	2003	2004	2006	2007	2008	2009	2011	2014	2015	2017	2018	2019	2020	2021	2022	2023	Total (USD M)
Hydro, Large (> 50MW)			720	276	220		417		417	65						118	2,233
Hydro, Small (< 50MW)		27		43		32											102
N/A	-		95	139													233
Natural Gas														1,002		1,082	2,084
Not Applicable					50			40									90
Solar, PV											52	429	245	228	250	1,622	2,827
Wind												151	140		1,945	533	2,769
Grand Total	-	27	815	458	270	32	417	40	417	65	52	580	385	1,230	2,195	3,354	10,338

Source: World Bank PPI Database 2025

The data demonstrate Central Asia's rapid transition from hydropower-dependent PPP portfolios to more diversified renewable energy investments, with wind and solar projects dominating recent financial closures. This shift reflects improved investment conditions—particularly in Uzbekistan—and growing international confidence in the region's renewable energy potential.

4.4. PPP Investment-to-Trade Capacity Translation: Closing the Analysis Gap

The dataset shows USD 193.9B in cumulative PPP investment across South Asia (USD 183.6B) and Central Asia (USD 10.3B) from 2003–2023. A key structural finding emerges when investments are disaggregated by cross-border trade potential: 65.7% of South Asia's PPP investment is concentrated in fossil fuels (primarily coal at USD 100.8B), which offer limited interregional trade value. By contrast, only 17% is directed toward trade-capable renewables (hydropower and wind). Central Asia presents a markedly different profile, with 49.4% of investment allocated to trade-capable hydropower and wind, reflecting its comparative advantage as a surplus-generating region (Table 13).

Table 13: Investment-to-trade capacity: Technology-disaggregated assessment

Technology	SA Investment (USD Million)	CA Investment (USD Million)	Trade-Capable?	Cross-Border Export Share	Trade Implication
Hydro, Large (> 50 MW)	17,504	2,233	✅ High	50–60%	Core interregional tradable asset; Bhutan/Nepal demonstrate feasibility
Hydro, Small (< 50 MW)	1,111	102	✅ Moderate	30–40%	Local grid-serving; partial export potential in Nepal/Tajikistan
Wind	12,553	2,769	✅ Moderate	15–20%	Exportable with storage/balancing; seasonal variability limits share

Technology	SA Investment (USD Million)	CA Investment (USD Million)	Trade-Capable?	Cross-Border Export Share	Trade Implication
Solar PV/CPV/CSP	15,839	2,827	❌ Low	< 5%	Domestic grid-balancing function; daily intermittency limits cross-border flow
Coal/Fossil/ Thermal	120,536	2,084	❌ None	0%	No interregional export value; stranded asset risk under energy transition
TOTAL	183,585	10,338	—	—	—

Source: Author's Calculation, World Bank PPI Data and other sources

Critical Finding: Trade–Capability Paradox:

South Asia's investment portfolio—dominated by coal (54.9% of total value) and domestically oriented solar—helps explain the **paradox of high cumulative investment alongside limited interregional trade growth**. Despite 727 recorded projects, only approximately 17.6% (128 projects, USD 18.6B) are directed toward hydropower, the region's most established tradable asset through Bhutan–India and Nepal–India–Bangladesh corridors. In contrast, Central Asia's 54 projects are smaller in aggregate value but more trade-oriented: Uzbekistan (USD 5.8B), Kyrgyzstan (USD 158M in hydropower), and Tajikistan (USD 940M in hydropower) together account for 49.4% of investment in trade-capable assets.

Policy Implications

Three redirections are required to convert investment into trade:

1. **Rebalance PPP incentives from coal and domestically oriented solar toward export-capable hydropower and wind**—particularly in Tajikistan and Kyrgyzstan (Central Asia), and

Nepal and Bhutan (South Asia), where hydropower investment remains below exportable potential.

2. **Align transmission PPP development with generation timelines**, as current lags between generation commissioning and cross-border transmission infrastructure (e.g., CASA-1000 delays) constrain trade realization.
3. **Establish long-term cross-border power purchase agreements (PPAs**) to enhance the bankability of hydropower and wind PPPs in export-oriented locations, building on the Bhutan–India PPA model.

Feasibility scenario: Redirecting 40% of renewable PPP investment between 2025 and 2030 toward export-capable hydropower and wind (from current levels of approximately 25% in South Asia and 49% in Central Asia), combined with CASA-1000 and REMIT infrastructure deployment, could increase regional electricity trade from approximately 22 TWh to 45–50 TWh by 2030, generating an estimated USD 1.8–2.0B in annual trade value (Author's Calculation).

5. Discussion: Financing Patterns, Institutional Constraints, and the Renewable Energy Trade Gap in South and Central Asia

5.1. Cross-Border Project Financing: Structural Innovations and Implementation Constraints

Cross-border renewable energy projects require financing architectures that navigate multiple regulatory jurisdictions, currency mismatches, and layered political risks while maintaining commercial viability. CASA-1000 represents one of the most advanced examples in the CAREC–South Asia corridor: the World Bank Group approved USD 526.5M in IDA credits and grants at project inception in 2014, against an initial total cost of USD 1.17B—later revised to approximately USD 1.14B—with co-financing from the European Bank for Reconstruction and Development (EBRD) (USD 110M), the European Investment Bank, the Islamic Development Bank, the Afghanistan Reconstruction Trust Fund, USAID, and UKAID/DFID.

The project's financing structure distributes risk across layered mechanisms. Sovereign guarantees from participating countries provide primary political risk mitigation, while the involvement of multiple multilateral development banks enhances creditworthiness across four legal and regulatory jurisdictions. Notably, the EBRD conditioned its USD 110M loan on Barki Tojik implementing sector reforms, including third-party transmission access and the establishment of an independent energy regulator, thereby linking financing to institutional reform rather than solely to physical infrastructure delivery.

Revenue Architecture and Tariff Design:

The CASA-1000 tariff structure illustrates how multi-country cost allocation can be operationalized. Pakistan's all-in delivery tariff of USD 0.0948 /kWh is composed of four elements: energy charges (USD 0.0515/kWh), transmission charges (USD 0.0298/kWh), Afghan transit fees (USD 0.0125/kWh), and Tajik wheeling charges on Kyrgyz energy (USD 0.0010/kWh). Each component reflects a distinct national contribution, creating transparent and modular revenue streams that can be renegotiated independently—an approach with strong replication potential for future regional energy corridors.

Implementation of Constraints and Governance Gaps:

Despite financial closure and advanced construction, CASA-1000's experience highlights three interrelated governance constraints that limit cross-border PPP effectiveness.

Political Economy Constraints. Project activities were suspended following political changes in Afghanistan after 2021, exposing the vulnerability of infrastructure corridors that depend on politically unstable transit states. In addition, longstanding policy differences between Tajikistan and Uzbekistan over water–energy trade-offs continue to complicate power exchange, while policy discontinuities in Pakistan have introduced delays in intergovernmental coordination.

Regulatory Fragmentation. The four-country framework operates under divergent regulatory systems: Tajikistan's vertically integrated, cost-plus tariff structure contrasts with Pakistan's competitive single-buyer model. Aligning billing, payment sequencing, and dispute resolution across these systems requires ongoing renegotiation of PPAs, increasing transaction costs and discouraging private sector participation beyond initial Multilateral Development Bank (MDB)-backed financing (World Bank, 2023).

Risk Allocation Insufficiency. The take-and-pay structure secures transmission revenue but concentrates demand risk on Pakistan, creating incentive misalignments in consumption forecasting. Transmission operators also lack access to independent arbitration mechanisms, resulting in reliance on state-to-state negotiations with extended resolution timelines. Currency risk remains insufficiently hedged, particularly given Tajikistan's exposure to foreign-denominated debt (ADB, 2019).

Structural Barriers to Broader PPP Effectiveness:

These constraints reflect broader structural limitations across both regions. Weak risk identification and allocation frameworks remain a primary barrier to PPP expansion, with public-sector entities often misallocating risks that private actors could manage more efficiently (Othman, 2024). Institutional gaps further exacerbate these challenges: the absence of comprehensive feed-in tariff systems, continued fossil fuel subsidies, and limited integration of renewables into national energy strategies increase perceived investment risk and financing costs. Technical capacity constraints—including limited expertise in renewable system operations, underdeveloped domestic manufacturing for specialized transmission equipment, and lack of standardized procurement specifications—further delay project execution and reduce investment attractiveness.

5.2. Geoeconomic Analysis: Cost-Benefit Quantification and Strategic Interdependence

Two complementary analytical frameworks are applied to assess the geoeconomic case for interregional energy trade between Central and South Asia (details in

Table 14). Framework 1 quantifies the direct economic value of trade using a regional cost–benefit model, while Framework 2 examines the geopolitical and structural vulnerabilities that arise as interdependence deepens. The frameworks are intentionally designed to operate in tension: the profitability logic of framework 1 is evaluated against the strategic exposure risks identified in framework 2.

Key assumptions underpinning both frameworks:

- Base case trade volume: 2,500–5,000 GWh/year via CASA-1000 at a 50–60% capacity factor
- South Asian coal generation cost benchmark: USD 0.08–0.12/kWh; Central Asian hydropower delivered cost: USD~0.04/kWh
- Shadow carbon price: USD 50/t CO_2 (standard for MDB project appraisal)
- 20-year project lifespan for net present value (NPV)/benefit–cost ratio (BCR) calculations
- Full CAREC integration scenario defined as the “2030 frontier,” rather than the current baseline

Table 14: Geoeconomic assessment frameworks for Central-South Asia energy trade

Dimension	Framework 1: Regional Cost-Benefit Analysis	Framework 2: Strategic Interdependence & Geopolitical Risk
Analytical lens	Economic efficiency; welfare maximization	Political economy; asymmetric vulnerability
Unit of analysis	Annual monetary flows; BCR	Dependence ratios; risk exposure scores
Trade volume modeled	5,000 GWh/year at full implementation	Same — but stress-tested under disruption
Primary economic gain	SA avoided generation cost: USD~200M/yr (5,000 GWh × USD 0.04 differential)	Foregone if supply disrupted: USD 150–200M/yr loss to Pakistan
Climate benefit (shadow)	USD~750M/yr (15Mt CO_2 × USD 50/t)	Benefit erased under drought/conflict scenario
Employment	15,000–20,000 permanent jobs (O&M, trading, technical)	Concentrating in CA — creates export-dependency political economy
Total annual benefit	USD~974M (2030 scenario)	USD 0–USD 974M depending on scenario (see risk matrix below)
Investment base	USD~5.4B through 2030 (CASA-1000 + TAPI + interconnections + harmonization)	Same, but risk-adjusted — Afghanistan segment suspension reduces realized returns
Benefit-cost ratio	3.6:1 (USD 19.5B cumulative vs. USD 5.4B investment over 20 years) — exceeds MDB 2:1 threshold by ~80%	BCR collapses toward 1:1 under high-disruption scenario (Afghanistan transit failure)
South Asia exposure	Positive: cost savings, energy security	Risk: 12–15% import dependence by 2030; 20–30% hydro output drop in drought years

Central Asia exposure	Positive: export revenue diversification	Risk: Tajikistan ~45% export revenue dependency; water–food–energy nexus tensions
Afghanistan risk	Transit fee revenue (+USD 0.0125/kWh to CA budget)	Single-point-of-failure for CASA-1000; Governance transition, international sanctions, and security considerations
Climate-physical risk	CO_2 avoided: 15Mt/yr = major climate benefit	CA hydro output volatile: −20–30% in low-precipitation years (climate change amplifies)
Institutional requirement	PPA guarantees, MDB financing, tariff agreement	Dispute resolution, regulatory harmonization, portfolio diversification across CA exporters
World Bank modeled benefit	USD 6.4B discounted economic gains (Central Asia + AFG + PAK, 2020–2030)	Benefits contingent on operational CASA-1000 + TUTAP and sustained political consensus

Source: Analysis developed by the author from various sources

Challenges and Issues:

The BCR of 3.6:1 is theoretically compelling, but its realization depends on assumptions that are unlikely to hold uniformly. Three structural challenges warrant explicit consideration:

1. The Afghanistan Bottleneck. Afghanistan's role as the CASA-1000 transit corridor underpins both the project's commercial logic and its primary vulnerability. Construction was suspended in August 2021 following the Taliban's return, and the Afghan segment remains the least advanced component as of 2025. Models assuming full 5,000 GWh annual trade without adjusting for transit risk are therefore overly optimistic. A more conservative baseline of 2,500–3,000 GWh (partial operational scenario) reduces annual benefits to approximately USD 487M–USD 585M and the BCR to roughly 1.8–2.2:1—still positive, but no longer substantially above threshold.

2. Asymmetric Risk Distribution. The take-and-pay revenue model concentrates demand risk on Pakistan, which has experienced persistent institutional instability and fiscal constraints. If Pakistan fails to meet contracted payments—particularly during balance-of-payments crises—the revenue structure weakens without necessarily triggering formal default mechanisms. Framework 2 correctly identifies this as a high asymmetry risk for South Asia that the cost–benefit model treats as fixed.

3. Climate–Physical Feedback Loop. The estimated climate benefit (USD 750M annually from avoided CO_2) assumes stable Central Asian hydropower output. However, ESCAP (2024) shows that hydropower generation is sensitive to precipitation variability, with potential reductions of 20–30% in low-precipitation years. This directly affects both supply reliability and emissions reduction estimates, introducing a structural tension between climate mitigation objectives and hydrological uncertainty.

Overall assessment: The combined frameworks present a strong case for interregional energy trade—high returns under stable institutional and political conditions—while also identifying the scenarios in which these returns diminish. A probability-weighted estimate places expected annual regional benefits in the range of USD 400–700M, below the headline USD 974M estimate but still strongly positive, contingent on sustained MDB engagement to mitigate political and institutional risks.

Central Asia and South Asia Cross-Border Connectivity Projects and Initiatives:

Regional cooperation in cross-border electricity connectivity has become a central mechanism for advancing energy security, decarbonization, and development objectives across Central and South Asia (ESCAP, 2018; ESCAP, 2024). The Economic Cooperation Organization Regional Electricity Market (ECO-REM), structured across three interconnected zones (Eastern: Afghanistan and Pakistan; Central: the five Central Asian republics; Western: Azerbaijan, Iran, and Türkiye), provides a comprehensive institutional framework for multilateral electricity trade linking Central Asian surplus with South Asian demand (ESCAP, 2024). ESCAP's phased roadmap anticipates secondary market mechanisms within four to seven years, followed by deeper system integration. Under full implementation, Central Asia alone could realize over USD 6.4B in cumulative economic gains, alongside emissions reductions and improved energy access (ESCAP, 2024).

These institutional developments build on strong renewable complementarities: seasonal hydropower surpluses in Tajikistan and Kyrgyzstan, expanding solar and wind capacity in Kazakhstan and Uzbekistan, and rapidly growing electricity demand in South Asia create clear economic incentives for multilateral trade (EDB, 2022; ESCAP, 2018). Projects such as CASA-1000, Turkmenistan–Uzbekistan–Tajikistan–Afghanistan–Pakistan Power Interconnection Project (TUTAP), TAPI, and ECO-REM can be interpreted as early-stage institutional experiments whose commercial outcomes will determine the feasibility of a fully integrated interregional power market by 2030.

South Asian Intraregional Trade: India-Centered Architecture and Emerging Multilateralism:

Energy cooperation in South Asia has historically been India-centric, organized around bilateral PPAs among Bangladesh, Bhutan, India, and Nepal. India's regional portfolio (2023–2024) includes imports of approximately 1,200–1,450 MW from Bhutan and exports of roughly 2,300 MW to Bangladesh, with additional connectivity planned toward Sri Lanka (ESCAP, 2018; World Bank, 2023). Nepal's position has shifted from net importer to exporter since November 2021, with growing bidirectional trade with India.

A key milestone occurred in October–November 2024 with the operationalization of the Bangladesh–India–Nepal (BBIN) tripartite agreement, enabling Nepal to export 40 MW of hydroelectricity to Bangladesh via India—the first trilateral electricity transaction in South Asia (India MEA, 2024). This marks a transition from bilateral agreements to transit-based multilateral interregional trade. Future interconnections, including India–Sri Lanka links and the potential India–Pakistan corridor, could deepen integration, although political constraints remain significant (ESCAP, 2018; ADB, 2019).

Despite progress, four structural barriers persist: the absence of a unified regional power market, reliability and supply adequacy challenges, limited cross-border transmission infrastructure, and regulatory divergence across jurisdictions (Wijayatunga & Fernando, 2013; REN21, 2019).

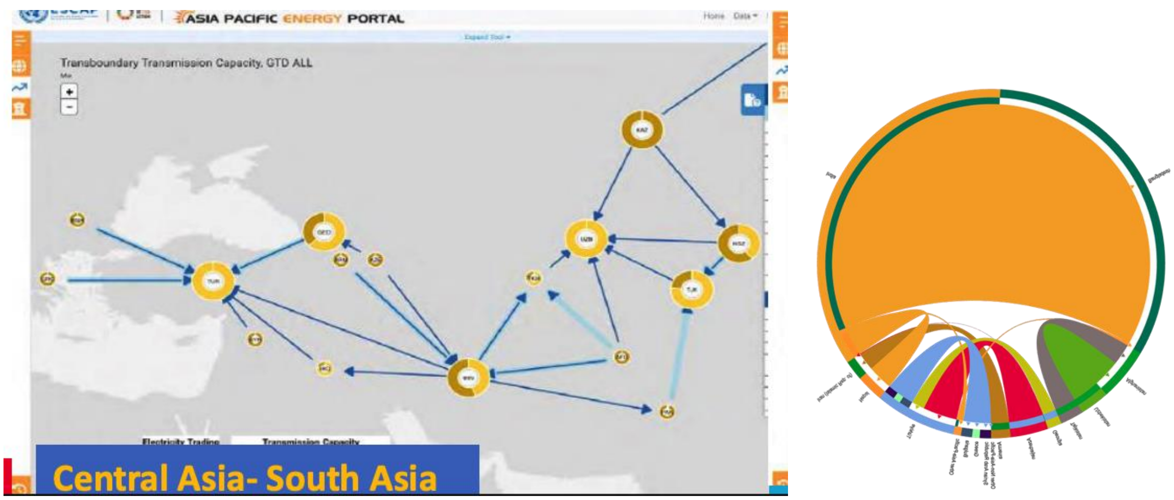
Interregional Connectivity: Central Asia to South Asia:

Interregional energy trade has historically centered on hydrocarbons, but electricity cooperation is expanding through dedicated transmission infrastructure. CASA-1000, TUTAP, and TAPI define the current interregional corridor, with Afghanistan serving as a critical geographic and political intermediary (Figure 2 and Figure 3).

Central Asian countries retain substantial export potential through 2030 due to relatively low domestic demand relative to generation capacity. Afghanistan currently imports approximately 78% of its electricity from Central Asia and Iran, highlighting both its dependence and its strategic role as a transit hub (World Bank, 2023; EDB, 2022).

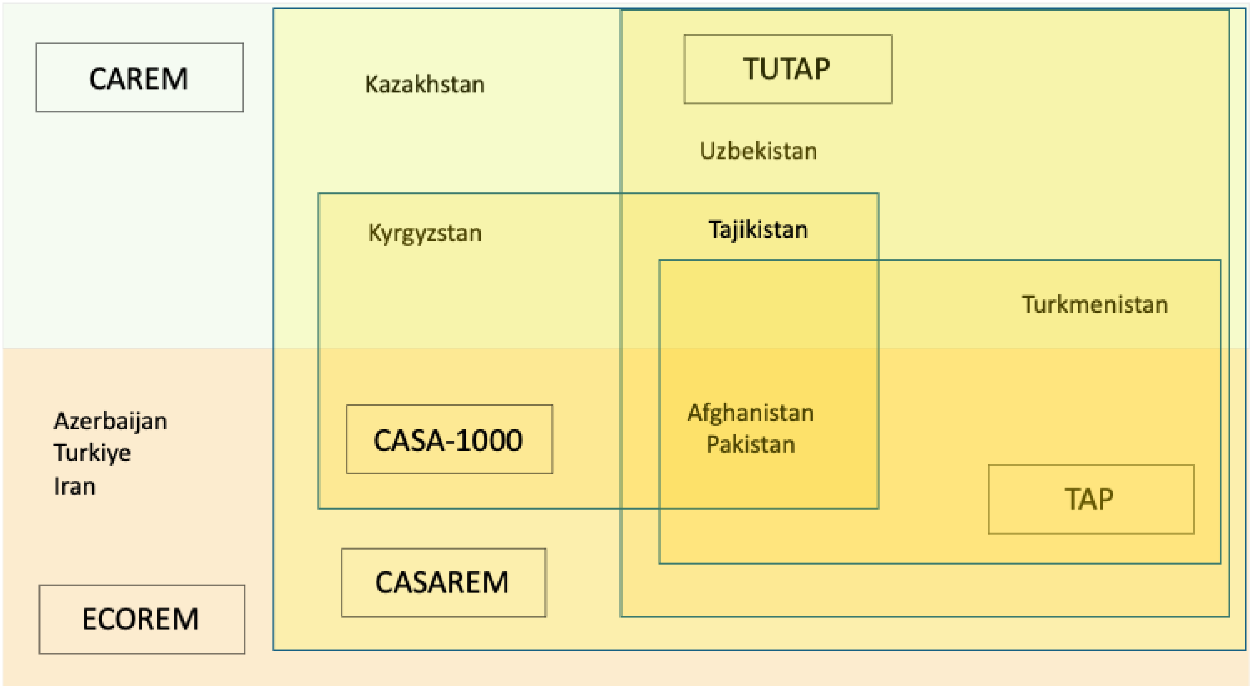
The CAPS, with Tajikistan's reconnection completed in June 2024, demonstrates the feasibility of coordinated dispatch, shared reserves, and cross-border system management (ESCAP, 2024). Scaling this model through ECO-REM will require sustained regulatory harmonization, institutional strengthening, capital mobilization, and political coordination across diverse governance systems.

Figure 2: Central Asia – South Asia Cross-border power system connectivity and South and South-West Asia Global* Electricity, 2023



Source: Screenshot from website from the Asia Pacific Energy Portal, accessed 22 January 2026 https://asiapacificenergy.org/apef/index.html#main/lang/en/graph/9/type/9/sort/0/time/[min,max]/indicator/[850029:75000]/geo/[SSWA]/legend/1/inspect/0

Figure 3: Cross-border power system connectivity initiatives in Central Asia and South Asia



Source: Adopted and reproduced by the author based on ESCAP, 2024

Note: Continued financing, logistical issues and political stability remain key challenges

Refer to Appendix 1 for acronyms and explanations

CASA-1000: Flagship Interregional Electricity Project:

The CASA-1000 project is the most advanced interregional electricity transmission initiative in the Central–South Asia corridor, spanning the Kyrgyz Republic, Tajikistan, Afghanistan, and Pakistan. Its core rationale is to channel approximately 5,000 GWh of surplus summer hydropower from the Kyrgyz Republic and Tajikistan to address Pakistan's peak-season generation deficits and Afghanistan's chronic electricity shortages (World Bank, 2023).

The system comprises a 477 km 500 kV AC transmission line linking the Kyrgyz Republic and Tajikistan, and a 750 km ±500 kV high-voltage direct-current (HVDC) line from Tajikistan through Afghanistan to Pakistan, for a total of 1,222 km. HVDC converter stations are located at Sangtuda (Tajikistan) and Peshawar (Pakistan), with the AC terminus at Datka (Kyrgyz Republic). Total transfer capacity is 1,300 MW (World Bank, 2023; Hitachi Energy, 2017). Total project investment is approximately USD 1.17B, financed by a consortium including the World Bank Group (USD 526.5M), EBRD (USD 110M), European Investment Bank (EIB), Islamic Development Bank, Afghanistan Reconstruction Trust Fund (ARTF), U.S. Agency for International Development (USAID), and U.K. Aid (UKAID).

Construction is largely complete in the Kyrgyz Republic, Tajikistan, and Pakistan, but the Afghan segment has remained suspended since August 2021 following the change in government—the primary source of delay, with COVID-19 as a secondary factor (World Bank, 2024; ESCAP, 2024). Commercial operation is contingent on political stabilization in Afghanistan and renewed international financing engagement, with no confirmed completion timeline as of 2025; earlier references to a 2025 target should therefore be treated as aspirational rather than scheduled.

TAPI Gas Pipeline: Strategic Natural Gas Corridor:

The TAPI gas pipeline is the principal interregional hydrocarbon infrastructure initiative, designed to transport 33B m^3 annually from Turkmenistan's Galkynysh gas fields through Afghanistan (814 km) and Pakistan (819 km) to India (approximately 140 km), for a total length of about 1,814 km. Updated project costs are estimated at USD 10B, reflecting scope expansion and construction-period inflation from the original USD 7.6B estimate (ADB, 2019).

As of early 2025, construction progress remains uneven. Turkmenistan's 214 km segment is complete, but only approximately 14 km of the Afghan segment had been constructed by April 2025, following project resumption in September 2024 under enhanced security conditions (AFintl, 2025; TimesCA, 2025). Pakistan and India have completed pre-construction activities. At the current pace, and with approximately 800 km of Afghan territory remaining, the widely cited 2027 completion target is not feasible and should be regarded as a long-term aspiration dependent on security stabilization in southern Afghanistan.

TUTAP: Multi-Country Power Interconnection Framework:

The TUTAP Power Interconnection Project positions Afghanistan as a regional energy transit hub linking five countries through six interconnection lines, combining existing and planned infrastructure (Energy Charter, 2020). The project builds incrementally on completed components, including the Uzbekistan–Afghanistan 220 kV line (commissioned 2009), the Tajikistan–Afghanistan 220 kV line (commissioned

2011), and the partially developed Turkmenistan–Afghanistan 500 kV corridor, which has stalled since 2021.

Characterizations of TUTAP as having defined “Phase I (2023)” and “Phase II (2026)” milestones conflate its bilateral components with the broader Central Asia–South Asia Regional Electricity Market (CASAREM) framework and are inconsistent with ADB documentation as of 2024. A more accurate interpretation is that northern Afghanistan’s bilateral interconnections are operational, while the expanded 500 kV backbone required for large-scale transfers to Pakistan remains incomplete and subject to the same political and security constraints affecting CASA-1000 (ADB, 2019; ESCAP, 2024).

5.3. Comparative Performance Assessment: Institutional Models for Cross-Border Energy Trade

South Asia–Central Asia energy relations are transitioning from hydrocarbon-based trade toward electricity integration but remain constrained by fragmented institutions, incomplete transmission links, and uneven regulatory reform across jurisdictions (ADB, 2019; ESCAP, 2018; World Bank, 2023). CBET remains structurally India-centric: Bhutan, Nepal, Bangladesh, and potentially Sri Lanka are connected through bilateral PPAs that provide reliability and fiscal gains but do not constitute an integrated regional market (ESCAP, 2018). The November 2024 operationalization of the BBIN tripartite transaction—the first multilateral electricity flow in South Asia—marks a qualitative inflection point, although the traded volume (40 MW) remains small relative to bilateral flows of 1,200–2,300 MW. Interregional cooperation is advancing through CASA-1000, TUTAP, and TAPI, demonstrating that Central Asia’s surplus hydro and gas resources can technically and economically supply South Asia’s deficits while highlighting the importance of risk allocation, tariff design, and Afghan political stability for long-distance transit corridors (ADB, 2019; World Bank, 2023).

CBET across both sub-regions operates through three primary institutional models (Table 15):

- Bilateral PPAs anchored on India’s grid;
- A project-based multilateral transit framework (CASA-1000); and
- A legacy but evolving multilateral dispatch system in Central Asia’s CAPS.

Bilateral agreements have produced the most consistent trade flows (Bhutan–India, Nepal–India) but create a hub-and-spoke structure that limits diversification, secondary trading, and price discovery. CASA-1000 demonstrates that multi-country revenue-sharing, MDB-backed blended finance, and harmonized technical standards are feasible in complex political environments yet also shows how concentrated demand risk and project-specific tariff structures can reduce price competitiveness. The CAPS model illustrates that centralized dispatch can lower system costs and optimize shared reservoir management but requires synchronous AC operation, capable system operators, and sustained political commitment—conditions not yet fully present across the CAREC–South Asia corridor (CAREC, 2024; ESCAP, 2024).

Table 15: Institutional models: Performance and strategic lessons

Model & Case	Core Design	Performance & Outcomes	Key Limitations	Strategic Lessons for CAREC–South Asia
Model 1 — Bilateral PPAs (India–Bhutan; India–Nepal)	Long-term G2G PPAs (25–60 years); sovereign guarantees; India finances, constructs, and offtakes; dedicated HV lines (e.g., Tala–Binaguri 400 kV; Dhalkebar–Muzaffarpur 400 kV)	Bhutan exports ~1,200–1,450 MW to India; power exports generate ~20–25% of GDP and dominant fiscal revenue (ESCAP, 2018). Nepal trade is now **bidirectional**: monsoon surplus exports to India via power exchanges, winter firm imports from India	Hub-and-spoke topology; limited third-country access; exposure to India-partner bilateral political dynamics; minimal price discovery (ESCAP, 2018)	Bilateral PPAs are the bankable foundation for first-generation export hydro and should anchor future CAREC–SA flows via long-term contracts with Pakistan and Bangladesh; design should progressively include third-party access rights and linkage to regional exchanges
Model 2 — Multilateral Transit PPP (CASA-1000)	Four-country HVDC project (KGZ, TJK, AFG, PAK); 1,300 MW, 1,222 km; ~5,000 GWh/year summer surplus; blended MDB finance USD~1.17B;	>90% physical completion achieved in KGZ, TJK, PAK despite conflict and regime change in Afghanistan; MDB-anchored treaty design proved	Take-and-pay design concentrates demand risk on Pakistan; all-in tariff (USD~0.0948/kWh) above regional coal benchmarks and new-build solar/wind	Multi-country transit corridors are essential where supply and demand are geographically separated; future phases should rebalance risk via

	tariff with separate energy (USD 0.0515/kWh), transmission (USD 0.0298/kWh), and Afghan transit (USD 0.0125/kWh) components = USD~0.0948/kWh all-in	robust; establishes transparent revenue-sharing template for TUTAP and future corridors (World Bank, 2023)	levelized cost of electricity (LCOE), partly due to project-specific overhead and political risk premium; seasonal-only HVDC asset utilization underutilized outside May–September window	capacity-based contracts and regional guarantees, and embed secondary trading to support CAREM–South Asia exchanges beyond single buyer–seller chains
Model 3 — Multilateral Dispatch (CAPS /CAREM)	Legacy Soviet synchronous grid rebuilt as CAPS; coordinated by CDC Energia regional dispatch center; common grid codes and balancing rules; CAREM program targeting modernization into a functioning regional power market; **Tajikistan formally reconnected June 2024**	Intra-CA trade recovering toward meaningful volumes post-reconnection; coordinated KGZ–TJK reservoir operation supports both irrigation and seasonal power exports while reducing system costs (EDB, 2022; ESCAP, 2024); Tajikistan's reintegration demonstrates political rifts can be reversed when mutual gains are clear	Requires synchronous AC operation; vulnerable to unilateral national exit; full compatibility with South Asia's asynchronous grids requires HVDC bridges and advanced control systems; institutio al capacity remains uneven	Dispatch-based markets can yield 10–20% cost savings through least-cost dispatch and shared reserves (ESCAP, 2024); for CAREC–South Asia, this is a post-2030 goal with interim steps focused on HVDC links between CAPS and India/Pakistan plus progressive alignment of grid codes and balancing rules

Source: Author's synthesis based on regional market design scenarios (ESCAP, 2024; ERIA, 2023)

The comparative analysis supports a **hybrid architecture** that combines the bankability of bilateral PPAs with the efficiency gains of multilateral exchange—a pragmatic intermediate pathway between the current hub-and-spoke structure and a fully integrated regional dispatch model (ESCAP, 2018; ERIA, 2023):

- Hybrid market design. Allocate 60–70% of base-load cross-border trade to long-term bilateral PPAs (extending the India–Bhutan/Nepal model to future India/Pakistan–Central Asia hydropower contracts), while reserving 30–40% of capacity for seasonal and day-ahead multilateral exchanges through platforms linked to Indian and Central Asian power exchanges (ESCAP, 2018; ERIA, 2023).
- Corridor-plus design for CASA-1000 and TUTAP. Transition CASA-1000 from a single buyer–seller project into a shared corridor with standardized access and wheeling charges, enabling multiple Central Asian suppliers and South Asian buyers. This transition is supported by the World Bank's REMIT Program (approved January 22, 2026), which provides USD 1.018B over 10 years across three phases to establish Central Asia's first regional electricity market, targeting 15,000 GWh/year in trade and expanding transmission capacity to 16 GW by the mid-2030s. Phase 1 alone (USD 143.2M across Kyrgyzstan, Tajikistan, Uzbekistan, and CDC Energia) is expected to enable approximately 900 MW of new clean energy capacity and catalyze USD 700M in private investment.
- Progressive regulatory harmonization. Align CBET regulation across SAARC, CAREC, and ECO-REM frameworks, focusing on common grid codes, open-access regimes, and dispute resolution mechanisms, while leveraging MDB programs to strengthen regulatory capacity in Kyrgyzstan, Tajikistan, and smaller South Asian markets (ADB, 2019; ESCAP, 2018). World Bank long-term projections indicate that enhanced regional connectivity could generate up to USD 15B in economic benefits for Central Asia by 2050, reinforcing the cost–benefit rationale developed earlier in this study.

5.4. China's BRI Energy Investments: Scale, Shift to Renewables, and Implications for the CAREC–South Asia Corridor

China has emerged as a major external investor in energy infrastructure across South Asia and Central Asia, reshaping project financing and PPP design in both regions. Since 2013, Pakistan alone has received over USD 41.5B in Chinese energy investment under the BRI, representing the highest country-level exposure globally (Green Finance & Development Center, 2026). Across both regions, data from the American Enterprise Institute's China Global Investment Tracker indicate cumulative Chinese energy and utility investments of USD 76.98B in South Asia—led by Pakistan (USD 41.49B), India (USD 16.63B), and Bangladesh (USD 12.96B)—and USD 38.45B in Central Asia, concentrated in Kazakhstan (USD 24.52B) (AEI, 2025).

From Fossil Dominance to Renewable Acceleration:

Historically, Chinese BRI energy investments in both regions were dominated by fossil fuel infrastructure. Coal-fired power plants constitute the majority of completed CPEC energy projects in Pakistan, including major facilities at Sahiwal, Port Qasim, Hub, and Thar (CPEC Authority, 2024). This fossil-heavy profile has attracted criticism and complicates assessments of the "Green Silk Road" narrative. However, recent data indicate a measurable shift toward renewables. China's BRI engagement in green energy and hydropower reached approximately USD 21.4B in 2025, up from USD 12.3B in 2024, while green energy construction projects increased to USD 13.7B from USD 10.3B over the same period (Green Finance & Development Center, 2026). Energy accounted for 43% of total BRI engagement in 2025, up from 32.5% in 2024.

In Central Asia, this transition is more pronounced. Chinese investment in the Eurasian electric power sector increased 2.1-fold over 18 months to USD 4.1B by mid-2024, with 85% directed toward solar and hydropower projects in Uzbekistan (EDB, 2025). China's total FDI stock in the region exceeded USD 66B by mid-2025, with energy representing a rapidly expanding share (EDB, 2025).

CPEC Renewables:

Within CPEC, verified renewable projects include 400–600 MW at the Quaid-e-Azam Solar Park, 100 MW UEP Wind Farm, 50 MW Sachal Wind Farm, 50 MW Dawood Wind Farm, 100 MW Three Gorges wind projects, 720 MW Karot Hydropower Project, and 884 MW Suki Kinari Hydropower Project (CPEC Authority, 2024). The commonly cited "300 MW Jhimpir Wind Farm" is more accurately understood as an aggregated cluster across the Jhimpir–Gharo corridor rather than a single installation (PIDE, 2025; World Bank, 2021). Additional hydropower projects, including the 1,124 MW Kohala and 700.7 MW Azad Pattan schemes, indicate continued expansion.

Technology Transfer and Financing Architecture:

China's role extends beyond capital provision to include equipment supply, technical training, and integrated financing. Firms such as Jinko Solar, Trina Solar, and JA Solar, along with wind developers including Goldwind and PowerChina HDEC, have established operational presence across South Asia and Central Asia (REN21, 2019; Eco-Business, 2024). Financing structures deployed by the China Development Bank and Export-Import Bank of China combine concessional and commercial lending, local-currency financing, and equipment-linked packages that address currency risk and long-term revenue uncertainty—key barriers to private investment (Eco-Business, 2024). Co-financing with institutions such as the Asian Infrastructure Investment Bank, ADB, and the World Bank indicates partial alignment with multilateral standards, although Chinese-financed projects retain distinct bilateral conditionalities (ADB, 2019; World Bank, 2023).

Contextualization within the PPP Discussion:

China's evolving role has direct implications for the PPP landscape. As a state-directed investor operating through policy banks and state-owned enterprises, China functions as a para-statal PPP actor rather than a conventional private-sector participant—providing capital and liquidity that markets alone may not supply while embedding strategic supply-chain dependencies in recipient economies (EDB, 2025; OECD, 2018). The increasing share of renewable energy within BRI engagement reflects not only market dynamics but also a coordinated industrial and geopolitical strategy that interacts with, and at times shapes, the multilateral PPP frameworks examined in CASA-1000 and the CAREC Energy Strategy 2030.

6. Conclusion

This study's central and most consequential finding is not a lack of investment, but a misallocation of capital: USD 193.9B in accumulated PPP investment across South Asia and Central Asia has been systematically directed away from assets that enable regional cooperation. Approximately 65% of cumulative commitments are concentrated in solar and domestic thermal generation that serve national grids but contribute little to interregional trade, while only about 25% is allocated to export-capable hydropower and large-scale wind—the technologies required to unlock the seasonal arbitrage underlying the Central Asia–South Asia energy corridor. This mismatch between investment composition and opportunity reframes the policy problem: the priority is not attracting additional capital but redirecting existing investment toward corridor-relevant assets.

The analysis demonstrates that the economic case is already well established. A USD 0.04–0.08/kWh generation-cost differential between Central Asian hydropower and South Asian coal generation represents an underutilized arbitrage of approximately USD 25–60M annually at current trade volumes, scalable to USD 1.8–2.0B with coordinated transmission expansion and open-access reforms. However, realization remains constrained by governance deficits that capital alone cannot address. CASA-1000 is instructive in this regard: it achieved financial closure while encountering institutional limitations, demonstrating that multi-country blended finance and revenue-sharing are feasible, yet also revealing how single-buyer, take-and-pay structures, regulatory asymmetries, and the absence of independent arbitration mechanisms can reduce market efficiency.

For policymakers, the implication is clear: corridor-level outcomes require corridor-level instruments, including open-access transmission frameworks, standardized wheeling charges that enable multiple buyers and sellers to use shared infrastructure, and blended political risk facilities that operate at the corridor rather than project level. For private sector actors and development finance institutions, the evidence supports a hybrid architecture that anchors base-load reliability through long-term bilateral PPAs while allocating residual capacity to seasonal multilateral exchanges, providing a commercially viable and politically durable pathway toward interregional market integration. The broader implication is that renewable energy cooperation between Central Asia and South Asia is no longer a conceptual proposition—it is an investable and quantifiable opportunity constrained primarily by governance design rather than economic fundamentals.

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Appendix 1: Central-South Asia Energy Initiatives

Acronym	Full Name	Countries	Key Info
CASA1000	Central Asia-South Asia Power Project	KGZ, TJK, AFG, PAK	High-voltage direct current (HVDC) transmission corridor linking Central and South Asia. Supported by the World Bank, Islamic Development Bank (IsDB), and other multilateral financiers to facilitate cross-border electricity trade.
TUTAP	Turkmenistan-Uzbekistan-Tajikistan-Afghanistan-Pakistan Power Interconnection	TKM, UZB, TJK, AFG, PAK	Multi-phase regional power interconnection concept supported by the ADB. Designed to integrate Central Asian grids with South Asia, establishing Afghanistan as a central energy transit hub.
TAP	Turkmenistan-Afghanistan-Pakistan Power Interconnection	TKM, AFG, PAK	Proposed 500 kV transmission corridor. Routes power from Turkmenistan to Pakistan via the southern Afghan corridor, rather than a direct bilateral line.
CAREC	Central Asia Regional Economic Cooperation Program	AFG, AZE, CHN, GEO, KAZ, KGZ, MNG, PAK, TJK, TKM, UZB	ADB-led economic integration framework encompassing 11 member states. The "CAREC Energy Strategy 2030" targets a reliable and reformed regional energy market, projecting $400 billion in investment needs by 2030.
CAREM	Central Asia Regional Electricity Market	KAZ, KGZ, TJK, TKM, UZB	USAID-supported initiative designed to establish a legally integrated and competitive electricity market. Aims to enhance energy security and

			cross-border trade among the five Central Asian republics.
CASAREM	Central Asia-South Asia Regional Energy Market	Interregional (Central Asia and South Asia)	Overarching conceptual framework led by the World Bank and ADB to facilitate interregional electricity trade. CASA-1000 serves as the foundational infrastructure phase for this broader market vision.
ECO-REM	Economic Cooperation Organization Regional Electricity Market	AFG, AZE, IRN, KAZ, KGZ, PAK, TJK, TUR, TKM, UZB	Regional electricity market framework covering 10 member states. Revitalized in 2024 after an 11-year gap through active consultations with UNESCAP to harmonize cross-border energy trade.
CAPS	Central Asia Power System	KAZ, KGZ, UZB (Active); TJK (Reconnecting); TKM (Disconnected)	Legacy Soviet-era synchronous regional grid. Essential for balancing regional hydro and thermal generation, with ongoing reintegration efforts to optimize regional dispatch and accommodate variable renewable energy.
CATCA	Central Asia Transmission Cooperation Association	CAREC member states (Targeting national TSOs)	Proposed under the CAREC Energy Strategy 2030 as a regional governance platform. Enables Transmission System Operators (TSOs) to develop long-term network plans and harmonize operational grid rules

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