Asia Green Grid Network

Connecting Asia: One region, one grid

Introducing the Asia Green Grid Network

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Asia Green Grid Network

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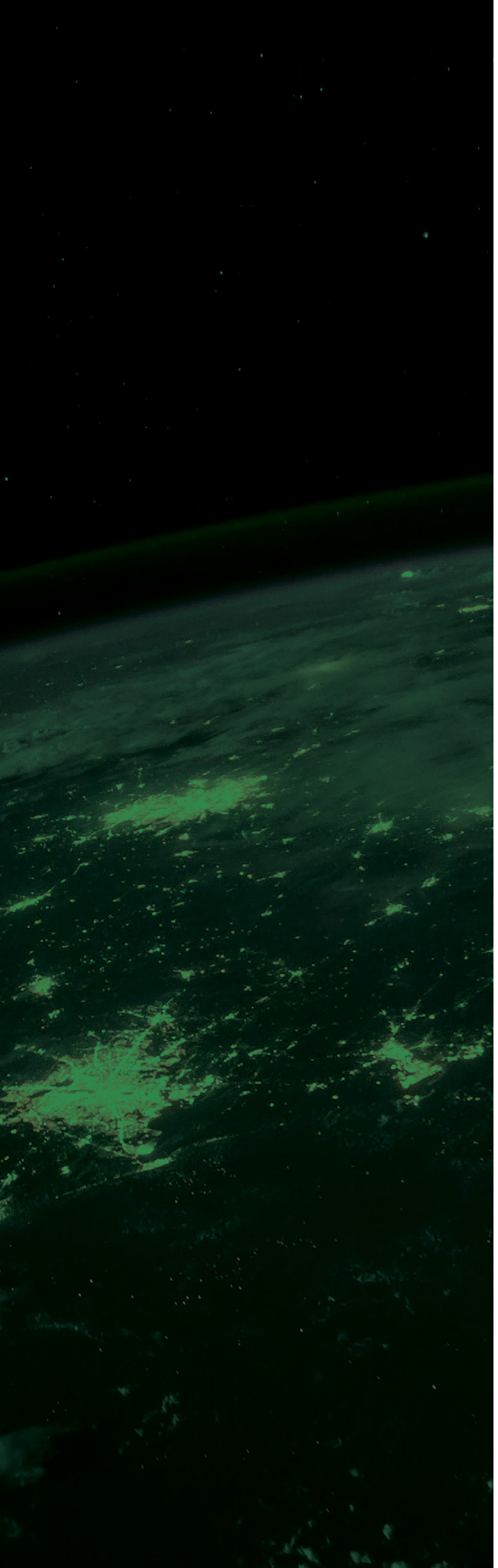

Partners

Sun Cable

Surbana Jurong

Agency for Science, Technology and Research — Singapore

NUS National University of Singapore

Nanyang Technological University Singapore

Singapore Institute of Technology

UNSW Sydney

Charles Darwin University Australia

James Cook University Australia

The University of Adelaide

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Summary

Cross-border electricity could transform Asia. Cross-border renewable electricity trade could be worth USD 493 billion annually in Asia by 2040, creating 870,000 jobs, and reducing up to 8.3 percent of current global emissions.

Creating an interconnected electricity grid in Asia requires a range of innovations to overcome potential challenges. Across the entire value chain of activities, there are a series of technical challenges to be overcome to create an integrated grid in Asia. These range from voltage improvements to minimize transmission losses in high voltage direct current (HVDC) cable through to finding ways to support dispatchability and energy security through high density energy storage systems. While the technical challenges are real, the good news is that many corporates and research institutions are developing the "know how" to tackle them.

Sun Cable, with our partners, are creating the Asia Green Grid Network (AGGN) to support this innovation. The AGGN is a virtual network of leading corporates and institutes of higher learning that have a shared vision of having an integrated green grid in Asia. The AGGN has three roles:

1. **Educating.** Provide briefings and seminars on key areas of the green grid (e.g., latest developments on HVDC transmission, best practice policy approaches, etc).
2. **Collaborating.** Bringing together leading academic institutions and corporates to share research on key topics associated with a green grid (e.g., microgrids, battery back up, etc.) and work together to form new connections.
3. **Innovating.** Providing a platform for research and development efforts. This would include key R&D funding required for the Australia-Asia PowerLink (AAPowerLink) project.

Cross-border electricity could transform Asia

Regional grid integration is accelerating rapidly with initiatives such as the European Commission's 2030 framework for climate and energy (which includes a 15% electricity exchange target for 2030) and the One Sun One World One Grid (OSOWOG) initiative. However, the Asia Pacific, despite its rapid energy demand growth and need for renewable energy, is lagging in grid integration. This chapter highlights the opportunity of grid integration for the Asia Pacific region.

Grid interconnection technologies are critical for future energy systems

An evolution in high voltage direct current (HVDC) now makes it feasible to connect energy grids over much longer distances in an economical manner. This evolution in HVDC includes improvements in voltage, reliability and operations.

The evolution in HVDC technology now makes it feasible to connect grids over much longer distances

Voltage improvements

Reduce transmission losses through higher voltages

10% annual growth

in voltage over the last 20 years

Reliability improvements

Increased reliability through improvements in cable material, engineering and design

Operational improvements

Increased cable lay depths

up to 3,000 metres

allowing cable routes to traverse previously inaccessible subsea terrain

System improvements

Increased transmission system lengths of up to

9x

over the past 20 years

Figure 1: Improvements in HVDC technology

Grid interconnectors allow electricity to be transmitted between regional grids, improving economies of scale and helping to balance demand during peak periods. Interconnection is particularly important as the penetration of variable renewable energy increases. As highlighted in Figure 2, grid connectivity brings a range of benefits.

Regional grid integration can provide a host of benefits

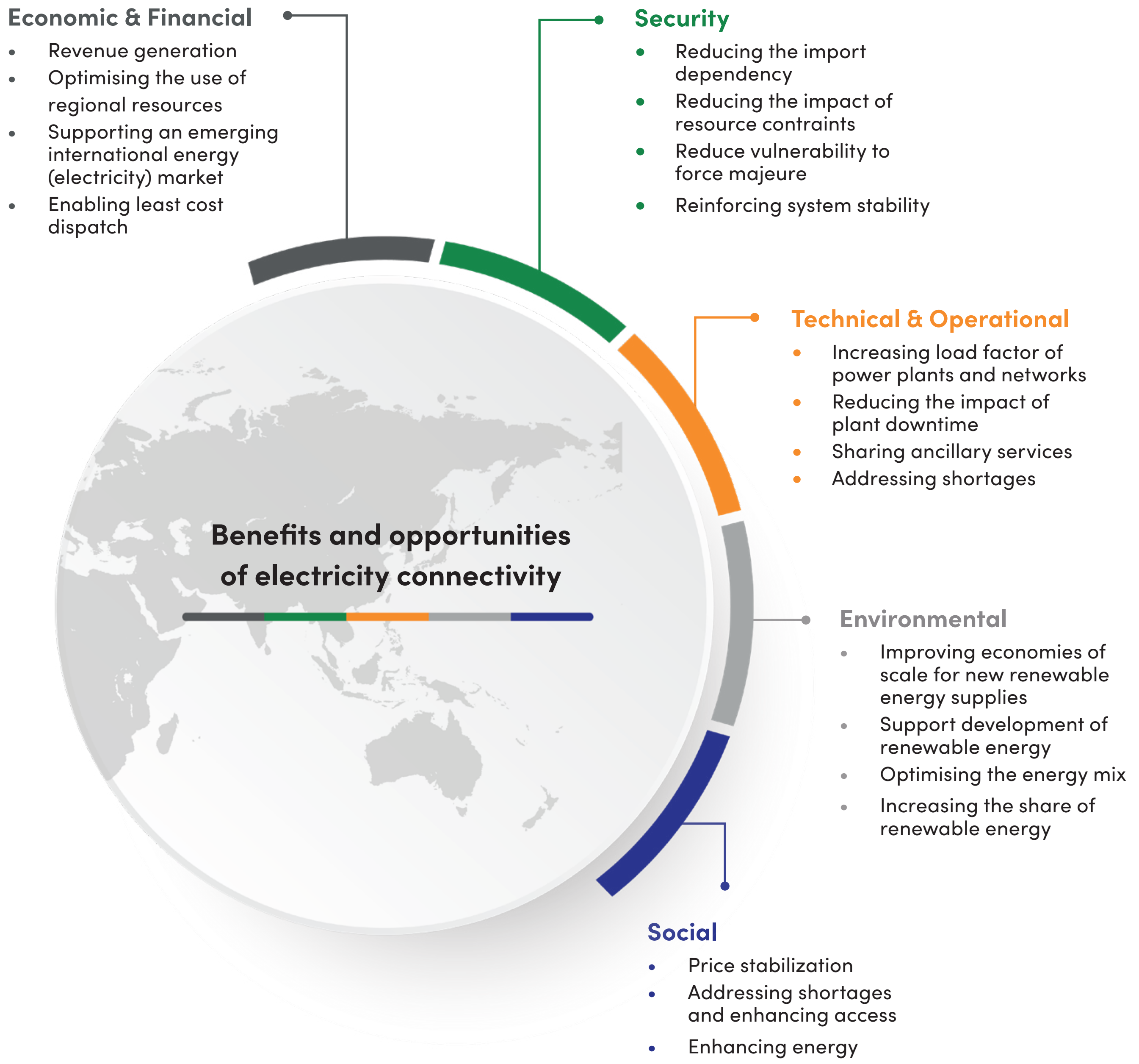


Figure 2: Regional grid integration benefits

Grid connectivity is particularly beneficial in Asia for several reasons:

- **Leveraging the region's diverse renewable energy assets.** The Asia Pacific has vast amounts of renewable energy potential. Take Southeast Asia for example. As a region, Southeast Asia has the potential to be the largest geothermal energy hub in the world, thanks to significant geothermal endowments in Indonesia and the Philippines. Indonesia alone has 29 GW in geothermal potential that it is currently developing.[1] Southeast Asia also has the potential to account for 16 percent of global estimated hydropower production capacity by 2050. Regional power integration can support renewable energy development by aggregating output over a large geographic region and deploying a mix of renewable technologies to help reduce the variability of renewable power supply and increase the resilience of the system.

- **Significant cost savings.** There are large potential cost savings from grid integration, particularly by reducing the required generating capacity. Research by the Economic Research Institute for ASEAN and East Asia (ERIA) has estimated that there could be net savings to the ASEAN power system of up to **USD 9.1 billion** by 2035 through an integrated transmission system enabling the growth of renewables.[2] An integrated transmission system will lead to lower O&M costs due to reduced labour costs, material repair costs, and travel costs. Additionally, in the "no-grid" case, countries such as Singapore and Brunei with smaller transmission systems relative to the scale of the installed generation, require higher reserves. However, with the integrated power grid, lower supply reserve margins are required for the same 24-hour loss of load expectation, thereby reducing costs. Previous research work by the Asian Development Bank (ADB) investigated the economic costs and benefits arising from electricity interconnection and trade between the countries of South Asia and between South Asia and the Central Asian region bordering Afghanistan. This study evaluated six existing or planned transmission interconnections between India and Bhutan, Nepal, Sri Lanka, Bangladesh and Pakistan as well as between Pakistan and Afghanistan. The study demonstrated clear benefits, including lowering of electricity costs and required generating capacity, and create annual benefits of **USD 3.9 to USD 4.1 billion.**[3]

- **Reducing carbon emissions and air pollution.** An integrated grid will facilitate the use of renewable sources of energy for electricity generation, thereby reducing emissions and pollution. The renewable electricity component of the total ASEAN electricity supply is forecast to be between 36 percent to 52 percent by 2040 under the ASEAN member states target scenario (ATS) and ASEAN progressive scenario (APS) respectively, in the fifth ASEAN Energy Outlook. Hydro power is anticipated to be the dominant source of renewable electricity followed by Solar PV. Per capita greenhouse gas emissions will increase by a factor of 1.5 and 1.2 under ATS and APS respectively, versus 1.9 under business as usual. This equates to 2,168 million tonnes of CO2e under APS versus 3,460 million tonnes of CO2e under business-as-usual in 2040. The difference in CO2e emissions between the business-as-usual and APS scenario is equal to the greenhouse gas emissions produced by almost 300 million vehicles annually.

- **Strengthening public finances.** Enhancing competitive renewable electricity generation can help reduce the need for expensive energy subsidies in Asia. The International Energy Agency (IEA) estimates that APAC countries spent at least USD 78 billion on fossil fuel subsidies in 2019. USD 61 billion was spent on oil products with the rest being spent on coal, electricity and gas. As more sectors of the economy electrify their energy demand (e.g., by transitioning ICE vehicles to Electric Vehicles), the need for fossil fuel subsidies is likely to reduce thereby strengthening the fiscal position of these countries.

1 Asian Development Bank (2018), Developing Indonesia's Geothermal Power Potential. Available at: https://www.adb.org/news/features/developing-indonesia-s-geothermal-power-potential

2 Economic Research Institute for ASEAN and East Asia (2014), Investing In Power Grid Interconnection In East Asia. Available at http://www.eria.org/RPR-FY2013-23.pdf

3 Asian Development Bank (2015), Cross-border power trading in South Asia: A techno economic rationale. Available at https://www.adb.org/sites/default/files/publication/173198/south-asia-wp-038.pdf

Grid connectivity in Asia lags Europe

Grid integration in the Asia Pacific region currently lags other regions of the world. For example, 70% of HVDC cable demand from 2022-25 is forecast to be in Europe (Figure 3).[4] In Europe, ~11.5% of electricity generated is traded among member states. In Asia this number is only ~0.3%. Many large economies such as Korea, Japan, Australia, do not have electricity import- export at all, and China imports only 0.1% of its total generation (Figure 4).

Moreover, export of electricity primarily takes place between neighbouring countries on a long-term bilateral basis. For example, India imports electricity from neighbouring Nepal and Bhutan, Laos exports almost half of its hydropower generated on the Mekong River to neighbouring countries – Thailand, Cambodia, Vietnam etc. Laos exported ~24 TWh or USD 1.33 billion in 2019, making it the 9th largest exporter of electricity in the world (more than Russia or Netherlands with ~20TWh of export). However, even with this volume the grid development is lagging - Laos currently supplies electricity mostly via a 115- 230 kV transmission lines (500 kV export lines only exist between Laos and Thailand).[5]

On the other hand, in Europe, interconnectors are supporting a much more robust electricity market enabling day- ahead/ intra- day trading, efficient price discovery, load- balancing and integration of intermittent supply from renewables. It took Europe more than 40 years to develop its system. In 1980, the amount of electricity import / export stood at ~100 TWh, it has since quadrupled reaching >400 TWh in 2019. However, due to the greater maturity of the HVDC manufacturing industry, it is possible to do this transformation 2x faster, achieving similar results to Europe within two decades (provided there is appropriate support).

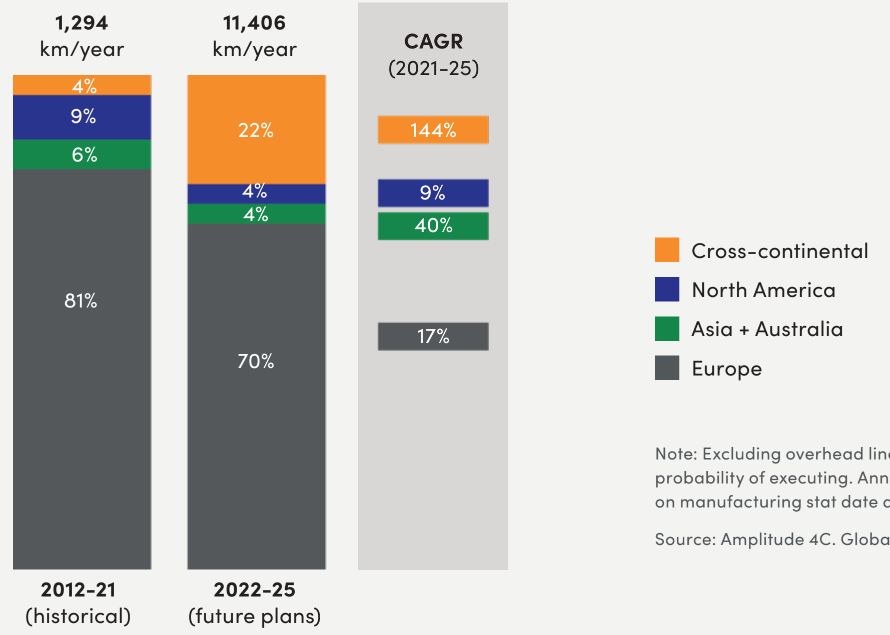
4 Data from 4C Offshore Global Cable and Offshore Wind Projects Database, Global Data Upcoming Interconnections projects, Amplitude; Sun Cable analysis.

5 The Study on Power Network System Master Plan in Lao People's Democratic Republic by Japan International Cooperation Agency, Henry Stimson Center.

Europe is currently dominating HVDC demand

Total Kilometres (km) of HVDC cable deployment

Km in average per annum



Note: Excluding overhead lines. Projects with Med/High probability of executing. Annual demand "smoothed" based on manufacturing stat date and target commission dates.

Source: Amplitude 4C. Global data

Figure 3: HVDC cable development by region

In Europe, ~11.5% of total generation is traded among member states; in Asia, this share is only ~0.3%

Electricity import and export as % of country's total power generation in 2019/2020

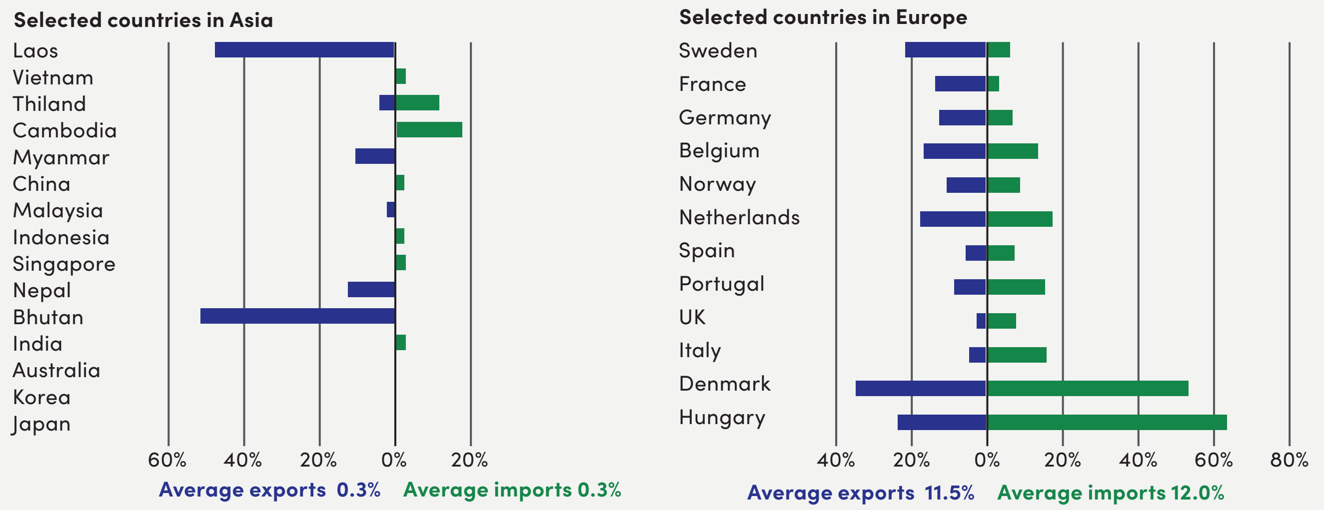


Figure 4: Electricity trade by region

The potential upside from grid connectivity in Asia is significant

As a thought experiment, we estimated the potential benefits to the Asia Pacific region if by **2040** we could match Europe's **2020 target** of cross-border electricity trade of 10% (which they have currently exceeded) and potentially achieve 15% (the **EU target in 2030**). This would achieve the following benefits:

Large new electricity market

Approximately 2,150 - 3,225 TWh of electricity in Asia Pacific[6] would be traded. Based on current retail electricity prices in each market, this is an annual market opportunity of USD 329-493 billion. There are large economic multipliers from this. For example, the indirect (linked to supply chain inputs) and induced benefits (linked to demand it creates downstream, including from wages) could be **7.5x** this number.

Investment and jobs

The investment associated with just the transmission component of this would be roughly USD 77-116 billion. This is an underestimate of the capital investment as it ignores the renewable energy, battery investment, voltage source converter investment, etc. Based on a job's multiplier from renewable energy projects, this could create approximately 580,000 -870,000 jobs. Applying the same multiplier of 7.5 for induced indirect and induced spending, this level of investment could trigger approximately USD 580-870 billion in economic activity in Asia Pacific.

Carbon savings

Assuming this electricity could displace coal (which is 56% of generation in the Asia Pacific) and natural gas (12% of electricity supply), this could reduce roughly **2,050-3,070** MtCO2e[7] per annum, which is equivalent to roughly 8% of global emissions in 2019.

6 Refers to ASEAN, Japan, South Korea, Taiwan, India, Sri Lanka, Pakistan, Bangladesh, Nepal, Bhutan, China, Australia, and New Zealand.

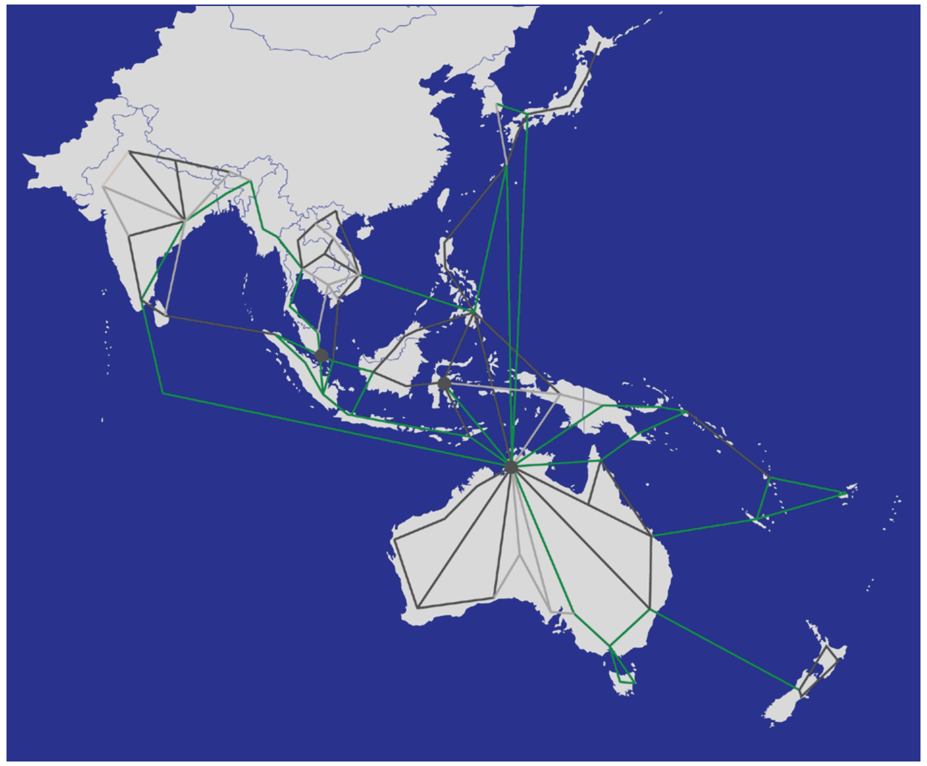
7 Assuming an emissions intensity of 0.92 tCO2e/MWh for coal and 0.62 tCO2e/MWh for natural gas.

If the Asia-Pacific were to match Europe's 2030 target for cross-border electricity trade of 15% by 2040, there will be **transformative economic, social and environmental benefits** across the Asia Pacific

Electricity	Value	Jobs	Emissions abatement
3,335 TWh	**USD 493 bn**	**870,000 jobs**	**3,070 MtCO2e**
Annual cross-border trade in electricity in the Asia-Pacific in 2040	Value of annual electricity traded in 2040 in the Asia-Pacific region	Potential jobs created in the Asia-Pacific region	Eliminated annually, equivalent to 8.3 percent of current global emissions

Figure 5: The economic, social and environmental benefits to Asia

A connected Asia could help transform the energy systems in Asia, **delivering jobs, new business opportunities, and major reductions in emissions.** Making it a reality will require overcoming a series of challenges, many of which will require breakthroughs in innovation.



A need for innovation

Creating an interconnected electricity grid in Asia requires a range of innovations to overcome potential challenges. Across the entire value chain of activities, there are a series of technical challenges to be overcome to create an integrated grid in Asia. These range from voltage improvements to minimize transmission losses in high voltage direct current (HVDC) cable through to finding ways to support dispatchability and energy security through high density energy storage systems.

While the technical challenges are real, the good news is that many corporates and research institutions are developing the "know how" to tackle them. This chapter explores some of these technical challenges and highlights areas where we believe innovation will be crucial.

The technical challenges to creating a green grid in Asia

Technology Readiness Levels (TRL) are based on a scale from 1 to 9, with 9 being the most mature technology. The definition of each level is provided as follows:

TRL 1	Basic research; basic principles observed and reported
TRL 2	Applied research; technology concept and/or application formulated
TRL 3	Critical function; proof of concept established
TRL 4	Laboratory testing of prototype component or process
TRL 5	Laboratory testing of integrated system
TRL 6	Prototype system verified
TRL 7	Integrated pilot system demonstrated
TRL 8	System incorporated in commercial design
TRL 9	System ready for full scale deployment

The TRLs vary for different components along the value chain, and there are some critical areas where research is needed. Figure 6 provides a few (non-exhaustive) examples.

There are a range of technical challenges across the value chain that must be overcome to enable cross-border electricity trade

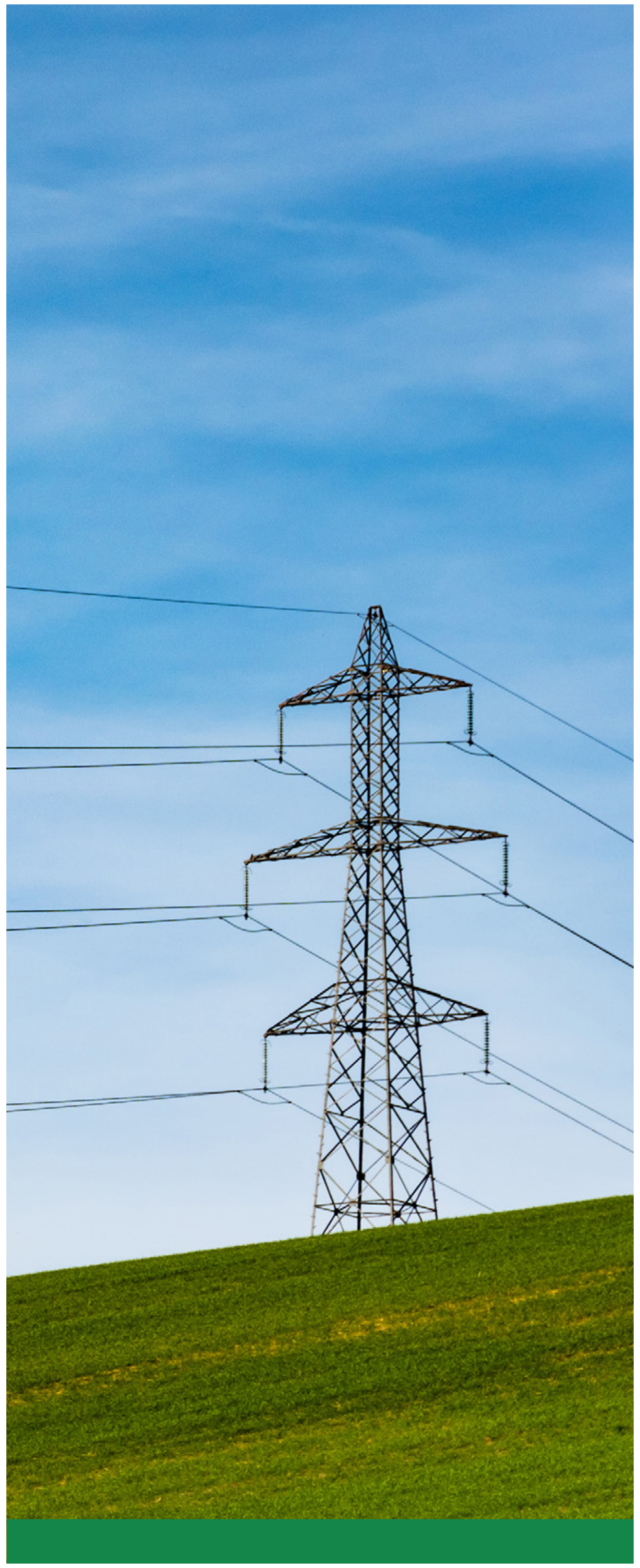
Simplified value chain	Share of spend of typical project	Current technology readiness	Examples of key research areas
Renewable energy generation	15-25%	Relatively mature with solar modules at TRL 9	• Automated deployment of solar arrays • Improvements in tracking algorithms
Energy storage system	20-30%	Varies by technology - lithium-ion batteries are more mature, others such as flow batteries, sodium sulphur batteries, thermal storage, and compressed gas storage less so	• Battery stacking • Long duration storage
Voltage source converter	5-7%	Mature (TRL 9)	• Reduce cost and increasing modularity
Overhead transmission line	5-7%	Mature	• Automation of line deployment (e.g. drone usage)
HVDC cable	Up to 45%	Varies by voltage	• Reducing transmission losses through alternative materials • Advance fault detection
Cable lay vessel		Mature	• Enhancement in design for repair versus deployment
End use		N/A	• Shifting to 100% renewable energy, including back up • Micro grid deployment

Figure 6: Research and innovation challenges

Key areas include:

- **Grid integration.** Understanding and overcoming the technical challenges around security, reliability, and control, when integrating many gigawatts of dispatchable, renewable power via HVDC at a destination, is critical, especially with a view towards entirely decarbonising entire generation and storage fleets. Optimal configurations for integration may include:
    - Physical microgrids, either grid-connected or standalone, which activate short-term, local backup for fast response to avoid downtime, while signalling to loads participating in the microgrid to ramp down demand, cease operations, or ramp up long duration energy storage systems.
    - Virtual microgrids, consisting of geographically-distributed interruptible loads and backup generators, coordinated remotely.
- **Future storage technologies.** Simulating combinations of established and emerging energy storage options, assessing technological readiness, and quantifying investment, land and material requirements, will lead to the design of optimal storage mixes to improve redundancy measures in areas. These novel systems may incorporate:
    - High-density energy storage facilities (e.g. battery stacking)
    - Li-ion, flow, therma, and gravity energy storage systems
    - P2X (power-to-gas, power-to-liquid) renewable fuels e.g. methane, methanol, and ammonia, derived from direct air capture of CO2 and electrolysis.
- **Long distance HVDC transmission.** Improving HVDC submarine cable performance will catalyse the development of myriad renewable HVDC projects. Operating voltage, conducting materials, insulation and armouring, and innovative O&M solutions will drastically augment power flow capabilities, and enhance reliability and security through efficient asset management and maintenance, maximising uptime.
- **Nextgen technologies.** Innovations spanning the technology stack of PV (e.g. perovskites, heterojunction, TOPCon, tandem), ESS (e.g. supercapacitors) and HVDC (e.g. superconductors) hint at potential step-changes in efficiency, degradation, customisation, and project economics, to drive the development of an Asian green grid. Effective modelling, prototyping, manufacturing and commercialisation efforts in these areas will demand deep collaboration through knowledge and capability sharing.
- **PV yield modelling.** Successfully and efficiently designing, financing, monitoring and operating PV gigaprojects will rely on breakthrough approaches to yield analysis. Integrated models that accurately represent optical phenomena, thermal losses, degradation modes, and soiling losses, will be used to optimise systems given specific site and equipment characteristics, reducing levelised cost of energy (LCOE) and improving asset performance.
- **PV automation.** Solely employing traditional methods to build and run the scores of multi-gigawatt-scale PV plants required for regional decarbonisation would prove immensely costly and challenging. The automation of construction, operations, and maintenance (potentially spanning civil works, equipment laydown, and electrical connections, to vegetation management, cleaning, and drone inspections) would substantially accelerate PV deployment while improving project economics, performance monitoring, and safety.
- **Power conversion system and plant control.** The development of customised power conversion equipment and control systems, in partnership with equipment manufacturers, offers opportunities in streamlined project integration, efficient design, and optimised dispatch.
- **Manufacturing opportunities and challenges at scale.** The enormous manufacturing drive spanning PV, ESS, HVDC cables, and power electronics required for an interconnected green grid in the region constitutes an equally large opportunity, as the demand for sustainably-sourced commodities and renewably-powered industrial processes can stoke upstream industry greening. The potential for circularity and low embodied carbon materials is substantial and needs to be understood so these options are realised as much as possible, minimising environmental impact and maximising social benefit.
- **Innovation in energy trade and use.** Establishing and operating renewable electricity and hydrogen trading hubs in the region may strategically assist green grid development, therefore assessment of industrial presence, finance and trading expertise, technology, infrastructure, and other techno-economic factors to understand the feasibility of establishing such operations in various locations is required. Downstream industries that require renewable electricity or fuels to decarbonise, including high-value manufacturing, carbon sequestration, food production, and information services will all be enabled and supported, but will require research and development efforts as new technological terrain is traversed.

Beyond the technical challenges, there are also a number of areas of policy innovation. Cross-border transmission involves a number of policy requirements, ranging from cable repair agreements through to underwriting mechanisms for reducing merchant risk (which is particularly crucial in large upfront capital investment projects). There is a need to curate and share policy best practices from around the world that could inform the approach in Asia.



The role of the Asia Green Grid Network

While many research institutions and corporates are tackling some of the technical challenges highlighted in Chapter 2, the current research landscape in Asia is characterised by its fragmentation and being sub-scale. There are significant potential benefits of finding ways to boost collaboration to speed up the process of innovation. This chapter outlines our plan for doing that.

What is the Asia Green Grid Network?

The Asia Green Grid Network (AGGN) is a virtual network of leading corporates and institutes of higher learning that have a shared vision of having an integrated green grid in Asia. The AGGN has three roles:

Educating. Provide briefings and seminars on key areas of the green grid (e.g., latest developments on HVDC transmission, best practice policy approaches, etc).

Collaborating. Bringing together leading academic institutions and corporates to share research on key topics associated with a green grid (e.g., microgrids, battery back up, etc.) and work together to form new connections.

Innovating. Providing a platform for research and development efforts. This would include key R&D funding required for the Australia-Asia PowerLink (AAPowerLink) project.

The **Asia Green Grid Network (AGGN)** will help drive the innovation to support a connected grid in Asia

What is the mission?

Drive the innovation needed to address the challenges to create a connected electricity grid across Asia, tackling issues ranging from transmission through to storage.

Who will be involved?

A range of research institutions and corporations from across Asia.

Figure 7: AGGN at a glance

How will it work?

Membership or partnership is open to any corporate or academic institution with a commitment to supporting cross-border renewable electricity trade and grid integration in Asia. For those interested in learning more, please email info@greengrid.sg

What is expected of members?

Members are required to carry out three activities:

1. **Contribute your expertise.** We would ask each organisation actively promotes the institute and encourages their researchers / experts to share their time in the lectures.
2. **Host discussions.** We plan to host the lectures and collaboration sessions at different partner organisations, and we would request your willingness to support this (e.g., offering a lecture hall or breakout rooms).
3. **Promote the network.** Encourage others to join.

More information can be found on the website, greengrid.sg

What is the timeline of activites?

We will provide detailed information on timelines of specific activities to members and partners. The AGGN will be organised into three thematic areas of research:

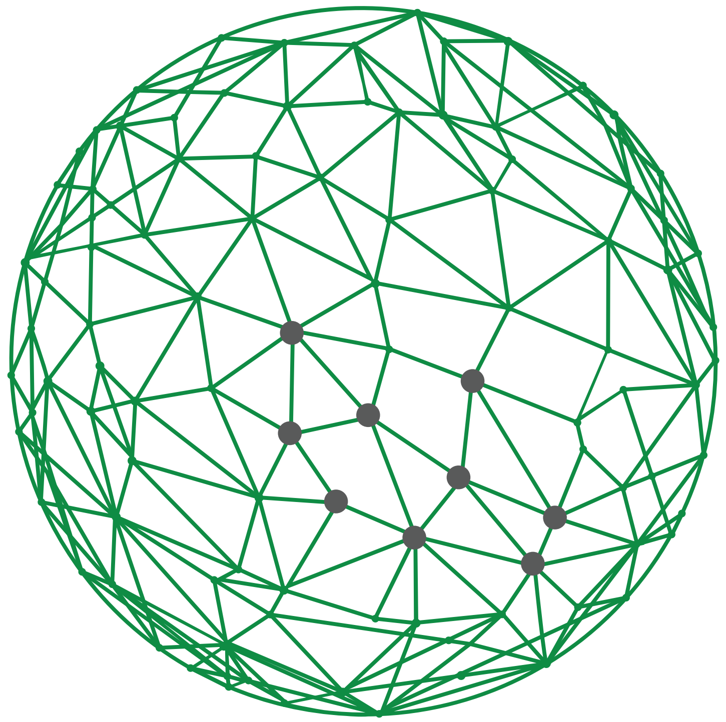
1. **Generation innovation.** Understanding technology opportunities to scale and improve the cost efficiency of renewable energy generation.
2. **Transmission innovation.** Understanding technology opportunities to improve the reliability, efficiency and implementation of HVDC transmission.
3. **Grid management and storage innovation.** Understanding technology opportunities to enhance grid management and storage, including topics such as microgrids, carbon free back up, and high density energy storage systems.

For the "grid management and storage innovation" thematic area, one initial working group will be commenced, based on the interest of AGGN participants. This will be focused on **High-density, long-duration energy storage:** Understanding opportunities to innovate energy storage systems to reduce their required land area, while maintaining performance and safety. Further priority topics for working groups will be determined by the advisory committee for that thematic area (comprised of members with a relevant background in that thematic area). The working groups will share existing research and knowledge on these areas, and to understand key research gaps which could involve research and development focus.

In addition, seminars are planned on the following topics:

1. Understanding advancements in HVDC and the opportunities in Asia
2. Understanding best practice policy approaches to supporting cross-border renewable electricity trade

Further activities will be informed by the interests of members of the AGGN.



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