ECOVE

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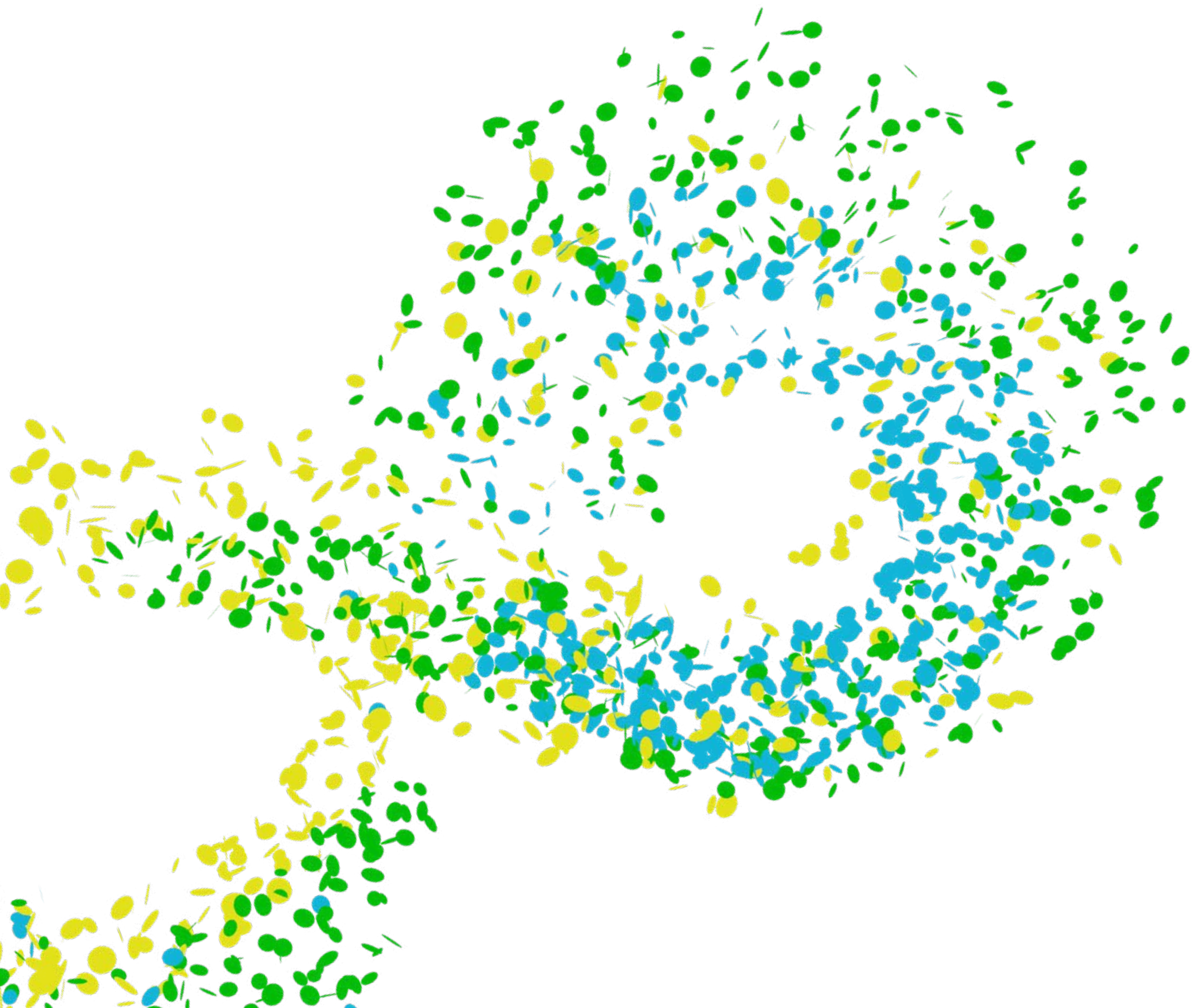
Taiwan: Limited Resources, Abundant Sunlight

Recommendations for Developing Solar Energy in Taiwan



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Executive Summary

Taiwan, a seismically-active nation that relies heavily on imported fossil fuels to generate electricity, is in an optimal position to take the next step in renewable energy development. Tsai Ing-Wen, the current president of Taiwan, has already implemented policy to this effect. She plans to increase Taiwan's renewable energy capacity to 20 GW by 2025 with the intent of completely eliminating nuclear power plants from the primary energy supply.

However, many question whether renewable energy is a viable alternative to nuclear; others doubt the government's ability to support the transition to large-scale renewable energy infrastructure. This paper hopes to erase these doubts, proposing solar energy as the ideal alternative to nuclear, outlining the benefits a transition to solar will have on the Taiwanese economy, environment, and society. In the final section, we will discuss challenges the government and industry has faced thus far, and offer suggestions to improve the government's approach to the transition to renewable energy.

Solar Energy: The Future of Taiwan

Solar energy is the most suitable renewable energy source for Taiwan for two main reasons:

1. As a sub-tropical nation, Taiwan experiences long, hot summers, and short, mild winters. This makes Taiwan an ideal location for solar energy development. Furthermore, solar electricity generation and electricity consumption are very compatible, as demand for electricity increases during periods of intense sunlight.
2. Increased land availability, by opening up land that would have otherwise been designated for use as an open dumpsite or landfill.

Policy Suggestions

Tsai Ing-Wen has already helped drive renewable energy development in Taiwan with the implementation of subsidies designed to encourage solar investment. This section offers suggestions to further strengthen policy in order to ensure Taiwan will reach its 2025 goal.

1. Seek an effective solution to waste management

We suggest Taiwan shift the focus away from roof-mounted systems, instead emphasizing ground-mounted solar development. Roof-mounted systems can lower electricity consumption by reducing a structure's internal temperature electricity consumption and can effectively use otherwise unused space. However, ground-mounted systems are imperative in achieving Taiwan's 20 GW by 2025 goal. Ground-mounted systems are:

A) larger, and therefore able to supply enough electricity for multiple households and

B) higher performing, due to self-adjusting bases that follow the path of the sun and increased air flow that cools the panel.

2. Cooperation between Agriculture/Aquaculture and Energy

We suggest Taiwan encourage communication between agriculture/aquaculture and renewable energy. "Solar sharing" is a method by which agriculture and solar energy can coexist, and can even improve agricultural yields by reducing solar intensity. Plans that encourage agriculture and solar energy to exist side by side can allow farmers to continue farming with extra revenue supplemented by solar energy. Similar projects can also be implemented on aquafarms, allowing aquafarmers to supplement their income, while also increasing solar generation efficiency and reducing pond evaporation.

3. Make Grids Smart

Traditional grids distribute electricity to multiple demand points from a relative few number of supply points. As Taiwan moves toward an electrical system powered by multiple, small-scale renewable energy sources that fluctuate according to weather patterns, the government will need to invest heavily in modernizing the electrical grid to accommodate the change. This includes investing in smart infrastructure and virtual power plants to assist in balancing both electricity supply and demand.

4. Increase Electricity Prices

Taiwan has the third cheapest electricity in the world; as a result, Taiwanese use 20 percent more electricity than their German counterparts, at a third of the cost. Increasing the price of electricity can both raise revenue for the state to invest in smart infrastructure and renewable energy tariffs, while also encouraging energy-saving habits, alleviating the burden for electricity suppliers.

5. Adjust Restrictive Regulations

Despite plans to install 1.52 GW of renewable energy capacity by mid-2018, very few projects have actually been planned, let alone begun construction. We suggest the government relax the following restrictions in order to expedite solar development:

1) Land allotted for solar development should be used for solar development

The Council of Agriculture recently passed a measure restricting solar investors to development on only 70 percent of the allotted land. This policy has not only had little effect on protecting agriculture, it has also significantly increased solar costs.

2) Settle the terms of electricity price, then sign the contract

Taiwan's electricity provider only confirms electricity price after all money has been spent on installing the solar system, hindering efforts to finance solar projects. In order to simplify solar financing, the terms of electricity price should be settled upon signing the contract, allowing solar investors to clearly provide a payback schedule to potential lenders.

I. Taiwan: An Energy Desert?

Energy Insecurity

Taiwan—a nation with a central mountain range covering two thirds of the total area, restricting 23 million Taiwanese to an area about the size of Qatar—is familiar with the concept of limitations. Unfortunately, Taiwan does not make up for land scarcity with abundant resources—Taiwan's domestic supply of fossil fuels were already exhausted three decades ago, when domestic fuels supplied 15-20 percent of Taiwan's energy supply.[1] Since then, Taiwan has become almost entirely reliant on imported fuels—in 2016, Taiwan imported over 98 percent of its total energy supply,[2] making it one of the least energy secure nations in the world.[3] In 2012, energy imports represented 14.55 percent of Taiwan's GDP, up from just 3.88 percent in 2002.[4] Energy imports as a share of total imports ballooned from 10.28 percent in 2002 to 25.41 percent in 2012.[5]

Imported fossil fuels are prone to dramatic fluctuations in price — oil prices have oscillated from as low as $17/barrel in 1998 to $157/barrel in 2008.[6] Volatile fossil fuel prices can cause problems in securing energy supplies and affect the ability of policy makers to plan for capacity expansion and other shorter term measures.[7]

Nuclear Power

Taiwan's three nuclear power plants supplied 12 percent of the island's energy supply in 2016.[8] While there has been strong opposition to nuclear power since the Chernobyl explosion in 1986, the anti-nuclear movement in Taiwan intensified following the Fukushima accident in 2011, due to the similarities between conditions at Taiwan's nuclear power plants and the conditions at Fukushima. Like Japan, Taiwan is located on the Pacific Rim of Fire, where 90 percent of the world's earthquakes occur.[9] While the nuclear facilities in Taiwan are guaranteed to withstand earthquakes up to magnitude 7, and tsunami waves of up to 15 meters, there are 14 recorded incidents of earthquakes above magnitude 7 shaking Taiwan in the past century.[10]

Following the explosion at Fukushima, the Japanese government mandated evacuation for people living within a circumference of 20 km of the accident, suggesting evacuation for those living within an additional 10 km[11]—despite protests from the International Atomic Energy Association (IAEA) and countries such as the United States, the United Kingdom and Canada who urged Japan to extend the evacuation circumference to 80 km.[12] Even so, Japan struggled to find accommodations for the 200,000 people living within 30 km of the site. Taiwan's Kuosheng and Jinshan plant have a respective 5.5 million and 4.7 million people living within a 30 km radius—representing two of only six nuclear facilities globally that have a 30 km radius with over one million people.[13] If a powerful earthquake were to hit Taiwan, it could be devastating for the densely-populated cities surrounding the nuclear facilities.

20 GW by 2025

Bolstered by a Taiwanese population largely opposed to nuclear energy, the current Taiwanese president, Tsai Ing-Wen, ran on a platform to transform Taiwan into a "nuclear-free homeland" by 2025. While most Taiwanese accept the dangers of nuclear energy, many are equally apprehensive about dismantling nuclear energy facilities too quickly, as Taiwan's heavy industry-dominant economy depends on a continuous flow of reliable electricity, most easily obtained through fossil fuel combustion and nuclear energy. Many fear that Taiwan's nuclear energy will be replaced by fossil fuel power plants, further exacerbating Taiwan's dependence on imported fossil fuels and vulnerability to climate change (See: "Climate Change").

To avoid a "nuclear-free homeland" powered by fossil fuels, Tsai Ing-Wen has proposed to replace all nuclear power with renewable energy, increasing Taiwan's renewable energy capacity to 20 GW by 2025. According to the Energy Bureau, Taiwan is well-equipped to reach Tsai Ing-Wen's ambitious renewable energy goal, estimating the potential to develop the following renewable energy capacity by

2025: solar (20 GW), on-shore wind (1.2 GW), off-shore wind (3 GW), geothermal (200 MW), bio-fuel (813 MW), hydropower (2.15 GW).[14] This will distribute energy generation between small-scale renewable energy plants, creating a balanced and resilient electrical grid, increasing Taiwan's energy security by stabilizing electricity and reducing reliance on imported fuels.

In order to encourage renewable energy installation, the Taiwanese government has imitated Germany's Feed-in Tariff (FIT) program to support solar development. Under the 2009 Renewable Energy Development Act, the state-owned utility is required to offer green energy suppliers a feed-in tariff (FIT), a premium fixed rate for their electricity, for a period of twenty years. In Germany, individuals installing solar panels on their home can expect to repay the investment within 10 years due to highly subsidized electricity. After Taiwan implemented the program, solar projects have swelled from a total capacity of 22 MW in 2010 to 842 MW in 2015.[15]

Despite this, many question whether renewable energy is a viable alternative to nuclear; others doubt the government's ability to support the transition to large-scale renewable energy infrastructure. This paper hopes to erase these doubts, proposing solar energy as the ideal alternative to conventional fuels, outlining the benefits a transition to solar will have on Taiwanese society, economy, and environment. In the final section, we will discuss challenges the government and industry has faced thus far, and offer suggestions to improve the government's approach to the transition to renewable energy.

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Climate Change

According to the most recent report from the International Panel on Climate Change (IPCC), human influence on the atmosphere is clear, and recent anthropogenic emissions of greenhouse gas emissions are the highest they've been in history. There is explicit evidence that the atmosphere and ocean have warmed, global snow and ice cover has decreased, and sea level has risen. If greenhouse gas emissions continue their upward trend, the observed changes in climate will continue to intensify.[16]

According to statistics derived from observations that have been gathered at meteorological stations across Taiwan[17] for over a century, the annual mean temperature in Taiwan has increased 1.4 °C per decade (significantly higher than the global average of 0.07 °C).[18] Agriculture is very sensitive to even minor changes in temperature. For example, during the heat wave in Europe during the summer of 2003, temperatures were recorded at up to 6 °C above long-term averages. As a result, maize yields in Italy dropped by a record 36 percent; in France, the maize grain crop and fruit harvests were reduced by 30 percent and 25 percent respectively.[19]

Although average annual precipitation would not suggest Taiwan is a country prone to water scarcity, surges of typhoon-induced torrential rain represents a large proportion of annual rainfall, causing flooding, landslides, and washing huge amounts of freshwater directly into the ocean. Indeed, 55 billion tons of water are discharged into the ocean every year.[20] According to the Council for Economic Planning and Development, the days of typhoon-induced torrential rain have significantly increased over the past fifty years, while days of light rain—the rain most suitable for agriculture—have dropped by four days per decade in the past thirty years.[21]

According to the 2014 IPCC report, the ocean temperatures have risen by 0.11 °C per decade from 1970-2010, resulting in an increase in the frequency and intensity of storms.[22] If greenhouse emissions continue to increase at its current rate, it is fair to assume this upward trend of frequency and intensity of storms will continue. As it stands, natural disaster relief costs the Taiwanese government approximately NTD 15 billion per year, 85 percent of which is spent on damage from typhoons.[23] If anthropogenic emissions fail to be properly mitigated, typhoons will continue to increase in frequency and intensity, worsening the current situation in Taiwan.

The IPCC reports with near certainty that the sea levels have risen since the turn of the century. From 1993-2003 the sea level in nearby basins of Taiwan rose at a rate of 5.6 mm/year, which is substantially higher than the global average rate of 3.1 mm/year.[24] The island nation of Taiwan will acutely feel the effects of rising sea level. According to estimated data using Japan's ALOS satellite, if sea levels continue to rise at their current rate, significant amounts of farmland in Taiwan's western province of Yilan could be totally submerged by the end of the century, while the southern port city of Kaohsiung could experience regular flooding downtown and around the airport.[25]

Not only is Taiwan particularly vulnerable to climate change, it also emits more carbon dioxide than nearly 90 percent of the world's nations.[26] As such, Taiwan has joined the global effort against climate change. Despite not being a United Nations Framework Convention on Climate Change (UNFCCC) member, Taiwan set a 50 percent emissions reduction target for 2050 compared to 2005 greenhouse gas levels,[27] making Taiwan one of only a few countries in the world to pass its own law reducing greenhouse gas emissions.[28] Developing Taiwan's renewable energy capacity will not only mitigate the impacts from climate change, it will help Taiwan stay true to its promise to reduce global carbon emissions.

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II. Solar Energy: The Future of Taiwan

Introduction

With 173,000 terawatts of solar energy striking the Earth at any given moment, solar energy is the world's most plentiful resource.[1] In 2016, the entire world used 21,191 terawatts of electricity.[2] That means in a single moment the sun generates enough energy to supply the Earth with 80 years of energy.

Abundant Sunshine

Unlike conventional electricity sources, such as nuclear and fossil fuel-fired power plants, that can continuously generate electricity regardless of external conditions, solar energy is an intermittent energy source, depending on the sun to generate electricity. As irradiance (the amount of sun hitting the earth's surface) increases, electricity generated also increases. This can be a problem at high latitudes, where energy consumption is highest during the dark and cold winter months, and rapidly decreases as soon as the sun comes out.

Environmental conditions in Taiwan, on the other hand, are optimal for solar energy generation. Taiwan has a relatively high solar irradiance compared to other countries, with annual averages as high as 2000 kWh/m2 (compared to an average of under 800 kWh/m2 in Scandinavia).[3] In complete contrast to Scandinavia, Taiwan's energy consumption rises concurrently with solar intensity. Indeed, the state-owned utility monopoly, Taipower, sells electricity at a slight price increase during the summer months in an attempt to curb electricity use.

Despite the high premium on summertime electricity, electricity demand surges during the hot summer months. This was clearly demonstrated on August 15, 2017. After several consecutive days of temperatures above 35 °C, Taiwan experienced the most severe blackout since the 1999 Jiji earthquake[4] when a single gas-fired power plant that supplies nine percent of the island's electricity shut down, causing a power outage for more than six million households.[5]

Adding 20 GW of solar energy to the system could help prevent such blackouts in the future. First, by diversifying energy supply across multiple, small-scale sources, Taiwan will be less dependent on a single power plant. Furthermore, a strong solar energy base can alleviate excess consumer demand during extended periods of high temperatures. As an example, Germany generated 87 percent of its electricity using solar, wind, hydro and biomass plants (compared to an average of 33 percent the previous year) on an especially sunny and windy day in May.[6] Expanding solar capacity is the best method for Taiwan to offset increased energy demand on hot, sunny days with reliable, emission-free electricity.

Economic Development

In May 2017, Taiwan's Ministry of Economic Affairs (MOEA) announced that it will spend NTD 992.8 billion (USD 32.8 billion) to increase electricity generated from solar panels; this is in addition to the estimated NTD 939 billion (USD 31 billion) private investors are inspected to inject into solar industry.[7] Not only will this large financial support for solar panels benefit Taiwan by providing Taiwanese with emission-free electricity, it will also help boost Taiwan's solar industry—Taiwan is the second largest producer of solar cells in the world.

Increasing renewable energy capacity will also improve Taiwan's carbon intensity rating, which may benefit Taiwan as major companies respond to consumer demand for more environmentally friendly products. Apple, for instance, already uses 100 percent renewable energy to power its data centers, and 96 percent renewable energy at its facilities worldwide, but it has also committed to moving its supply chain to 100 percent renewable energy. As Apple's supply chain includes many Chinese and Taiwanese companies, Apple's commitment to powering its manufacturing with renewable energy could have a major impact on Taiwanese industry. While Taiwan's energy intensity is currently lower than China's, it has decreased at a glacial place over the last decade, from 0.14 Ton of Oil Equivalent (TOE)/USD in 1996 to 0.12 TOE/USD in 2014. China's energy intensity, on the other hand, has plummeted from 0.32 TOE/USD to 0.18 TOE/USD during the same period of time. As China is rapidly increasing its share of non-fossil fuels in primary energy, with the goal to reach 20 percent by 2030,[8] Taiwan will need to increase its share of renewable energy in order to remain competitive with China.

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Types of Solar Energy

There are three main photovoltaic power systems being considered in Taiwan: roof-mounted, floating, and ground-mounted. The following section will briefly introduce each of these systems, and define benefits and limitations associated with each one.

Roof-Mounted

This type of PVPP system can be mounted on any type of roof, including agricultural buildings (i.e. greenhouses, livestock enclosures), factories, public buildings (i.e. train stations, schools), and private homes. There are two main benefits to using this type of PVPP system. First, it can dramatically reduce transmission costs, as the distance between energy supply and consumers is reduced to mere meters. Second, solar panels reduce the temperature of buildings, adding an extra layer of insolation and reducing energy consumption.[1]

Floating

Floating systems are installed on bodies of water, including water reservoirs and lakes. The Energy Bureau estimates that Taiwan has the potential to install 1.8 GW of floating systems on 2,700 hectares of land.[2] There are many benefits to floating systems. First, it reduces the temperature on the solar panels, increasing electricity generation efficiency by an average of 11 percent. Additionally, it can reduce the evaporation rate from water reservoirs by 70 percent.[3] This is especially important for Taiwan, a nation that experiences chronic water shortages.

Ground-Mounted

Ground-mounted systems have the most potential in Taiwan, with the Energy Bureau estimated potential to build 17 GW of capacity in Taiwan[4]—however the Center of Energy Economics and Strategy estimates there is potential to build over 60 GW of ground-mounted solar power on degraded or polluted land in Taiwan.[5] Ground-mounted systems reduce the overall cost per watt of electricity as they operate on a larger scale. They are also designed to follow the movements of the sun, maximizing the amount of sunlight absorbed by the panels.

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What About Wind?

As Taiwan's land-based wind capacity has almost been developed to full capacity, off-shore wind has become the major focus of wind power development in Taiwan. The Taiwan Strait, the narrow channel separating Taiwan from mainland China, is one of the windiest regions in the world, estimated to generate power at full capacity 29 percent of the year, compared to just 17 to 23 percent in Germany.[1] As such, the Energy Bureau has estimated Taiwan has the capacity to develop 3 GW of off-shore wind energy by 2025. However, high cost, inaccessibility, discrepancy between periods of high electricity generation and consumption, and high risk of destruction make wind energy only the second-best renewable energy solution for Taiwan. As such, Taiwan should instead focus attention on ramping up its solar energy capacity.

1. High Cost and Inaccessibility

As wind technology and equipment is concentrated in Europe, offshore wind development is completely impossible without support from European partners. Both the 164-ton wind turbines themselves, in addition to the specialized equipment—500-ton-plus crane vessels and offshore platforms— required to install wind turbines offshore must first be imported from Europe, adding high transportation costs on top of the initial cost of a conventional 2 GW wind turbine (USD 3-5 million). [2]

Wind turbines have an annual maintenance cost ranging from 1.5-3 percent of the original cost of the turbine; as wind turbines move off-shore, maintenance becomes even more burdensome.[3] Off-shore wind turbines are subject to higher technical risks through mechanical force, corrosion, and biofouling—maintenance typically represents 25-30 percent of total lifecycle costs for offshore wind farms.[4]

2. Seasonal Variations in Wind Patterns

As Taiwan is a sub-tropical country characterized by hot summers and mild winters, electricity consumption generally peaks in the summer as air conditioner use rises, and teeters off in the winter. Wind patterns follow the exact opposite trend. Throughout the winter months, Taiwan is bombarded with strong gusts of wind. In the summer, wind nearly disappears, save for the occasional typhoon that brings wind so violent that wind turbines need to be shut down in order to prevent damage.

Wind technicians can reach off-shore wind turbines by helicopter or boat, but can only make the journey under calm conditions. In Taiwan, high wind speeds and rough sea waters persist throughout the winter months. As such, wind turbine repairs can only be made for six months of the year. If a turbine were to shut down at the beginning of the winter, it would not be able to generate electricity until the following summer.

3. Natural Disasters

As wind technology has developed in European nations such as Germany and the Netherlands that rarely suffer from earthquakes or typhoons, wind turbines have not been sufficiently tested against these natural disasters. Typically, typhoons enter Taiwan in the East, weakening as they blow over Taiwan's central mountain range before reaching the Taiwan Strait. These weakened typhoons have twisted, cracked, and broken wind turbines and their blades, even causing the 100-meter tall turbines to completely collapse.[5]

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Wind vs Solar

CONDITION	WIND	SOLAR
Maintenance	High maintenance Very expensive — maintenance cost represents a third of total cost of off-shore wind turbine Can only be maintained during calm weather (6 months of the year)	Very low maintenance Inexpensive — occasional panel rinsing to maximize light available to turn into electrical power Can be maintained anytime
Access	Industry centered in Europe. Wind turbines and related equipment must be imported. Requires European assistance to install, operate, and maintain.	Industry centered in Asia. Panels and related equipment are all produced in Taiwan and other Asian countries. Taiwan can install, operate and maintain without foreign assistance.
Intermittency	High wind speeds occur during times of low electricity consumption	High irradiance corresponds with high electricity consumption
Natural Disasters	Wind panels frequently twist, crack, and break, especially during typhoons.	Solar panels are very durable; they rarely crack or break during typhoons.

III. Policy Suggestions

1. Focus on Ground-Mounted Systems

For land-scarce Taiwan, roof-mounted systems seem an ideal solution for several reasons. Most obviously, a roof without solar panels is not serving any purpose other than protection from the elements. Installing a few photovoltaic panels to any roof will allow the homeowners to both earn extra income from electricity generation and also save electricity as a result of added insolation—indeed, a study from the University of California San Diego found that internal temperature can be reduced by 5 °F (2.8 °C) with the addition of solar panels, reducing annual air conditioning load by 38 percent.[1]

Despite these benefits, roof-mounted systems are not the unequivocal solution to increasing solar capacity in Taiwan. First, there aren't nearly enough roofs in Taiwan to supply all the country's energy needs—the Energy Bureau estimates a mere 3 GW of the total 20 GW could potentially be supplied by roof-mounted systems, compared to 17 GW from ground-mounted systems.[2]

Roofs angled away from the sun, or roofs that are shadowed by other buildings or trees, will not perform nearly as efficiently as ground-mounted systems that are specially designed to maximize the amount of light hitting the panel by following the sun on its path across the sky, self-adjusting according to season. Further, constant air flow underneath ground-mounted panels acts as a cooling agent, further increasing efficiency. Roof-mounted systems, on the other hand, are firmly attached to their roofs, with little space for cooling airflow.

In a final and uniquely Taiwanese problem, illegal roofing has served to be a significant hindrance to solar roof development.[3] Many homeowners across Taiwan have added an additional floor on top of the original structure in order to keep the temperature inside cooler; these illegal constructions are not eligible for solar panel development.

Taiwan's current policy emphasizes a focus on roof-mounted systems first, followed by a ramping up of ground-mounted systems. Originally, the Energy Bureau planned to develop 910 MW of roof-mounted and 610 MW of ground-mounted systems by 2018.[4] In order to ensure Taiwan reaches its original renewable energy goals, we would suggest Taiwan adjust this policy to shift the focus onto ground-mounted systems, while slowly building up roof-mounted solar capacity.

2. Cooperation between Agriculture / Aquaculture and Energy

As discussed earlier, Taiwan's high reliance on imported fuel, vulnerability to climate change, and nuclear energy facilities in precarious proximity to fault lines make Taiwan an ideal location for renewable energy development—its long, hot, and sunny summers make solar energy development particularly appealing. At the same time, Taiwan's position as a small island nation with two-thirds of its area covered in high mountains leaves 24 million Taiwanese to scramble over the remaining third for agricultural, industrial, residential, and energy development. With Taiwan's new commitment to develop 20 GW of renewable energy by 2025, cries of dissent have emerged against using Taiwan's precious land resource for energy development, instead preserving the land for local agriculture.

The Council of Agriculture has recently approved 12,000 hectares of degraded or subsided land for solar panel development, representing 8 GW of solar energy development potential. While this is certainly a step in the right direction, much more can be done. According to the Center of Energy Economics and Strategy Research, there is a total of 96,319 hectares of subsided, polluted, degraded, and idle land in Taiwan, representing over 64 GW of solar energy development potential—more than three times the 2025 goal.[5]

We believe there exists no intrinsic conflict between agriculture and energy. The following section will outline the several methods whereby agriculture and energy development can be mutually beneficially for both farmers, solar providers, and also Taiwanese people, all of whom can benefit from a cleaner Taiwan.

Agrivoltaics

In a measure to protect the agricultural sector in Taiwan, the government forbids the use of arable land for solar development. Despite this restriction, 81 solar plants constructed on arable land have been discovered—upon discovery they were fined and dismantled.[6] While the intent of such a policy is admirable, the implementation has resulted in a colossal waste in time and resources. Instead of punishing cash-strapped farmers and green energy developers, we suggest the government actively encourage dual use of agricultural land for both crops and solar panels. This will give farmers the chance to stay true to their trade while also benefitting from added revenue solar panels can provide.

As Japan began ramping up its renewable energy program, it faced a problem similar to Taiwan. In 2012, after Japan first implemented the Feed-in Tariff (FIT) program designed to incentivize solar developers to invest in solar energy, the Agricultural Land Act prohibited solar generation on farmland—productive or idle.[7] Akira Nagashima, a retired agricultural machinery engineer, stumbled across the concept of a "light saturation point" in his studies of biology. This concept explains that the rate of photosynthesis increases as irradiance increases, but it levels off at the light saturation point. Nagashima used this concept to develop "solar sharing" systems, or Agrivoltaics, which allows productive agricultural land to exist in tandem with solar panels. In order to provide crops with enough sunlight, there is twice as much empty space for each PV module installed compared to traditional ground-mounted solar systems. In April 2013, the Ministry of Agriculture, Forestry and Fisheries (MAFF) in Japan approved the installation of PV systems on existing crop-producing farmland. As a result of this program, Japanese farmers are able to supplement their income tenfold using revenue collected by selling electricity generated from solar power systems.[8]

Solar sharing projects are increasingly being introduced on aquafarms, where clean electricity can be generated without sacrificing Taiwan's precious land resource. The epicenter of Taiwan's aquaculture industry is located in southern Taiwan—which also boasts the highest solar irradiance in Taiwan, making it ideal for solar energy generation. Combining these two resources with solar sharing projects will allow aquafarmers to increase their income with the generation and sale of clean, emission-free electricity—without any reduction in aquaculture yields. Furthermore, floating solar projects further improve electricity generation by 11 percent, while also reducing pond evaporation by a third (See: Floating Solar).

The Council of Agriculture has already issued a statement supporting solar sharing in Taiwan,[9] and solar sharing programs between energy companies and small-scale farmers are being implemented to a limited degree. In order to make this a reality on a large-scale, we suggest the government establish a task force made up of representatives from various sectors of the government, most importantly agriculture and energy, to facilitate cooperation and communication between members of the agricultural and energy sectors.

Provide the Rural Community with Reliable Information

It is the responsibility of the government to make accurate, relevant and recent information available to concerned parties. Government-sponsored organizations can provide farmers with accurate information about solar policies, costs, benefits and regulations. This ensures farmers are getting the information they need and enter fair agreements with solar providers. Such organizations can also pull resources to connect reliable and financially stable solar investors[10] with farmers, to encourage them to work together to create a greener future for everyone.

3. Make Grids Smart

While the cables and metals boxes that help transmit electricity to our homes do not evoke the same reaction as fields of glistening solar panels pulsing with clean energy, developing reliable infrastructure is arguably the most important aspect of developing renewable energy capacity. Even if 20 GW of solar farms were installed in Taiwan tomorrow, the current electrical grid would not be able to handle the sudden influx of renewable energy.

Traditionally, electric grids have multiple demand points with relatively few supply points. These supply points are separated into "baseload plants", whereby a continuous stream of electricity is generated using continuous energy sources, such as nuclear, coal, or natural gas, and "peaker plants", which can be activated to satisfy electricity demand during peak hours.[11] In the past, the only moving variable in the electricity "supply chain" was demand, which could easily be met by ramping up or down conventional power plants.[12] The face of the electric grid has completely changed in the modern age of renewable energy. Renewable electricity is supplied from multiple small-scale power sources, scattered across residential, commercial, and industrial sectors, waxing and waning according to fluctuations in natural energy flows.

As a country that supplies nearly 29 percent of its electricity using renewables,[13] Germany already clearly understands the limits of traditional grid systems and is investing extensively in revamping its infrastructure to make room for renewable energies.[14] Currently, German power providers use irradiance and wind predictions (with 93-98 percent accuracy)[15] to estimate the amount of renewable energy supply, adjusting inputs from conventional power plants accordingly. However, this system of tweaks and balances creates much opportunity for waste. When supply exceeds expectations, the electricity provider will shut off electricity from conventional and/or renewable energy sources in order to avoid power surges, resulting in unnecessary carbon emissions and expense—according to the Feed-in Tariff (FIT) laws, designed to encourage renewable energy investment, all electricity produced by renewable energy sources must be purchased by providers. In Germany, most of this burden falls on the shoulders of German consumers, who pay over €500 million (USD 587 million) per year for wasted electricity.[16]

In order to reduce future waste, Germany expects to invest €23.6 billion (USD 27.7 billion) by 2026 to update and expand grid infrastructure, both for transmission lines and distribution grids, as well as for smart metering and technologies to support advanced strategies such as virtual power plants.[17] These systems use data collected across households, business, industry, and energy suppliers to balance energy supply and demand, adjusting both supply and demand to find an equilibrium. Demand-sided adjustments are key in this new order of smart infrastructure—individual businesses and residences will be equipped with smart metering systems, which will reduce energy usage to adjust to the needs of the grid.

While the current Taiwanese government has already pledged NTD 100 billion (USD 33 billion) to the 5+2 Innovation Industrial Plan, which emphasizes green energy and the Internet of Things (IoT), as of 2017 none of these funds have been allotted specifically for developing smart infrastructure.[18] This is rather surprising, considering Taiwan hopes to expand its renewable fleet by a factor of over 20. Even if Taiwan can successfully install 20 GW of renewable energy by 2025, efficiently balancing inputs of conventional and renewable energies to deliver a reliable stream of electricity to consumers will be, at the very least, difficult without an adaptive and flexible infrastructure. As such, we recommend Taiwan follow Germany's lead in heavily investing in smart infrastructure, to ensure it can uphold its promise to become a "Nuclear-Free Homeland" by 2025.

4. Increase electricity prices

From 2012 to 2014, Taiwanese electricity consumption increased by 3.7 percent[19], while Germany's decreased by 3 percent during the same period.[20] This decrease was not due to economic downturn, as the economy had consistently grown throughout that period;[21] rather, the drop in electricity consumption can be directly attributed to high electricity prices. Despite using 20 percent more electricity,[22] Taiwanese consumers paid the equivalent of USD 856.75[23] compared to Germany's USD 2,465.[24] In order to spur industry and alleviate the burden of high electricity prices on households, Taipower, Taiwan's state-owned utility monopoly, has kept electricity prices artificially low.[25] Indeed, Taiwan has the third cheapest electricity in the world, where users pay an average of 0.09 USD/kWh[26], compared to Germans who pay USD 0.34/kWh.[27]

In 2016, Germany spent €25 billion (USD 26 billion) on renewable energy, most of which—€23 billion—consumers paid through a surcharge on their electricity bill.[28] The added costs of infrastructure development will also be reflected in consumers' electricity bills. Many Taiwanese oppose raising electricity prices, out of fear manufacturers will abandon Taiwan for a country with cheaper electricity; however, Germany's example proves that high electricity prices does not necessarily spell economic doom. Despite some of the highest electricity prices in the world, Germany remains an industrial giant, boasting a significant trade surplus, and experiencing comfortable economic growth, even as it makes the expensive transition to renewable energy.[29]

While increasing electricity prices is politically unpopular, there is a direct correlation between high electricity prices and energy-saving behavior, including purchasing energy-efficient lights, appliances, and machinery.[30] We suggest Taiwan raise the price of electricity enough to incentivize both industrial and residential consumers to switch to high efficiency appliances and machinery, and encourage energy saving habits. Increasing the price of electricity can both raise revenue for the state to invest in smart infrastructure and renewable energy tariffs, while also alleviating the burden for electricity suppliers.

5. Adjust Restrictive Regulations

While Taiwan has already made important steps to encourage renewable energy development, such as implementing the Feed-in-Tariff as a measure to use subsidies to counteract the high cost of renewables. Despite this measure, solar farms in Taiwan are not increasing nearly as quickly as originally forecast, already falling short of 2018 goals—of the 1.52 GW of installed capacity planned for mid-2018, very few projects have begun construction, or even been approved.[31] Many attribute this failure to restrictive government policies. We suggest the government relax the following policies in order to expedite the solar development process.

1) Land allotted for solar development should be used for solar development

The Council of Agriculture recently passed a measure that stated solar investors could only develop on 70 percent of land allotted for solar investment, with the intention of protecting agriculture.[32] As the only land approved for solar development thus far has been degraded to a degree that would make any agricultural production nearly impossible,[33] this policy has had a limited impact on agriculture, but has significantly increased the cost of solar development.[34] We recommend the government eliminate this unnecessary restriction, instead promoting solar sharing projects (See: Cooperation between Agriculture and Energy) to encourage cooperation between agricultural and energy sectors, rather than fostering animosity.

2) Settle the terms of electricity price, then sign the contract

Only after solar investors have fronted all installation costs and are ready to connect to the grid will Taipower finally reveal the price at which solar electricity will be bought. Taiwan's restrictive solar pricing policy creates unnecessary obstacles to financing solar projects, as investors are unable to provide a clear payback schedule until money has already been spent.[35] We recommend Taipower confirm the price of electricity upon signing the contract in order to encourage investors to invest in Taiwan, rather than another country with more relaxed policies.

IV. Conclusion

While many critics claim President Tsai's policy is ambitious at best, we are firmly convinced the president's goals are not only feasible, but also necessary. Taiwan's reliance on fossil fuels is becoming more risky as the implications of climate change are becoming more apparent, while safe generation of nuclear energy depends on the whims of the tectonic plates. If the government improves existing policies and implements new policies based on our suggestions, we are confident Taiwan in 2025 will be a cleaner Taiwan.

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