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FUTURE OF TAIWAN'S ECONOMIC COMPETITIVENESS

# Overcoming Taiwan's Energy Trilemma

Evan A. Feigenbaum and Jen-yi Hou

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## Future of Taiwan's Economic Competitiveness

In 2019, the Asia Program of the Carnegie Endowment for International Peace, in collaboration with the Taiwan WTO & RTA Center of the Chung-Hua Institution for Economic Research, began to jointly convene a series of roundtables with U.S. and Taiwan stakeholders.

The initiative has two major goals: first, to examine challenges to Taiwan's future competitiveness and comparative advantage amid technological change, global economic disruption, and rapidly evolving political risk; and second, to explore where and how fresh partnerships between U.S. and Taiwan players can help to bolster Taiwan's economic future.

The initiative is focused in three areas:

1. assuring Taiwan's technological advantage amid significant challenges to its innovation ecosystem;
2. disruptive energy futures as Taiwan grapples with the trilemma of security, affordability, and sustainability; and
3. improving Taiwan's investment climate to attract not just more but also highest-quality foreign investment.

This paper on Taiwan's energy future is the second in a series. For this study, Carnegie and Chung-Hua are joined by a third collaborator, the Taiwan Research Institute in Taipei.

The principal authors, Evan A. Feigenbaum (Carnegie Endowment for International Peace) and Jen-yi Hou (Taiwan Research Institute), have drawn on the extensive insights and contributions of a distinguished group of policy and industry practitioners in both Taiwan and the United States, as well as leading academic and policy analysts.

We particularly acknowledge the comments and critiques on a draft of this paper received from Ssu-li Chang, Hung-Ju Chiu, Hui-Chien Chung, Henning Gloystein, Marsden Hanna, Jane Nakano, Allen Wang, and Cathy Yeh.

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## Executive Summary

Because it imports nearly all of the fuel that powers its economy, Taiwan is unusually vulnerable to energy market risks. Volatility has grown in the world's major oil-producing regions, especially the Middle East, where the specter of conflict between the United States and Iran looms ever larger. What is more, over the long term, countries dependent on oil export revenue will need to successfully adapt to a world characterized by declining oil demand. They will likely struggle to diversify their economies and ensure employment, yielding another significant source of instability. Meanwhile, commodity markets, from crude oil to natural gas, have been buffeted by geopolitical volatility, political and investment risks, and technological disruption.

Still, Taiwan has had to manage such traditional risks before, and while political and market disruptions can of course be challenging to any economy, it can most likely weather these types of prospective shocks.

Taiwan's more pressing energy challenge, therefore, is that these risks are being eclipsed by new dynamics that are reshaping future energy security, affordability, and sustainability—the so-called energy trilemma. Bluntly put, a paradigm shift is underway in how major energy stakeholders—such as government policymakers, producers, utility companies, and industrial end-users—approach their energy needs.

Taiwan needs to look not just to the energy it needs right now but also to the energy it will need ten to twenty years from now if it is to power its future. The number one and two drivers of this will be technological change and decarbonization, not necessarily the old drivers of cost and security.

The most acute dilemma facing Taiwan is whether it can bring its energy thinking and policies into line with this paradigm shift in global energy markets. In simplest terms, a good deal of market analysis has moved away from the idea that the number of large-scale oil fields left to find has shrunk forever—or that the world is running out of a depleting, finite resource. Instead, market thinking has shifted toward such issues as stranded assets.

The prime imperatives for forward-thinking energy users have become decarbonization and how to leverage technology, rather than simply focusing on cost and security as was the case for so many decades. For this reason, Taiwan needs to grapple with the same challenge that faces so many other major industrial economies today: how to achieve decarbonization while retaining the adherence to other imperatives.

The new coronavirus pandemic compounds these challenges because, while it is unlikely to change the fundamentals of Taiwan's long-term energy needs, it reinforces the importance of diversifying supply chains. The pandemic has shown just how vulnerable the world is to supply chain disruptions. So, it makes less sense than ever for an economy to become too reliant on any single source for essential goods and commodities, whether that is China for manufactured components, India for pharmaceuticals, or a handful of Middle Eastern oil and gas producers for essential energy imports.

This paper focuses on two elements of the paradigmatic transformation that are especially relevant to Taiwan's future: (1) the rise of new energy and storage technologies, and (2) the dynamics of liquefied natural gas pricing.

In particular, it looks at several ways in which new investment partnerships between Taiwan and U.S. players could bolster Taiwan's ambitious effort to build out renewable energy as a source of industrial and residential power.

## Introduction

Because it imports nearly all of the fuel that powers its economy, Taiwan is unusually vulnerable to energy market risks. And the fact is, traditional risks to Taiwan's energy future—political instability in oil-producing countries, temporary price swings, and the potential for ad hoc supply disruptions—have only become more acute in recent years.

Volatility has grown in the world's major oil-producing regions, especially the Middle East, where the specter of conflict between the United States and Iran looms ever larger. What is more, over the long term, countries dependent on oil export revenue will need to successfully adapt to a world characterized by declining oil demand. They will likely struggle to diversify their economies and ensure employment, yielding another significant source of instability.

Meanwhile, distinctive commodity markets, from crude oil to natural gas, have responded in complex ways to geopolitical volatility, political and investment risks, and technological disruption. Even before the near-total collapse of oil prices in April 2020, the March outbreak of a price war between Russia and Saudi Arabia had showcased these traditional risks in stark relief, with U.S. benchmark West Texas Intermediate (WTI) showing oil prices falling by some 22 percent and global benchmark Brent crude prices by 24 percent within the span of just a week.[1]

Still, Taiwan has had to manage such traditional risks before. So, while political and market disruptions can of course be challenging to any economy, Taiwan can most likely weather these types of prospective shocks.

Taiwan's more pressing energy challenge, therefore, is that these risks are being eclipsed by new dynamics that are now reshaping future energy security, affordability, and sustainability—the so-called energy trilemma.[2] Bluntly put, a paradigmshift is underway around the world in how the major energy stakeholders—such as government policymakers, producers, utility companies, and industrial end-users—approach their energy needs.

The new coronavirus pandemic compounds these challenges because, while it is unlikely to change the fundamentals of Taiwan's long-term energy needs, it reinforces the importance of diversifying supply chains. The pandemic has shown just how vulnerable the world is to supply chain disruptions. So, it makes less sense than ever for an economy to become too reliant on any single source for essential goods and commodities, whether that is China for manufactured components, India for pharmaceuticals, or a handful of Middle Eastern oil and gas producers for essential energy imports.

Taiwan needs to look not just to the energy it needs right now but also to the energy it will need ten to twenty years from now if it is to power its future. The number one and two drivers of this will be technological change and decarbonization, not necessarily the old drivers of cost and security.

In a postpandemic world, these two factors will constitute the principal shifts affecting global energy markets. Thus, Taiwan needs to grapple with the same challenge that faces so many major industrial economies today: how to achieve decarbonization while retaining the adherence to other imperatives.

The good news is that Taiwan has assertively tackled some of its most pressing energy challenges already, with the government setting ambitious targets into place for power from offshore wind, solar, thermal, and liquefied natural gas (LNG). Taiwan has also put in place an array of ambitious plans and balanced policies, including a stable regulatory framework and several productive policy incentives including feed-in tariffs. Such initiatives include a targeted power mix of 20 percent renewables, 50 percent natural gas, and 30 percent coal by 2025, as well as recent amendments to its Electricity Act and Renewable Energy Development Act.

But precisely because global energy markets are changing, especially as a result of new technology, Taiwan will continue to face challenges in all three core dimensions of the energy trilemma. To meet those challenges, it needs broader policy reforms but also enhanced international partnerships, not least with the United States.

## Energy Trilemma, Risk Trilemma

### 1. Energy Security Risks

Taiwan's energy security is at intrinsic risk because of its overwhelming dependence on imports. Some 98 percent of the energy Taiwan uses is imported, and that import mix depends especially on fossil fuels, which comprise a whopping 93 percent of Taiwan's overall energy supply.

Such a high level of import dependence is an intrinsic security challenge because some 76 percent of Taiwan's oil came from the Middle East in 2018, a region that could turn even more volatile as the collision between the United States and Iran (and between Iran and Middle East Arab states, including oil producers such as Saudi Arabia) intensifies. As of September 2019, Saudi Arabia alone comprises some 30 percent of crude purchases by Formosa Petrochemical, one of Taiwan's two leading oil refining companies.[3]

Import dependence also exposes Taiwan to the instability of reserve margins, which have dropped to some precipitous lows in recent years—reaching their lowest point in 2017 when Taipower, the state owned utility, had an operating reserve margin of just 1.7 percent.[4] As a result, during a blackout in August of that year, Taiwan lacked the reserve capacity to avoid widespread power outages.[5]

Happily, the reserve margin of power improved to 16.8 percent in 2019.[6] Indeed, one reason for the low reserve margin prior to 2018 was that Taiwan's fourth nuclear power plant had been scheduled to begin operating in 2014 or 2015 but was instead sealed in 2014. Reserve margins have gradually improved since the commissioning of coal-fired units in Linkuo and Dalin and the gas-fired unit in Tongxiao.

But Taiwan's energy security is also at risk because its opportunities for international cooperation, including in the event of global supply and price shocks, have been so constrained.

Unlike two leading neighboring economies, Japan and South Korea, Taiwan is not a member of the Organization for Economic Cooperation and Development (OECD). It is not, therefore, a member of, or even associated with, the International Energy Agency (IEA), the Paris-based intergovernmental organization within the OECD framework that coordinates strategic reserve stockpiles.[7] The IEA also hosts the world Clean Energy Ministerial (CEM) Secretariat and Energy Efficiency Hub. It undertakes a variety of data sharing and technology development initiatives from which Taiwan—an economy among the world's top twenty-five by nominal gross domestic product—could benefit.

With Taiwan excluded not just from the IEA but also from most other international energy coordination mechanisms such as the World Energy Council, creative efforts to revitalize, strengthen, and intensify ad hoc partnerships with a wider variety of international players could multiply its opportunities.

## 2. Equity and Affordability Risks

Energy equity remains a challenge too.

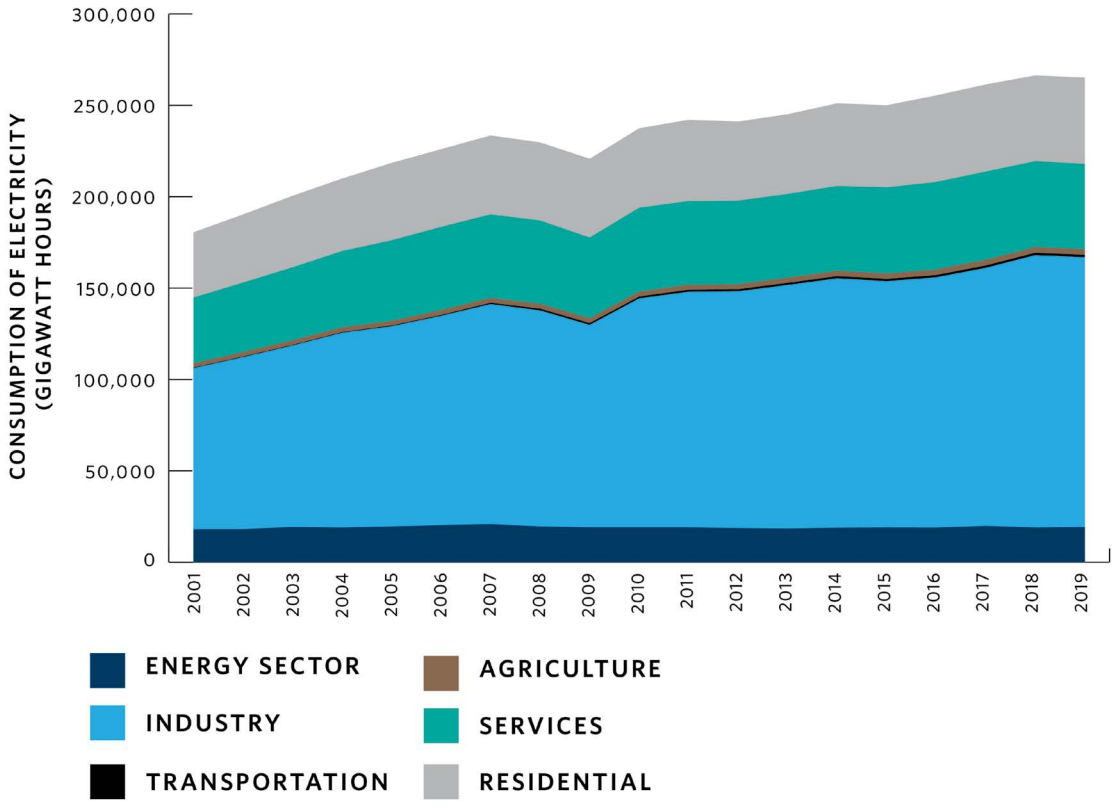
Fiscal and investment obstacles have impeded the creation of a more efficient energy market in Taiwan. And while the government has worked to find a proper balance between, on the one hand, keeping power prices low and, on the other, ambitiously building out renewables in the overall fuel mix, Taiwan's next set of policy choices about subsidies and regulation could yield new pressures on power pricing.

Household electricity prices in Taiwan are relatively low ($0.09 per kilowatt hour [kWh] as of September 2019 compared to a world average of $0.14/kWh), yet the burden of heavy subsidization is ultimately shouldered by Taipower, whose electricity business suffered NT$14 billion in losses in 2018 and an additional NT$10 billion in the first two months of 2019 alone.[8] This has left Taipower in a financially precarious position at a time when investment in grid upgrades is sorely needed to address periodic blackouts, both planned and unplanned. The sustainability of this pricing model will hinge on future declines in fuel costs as Taipower's debt burden continues to increase.[9]

Taiwan especially needs additional energy storage and gas-fired generation capacity, as well as further price rationalization reforms to its power market. One reason is that Taiwan's electricity consumption continued to rise at a rate of 1.76 percent per year from 2004 to 2019, with industrial consumption making up 56 percent of the total in 2019, the largest share among all sectors.[10] And Taiwan's gross electricity generation increased by 14 percent between 2005 and 2015, from 227 terawatt hours (TWh) to more than 258 TWh (see figure 1).[11]

Figure 1.

**Recent Sectoral Trends in Taiwan's Electricity Consumption**




**SOURCE:** Bureau of Energy, "Electricity Consumption," Ministry of Economic Affairs, accessed April 20, 2020, https://www.moeaboe.gov.tw/ECW/populace/web_book/wHandWebReports_File.ashx?type=office&book_code=M_CH&chapter_code=K&report_code=09.

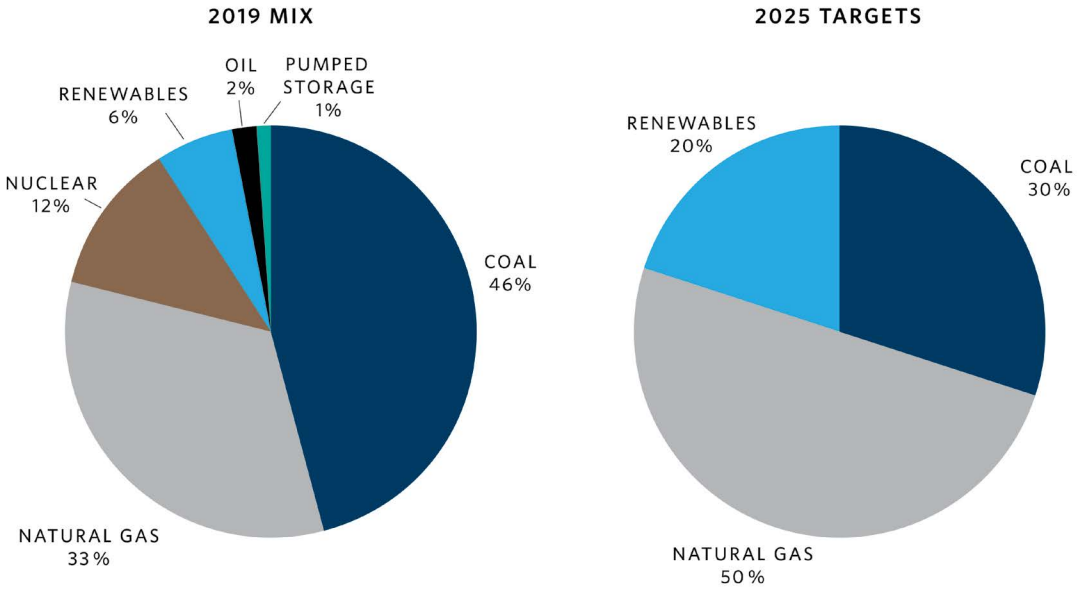
But Taiwan's grid system is isolated, which could make it susceptible to power shortages in the event of a sudden supply shock. This problem is potentially made worse by the continued overreliance on fossil fuels—for instance, if reserves are low due to shipment delays caused by instability in the Middle East.

### 3. Sustainability Risks

The third leg of Taiwan's energy trilemma also remains a challenge. Enhanced international cooperation could be essential to Taiwan's buildout of environmentally sustainable power.

Nuclear power, which once generated as much as 20 percent of Taiwan's electricity, has fallen by the wayside amid decades of political controversy (see figure 3).[12] Taiwan's last nuclear generating unit, at Maanshan in the southern county of Pingtung, will reach the end of its operating license in May 2025, bringing to an end a once-flourishing era of nuclear power generation on the island. This will mean a crunch for the government's ambitious effort on renewables, so improved policies will be needed to help further incentivize international partnerships and investments in offshore wind, solar, and next generation energy technologies.

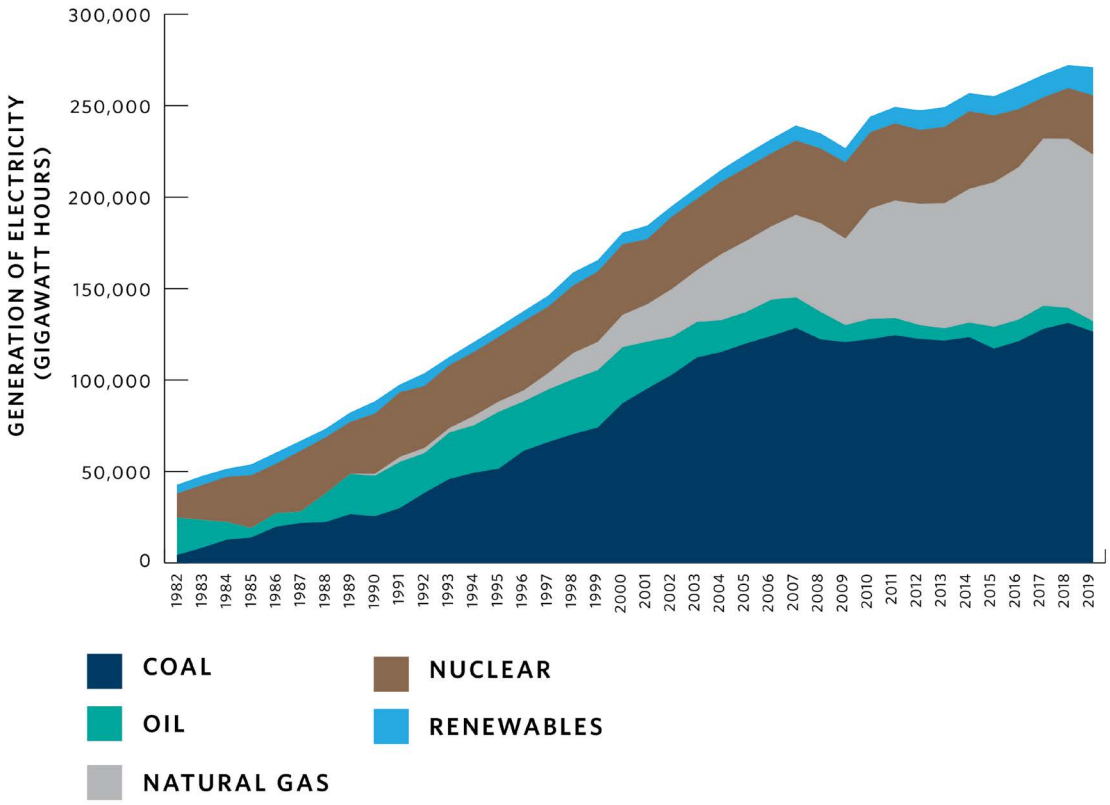
Figure 2.
**Taiwan's 2019 Fuel Mix and 2025 Targets**




**SOURCE:** Bureau of Energy, "Composition of Electricity Generation," Ministry of Economic Affairs, accessed April 20, 2020, https://www.moeaboe.gov.tw/ECW/populace/web_book/wHandWebReports_File.ashx?type=office&book_code=M_CH&chapter_code=K&report_code=11.

Figure 3.

**Taiwan's Electricity Generation by Source, 1982–2019**




**SOURCE:** Bureau of Energy, "Electricity Generation," Ministry of Economic Affairs, accessed April 15, 2020, https://www.moeaboe.gov.tw/wesnq/Views/B01/wFrmB0101.aspx.

The government has set ambitious targets to change the underlying fuel mix—a "20-30-50" formula that would see 20 percent of Taiwan's power generated by renewable sources, just 30 percent from coal, and 50 percent from natural gas by 2025. Yet Taiwan still has a long way to go to meet that bold aspiration. In 2019, renewables comprised just 6 percent of Taiwan's electricity supply (see figure 2). And the system is likely to come under strain as the grid is fitted to manage new capacity (see table 1).

What is more, the turn from coal to gas could lead to an array of stranded assets. Taipower expects to operate some 25 gigawatts (GW) of gas power plants by 2028. Along with nearly 10 more GW of gas-generated electricity from independent power producers, this could pose challenges of overcapacity in the system.

Table 1.

**Taiwan's Renewables Buildout**

| Type of Renewable Energy | Current Capacity, February 2020 | Planned Capacity by 2025 |
|---|---|---|
| Solar | 4.150 GW | 20 GW |
| Wind | 0.845 GW | 7.7 GW |
| Hydro Power | 2.092 GW | 2.15 GW |
| Biogas | 0.741 GW * | 0.813 GW |
| Geothermal | 0.3 MW | 0.2 GW |

* as of September 2019

**SOURCES:** "Energy Transition in Taiwan," Energypedia, accessed April 15, 2020, https://energypedia.info/wiki/Energy_Transition_in_Taiwan-#Divestment_from_Fossil_Fuel; Celeste Tsai, "Taiwan Officially Sets Renewable Energy Target, Aiming 20GW of PV Installations by 2025," EnergyTrend, June 28, 2016, https://m.energytrend.com/news/20160628-10692.html; Bureau of Energy, "發電裝置容量," Ministry of Economic Affairs, accessed April 20, 2020, https://www.moeaboe.gov.tw/ECW/populace/web_book/wHandWebReports_File.ashx?type=office&book_code=M_CH&chapter_code=K&report_code=05.

The bottom line is that Taiwan faces a high bar—and competition from other economies in Asia—as it seeks to meet its bold sustainability targets and attract the investment needed to do so.[13] To add some 27 GW of generation capacity from renewables, the government aims to attract as much as $59 billion (NT$1.8 trillion) in foreign investment.[14]

Just take offshore wind power. Asia is projected to be by far the world's largest offshore wind market, hosting as much as 60 percent of global capacity by 2050. But in that context, Taiwan is already a regional leader. The Ministry of Economic Affairs has built out offshore wind development through competitive auctions that explicitly target foreign partners, including the $627 million, 128 megawatt (MW) Formosa 1 wind complex off Miaoli County in west Taiwan, the first of its kind to be commissioned in the Asia-Pacific region.[15] It includes four foreign partners: Japan's JERA (32.5 percent ownership stake), Denmark's Ørsted A/S (35 percent), Australia's Macquarie Group Limited (25 percent), and Taiwan's own Swancor Holding Co. (7.5 percent).

This is just one of eleven offshore wind projects that have attracted substantial investment to Taiwan, particularly from the Nordic countries, and that are expected to add 5.5 GW of capacity to Taiwan's electrical grid by 2025, with an additional 10 GW targeted for 2035.[16] But these projects have faced challenges, not least with the permitting process.[17]

As investment activity in Taiwan's renewables sector picks up—the offshore wind projects alone are expected to generate nearly $31.7 billion in new investment—more U.S. investors should, quite clearly, be a central part of the mix.[18] And although attracting funding remains a challenge that

introduces significant risks and uncertainties, the good news is that some have already pursued the opportunity. For example, in August 2019, a New York–based asset manager, Stonepeak Infrastructure Partners, acquired a 95 percent stake in Swancor's renewables subsidiary.[19] But many more could be encouraged and incentivized to do so. Foreign partners and investors, including Americans, can play an important and constructive role in enabling Taiwan's energy transition.

## New Market Realities, New Paradigms

Just five years ago, any discussion of Taiwan's energy future would inevitably have been dominated by questions around security in the Strait of Hormuz and its impact on oil shipments or the rise of LNG and prospective U.S. exports to Taiwan. Those issues remain relevant in the near term, especially in the face of the recent attack on Saudi oil facilities. Yet even that dramatic event, which might once have caused a market earthquake, did not send the global oil market into a panic. Nor did the price of oil skyrocket as a result of the attacks.

The central reason for this comparative calm is that a paradigm shift has taken place in global energy thinking in recent years. Taiwan's most acute dilemma, therefore, is whether it can bring its own energy policies into line with this new thinking.

In simplest terms, a good deal of market analysis has moved away from the idea that the number of large-scale oil fields left to find has shrunk forever—or that the world is running out of a depleting, finite resource. Instead, market thinking has shifted toward such issues as stranded assets.

Oil has proved to be cheaper and simpler to find and extract than many had long presumed because a wide array of alternative energy technologies now exists. Specifically, it has become easier than ever to produce unconventional oil. And many energy services no longer require oil at all.

But that is not all. The recent plunge in oil prices triggered by the price war between Saudi Arabia and Russia and the collapse in demand as a result of the coronavirus will likely further accelerate these trends. Demand may never again return to pre-coronavirus levels, spelling very tough times indeed for many oil-producing nations.[20]

For these reasons, the prime imperative for forward-thinking energy users has become decarbonization—and how to leverage technology rather than simply focusing on cost and security as was the case for so many decades. Companies that produce or use energy live and breathe this transformation on a daily basis. All of them face the pivotal question of how to achieve longer-term decarbonization without losing sight of other challenges in the near term.

For Taiwan, two elements of this paradigmatic transformation are especially relevant: the rise of new energy technologies and the dynamics of LNG pricing.

## A World of New Technology

The commercial scale deployment of fracking has, of course, been the most dramatic new development in energy production. Both horizontal drilling and hydrologic fracturing had been under development since the 1970s, but the low price of natural gas did not merit the large-scale application of these technologies or their fine tuning until the early 2000s.

But with the application of these technologies to both crude oil and natural gas production, fracking has altered the market. In the United States, fracking has taken on political connotations because of environmental and other controversies, but as a technology it is now an acknowledgment that the U.S. oil industry has learned to produce at commercial scale from source rock rather than reservoirs.

This has wide-ranging implications for production. For one, energy security will no longer require only that the world's largest oil companies spend billions of dollars on offshore exploration. Shale exploration allows producers to access oil that has been locked in rock the world over. It has long been apparent that this rock exists, and where. But the technologies to produce from it quite simply were not being deployed at commercial scale. Now, that has changed. And so there has been a burst of technological development in the United States aimed at producing oil from source rock. That, in turn, has fed an underlying paradigm shift on global energy thinking by making clear that fields will not simply disappear. Nor is oil, as a result, a depleting resource that the world will soon run out of.

A second, and associated, change is the rise of LNG. More aggressive exploration combined with new extraction technology has led to a surplus of natural gas. Indeed, there is now so much natural gas in the United States and around the world that it is difficult to see how producers can find a home for it all. Meanwhile, with the rise not just of U.S. shale-based LNG supplies but also of LNG from Australia and other sources, a vibrant Asian LNG market has emerged that offers new opportunities for Taiwan. Growing natural gas supplies in the liquefied form makes particular sense for Taiwan because pipeline import has not really been an option.

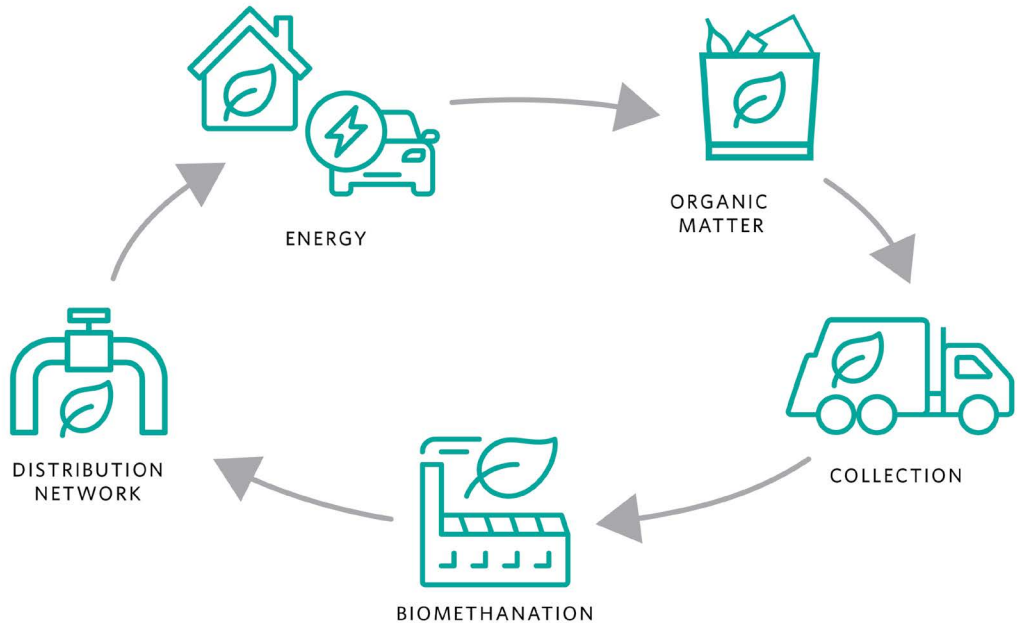
Taiwan's buildout of renewables also stands to benefit from the rise of new technologies. Many technologies that could be leveraged in Taiwan are already being prepared, from new wind, solar, and geothermal systems to the development of electric vehicles.

Take renewable natural gas (RNG). It offers promise by integrating gas and waste in ways that may mirror the uses of conventional natural gas.[21] Carbon-neutral RNG results from the capture and conversion of methane—for instance, from wastewater treatment or industrial facilities, both of which are prevalent in Taiwan—and its conversion into renewable energy.

Biogas upgrading could create new waste-to-energy possibilities for fuels and high-value co-products as pathways, using biomass waste feedstock, such as methane from current waste treatment processes, that are used to recover energy and produce fuels and chemicals.[22] It has the additional benefit of supplying continuous power as opposed to the intermittent nature of solar and wind (see figure 4). There has already been some modest movement on this in Taiwan. One papermaking company in the northwestern special municipality of Taoyuan, for instance, is installing a system of three biogas-powered generators with the aim of providing 32,000 megawatts per hour (MWh) of electricity to 10,000 local households.[23]

Another example is a pilot project developed jointly by Microsoft and Vattenfall that uses smart meters to track renewable electricity consumption on an hourly basis, which is the first of its kind.[24]

Figure 4.
**High-Level Renewable Natural Gas Production**




**SOURCE:** Adapted from "Integrating Renewable Natural Gas," Planet Engineering, March 26, 2019, https://www.plantengineering.com/articles/integrating-renewable-natural-gas/.

By implementing this technology, Taiwan could leverage its strengths in the Internet of Things and artificial intelligence to encourage innovation and cross-domain collaboration.

These kinds of pilot projects could potentially be scaled up. And some of these new technologies are already being deployed on a larger scale in the United States—for instance in places like California. So, for Taiwan, where the administration of President Tsai Ing-wen has put considerable emphasis on the goal of meeting its ambitious renewables targets, it is more imperative than ever to refract that buildout through the lens of new and emerging technologies.

The same is true of gas. To reach a 50 percent generation share of gas by 2025, new turbine technologies, for example, could offer both fast response and ramping capability. Such turbines can partner with renewables to provide intermittency support until battery storage costs decline. Coal and combined cycle gas turbines can offer baseload to the system and some of these gas units would serve the mid-merit and peaking demand.

Ultimately, these kinds of technological advancements mean that traditional ways of thinking, whether about sea lanes or exporter relationships, will give way to ideas about how to shift from traditional to new energy sources. Creative energy thinking in Taiwan will need to focus there. And it will need to focus, too, on how digital technologies can enable energy efficiency and lower emissions.

Already, that kind of disruptive thinking is being operationalized elsewhere. Take two Tesla projects—one in California, and a second in Australia.[25] The first—megapack—is a utility scale wind or solar project that promotes storage solutions to meet peak demand. The second, a virtual power plant in the state of South Australia, uses virtual batteries—large complexes of housing where each residential user has a small-scale battery but agrees to lease a certain percentage of storage for use during periods of intermittency or sudden peak demand.

For Taiwan, these kinds of innovative storage solutions would be unconventional but have considerable potential. And one way for Taiwan to leverage that opportunity would be to emulate the effort among U.S. businesses that have issued a "call for solutions."[26]

In this model, Taiwan policymakers would take a hard look at their grid, with a particular eye to places where demand increases are needed because of high power usage. Policymakers would then call on providers to bid on the technology solutions that best meet demand load at a particular location while also ensuring grid stability. Such an approach would, of course, be a break from the traditional, more centralized one through which Taiwan has relied on command and control targets for its energy mix.

Such opportunities to leverage and deploy new technology abound. Yet, they cannot be realized without policy reforms to pricing and contracting. A key question facing Taiwan now, therefore, is how best to stratify the difference between prices for industry and prices for households. But leveraging a mix of technologies and grid integration might offer dynamic new opportunities to do so.

## A New Approach to LNG Pricing

A second part of what Taiwan needs to meet its future energy requirements is a more dynamic approach to LNG pricing. Taiwan seeks to generate 50 percent of its power from natural gas by 2025. To achieve that, Taipower will need to exponentially ramp up its LNG imports, which in turn suggests the need for a more flexible and risk tolerant approach to the LNG market—one that relies on greater flexibility to tap the spot market and rely on increased storage capacity rather than just depending on long-term contracts.

Taiwan produces very little of the natural gas it uses, importing 98 percent of it principally in the form of LNG. In 2019, some 70 percent of those imports came from just three countries—Qatar, Australia, and Malaysia (see figure 5). And those sales were based on long-term contracts with state-owned China Petroleum Corporation, Taiwan's sole LNG importer, which also has a monopoly on all gas terminals, transmission infrastructure, and storage facilities in Taiwan.[27]

But with the rise of the global LNG spot market, alternatives now exist.

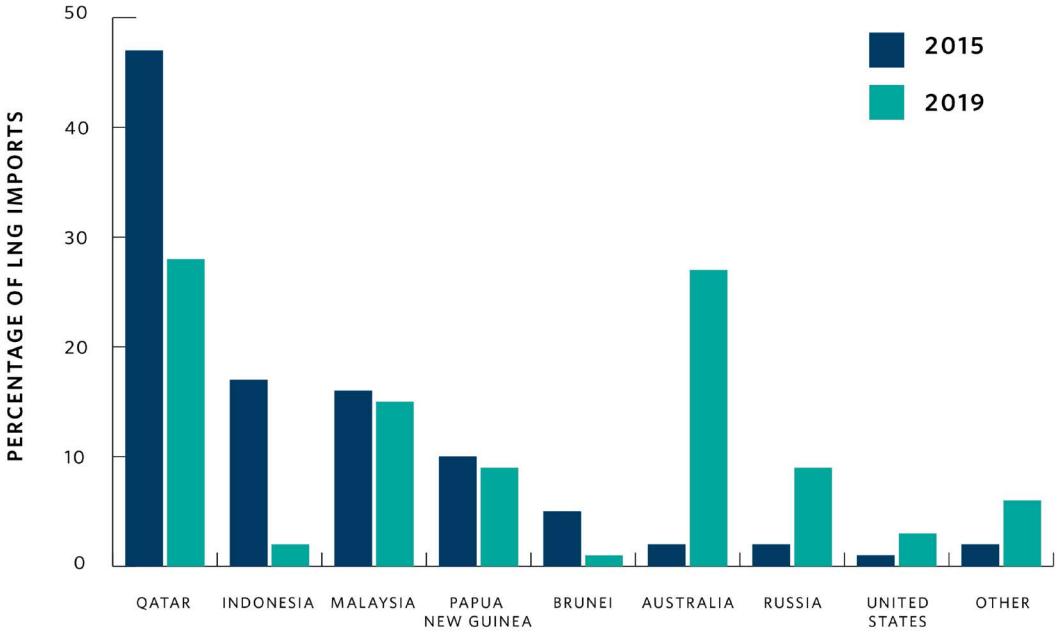
For good reason, Taiwan has preferred the comparative stability and predictability of long-term contracts. Yet, it is increasingly the case that LNG can be acquired under new pricing methods. In the United States, for example, there is the Henry Hub for natural gas futures on the New York Mercantile Exchange (NYMEX) and over-the-counter swaps on the Intercontinental Exchange.[28] So, if Taiwan were less averse to spot trading, it would have new chances to expand its gas opportunities.

Tapping spot markets can open up considerable potential for economies like Taiwan. It needs a more strategically considered mix between how much LNG it purchases through long-term contracts, with an eye to stability, while also pursuing the flexibility to tap spot prices. The choice does not need to be an either-or: there are also short-term contracts of six months and up (but generally of one to three years duration) that could be considered as a diversification element of Taiwan's gas purchase mix.

The fact is, if political instability worsens in the Middle East, it will inevitably touch Taiwan's LNG partners in the Gulf, such as Qatar, which alone supplies close to 30 percent of Taiwan's gas imports (although this share has come down from 47 percent as recently as 2015 through Taiwan's intensive

Figure 5.

**Taiwan's LNG Suppliers in 2015 and 2019**




**SOURCES:** Bureau of Energy, "Origin of Imported LNG," Ministry of Economic Affairs, accessed April 20, 2020, https://www.moeaboe.gov.tw/ECW/populace/web_book/WebReports.aspx?book=M_CH&menu_id=142; author's calculations.

effort to diversify its gas partnerships away from the Gulf in favor of countries like Australia). This is connected to the first part of the energy paradigm shift described above—the rise of new technologies and solutions. As the world decarbonizes, Gulf countries like Qatar run the risk of being saddled with stranded assets amid worsening political, social, and ultimately strategic instability.

Street protests across the Middle East, including in oil-producing states like Iraq, have coincided with a clear recognition that the runway for oil will not last forever. Indeed, social unrest across the Middle East has emerged at the very moment governments across the region face the challenge of planning for the next thirty years by transitioning from oil and gas dependence to more diverse economies.

These social and economic transitions compound the strategic challenges of geopolitical tension and malevolent actors in the Middle East. Supply will almost surely be less stable in the decade ahead as investments in oil diminish and these underlying political challenges proliferate.

For Taiwan, it is imperative to look at current cost structures. Today, about 80 percent of the levelized cost of energy (LCOE) comes from fuel costs; thus, it will be important for Taiwan to lower fuel prices if it is also to lower overall average costs—particularly if LNG comprises a larger share of the fuel mix in Taiwan's targets for 2025 and beyond.

## Structural Challenges to Taiwan's Energy Future

The focus of Taiwan's next set of energy policies should be on three structural issues:

1. improving energy storage systems to accommodate the projected surge in renewables;
2. further rationalizing prices in an already relatively cost-effective electricity market; and
3. enabling highest-quality energy investments, not least from the United States.

### Improving Storage Systems and Surging Renewables

Taiwan's energy future is now deeply tied to the government's determination to increase the share of renewables in the power generation mix. But wind and solar are known as "variable" not "dispatchable" power sources because, as David Roberts has written, they depend on the vagaries of weather, time of day, and season.[29] Simply put, because they depend on nature, "they cannot be turned on and off, or up and down, according to the grid's needs. They don't adjust to the grid; the grid adjusts to them." So, a grid with a high penetration of renewable energy needs to be shifted, smoothed, and responsive to sudden decreases or increases. To put this another way, because the main sources of renewable power—sun and wind—are intermittent by nature, a utility needs to ensure a stable power supply.

One solution is to deploy more storage systems. But while the costs of renewables and battery storage are coming down, there are intrinsic limits to how much power can be stored at any given moment. Each of Taiwan's power providers will need to look at shifts within a season not just in a day. Battery technology, unfortunately, has not advanced far enough to be able to deal with such seasonal shifts. At present, the largest energy storage system is a pumped storage power plant, but it can only store energy on a daily basis, not weekly, let alone monthly or seasonally.

For Taiwan, this means that both gas and batteries will be required to keep the grid viable and running smoothly for industrial and residential customers alike. Storage is not cheap. So, Taiwan will need incentives that encourage new players to enter the market for better storage. One example could be a virtual power plant (VPP) for residential batteries, which can both reduce loads and be configured in a flexible way.[30]

This has worked elsewhere. For instance, Tesla's 50,000-home VPP in South Australia compensated for as much as 748 MW of reduced system supply when a coal-fired unit in the state of Queensland tripped offline in October 2019. According to industry outlet Utility Dive, the VPP injected "power from hundreds of individual residential batteries to help return the system frequency back to stable levels."[31] This had happened at least two other times before in Australia.

For Taiwan, the challenge is to look at sectors in an integrated way, not as disconnected parts of the energy system. One example is transportation: autonomous vehicles, electric trucks, and LNG trucks should be viewed comprehensively—these and other technologies comprise a range of related solutions that can be married together across and between sectors.

The same is true of other parts of Taiwan's renewables buildout. Take solar panels. The expansion of photovoltaic (PV) systems makes the recycling of solar panels more urgent. Indeed, the Institute of Natural Resources Management at Taipei University estimates that Taiwan's current expansion goals mean that 10,000 tons of solar panels will need to be recycled—and that this will grow to 100,000 tons of panels by 2035.

Taiwan needs to prepare now for such a future. So, the solutions it looks to cannot simply be in the power sector. Power and transport, among other sectors, need to be thought of in this integrated way.

## Cost

One reason Taiwan is well-positioned to attract more American and other international investment is that it is one of the most cost-effective electricity markets in Asia. But precisely because electricity prices are cheap, Taiwan will need to rationalize prices gradually. Any sudden jump would be both politically and economically disruptive.

Once again, the renewables buildout poses a special challenge. Renewables in Taiwan are very expensive compared to other parts of the world. For instance, solar power costs around $130/MWh in Taiwan compared to $40 or less in the United States. And because solar has an approximately 75 percent cost premium over standard power sources, there is a broad need to add capacity for solar yet reduce costs as quickly as possible.

Here is one example: the U.S.-based company Google has begun purchasing renewable energy for its operations in Taiwan—first, because the firm sources much of its own power and has established solar and wind projects on four continents; second, because that effort meshes well with Taiwan's new, renewables-focused energy policy; and third, because Taiwan's amended Electricity Act, adopted in 2017, permits nonutility companies like Google to directly purchase renewable energy.[32]

In 2019, leveraging the amended law, Google teamed up with several others, including Diode Ventures, Taiyen Green Energy Co. Ltd., J&V Energy Technology Co. Ltd., and New Green Power, to establish a solar array connected to the same regional power grid from which Google's data center in Taiwan's Changhua County draws its power.[33] Projected to be built over fishing ponds, this floating solar photovoltaic—or "floatovoltaic"—project uses water-based support structures to float the solar panels.[34] But the high cost premium over standard power sources poses problems for such a project.

For instance, Google has a goal of 100 percent renewable usage in its operations but, company sources say, would be hard-pressed to justify the 75 percent cost premium in solar production hours that it would need to pay to do so.[35] Taiwan's industrial rates are time-of-use and vary by the hour, so this reflects a comparison of the Taipower rate in solar generation hours to the solar feed-in tariff (FIT) rate in those same hours.

The question for Taiwan, then, as it seeks to attract more such investments is how to drive down costs. And the primary mechanism to date, Taiwan's twenty-year FIT, simply locks in costs that will have to be paid either by the government or by Taiwan's electricity consumers.

These costs will substantially affect economic performance as Taiwan adds ever greater baseloads of renewable power to the grid. Bringing down costs should therefore be an especially urgent priority.

Many other countries that historically used bureaucratically determined FIT rates have shifted away from this to auctions or other market-based mechanisms. Relatedly, some of Taiwan's FIT rates are substantially higher than the real underlying costs, most notably with solar. Bloomberg New Energy Finance recently estimated that the cost of solar in Taiwan would be about $76/MWh if the price were allowed to float and other local cost drivers were addressed—a stark contrast to the $130/MWh FIT rate for 2020.[36] This would make solar energy a cost-competitive supply option for many businesses, whose Taipower rates often hover in the $75–$85/MWh range.

Nor is this the only problem Taiwan faces in paying higher costs. As noted in the last section of this study, Taiwan also pays some three times what it could pay for LNG if it chose to acquire it on the spot market instead of via long-term contracts. In effect, Taiwan pays a high price for oil-related politics by absorbing the cost of U.S. sanctions on Iran, supply cuts by the Organization of the Petroleum Exporting Countries, and other politically driven market movements.

Costs are a feature, not a bug, of contract-based LNG purchasing. Although Taipower and Taiwan's government have made robust commitments to increasing LNG capacity, especially as Taiwan phases out nuclear power, this will only multiply those costs. Taiwan has significant problems of power

density: its main and offshore islands have limited acreage, which means it will have to pack a lot of MW per acre into its power solutions. Yet there are limitations of capacity per acre of land for PV and wind systems, so gas—including smaller gas turbines that can provide reactive power—will be crucial to the future of the grid alongside investments in batteries and renewables.

The bottom line on costs is that Taiwan needs more options as it pursues its imperative to diversify the fuel mix. It aims to move away from coal and nuclear-based power, while increasing gas, photovoltaics, and wind. But it will have too few opportunities to reduce costs immediately other than by holding down fuel costs and procuring world-class technology to better utilize that fuel.

## Investment Climate

The need to procure world-class technology means that improvements to the investment climate will be essential to attract global energy partners, not least from the United States.

Two issues merit special focus—land prices and policies, and challenges of scale.

Land matters because the parcels of land used in solar projects are often not contiguous. Taiwan's grid connection costs are substantial. So are product costs. And its engineering and procurement contractors (EPC) charge very high margins for construction.

To see why this matters to a U.S. firm, just consider Google's global power purchase agreements, which have now expanded to Taiwan with the floatovoltaic project in Tainan County. Google has data centers across the world—and has become a very large energy consumer as a result. Indeed, the company consumes more than twice the power of the entire city of San Francisco.

So, the fact that Google situated its largest Asian data center in Taiwan gives Taipei considerable opportunity to attract additional investment. Yet, according to company officials, Google has invested $600 million to date but, despite acquiring land for a second site in Taiwan, has not entered into more power purchase agreements because of the high costs of renewable energy.

So, to attract more and best-quality investment in the energy sector, especially around solar, Taiwan will need to deal assertively with these underlying cost constraints.

Meanwhile, scale matters too because it deters other prospective U.S. investors from expanding into new areas that Taiwan covets. An example here is hydrogen-based fuel: General Electric Gas Power has built out a fleet of more than seventy gas turbines worldwide that can run on hydrogen blended

with natural gas.[37] Hydrogen technology produces electricity in fuel cells by combining hydrogen and oxygen atoms. And hydrogen also has the potential to be utilized in energy storage systems, minimizing the impacts of seasonality for wind and solar power.

But while these solutions could be technologically feasible for Taiwan, they are not economically or logistically so. And this is true in other parts of the world as well. For hydrogen to play a role in power generation using existing technology, the hydrogen itself will have to be made and delivered in sufficient quantities. A U.S.-based firm like General Electric Gas Power does not invest much in Taiwan today because its fleet is simply not deployed at scale there in a way that would warrant assembly, production, or service shops in Taiwan.

## Solutions and Partnerships

As Taiwan looks to address these issues, forward-looking partnerships, especially with the United States, can and should play an important role.

Three areas for prospective collaboration stand out:

1. co-deployment in Taiwan of an array of high-technology energy solutions that have been utilized in the United States;
2. enhanced energy-related trade and direct investment; and
3. commercial energy partnerships between U.S. and Taiwan firms in third economies (these would reflect the spirit of the U.S. Indo-Pacific Strategy but focus, for example, on greater use by U.S. energy firms operating in, say, Southeast Asia of EPC partners based in Taiwan).

### Technology Solutions

A vast array of U.S.-pioneered energy technology solutions can be made directly relevant to Taiwan's energy goals.

One such example is solar recycling, which fits with Taiwan's ambitious renewables buildout. Material recycling systems are already being developed in the United States—for instance, by the Solar Energy Industries Association's National Photovoltaic Recycling Program, which recycles PV modules, inverters, and related equipment.[38] Enhanced partnerships in this area could include mutual access to data, the forging of transpacific connections among the two sides' vendor and/or user networks, and the sharing of best practices on end-of-life management solutions for solar technology.

The good news is that there is a basis for enhancing these sorts of waste-focused partnerships. The U.S. Environmental Protection Agency (EPA) has worked closely with Taiwan counterparts on a mechanism to manage solar PV waste.[39] So, building out this U.S.-Taiwan cooperation, not least on solar recycling, should be prioritized through the EPA.

And Taiwan already has another vehicle for doing so with the International Environmental Partnership (IEP), launched in Taipei in 2014, which has included a focus on climate change that might incorporate its growing emphasis on and experience with renewable power.[40] The rationale for using this vehicle is straightforward: Taiwan has leveraged this mechanism in the past not just to help remediate climate impacts and share experiences but to do so with a wide array of partners across the Asia-Pacific region.

And since Taiwan's international space is squeezed, not least by pressures from Beijing, this model offers a legacy of success. In 2014, for instance, the U.S. EPA and Taiwan's Environmental Protection Administration jointly hosted the Pan-Pacific Partnership on Climate Change Adaptation, which included two U.S. agencies—the EPA and the National Oceanic and Atmospheric Administration—alongside delegates from key Southeast Asian countries Laos, Malaysia, Thailand, and Vietnam, in addition to Taipei's long-standing partners in the South Pacific.[41]

But there are many additional opportunities. In both the United States and Europe, there has been a growing emphasis on building capacity for solar recycling. There is considerable competition for recycling of lithium batteries, for example, but there will be a huge and analogous need for recycling of solar PVs. So, if recycling costs in Taiwan can be brought down by the deployment of innovative U.S. technology, that will make renewable energy more affordable in Taiwan generally.

And there are other U.S. models on which Taiwan can draw. One example is California's experience with ancillary services in electricity market operation.[42] Ancillary services are those that are needed to ensure electric grid stability and reliability when using renewable power while keeping these at levels comparable to the use of fossil fuels.

Much like Taiwan, California has targeted a huge renewables buildout for its electric grid but has had to rely heavily on natural gas for these ancillary services.[43] As one study puts it, "given their inherent variability, as more renewables come online, grid operators will need additional ancillary services to ensure grid stability."[44] So, Taiwan and California, for example, can learn much from one another about how more clean energy in ancillary services markets could enhance and expand these services.

Two other areas for technology collaboration stand out: storage technology, and carbon capture and sequestration (CCS).

The United States is a leader in storage technology, so there are natural complementarities with Taiwan's strengths in manufacturing for electronic parts and batteries. U.S. companies like Tesla have particular experience with large-scale projects. The two solutions it has deployed in Australia, for example, the VPP model and megapack, could be models for Taiwan as it looks to deal with issues like reduced system supply and grid stability.

There are already U.S.-Taiwan commercial storage partnerships falling into place. U.S.-based Powin Energy, for instance, has cooperated with iBase Gaming Inc. in Taiwan and Murata Manufacturing in Japan on manufacturing parts for energy storage.[45]

CCS likewise offers very considerable space for new U.S.-Taiwan partnerships, especially as the technology itself could help to accommodate some of Taiwan's constraints, including the lack of available land and the challenges of maintaining grid stability. Because Taiwan is still using a significant amount of coal and will need to use natural gas to stabilize its grid, CCS could be a strong point for the United States and Taiwan to collaborate.

Indeed, CCS is an especially good play for Taiwan because it is an area where no major economy has yet established a dominant advantage. U.S. companies are looking hard at it, while the U.S. Congress has both allocated funds and views it as a major energy priority.[46] Yet, CCS is still a nascent energy technology in many ways, giving Taiwan a unique opportunity to be part of the first wave of big movers.

On the U.S. side, research and development has increasingly turned "from demonstration projects to exploring the use of sequestration as a technically and commercially viable method for storing large volumes of captured $CO_2$," according to a report written for the U.S. Congress.[47] So, with the U.S. Department of Energy in the lead on much of this R&D, an expanded U.S.-Taiwan CCS initiative could be useful.

Such an initiative could have three components: (1) expanded dialogue and exchange between the U.S. Energy Department and the Ministry of Economic Affairs' Bureau of Energy in Taiwan, (2) exploration of R&D pilot projects, and (3) brokering prospective connections between U.S. and Taiwan firms.

Other new energy technologies, such as hydrogen fuel cells, should also be part of an expanded U.S.-Taiwan buildout of collaborative, energy-related R&D. For a time, many nations have sought to pool resources under a shared concept of "mission innovation," but this simply has not advanced far enough.

What is more, the main line of international effort came out of the Paris Climate Conference, COP21, in November 2015, in which Taiwan was not able to participate.[48] So, as in the case of pooled R&D on CCS, the United States and Taiwan will need to build ad hoc partnerships to work around this limitation with the existing global energy frameworks.

And there should be opportunities to do this in such areas as lithium processing, especially because the United States aims to have this done in a variety of different locations while diversifying its supply chain. In the U.S. Congress, there is considerable focus today on these technologies too—and on what needs to be done for the United States to stay competitive. Inevitably, this will involve trade with partners like Taiwan to build secure supply chains for processing and recycling.

### Trade and Investment

Attracting more energy-related trade and investment from the United States should also be a crucial part of building next-generation transpacific partnerships.

The United States has, in recent years, become the third-largest energy exporter to Taiwan, including LNG.[49] And U.S. progress with shale gas, in particular, suggests that there will be more such opportunities for U.S. exports of LNG in years to come.

An August 2018 deal between the China Petroleum Corporation and U.S.-based Cheniere Energy for 2 million tons of LNG to Taiwan every year for twenty-five years starting in 2021 hints at the possibilities.[50] Under Taiwan's ambitious fuel mix plan, the share of natural gas is targeted to increase from 33 to 50 percent by 2025. To meet that target, Taiwan will inevitably need to increase imports; thus, more LNG from the United States could be a significant part of the solution.

As noted in an earlier section of this paper, Taiwan should more aggressively aim to tap the spot market, including Henry Hub. Beyond Henry Hub, however, Taiwan could also look to a wider variety of gas import partners, such as Australia and Canada—countries with stable politics, close partnerships with the United States, and an interest in a stable Indo-Pacific region and a thriving Taiwan. Australia is already playing a bigger role in Taiwan's gas mix through the China Petroleum Corporation's 5 percent equity stake in the Prelude FLNG (floating LNG) project in the state of Western Australia, which has yielded LNG shipments to Taiwan and a projected annual 180,000 metric tons of LNG, 20,000 metric tons of LPG, and 65,000 metric tons of condensate.[51]

Another area for potential investment is energy-related manufacturing, including of equipment and installation.

## Third-Economy Partnerships

But perhaps the biggest opportunities for expanded collaboration lie in third economies, especially in the Asia-Pacific region.

The U.S. Indo-Pacific strategy has brought into sharp focus the potential for collaborative commercial partnerships between U.S. and Asian firms, especially to provide options and alternatives to Chinese contractors who so dominate certain markets that it could create monopsony-like pressures that reduce the bargaining power and flexibility of these third-country governments and firms.[52]

International energy cooperation under U.S. President Donald Trump's Free and Open Indo-Pacific Strategy already aims to secure a stable and reliable supply of energy to Taiwan. In this sense, there are also opportunities to work with the United States on the building of infrastructure, including power plants, around the region, particularly in Southeast Asia.

The Asia-Pacific Economic Cooperation (APEC) energy working group offers additional coordination possibilities, not least because it is one of the few regional forums where Taiwan is present and active and also includes the United States, Japan, and all of the pivotal Southeast Asian countries where joint or coordinated market opportunities may exist.[53]

A key building block for that would be for U.S. firms to increasingly look to their Taiwan EPC partners to work beyond Taiwan. Many of these U.S. companies are already working with local EPCs on their projects inside Taiwan. And some of them, such as GE, work extensively with EPCs around the world. Those commercial partnerships could be leveraged as the basis for future collaborations not just in Taiwan but elsewhere.

These sorts of U.S. contractor–Taiwan EPC partnerships could be simple—for instance, collaborating to build a combined cycle plant in an emerging economy in Asia. In many Asian countries, procurement is done directly by governments or by government-owned utilities. Most of the time, such U.S. firms do not wish to be the prime bidder to take responsibility for plant construction but instead wish to be technology providers.

One model, then, would be to leverage existing U.S.-Taiwan EPC partnerships so that Taiwan-based EPC firms could be bid partners for such projects. But ultimately, this would of course require measures to bring down costs: Taiwan needs policies that incentivize competition at the EPC level.

## Conclusion

Taiwan is a high-performing economy whose energy needs are certain to grow in coming decades. But it is also an innovative economy—one that has successfully surfed past waves of technological change in sectors from manufacturing to healthcare to agriculture.

This commitment to technology positions Taiwan well to adapt to the changes now reshaping energy markets—changes that will be meaningful for producers, consumers, utilities, regulators, and government policymakers. Many of these, especially those that are driving the generation and storage solutions Taiwan badly needs, are anchored in the new and emerging technologies discussed at the heart of this paper.

The good news is that Taiwan has met an important part of its energy challenge through its commitment to change the fuel mix. Taiwan's renewable energy targets are ambitious and have set Taiwan squarely on a pathway to decarbonization.

But Taiwan needs to expand its use of technology much more broadly across its energy sector. And it must rely more heavily on market forces, not least through risk taking on spot markets, to better meet its energy requirements.

These twin pillars—technology and markets—are keystones that can help Taiwan to overcome its energy trilemma. The United States, as both an energy technology leader and a major source of energy-related direct investment, should be a partner in helping Taiwan do so. That is manifestly in their mutual interest. And at a time of increasing strategic risk and market turbulence, it is essential for their shared future.

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