



OUTLOOK FOR DEEPENING LANCANG-MEKONG REGIONAL POWER CONNECTIVITY AND COOPERATION OF KEY AREAS

November 2023

Mekong Institute

Lancang-Mekong Energy & Power Cooperation Research Center

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Executive Summary

The Lancang-Mekong region is one of the most dynamic regions in global economic development and has achieved sustained and rapid development in the power sector. Countries in the region complement one another in resource endowments facilitating natural advantage in energy connectivity. The scale of power interconnection and cross-border power trade keep growing thanks to bilateral and multilateral cooperation mechanisms.

As carbon neutrality and net-zero emissions as well as the upgrading and iteration of green energy technologies speed up, intermittent renewables such as PV and wind power will become major players in the future. How to achieve efficient consumption of massive renewables penetration and serve the intrinsic needs of secure energy development in the context of fast-growing terminal demand will be common challenges faced by Lancang-Mekong countries when they pursue green energy transition. By enhancing flexible complementary of power resources in the region, exploring a regional power market, deepening power interconnection, and using the regional trade system to facilitate green industry cooperation, consumption of renewables will become more affordable, reduce investment in redundant installation, and facilitate coordinated transformation of energy that is safe, affordable, green and efficient.

To deepen regional energy connectivity, Lancang-Mekong Countries are suggested to leverage regional cooperation foundation, institutional strengths

Executive Summary

and existing technological edges. It is necessary for Lancang-Mekong Countries to advocate the mission of extensive consultation, joint contribution, and shared benefit. Under the objectives of energy security, economy, efficiency and green development, problem-oriented and demand-oriented approaches should be carried out and be driven by two engines----soft connectivity and hard connectivity. It is proposed to start with bilateral and multilateral agreements, with unimpeded electricity trade as the premise, grid interconnection as the means, and green industry cooperation as the support, the energy connectivity in LM Countries can work toward **unimpeded power trade, power system facility connectivity, and green industry integration**, striving for green and low-carbon energy transformation.

In terms of unimpeded trade, a Lancang-Mekong Regional Power Market is recommended to realize free and competitive cross-border trade of clean energy and resources for regulation purposes in the medium- and long-term power market and spot market, unleashing their green value. **In terms of power system connectivity**, it is proposed to tackle the technical barriers to the security and stability of multinational interconnection and realize the multilateral Grid-to-Grid AC and DC interconnection in the region. **In terms of green industry integration**, setting up Lancang-Mekong green industry and financial cooperation and development alliance will enable an efficient circulation of the green innovation chain, industrial chain, talent chain, and capital chain in the region.

Chapter 1

Foundations, Opportunities and Challenges for Energy Connectivity

1.1 Fundamentals for Connectivity and Power Trade

As of June 2023, there were 55 interconnection lines of 110 kV and above between the Lancang-Mekong countries, of which 24 are Laos-Thailand interconnection lines, accounting for the highest proportion (43.6%). In terms of voltage-level distribution: 9 circuits of 500kV lines are Point-to-Grid cross-border lines, including 8 circuits of Laos-Thailand line, 1 circuit of Myanmar - China line; There are 23 circuits with the voltage level 230/220kV, of which 16 circuits are Point-to-Grid cross-border lines; There are 23 circuits with the voltage level 230/220kV, all are Grid-to-Grid interconnection.

In 2022, the total electricity trade of Lancang-Mekong countries was about 43 TWh, of which Lao-Thailand power trade accounted for over 85% . Laos, a major exporter, accounts for nearly 90% of regional electricity exports, while Thailand, a major importer, accounts for nearly 80% of regional imports.

1.2 Favorable Conditions of Deepening Energy Connectivity

1. Resource complementarity among Lancang-Mekong countries brings advantages of deepening connectivity.

Laos, Thailand, Vietnam and Myanmar enjoy sound conditions to develop wind power; Laos, Myanmar, Vietnam and China's Yunnan Province are rich in hydropower resources, and there is still room for development in Laos and Myanmar ; In terms of fossil energy, Myanmar has the relatively abundant natural

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gas resource, with a storage capacity of over 630 billion cubic meters, or 0.6% of global reserves. China's Yunnan and Vietnam's coal resources are relatively abundant. Lancang-Mekong countries complement one another in resources, which constitute favorable conditions for stepping up connectivity.

2. Sound platforms of Existing Lancang-Mekong cooperation mechanisms have promoted cross-border trade.

In recent years, the Greater Mekong Subregion (GMS) Cooperation mechanism and the Lancang-Mekong Cooperation (LMC) Mechanism have enhanced regional power cooperation.

Under the GMS mechanism, *Regional Power Trade Coordination Committee* (RPTCC) was established, who has been hosting discussions on key issues such as regional connectivity and electricity trade rules and has advanced a number of bilateral electricity trade projects. In 2023, based on RPTCC, the regional Energy Transition Task Force (ETTF) was established, which is committed to further broadening areas of cooperation among countries and promoting integration of regional green transition and a regional power market.

Under the LMC Mechanism, regional utilities jointly launched the Lancang-Mekong Power Utility Summit, which facilitated multilateral power cooperation dialogues, and established the *Technical Working Group on Lancang-Mekong Power Interconnection* and the *Lancang-Mekong Electricity Standardization Council* to bring regional entities together to jointly research on key issues such as interconnection and standard aligning, providing a favorable platform for breakthroughs in Lancang-Mekong interconnection technology.

3. RCEP facilitates great potential to boosting green energy trading via enhancing green energy industry and financial cooperation.

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RCEP became effective since January 2022, thus regional market and investment access, rules and standards are getting increasingly open. By deepening wide-area cooperation in green industries and green finance, RCEP will facilitate efficient circulation of raw material, capital, technology, and talent in green industries, foster closer green industry trade and industrial division of labor system in the region, reduce construction and transaction costs of green power projects, and increase price competitiveness of green power trading.

4. Continued upgrading of renewables and asynchronous cross-regional interconnection technologies pave the way for multilateral interconnection green power trading.

Enormous green energy technologies are more mature by day, large-scale centralized PV installed capacity continues to increase, and gigawatt-level offshore wind and pumped storage technologies have been successful applied. Electrochemical energy storage is now in high-speed iteration, and the technical parameters and cost effectiveness have been elevated. Power trade centering on the integration of water, wind, PV and storage enjoys great room for development.

In terms of grid, asynchronous interconnection technology (such VSC-HVDC) has been widely applied in cross-provincial power mutual complementary, and all aspects of equipment manufacturing, standardization, planning and design, and system operation and maintenance are improved, which offers a solution for technical issues regarding safe and stable interconnection of differentiated grids.

1.3 Necessity to Deepen Energy Connectivity

- **Lancang-Mekong region will face new challenges in balancing intermittent supply and increasing demand, adding issues in terms of the system security and stability brought by high proportion of renewable energy. It is urgent to deepen interconnection to realize green transformation with**

energy security as the premise.

Against the backdrop of global energy transition, Lancang-Mekong countries have all made carbon neutrality and net-zero emission commitments. With the proportion of variable renewables (VRE, mainly PV and wind power) continuing to increase, the challenges of consumption will be increasingly prominent. Without cross-border electricity complementarity, balancing high proportion of intermittent VRE and increasing power demand **within a single country** will increase redundant infrastructure investment, coming with long-term system security and stability issues as well as higher costs and risks of energy transition.

Therefore, expanding interconnection among countries for a wider range of green power allocation and trade, sharing regulation resources and cross-border grid infrastructure have become common and urgent needs of countries in the region to enjoy secure, efficient, affordable, and green electricity.

- **It is a common need for Lancang-Mekong countries to establish regional power market and execute Grid-to-Grid-dominated multilateral interconnection to realize flexible and efficient power complementary towards carbon neutrality and net-zero emission goals.**

With rapid growing in capacity and wide-spread distribution of VRE in LM Region, the complementary advantages in time and space of regional large-scale VRE output will gradually emerge. The boundaries between ‘sender-end’ and ‘receiver-end’ will be blurred.

Existing Point-to-Grid bilateral interconnection and current market mechanisms have limitation to meet the needs of these countries to expand flexible trading in electric power and regulation resources. Building a regional power market and initiating a Grid-to-Grid-dominated interconnection based on secure and advanced interconnection technologies are the common needs and a preferred

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path for Lancang-Mekong countries to realize of carbon neutrality and net-zero emissions in the energy sector.

1.4 Challenges

Despite certain foundation for interconnection, grid infrastructure hinders cross-border and multi-directional power flow and existing power market mechanism hardly meets the needs of expanding green power and regulating resources. In addition, the price competitiveness of green power trading has no edge, and it is necessary to bring down cost by strengthening industrial cooperation.

1.4.1 Grid Infrastructure Hinders Cross-border and Multi-directional Power Flows.

- **Interconnection presents the characteristics of "scattered" and "one-way" development, and the scale of cross-border transactions is still expected to scale up.**

In April 2005, at the third seminar of RPTCC, the regional power trade operating agreement (RPTOA) was deliberated and approved, which clarified the 4 stages of the development of regional power from Point-to-Grid bilateral transactions to multilateral, multi-directional electricity trade, and finally a competitive regional power market with multiple buyers and sellers.

Table 1 Four Stages of Lancang-Mekong Power Trade Development

Stage	Description
Stage 1	trading through bilateral cross-border connections associated with specific power purchase agreements (PPAs);
Stage 2	Grid-to-Grid power trading between any pair of GMS countries, eventually using the transmission facilities of a third country;
Stage 3	developing transmission links dedicated to cross-border trading;
Stage 4	a situation in which most GMS countries have completed the transition to regulatory frameworks with multiple sellers and multiple buyers, to enable a regional wholly competitive market to be implemented.

1 Foundations, Opportunities And Challenges for Energy Connectivity

As of July 2023, most of the interconnection between Lancang-Mekong countries with 220 kV and above were Point-to-Grid transmission lines. Among the Grid-to-Grid interconnection projects of 220 kV and above that are operational, most are one-way with agreements, so regional interconnection is still in the first stage. Existing interconnection projects haven't yet fully functioned to optimize resource allocation. The cross-border power trade scale of transactions remained limited.

■ **Power Grid Infrastructure and Coordination Between Generation and Power Grid Needs Further Strengthen**

In recent years, many Lancang-Mekong countries prioritize development and utilization of clean energy, and the installed capacity of hydropower, PV etc. continue to grow rapidly, but investment into local grids has not been matched with the development of sources in time and space, and the resource allocation capacity of grids is still restricted.

On one hand, massive curtailment of high-quality clean energy has already taken place, which discourages investors and affects the sustainable industrial development. Meanwhile, dissatisfactory grid security and stability makes it difficult to support further interconnection and joint dispatching, to a certain extent limiting the expanding of green power trade and interconnection. The transmission and distribution network infrastructure still needs to be further strengthened.

■ **Technical Barriers in Security and Stability Creating Obstacle in Expansion of Synchronous Interconnection.**

Lancang-Mekong countries are in different stages of electricity development, with different standards for power system planning, construction and operation. To safeguard national power security, difficulty lies in expanding cross-border

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backbone grid connectivity by synchronous interconnection, except for Point-to-Grid mode or isolate terminal grid being supplied by neighboring country.

1.4.2 Singular Market Mechanism Hardly Satisfies Multilateral Power Trade

- **Power trade products and time Domain are single, there is still a long way towards regional multilateral power market.**

Most current transactions are bilateral, medium-and-long-term electricity agreements that are bound to designated sources. Existing trading system leads to problems including limited room for renewable consumption, failure to serve as price signal, absence of sharing mechanism of resources for regulation purposes, and inability to release the value of green electricity.

Firstly, there exists a lack of market for surplus renewables such as hydropower, which leads to serious water curtailment; **Secondly**, there is no short-term trading mechanism such as monthly and day-ahead spot market, making it difficult to serve as price signals for cross-border transactions; **Thirdly**, regulation resource sharing mechanism is not yet established. The regulation resources, such as hydropower, pumped storage, electrochemical energy storage, etc. have difficulty to retrieve ancillary service value return when supplying services like peak shaving, frequency modulation, and black start, etc. **Finally**, the untapped value of renewables hampers competitiveness of cross-border power trade in the region.

- **Lack of Joint Studies into Power Market Policies and Think-tank Cooperation Mechanism**

It is necessary to establish a think tank cooperation mechanism led by national energy research institutions. Without certain joint-research mechanism, potential information barriers and conceptual differences exist throughout planning, market rule research, and coordination of trading policies, joint

1 Foundations, Opportunities And Challenges for Energy Connectivity

studies and discussions into underlying needs including key technical obstacles and commercial demands for building a regional market are needed.

■ Green Power Trading is Still Lack of Competitive

In actual bilateral power trade in which the power is generated by renewable energy, the utilization rate of cross border transmissions lines will be strictly defined. Without a grid that can allocate sufficient regulation resources, massive energy storage will be needed to supplement wind power and PV to ensure security and stability. Cost analysis shows that VRE + energy storage feed-in tariff will often reach \$8-9 cents/kWh, which is commercially inviable undercurrent terminal electricity prices, it is necessary to improve Lancang-Mekong green energy industry chain and supply chain, reduce financing costs, accelerate technological upgrading, strengthen green industry and financial cooperation, and bring down green electricity costs.

Chapter 2

Outlook for the Direction of Energy Connectivity in LM Region

Energy Connectivity in Lancang-Mekong Region should leverage regional cooperation foundation, institutional strengths, and existing technological edges. It is necessary for Lancang-Mekong Countries to advocate the mission of extensive consultation, joint contribution, and shared benefit. Under the objectives of energy security, economy, efficiency, and green development, problem-oriented and demand-oriented approaches should be carried out and be driven by two engines----soft connectivity and hard connectivity. It is proposed to start with bilateral and multilateral agreements, with unimpeded electricity trade as the premise, grid interconnection as the means, and green industry cooperation as the support, the energy connectivity in LM Countries can work toward **unimpeded power trade, power system facility connectivity, and green industry integration**, striving for green and low-carbon energy transformation.

In terms of unimpeded trade:

Energy Authorities and power utilities in LM Countries can work towards the transition from bilateral electricity trade to a **Lancang-Mekong Regional Power market**, and diversity products to include medium-and long-term trading, spot trading, ancillary services trading, and green electricity trading.

In terms of power system connectivity:

It is recommended to gradually transform singular Point-to-Grid into grid-grid interconnection, resolve the bottlenecks of safety and stability regarding multi-country interconnection, and realize the shift from 'locally interconnection' to 'regionally interconnection' based on strengthening grid infrastructure, and realize the multilateral Grid-to-Grid AC and DC hybrid interconnection among Lancang-Mekong countries.

In terms of green industry integration:

Lancang-Mekong green industry and financial cooperation and development alliance can be further established to form a mature industrial division system, and a green financial cooperation mechanism and product system, so as to enable efficient circulation in the innovation chain, industrial chain, talent chain and capital chain.

2 Outlook for the Direction of Energy Connectivity in LM Region

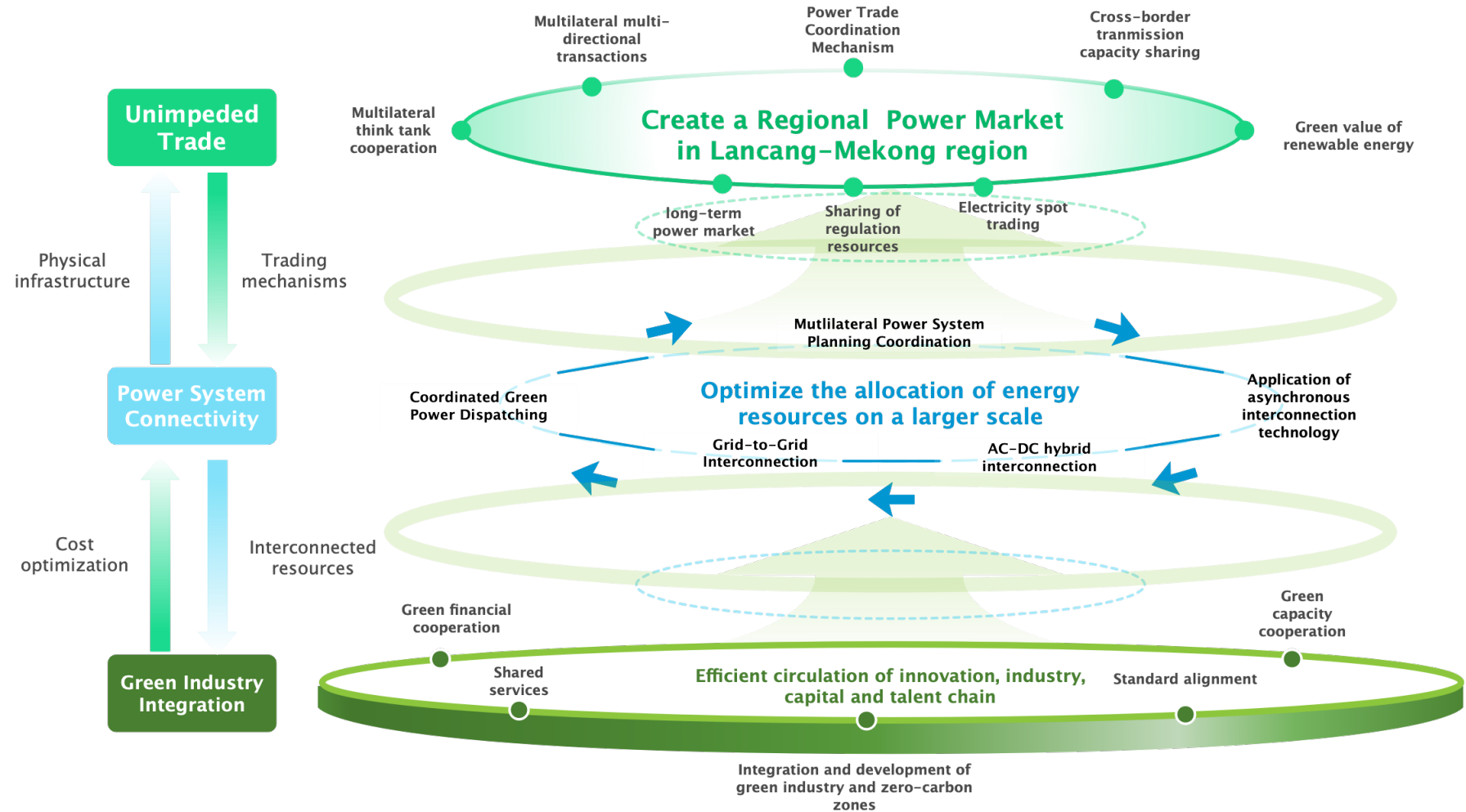


Figure 1: Outlook for Energy Connectivity Direction of LM Region

2 Outlook for the Direction of Energy Connectivity in LM Region

IPP and Contract-Based Single Direction Interconnection



Multilateral Interconnection and Regional Market

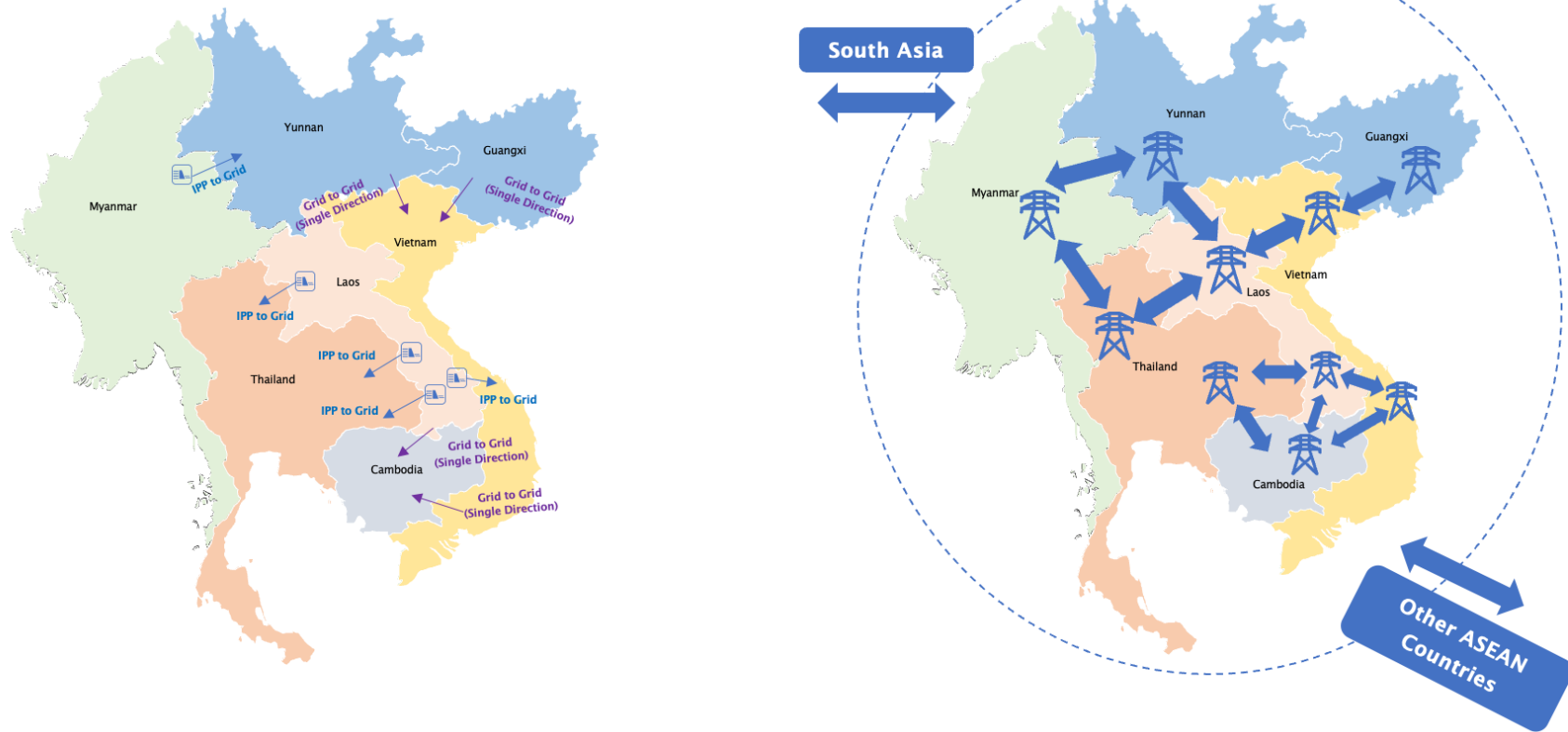


Figure 2: Outlook for Power System Interconnection in LM Region (220kV or above)

Disclaimer: The boundaries and names shown and the designations used on this map do not imply official endorsement.

Chapter 3

Preliminary Proposal on the Roadmap of Energy Connectivity in LM Region

3.1 Short Term (2025-2030)

In terms of unimpeded power trade, we recommend pushing forward:

- Pilot bilateral Two-way common power market mechanism based on high voltage cross-border interconnections,
- Building a regional think tank cooperation platform and bring together research entities in the region to work on major issues regarding the power market.

In terms of power system connectivity, it is proposed to:

- Establish the multilateral coordination of power planning, promote the construction of high voltage¹ interconnection projects at an early date,
- Advance Grid-to-Grid interconnection projects with preliminary work done,
- Study the essential conditions and interaction mechanisms for power system interconnection and coordinated system dispatching.

In terms of green industry integration, the following approaches are proposed:

- Research on the cooperation model and layout of the industrial chain, designate several bilateral cooperation industrial parks,
- Initially explore support of green finance for the development of green

¹ High Voltage refers to the power grid infrastructure with the voltage level of 220kV or above

industries.

Specific Measures are recommended as follows:

Unimpeded Power Trade

- **Explore bilateral and two-way electricity trade based on Grid-to-Grid interconnection project.**

Based on the China-Laos 500 kV interconnection project and planned power agreements, the two sides are recommended to bring in market competition electricity, advance medium and long-term electricity energy trading, spot trading and ancillary service transactions to form a bilateral power market with diversity and multi-time scale transactions.

- **Launch a think tank union for green power cooperation in Lancang-Mekong countries.**

Leaded by multilateral organizations, supported by national and utility think tanks and other institutes for joint researches into key policies including regional energy transition, interconnection pathways and common markets.

Power System Connectivity

- **Establish coordination of planning and facilitate construction of high-voltage interconnection projects at an early date.**

To promote coordination of power system planning within LM countries, clarify on the strengthening of grid infrastructure that adapts to interconnection progress, study the needs of high-voltage (230kV and above) transmission grid interconnection and interconnection projects that match the supply and demand in the near future, and speed up projects whose construction already began, such as the China-Laos 500 kV interconnection project and etc.

- **Explore the essential operating conditions and interaction mechanisms**

for Lancang-Mekong Interconnection

Cooperation of Technical Working Group on Lancang-Mekong Power Interconnection should be further push forward to keeping carrying out joint research on key technical issues of bilateral and multilateral connectivity, focusing on the system stability under high-proportion renewable energy access and improvement of the utilization rate of cross-border transmission channels, so as to basically form a consensus on the basic conditions for the operation of Lancang-Mekong power system interconnection and improve relevant technical standards and guidelines.

Green Industry Integration

- **Study the Lancang-Mekong Green Energy Industry Chain and Complete Industrial Park Layout.**

Utilizing the multilateral think tank and focusing on PV, wind power, and electric vehicle, research can be carried out on green industry cooperation model, industrial chain layout from the perspectives of talent, technology, capital, and other resources, and complete the layout of several demonstration industrial parks.

- **Explore Integrated Development Model of Green Finance and Green Production Capacity Cooperation Based on Industrial Parks.**

The above-mentioned industrial parks will nurture green production capacity cooperation projects. Green financial funds can be applied focusing on supporting innovative demonstration projects, so as to realize initially coordinated circulation of innovation chain, industrial chain and capital chain.

3.2 Mid Term (2035-2040)

In terms of unimpeded power trade, we recommend exploring trilateral trading mechanisms and joint dispatching mechanism.

In terms of power system connectivity, according to actual need and circumstances, it is proposed to:

- attempt to transform expired concessional Point-to-Grid transmission projects into Grid-to-Grid interconnection, if needed.
- Promote pilot asynchronous interconnection.

In terms of Green Industry Integration, the following approaches are proposed:

- improve green finance cooperation mechanisms and product lineup.
- build a standardized system for Lancang-Mekong green industries.
- facilitate integrated development of green industries and digital-driven plus low-zero carbon parks.

Unimpeded Power Trade

■ Study and Establish a Trilateral Power Market Mechanism

A Trilateral electricity trade coordination mechanism can be explored under the experience of bilateral power market, in which relevant trade participants take part in power trading, market clearance and settlement. Participation of VRE in competitive medium and long-term and short-term trade is proposed to be initially explored.

The *Technical Working Group on Lancang-Mekong Power Interconnection* will establish joint dispatching to review safety and stability of Lancang-Mekong power trade.

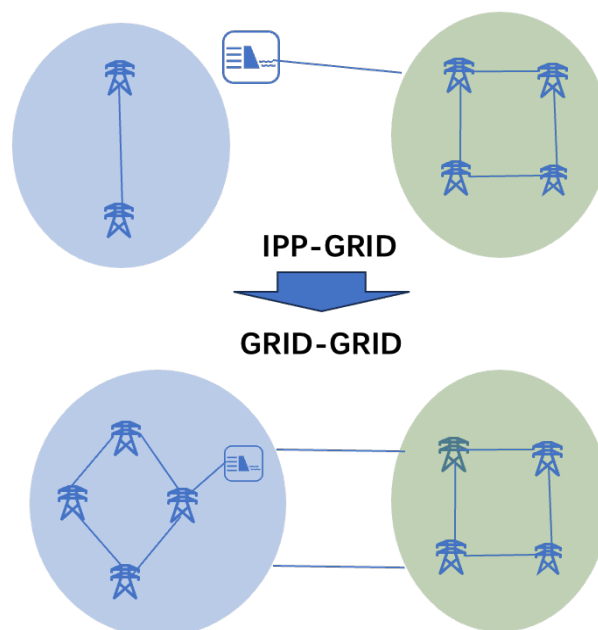
Power System Connectivity

■ Pilot Application of VSC HVDC Asynchronous Interconnection

Countries' varied power sector development and consequent safety and stability issues are major technical obstacles for interconnection. It is suggested to establish pilot back-to-back VSC HVDC asynchronous interconnection for potential Grid-to-Grid projects, and existing Grid-to-Grid projects can be explored to be gradually upgraded to asynchronous interconnection according to actual necessity and circumstances.

■ Explore Transmission Schemes for Expired Concessional Point-to-Grid Plants into Grid-Grid Interconnection

If there will be some concession-expired Point-to-Grid plants with the feasibility to connection into their transmission grids, it is possible to transfer the current status form into Grid-Grid transformation making full use of the current interconnection infrastructure, following existing trading agreements and power flow patterns.



Green Industry Integration

■ Improve Green Financial Product Lineup

To reduce the financing cost and improve risk averse ability of green industries, it is recommended to explore a green finance cooperation mechanism in the region, and attempt to set up a special fund for green industrial development and improve product lineup of green bonds, green insurance, green trusts, etc.

■ Establish a Green Industrial Standard System within LM Region

Relying on the *Lancang-Mekong Electric Standardization Council*, a standardized system is proposed to set up for multiple dimensions such as equipment manufacturing, grid-connected power quality, engineering design, and device security, focusing on the industrial areas of PV, wind power, and EV charging infrastructure.

■ Foster Integrated Development of Green Industries and Zero-carbon Parks

Utilizing above-mentioned green industrial parks, application of "low-zero-carbon" and "digital" innovative technologies should be promoted with priority financial support.

Creating several digitally driven 'low/zero carbon parks' with global influence is also favorable to build a Lancang-Mekong green industry brand.

3.3 Long Term Outlook (2035-2040)

In terms of unimpeded power trade, the Lancang-Mekong Common Power Market is expected to initially take shape. The multilateral power trade coordination, transaction settlement and joint dispatching in power trade will be in place.

In terms of power system connectivity, Lancang-Mekong countries will feature asynchronous(dominant) plus synchronous(supplementary) and AC/DC hybrid Grid-to-Grid interconnection.

In terms of green industry integration, a Lancang-Mekong green industry financial cooperation and development alliance is proposed to be established for in-depth industrial technology exchanges, formulating industrial standards and policies, sharing services for green industries, and collaboration in production capacity, so as to realize efficient circulation of various factors (*such as capital, innovation, talent, etc.*) of green industries.

Specific Measures are recommended as follows:

Unimpeded Power Trade

- **Lancang-Mekong Regional Power Market can be initially in place.**

Multilateral trading coordination mechanism is expected to set up within the LM Region based on Trilateral power trade. Trading rules and joint dispatching should be kept improving in sync with green power mutual aid needs.

Regional utilities and regulators can participate in multilateral electricity trade as proxy, perform domestic electricity trade with relevant domestic entities after trading in the LM regional power market.

Power System Connectivity

- **AC/DC hybrid Grid-to-Grid interconnection is expected to take shape.**

According to actual need and circumstances, existing Point-to-Grid transmission projects and Grid-to-Grid synchronous interconnection projects can be gradually transformed into VSC HVDC back-to-back asynchronous interconnecting while certain border power mutual aid interconnection can remain synchronous. It is expected to form an ‘asynchronous as main, synchronous as supplement’

interconnection pattern in LM Region. The physical footing of multilateral and multi-directional power trade will be in place.

Integration of Green Industry Cooperation

■ **Set up a Green Industry Financial Cooperation and Development Alliance in the Region**

Based on basic green finance and production capacity cooperation, the Lancang-Mekong green industry financial cooperation and development alliance can be further established consisting of regional power grid, generation, equipment manufacturing and project service enterprises, as well as regional financial institutions to promote technology exchanges, formulate industrial standards and policies, deepen production capacity cooperation, and provide a shared service platform for green industry projects.

BOX: Cooperation of Green Industry Financial Cooperation and Development Alliance***Industrial technology exchanges:***

Regularly carry out academic research exchanges on green development and industry, share latest industrial updates, and leading global industrial development models, and success stories.

Formulation of industrial standards and policies:

Jointly discuss industrial cooperation policies suitable for the circulation of green industry factors in the Lancang-Mekong region and formulate standards in green industry-related fields.

Shared support:

Provide industrial planning and development consulting, investment and financing, green insurance, talent training and other services for local governments, green energy enterprises.

Production capacity cooperation:

Utilizing bilateral industrial parks for production capacity cooperation in PV, VRE, storage, and EV, etc. Build several demonstration and application bases of green and innovative technologies, jointly transform green technology innovation outcomes, execute green technology transfer and transformation demonstrations, facilitate integrated development of green industries and zero-carbon parks, and offer a zero-carbon development path of industrial parks.

3 Preliminary Proposal on the Roadmap of Energy Connectivity in LM Region

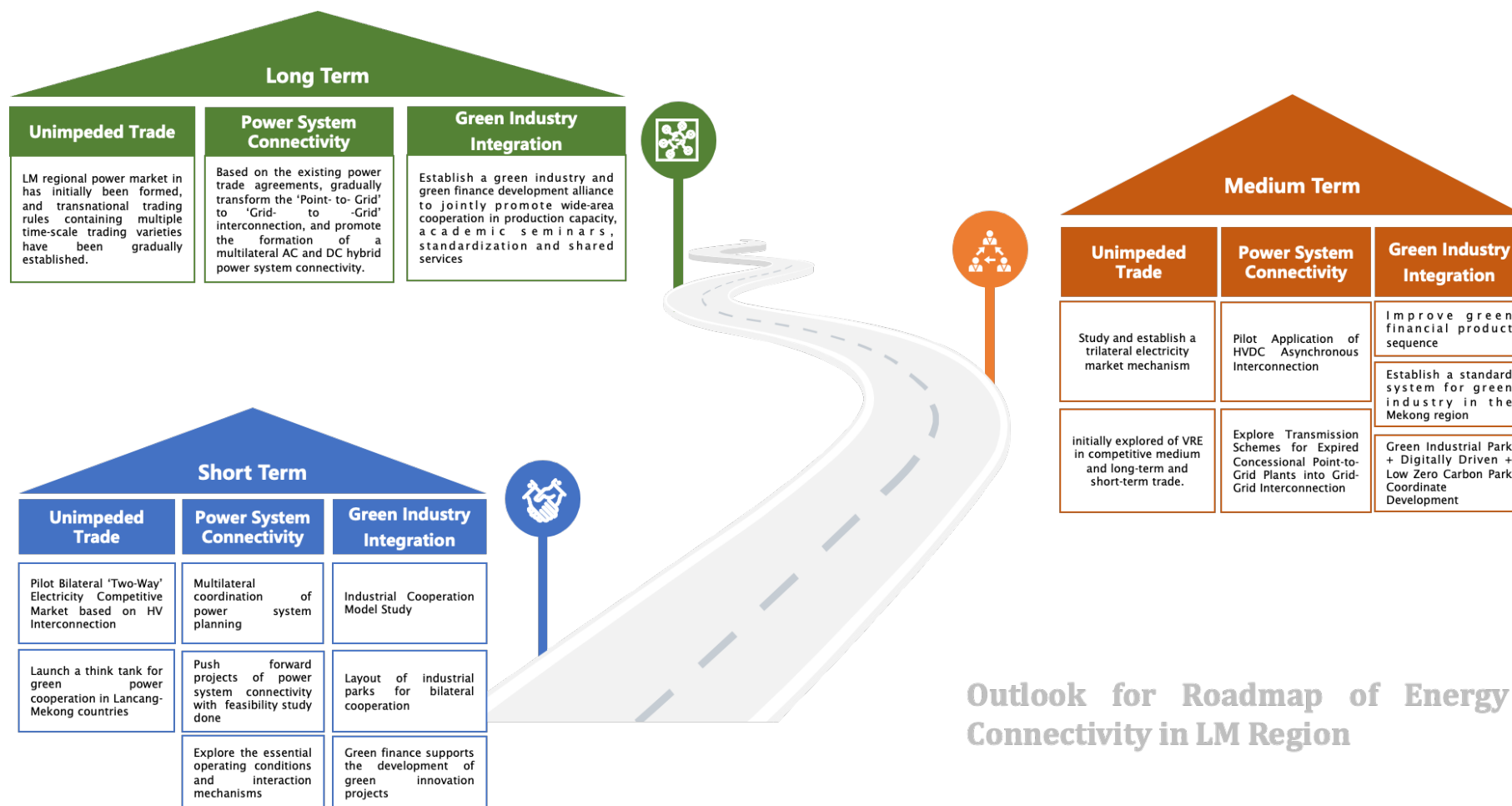


Figure 3 Outlook for Roadmap of Energy Connectivity in LM Region