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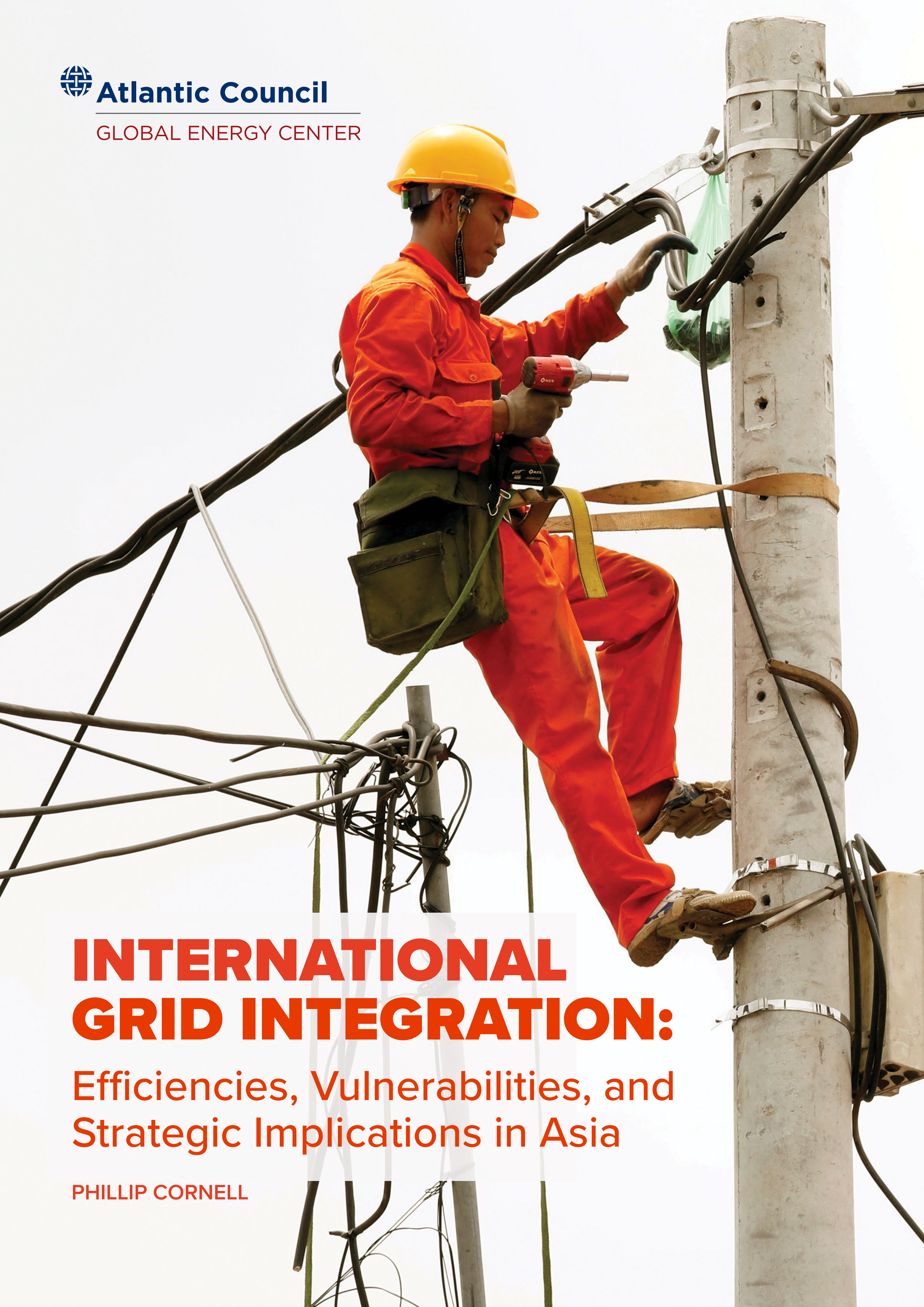

INTERNATIONAL GRID INTEGRATION:

Efficiencies, Vulnerabilities, and Strategic Implications in Asia

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ISBN: 978-1-61977-083-6

Cover Photo: Workers repair an electric grid in Hanoi, Vietnam, July 25, 2019. *REUTERS/Kham*

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January 2020

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Executive Summary

The new decade is poised to be one of fundamental change in the global electricity sector, with the widening cost advantages and spread of renewable energy. One result of that trend is that power networks and markets have entered a new phase of international and regional integration. More renewables benefit from larger, varied, and more flexible grids, which has spurred transmission build-out and grid modernization worldwide. Trading power across international borders and facilitating more complex markets both deliver increasing cost savings and efficiency gains, especially with rising demand and growing shares of renewables in the power mix. That is the case across many (otherwise very different) developing Asian economies. Evolving international electricity grids and markets also have regional political implications in a world where critical infrastructure informs trade and national security.

This report is intended to inform US policy responses to the energy transition as it spurs new interdependencies and reshapes geopolitical relationships.

As economic growth and power demand both increase in developing Asia (including the Middle East), countries are integrating cheaper renewables and shifting away from dependence on fossil fuels. Meeting demand while reducing costly emissions has encouraged new infrastructure and policy changes to increase cross-border trade. The changing political economy of electricity trade in the Middle East, South Asia, and Southeast Asia reflects trends that are likely to accelerate in this decade, and highlights the institutional challenges of international grid integration.

China's role is significant. Its program to supply grid infrastructure that can support the energy transition, and a particular vision of global interconnection, are products of the country's drive to engage its industrial capacity and sell to the region; to build a soft-power case for Chinese climate leadership; to expand regional political and economic influence; and to raise its national profile in a quiet rework of international energy governance. It is also a bet on a particular view of future continental electricity markets and architecture. The wider Belt and Road Initiative (BRI) to develop regional infrastructure networks with attractive financing and Chinese suppliers has raised concerns about debt traps and adequate standards, but transmission and smart grid technology can have additional implications for energy security, cybersecurity, and technology supply chains.

Against the backdrop of China's efforts to become a global leader in energy infrastructure, the US has had to face its own domestic grid challenges—especially the lack of domestic interconnections and the need for improvements in cybersecurity—as well as contend with rapid innovation at the distribution level and the need for market reform to support distributed generation and microgrids. At the same time, the US is seeking to formulate a coherent foreign policy to address Chinese influence.

This report argues that providing institutional support for regional electricity trade, and also promoting innovation in decentralized electricity models, can contribute to a wider US policy in the region. A response to emerging challenges posed by integrated power infrastructure in Asia will require a comprehensive approach.

- Bolster technical, policy, governance, and legal support to Asian and Middle Eastern partners and regional bodies to promote fair trade, domestic reform, transparency, and the effective management of regional and local electricity systems.

- Build upon the Free and Open Indo-Pacific strategy and regional energy programs to internationalize higher standards for 'quality' energy infrastructures; to leverage private investment in energy network technologies and infrastructures; to pool and coordinate funds among allies and multilateral institutions to compete for projects; and to promote market reform and new technologies.

- Innovate, pilot, and share models for integrating high levels of distrubted energy resources (DERs) through coordinated decentralization, including platforms to aggregate distributed generation, fully engage in capacity markets, and reinforce 'islanding' capacity of local distribution areas.

Introduction

Around the world, more and more countries and politicians are advocating deep decarbonization and ambitious renewable energy goals. Cost curves are helping, with new renewable generation undercutting greenfield fossil fuel projects in most circumstances, but achieving 80-100 percent renewable energy penetration requires new ways of thinking about the electricity grid. One is to interconnect grids and increase electricity trade across domestic and international borders.

The widespread growth of renewables complicates grid operations and market management with the need to smooth both daily and seasonal variability, which is partly managed through geographic diversity and aggregation. Renewable growth benefits a larger balancing area over which supply and demand are matched, so increasing interconnections, balancing, and trade across existing jurisdictions improves reliability with less generation capacity. Short-term energy and ancillary services markets must also adapt to accommodate both supply variability and energy market price impacts associated with intermittent generation at scale.

The nature of grid integration looks very different in North America, where demand is relatively stable and various subnational markets have been liberalizing at different paces for decades across a jurisdictional patchwork, compared to developing Asia, where national market reforms, renewable energy penetration, and infrastructure buildouts are often happening simultaneously in rapidly growing subregions. New energy technologies and financing opportunities are changing the economic calculus for power interconnectivity among Asian nations. As a result, a new round of regional initiatives for trade and grid integration may be better placed for success than the failed donor-driven[1] attempts of the past few decades.

The contrast across the Pacific is more than a technical question, particularly in a future where the control of interconnected cyber and energy networks can determine international relations and strategic power. Or, indeed, in a future where the pace of decarbonization may be affected by how smart technologies manage cleaner power system operations and transactions on a wider and more complex scale.

Southwest Asian (Middle East), South Asian (Indian subcontinent), and Southeast Asian (Greater Mekong) efforts toward regional power grid and market integration are impacting international political developments, even as the story of electricity trade in each subregion is politically distinct. Governments looking to develop sustainable generation capacity and drive economic growth are finding it harder to turn down the economic efficiencies offered by power sector reform and integration. They are contending with the need to develop institutions and modes of political cooperation with neighbors to make that happen. The infrastructure requirements are not cheap: under the International Energy Agency's (IEA) Sustainable Development Scenario (with double the current annual investment in renewables, leading to 4.7 times more installed renewable capacity in Asia by 2040), annual transmission investment worldwide to 2040 rises from current levels by a third to $103 billion, and network investment rises more than 71 percent to $475 billion.[2]

Costs are high and benefits are region-specific, even if they are significant in aggregate. The question is whether the changing calculus will be enough to overcome the usual political distrust among neighbors and the perceived security risks of critical infrastructure dependence.

China, with its Belt and Road Initiative (BRI) infrastructure mega plan, looms large in these subregional contexts, ready to provide financing to build and connect power infrastructures with Chinese technology in order to feed its own industrial base. A Chinese vision for "global energy interconnection" (GEI) has distinct political implications, and its main champions are close to the leadership in Beijing. Subregional groupings have incentives to insulate themselves from outside political and cyber influence, but the temptation is strong for individual states to green-light Chinese projects that are faster and cheaper to realize.

If US policy is to contend with this emerging reality, it will need to grapple first with its own model of grid modernization, and then with a realistic strategy to offer support (and a viable investment and political alternative) for developing partner countries to manage energy security. The United States struggles to build the long-distance high-voltage (LDHV) transmission infrastructure needed to facilitate its own national grid, despite the economic benefits of doing so. At the same time, the challenging legal environment arguably encourages models of more local distributed energy resources (DER) and helps to incubate cutting-edge US solutions to deliver grid stability without the need for ever-larger networks. Significant improvements in storage are still needed, but according

1 In this case, "donor" refers primarily to established national and multilateral development finance and aid institutions, including but not limited to the World Bank Group (WBG), the Asian Development Bank (ADB), the US Agency for International Development (USAID), and the UK Department for International Development (DFID)

2 *World Energy Outlook 2019*, International Energy Agency, November 2019, https://www.iea.org/reports/world-energy-outlook-2019.

to the 2017 Quadrennial Energy Review, “If hybrids [renewable plus storage systems] can self-power even a portion of a significant load, then tomorrow’s future electricity sector will be able to achieve national objectives for clean, secure, and affordable electricity supplies in a system that is imminently flexible and considerably resilient.”[3] The United States should work to promote DER technologies and decentralized models abroad, particularly where countries may be concerned about grid interdependence and foreign infrastructure investment.

How networked power markets around the world function, and the technologies that enable them, comprise an emerging field of competition for strategic energy security. Technology and energy governance can reflect and advance distinct political values. This paper provides an overview of the the challenges and opportunities presented by increased interconnections in the Middle East, South Asia, and the Greater Mekong Subregion, and a discussion of China’s role in energy infrastructure and connectivity. It also examines the US experience with interconnection and the development of new distributed technologies. The report concludes with recommendations to support regional electricity trade and to promote innovation in decentralized electricity models as part of a wider US foreign policy in Asia.

3 *Quadrennial Energy Review Second Installment: Transforming The Nation’s Electricity System*, US Department of Energy Office of Policy, January 2017, https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf.

1. Cross-Border Trade: A Boost for Economic Efficiency and Sustainability

International electricity trade grew significantly after 2000 (largely in Europe), but new transmission projects and energy technologies in developing countries have picked up since 2014. This new impetus is driven partly by new renewable energy generation, which makes regional integration particularly attractive in terms of economic efficiency. But interconnecting power grids is not an easy process. It requires cultural changes, domestic and institutional reform, and the building of trust between countries over sustained periods of time.

Markets and transmission systems are being forced to contend with intermittent generation, and daily and seasonal variability can pose a serious challenge. Expanding power systems across borders allows developers and market participants to take advantage of economies of scale on both the supply and demand sides, enabling the development of more widespread resources and access to cheaper supply sources. Constructing transmission interconnections alone is not enough—market design and regulatory approaches determine whether they deliver potential savings, which can be significant.

In various Asian subregions, total system cost savings are calculated to be on the order of 5–19 percent with regional power trade.[4] In North America, the National Renewable Energy Laboratory (NREL) calculates that improving transmission interconnections at the seams between subnational grids could reduce production costs by up to 4 percent.[5]

Savings can also vary depending on carbon and natural gas pricing. Indeed, it is often difficult to provide an accurate and concise accounting of existing and potential gains from cross-border electricity trade. In developing his model of trade for reciprocal load smoothing, Werner Antweiler notes that "any of the existing gains are realized at the sub-monthly level, and potential future gains from trade are contingent on modelling increased transmission capacity and measuring the benefits of improved sustainability."[6]

Still, it is possible to compare broad system costs between a fully unified grid with pooled supply and a collection of closed grids where each country or jurisdiction must maintain the capacity necessary to meet its own demand peaks. Unlike other commodities, electricity is difficult to store at scale, so supply and demand must be matched instantaneously. In order to keep the lights on during moments of peak demand, self-reliant jurisdictions must maintain enough reserve capacity to meet that demand. By engaging in cross-border trade, they can maintain the same level of reliability with less reserve generation capacity; they can also benefit from comparative natural resource advantages.

The environmental benefits of cross-border integration derive primarily from the fact that larger power systems are able to integrate higher shares of renewables. With larger balancing areas there is a natural smoothing of the underlying resource (for example, the wind blows and the sun shines with different levels of intensity across large geographic areas). As renewable generation becomes more competitive than traditional fossil fuel generation in many parts of the world,[7] the intermittency of the technology is encouraging larger international grid and driving domestic energy market reform in order to match pricing across borders. In times of abundant generation from renewables in one part of an interconnected system, excess electricity does not need to be curtailed at zero value and can be exported to other parts where its value at the same time is higher, for example, due to a low availability of domestic resources or because of higher demand patterns.

Challenges

While the economic gains of increasing cross-border electricity trade and integrating markets are often clear and growing around the world, implementation is often difficult

4 Govinda R. Timilsina et al., "How Much Could South Asia Benefit from Regional Electricity Cooperation and Trade?," World Bank Group, June 2015, http://documents.worldbank.org/curated/en/846141468001468272/pdf/WPS7341.pdf; *Pan-Arab Regional Energy Trade Platform Initiative: A Brief on World Bank Support to Electricity and Gas Trade in the Pan-Arab Region*, the World Bank, 2019, http://pubdocs.worldbank.org/en/299571572861656857/mena-arab-energy-conf-booklet-nov-6.pdf; and *Building a Sustainable Energy Future: The Greater Mekong Subregion*, Asian Development Bank, December 2009, https://www.adb.org/publications/building-sustainable-energy-future-greater-mekong-subregion.

5 Aaron Bloom, "Interconnections Seam Study," National Renewable Energy Laboratory, (presentation at the TransGrid-X 2030 Symposium, Ames, Iowa, July 26, 2018), https://www.terrawatts.com/seams-transgridx-2018.pdf.

6 Werner Antweiler, "Cross-border trade in electricity," *Journal of International Economics* 101 (2016): 42-51, accessed November 2019, https://www.sciencedirect.com/science/article/pii/S0022199616300423.

7 Among 2020 projects in the IRENA database, 77 percent of onshore wind project capacity and 83 percent of utility-scale solar PV have costs that are lower than the cheapest fossil fuel alternative, and costs are falling. See: *Renewable Power Generation Costs in 2018*, International Renewable Energy Agency, May 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/May/IRENA_Renewable-Power-Generations-Costs-in-2018.pdf.

The Bạc Liêu province offshore wind farm in Vietnam, December 2015. *Wikimedia Commons/Tycho*

in practice. Economic benefits are rarely distributed evenly across parties. Since benefits can be hard to measure, it can be difficult to agree on cost-sharing for interconnection.

Interconnection can provide benefits, but also challenges, for the energy security of the system. Countries or jurisdictions may expect to maintain self-sufficiency; tight coupling of power systems across borders can increase the risk of blackout spillover; and synchronized systems must deal with unexpected cross-border power flows (often called "loop" or "transit" flows), particularly where a high penetration of renewables increases the impact of weather-related fluctuations.[8] Finally, local policies (for example, to promote investment in renewables or to subsidize less economic fossil generation), can increase uncoordinated cross-border power flows. Local capacity mechanisms can result in an oversupply of capacity in one jurisdiction relative to total system needs. On the other hand, policies to phase out particular plants or fuels can also result in a rapidly changing regional resource mix.

Technologically, a significant barrier to increasing continental-scale electricity trade is the challenge of realizing long-distance power transmission projects.[9] Long-distance transmission projects are comparatively difficult to build in Europe or North America, requiring ten to fifteen years to realize (including planning, scoping, mapping, environmental review, public comment, project approval, permitting, land acquisition, and construction). Cross-border interconnector development takes even longer, requiring coordination among multiple jurisdictions, regional planning, and agreements on how to share investment costs. In contrast, the recently opened Shandong-Hebei 2,800-km 1-million-volt line in China took less than two years from project approval to operation.[10]

Whether for power line construction or managing international electricity trade, the underlying issue is one of energy market governance and the need for increased cross-border coordination. Both are best enabled through governing institutions and regional market frameworks, for example, to develop regional power pools, but these are also subject to political negotiation and involve some relegation of sovereignty. Political institutions, therefore, have a key role to play in terms of supporting overall coordination. Regulatory institutions are important because they determine the rules for operations to ensure reliability and to allow local market participants to benefit fully from the gains of trade (for example, to ensure reciprocal market access). Finally, while market frameworks are

8 *Integrating Power Systems Across Borders*, International Energy Agency, June 2019, https://www.iea.org/reports/integrating-power-systems-across-borders.

9 Werner Antweiler, "Cross-border trade in electricity."

10 "Shandong-Heibei 1000kV UHVDC Transmission Line Project," Zawya, accessed November 2019, https://www.zawya.com/mena/en/project/121118080117/shandong-heibei-1000kv-uhvdc-transmission-line-project/.

necessary to enable trade, they depend on the underlying market structures of the interconnected jurisdictions.[11]

In many cases that means effective electricity trade also requires reform at the domestic level. Energy or fuel input subsidies can mask the true price of the traded power, making price discovery at the border difficult without cross-subsidizing neighbors. If countries do not allow third-party access to the transmission network, it can be difficult to facilitate power transit through a jurisdiction and to determine accurate transit (or wheeling) charging. Trade may still happen in the absence of significant market reform, but it may be limited to one-off or emergency trade with specific approved rates. Benchmarking prices to better reflect marginal cost can help, but reaping the economic benefits of intra-day trading and continuous commercial exchange ultimately requires a more flexible market structure.

The same is true for effective large-scale introduction of variable renewable power. Countries are already grappling with how to design markets and transmission systems to handle both intermittency and the requirement for backup power that renewables entail. More advanced countries need to develop better capacity markets and scarcity pricing mechanisms, and grid operations must contend with higher frequency scheduling and dispatch. But developing countries with a legacy of vertically integrated monopoly utilities may still be operating under a single-buyer model or only starting to accommodate private sector participation. The process of domestic power market reform has been reignited in many countries, often after years of stop-start progress. It is politically challenging, but easier where political power is nationally concentrated and there are fewer and more homogeneous jurisdictions.

11 *Integrating Power Systems Across Borders*, International Energy Agency.

2. Connecting in Asia

Across Asia, economic growth and rapid development is driving up demand for electricity and the need for power generation capacity. The outlook for government budgets, particularly in countries that have relied on fossil fuel exports, is not necessarily bright. Integrating new power sources, including major plans for large-scale renewable energy expansion, requires greater private sector and external financing, and the domestic market structures to enable it. Many countries are pushing ahead with power market reforms that had been stalled for years, and also reexamining how to increase cross-border electricity trade.

China is a significant factor. Its program to encourage power interconnection in Asia and beyond is the product of the country's drive to engage its industrial capacity and sell to the region; to build a soft-power case for Chinese climate leadership; to expand regional political and economic influence; and to raise its national profile in a quiet rework of international energy governance. The possibility of cyber leverage opens the door for more sinister activity, now or in the future, to the degree that such intentions may exist.

China's Role in Asian Interconnection

China's role in the story of Asian transmission infrastructure starts at home.[12] Decades of Chinese economic growth, facilitated by cheap lending by state-owned banks and enterprises, led to massive industrial capacity overhangs, including in the energy sector. Beijing's Keynesian free-spending approach to the 2009 global slowdown also meant a significant infrastructure build in the subsequent decade. Under Chinese President Xi Jinping, the government began restructuring the power sector and moving away from coal, which in 2014 accounted for 84 percent of electricity generation (it is now 67 percent). Huge new capacity additions, particularly in large hydroelectric projects (in the southwest) and thermal projects (in the midwest), made the country self-sufficient in electricity and moved generation further from major eastern cities, but required new long-distance high-voltage (LDHV) transmission lines to connect supply and demand. Two transmission companies, State Grid and China Southern Power Grid (CSPG), had emerged from the 2002 unbundling of transmission and distribution, and by 2006 they were constructing ultra-high voltage (UHV) lines across the country.

China has since been pushing the boundaries of UHV transmission technology (in conjunction with foreign suppliers like ABB). In 2019, State Grid completed a 3,300-kilometer 1.1-million-volt line from Xinjiang to eastern Chinese cities, and also a groundbreaking UHV gas-insulated enclosed and underground line in Jiangsu Province. The unprecedented build-out was thanks to heavy state subsidies and a streamlined construction process. Chinese dominance in the sector is partly because building transmission lines in China is faster and easier than in countries where property rights and local political power pose greater impediments. However, a lack of coordination between the huge Chinese energy bureaucracy's renewable energy ambitions and large state-owned transmission operators has resulted in significant network congestion and subsequent curtailment of some renewable generation—and a great deal of excess capacity in regions like the southwest.

As China now reorients its economy toward consumer-led growth, it needs to develop its near-foreign markets to offtake surplus supply from the energy, construction, and engineering sectors. The IEA counts at least 7,000 km of Chinese-built transmission lines coming online in developing Asia between 2013 and 2022, particularly in Cambodia, Laos, and Pakistan.[13] Most projects are financed by the Exim Bank of China, and adopt Chinese design and equipment standards. The majority of projects involve the construction of substations, roughly one-third of the projects are of 500 kV and higher, and some are cross-border projects. The 500-kV "Backbone & Subregion Transmission Line Project" is funded by Exim Bank and will allow electricity trade between Cambodia and Laos from 2021.

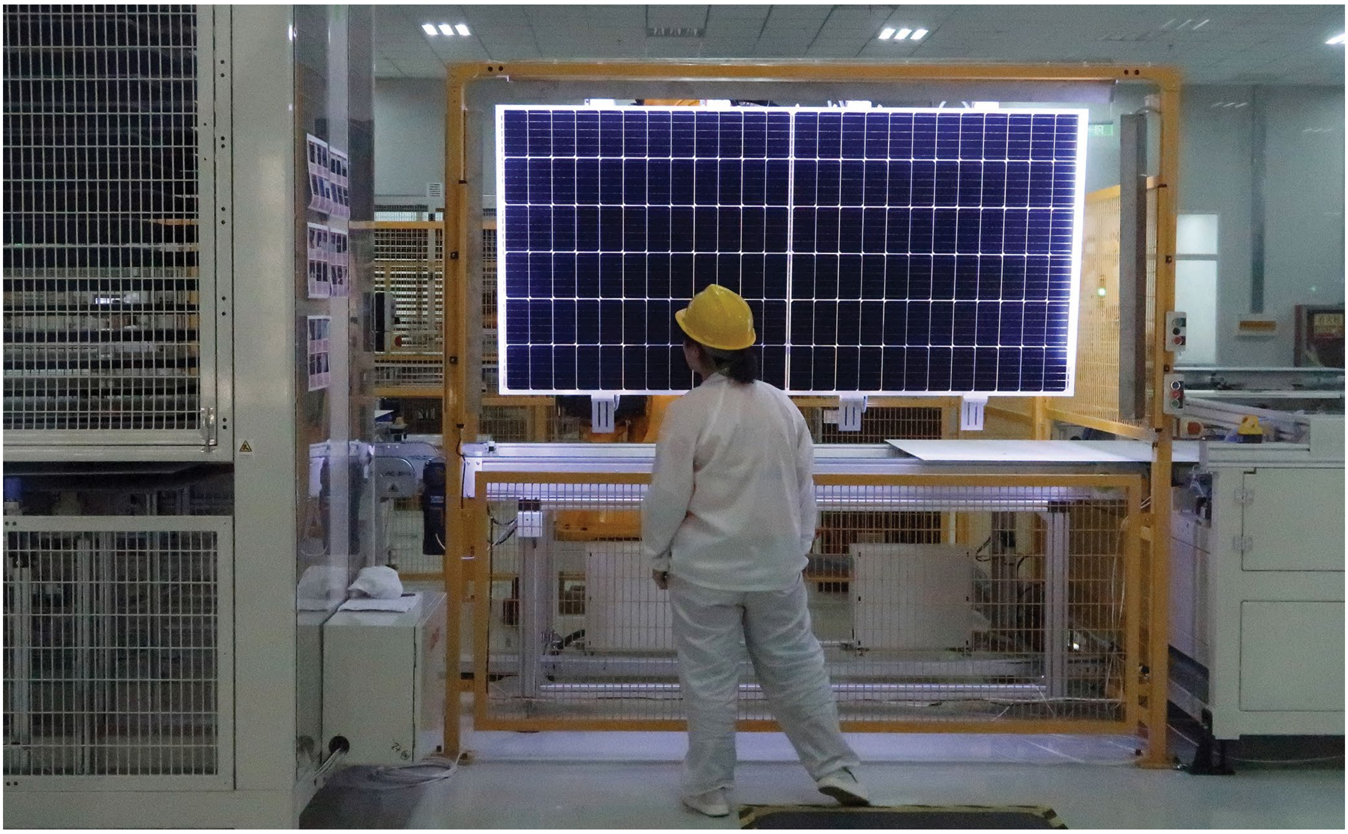
Energy projects have always been a major part of China's BRI infrastructure mega plan for Eurasia. At the Second Belt and Road Forum for International Cooperation in April 2019, an official report estimated that energy investments in the BRI countries would add up to $27 trillion by 2050, with $7 trillion alone going to power grid construction, and more than 200 million new jobs would be created in the process.[14]

That report was published by the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), a young international

12 This section is adapted from: Phillip Cornell, "Energy governance and China's bid for global grid integration," EnergySource, May 30, 2019, https://www.atlanticcouncil.org/blogs/energysource/energy-governance-and-china-s-bid-for-global-grid-integration/.

13 *Chinese companies energy activities in emerging Asia*, International Energy Agency, April 2019, https://www.iea.org/reports/chinese-companies-energy-activities-in-emerging-asia

14 *Research Report on the Belt and Road Energy Interconnection*, Global Energy Interconnection Development and Cooperation Organization, April 2019, https://img1.nengapp.com/tech/ydyl/yjbg_en.html.



A worker conducts quality-check of a solar module product at a factory of a monocrystalline silicon solar equipment manufacturer in Xian, Shaanxi province, China, December 10, 2019. *REUTERS/Muyu Xu*

organization set up by State Grid in 2016 under the leadership of its former chief executive to advance GEI. That strategic plan, to build out and then connect the power grids of Eurasia and beyond, overlaps with BRI's energy component and is "a personal project of Xi Jinping."[15] Its potential to bolster Chinese influence highlights the role of interconnected infrastructures to distribute political power in the modern global economy. China's advancement of GEI through established international regimes like the United Nations (UN) Framework Convention on Climate Change (UNFCCC), the UN's 2030 Agenda for Sustainable Development, the Clean Energy Ministerial, the African Union, and the Gulf Cooperation Council (GCC) is a stark example of how the US retreat from the international order is impacting power and influence in the twenty-first century.

The efficiencies gained by trading power among distant markets with price disparities are real, and the free trade argument for GEI is certainly one employed by its proponents. However, this argument suffers from the same critique as other unqualified free trade ideologies by ignoring disparities among local policies and values, whether about government subsidies, labor rights, or environmental standards. This argument favors state-subsidized equipment and generation, and rewards cost efficiencies from unregulated or corrupt spaces. Carbon leakage can occur where emission-intensive electricity produced in countries without strict regulation undercuts power elsewhere. By trading the end product directly, free power trade also masks the myriad state interventions or poor conditions along the value chain. All of this favors the Chinese model, with capacity overhangs and state-supported energy companies looking to offload onto the world market.

However, Chinese authorities also recognize the potential of continental grid integration to foster regional economic and political influence.[16] Developing international grids creates demand for solar panels and digitalized distribution technologies, where China excels, but also for all the consumer products and services that rely on cheap and reliable power supply—particularly in conjunction with new Chinese information and communications technology (ICT) infrastructure. During the financing and construction phase, China reaps the leverage of other big BRI projects—dictating guarantees, lending conditions, and debt repayment while setting technical standards.

15 James Kynge and Lucy Hornby, "Truly Wielding Power: How China Wants To Create The World's First Global Electricity Grid," OZY, June 14, 2018, https://www.ozy.com/fast-forward/truly-wielding-power-how-china-wants-to-create-the-worlds-first-global-electricity-grid/87270/.

16 Jonathan E. Hillman, *Influence and Infrastructure: The Strategic Stakes of Foreign Projects*, Center for Strategic and International Studies, January 2019, https://csis-prod.s3.amazonaws.com/s3fs-public/publication/190123_Hillman_InfluenceandInfrastructure_WEB_v3.pdf.

Where State Grid or CSPG acts as owner or operator, there are also possibilities for intelligence gathering or even access denial. Furthermore, as national and regional grids become interconnected, supranational market governance is necessary to facilitate trading, load balancing, and wider network operations. Even if local grids are independently operated, deep interconnection means that supply and demand will increasingly be matched across the super-grid, making them more interdependent.

It is also worth noting that, despite claims to be greening the BRI, the advantaging of Chinese energy investments does not necessarily imply cleaner outcomes. While cost curves imply a greater role generally for renewable energy generation going forward, to date Chinese cross-border transmission has mostly linked Chinese-built coal and large hydro projects. While grid expansion can promote grid stability in the presence of variable renewable technologies, UHV lines are optimal to link concentrated large-megawatt projects. Indeed, most of the calculated gains of the reduction of CO_2 emissions from interconnections in Asia derive precisely from increased shares of large hydropower, with its attendant environmental issues.

The BRI is largely focused on the wider Asian continent, but especially the populous and growing markets of southern Asia. This makes the processes of regional interconnection in those regions all the more important, particularly in terms of how BRI financing and construction can facilitate the infrastructure requirements—and also in terms of how it may advantage Chinese firms looking to sell generation, grid management, and distribution-level technologies.

Middle East

In the Middle East, three separate interconnectors link the Maghreb countries (since the 1950s); the Mashreq countries (since the 1980s); and the GCC (since the 2000s). Some countries are synchronized to the European grid, Morocco is a net exporter to Spain, and the defunct Desertec plan once envisioned large-scale export of Saharan solar energy to Europe. However, trading activity within the region is very limited, and usually takes the form of one-off or emergency trades. The GCC interconnection has a particularly advanced institutional arrangement designed to handle regular commercial activity, but only operates at 4–5 percent of capacity (compared to almost 50 percent for European interconnections). That is largely because of domestic fuel subsidies for generation feedstock that get hidden in electricity prices, making it difficult to price traded power without cross-subsidizing neighbors. Changes in the global energy system are pushing many countries in the region to transform their domestic economies, and, in the process, to increase regional electricity trade.

The Middle East is home to major fossil fuel producers and exporters, where the prevailing political bargain traditionally offered cheap energy and state-funded development in return for political acquiescence and allowing the state to retain monopoly control over energy resources and their (very profitable) sale abroad. However, the outlook for the oil price is constrained in the short term by global trade disputes, in the medium term by a flood of unconventional supply, and in the long term by the prospect of peak oil demand—making the underlying political bargain fiscally untenable.

As countries across the region confront rapidly growing electricity demand, structurally weaker oil prices, and a changing fuel mix, greater intra-regional trade and market integration can deliver market efficiencies to more securely meet growing demand while supporting economic development and energy sector transitions.

Domestically, many oil-producing countries are engaged in programs to diversify their economies. National economic reforms across the region often include energy sector reform and ambitious clean energy targets. Grid interconnection could improve the efficiency of variable renewable energy integration, reduce costs, and improve reliability.

A recent World Bank study identified the potential economic benefits that the Middle East and North Africa (MENA) region could accrue if all of its eighteen countries engaged in full regional bilateral electricity trade. These benefits include direct sector-level gains from optimizing regional generation assets. In scenarios with natural gas priced at current domestic levels, the introduction of electricity trade decreases the total system cost (in present-value terms) by $83.6 billion, or 6 percent.[17] The savings from trade are further enhanced in the scenarios with unsubsidized (international) gas prices, where the total system cost decreases by $90.9 billion, or 6.7 percent. Finally, when gas price liberalization is also accompanied by the introduction of carbon caps, the benefits from trade are even greater, reducing the system costs by $135 billion, or 9.2 percent.

There is a strong economic case to be made in favor of fostering regional power markets, particularly given endemic budget constraints, but political considerations and rivalries can pose impediments. Motivated champions of regulatory alignment are lacking due to concerns about implicit wealth transfer (from trading subsidized resources), overdependence on neighbors for strategic resources (especially where there are political difficulties, for example, with Qatar, Iran, or Israel), and the low number of market participants. As a result, cross-border infrastructure is difficult to build and reliably operate, and domestic market reform is taking place at various speeds. In 2019, the League of Arab States (LAS) and the World Bank spearheaded renewed efforts to establish a

17 *Pan-Arab Regional Energy Trade Platform Initiative*, the World Bank.

Pan-Arab Electricity Market (PAEM) to deliver hundreds of billions of dollars in system savings and reduce the need for generation capacity by almost 50 gigawatts (GW) by 2035.[18]

Yet when it comes to the need for national infrastructure investment, there is a tension between various models of transparent and competitive bidding open to outsiders on the one hand, and one of fiscal-expansionary, state-driven strategic investments coupled with closed-door deals (for example, with favored national champions that crowd out local competitors, or with foreign companies or foreign state-owned banks where deals are part of a political quid pro quo) on the other hand. In Saudi Arabia, early efforts in the context of its Vision 2030 economic transformation plan to reform the electricity market and hold competitive auctions for new renewable energy capacity have given way to strategic financing by its sovereign wealth fund (Public Investment Fund, or PIF) and a penchant for local champions or big foreign partners. ACWA Power, an energy developer and success of the Saudi private sector in 2018, is now mostly owned by the PIF and the Chinese Silk Road Fund. Public financing or cheap credit that is coupled with long-term foreign control of assets or technology, can be seductive ways to circumvent close scrutiny of the creditworthiness of projects or borrowers. However, they can also pose long-term strategic risks.

Chinese firms have established a foothold in the region, with major energy projects in the United Arab Emirates (UAE), Egypt, Jordan, and Turkey. Egypt started cooperation with State Grid to construct 1,210 km of high-voltage transmission lines, and also engaged Chinese companies such as Huawei Technologies Co., Ltd. and ZTE Corporation on smart meters. A long-delayed interconnection between Egypt and Saudi Arabia is planned to link two of the largest regional power markets and extend the GCC power pool; State Grid is a main bidder. In 2019, State Grid also signed a memorandum of understanding (MoU) for international interconnections with National Grid Saudi Arabia[19] and announced its partnership to revive Desertec 3.0.

South Asia

In South Asia, India serves as the major hub of regional electricity trade, both because of its size and its geographic centrality. Over the past decades, India successfully integrated its separate regional grids into one national power market. A major new push to connect South Asia was initiated after the turn of the century. Since the concept of the South Asian Association for Regional Cooperation (SAARC) Energy Ring was announced in 2004, limited progress has been made to advance this plan for an interconnected electricity system. Donors and international organizations who pushed the idea had hoped that the South Asian interconnection would form a key building block for an Asia-Pacific power system. Indeed, the economic case for South Asian power trade is particularly strong. The region faces a combination of uneven distribution of energy sources, persistent electricity shortages, and growing demand. Countries in the region have also committed to pursuing a low-carbon energy system and increasing their share of renewables.

World Bank analysis from 2016 calculates that increased regional electricity integration and trade could generate, on average, direct cost savings on the order of about $9 billion per year relative to the status quo, or 5 percent cost savings to 2040. The system savings exceed the costs to facilitate interconnection and trade by more than five times over twenty-five years.[20] Regional power trade could also reduce greenhouse gas (GHG) emissions by more than 9 percent compared with business as usual, partly from an increased use of hydro power (+72 GW) and decreased use of coal (-54 GW) to 2040.

To help realize those savings, a number of subregional initiatives have been mobilized by SAARC, the World Bank, the Asian Development Bank (ADB), the UK Department for International Development (DFID), and the United States Agency for International Development (USAID). US technical assistance helped to construct interconnections between India and Bangladesh, and to develop Nepal's Energy Regulatory Commission Act. The SAARC Energy Centre was established in 2014 as a subregional institution and secretariat.

A 2018 UN report concluded that:

> An interconnected grid covering the subregion is an essential enabler for power generation infrastructure and the development of cross-border electricity trade. With the right mix of national complementary policies, power grid connectivity could form the basis of a subregional delivery system for low carbon energy, facilitating the transition to renewable energy, and as such become a regional public good for South Asia.[21]

It also acknowledged that there exists an enormous political

18 Ibid.

19 "The National Grid Saudi Arabia, Chinese Cet, And Acwa Power Sign An Mou For New Opportunities In Cross-Border Interconnections And Power Grids," ACWA Power, press release, June 26, 2019, https://www.acwapower.com/news/the-national-grid-saudi-arabia-chinese-cet-and-acwa-power-sign-an-mou-for-new-opportunities-in-cross-border-interconnections-and-power-grids/.

20 Govinda R. Timilsina et al., "How Much Could South Asia Benefit from Regional Electricity Cooperation and Trade?"

21 "Integrating South Asia's Power Grid for a Sustainable and Low-Carbon Future," United Nations Economic and Social Commission for Asia and the Pacific, April 3, 2018, https://www.unescap.org/sites/default/files/Integrating%20South%20Asia%E2%80%99s%20Power%20Grid%20for%20a%20Sustainable%20and%20Low%20Carbon%20Future_WEB.pdf.

and institutional challenge among multiple countries to implement an interconnected grid—perhaps, most importantly, galvanizing strong political ownership of electricity trade as an issue by leaders and high-level policymakers in South Asia is required. Another challenge is to improve institutional capacity among system operators and regulators, both of which play important roles in trade and integration.

It is true that regional cooperation can play a role in bridging these gaps. Initiatives such as SAARC's can provide a focal point with important analysis and policy coordination. Development institutions and the IEA can provide key data and technical advice. However, in the end, domestic politics and the perception of risks to national security or sovereignty will often have more impact than technical arguments.

With the launch of the BRI in 2014, it became clear that the initiative's major elements would include power infrastructure in South Asia, including in countries like Bangladesh and Pakistan. There was a hope that with regional agreements and a political framework to facilitate trade, Chinese financing and construction could provide the infrastructure to enable it. Indeed, the SAARC Framework Agreement for Energy Cooperation[22] and the India-Nepal Power Trade Agreement were also signed in quick succession in 2014. Indian Prime Minister Narendra Modi's newly elected government was supportive of regional cooperation and trade. It was also determined to liberalize India's economy, reform the power sector, and develop the institutional structure to introduce private sector participation and facilitate commercial electricity trade. When SAARC energy ministers met that year, Piyush Goyal, India's minister of state for power, coal, new and renewable energy, said he dreamt of "a seamless SAARC power grid within the next few years" and offshore wind projects "set up in Sri Lanka's coastal borders to power Pakistan or Nepal."[23]

Five years later, those hopes have proven unfounded. The region has instead become a prominent example of contention over the BRI. India acts as its chief opponent, rival Pakistan is a main proponent and recipient, and countries like Nepal, Bhutan, Sri Lanka, Bangladesh, and the Maldives face economic choices that are now highly politicized.[24]

In 2016, India's Ministry of Power issued guidelines that imposed a slew of major restrictions on who could engage in cross-border electricity trade. Aditya Pillai argued in the *Hindu* that "there was a strong undercurrent of defensiveness in the guidelines, which seemed to be a reaction to perceptions of increased Chinese investment and influence in the energy sectors of South Asian neighbors."[25] After objections by Bhutan (which relies on hydroelectricity exports to India for 40 percent of its income) and Nepal, the Indian government repealed the most stringent provisions of the 2016 legislation, which permitted only companies fully owned by partner governments, or majority-owned Indian companies, to export power to the Indian market. According to Pillai, "earlier concerns that India was enabling the incursion of foreign influence into neighboring power sectors seem to have been replaced by an understanding that India's buyer's monopoly in the region actually gives it ultimate leverage. More broadly, India seems to have acknowledged that the sinews of economic interdependency created by such arrangements have the political benefit of positioning India as a stable development partner rather than one inclined to defensive realpolitik."[26]

The politics of hydroelectricity and its importance to India's northern neighbors highlight the energy-water nexus in South Asia, and the need for integrated planning when considering regional electricity trade. Over-reliance on hydroelectricity can have severe downstream impacts along the various Himalayan tributaries and impact seasonal power supply. Run-of-the-river hydroelectric projects, which are common in Nepal and Bhutan, often fail to meet electricity demand during the dry season (when water is needed for residential and irrigation uses). Plans that only consider water for hydropower can undermine downstream benefits such as navigation, regional connectivity, and flood control.

The amended regulations may show some sign that India is ready to reengage, at least with its smaller regional neighbors. Since his reelection in May 2019, Modi has doubled down on his "Neighborhood First" strategy, even if the aim is to maintain India's sphere of influence in the face of Chinese deals.[27]

Indeed, political distrust of Chinese intentions remains high in India, suggesting that for the time being intra-South Asian interconnections will exclude BRI financing or construction. Meanwhile, new domestic transmission infrastructure within Pakistan (for example, the Matiari-Lahore line and the Port Qasim line) and Bangladesh (Chittagong

22 See: "SAARC Framework Agreement for Energy Cooperation," Government of India Ministry of Power, November 27, 2014, https://powermin.nic.in/en/content/saarc-framework-agreement-energy-cooperation-electricity.

23 "Shri Piyush Goyal calls for Building SAARC Power Grid," Government of India Ministry of Power, October 17, 2019, https://pib.gov.in/newsite/PrintRelease.aspx?relid=110632.

24 Andrew Small, "The Backlash to Belt and Road: A South Asian Battle Over Chinese Economic Power," *Foreign Affairs*, February 16, 2018, https://www.foreignaffairs.com/articles/china/2018-02-16/backlash-belt-and-road.

25 Aditya Valiathan Pillai, "Powering South Asian integration," *the Hindu*, January 3, 2019, https://thehindu.com/opinion/op-ed/powering-south-asian-integration/article25892808.ece.

26 Ibid.

27 "Wary of China, Modi Courts India's Neighbors," Stratfor, September 4, 2019, https://worldview.stratfor.com/article/wary-china-modi-courts-indias-neighbors-bri-china-infrastructure-belt-road.

The Punatsangchu hydroelectric power project in Bhutan, December 13, 2017. *REUTERS/Cathal McNaughton*

transmission system) are likely to be financed, built, owned, and operated (BOO) by China (if eventually transferred, BOOT).

Greater Mekong Subregion (GMS)

In Southeast Asia, contemporary electricity cooperation began as part of the Greater Mekong Subregion (GMS) Economic Cooperation Program launched in 1992. The GMS groups Cambodia, Laos, Thailand, Vietnam, Myanmar, and the Chinese provinces of Guangxi Zhuang Autonomous Region and Yunnan. The ADB has provided support, and energy was identified as a critical area of cooperation.

The economic and environmental benefits of GMS energy sector integration are estimated at about 19 percent of total energy costs, or about $200 billion.[28] The savings from expanding the interconnection of power systems alone are estimated at $14.3 billion,[29] mainly due to the substitution of fossil fuel generation by hydropower.

Indeed, the regional power sector is marked by massive hydroelectric projects. Where China built big dams in Southeast Asia, overcapacity in places like Laos and Myanmar meant that those countries needed infrastructure and facilities to sell excess power abroad—mostly to China itself, but also to regional demand centers in Thailand and Vietnam.

However, the landscape in Southeast Asia is changing. China, historically a net importer of power, invested massively in its own generation capacity as well as regional projects. Since 2010, China's investment in hydropower, wind, solar, and nuclear reversed its need for imports while also increasing capacity in Laos and Myanmar. Laos is seeking to redirect excess power (much of which was originally meant for the Chinese market) and Myanmar has five times the hydropower potential of Laos. Both Myanmar and Cambodia (where Chinese companies own almost 80 percent of generating capacity) are poised to become exporters with further development. In China, new generation capacity in the southwest is already underutilized as a result of grid congestion and local competition, and excess hydropower capacity in Yunnan already eclipses total installed hydropower capacity across the rest of the GMS.[30] China wants to relieve

28 *Building a Sustainable Energy Future: The Greater Mekong Subregion*, Asian Development Bank.

29 *Update of the GMS Regional Master Plan*, Asian Development Bank, October 15, 2010, https://tinyurl.com/tgbuyf8

30 Courtney Weatherby and Brian Eyler, *Mekong Power Shift: Emerging Trends in the GMS Power Sector*, Stimson, June 2017, https://tinyurl.com/tlzu8by.

Hoa Binh hydroelectric power plant opens the flood gates after a heavy rainfall caused by Talas typhoon in Hoa Binh province, outside Hanoi, Vietnam, July 20, 2017. *REUTERS/Kham*

domestic congestion and also provide the infrastructure to send excess power to major Southeast Asian demand centers, which is "why 18 trans-provincial and trans-regional power transmission channels of 500 kilovolts KV and above have been built by China Southern Power Grid so that clean energy could be continuously delivered to load centers thousands of miles away," according to CSPG Vice President Bi Yaxiong.[31]

These shifts, likely in the short term for China and in the longer term for Myanmar and Cambodia, will impact dynamics of regional power trade and have implications for broader regional relations. Evolving patterns of electricity trade flow and demand growth mean that Southeast Asia could likely reap even more direct savings from expanding interconnections than the ADB calculated in 2010. In terms of sustainability, the ability to export existing excess power capacity can reduce the need for future dams (with their unique environmental costs), and developing a regional power market can help to support the variability of non-hydro renewables as well. Trade, energy efficiency, and variable renewables can all help reduce Southeast Asia's rising imports of fossil fuels, and mitigate the serious downstream impacts of overreliance on hydropower.

However, Southeast Asian governments have been relatively slow to facilitate widespread variable renewable energy integration, and to consider the ways that supply and demand shifts may impact the national electricity market. National power planning models are only recently changing focus from point-to-point transmission connecting large, centralized coal and hydropower projects. Demand centers like Vietnam have not fully recognized the potential for efficiency, emissions, and cost savings through increasing electricity trade, and Thailand has only recently embraced its potential as a regional hub to transit power, for example, to Malaysia (it wants to triple the power it sells southward as part of a pathfinder project[32] to demonstrate multilateral power trading).[33] All of these developments will create an increasingly crowded supply side, so countries like Laos whose electricity sector development has been predicated on exports, may find themselves undercut by Chinese electricity or by increasingly cheap renewable energy, making it harder to service the original debt.[34]

The Association of Southeast Asian Nations (ASEAN) has advanced efforts to improve national power planning, and to develop an ASEAN Power Grid (APG), but those initiatives must overcome institutional, human capital, and

31 "China to speed up creation of world-class energy interconnection," *XinhuaNet*, September 11, 2019, http://www.xinhuanet.com/english/2019-09/11/c_138382743.htm.

32 The Lao PDR–Thailand–Malaysia–Singapore Power Integration Project (LTMS–PIP) establishes a framework for further regional multilateral trade, including a wheeling charge methodology that could form the basis of a harmonized regional model.

33 Randy Thanthong-Knight, "Thailand Aims to be Southeast Asia's Power Trading Middleman," *Bloomberg Politics*, August 25, 2019, https://www.bloomberg.com/news/articles/2019-08-25/thailand-wants-to-be-southeast-asia-s-power-trading-middleman.

34 Courtney Weatherby and Brian Eyler, *Mekong Power Shift*.

political barriers. The APG project has gained momentum, but suffers from political concerns about mutual interdependence, which stifles the development of common regulations and institutions to advance the project. GMS experience in information sharing and grid plans can inform APG efforts, but its own political difficulties portend challenges for ASEAN. For example, a key GMS proposal to develop a regional control center stalled not for technical reasons, but over disagreements about where the institution should be located.[35]

35 *Establishing multilateral power trade in ASEAN*, International Energy Agency, September 2019, https://www.iea.org/reports/establishing-multilateral-power-trade-in-asean.

3. Technical and Cybersecurity Vulnerabilities

Evolving power grids raise new questions of cybersecurity vulnerabilities. ICT is becoming even more integrated into the grid and its operations, supporting increased observability of systems by allowing more real-time awareness through sensors, and the ability to collect and analyze more data faster.

The 2015 attack on Ukraine's power grid was an early example of state-sponsored cyberattack on country-level grid infrastructures. Hackers managed to take thirty substations offline and interrupt service to 230,000 customers for almost six hours. It was the relative lack of connectedness, and ability to switch to manual operations, that helped Ukraine recover as quickly as it did.

Digital electricity systems are already vulnerable. New generation and storage technologies increase the need for grid management ICT, and distribution technologies add many new entry points to the increasingly smarter grid, opening up vulnerabilities to cyberattack. Advanced metering capabilities allow greater understanding and control of the grid, but also create vulnerabilities due to increasing dependence on monitoring devices. While cybersecurity has already been a key issue for traditional generation, more complex load management and distribution technologies increase the surface area prone to attack.

Mitigating those vulnerabilities and protecting assets from attack requires effective countermeasures on the part of grid system operators. Establishing standards to protect the grid, and developing contingency plans to protect against cyberattacks, are important steps companies and governments are taking as they become more vigilant. While smart grids may be multiplying entry points and increasing surface area, they are also prioritizing cybersecurity in their underlying design. Some advocate international coordination to develop common cybersecurity norms and rules, to specify a minimum set of controls and processes that power generation and transmission companies should follow.[36]

Some experts contend that supergrids heighten vulnerability to cyberattack for three reasons:

> First, the cyber vulnerabilities of the weakest country on the supergrid are likely inherited by all other countries reliant upon that grid. Second, a cyberattack on one country may impact other countries reliant upon the same supergrid. Finally, a skilled cyber attacker might be able to use the interconnected nature of the supergrid to selectively generate mistrust or create conflict between nations reliant upon the same infrastructure. If one nation, among the many that rely on that supergrid, finds itself without power, it may accuse a neighbor of being responsible for the shortage, especially in the face of limited or confusing evidence.[37]

Cybersecurity takes on new dimensions in the context of cross-border infrastructure builders, owners, or operators that may face pressure to allow room for state-sponsored manipulation or surveillance. As entire power grids are sewn up with unified network technology from a few Chinese suppliers who answer to Beijing, the state gains power to interfere abroad. According to the *Financial Times*, Liu Zhenya, the former chairman of State Grid and main proponent of GEI, has referred to it as "the ICBM of the power industry."[38]

The construction of high-voltage interconnectors also includes the laying of fiber optic optical ground wire that, in addition to providing shielding for conductors and communication among substations, can also be leased to telecommunications service providers. As such, they can represent significant components of a developing country's telecommunication system. Cybersecurity risks, and the potential for transmission network equipment to be subverted, can reach beyond Supervisory Control and Data Acquisition (SCADA) systems.

It is frankly unclear to what degree Chinese transmission infrastructure or grid management technologies present immediate cybersecurity threats or provide precooked backdoor access as such (the same can be said for Huawei). However, the 2017 Chinese National Intelligence Law requires domestic companies to cooperate on furthering Chinese interests, so any data collected is in principle fair game for Beijing to demand access to later. In any case, how countries deal with that uncertainty is telling. Cautious approaches to potential security risks in advanced economies could well be emulated in developing Asia, if alternatives are sufficiently competitive.

36 *A New World: The Geopolitics of the Energy Transition*, International Renewable Energy Agency, January 2019, https://www.irena.org/publications/2019/Jan/A-New-World-The-Geopolitics-of-the-Energy-Transformation.

37 Meghan O'Sullivan, Indra Overland, and David Sandalow, *The Geopolitics of Renewable Energy*, Harvard University Kennedy School, July 2017, https://www.hks.harvard.edu/publications/geopolitics-renewable-energy#citation.

38 James Kynge and Lucy Hornby, "China eyes role as world's supplier," *Financial Times*, June 6, 2018, https://www.ft.com/content/bdc31f94-68aa-11e8-b6eb-4acfcfb08c11.

4. Strategic and Commercial Risks of GEI

Proponents of China's GEI strategy stress that China's push for interconnectivity does not have to mean that Chinese companies own or operate the grid. That may be true, but Chinese companies are in fact aggressively seeking stakes in various foreign grids, while also pushing to link them up.

Over the past several years, authorities in various countries have prevented State Grid from acquiring stakes in certain grids and utility companies—for example, Australia (Ausgrid), Belgium (Eandis), and Germany (50Hertz). While the reasons were never fully elaborated by the intelligence agencies that recommended them, the assessed risks probably included cyber espionage as well as foreign control over critical national infrastructure.

As more power grids have Chinese owners, operators, or technologies, they can support the buildup of new Chinese-centered supply chains.[39] Grid investments (representing about $12 billion of BRI spending) open the door to further renewable energy investments with favored Chinese suppliers, advancing a strategy to gain market share in power generation that is articulated in the BRI documents[40] and consistent with the objectives of Made in China 2025. They also facilitate the introduction of Chinese smart grid technology into the network. ENN Group's Pan Energy Net technologies already create regional smart energy networks that take advantage of State Grid's physical power grids.

The International Renewable Energy Agency's (IRENA) Global Commission on the Geopolitics of the Energy Transformation warns that if a small number of players were to dominate clean energy and energy data technology, it should raise concerns that this may stifle competition, suppress innovation, and distort markets. "Countries that do not control key energy technologies may become heavily dependent on the few countries and companies that do. In this context, industrial policy becomes increasingly important; countries will need to create a competitive manufacturing value chain around certain technologies within a fair and rules-based trading system," according to the commission.[41]

The BRI and the GEI undoubtedly have strategic objectives, both commercial and security related. The ability to dominate regional supply chains, gather information, and establish Chinese ownership of foreign critical infrastructure enhances Beijing's soft power. It is also a way to guarantee secure access to resources and world markets, and to bypass maritime choke points. It is said that China's infrastructure diplomacy could be "as important to 21st century geopolitics as the protection of sea lanes was to the hegemony of the United States in the 20th century."[42] China's strategy has raised concerns about indebtedness, transparency, the prominent role of Chinese contractors, and the environmental sustainability of these projects.[43] The sea lane analogy might be extended to the story of the Suez Canal, whose financing delivered Egypt into British imperial domination.

Even if companies like State Grid do not seek to willfully endanger the national security of its foreign customers, and absent malicious or intentional backdoor cyber manipulation, control of infrastructure and cross-border electricity flows in itself bestows power. In an extreme case, the potential for strategic denial of service would be a form of weaponized interdependence in which one country uses a shared relationship to extract political concessions.[44] A Council on Foreign Relations report contends:

> Shutting down power service across a transmission system is just a matter of operations control (in the absence of good governance, power markets, contracts, etc. that are all in place to avoid disconnection of service)... Ideally, markets, contracts, and legal forms of dispute resolution would also help ensure that politically motivated service denials do not happen, but market mechanisms on their own are unlikely to establish confidence in grid integration across borders.[45]

The report goes on to argue:

> In the absence of institutions to guard against politically motivated service denials, countries will remain disconnected or even seek to decouple their systems from neighbors deemed too risky. In

39 Thomas S. Eder and Jacob Mardell, "Powering the Belt and Road," Mercator Institute for China Studies, June 27, 2019, https://www.merics.org/en/bri-tracker/powering-the-belt-and-road.

40 "The Belt and Road Initiative: Progress, Contributions and Prospects," Belt and Road Portal, April 22, 2019, https://eng.yidaiyilu.gov.cn/zchj/qwfb/86739.htm.

41 *A New World: The Geopolitics of the Energy Transition*, International Renewable Energy Agency.

42 Ibid.

43 Christopher Balding, "Why Democracies are Turning Against Belt and Road: Corruption, Debt, and Backlash," *Foreign Affairs*, October 24, 2018, https://www.foreignaffairs.com/articles/china/2018-10-24/why-democracies-are-turning-against-belt-and-road.

44 Henry Farrell and Abraham L. Newman, "Weaponized Interdependence: How Global Economic Networks Shape State Coercion," *International Security* 44:1 (2019): 42-79, https://www.mitpressjournals.org/doi/full/10.1162/isec_a_00351.

45 Joshua Busby, Sarang Shidore, and Morgan Bazilian, "Electricity as Coercion: Is There a Risk of Strategic Denial of Service?," Council on Foreign Relations, August 20, 2019, https://www.cfr.org/blog/electricity-coercion-there-risk-strategic-denial-service.

much of the electricity space where the potential is largely untapped, it would mean foregoing many of the benefits associated with integrated grids.[46]

In recent years, other major countries have promoted their own infrastructure plans. In July 2018, US Secretary of State Mike Pompeo declared a new era in US commitment to a "Free and Open Indo-Pacific" strategy together with Japan and Australia.[47] The package included $113 million in US support, including $50 million to help partners manage energy resources. ASEAN has developed a "Connectivity 2025" strategy, while the European Union (EU) recently unveiled a "Strategy on Connecting Europe and Asia." The Asia-Pacific Economic Cooperation (APEC), the ADB, and the US International Development Finance Corporation (DFC) are also active in the Indo-Pacific region.[48]

The reality of international grid investment, and the role that the BRI plays in it (particularly in Asia), means that it is incumbent upon US policy to define a more comprehensive response.

This response should build on the Free and Open Indo-Pacific strategy by working with regional allies as well as China to internationalize new standards on quality infrastructure beyond the existing G20 guidelines, to include cybersecurity and legal standards, platform neutrality and interoperability, resiliency, local operational control, and environmental sustainability. It should also support the development of regional electricity markets. At the ASEAN Foreign Ministers Meeting in August 2019, the US and Japan announced the Mekong Power Partnership to develop regional grids in the Lower Mekong region, in accordance with standards for quality energy infrastructure. This new initiative can form a useful template for other subregions and a wider program.

Given the range and ambition of these developments, electricity infrastructure and associated ICT connectivity could become the future of strategic energy competition. They could also establish interdependencies that bind countries together peacefully, as proponents of grid integration have traditionally hoped. Highly networked regions will need to overcome long-standing distrust in order to establish interconnectivity and the governance necessary to manage it. If concerns about foreign influence and cyber risk are adequately addressed, the gains can be political as well as economic.

Fundamentally, countries that are confronted with the need to transform and expand their power sectors will need viable alternatives. It is perhaps ironic that the United States' difficulties in developing long-distance transmission infrastructure and integrating its power grids may also yield technology advantages that are starting to provide some of those alternatives.

46 Ibid.

47 *A Free and Open Indo-Pacific: Advancing a Shared Vision*, US Department of State, November 4, 2019, https://www.state.gov/wp-content/uploads/2019/11/Free-and-Open-Indo-Pacific-4Nov2019.pdf.

48 Jeffrey Wilson, "Calibrating a U.S. Infrastructure Strategy for the Indo-Pacific," Center for Strategic and International Studies, March 5, 2019, https://reconasia.csis.org/analysis/entries/calibrating-us-infrastructure-strategy-indo-pacific/.

5. US Grid Interconnection: Struggle to Connect and New Grid Technology Models

Microgrid testing and analysis at Idaho National Laboratory. *Flickr/Idaho National Laboratory*

The United States lacks significant domestic interconnections, even among multiple subnational grids that effectively function as electricity islands. The US national grid comprises three main regions—the Eastern, Western, and Texas (ERCOT) interconnections—each operating independently of the others. Neighboring states or jurisdictions in different interconnections cannot reap the benefits of trade with each other (or with more variously endowed jurisdictions across North America). Within the three interconnections, there are a number of regional transmission organizations (RTOs) and independent system operators (ISOs), nonprofit entities that manage the transmission and generation of electricity by utilities in their region. The US Department of Energy (DOE) and the Federal Energy Regulatory Commission (FERC, an independent agency within the DOE) are responsible for identifying when and where new transmission is needed, but states determine where transmission lines are built, while utilities and regulators decide how to pay for them.

Transmission lines spanning across several states raise complex questions about cost allocation, which requires determining who benefits most from the new infrastructure. Given the economic and legal complexities involved with interstate and interregional transmission, most of the new renewable energy sources that have been added to the US grid in the past two decades have been developed within individual states or regions. This simplifies the cost-benefit calculations and also makes securing the permits required to build the transmission lines much easier, but it means that cross-border infrastructure is not prioritized.[49]

There are a host of issues, both institutional as well as economic, that make it difficult to construct more transmission infrastructure. The US-Canadian bulk electricity system is comprised of a complex mix of individually operated, but interconnected, utilities that may be investor-owned, municipal, cooperative, state-authorized, provincial, or US federal. The hodgepodge market structure continues to change from vertically integrated utilities owning generation, transmission, and distribution systems to the increased use of ISOs and RTOs. Numerous institutional barriers are still impacting vulnerabilities, response and recovery options, and outage durations. Many of those same barriers also inhibit interconnection and trade that might mitigate the effects of

49 Daniel Oberhaus, "The Real Challenge for the Green New Deal Isn't Politics," *Wired*, July 9, 2019, https://www.wired.com/story/real-challenge-green-new-deal-isnt-politics/.

Microgrid testing and analysis at Idaho National Laboratory. *Flickr/Idaho National Laboratory*

introducing ever more complex technologies and generation sources.

Despite all these difficulties, the rising economic value of transmission means a few projects are finally materializing. The Plains & Eastern Clean Line transmission project will be the first overhead HVDC project in the United States in more than twenty years. It should also be noted that north-south international interconnections with Canada are even more significant than east-west domestic links (in either country). These interconnections are operating at full capacity, and Canadian hydropower already helps some US states to meet their clean energy goals.

There are ways to improve transmission planning in the United States, for example, by using scenario-based planning that calculates wider benefits beyond reliability and direct cost savings, and that considers system-level benefits rather than within single jurisdictions.[50] However, in the absence of sufficient system-wide planning, independent developers and new technologies are stepping in.

Technological Adaptation: Distributed Generation and Microgrids

In the late 1990s, concerned about the reliability of US power transmission, the US Congress called on DOE to look at maximizing distributed generation to reduce stress on the grid. A number of research projects were launched over the years, leading to demonstration projects of microgrid technology for utilities, universities, industry, school districts, jails, hospitals, laboratories, military bases, and industrial parks.[51]

Distributed energy resources (DER) refer to small-scale localized generation that can be connected to the grid at distribution level (or, indeed, operate independently of the grid altogether). They can take the form of rooftop solar units, wind turbines, biomass generators, natural gas turbines, or fuel cells. Decentralized generation necessitates two-way power flow to enable small-scale producing customers to sell back to the grid, or to engage in peer-to-peer transactions directly with other consumers. DER systems may also include energy storage, inverters

50 *Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission is Key to the Transition to a Carbon Constrained Future*, Brattle Group, June 2016, https://brattlefiles.blob.core.windows.net/system/publications/pdfs/000/005/295/original/well-planned_electric_transmission_saves_customer_costs_-_improved_transmission_planning_is_key_to_the_transition_to_a_carbon_constrained_future.pdf?146524694.

51 Lisa Cohn, "History of Microgrids in the US: From Pearl Street to Plug-and-Play," Microgrid Knowledge, July 22, 2019, https://microgridknowledge.com/history-of-microgrids/.

to convert from direct current to alternating current, and various forms of smart meters and data services.

After a series of weather-related blackouts in 2011–2012 (particularly in New York state after Hurricane Sandy), policy support for microgrids expanded thanks to their reliability. Resilience also made them attractive for the US military. In 2018, regulators approved the first utility-scale microgrid cluster in Chicago.[52]

As a transmission developer recently told a University of Chicago audience,

> We are now seeing a revolutionary change in the organization of consumers—micro-transactions that are happening in most places. This will become an enormously important part of how we transact energy with each other. . . . The more of that happening and the fewer new transmission lines we'll need. The marriage of transmission lines and microgrids is where the future is.[53]

Indeed, distributed generation and microgrids still benefit today from connection to the wider grid for balancing, necessitating more sophisticated grid management, and ultimately supporting the case for wider grid integration, including across international borders. Integrated high-voltage transmission will also continue to be critical for increasing renewable energy sources (for example, offshore wind).

However, the future grid architecture will have to support a high penetration of DER, potentially favoring models of grid optimization (such as decentralized layered grid architecture) that prioritize grid balancing from the bottom up.[54] Together with falling costs of energy storage and more advanced inverters, market design innovation is helping to make local or microgrids independently secure, and in many cases can eventually eliminate the economic or reliability incentive to connect to the grid in the first place. Those trends portend a very different future for transmission needs—one that does not imply the need for ever-larger interconnected grids to achieve the efficient deployment or operation of ever-cheaper renewable energy sources, but which will rely on complex decentralized data management to facilitate micro exchanges and maintain reliability.

Distributed Energy Promotion as a US Strategic Response?

The argument underpinning expectations that the trend will be toward deeper international grid integration is that wider networked grids deliver greater efficiencies due to their ability to balance more heterogeneous supply and demand patterns. With rising demand, more need for capacity expansion, increasing cost effectiveness of variable renewable energy, and mounting fiscal pressures, countries in rapidly developing Asian subregions have more incentive than ever to reform domestic power sectors to facilitate private sector investment and to engage in regional energy trade. That raises questions of how to build secure transmission infrastructure, and how to develop regional systems and institutions to manage regular trade and grid balancing. State Grid proposes grid interconnection on a continental scale, and state development banks offer attractive terms to build the transmission infrastructure to do it.

The United States is naturally disadvantaged when it comes to building large networked infrastructures across jurisdictions. It is much harder to marshal financing for large national projects, and local legal resistance is significant. That hampers efforts to build long-distance transmission lines in the country. Furthermore, the United States will never "out-China" China in terms of large infrastructure projects abroad. The establishment of the DFC is an important step forward, and provides an important new tool to support US companies abroad while enabling strategic infrastructure projects, particularly in the context of the Free and Open Indo-Pacific strategy. However, it is comparatively small, and US industry and finance are finally guided by free market principles, not state direction.

The United States should promote an alternative vision, and one more directly consistent with a lower-carbon energy system that the climate challenge necessitates. Changing technology, both in terms of digitization and energy storage, may be poised to provide one such vision.

With falling costs of power storage (whether batteries or thermal), and local smart grid technologies to engage in limited decentralized trade (enabled, possibly, by blockchain), distributed energy models will be increasingly cost competitive while providing comparable system-wide

52 Ibid.

53 Ed Krapels, "Pipelines and Power Lines: The Future of U.S. Energy Infrastructure and the Implications for Clean Energy," (panel discussion at the Energy Policy Institute at the University of Chicago, February 21, 2018), https://epic.uchicago.edu/events/event/pipelines-and-power-lines-the-future-of-u-s-energy-infrastructure-and-the-implications-for-clean-energy/?_paged=3.

54 Lorenzo Kristov, Paul De Martini, and Jeffrey D. Taft, "A Tale of Two Visions: Designing a Decentralized Transactive Electric System," *IEEE Power and Energy Magazine* 14:3 (2016): 63-69, https://ieeexplore.ieee.org/document/7452738.

security, without the need for progressively wider grid integration or long-distance high-voltage transmission lines.

Total generation capacity of more advanced distributed models is still small. At the end of 2018, planned and installed global microgrid capacity stood at 19,575 megawatts (MW), with utility microgrids accounting for 40 percent of new capacity.[55] North America leads the microgrid market in terms of total capacity, followed by the Asia-Pacific, where utility microgrids are driven by lack of robust infrastructure.

Southern Asian geography is already conducive to microgrid application. Mountainous terrain and islands are areas where energy poverty tends to be concentrated, and where distributed generation-and-storage solutions can already be significantly cheaper than grid expansion. Solar Philippines has been spearheading unsubsidized solar-and-storage mini-grids in island communities with equipment from Tesla, SEL Construction, and Fronius International.[56] In India, Tata Power has partnered with the Rockefeller Foundation to launch the world's largest microgrid developer, TP Renewable Microgrid, with a mandate to provide clean power to nearly 5 million households with over 10,000 microgrids in the next decade, and Singaporean consortium CleanGrid Partners (comprised of Japan's Tokyo Electric Power Company, or TEPCO, and local partners) is poised to expand projects in the region.[57] US firms like GE Power and Tesla have been active partners with Southeast Asian governments to provide mobile fast-power generators and electricity storage.[58] In a recent report, Wood Mackenzie expects the average solar-plus-storage levelized cost of energy (LCOE) in the Asia-Pacific to decrease 23 percent by 2023 to $101 per megawatt hour (MWh), at which point the figure in Thailand will fall below the average wholesale electricity price there.[59]

Policies like the introduction of net energy metering in the region are helping to empower domestic, commercial, industrial, and agricultural prosumers to sell locally generated energy to other customers or back to the main grid, competing directly with traditional utilities and grid-centric providers. Sophisticated microgrids can participate in certain wholesale markets and leverage their assets to reduce costs. Pushing the bounds of market design innovation in the United States by supporting maximum distribution system operators (DSO) and then sharing those lessons with allies through technical programs, can transform wholesale markets while improving resiliency and local sustainability.

Mera Gao Power (MGP) designed a solar-powered, village-level microgrid to provide electricity to off-grid villages in India. Through the microgrid model, renewable power is generated by solar panels and stored in battery banks that charge during the day and are discharged at night. DIV provided Stage 2 funding for MGP to establish its first commercial microgrids. *Flickr/DIVatUSAID (US Agency for International Development's Development Innovation Ventures program)*

As battery and power storage costs fall, hybrid generator offerings from US champions like Caterpillar and Cummins can form the core of increasingly self-sufficient storage-plus-generation microgrids.

US companies are already leaders in distribution-level advanced technologies, and models of microgrid development and financing. USAID programs like Asia-EDGE, the Energy Utility Partnership Program, the Energy Regulatory Partnership Program, and the Infrastructure Transaction and Assistance Network (ITAN) can help to facilitate greater integration for those technologies in Asia. In the region, Japan is an ally and a market leader.

The technology itself is certainly not a panacea when it comes to cybersecurity or competitive influence. Even where microgrids are not attached to the grid, they can rely on sophisticated cloud-based operations management. New technologies promise to make transactive energy easier, empowering end users to produce and transact with each other as well as with the utility.[60] Yet

55 *Navigant Microgrid Deployment Tracker 4Q18*, Navigant Research, January 2019, https://www.navigantresearch.com/reports/microgrid-deployment-tracker-4q18.

56 Tom Kenning, "'Solar for the country': Inside Southeast Asia's largest micro-grid," November 22, 2018, https://www.pv-tech.org/editors-blog/solar-for-the-country-inside-southeast-asias-largest-micro-grid.

57 "1Q 2019 Off-Grid and Mini-Grid Market Outlook," ClimateScope, March 26, 2019, https://medium.com/climatescope/1q-2019-off-grid-and-mini-grid-market-outlook-ec4a400ced93.

58 Bentham Paulos, "Southeast Asia Looks to Microgrid Technology to Electrify Remote Areas," March 5, 2019, https://www.ge.com/power/transform/article.transform.articles.2019.mar.southeast-asia-looks-to-microgrid.

59 "Asia Pacific's solar-plus-storage could see key developments in next five years," WoodMackenzie, May 14, 2019, https://www.woodmac.com/press-releases/asia-pacifics-solar-plus-storage-could-see-key-developments-in-next-five-years/.

60 Some believe blockchain may be among those technologies, but critics argue otherwise. See: Ben Hertz-Shargel and David Livingston,

distribution-level systems are still susceptible to cybercrime, and consumer products are generally less secure than industrial systems. Plus, Chinese players are quickly catching up. In 2019, State Grid announced a new initiative to build microgrids under the rationale of a non-wires alternative of its own, to further its stated mission of providing reliable electricity to all customers. This will bolster the growth of microgrids in China, but may be bad news for outside vendors.

However, outside of China, countries with rising demand and endemic budget constraints may soon have viable alternatives to large subsidized foreign state-owned power infrastructures to deliver cost-effective, reliable, and sustainable electricity. Those alternatives may also help to address political concerns of engaging in cross-border electricity trade in order to balance national electricity portfolios that are increasingly marked by high penetration of ever-cheaper variable renewable generation.

The need for transmission infrastructure is not going away, but by promoting a model of variable renewable energy integration and grid development that eschews the need for ever wider integrated power networks, the United States can address global concerns about centralized grid management or interdependence. Starting with the low-hanging fruit, these technologies can already provide cost-effective and reliable electricity to address energy access and development in isolated areas. As they mature, they will provide a local solution for reliable renewable energy on a competitive basis with the main grid in more and more utility-scale situations. A technological future centered on local production, storage, and use advances a political model for energy governance that also adheres to values of local independence.

Assessing blockchain's future in transactive energy, Atlantic Council, September 23, 2019, https://www.atlanticcouncil.org/in-depth-research-reports/report/assessing-blockchains-future-in-transactive-energy/.

6. Conclusion: Political Values and Energy Infrastructure

Across the world, there is growing uncertainty about models of unelected supranational economic governance, despite the efficiencies it can bring. Development organizations like the World Bank and the ADB have long championed international energy market integration in developing countries broadly along the European model, with the intention of reducing costs, spreading access, and improving service reliability—but also furthering noble goals of fostering peace through economic interdependence and improving environmental sustainability. However, efforts by those institutions to implement EU-style energy economic integration and Organisation for Economic Co-operation and Development (OECD) liberalization reforms of the 1990s did not get far because they failed to account fully for local priorities, political conditions, and the need for buy-in.

Technological change, and the continually improving competitiveness of renewable energy, means that, on one hand, the moment is suddenly ripe for cross-border energy trade and regional grid integration. Yet at the same time, the geopolitical and economic environment has also changed. Large-scale infrastructure interconnectivity in Asia (and elsewhere) is led by China's investments and the BRI. Chinese expertise has been nurtured in a domestic regulatory environment where authoritarian state power makes the rapid buildup of large-scale infrastructure networks feasible. In the absence of strong international governance and competition authority, China is now offloading its excess subsidized industrial capacity while taking leadership in key technology sectors that drive networked critical infrastructure. This has real strategic implications for recipient countries as well as for the United States. Recipient countries must contend with a tension between affordable and quick infrastructure options to advance legitimate development and climate goals, and political concerns vis-à-vis neighbors as well as about the security implications of foreign critical infrastructure financing or ownership.

US policy should consider the following steps:

1. Bolster technical, policy, governance, and legal support to Asian partners and regional bodies to promote transparent and effective management of regional and local electricity systems. Regional electricity organizations supported by US and Western assistance can help develop the regulatory frameworks and coordination needed on procurement, investment, and cybersecurity.
    - Encourage the development of regional electricity trade with transparent pricing, neutral technical standards, and transnational coordinating institutions that fairly represent participating members and respect local sovereignty.
    - Support ongoing domestic energy market reform to integrate more variable renewables, remove fuel subsidies, and facilitate cross-border trade.
    - Provide cybersecurity support for energy utilities and operations, and set standards for digitized cross-border pricing and trading exchanges.
    - Enhance local institutional capacity to manage new capacity markets and regulatory reform.
2. Build on the Free and Open Indo-Pacific strategy, enhanced Asia-EDGE program, and regional energy programs to support higher infrastructure standards, leverage private investment, coordinate international financing, and promote market reform and new technologies. Large interconnected power systems will play an important role in decarbonization, and the United States should do more to ensure that both markets and new infrastructure are secure and sustainable.
    - Direct more funding, such as through the new DFC and multilateral development banks, to leverage private investment in energy network technologies and regional infrastructure, with a focus on decentralized solutions from trusted suppliers.
    - Cooperate with China and regional partners in further setting higher standards for energy infrastructure projects, including platform neutrality and interoperability, resiliency, domestic operational control, and environmental sustainability.
    - Further develop models for cooperation such as the recent Mekong Power Partnership to support market development in other subregions.
3. Innovate, pilot, and promote models for integrating high levels of distributed energy resources (DERs) domestically, including platforms to aggregate distributed generation, fully engage in capacity markets, and reinforce islanding capacity of local distribution areas.
    - Explore long-term market reform options to support coordinated decentralization, such

as decentralized layered grid architecture, to prioritize distribution-level generation.

- Engage with partner countries to test, implement, and innovate upon such new models.

A highly-networked geoeconomic future will be marked by concurrent trends – the efficiencies of large-scale international network and information management, and the resilience and innovation of interconnected decentralized systems that keep more decisions local. The first will require robust engagement within a rules-based international system to ensure that investments and technical coordination are transparent, fair, and secure. Promoting the second is smart US commercial policy and advances competition, innovation, sovereignty, and subsidiarity when it comes to how electricity is supplied.

About the Author

Phillip Cornell is a senior fellow at the Atlantic Council's Global Energy Center. He is a specialist on energy and foreign policy, global energy markets and regulatory issues, critical energy infrastructure protection, energy security strategy and policy, Saudi Arabian oil policy, Gulf energy economics, and sustainable energy transition policy.

Prior to joining the Atlantic Council, Cornell was a senior corporate planning advisor to the chairman and CEO of Saudi Aramco, where he provided market analysis and business development support to the executive management during the implementation of Saudi oil price strategy. In that capacity, he also provided advice to the Royal Court in the context of Saudi economic transition and foreign policy.

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Before joining the IEA, Cornell served with NATO as the senior fellow and director of international programs at the NATO School (NSO) in Oberammergau, Germany, where his policy research focused on NATO and energy security. During that period, he also served on the secretary general's committee in Brussels to develop NATO policy in the area of energy infrastructure security.

Cornell has held research positions at the Naval Postgraduate School (Monterey), the Royal United Services Institute (London) and the Center for International Security and Cooperation (Stanford), and he is the author of a number of articles and volumes on energy security and security policy. He holds Masters degrees with distinction in International Economics (energy focus) and European Studies (security focus) from the Johns Hopkins School of Advanced International Studies. He received his BA *cum laude* in International Relations from Stanford University.

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