A LANDSCAPE APPROACH TO THE CONFLICTS OF "GREENS"

PLANNING FOR ENERGY AND WETLAND LAND-USE GROWTH
IN SOUTHWESTERN TAIWAN'S COASTAL LANDSCAPE
IN A CLIMATE-CHANGING ERA

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ABSTRACT

Taiwan's national plan to expand solar energy by 2025, including rooftop photovoltaics and ground-level photovoltaics, triggered numerous public debate and land-use conflicts since Taiwan's 2016 presidential election. In particular, the wetlands along the southwest coast have been attracting many solar farms because of their excellent solar radiation potentials as former saltpans; however, this abundant wetland ecosystem also supports many endangered migratory bird species, which has been leading to the conflicts of "Greens" between solar energy and critical habitats. This project developed alternative future scenarios to assess the solar generation potential and other land uses of the southwest coastal landscape for the 40 years' timeframe from now to 2060. Based on the scenario guide input from the experts, solar zoning overlay and developmental rights, plans for two different future scenarios that give priority on climate adaptation and photovoltaic expansion, respectively. These scenarios project areas for solar energy development considering their priority in relation to flooding conditions, ecological conservation, and land-use developmental strategies. Future scenarios are evaluated according to its land area and associated performance of flood mitigation, ecological conservation, energy generation, and land-use efficiency. Findings show that the total solar developmental rights of the expansion scenarios grow slightly (13.57GWc in 2040 and 15.03GWc in 2060), while the CO2e emission avoided dropped from 4424 kilo-ton to 3796 kilo-ton CO_2e. Adaptation plans have a constant growth of solar developmental rights (7.97 GWc in 2040 and 15.42 GWc in 2060), while CO2e emission avoided grows 2486 kilo-ton to 4464 kilo-ton. Although the expansion plan saves more carbon emission in 2040, the adaptation plans are more efficient in land-use, impacting less agricultural land and wetland than expansion scenarios in both 2040 and 2060 while saving compatible carbon emission. This indicates that adaptation planning is more a systematic approach that brings multiple benefits over photovoltaic expansion planning in the southwest coastal Taiwan context.

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1 INTRODUCTION

The Taiwanese government has set a renewable energy goal to meet in 2025. The 20GW capacity for photovoltaic development goal includes 17GW of ground-level and 3 GW of rooftop implementation. The implementation of ground-level solar has caused many controversies. One of them is that photovoltaic is taking place in or next to areas that have high ecological value. When the photo figure 1-1 was first made public on social media (Wang & Su, 2019), the criticism of “excavator scares the birds” can be easily made. On the other hand, one can also applaud renewable energy development like photos figure 1-2 that can help us advance the energy system “cleaner.” However, some question needs to be asked to achieve this goal. What happened behind the scene? What are these developments? How are birds affected? Are there other places more suitable for this development? The only means to answer these questions is to investigate the spatial and social relationships among the regional landscape system, photovoltaics development, as well as in what context they are situated.

Figure 1-1 Excavator Photo in Wetland Adjacent Area (Wang & Su, 2019)

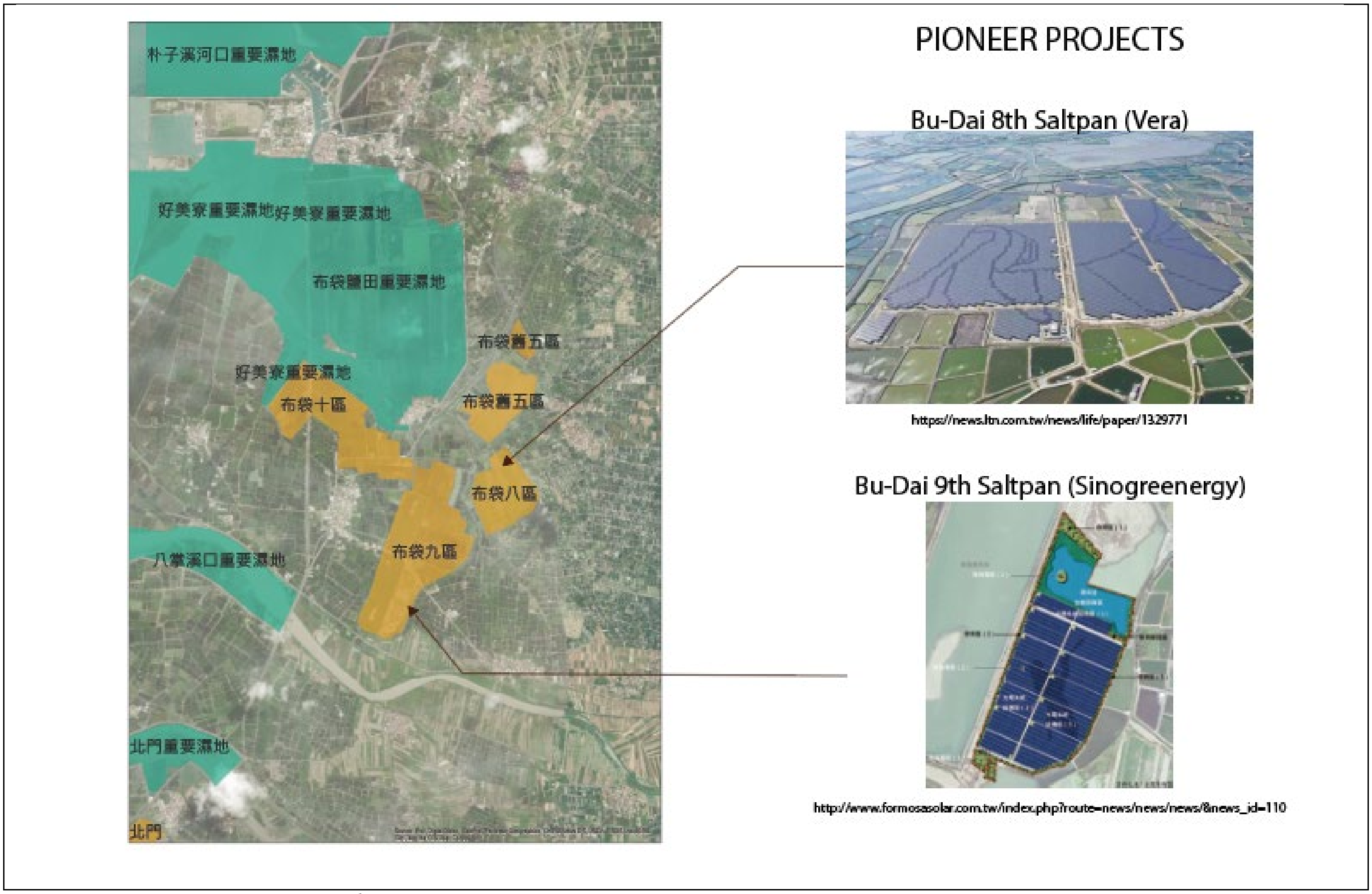


Figure 1-2 Bu-Dai 8th Photovoltaics

1.1 PROJECT PURPOSE

The initiative of this project is to inform policy decisions focusing on the spatial conflict between ecological land-use and renewable energy development. While pushing forward for climate change mitigation through photovoltaic development, Taiwan's southwestern coastal landscape is experiencing flooding due to climate change directly and indirectly. Rural towns in this region have relied on aquaculture and agriculture for decades. Their social-economic needs were challenged by industrial development in the past and will remain uncertain as more frequent flooding potential in more areas, as well as more photovoltaic projects coming into the region. To inform policy decisions, some external trends and concepts should be considered. They are such as world trends in the energy transition, energy sprawl, and lawsuits from green activists and watchdog organizations in Taiwan.

World Trends in Energy Transition

Transitioning electricity systems to partial, or hundred percent renewable energy is an inevitable trend across the globe. According to Emission Gap Report 2019 (UNEP, Emissions Gap Report 2019, 2019) launched by United Nations Environmental Program, "Collectively, if commitments, policies, and action can deliver a 7.6% emissions reduction every year between 2020 and 2030, we CAN limit global warming to 1.5°C.". This reduction requires emissions from all sectors globally. However, Emission Gap Report 2018 (UNEP, The Emissions Gap Report 2018, 2018) considered the mitigation effort is insufficient and has no sign of peaking. This situation, which has a high potential to trigger extreme weather events, is often called a "climate emergency." Twenty-six countries launched some form of climate emergency declarations at the end of 2019 (Aidt, 2020). The emergency has a high chance of contributing to extreme weather all over the world. However, Yen concluded that energy studies often use Representative Concentration Pathways 8.5 (RCP8.5) as a baseline background for estimation. Whereas, Yen considered it might be an over-estimation. Yen considered the baseline for estimation should be around RCP4.5 to RCP6.0 (Yen, 2020).

Despite minor arguments about what degree of climate change baseline model should be used in scientific studies continuing, IPCC (IPCC, 2019) particularly warned communities in the coastal environments of potential exposure to higher risks of sea-level rise and an extreme sea level. Moreover, the changes in ocean patterns can lead to weather pattern changes such as severe weather.

Along with the consideration of peak oil and greenhouse gas reduction, renewable energies are the only few options of low carbon future technically available so far. With new policy implementation, IEA envisions "by 2040, low-carbon sources provide more than half of total electricity generation," and the rate of the implementation (figure 1-3) in the World Energy Outlook 2019 report (IEA, 2019). It is undeniable that the whole world needs to boost up the percentage of renewable energy in the electricity sector to meet the transition goal, but "where" is the question.

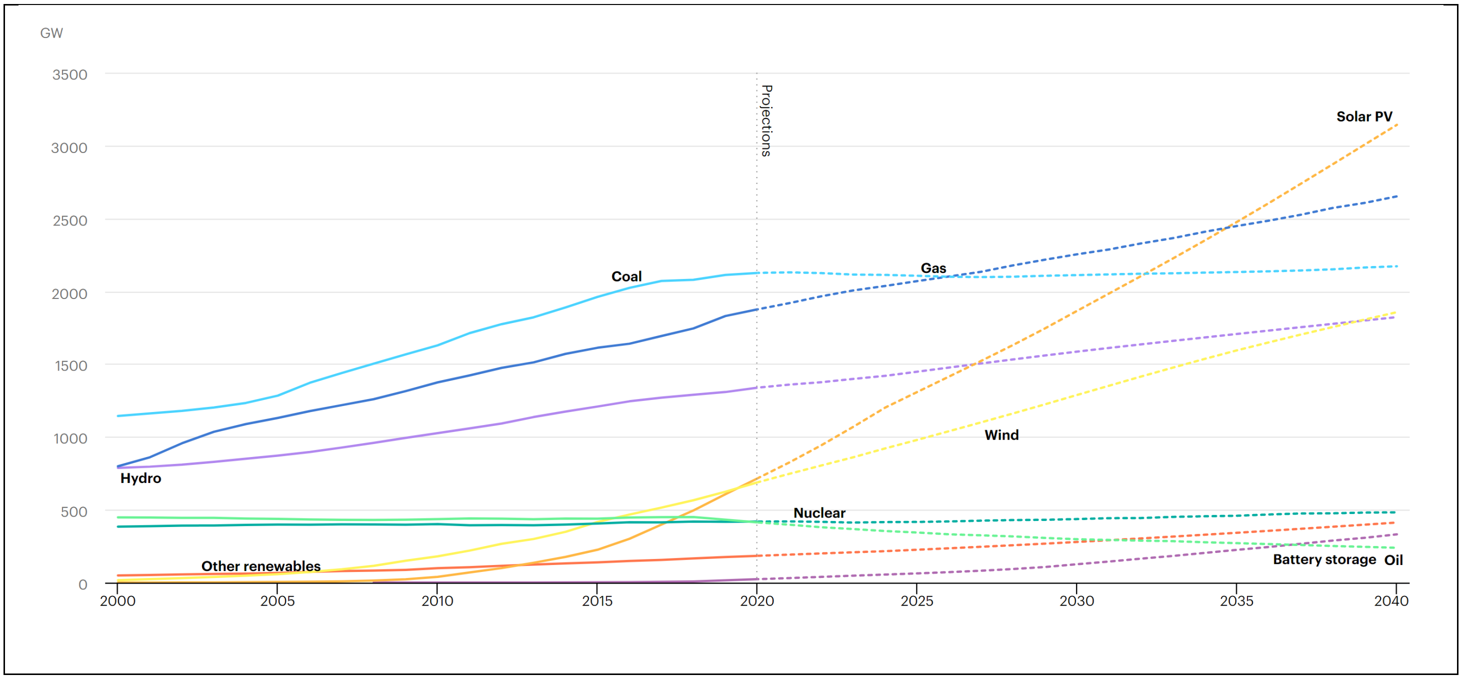


Figure 1-3 Installed power generation capacity by each source in the Stated Policies Scenario, 2000-2040 (IEA, 2019)

Energy Sprawl

Energy generation takes up space. Even though renewable energies have minimal carbon emission, their land-use impacts cannot be ignored. McDonalds et al. referred "energy sprawl" as "the spatial extent in which production activities occur" in energy production techniques (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009). Energy sprawl can also put as "the land required to produce and move energy, measured in acres per total quantity of energy production" according to Bronin (Bronin, 2010). "Energy sprawl is the largest driver of land-use change in the United States," Trainor et al. concluded that it takes 5.2 years for photovoltaic to justify the time to land-use equivalency (TTLUE) compared to that of conventional natural gas, or 23.6 years compared to conventional coal (Trainor, McDonald, & Fargione, 2016) . Energy sprawl is one of the primary drivers of the land-use conflict between ecological health and renewable energy because the footprint of renewable energy often takes up much land, including areas with ecological values or services. McDonald et al. reveal that the expected land-use intensity of photovoltaics is 36.9 km2/TW-hr/yr, which is half compared to wind, two times compared to gas, and fifteen times compared to nuclear power (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009). Less land-use intensity may become an argument to support nuclear power usage if one disregards its catastrophic threats and extended temporal scale of impact of high-level nuclear waste. Notwithstanding, the critical lesson to learn from this study is to focus on efficiency improvements in electricity and liquid fuel, which conserve significant units of area. We can also extend that lesson and apply to the position of this project: the effort in improving inefficiency should always take place before planning for renewable energy development in landscapes as much as possible.

From a critical perspective, we should consider energy transition in physical space and energy sprawl of renewables as a process of "spatial fix" in David Harvey's notion (Harvey, 2001). Without questioning the productional relationship of the energy production and consumption in the capitalist society, shiting away from the fossil-fuel-based energy system to the "cleaner" system is only an act of continuation of the reproduction of the capitalist system. As energy gets transmitted to dense cities and industrial sectors, the transformation towards the energy landscape can be seen as a form of the urbanization process. Moreover, the investment of the "cleaner" system and its energy sprawl can be seen as a spatial fix to the climate emergency in order to sustain the capitalist system. That has been said; the effort of fighting climate emergencies can not be denied.

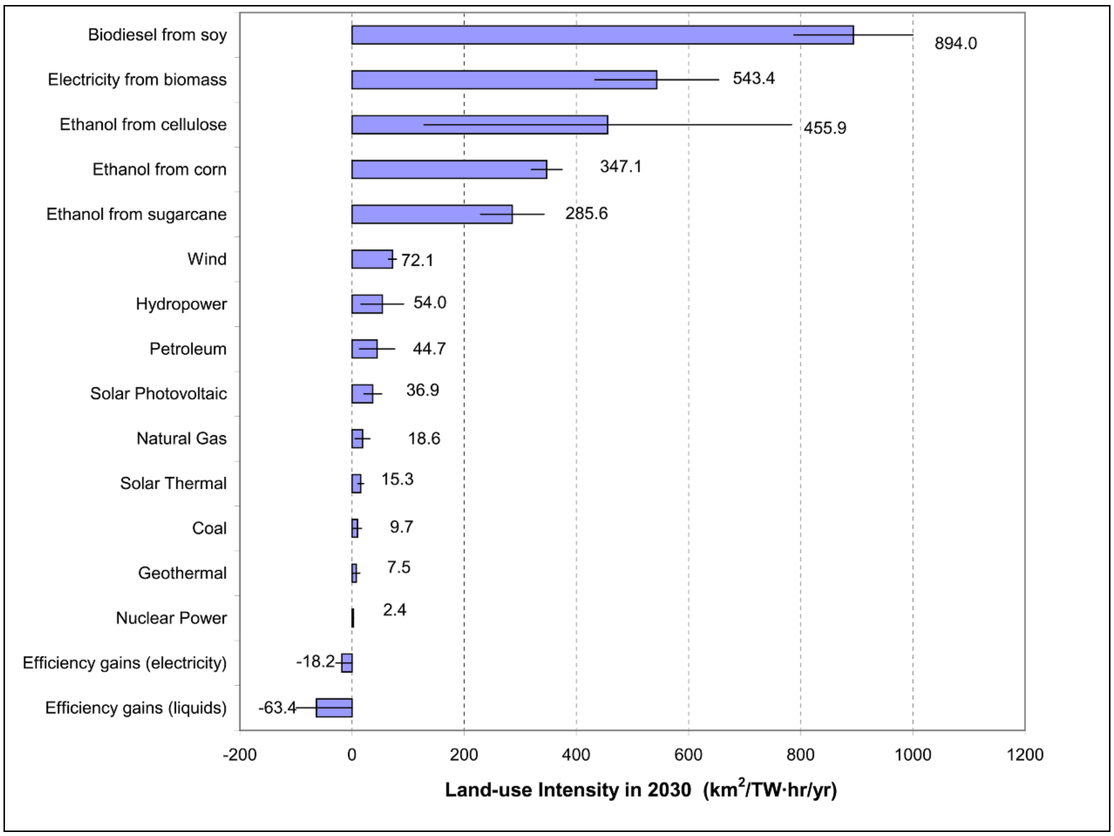


Figure 1-4 Land-use intensity for energy production/conservation techniques. (McDonald, Fargione, Kiesecker, Miller, & Powell, 2009)

Conflict of Greens driven by Taiwan's national energy policy

The Taiwanese government (BoE, 2017) has set a specific renewable energy goal to meet in 2025. They are 20000 MW capacity for solar, 1200 MW capacity for the land wind turbines, and 3000 offshore wind turbines. The possible location, planning implementation, and government incentive programs are still being developed. In Taiwan, there have been various conflicts between "clean" energy and other types of land-uses. The following energy development cases revealed the lack of public hearing process and the lack of updates on legal protection based on scientific facts.

1. In Yuan-Li Town, Miao-Li County, in 2010, residents opposed the fourteen new wind turbine development for them being too close to the residential area.
2. In Yong-An Township, Kaohsiung, in 2011, the photovoltaic development of a 6,900 kW farm was placed on a corner of Yong-An wetland. In 2019, the Taiwanese government also planned to build an expansion of gas power plants, which would take up two-thirds of the wetland area of Yong-An wetland.
3. At the central Taiwan coast, in 2017, the Taiwanese government launched the offshore wind turbine development, which has the potential to drive *Sousa chinensis taiwanensis*, or Taiwanese dolphin, to extinction for the noise pollution and the habitat degradation from the construction (Tougaard & Mikaelsen, 2017) (Shih & Wu, 2016).
4. In Da-Tan, Taoyuan City, the government proposed the third national liquid natural gas terminal port in 2017. The proposing site is adjacent to the habitat of crustose coralline algae on coastal reefs, where protected coral species were found.
5. In Chi-Ben wetland, Taitung, which is not a protected wetland by law, is in the Kanaluvang Aboriginal Territory. Tribal members voted to agree on the solar panel development. Some tribal members have been using this land for grazing and foraging, and the wetland is also the habitat of 134 species of birds, including 21 endangered species.

These developments are all ongoing "conflicts of greens" cases. Ko et al. define conflict of greens as conflicts between "green" goals, often being "green" developments and habitat preservation. One can utilize Ko's notion to determine that these controversies occurred under the claim of "segmented green" approaches, which is "a piecemeal approach, improving part of an environmental problem at one scale but causing other ecological or social problems at another scale" in Ko's word. Besides, Ko expects more conflicts of greens would appear in the twenty-first century. Ko called for a "systematic greens" approach "considering a wider range of alternatives, allowing more time for a thorough review by the local community and by relevant experts and then addressing their suggestions fairly, government officials, in turn, should give more weight to these assessments in their ultimate decision to pursue or forgo a project." (Ko, Schubert, & Hester, 2011) Notwithstanding, Chou considers Taiwan is in the structure of high-carbon society and require creative governance with self-criticism and self-reflection embedded in local society. Chou suggests the creative governance should consider "health, ecology, agriculture, energy, economics, and social distribution" in a technology-society complex system. (Chou, 2017)

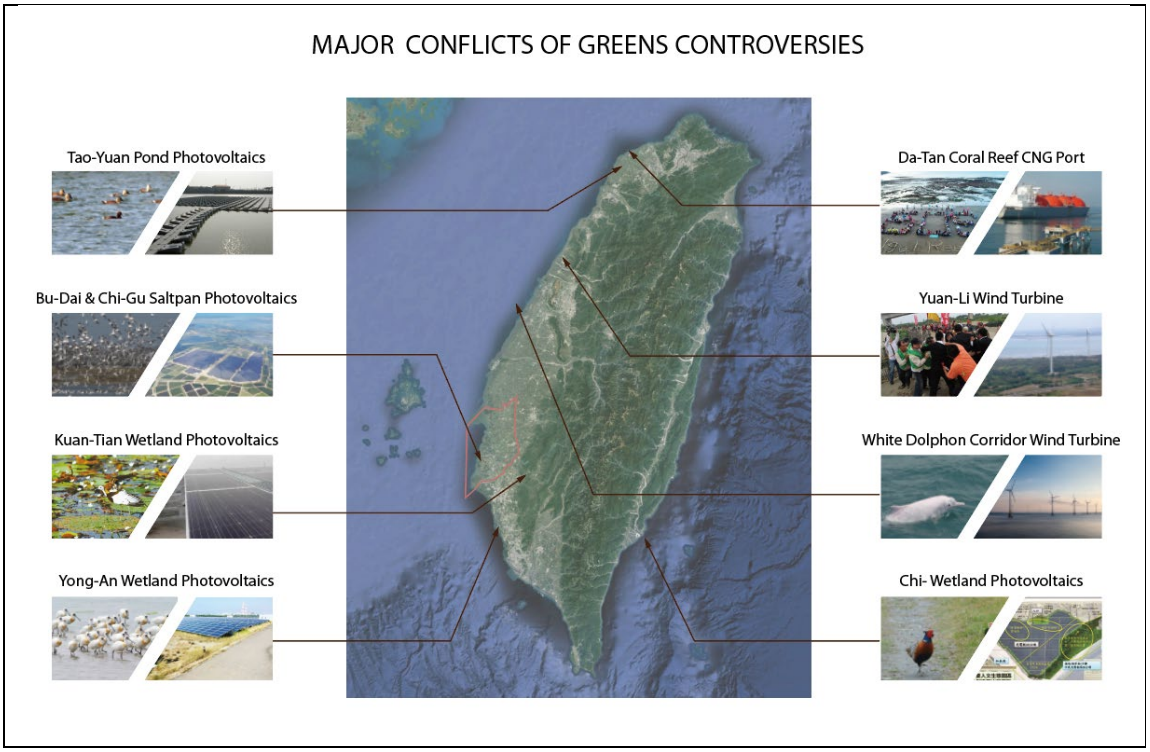


Figure 1-5 Major Conflicts of Greens Controversies in Taiwan

1.2 PROJECT SCOPE

The scope of this project constitutes research questions, research objectives, and expected outcomes. The objectives and outcomes are categorized into three aspects, including method, planning, and typology, resonating the chapters of project framework, planning analysis, and representation of types.

Research Question

This project aims to develop a systematic framework in order to approach the controversy around the "conflicts of greens." To study the solar energy development for southwestern coastal Taiwan in the context of the increasing flood risk and sea-level rise, the research questions are:

> **What would the solar energy development for southwestern coastal Taiwan in the context of increasing flood risk and sea-level rise look like?**

Research Objectives

Following the projects research questions, the research objectives are as follow:

1. Adopting alternative future methods for photovoltaic development in coastal Taiwan to visualize two different green development strategies:
   The scenarios developed with the alternative future method will be assessed in the project. Bridging the landscape ecology knowledge and energy landscape planning knowledge with the alternative future method will be the main task in the project framework session. The scenario planning process should help one understand what elements in the landscape may be compromised in the changing landscape while gaining benefits in other elements under two different developmental strategies.
2. Developing and analyzing trajectories of developments of photovoltaics and their implementation and evaluating their environmental performances:
   A series of scenario drives, land-use change parameters, and the guided future plan will be developed. Specifically, where and how dense should the photovoltaic site be developed, and what are the impacts? What would be the environmental performances of each scenario?
3. Visualizing selected land-use change types for further understanding of how the landscape would look:
   Representation of type phase will illustrate the co-location strategies for selected land-use types in the flooded rural land-use. Selected from four types of land-use, the generic perspective views will explore the landscape look. The coastal dynamics of these types of land-use will be explored in sections.

Expected Outcome

Along the planning process, there will be related maps and layers related to wetland protection, land-use changes, flood prediction, and solar zoning. The primary outcome is a series of maps of scenarios in two forms, including solar zoning overlay and land-use changes. They will also be assessed with their environmental performance. Ultimately, these maps indicate how the land-use change, in its highest potential, would look like in the plan.

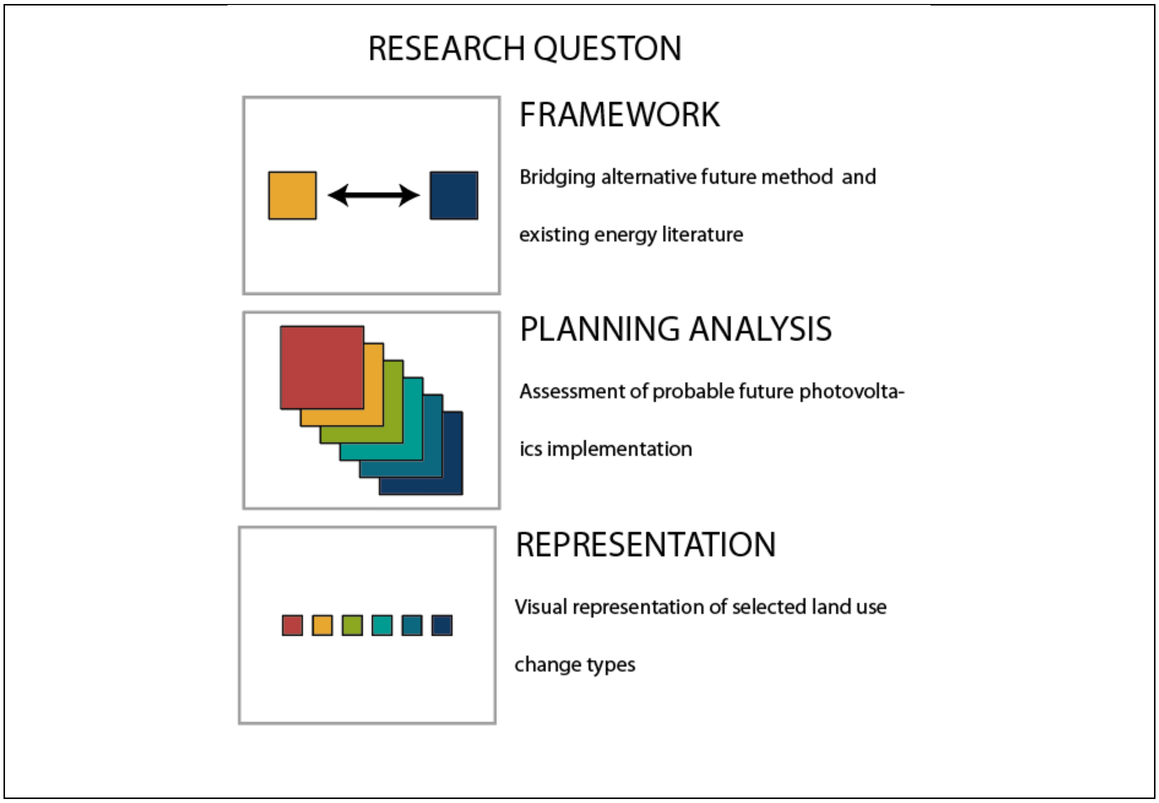


Figure 1-6 Project Scope

1.3 PROJECT SIGNIFICANCE

It has been a long debate where we should put solar panels into the broader landscape globally in the past decade. In the case of Taiwan, densified urban areas contribute to the lack of average solar exposure. Moreover, the unpermitted rooftop add-ons stopped many homeowners from considering photovoltaic installation. On the other hand, the current development of utility-scale solar projects can have negative impacts on ecologically sensitive sites due to the lack of systematic spatial planning and public engagement. Projects across the globe have shown that the lack of landscape hierarchy leads to not only ecological impacts but also community objection towards renewable energy development. A thorough planning process is critical to offer a better practice of intentional land-use change involving the expansion of the energy landscape. By that, other post estuary landscapes with wetlands and saltpans can adopt this approach. The process have to critical element,

A Comprehensive Landscape Approach

Enright concluded that the key components of a landscape approach to ecosystem services include landscape-scale biophysical processes and human experiences, identification of critical ecosystem services of the landscape, understanding of human relationships to ecosystem services, and intentional landscape change. This framework offers useful general guidance of how landscape approach in planning for landscape-scale changes. There is little existing literature on landscape change studies using an alternative future method that focuses on photovoltaics development. Projects using scenario planning to plan for energy landscapes were only seen in very few pieces of literature, such as Stremke's five-step approach (Stremke, 2012) (Stremke, 2010). Therefore, this project offers the potential to fill the gaps of knowledge in multiple ways, including applying methods to energy landscape planning, consolidating considerations in planning for wetland species, exploration in designing energy transition, and understanding its impact on rural land use.

When planning for wetland species in this region, it is critical to take advantage of landscape ecology understandings of *Platalea minor* (black-faced spoonbills, BFS), an endangered umbrella species of the east-Asian migratory flyway and culturally important species beloved by Taiwan general public. This research explores the new relational organization of a wetland's buffer distance from the disturbance in the post-estuary landscape and can inform the landscape planning process with landscape ecological knowledge.

Regarding designing an energy transition, this project echoes the particular government policy "Saltpan Solar Projects" by criticizing its lack of consideration of landscape hierarchy and the impact of rising sea levels. Some may challenge that if the policy were to be withdrawn due to political changes, there would be no reason to continue this research. However, it can be argued that the importance of this project not only lies in the criticism of the government policy but also designing for an urgent need for the energy transition in responsible and intentional means. Regardless of the government agenda tied to saltpan solar development, this project aims to show that the spatial organization matters in the future in this changing and ecologically sensitive landscape. A longer time frame and understanding of the human-infused landscape for planning is what is needed.

From a landscape approach standpoint, scenario planning offers the potential to work with the dynamism of the estuary landscape and rising sea-level. Only by recognizing the historic integrity of this estuary-derivative landscape can the intentional landscape change be a careful and responsible intervention. By setting the spatial scale of the southwest coastal landscape of Taiwan and the temporal scale of twenty years in scenario planning, this project aims to offer a potential solution to the urgent need for the renewable energy transition in an area-specific context.

Addressing Conflicts of Greens in Southwestern Taiwan's Coastal Landscape

Since urban areas are not likely to be self-sufficient in solar energy production, the photovoltaic development is often placed in agricultural land and state-owned marginal land, in this case being former saltpans. This project focuses on southwestern coastal Taiwan's conflicts of greens where photovoltaic projects are proposed to go; these are former saltpans, which are now wetlands with ecological functions. These formerly productive lands before 2001 have evolved into highly ecologically functional areas over time. However, placing solar panels on these saltpan wetlands might have direct impacts on their ecological functions and services. This can destroy existing migratory bird habitats which include many endangered species.

On the other hand, the conflict also expands to aquaculture ponds and agricultural lands in this region. The Council of Agriculture of the government of Taiwan requires aquaculture ponds and farmlands with photovoltaic energy to maintain seventy percent of production and the photovoltaic farm should not exceed a forty percent area ratio (Yang M.-C. , 2017). However, there are some critics on these policies use of the potential miscalculation of the base year of production and how this formula is applied. In short, these regulations, as well as this project, only consider the area and ratio of a photovoltaic energy project while ignoring the factor of ecological functions and ecological services. This kind of discussion has the danger of leading the conversation to vague area calculations instead of taking the quality and the characteristic of each land area into account.

These two types of conflicts, energy, and agriculture, as well as energy and habitat, in the southwestern Taiwan coastal environment have some causes: the government tries to meet the energy capacity goal without evaluating the impacts of the plan on the planning scale. The feasibility and evaluation of impacts can only be assessed if there are parameters set up to envision future trajectories and how to implement them. That is to say, the energy capacity goal should be set based on a projected future with a clear road map. Scenario planning allows us to test out how much potential capacity is truly feasible if policies were set to push such parameters forward in different scenarios. This would help policymakers or the general public what the trade-off between different goals is and not be too hung up with one particular scene.

From a research standpoint, literature regarding scenario planning projects around land-use changes have been focusing on housing developments and conservation land-use, with little coverage on energy landscape implementation. The application of energy planning offers potential research in supplementing the means of approaching conflicts between the greens.

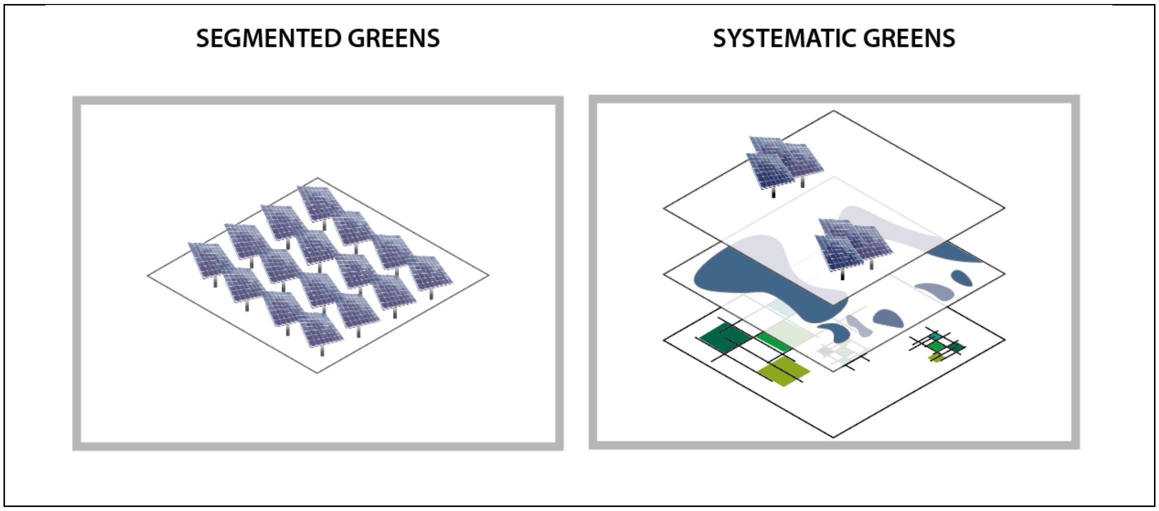


Figure 1-7 "Segmented Green v.s. Systematic Green" Concept (Ko et al. 2011); Image is original to this project.

2 STUDY AREA CONTEXT

The context of the study area can break down into three aspects. They are natural, cultural history, current land use, as well as regulations and policy.

2.1 STUDY AREA

The study area of this research is in southwestern Taiwan's coastal landscape. There are four counties in this region, which are: Yunlin, Chiayi, Tainan, and Kaohsiung. This project focuses on the middle part, Chiayi and Tainan, where wetlands aggregate. The two counties mentioned above are selected for three reasons, including; its best radiation in Taiwan, the surrounding critical habitat, and availability of its geographical data.

Southwestern Coastal Taiwan has the best radiation-level on the island; therefore, solar projects are taking place in these counties with increasing frequency. According to the annual radiation map of Taiwan (CWB & BoE, 2018) and the table of year-round county photovoltaic efficiency (Taipower, 2020) (DBA, 2020) , these conditions revealed that the area is one of the most efficient places to implement solar energy facilities, which are mainly photovoltaic development in Taiwan's case.

Southwestern Coastal Taiwan is also currently an ecologically healthy landscape. According to Ramsar standards (RAMSAR, 1971), wetlands are considered important. Besides, some of them are protected by The Wetland Act. This coastal landscape has suffered from land subsidence for many decades. With no indications of slowing, the threat of flood increased due to the sea-level rises and changing rain event patterns. Notably, the distribution of wetland and solar projects is not coincidental. The wetland used to be former salt pans gradually turned into habitat after 2001. Many endangered migratory avian species rely on these habitats for forage and roosting activities. Any development in or adjacent to these ecologically important areas requires careful planning and protection while considering the impact of the development of the rural landscape.

The availability of data also constrained the area of the project. With different levels of details, various types of data around Chiayi and Tainan are the most available among the four counties due to the survey and previous researchers' efforts.

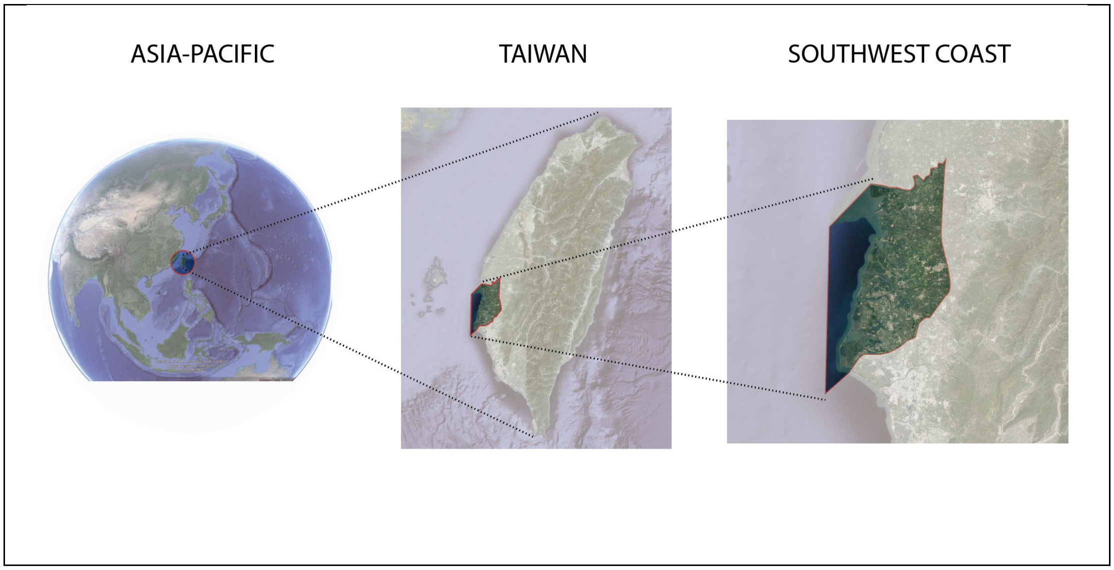


Figure 2-1 Southwest Coastal Region and Study Area

2.2 NATURAL AND CULTURAL HISTORY

The natural and cultural history of the region guided the project. Understanding the natural history, such as ecology and landscape changes, as well as cultural history, including economy and social movements, are critical to further comprehend the temporal side of the project.

Landscape Connectivity

This landscape is a post-estuary landscape, which was a wide area of the lagoon, and it carries a wide variety of post-estuary economic activities. The early day fishers called the lagoons “inner sea” back in the 1800s. Two of the three main inner seas in Taiwan are in the study area. The inner sea was filled due to river channel migration later on. In the twentieth century, the inner seas no longer appear on maps. Regardless of the long-term landscape changes, this region remains to be a relative lowland area, and forms a managed post-estuary agricultural landscape of saltpans, wetlands, and aquaculture pond, as well as wetlands and lagoons.

The umbrella species in this landscape, black-faced spoonbill, has strict roosting and foraging requirements for their habitat. Hester illustrated the spatial requirements of the species' habitation in Figure 2-2 (Hester R. T., 2006). Ueng (Ueng Y.-T. , 2015) also mentioned in a personal conversation that these wetlands habitats serve as core and steppingstone habitats. Lin and Chen utilized landscape development intensity to study the connectivity of these wetlands. It is notable that after 2001, the year saltpan production is abandoned, the BFS number grew significantly (Chen, Lin, & Huang., A Framework on Habitat Connectivity among Taiwan's Wetlands for Overwintering Black-Faced Spoonbill, 2015). Lin argued that BFS growth after 2001 has a causal relationship with the saltpan stop producing salt transforming into wetlands (Lin K.-H. , 2019).

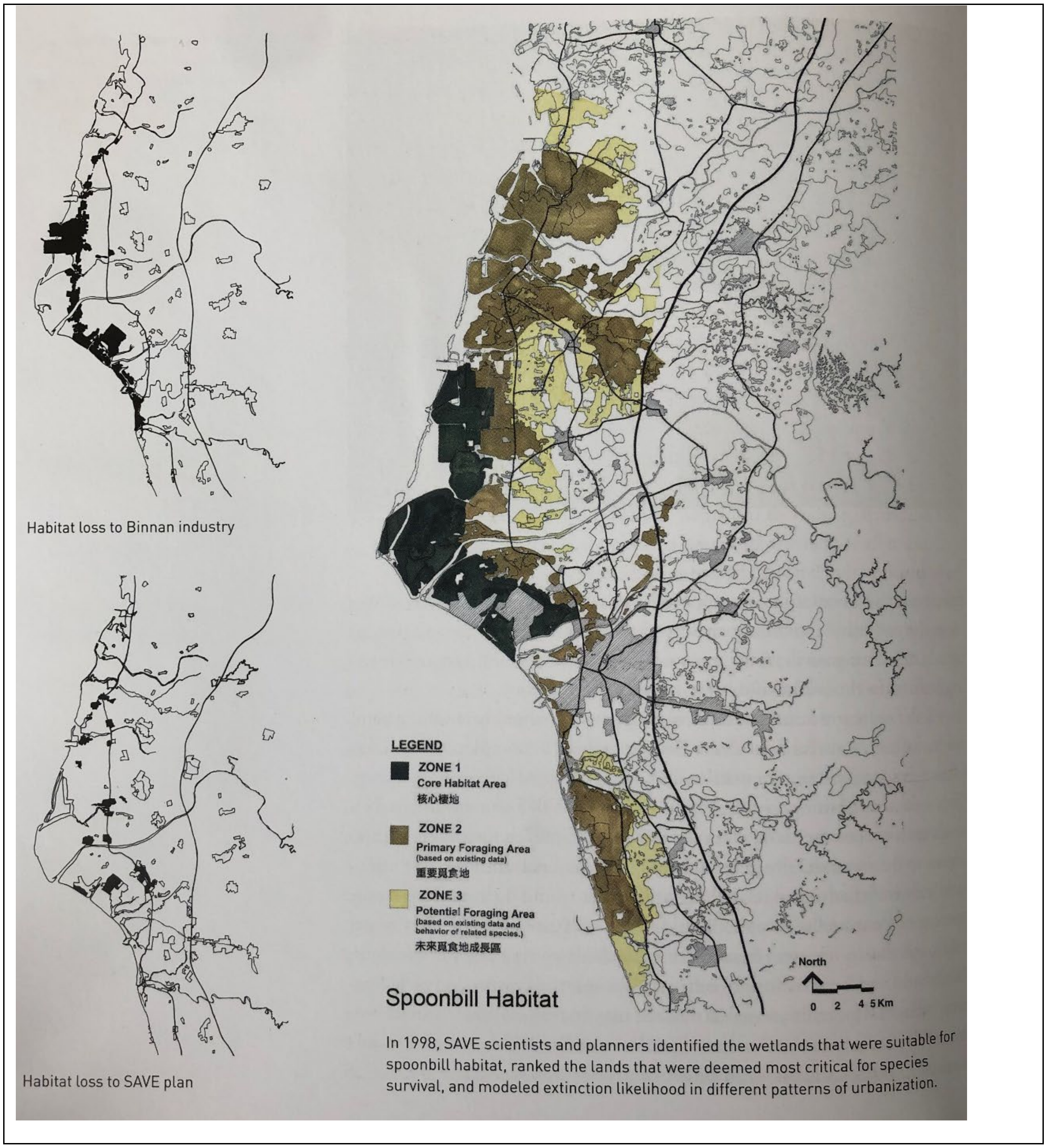


Figure 2-2 Black-faced Spoonbill Habitat (Hester R. T., 2006) (Hester, et al., 1997)

Species-Inspired Regional Identity

From the Anti-Binnan Petroleum Complex Movement to saltpan solar development, this area also has a strong identity formed in past social movements, and it carries on. Also, it is critical to see the site as part of the southwest coastal wetland system while understanding the pressure of development in this area.

The coastal region has been one of the areas under the most pressure of development in the past.

1. The Mai-Liao petroleum plant, or the sixth petroleum plant, claimed the tidal zone and turning it into a petroleum complex. This plant is at the north of the site. Although it encountered significant opposition from the community, it was still built and permitted around 1994. It still has significant pollution issues affecting mariculture, aquaculture, and agricultural practices today.
2. The 1990s Anti-Binnan Petroleum Movement (proposed seventh petroleum plant) also marked important progress in the study site. This movement was one of the first environmental movement that was successfully stopped the petroleum development. Hou concluded that the movement contributed to the cultural construction of place. Following that argument, we can consider the reason of this area became the current Tai-Chiang national park in 2009 (Hou, From Dual Disparities to Dual Squeeze: The Emerging Patterns of Regional Development in Taiwan, 2000) (Hou, Cultural Production of Environmental Activism: Two Cases in Southern Taiwan, 2000).
3. The proposed eighth petroleum plant, or Kuo-Kuang Petroleum development, was proposed in a coastal lagoon wetland area. This site is a county away from the study sites, where many bird species and endangered dolphins (*Sousa chinensis*) have their habitat, and where aquaculture ponds exist. The prominent opposition earned national concerns and stopped the development.

With this series of proposed development at sites on the southwest coast in Taiwan, it is not hard to disclose their similarities. The big land area with vibrant coastal ecosystems next to poor coastal towns are living off aquaculture and mariculture. After Takahashi Tetsuya's notion "the System of Sacrifice," these areas sacrifice their environments to serve a "bigger good" of the imagined community, such as state, market, or corporate profits from which we benefit (Tetsuya, 2012). The Saltpan Solar Project and its attempt to expand energy generation without considering the agricultural sector and ecological health, can also repeat the danger of the above mention development. We can also see that the grassroots organization of fishers against solar development emerge in Chi-Gu, where the seventh petroleum plant is proposed.

The study site has the best radiation on the island, and it was evident that the big wetland areas and area experiencing flood would be a perfect place to implement these photovoltaics panels. It is critical to recognize that the Energy and Ecology Nexus of this area or the Conflicts between Solar energy, wetland, and human habitation would be a constant struggle of this area if we continue the system of sacrifice. One can foresee more development will be proposed on the "empty" wetlands and flooded area (Lien, 2017). On that note, Lai proposed a potential framework to the energy transition that we should not only be looking at due to the amount of energy generation but also in consideration of a multi-layer, cross-industry system, which is the system of support (Lai W.-C. , 2015).

Figure 2-3 Black-faced Spoonbill as Regional Identity

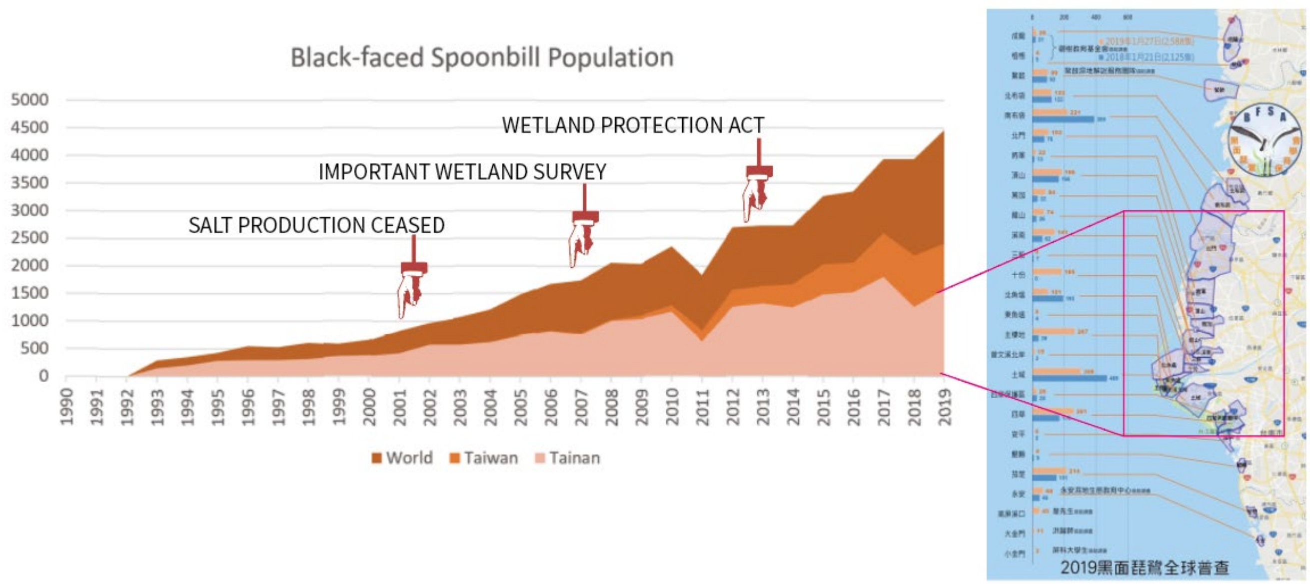


Figure 2-4 Black-faced Spoonbill Population Compared to Observation Data

2.3 CURRENT LAND-USE PATTERN

Understanding the current land-use can help us reveal the spatial context of the area. The current land use will be introduced in the section, including all major types of land use.

The following map figure shows the major land-use types in the study area. The coastline of two counties is about 52 kilometres, or 32 miles. The landscape constitutes of the rural residential and rural town, agriculture, (general agriculture, prime agriculture, rural designated agriculture), and some industrials showed in Figure 2-5. The Tourism agency in Southwest Coast National Scenic Area administrates and also manages much land in the study area, including most of the former salt pan. Urban planning and industrial areas are not considered in this project in order to simplify the analysis.

Current ecological land-use includes a national park, designated wetland, a national protected coastal forest, designated wildlife habitats, and other habitats recognized by the experts, although without legal status. Notably, various sources have emphasized the “island ecology” of black-faced spoonbill in landscape habits across wetlands in four counties as one ecological area with multiple steppingstones, including SAVE International (Hester, et al., 1997), Chen (Chen, Lin, & Huang, Development of a Framework for Habitat Connectivity of the Black-Faced Spoonbills – An Example of Taiwan Wetlands of Importance), and Ueng (Ueng & Liu, 2006),

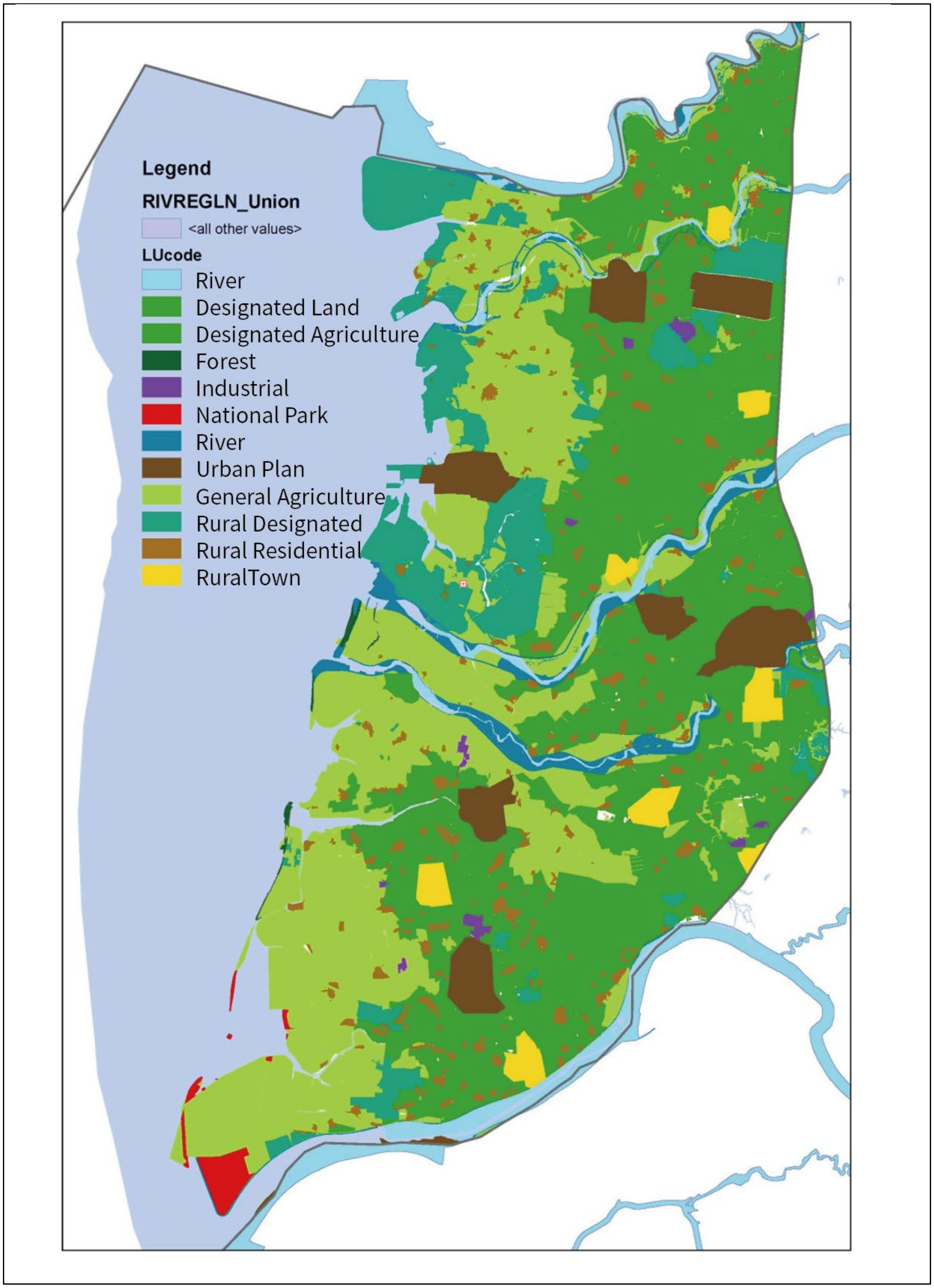


Figure 2-5 Regional Land Use Pattern

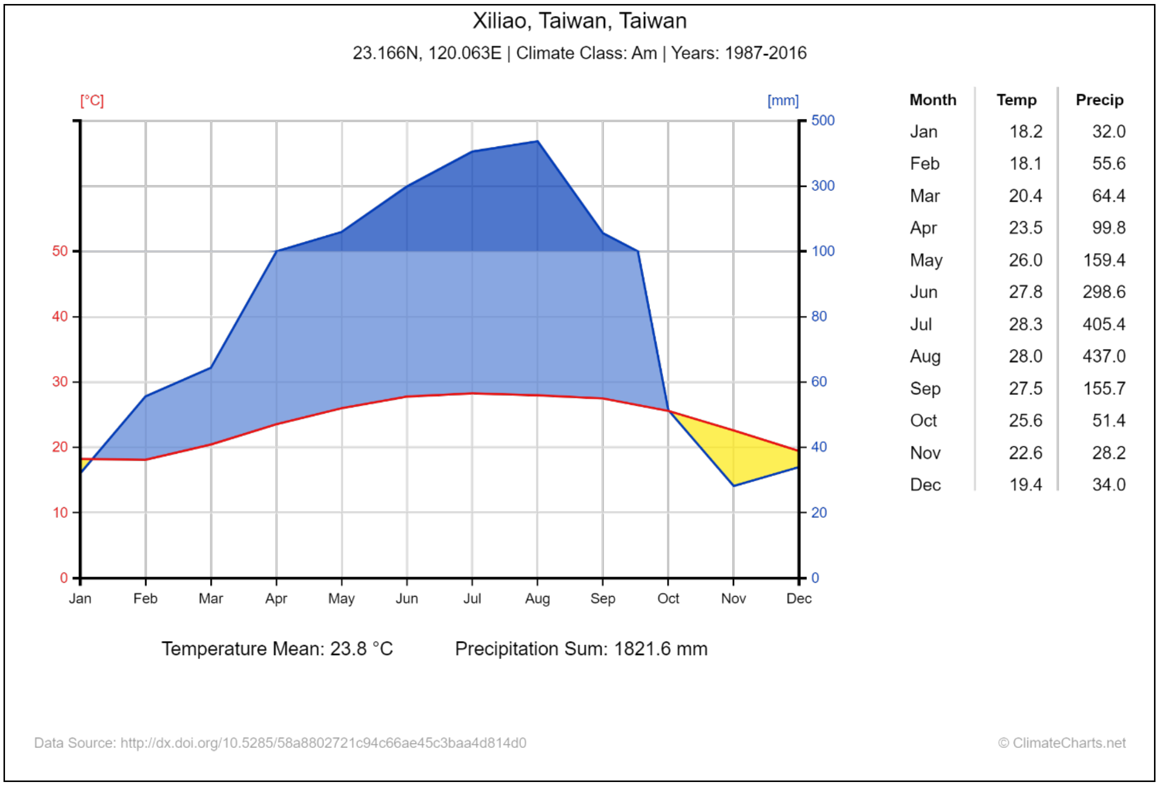


Figure 2-6 Eco-Climate Chart of the Study Area (TU Dresden, 2016)

Figure 2-7 Black-faced Spoonbill Count 2020 Map (BFSA, 2020)

2.4 SOLAR DEVELOPMENT

Several solar photovoltaic power plants have been built in the region. The first utility-scale solar photovoltaic power plant developed in wetlands was at the Yong-An Wetland in 2008. Yong-An Wetland has various features, including a saltpan cultural landscape, park space, Ramsar IBA, raft eco-tourism, and an historic saltwater watch-tower (Lin K.-H. , 2008). Kaohsiung Birds Association and other Non-Governmental Organizations negotiated with Tai-Power to come up with rezoning, and the PV area is 9.5 hectares. The final photovoltaic plant takes up 6.5 hectares. Avoidance measures were taken in the north part of the site. These areas are usually viewed as marginal land for photovoltaic energy, the idea of "wasted land," and "empty land" (Lien, 2017). The single ownership, big area, and abundant solar radiation makes it "suitable" and "ready" for development.

Vera Energy invested photovoltaic powerplant in Section 8 in Bu-Dai with 70.2MW capacity, occupies 79.4 hectares. The powerplant produces a hundred million kWh electricity, saving up to sixty-thousand tons of greenhouse gas emissions. This powerplant, "Yi-Zhu solar powerplant," got the operation permit to start selling electricity to Tai-Power in 2019/10. The photovoltaic power plant is 79.5 hectares in total, which includes 55.4 hectares of photovoltaic and 24 hectares of wetland (Vena Energy, 2019). The whole power plant has a 70.2 MW capacity. Sinogreenergy invested another photovoltaic powerplant in section 9 in Bu-Dai (Chen W.-T. , 2019). They worked with NGOs to develop strategies for the coexistence of wetland and solar in powerplant development. They have biology and hydrology experts suggesting wetland management strategy for the site.

The saltpans evolved into wetlands after the southwest coastal salt production ceased. Saltpans, therefore, become important substitutional habitats. Both sites are not protected wetland by law but are recognized as Ramsar IBA. The two solar pioneer projects done by Vera and Sinogreenergy both have 30% area designated as conservation and flood detention area in repose to the NGOs and citizens opposition in damaging habitats (CET, 2019). Furthermore, there would be 20 years ecological survey executed by both companies to understand the ecological impact of utility photovoltaic development.

There will be a few new photovoltaic developments complete in 2020 as well, adding 2GW capacity of utility-scale solar in a single year (Taipower, 2020). A 100MW in Chang-Hua industrial Park and another 180MW development by Formosa Solar in Chang-Hua County, which is two-counties to the north, will be implemented in 2020-2021. A 150 MW Chi-Gu powerplant will be permitted by 2021.

The Chi-Gu powerplant takes up 214 hectares. The site is adjacent to the designated wetlands and is considered an ecologically functioning wetland by experts. These wetlands, regardless of their designation status, are all part of the conservation plan conducted through participatory design. The conservation plan went through the participatory method to understand the locals' needs, including flooding protection, tourism, economic opportunity, infrastructure, and community gathering spaces (NCKU, 2017). The plan recommended using a wetland zoning plan to allow these activities or need to be met. These include levee-road repair, water gate operation plans, and creating diversity in water-level with mainly low water-level to allow birds to forage in the wetland during flood mitigation. The plan recommends using part of the former saltpan as cultural landscape tourism and also emphasizes that the threats of sea-level rise and land subsidence would be more severe in the future.

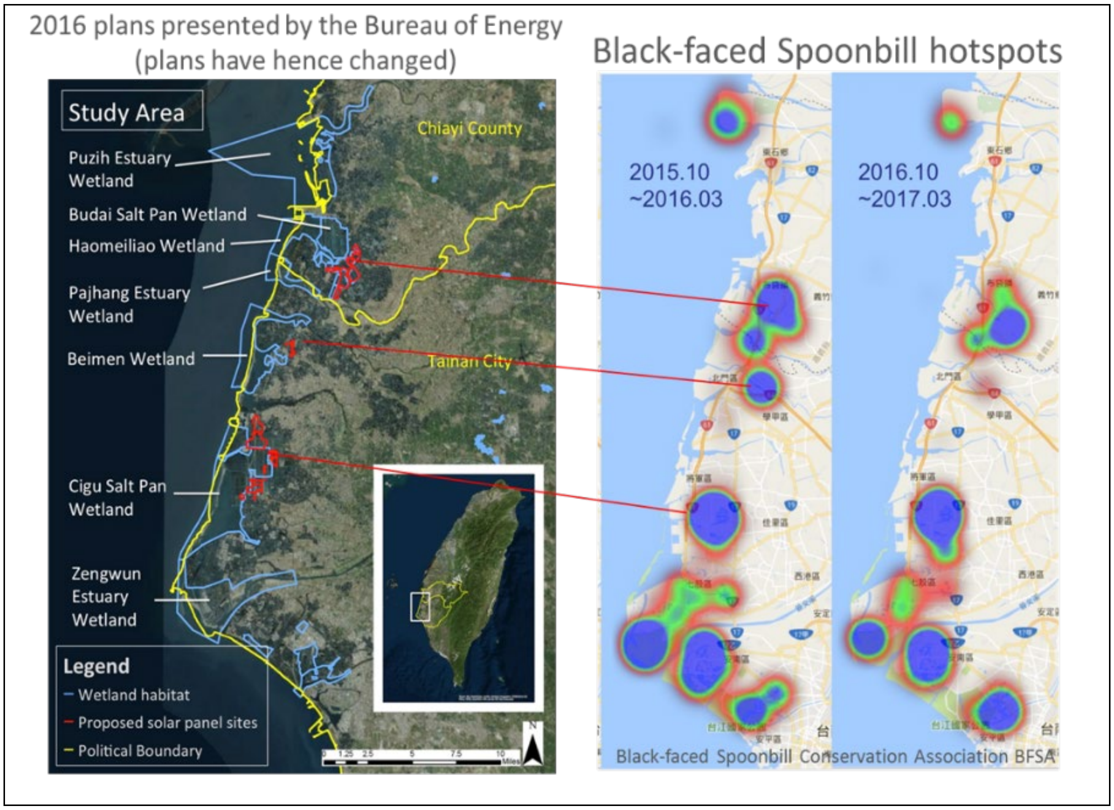


Figure 2-8 Areas with potential solar development (Wang, Ko, Hester, Dodd, & McNally, 2018) (Dodd, Wang, & Wang, 2018)

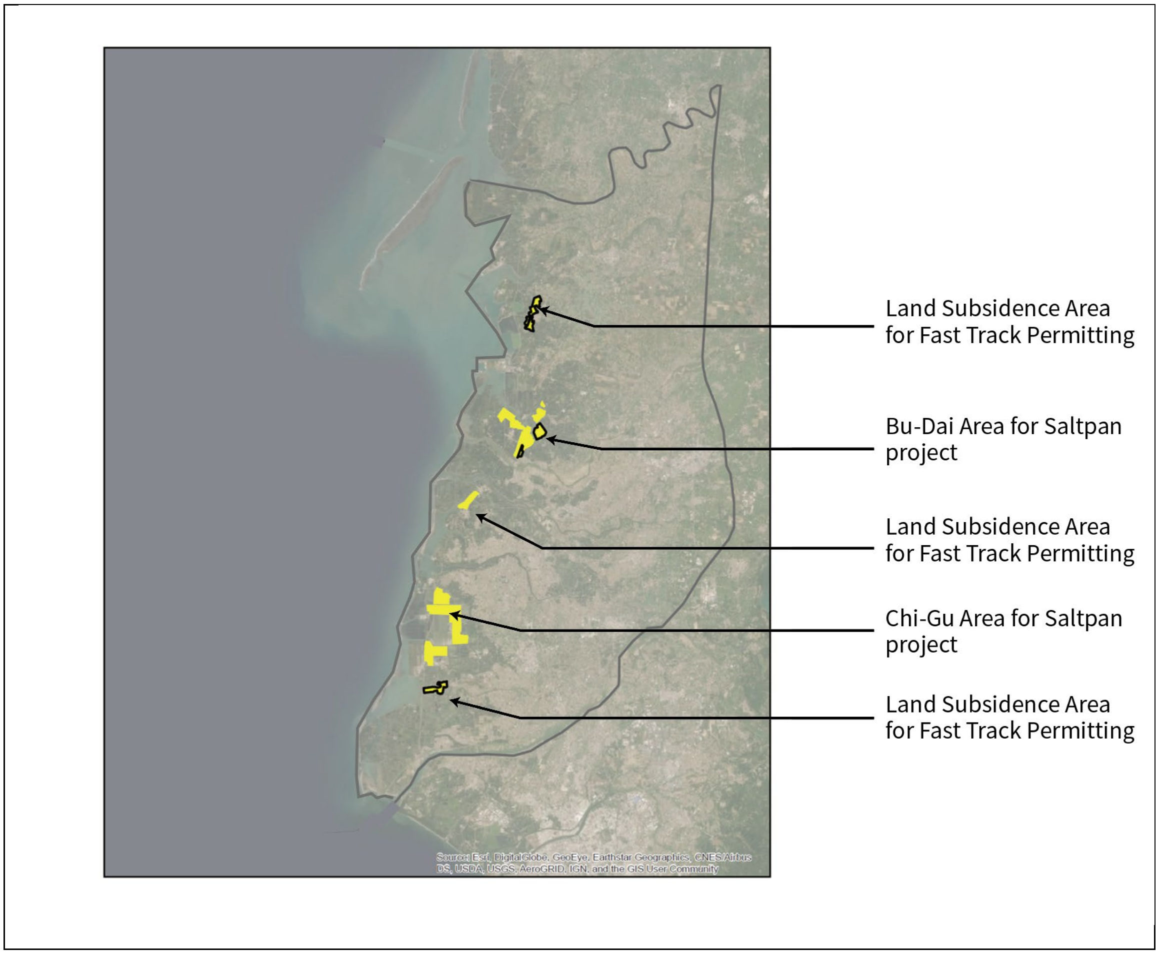


Figure 2-9 Current and Proposed Area for Utility-Scale Photovoltaic Development

2.5 FUTURE FLOOD SITUATION

Flood concern is critical in planning for Taiwan's southwest coastal landscape. It is a long-term landscape change driver across temporal and spatial projections. As a former estuary landscape, it is not surprising that the Increasing flood risk exists. However, the changes in flood risks and changes in the flood zone were never previously considered in the spatial planning or rural planning of Taiwan. This adaptation measure is lacking in the planning process. Because this area is constituted of a post-estuary landscape, which had to adapt to an evolving industrial presence and because cultural practices rely upon and coevolve with water management, it is crucial to consider changes like sea-level rise, land subsidence, and increasing extreme rain events in this context. Besides, it is notable that, due to the availability of this data, that exact estimation in this project can be barriers to realisation of this project, however; they are the best available estimations given at this time.

On the impacts climate change has on coastal industries, Meynecke focuses on climate change and rainfall impacts on fisheries, including water temperature, nursery habitats, and fish species (Meynecke & Lee, 2011). Arroyo reports that the temperature of the sea surface, sea-level rise, and the precipitation pattern affects community fisheries (Arroyo, Naim, & Hidalgo, 2011). Cheung reveals that the rising sea temperature increases the risk of the fisheries and coastal economies in terms of food insecurity in tropical areas (Cheung, et al., 2010). Kuo and other researchers funded by Taiwan DoT concluded that sea-level rise, vertical land motions, and predicted extreme tides will contribute to the total inundation in coastal Taiwan in 2112, and figures that 75% of the wetland would exist under sea-level at that time (Kuo, Lin, Lan, Lee, & Juang, 2016). The research concluded that the sea-level rise rate was about 8-12mm/year in the region in 1993-2012. It is critical that understanding land under sea-level does not necessarily mean flooding. According to local conditions, the management of a landscape or its topography can have a different level of impact on flood conditions.

Sea-Level Rise

Since sea-level rise is one of the main drivers of landscape change in this area, it is critical to understand how and what other scholars have done in predicting rising sea-levels globally and locally. It would also be necessary to critically analyse the underlying assumption in these predictions to provide a better base layer for this project. If the solar energy facilities are unable to respond to sea-level rise, they would be unsalvageable. Moreover, if wetland zoning fails to respond to landscape system change, the ecological health of coastal landscape can be compromised. A study on climate change affects a wetland system, and aquaculture utilizes the IPCC's Representative Concentration Pathways(RCP) 8.5 and 4.5 to define the drive of future scenarios in 2020 to 2040 by comparing it to the base period of 1993 to 1999. Also, the study classified adaptation issues into threats, vulnerability, and exposure. The study indicates that the rising temperature and other factors may decrease the ecosystem productivity (Lin H.-J. , Lu, Yen, & Ho, 2015). Therefore, coastal towns should prepare adaption for experiencing less production in mariculture, aquaculture, and offshore fisheries. The study did not consider the spatial impact of rising sea-level into account nor offer what rainfall patterns would look like in the future.

Land Subsidence

Land subsidence has a much bigger impact in this area. Townships in two coastal counties are seeing land subsidence ranging from 2.4-3.3 centimetres per year (WRA; NCKU, 2019). The official data reveals that more than a half of the agricultural water used was extracted from groundwater (490 million ton in 890 million ton) in Tainan in 1996, the agricultural water usage was 894 million tons per year, and overall water usage was 1140 million tons. The overall water supply is 1237 million tons, but the water supply is insufficient in the dry season from September to April. Chiayi county uses 769.5 million tons of water per year, while the overall groundwater supply and available surface water adds up to 638 million tons of water, which is an insufficient water budget. The groundwater extraction is much more serious in Chia-Yi. Therefore, the coastal villages are seeing about 355.7 square kilometers in size with significant shrinkage. Mao pointed out that groundwater extraction is twice this rate in the dry season compared to the rainy seasons (Mao, 2002)

. It is notable that even though these hydrological models and data are released by officials, they can still be measure going on estimations from 1990-2019. Researchers need to be cautious when applying these numbers to 2040 and 2060 scenarios. It is clear that the land subsidence had had much impact on flood compared to sea-level rise.

Overland Flow

Overland flow is a significant concern in this lowland area too. Wang concluded that southern Taiwan has significant climate pattern change. From 1991 to 2010, the area affected by drought has increased and has impacted inland regions (rainfall intensity increases sharply in the rainy season). The large-scale drought has a 0.02 probability of occurring in the study area (Wang C.-Y. , 2012). A study by Lin and Lu conducted on rain events in recent years, Typhoon Morakot in 2009 and Typhoon Luis (WP242018) in 2018, both exceed the 200-year recurrence interval (Lin & Lu, 2010). The Water Resources Agency (WRA, 2020) and a group of researchers from NTU issued a set if GIS datasets reveal the area with high fragility and threats from overland flow (Chang, 2018). The threat data categorized by the amount of rainfall in certain hours is the best available data. It is because the recurrence calculation can be affected by recent extreme events, whereas intensity data utilizes a set baseline. Wang also mentioned in an interview that flooded area estimation from rainfall intensity would be inaccurate in twenty years since the elevation has changed, affecting the function of dikes and water gates. Therefore, it is critical for further study to examine the multiplier effect of climate change on three different factors when considering these hydrological changes (Wang H.-W. , Personal Communication, 2019).

Wang also examined the inundation hazard of southwestern coastal Taiwan to a greater extent; severe flooding would result from land subsidence and climate change. They also suggest the infrastructural measure would be insufficient to adapt to the severe changes, but spatial planning and basin management needs to be taken seriously (Wang, et al., 2018).

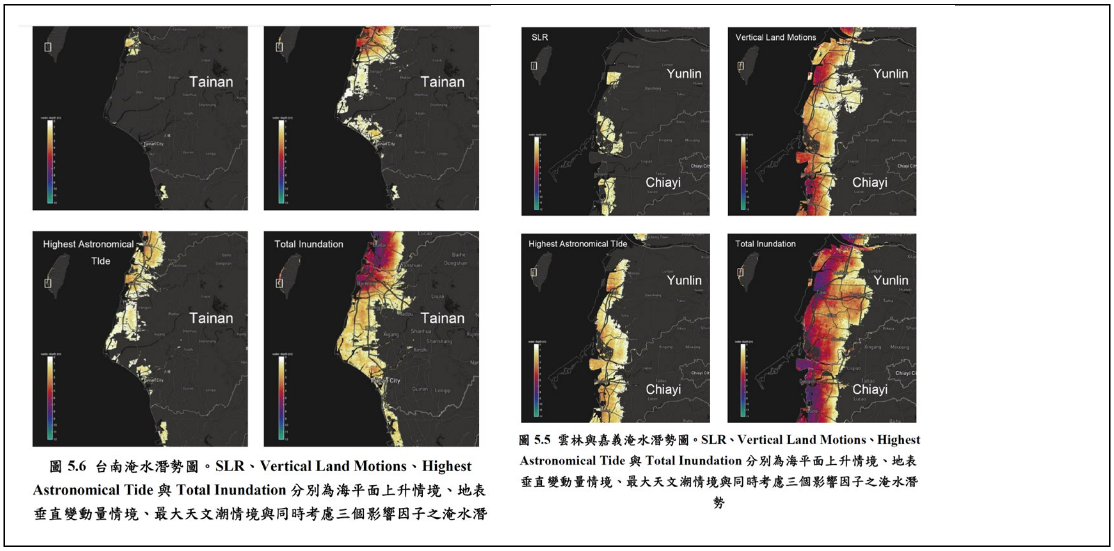


Figure 2-10 Area Impacted by Flood in 2100 (Wang, et al., 2018)

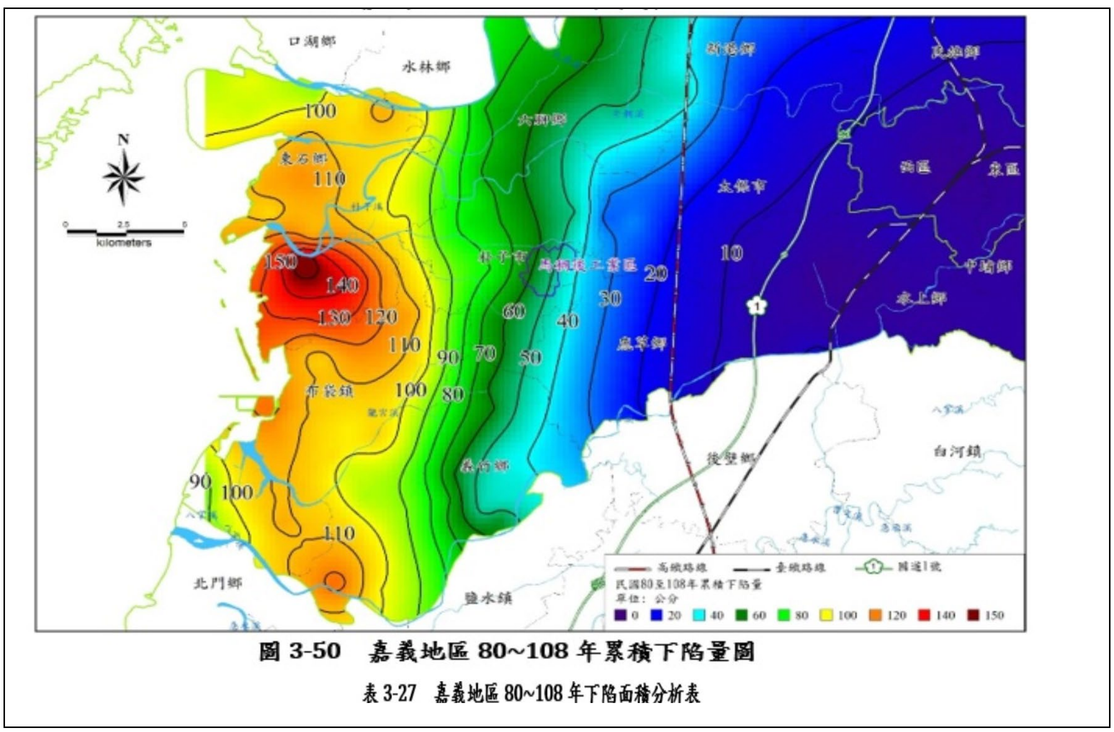


Figure 2-11 Accumulated Land Subsidence in Chia-Yi from 1991-2019 in Centimeter (WRA; NCKU, 2019)

2.6 REGULATIONS AND POLICIES CONTEXT

The regulations and policies have much influence in this area as legal contexts. These include regulations on ecological protection, environmental management, renewable energy encouragement, agricultural and rural related laws, spatial planning, and others.

Ecological Protection

The zones which have legal protection over its environments include national parks, wetlands, designated wildlife habitats, some coastal areas, and coastal forests. The legal status of these areas is critical to the protection of habitats.

The *Wetland Protection Act* protects the status of an important wetland habitat. It is critical that the "Wise-Use" defined in the *Wetland Protection Act* Article 4.4 allows creative usage of wetland. However, in some cases, it has been abused by government-led projects, including some photovoltaic development proposals. It is also notable that, in the *Wetland Protection Act*, Article 15: "conservation plan could include adjacent wetland," which resonates with the idea of considering the expert-recommended wetland in this project. The *Wetland Protection Act* requires that the government makes decisions based on science and comes up with a multi-goal and multi-principle plan. The former Chief of the Society of Wilderness, Lai, questions the legitimacy of considering photovoltaic development on designated wetlands as a type of "wise-use" of the wetland (Lai R.-H. , 2019). Shifting to another framework of wetland status, it is notable that Taiwan was not a signer of the Ramsar Convention, or the "Convention of Wetlands of International Importance Especially as Waterfowl Habitats." Therefore, many habitats in the study site considered as Ramsar IBAs, or Important Bird and Biodiversity Areas, are not protected by The *Wetland Protection Act*. Director of Energy Advocacy of Citizen of the Earth, Taiwan (CET), Tsai, suggests that ecosystem services of wetlands and aquaculture ponds in the study site need to be preserved. Tsai explains that local residents used these sites for seaweed foraging and fishing (Tsai, 2019). Cultural and daily subsistence practices are essential to the region. Also, Wu argued that the compensation measure needs to be considered in these photovoltaic developments (Wu P.-N. , 2019).

Director of Environmental Right Foundation, Chung, argues in the interview that the 20GW solar goal at the national scale, as well as the salt pan solar at the scale of regional-scale, would benefit from Strategic Environmental Assessment to evaluate the feasibility of the project (Chung, 2019). However, there were only a few SEA done in Taiwan. Besides SEA, another policy review tool available is the Environmental Impact Assessment (EIA). EIA does not require renewable energy development to be reviewed in accordance with current regulations, and some argue it is flawed. Even so, The *Wildlife Protection Act*, The *Coastal Zone Management Act*, The *Forest Act*, and The *National Park Act* all provide some layers of protection to the ecological area cooperating with the EIA process. Notably, this project can offer potential to SEA in presenting the performance of the set goals of energy capacity and provide a roadmap to growth for different scenarios.

- *Standards for Determining Specific Items and Scope of Environmental Impact Assessments for Development Activities*: "Where one of the following circumstances applies with respect to the development of energy or power transmission/transformation, an environmental impact assessment shall be required:" and Article 29.7 "Installation of a photovoltaic power generation system in an important wetland."

Renewable Energy Development

On regulations related to renewable energy encouragement, which guide the photovoltaic development goal, there are The *Renewable Energy Development Act*, and its related standards as follow:

- *Renewable Energy Development Act*: Article 6 "the promotion objectives for the total amount of electricity generated by renewable energy power generation facility by 2025 is set to be more than 27,000,000 kilowatts".
- *Permit Exemption standard for Renewable Energy Facility*: Article 5.1.3 "facilities below 4.5 m level do not require a permit."
- *Standards of Ecology and Landscape Quality Reviewing Ground-Level Solar Facilities*: regulates design and construction requirements

The government is pushing for Taiwan Solar Goal 2025, a goal launched in 2016, which includes 17 GW of ground-level solar and 3 GW of rooftop solar. The second line in the figure 2-12 represents the energy goal achieved at the end of 2019, which 0.5 GW in 17GW of ground-level solar, and the 3 GW rooftop solar that was accomplished. The new goal amendments are 14 GW ground level and 6 GW rooftops. From the scope of the energy sprawl, the land area demand is shown as follows in figure 2-13. According to government policy, the Salt-Pan Solar Project and its many sites will be placing utility-scale solar around former saltpans across Taiwan, mainly in the two counties this project focuses on. The Bureau of Energy selected 803 hectares for solar development with a low ecological value from 4000 hectares of public-owned saltpans. Within that, 102 hectares of PV had been built. On the left, for 14GW, about 11200 hectares are required to achieve 14GW for the technology we have today. After a series of public campaigns, the implementation area dropped from 800 to a 104-hectare for the pilot study. It is critical to separate the 2025 goal of the government, which is short-term photovoltaic growth, from what this project attempts to achieve – a comprehensive study on the performance and capacity in a changing landscape.

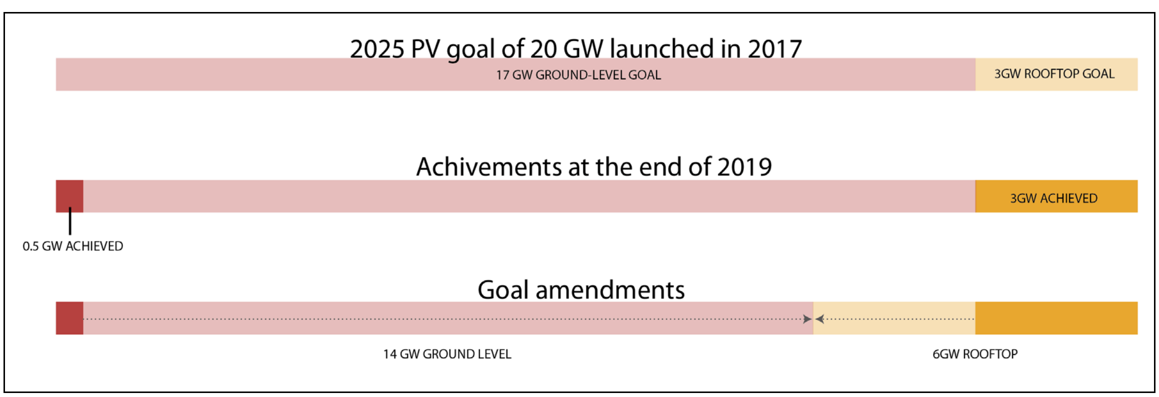


Figure 2-12 2025 Goal for Photovoltaic Capacity

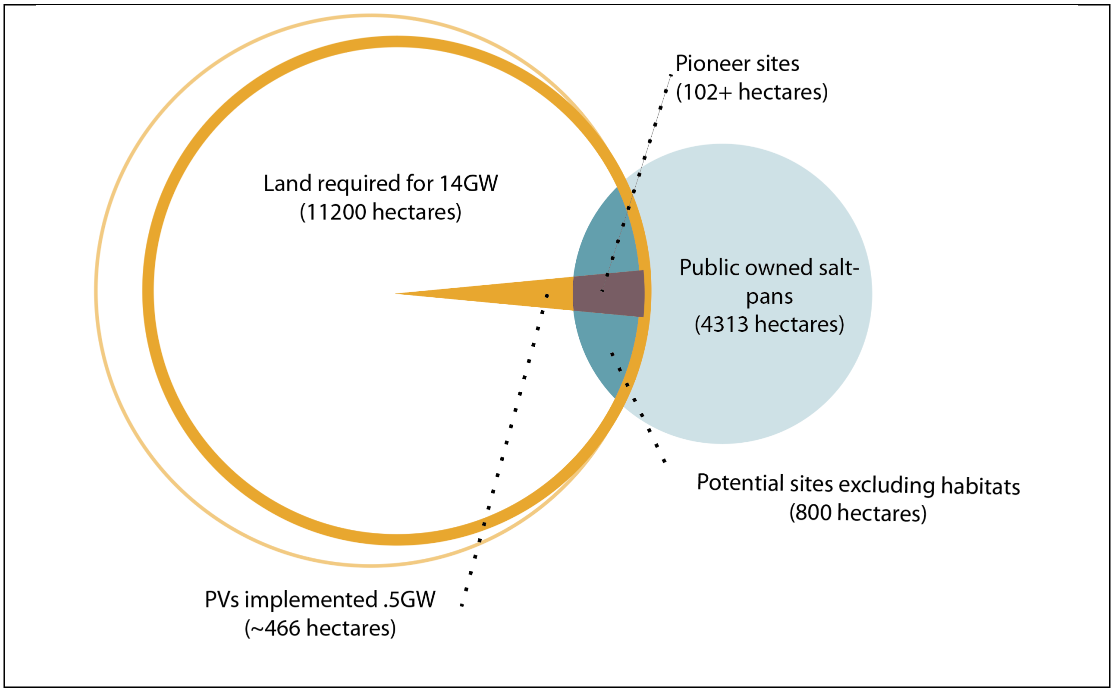


Figure 2-13 Land Area Required for 2025 Goal

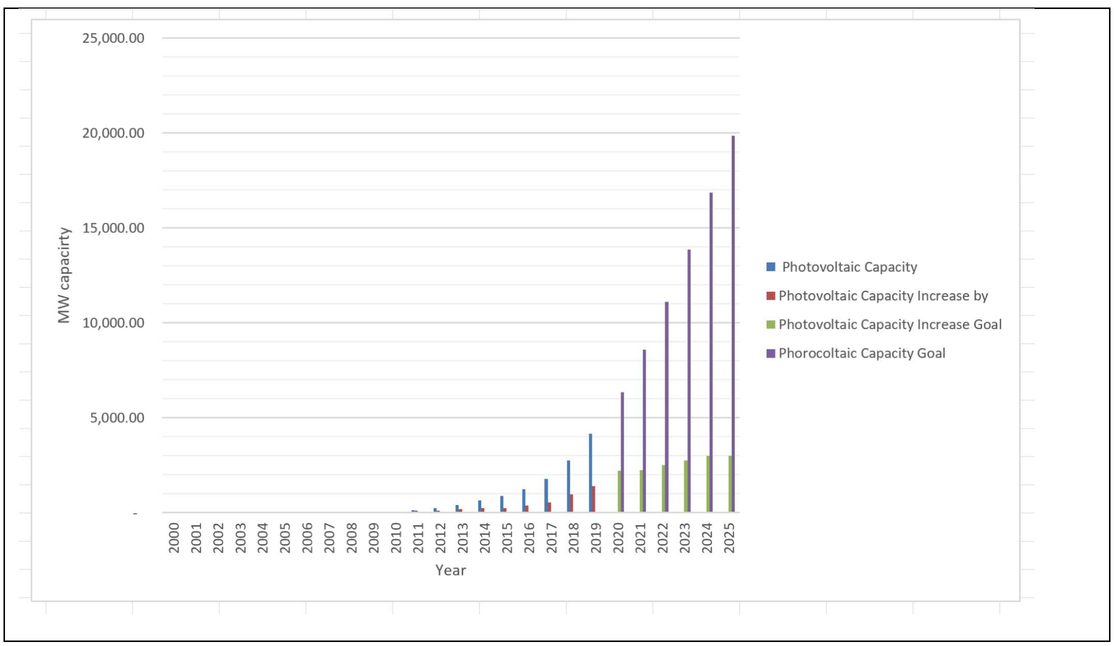


Figure 2-14 solar progress diagram for 2025

Agriculture and Rural Land-Use

The regulation for rural land use control remains scattered in different categories of laws. In *Agricultural Development Act*, Article 8.1.3: “allows facilities in farmland” and Article 10: “The delimitation or change of agricultural lands to non-agricultural purposes shall not affect the integrity of production environments and shall be subject to the prior approval of the competent authorities. Requirements and procedures for the aforesaid change shall be subject to the governance of applicable laws which are yet to be drafted.” Standards that are stated in another law; *Examination Regulations for Application To Agricultural Facility Permit*, Article 7.1, Article 27, Article 28, Article 29, and Article 30 are all relevant to the examination. The general summary of the rule is that agricultural land with photovoltaic development, or “agrivoltaic”, should have the coverage of photovoltaic below 40 percent area and should maintain produce production above 70 percent. If the agricultural land is considered unfarmable, the photovoltaic would still fall below 40 percent area coverage without production requirements. CET and Tsai argued that the ground-level photovoltaic implementation should be reviewed with the checklist to avoid impacts on farmlands as well as ecological areas with endangered species even without legal protection status (CET, 2019). Wang, who has been a long-time director of fishery activism and environmental art project in Cheng-Long Wetland area, argued that not all fishery products have the same life cycle suitable to the 40/70 guideline (Wang C.-M. , 2019). For example, clam production requires intense sunlight to support its algae and nutrition cycles. Since the land subsidence is more severe in these areas, Wang also observed some renewable energy developers are renting flooded land for potential solar development without any zoning review and close assessment of the ecological condition of the area. Wang (Wang C.-M. , 2019) and Liu (Liu S.-S. , 2019) observed that developers are paying ten time of regular rent compared to aquacultural usage. A group of developers, usually financial backed by banks, jumping into agricultural land market with its new form of value chain. This reveals the incompatibility of productional landscape and improperly-planned photovoltaic. The incompatible usage of production, including salt, agriculture, electricity and habitat, is a conflict of modernity land-use deployments and photovoltaic-induced displacement. This is an abuse of agriculture as a public good and as land common.

Spatial Planning Framework

Spatial planning in Taiwan has been a battlefield for developers, politicians, and citizens. Hsu criticized Authoritarian practices remains in land-use planning and land policy in Taiwan 33 years after the end of the martial law (Hsu S.-J. , 2007). von Haaren examines the characteristics of the preconditions for the ecological planning of Taiwan with the degree of public participation, Planning decision system, and property rights (von Haaren, 2019). It reveals that the land planning system in Taiwan leans toward relatively expert-based and strong local power. Spatial planning regulation in Taiwan scattered around regulation in the *Spatial Planning Act*, *The Enforcement Rules of the Spatial Planning Act*, *Regional Plan Act*, *Enforcement Rules for the Regional Plan Act*.

A careful and science-based decision making is critical to land-use planning. CET proposed county government adopt to deploy the Environmental and Social Checklist system to better guiding the photovoltaic development process (Lee, 2019). The checklist, as they proposed, could benefit from inter-ministries cooperation, NGO input, and stakeholder participation (CET, 2019). They also specify the checklist should base on the analysis of the ecological and social-economic conditions on the ground to co-benefit the community and ecological environment.

This project recognizes the importance of urban solar energy development. Government should prioritize spatial planning and enforce building codes to push for solar installation and avoid using ecological and agricultural land. It is without doubt from the principle of minimum impacts; the government should prioritize photovoltaic energy in the industrial and the residential areas first. However, Taiwan is currently doing the exact opposite, extracting land resources from wetlands, Tai-sugar farmlands, and other marginal land-use. In John Bellamy Foster's notion, the extraction of natural resources to the irrecoverable point is a form of "metabolic rift" (Foster & Clark, 2020). it is critical in implementation to revaluate whether the project is impacting ecological health of wetlands and biodiversity to the degree of irrecoverable.

CET argues that the guidelines should touch on issues like rent, production rate, and contamination of cleaning water for panels by holding public hearings with all stakeholders to mitigate the impact. The issues reveal the importance of spatial planning (Li, Tsai, & Li, 2019). It would need a bigger scale solution to resolve the conflicts of wetland conservation and energy land use such as powerplants and PVs.

Tsai argues that floods and disasters are not considered in current planning (Tsai, 2019). Also, current planning has no proper toolkits to respond to the planning for photovoltaic development, such as density control, prioritization process, and avoidance standardization. CET also considers that the zoning should allow for people to become "prosumer" suitable for their own context. Dodd considers renewable energy development as equitable for rural communities to access, such as community-supported energy cooperatives (Dodd A. , 2019). Building resilience in these community is the key to gaining acceptance. Both mention stakeholder participation as critical to policy making. As a current legislator Hung sees the spatial relationship to be a productive relationship (Hung, 2019). The rural value chain has been vacant for decades, and photovoltaic energy can be a threat as well as an opportunity. He proposes using solar developmental as a right and as an added expected value to the land and rural communities which can benefit from these assets.

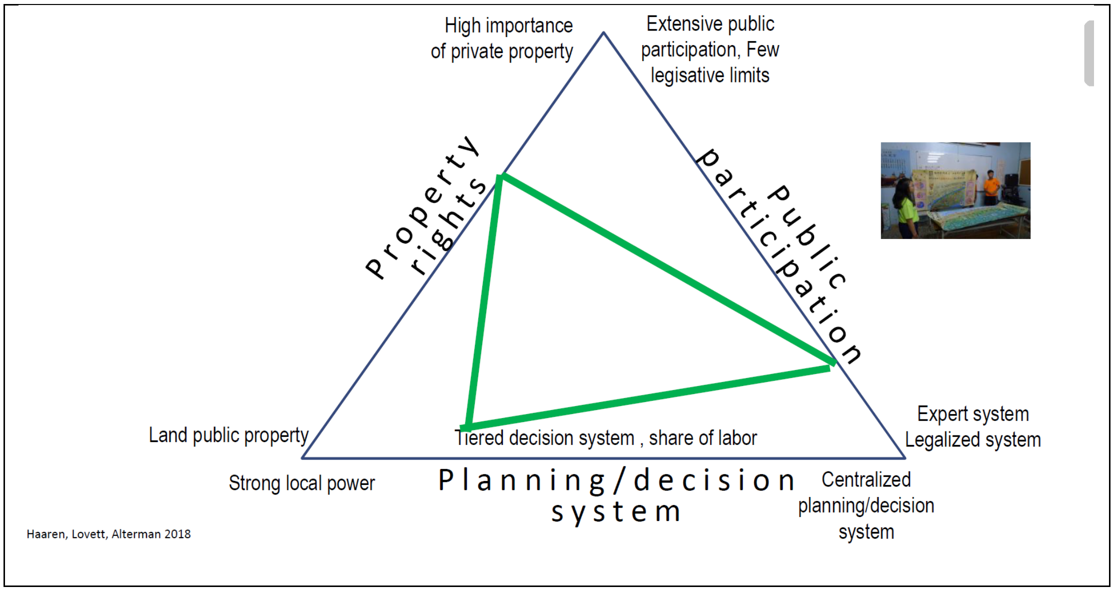


Figure 2-15 von Harran Land use control (von Haaren, 2019)

3 PROJECT FRAMEWORK

This master's project was developed from the controversy over Taiwan's "Salt-Pan Solar Projects" as an attempt to plan and design intentional land-use changes. A thorough investigation of environmental impact, spatial planning tools, and zoning tools would be essential to deconstruct the prior discussion of the 2025 goal. This section is a comprehensive review of relevant research, background analysis, and study of precedents in further developing the study framework for this project.

3.1 ENVIRONMENTAL IMPACTS AND CONSIDERATIONS FOR PHOTOVOLTAICS DEVELOPMENT

Photovoltaic development has potential environmental impact on multiple aspects, including ecosystem services, biodiversity, and agriculture. These pieces of literature result from empirical study, second-hand review, and data analysis. The purpose of this subchapter is not to form an opinion against photovoltaic development, but to study what are the considerations that need to be carefully examined when implementing such form of development. Therefore, this project will try to accommodate the considerations mentioned in scenario planning.

Impacts on Ecosystem Services and Biodiversity

Utility-scale solar energy includes concentrated solar power and photovoltaic systems. This project is mainly concerned with photovoltaic systems, although some of the literature discusses concentrated solar power systems as well.

Mulvaney investigates opposition against utility-scale solar energy systems in southwestern states in the United States. Common reasons such as: polarized results in ecological surveys in the same areas, animals killed by solar facilities, habitat fragmentation, lack of ecological records for decision making, water usage of the facilities, impacts of road construction, groundwater depletion impacting plants and animals, exposures to fungal epidemics from soil-borne spores, surface reflectivity causing heat island, and broken glass by tornados were given as reasons. Mulvaney also urges that decision-making should include experts and public opinion to better support utility-scale solar energy (Mulvaney, 2017).

Pearson studied the decision-making process of the Landcare Council of the Northern Territory, accommodating the impact of solar energy development on ecosystem services and the cultural heritage of Aboriginal Australians. The Landcare Council of the Northern Territory was authorized by the government to make decisions by involving key stakeholders, including conservation groups, farmers, and aboriginal groups. The process utilizes a participatory method by using GIS and visualization tools to "1. allow their world views to be represented, 2. help them see the world through the eyes of other stakeholders and 3. facilitate negotiations about possible futures". The study's focus is on holistic landscape management rather than maximizing energy production. It emphasizes the importance of ecosystem services to the Aboriginal Australians, although there is a lack of a clear definition of which ecosystem services are particular to this place (Pearson & Gorman, 2010).

Hernandez et al. emphasizes the distinction between photovoltaic and concentrated solar power for further discussion. It states that, at a utility-scale, photovoltaic and concentrated solar power might negatively impact the environment. Concentrated solar power affects biodiversity by increasing birds' death and increases water consumption in hot-drought areas. Photovoltaic and concentrated solar power both impact the environment by increasing loading of a newly built powerline corridor, increasing the potential of soil erosion, and increasing microparticles. It suggests that the integration between photovoltaic with other land covers, such as ponds, grazing lands, or other power systems, would help reduce these negative impacts. However, the paper does not state detailed consideration for these mixed-use land covers (Hernandez, et al., 2014).

Another study of Hernandez et al. indicates that most of the utility-scale solar energy projects in the United States are in remote areas. The land cover types where solar projects are implemented include scrubland, cropland, and grassland, where biodiversity may exist. These lands are usually far from existing transmission infrastructure. Hernandez recommends diversified development deployment, including the Germany model achieving most photovoltaic development in the built environment (Hernandez, Hoffacker, Murphy-Mariscal, Wu, & Allen, 2015).

Gasparatos acknowledges the need for renewable energy expansion yet to emphasize on the biodiversity and ecosystem impact of renewable energy using the Millennium Ecosystem Assessment (MA) framework. This study indicates that solar energy has strong evidence of contributing to habitat loss or habitat change, and potential impact on pollution (Gasparatos, Doll, Esteban, Ahmed, & Olang, 2017).

Impacts on Agriculture

There are many forms of impact of photovoltaic development on agricultural sectors. One form of impact is from mixed-use of agriculture and photovoltaics, often called agrivoltaic. The other form is the conflict between spaces and productional resources.

The Calvert's study of the suitability of energy crops or photovoltaic systems in rural Ontario, Canada considers that energy crops and photovoltaic projects are conflicting land uses. Calvert evaluates the trade-offs by assessing the distance to electricity stations, soil types, and wetlands and riparian areas. Exclusion areas are based on ecological and cultural value. By identifying marginal farmland, which is more suitable for photovoltaic, Calvert argues that the conflict between energy crops and photovoltaic could be coordinated across seasons. (Calvert & Mabee, 2015)

Yang studies the policy encouraging photovoltaic in the flooded areas, or "keeping water, growing electricity," in southwest coastal Taiwan, using actor-network theory. Yang considers that the government's attempt to reconstruct the area from Typhoon Morakot and approaching land subsidence from groundwater over-extraction pushes multiple policies and heterogeneous actors working together, forming a post-disaster landscape of marginal lands. These forces convert fertile farmland into marginal farmland, which usually are flooded or saltificated. The technological practices in the landscape result in “high-post photovoltaic” and “concentrated patches” of photovoltaic practices. Yang concluded that “keeping water, growing electricity” policy is then translated and appropriated to policy of agrivoltaic implementation. Therefore, fertile farmlands are facing pressure of photovoltaic development while the original intend of the policy is to utilize the marginal farmland (Yang H.-J. , 2017).

Liu (Liu S.-S. , 2019) and Wang (Wang C.-M. , 2019) both mention in interviews that the aquaculture industry suspects that the installation of photovoltaic facilities might affect the “kha-lōo” and “tshiú-lōo”[1] in their operation. “Ka-low” literally means foot-ways, which refers to the spaces to stand and to move machinery. “Chu-low” literally means hand-ways, which refers to the operation spaces and angles for tools, nets, or baskets.

[1] In Taiwanese, “kha-lōo” written as 跤路 and “tshiú-lōo” written as 手路

3.2 SPATIAL PLANNING TOOLS AND CONSIDERATION

Energy transitioning for cleaner and more sustainable energy would require spatial planning. Previously, the idea of energy sprawl and land-use impact of solar energy is explored. In this section, spatial planning tools and consideration for photovoltaic energy will be explored. There are three different aspects to better understand and plan for energy landscape systems. They are renewable energy systems and their social implications, planning analysis for renewable energy landscape, and co-location strategies.

Understanding the available renewable energy technology and their social implications is essential. Wustenhagen investigates the social acceptance of renewable energy innovation by socio-political, community, and market acceptance, and further explores the challenges in implementing projects at the local scale, especially dealing with "not-in-my-back-yard" idea, or NIMBYism (Wüstenhagen, Wolsink, & Bürer, 2007). Therefore, thorough planning that eliminates the negative connotation of renewable energy development and utilizing positive externalities is the key to increasing acceptance.

The three following sections discuss the green goal negotiated in energy land-use, planning advice for photovoltaic development, and wetland ecological health. Lessons learned in the literature below will provide insights for developing the research flow of this project.

Negotiating Green Goals

The conflicts are almost unavoidable when energy planning meets ecological planning at the landscape scale. Scholars have been investigating how green goals were negotiated. The ground issues of the expansion of renewable energy is where to locate them in actual space to minimize its impact and how to implement them in the actual space to mitigate its externalities. This brings the "conflict of greens" theory to the center of the discussion.

Ko, Schubert, and Hester define the theory of this "conflict of greens" as conflicts between two different "green" goals to spatial organization (Ko, Schubert, & Hester, 2011). They identify two approaches regarding the conflicts of greens, including "segmented greens" and "systematic greens." An actual example they provide is whether Incheon should implement the cluster of the world largest tidal energy facilities that show strong potential for damaging the tidal ecosystems and local communities. Most importantly, they call for approaching the conflict of greens from an environmental planning perspective, which should include the latest scientific research and the opinions of residents.

Other pieces of literature also provide essential insights. Jackson's study shows that the European Union's strong ecological protection regulations, such as Natura 2000, can prevent some big projects from implementation. However, Jackson considers that these protection measures should not be considered obstacles, but opportunities. The progressive interpretation and measures for compensation are necessary in response to the complex landscape when dealing with different developmental goals, in this case, habitat preservation and renewable energy (Jackson, 2011). Others, like Von Harran, argue that Germany's strong spatial planning protects the scenery and ecological areas. The early participation in decision making is the key to the acceptance of projects. Von Harran considers that the measure is crucial for Germany in balancing green goals due to its strong spatial planning (von Haaren, 2019). Brunette considers "renewable energy and wildlife policies must operate under a commons paradigm in order to mitigate commons-based problems." (Brunette, Byrne, & Williams, 2013) They call for a paradigm shift from commodity-based development to commons-based policy.

Planning for Solar Landscape

Adil and Ko give full insight while reviewing social-technical aspects in decentralized energy systems in the urban space. They conclude that the configuration of the energy system and urban structure should respond to the "resilience of urban energy infrastructure as the threat of climate change related disasters draw near"; in some cases, the smart micro-grid system and the distributed system can be the solution. This concept should not be limited in urban settings; all energy infrastructure planning should be considering the resilience aspects by cooperating spatial configuration and energy system types (Adil & Ko, 2016).

Desert Renewable Energy Conservation Plan, often called DRECP, utilizes a detailed planning process for site areas for solar development (BLM, 2016). The process includes the exclusion of "Existing Protected Areas," applying principles of conservation biology in "Biological Goals and Objectives," and applying the "Focal Species, Communities, and Processes" as driver resources. The whole project is a set of constraints and suitability analysis revealing low biological resources areas and high renewable energy potential areas. Notably, the "Focal Species, Communities, and Processes" approach can be informative when it comes to communicating with the public as well as adhering to conservation measures. By identifying species which require special attention, in this case, a Focal Species List, the conservation measure can be targeted, and the discussion can be more effective. However, it is essential to recognize that species requiring special attention is only part of the broader biodiversity.

A white paper from Berkeley Law advocates for four goals in county-level solar landscape planning (Elkind & Lamm, 2018). These include: "local buy-in, trust, incentives, and perceived benefits; coordination among utilities, regulators and land-use and grid planners across federal, state, and local levels; mismatch between ideal lands, viable economics, and transmission infrastructure; and lack of data and information that are reliable, relevant, commonly agreed and accessible." They also advocate for shifting from map-based zoning to mixed and standard-based zoning to better incorporate local conditions.

Wu developed the Optimal Renewable Energy Built-Out Model (ORB) and Renewable Portfolio Standard (RPS) to plan for solar energy (Wu & Schlag, 2015). The model is a two-step process. The ORB filtered the environmental constraint into four different levels of protection and then optimized the energy generation outcome base on specified energy generation targets. The impacts estimated are: the cost-and-benefits of energy, impacted areas and land cover types, as well as water consumption. This GIS tool utilized 4 kilometres by four kilometres resolution. The ORB-RPS tool is particularly helpful for decision-makers for its estimation of environmental impacts and cost-and-benefits analysis. The Africa Clean Energy Corridors and International Renewable Energy Agency also utilize this tool for long-term energy planning.

Gret-Regamey and Wissen Hayek utilize multicriteria decision analysis (MCDA), particularly the analytical hierarchy process (AHP), to create two scenarios: highest energy output scenarios and lowest landscape impacts scenarios (Gret-Regamey & Wissen Hayek, 2012). They further utilize GIS-based visualization tools for perspective views for future participatory workshops.

The above literature demonstrates various methods and presentation in planning for solar landscapes. When planning for solar landscapes, standards such as resilience and focal species should be considered. Also, the zoning methods and processes should be creative and speak to the local condition. Presentation such as impact evaluation and visualization can help readers and the public better perceive the project.

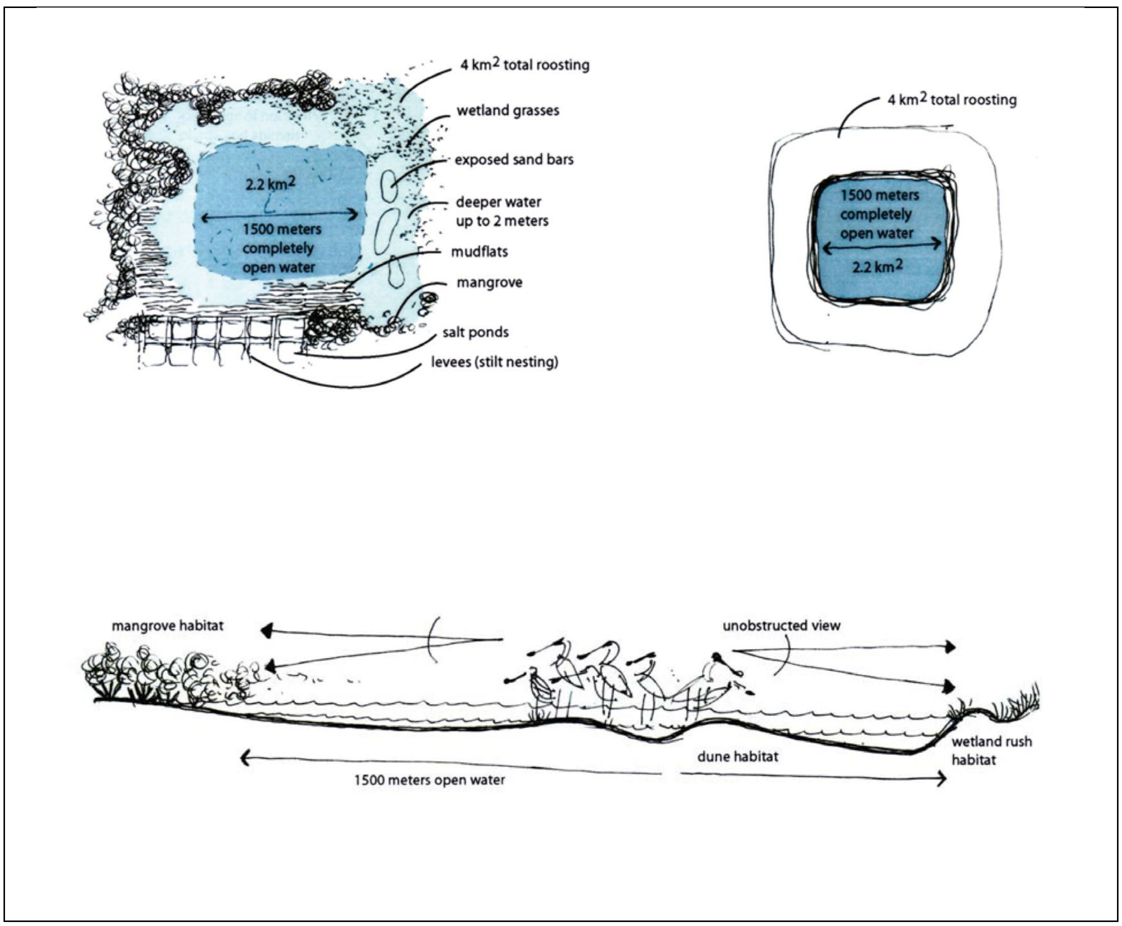
Spatial Criteria for Ecological Health

In order to conduct this project with systematic and ecologically informed planning, it is critical to closely review relevant literature on planning implications at the species level, habitat level, and the landscape level to achieve ecological health tailored to this region.

In *Conservation by Proxy*, Caro makes it clear that the usage of the concept of umbrella species is a short-cut of conservationist planners hoping conservation efforts over a single species can stretch to other species (Caro, 2010). That is to say; the umbrella species have the same, if not stricter, habitation condition in terms of location, size, and shape of areas. The black-faced spoonbill is the well-recognized umbrella species across the East-Asian Flyway. SAVE international conducted this report of planning for alternative development in Jiading, Kaohsiung, which is to the south of the study site (SAVE International, 2014). SAVE conducted the flight initiation distance of the black-faced spoonbill. Usually, the distance disturbing foraging is 100 meters, and the distance disturbing roosting is 400 to 700 meters. This usually includes wetlands as an ecological core and productive aquaculture landscape as a buffer. Hester emphasizes that the planning was lacking consideration of foraging territory together with roosting habitats (Hester R. T., 2006). Therefore, it would require knowledge of wetland landscape ecology to support the planning process further to bring planning principles into the project’s scenario planning.

Dobson and Bradshaw emphasize that restoration ecology offers crucial tools to preservation of biodiversity with an integrated understanding into how human population growth and changes in agricultural practice utilizing natural processes (Dobson, Bradshaw, & Baker, 1997). Dramstad et. al. analyse the importance of steppingstone habitats and patches as a framework to guide design (Dramstad, Olson, & Forman, 1996). The quality, geometry, niche types, and many more factors can affect conservation. Caro also define management umbrella species as an indicator of planning and managing habitat, including anthropogenic disturbance (Caro, 2010). This lends the project a critical key in considering the role of habitat design in landscape ecology, and requires that the distance-disturbance relationship between the Core-Buffer-Disturbance model can be further translated into conservation measures. Wenston et. al. argue that buffers do not always work when anthropogenic activities creep over to buffer zones. They concluded that the success of buffers as a conservation tool requires clear objectives, careful design and management, and evaluation (Weston, Antos, & Glover, 2008). It is notable that Hester also emphasizes that the core roosting requires certain water depth and community elements to function (Hester R. T., 2006) (Hester, Dryden, Minick, & McNally, 2010). Similarly, Wang and Kuo argue that water management is critical to a wetland's ecosystem services (Kuo & Wang, 2018). From both pieces of research, one can conclude that the quality of the habitat also matters in planning for habitat conservation.

At the landscape planning level, the above-mentioned literature offers different requirements, and considerations need to be taken into account when planning for wetland health in this project. The planning process for wetlands in this project will utilize protected areas as constraints, expert input for identifying important habitats, and consideration of conservation measures such as compensation. Ho et. al. (Ho, Lo, Lu, Chen, & Shiu, 2012)conducted a detailed study on measures that should be taken when managing black-faced spoonbill habitats, including protected area reviews, integrated habitat and surround monitoring, buffer zone management, food source, habitat environments, legal supports, and local collaboration. Weinstein notes that in a human-dominate world, goals of managing estuarine landscape might shift from returning or preserving the natural function of the system to rehabilitating the service function and reliability (Weinstein, 2007).



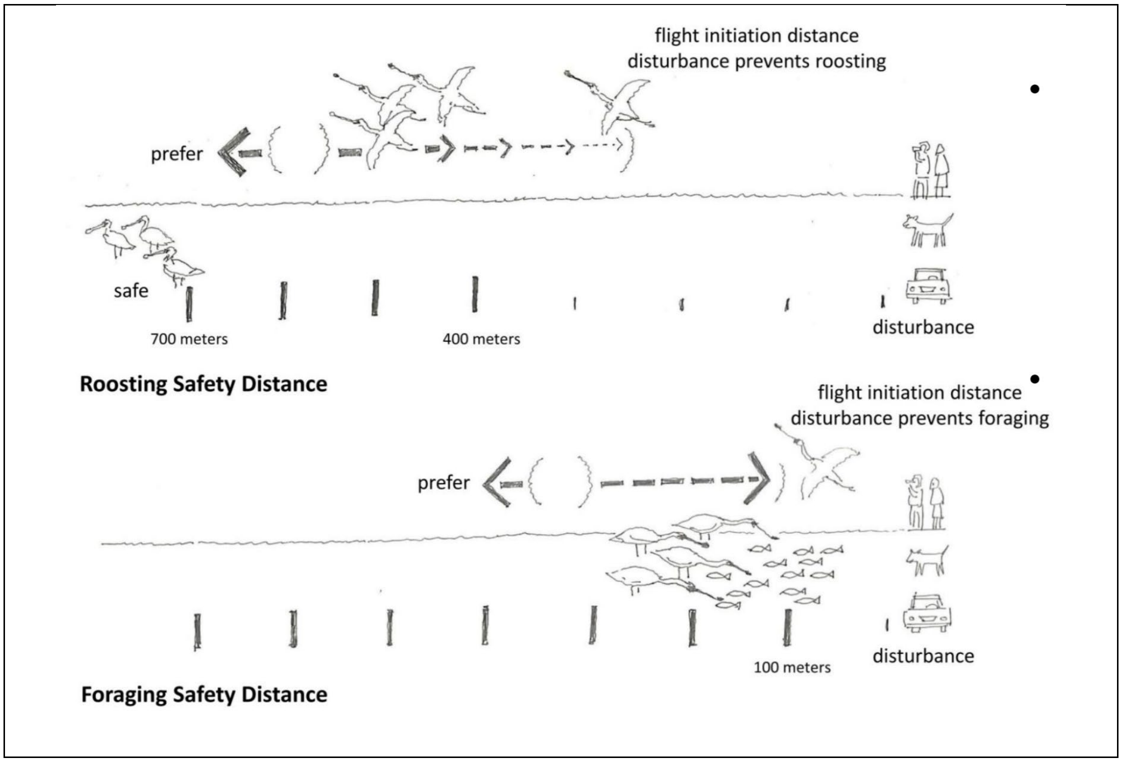


Figure 3-1 Spatial Requirement and Flight Initiation Distance for Black-faced Spoonbill (SAVE International, 2010) (Hester R. T., 2006)

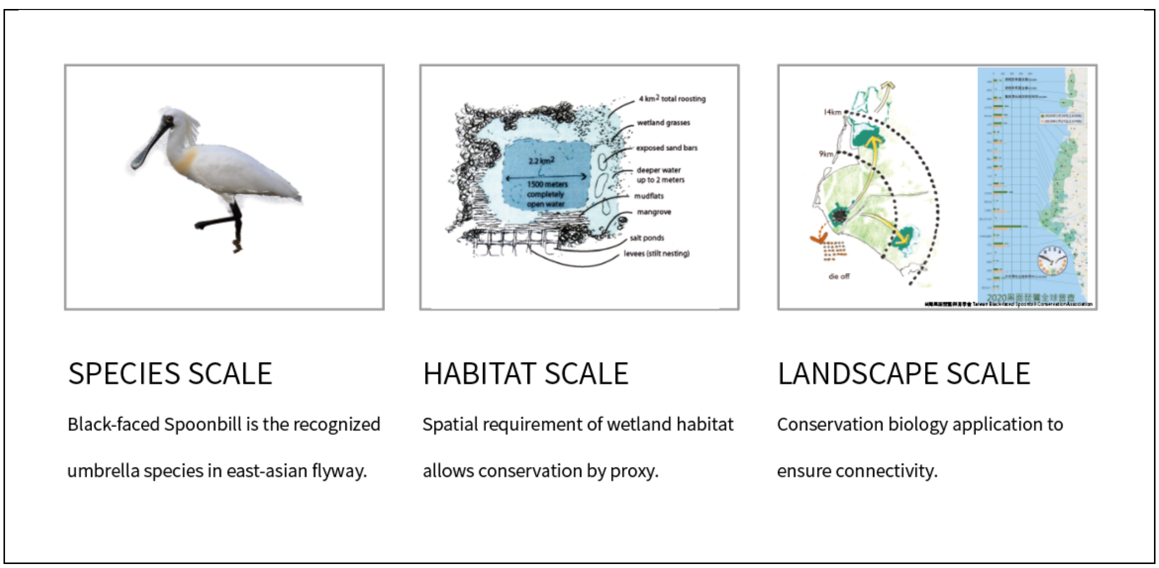


Figure 3-2 Species-Habitat-Landscape scale implication

ROAD ECOLOGY

The following table, figure 3-3, reveals the effects of roads on bird behaviour in various studies. These studies have various ecosystem types and road intensity. It is useful to refer to road ecology information that this project can further translate into the distance, defining where the impact should be concentrated. This project utilizes the 120 meter and 360 meter infrastructure adjacency to aggregate the Impact of photovoltaic development in adaptation scenario.

Bird Type	Road Type	Presence	Breeding	Source
Grassland	local collector street(3000-8000 vehicles/day)	Not significant	Not significant	(Forman, Reineking, & Hersperger, 2002)
Grassland	through street (moderate traffic 8000-15,000	Not significant	400 m offset	eid.
Grassland	two-lane highway (heavier traffic of 15,000-30,000)	700 m offset	700 m offset	eid.
Grassland	multilane highway(heavy traffic volume of > or =30,000 vehicles/day)	1200m offset	1200m offset	eid.
Woodland	55-60 db (A quarter number drop. Some species drop completedly)	50m		(McClure, Carlisle, Carlisle, Kaltenecker, & Barber, 2013)
Grassland	5000 cars/day	120 (90-315)		(Reijnen, Foppen, & Meeuwsen, 1996)
Grassland	50000 cars/day	560 (425-115)		eid.

Figure 3-3 road ecology table

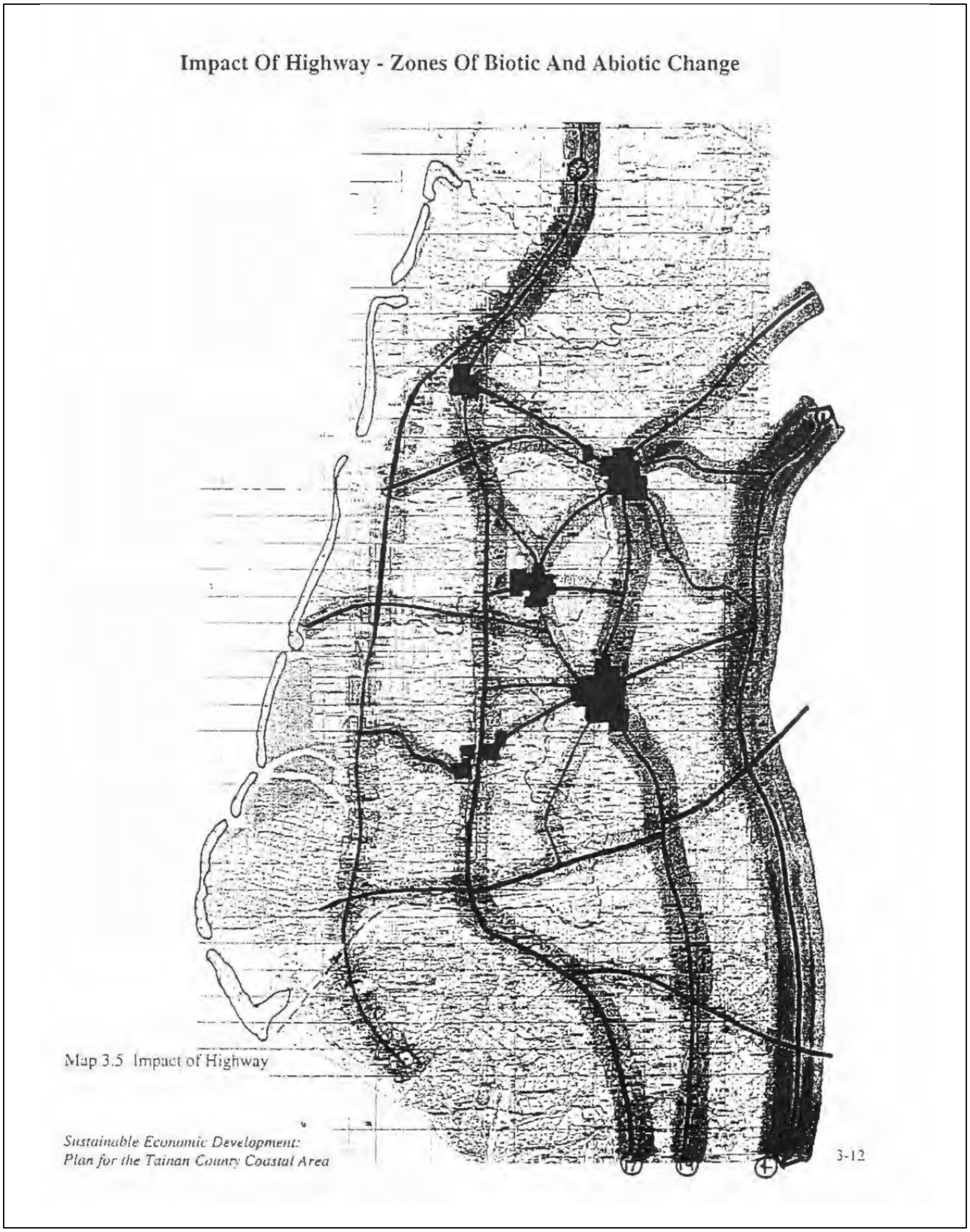


Figure 3-4 The Area Potentially Impacted by Highway (Hester, et al., 1997)

3.3 DEVELOPING SOLAR ZONING OVERLAY

In order to plan for photovoltaic development at the landscape scale, it is critical to understand how solar energy land-use is zoned to develop critique for improvement. This subchapter reviews issues related to solar zoning; they are:

1. How is solar energy land-uses zoned?
2. Why is overlay zoning for planning for solar landscape utilized?
3. What are the potential considerations and limitations to solar zoning?
4. What is the solar zoning overlay method in this project?

HOW SOLAR ENERGY LAND-USES WERE ZONED

In the land-use planning realm, the American Planning Association (APA) conducted two studies that analyse types of solar zoning. The APA considers that there are three types of local plan types, including: community comprehensive plans, sub-area plans, and functional plans (Morley, 2014). In these three types of plans, local governments can engage with solar energy to different degrees. For example, local governments may regulate a certain amount of solar-integrated design in comprehensive planning, identify requirements for utility solar power sites and operations in sub-area planning, and have an overall functional plan to help develop solar energy expansion. APA also identifies solar energy that may be presented as primary or secondary land-use at a site. Primary land-use would be utility-scale facilities or communal solar facilities, while secondary refers to co-location and mixed land use. This informs ecological planning in two ways: planners need to identify the land-use incorporating landscape as the primary or secondary land-use in addition to what plan types are already being incorporated; which brings the question of the level of intensity of photovoltaic energy and what would be zoned in certain areas.

An Info Packet *Planning and Zoning for Solar Energy* conducted by APA for planners organizes other measures that local and state governments can take in order to plan and to zone for solar energy (APA, 2014). These measures in the zoning ordinances include model solar ordinance, solar access ordinances, solar siting ordinance, solar homes, small-scale solar energy systems, and in large-scale energy systems. In large-scale energy systems related regulations, government-specified managements, sizes, and permit requirements are considered. One can conclude that the spatial, ecological, and social-economic standards have much room to be explored.

Wu developed the “Competitive Renewable Energy Zones” for the county-scale energy planning units (Wu & Schlag, 2015). These zones are calculated in ORB and RPS models, considering four levels of Environmental Exclusion Level and energy suitability in units, energy goals, cost, and impacts of transmission. Each unit is divided using a 2 to 20 square kilometres as “development zones.” The other solar zones that have been developed are the Solar Energy Zones (SEZs) and BLM Variance Areas used in the Desert Renewable Energy Conservation Plan (BLM, 2016; DRECP, 2016). The plan utilized ecological and land-use constraints to identify areas with less biological importance or resource conflicts for potential solar development. Requirements such as transmission adjacency, road adjacency, 1 to 2% slopes, and minimum 10.1 square kilometers are used for feasibility purposes. The zoning also utilizes the design for mitigation requirements—the measures such as avoidance or minimization of the impact, restoration, maintenance, and compensation (DOI; BLM; DOE, 2010).

The County of Blaine allows solar energy systems implemented in all districts, with extra standards in overlay districts such as mountains, scenic highways, FEMA, floodplains, and wetlands. Different from Taiwan's case utilizing flooded areas, the County of Blaine restricts flooded areas for solar development (County of Blaine (Idaho), 2013).

From the above-mentioned ways of zoning solar or renewable energy, one can conclude that these are large-scale zoning for solar landscape. Little control on land-use intensity is seen in these zoning measures.

WHY OVERLAY ZONING

Overlay zoning is defined as "Additional or stricter standards to existing zoning that can be used to protect particular natural or cultural features or to avoid or mitigate potential hazards." Moreover, overlay zones are "often used to deal with areas with special characteristics… Development of land subject to an overlay must comply with the regulations of both zones" (CA-ILG, 2010). Massachusetts Executive Office of Energy and Environmental Affairs prepared a document assisting cities and counties to facilitate solar energy development (EEA, 2014). It mainly offers commentary on how local governments adopt state land use ordinance, as well as provide recommendations in the specific guideline in citing preferences and in considering overlay zoning districts. Notably, no other information shows that the local government utilizes overlay zoning district when regulating solar zoning. The document drafted that model zoning can use site plan review or special permits as tools to review development for balance within districts. It also recommends a feasibility analysis for large-scale solar planning to prioritize the most feasible locations most. After seeing this example, it would be worthwhile to explore what characteristics that an overlay zoning can offer to secondary zoning like solar development.

Centre for Land Use Education indicated that the zoning overlay costs less to the community (CLUE, 2005). However, overlay zoning sometimes draws concerns in public acceptance. They specify that ensuring fairness, developing clear goals and purposes for each zone, providing specific rules for governments and the public is the key to succeed in the overlay zoning district. A zoning tool, which can cooperate with current planning, adding additional requirements to solar developments in a region at the landscape scale, and capable of controlling intensity, would be essential to this project. As other zoning tools, the intensity control can be creatively used while protecting the land resources; that includes trading solar developmental rights, specifying ordinance, implementing stakeholder processes.

CONSIDERATION TO SOLAR ZONING

Two potential issues need to be considered in developing solar zoning in the study area. One is the cautions in using planning power, and the other is the policy tools that can help implement the solar zoning.

Planners should always take caution in utilizing the state's planning power. Criticism of the idea of "acceptable locations" in the planning process is critical to reveal the power relation around energy landscape planning. Crowell's study argues that the concept of "acceptable site" is flawed. Instead, it is the socially constructed concept of top-down evaluation generated from criteria such as absolute constraints, localized constraints, electricity distribution issues, and additional criteria for area selection. Crowell argues that spatial planning favors evaluating primarily measurable qualities at a distance, which may not reflect the actual need in environmental planning. On the other hand, Hester emphasizes that people have the desire to participate in decision making and governance, and applied ecology is needed for reorganizing the human habitation. Ecological democracy by Hester's words, "is government by the people emphasizing directs, hands-on involvement." A concrete example like citizens identifying the sacred places in the City of Manteo to guide further planning offers a great lesson of how planning can utilize people's knowledge to create a sense of place (Hester R. T., 2006).

Another issue in this project is how the intentional landscape change along with solar zoning overlay shall be implemented. When sea-levels rise and wetlands need to be compensated, from where will land be produced or made?

Wilson argues that Germany shifted its agricultural policy to strong rural focuses after unification and with adopting an EU agricultural policy. Along with robust land-use control, Germany shifted the production-oriented agricultural policy to a multifunctionality-oriented agricultural policy. In addition, OECD indicates that there is a potential for exploiting new markets; such as: renewable energy, farm tourism, marketing of farm produce, maintenance of rural landscapes, and services for farmers cooperating with existing opportunities for sustainable economic development in terms of both agriculture and non-agriculture land uses in rural Germany (OECD, 2007). Two rural land use tools worth mentioning implemented in this project are land consolidation and voluntary land exchange.

Liu points out that rural land consolidation is used in Germany for infrastructure renewal, livelihood improvement, community wellbeing, farmland arrangements, irrigation renewal, wildlife protection, and landscape conservation (Liu C.-Z. , 2017). The method includes resizing, regrouping, and the rearranging of rural land parcels. Instead of implementing eminent domain, land acquisition, or compulsory purchase, land consolidation extracts a small percentage of land resources from all individuals for public facilities and commons. Some forms of participatory measures or public hearings are always taken per law to ensure meeting people's needs in these processes. "Voluntary land exchange" a simpler and faster version of land consolidation. Thomas argues that voluntary land exchange helps rural communities to accommodate productional or other needs with two or more parcels' owners in agreement to all measures, compensations, and decisions, such as; comparative valuation, merging, or transferring parcels with state's or a consulting agency's mediation (Thomas, 2004). In some cases, local rural development agencies can also participate in its land pool.

In the landscape with increasing flood risk, land consolidation provides a policy and legal tool to mediate the conflicts between productional needs, energy needs, and a changing flood situation. State or local government can utilize agricultural policy by encouraging retired farmers to release their farmland for acquisition, farming rights lease, or farming rights transfer. These farmlands can be included as part of the land pools supporting land consolidation. The farmers and fishers affected by floods can participate in the land consolidation to exchange for other pieces of land that suitable for farming and aquaculture operation.

SOLAR ZONING OVERLAY TABLE

In order to proceed with this project, a planning tool of solar zoning overlay (SZO) district would help setting up intensity control, standards, and communicating spatial arrangements for the changing landscape. Based on the literature review above, I developed the following table 3-5 showing the intensity of the photovoltaic facility in each zone in the solar overlay and will apply this SZO to scenario planning. Figure 3-6 translates that the intensity control of developmental rights into the section views, showing how it feels like in the landscape.

Solar Zoning Overlay	**Development Rights:**	**The intensity of the developmental rights**	**Overall Intensity Calculation**	**Overall Intensity**	**Planning Implication**
	Percentage of the parcel size allowed for PV and its supporting facilities	The actual percentage dedicated to PV within development rights	The actual percentage dedicated to PV (in multiplying form)	The actual percentage dedicated to PV (in numbers)	
S0	0%	0%	0%	0%	No solar development right
S1	20%	70%	20% x 70%	14%	Lowest solar development right, suitable for farmland
S2 (currently maximum for Taiwan's farmland)	40%	70%	40% x 70%	28%	Medium Low solar development right, suitable for farmland
S3	60%	70%	60% x 70%	42%	Medium solar development

					right, suitable for rural residentials
S4	80%	70%	80% x 70 %	56%	Medium high solar development right, suitable for high disturbed area and residential
S5	100%	70%	100% x 70%	70%	High solar development right, suitable for Utility scale solar farm

Figure 3-5 SZO Diagram

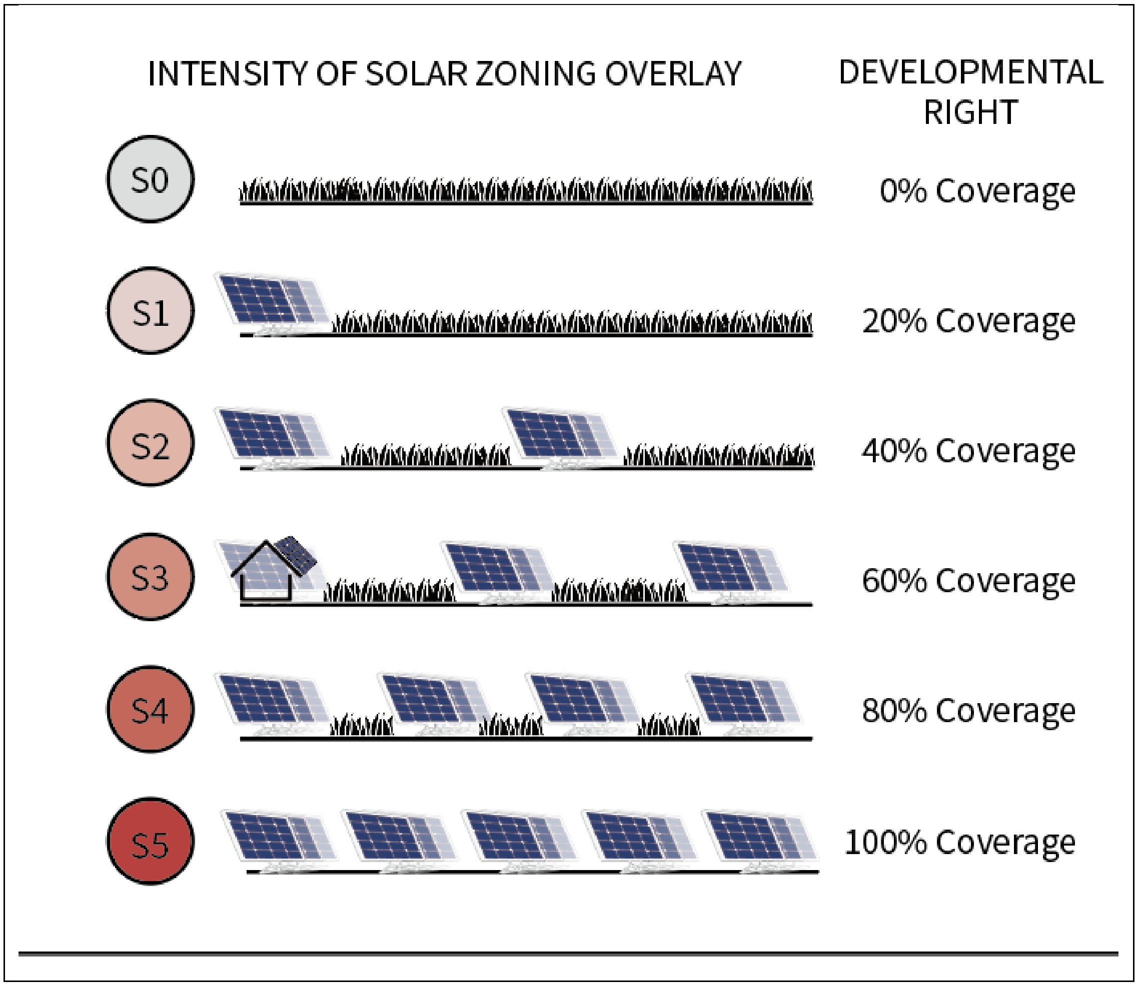


Figure 3-6 SZO Sections Diagram

3.4 DEFINING SCENARIO FOR ALTERNATIVE FUTURE

Giddens argues that proactive adaptation helps communities better react to threats and reduce vulnerability. It also helps to better communicate and govern risk in a climate change era to the public (Giddens, 2011). One could conclude that scenario planning for an alternative future is an informative method in this project since it makes assumptions to create trajectories of futures to help the public and decision-makers to better understand the consequences and comparison of different conditions of the future.

FORMING SCENARIO PLANNING METHOD

Studying the future with alternative futures is established in multiple disciplines, including agriculture, business, and more. Alternative future studies of landscapes can be used to analyse multiple types of landscape changes in relation to the changing drive, including housing-urban developments—one of the very early studies conducted with the alternative future method in landscape architecture disciplines is with Steinitz. Steinitz studied the growth of Monroe County from 1993 to 2001, using a focused process by applying ecological guidelines on six scenarios (Steinitz & McDowell, 2001). Geologic landscape, biologic landscape, visual landscape, demographics, economics, and politics are explored to visualize the land-use changes. Shearer's study aims to locate 500,000 to 1,000,000 houses in southern California as more housing is needed and along with assessing this Is the impact population will have on biological and hydrological processes, as well as biodiversity. The paper uses land-use-land-cover adjacency for its hydrological analysis, and species richness as two indicators for planning alternative futures. Four scenarios are produced; including the coastal future, the northern future, the three-centers future, and the low-density future by using two primary factors and four different futures presented for a housing policy choice. Notably, the future forecast is a housing-driven land-use future trajectory one (Shearer, 2006).

Some alternative futures studies also look into opportunities for design and planning interventions in natural processes. Hulse studies the effects of desired futures on biodiversity and hydrological environments in western Oregon (Hulse, Eilers, Lindsay, Hummon, & White, 2000). Utilization of hydrological models such as non-point pollutant sources and surface water runoff reveals the impacts of development. Results from the water quality model show increases in the volume of surface water runoff and total suspended solids under a development-oriented future. Results from the biodiversity model show that all native species have at least some habitat in all alternative futures. If land-use trends in the watershed continue unchanged or become more highly developed, there will be an increased risk to the abundance of extant native species. The set of species at risk in the development-oriented futures differs significantly in composition and is placed at risk at a higher rate than in the past, suggesting that the kinds of habitat changes to date differ from those envisioned in the alternative futures. In another study, Hulse managed to anticipate "surprises" of probable fire with an alternative future trajectory compared to past fires. Hulse recommends shifting from a deterministic approach to a probabilistic design approach in such a context (Hulse D. W., et al., 2016). Enright utilizes alternative futures in studying ecosystem services in southern Willamette Valley, Oregon, by offering a landscape approach to understand the pathways of ecosystem services in a coevolving agricultural landscape (Enright, 2013).

The method that this project is using refers to two prominent studies done by Steinitz and Hulse. These two studies are more detailed and comprehensive. Steinitz studies the San Pedro River Basin with stakeholders' input approach to form a set of scenario guides regarding population, water management, and land management strategies with assumptions to guide three groups of scenarios of PLANS: constrained and open considerations (Steinitz, et al., 2003). The study further assesses the impacts of these scenarios and presents them again to stakeholders in order to anchor the trajectories assigned. Hulse studies the Willamette River Basin 2050 to spatialize three different futures, understand the impacts, and prioritize areas for future conservation uses. The project asked four hierarchal levels of citizen involvement in different frequencies to help guide the 2050 alternative future map in an early stage of the study. Later on, the project used citizen guidance to identify conservation and restoration opportunities (CRO) from the Conservation 2050 plan. With the help of the Biodiversity Technical Group overlay vegetation map before pre-European settlers, the research identifies ecosystem correspondance with land-cover type restoration. The results shows the expansion of urban growth boundaries (UGBs) which preserve farmland and convert parts of prime farmlands to native vegetation (PNW ERC, 2002). Diagrams of both plans are presented in figure 3-7.

This project, referring to both prominent projects, utilize existing conditions, expert input scenario guides, and literature to form a scenario and land-use change parameter. The land-use change parameter then helps form two scenario simulations. The plans created by two sets of scenarios then were evaluated for their performance. The types of land-use changes within the plan were identified to have representation in views to help readers understand how the landscape would look in such conditions.

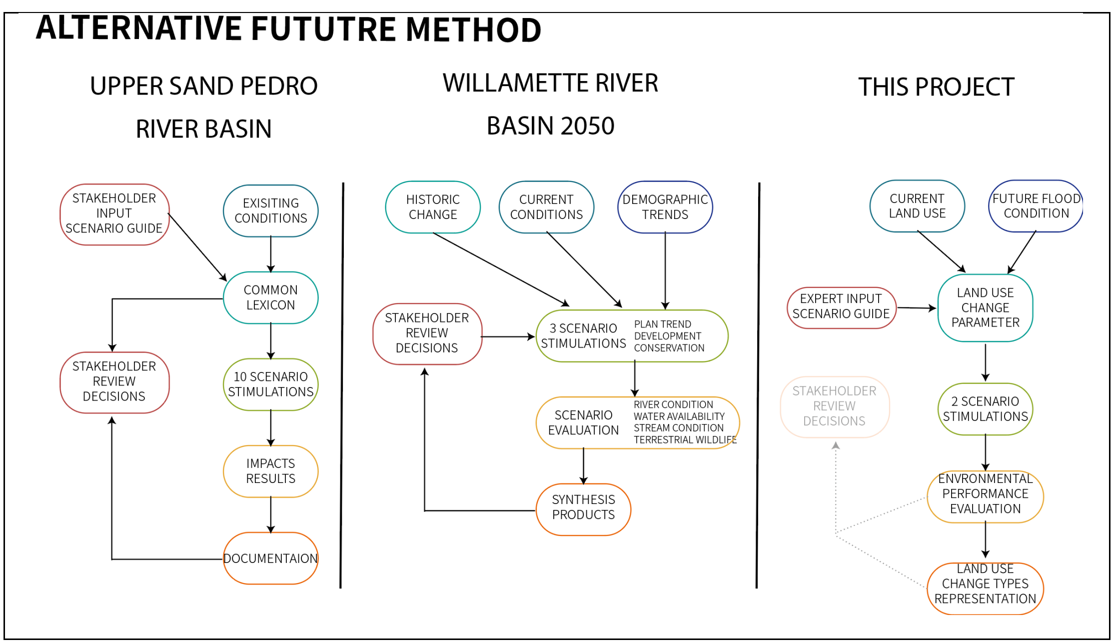


Figure 3-7 Alternative Future Method Precedent in Relation to This Project's Method.

CONSIDERATIONS IN SCENARIO PLANNING

Applying scenario planning in energy-specific land-use research is rare in the literature. This project has the potential to supplement the body of knowledge related to the landscape approach to the conflict of greens using alternative future methods. There are some considerations and issues that need to be recognized when conducting such studies. They are related to the resources available for the project, uncertainties in data, and the degree of participation.

The resources put into big alternative future projects are tremendous. The Willamette River Basin and Monroe County plan were the product of scholars' collaboration with the Environmental Protection Agency and local governments. They both went through the participation processes. They can be seen as strategic assessments of development. Chung mentions in the interview that strategic environmental assessment and environmental impact assessment in Taiwan also went through the process of assessing alternative plans (Chung, 2019). However, these were usually done in superficial and procedural manners without explicit guiding assumptions. This project argues that the government should include alternative planning before proceeding with strategic environmental assessment. Through the participation and the public hearing process, these projects have a higher chance of gaining acceptance from their communities. However, within a limited timeframe and limited financial resources, these projects only focus on the development of land-use change and solar zoning overlay and its impacts of two sets of scenarios.

The Willamette River Basin 2050 (PNW ERC, 2002) also discusses several sources of uncertainty in alternative futures studies. The generalization, resolution, and temporal accuracy of the data used affects the level of uncertainty. Some degrees of data error always exist in projections and surveying when working with control points in geospatial data science. All maps are imperfect. depending on sources and availability, different maps can contain differences in boundaries or quality data.

All alternative future studies utilize assumptions, and assumptions are not predictions. Not only are projects using best-informed assumptions, which can be proven "wrong" later, but there are also factors that did not or cannot be included in the assumptions. Reviewing previous studies, one of the issues that came up in early studies is that climate change was not a significant factor to consider at the time. Scenario planning, used as the controlled "laboratory" in Latour's sense, simplifies and makes the conditioned future into several sets of trajectories (Latour & Woolgar, 1986). Transparency regarding these assumptions is the key to better facilitate the decision-making process and reveal the "black box" of the production of science.

Hulse utilizes a metanalysis to compare two types of alternative future approaches in floodplain trajectories. The trajectories include a few 10-year time span with two separate results which are generated by citizen/deterministic-based and expert/agent-based alternative future approaches (Hulse D. , Branscomb, Enright, & Bolte, 2009). They found that expert-based alternative futures faced more resistance in implementation than a citizen-based approach for its lack of consideration of contexts. However, it found the agent-based approach more compelling in incorporating the unpredictability of river dynamics. They also conclude that landscapes in rapid transition can usually be identified by expert-informed, agent-based policies, while citizen-led processes can better inform the choices regarding pivotal parcels.

SCENARIO GUIDE: LAND USE DEVELOPMENT STRATEGY

The scenarios in alternative future studies are usually guided by scenario guides. In Upper Sand Pedro River Basin Plans, ten scenarios are all different from each other, guided with 19 standards (Steinitz, et al., 2003). Three scenarios in the Willamette River Basin utilized seven scenario developments to define trajectories (PNW ERC, 2002). These two studies offer some coordination for us as anchors in complex landscape systems. That is to say, the goals of the planning process are to establish a **better spatial organization and landscape hierarchy**. The questions we should ask according to the landscape changes expected are:

1. When and wherein the landscape, shall we allocate and change specific land-use designations in a rising sea-level and coastal landscape context?
2. To what extent are we willing to preserve or expand ecological cores such as wetlands across the coast? How can we find buffers in between in order to use solar panels as opportunities to serve nearby communities and rural industries best?
3. To what extent can intensive solar farming be implemented in order to fulfill community needs?

Accordingly, three sets of standards are identified—they are: prioritization of flood areas, ecological protection, and developmental strategies.

1. Prioritization:
    a. Flooded areas should receive priority in developing photovoltaic energy compared to the non-flooded areas when land-use designations are the same.
2. Ecological Protections:
    a. Wetlands regulated by the Wetland Protection Act should be protected.
    b. Wetlands not regulated by Wetland Protection Act, but identified by experts should be protected.
    c. Wetland should be buffered for forage distance (400 meters) to minimize disturbance.
3. Development strategies:
    a. Photovoltaic development should aggregate towards existing infrastructure such as towns and highways(120 meters in 2040; 360 meters in 2060).

The land-use strategies, regulations, and experts' opinions in the above-mentioned chapters help forms the scenario. This project tested multiple combinations of the standard and landed on two of them. One of them is the business-as-usual scenario, and the other is the adaptation scenario. Using the recommendation from A *New Solar Landscape*, two different types of planning methods are used. One is “map-based” zoning, which utilizes the current zoning to identify the opportunities for the development (Elkind & Lamm, 2018). The other is standard-based zoning, which uses sets of standards to identify critical measures to achieve the objectives of the planning. The following tables show how these two sets of zoning matter in relation to the recommendations. Notably, With other inputs and planning thoughts, different scenario guides can be explored further.

GUIDES	BUSINESS-AS-USUAL SCENARIO	ADAPTATION SCENARIO
PRIORITIZATION		
PRIORITIZE FLOODED AREA	V	V
ECOLOGICAL PROTECTION		
WETLAND PROTECTION	V	V
IDENTIFIED BY EXPERTS		V
SENSITIVITY BUFFERED		V
DEVELOPMENTAL STRATEGY		
IMPACT AGGREGATED		V

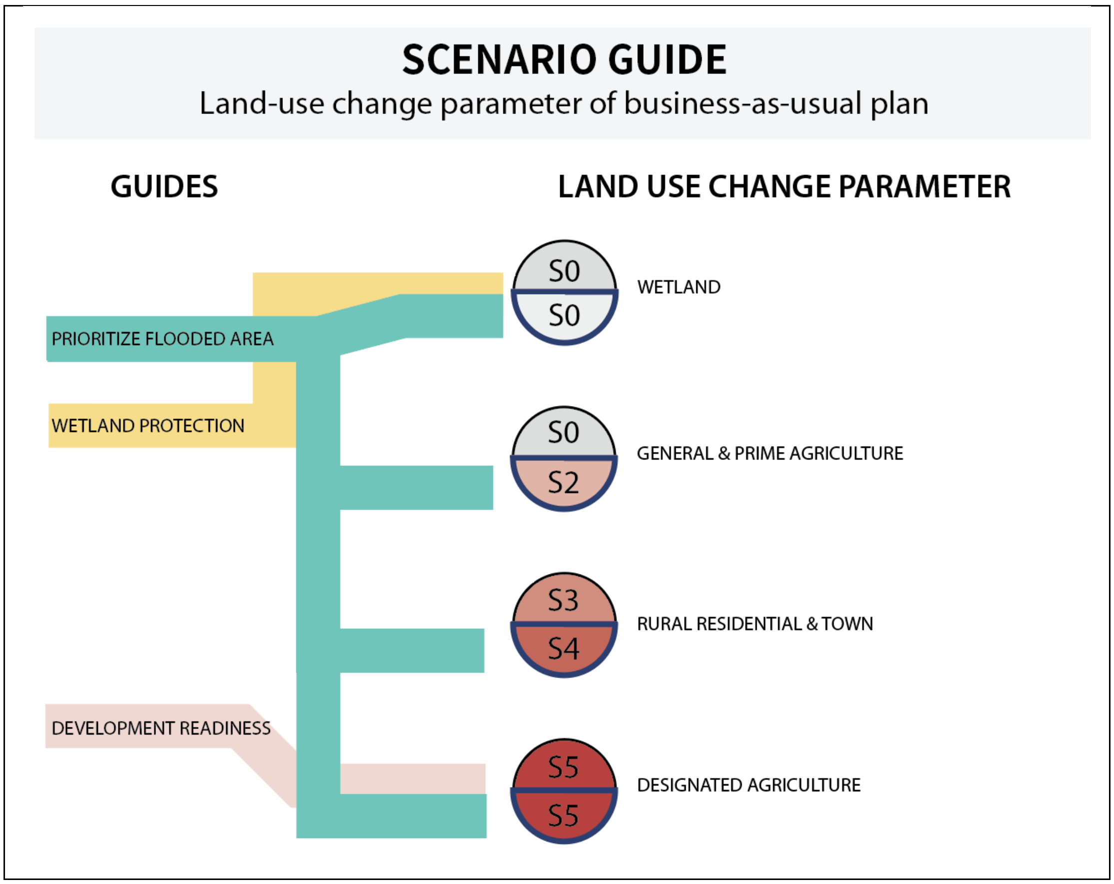
Figure 3-8 Scenario Guide

	Business-as-Usual	**ADAPTATION**
New Solae Landscape recommendation	Map-based zoning	Standard-based zoning
Negotiating Greens	Segmented greens (solar development)	Systematic greens (multifunctionality)
Policy Relm	Development Readiness (Using lands of public/single owner such as Tai-Sugar's and Tai-Salt's lands)	Expert-input
Development Strategies	Sprawl	Impact aggregation (Aggregate toward current infrastructure to minimize the land use impact.)

Figure 3-9 Scenarios Development and Spatial Distribution

LAND USE CHANGE PARAMETER AND SCENARIO GUIDE

The land-use change parameter is a set of algorithms that determine what solar zoning overlay would go on top of the land-use according to its flood condition, habitat status, developmental readiness, and existing infrastructure adjacency. All flooded areas have higher priority in photovoltaic development. In the business-as-usual plan, designated agriculture lands, which usually are Tai-sugar and Tai-salt lands, have the highest Intensity of developmental rights. Whereas in adaptation plan, rural residents and roadsides have higher developmental rights than other types of land-use and another conservation layer is added for habitat and buffer zones to improve wetland habitat health and functions. For the business-as-usual plan, the Taiwanese government's two-year pilot plan is also referred (BoE, 2017) (BoE, 2019).



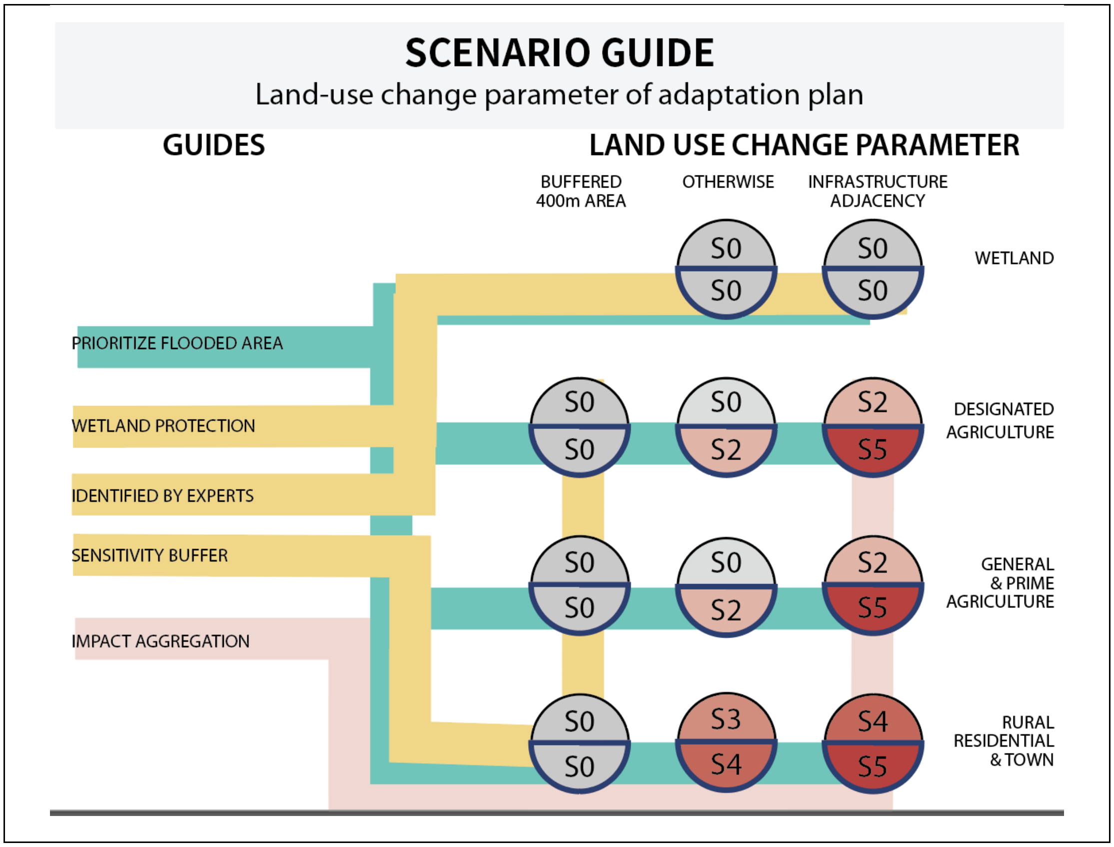


Figure 3-10 Land-Use Change Parameter

Noting that this is an extract of possible trajectories of land-use changes, it cannot represent all the types of land-use. Moreover, the result of this land-use change parameters can only be seen as a set of simplified attempts to explore the maximum potential of photovoltaic energy potential in the landscape. We need to see the forever changing estuary landscape as a complex system. Humans in such a landscape have engaged in the dynamic process of (re) industrializing and (re) naturalizing landscape, rather than in a fine line distinguishing built environment from the natural environment. The best example is that aquaculture pond raising milkfish can serve as forage habitat and buffer zones.

3.5 EVALUATING ENVIRONMENTAL PERFORMANCE

Environmental Performance Evaluation is an evaluation process that helps reveals the environmental performance of two scenarios. Readers, such as decision-makers and civic participants, have the autonomy to judge the gives-and-takes of each scenario. Recognizing that by breaking down the impacts, readers can make their judgments on which scenario is “better” by themselves, this project remains neutral in judging which scenario is “better” but attempt to be as transparent as possible in how these evaluations are calculated.

ENVIRONMENTAL PERFORMANCE DONE IN PREVIOUS STUDIES

In the study of Upper San Pedro River Basin, researchers led by Steinitz summarized the impacts of 11 given conditions that test the performance of different scenarios. These categories include the attractiveness index of different built environments, water resources and wastes volumes, hectare changes of vegetation, hectare changes and richness of critical habitats, and visual values changes (Steinitz, et al., 2003).

In the study of Willamette River Basin 2050, researchers led by Hulse evaluated five plans of three different times with six trajectories. The categories of these evaluation are natural vegetation, riparian areas, agricultural land use, forestry land use, urban land use, and rural residential land use. They also explicitly measured changes in future water availability and use, stream condition, river condition, and terrestrial wildlife (PNW ERC, 2002).

ENVIRONMENTAL PERFORMANCE EVALUATION IN THIS PROJECT

In this project, the impacts were broken down into three main categories. They are wetland functions and services, energy land use and outcomes, and overall cost and benefits of the scenarios.

1. **Wetland and Flooded land Functions and Services**

There are two measures to understand wetland quantify wetland functions and services. They are wetland area change and flood detention capacity. These two measures can help decision-makers to understand the give-and-take in order to assess the plan further.

Wetland Area Change (Hectare)

- Definition: Wetlands to be permanently flooded will no longer be considered wetlands
- Calculation: This is calculated using calculate geometry in ArcGIS

Flood detention capacity (water volume)

- Definition: the remaining wetland will be asses with its area, and surface volume will be calculated
- This is calculated through the volume lost using the ArcGIS Surface Volume tool according to the sea-level at 2040 (0.611 meters) and 2060 (1.028 meters)

Wetland Carbon Sequestration Capability Change (Marshes)

- Definition: Changes in the capability of wetland sequestrating carbon dioxide equivalent per hectare per year
- Calculation: multiple studies on wetland sequestration in Taiwan are referred.

Settings	Carbon emission avoided	Citation
River mangrove system	4.61 Mg C ha^(-1) yr^(-1)	(Chen P.-H. , 2014)
River Marshes system	27.20 Mg C ha^(-1) yr^(-1)	(Chen P.-H. , 2014)
Microphytobenthos (MPB), Zostera japonica (ZJ) and Bolboschoenus planiculmis (BP) communities	– 11.57, 20.92, and 9.20 g C m-2 yr-1 in	(Liao, 2012)
the seagrass bed of Dongsha area	9.78 ton C ha^(-1) yr^(-1)	(Huang, 2012)

2. Energy Sector

There are two measures to understand the energy output and its impact. Solar zoning overlay will be utilized to calculate the maximum potential of electricity generation and renewable energy land use. These two measures can help decision-makers to understand the give and takes in order to assess the plan further.

Renewable Energy Land Use (Hectare)

- Definition: Area affected by photovoltaic development, disregard the level of solar zoning overlay
- Calculation: This is calculated using calculate geometry in ArcGIS

Electricity Generation (kW-hour)

- Definition: the maximum probable annual kWh with full installation.
- Calculation: using kWh/kWc factor of 1250 as stated in this region (Taipower, 2020).

Electricity Capacity (kWc)

- Definition: Capacity of potential total photovoltaic developmental rights
- Calculation: using 1.25 kWh/hectare (Vena Energy, 2019)

CO_2 equivalent emission avoided from energy compare to natural gas or coal

- Definition: Amount of the CO_2 equivalent as gas or coal powerplant emission
- Calculation: using 0.373 kg CO2e/kWh(gas) or 0.823 kg CO2e/kWh(coal) (Pan, 2011)

3. Agriculture and Aquaculture Sector

Farm Land Area Change

- Definition: Actual area of farmland use no longer farmable due to PV or flood
- Calculation: This is calculated using calculate geometry in ArcGIS

Farm Land Carbon Change kg-CO2

- Definition: Carbon sequestration change from Farm Land every year
- Calculation: Rive plantation Oryza sativa Total Absorb 137.51 Ton-CO2/yr-ha (Yang C.-S. , 2012) (Wu & Lu, 2010)

Aquaculture Area Change

- Definition: Actual area of Aquaculture land-use changes due to flood. Assuming all flooded agricultural land will convert to aquaculture land
- Calculation: This is calculated using calculate geometry in ArcGIS

Aquaculture Carbon kg-CO2 yr

- Definition: Carbon sequestration change from aquacultural sector every year
- Calculation: milkfish production produce 8040 KgCO2e / Ha-yr (Ku, 2013) (Hsu, Ting, & Yang, 2018)

4. Overall CO2 equivalent emission avoided and Environmental Performance.

Overall land-use change and CO2 equivalent emission avoided will be assessed. In order to communicate the opportunity cost, agriculture, and aquaculture area loss and gain will be measured to understand what the likely landscape change would take from the agricultural sector. The carbon emission avoided will also be an essential part of the performance assessment since climate change mitigation is the initiative of the renewable energy facility implementation. This project recommends that the carbon emission avoided, and an opportunity cost of carbon emission avoided, would be most accurate comparing to the gas powerplant and management wetland as marshes.

- Definition: Total Carbon emission avoided compared to gas energy when wetland managed as marshes
- Calculation: ΔC energy(gas) + ΔC wet(marshes)+ ΔC aquaculture + ΔC agriculture

4 PLANNING ANALYSIS

This chapter will demonstrate the steps of planning analysis of scenarios and will explain the results. This contains three parts, including trajectories development, scenarios, and their environmental performance evaluation. The following graph represents the process of scenario planning.

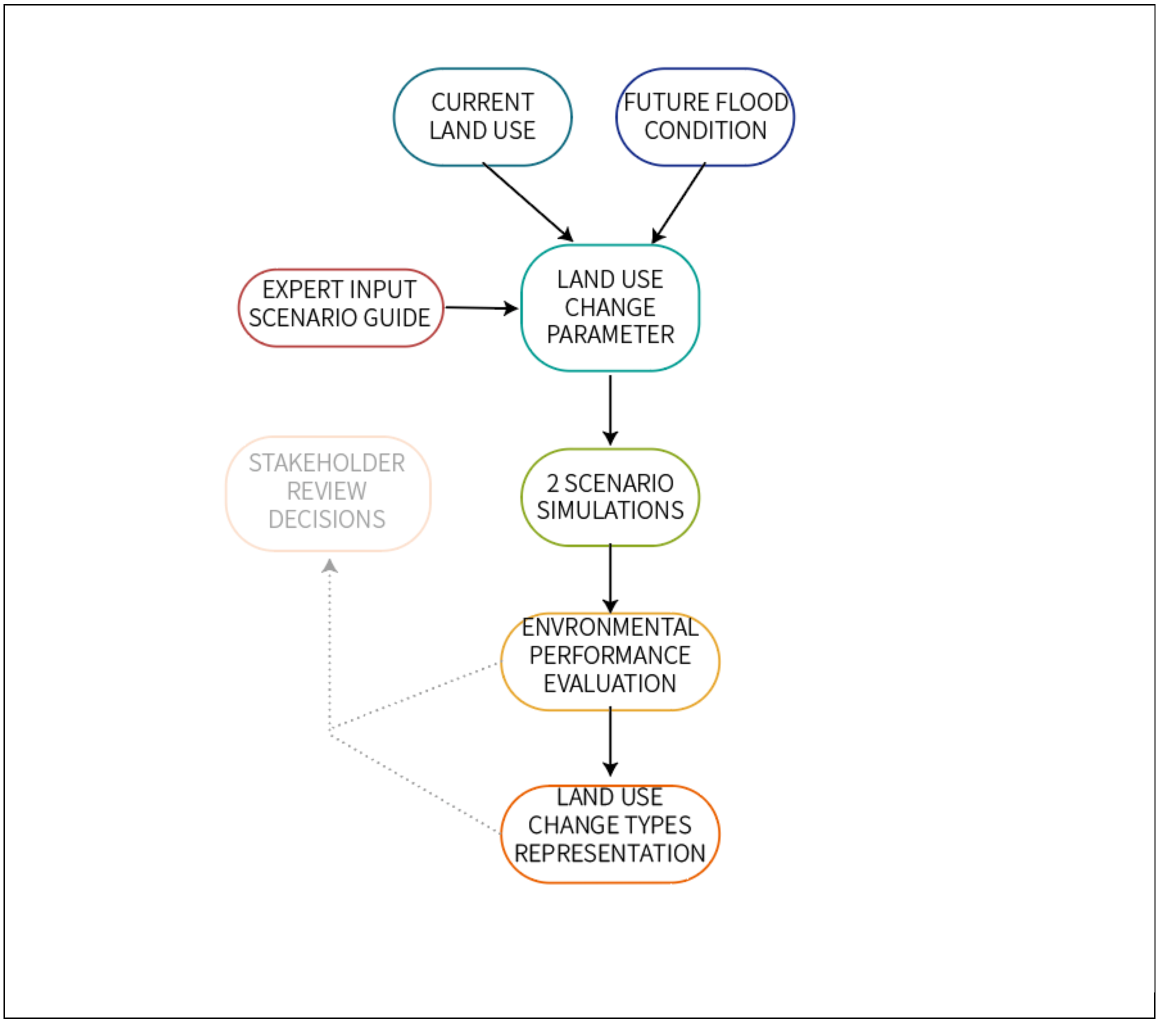


Figure 4-1 Planning Process of scenarios.

4.1 SCENARIO DEVELOPMENT

As stated previously, scenario planning in this project utilizes flood conditions in 2040 and 2060 as driving landscape changes which alter the land-use and solar zoning from current land use. This requires the following layers of maps to proceed. See figure 4-2 for the process diagram for trajectories development.

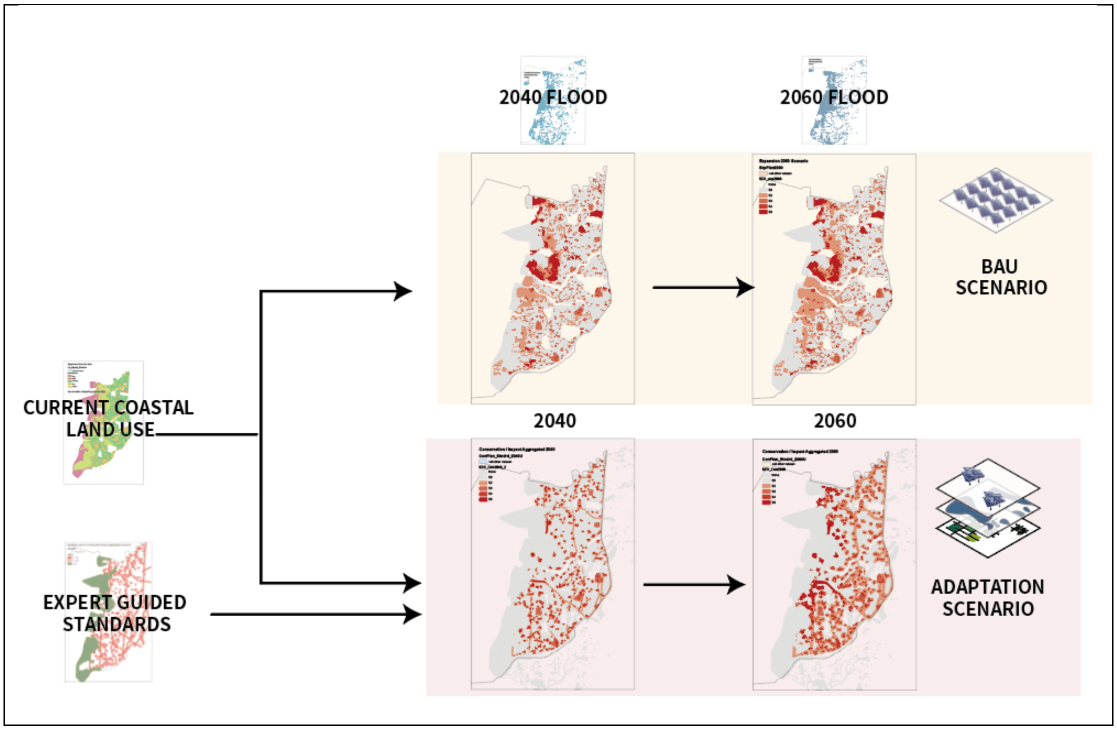


Figure 4-2 Scenario Developments

Current Coastal Land Use Layers

This current land-use layer serves as a base map for further processing. Figure 4-3 shows the simplified current land use map combing ecological land-use and other rural land- use. The main land-use types are rural towns and residents, designated agriculture, prime agriculture, general agriculture, and ecological areas.

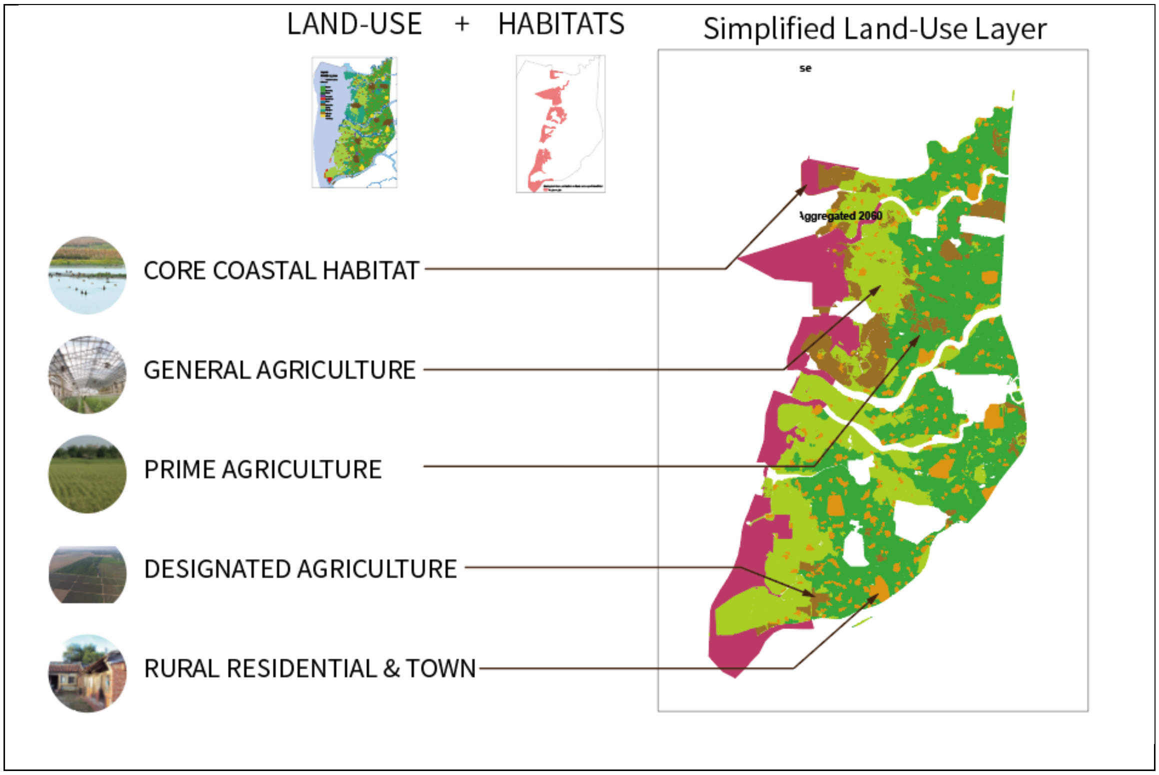


Figure 4-3 Current Land Use Layer

Future Flood Conditions

Future flooding conditions is the essential landscape driver. Figure 4-4 shows the overall flood situation of 2020, 2040, and 2060. The future flooding conditions are created with three types of data, including sea-level rise, land subsidence, and overland flow; see figure 4-5 and figure 4-6 for the process diagram of the combination of flood conditions. The permanently and frequently flooded areas are identified within each map. Subsequently, the permanently and frequently flooded areas are overlaid to create the 2040 and 2060 flood layers.

According to various sources, this project set sea-level rise at 40 cm every 20 years, which creates a 0.4-meter and a 0.8-meter decrease in DEM. The land subsidence data shows the maximum depth of subsidence is 0.61 meters and 1.23 meters in 2040 and 2060. The overland flow data utilizes the 150mm/6hr to identify places that have high chances of frequent floods.

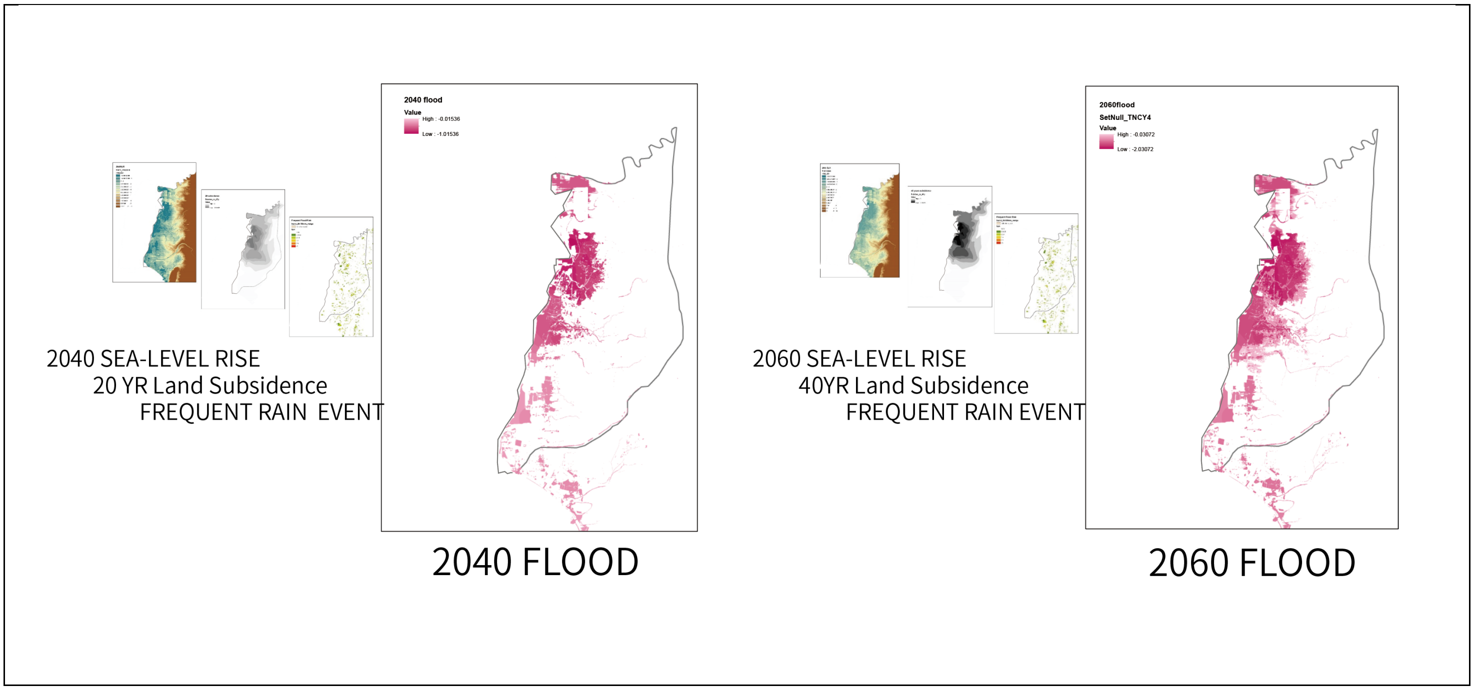


Figure 4-4 Flood Conditions from 2020 to 2060

Experts-Guided Standards

This adaptation plan follows the suggestion from Berkeley Law's manual, utilizing expert suggestion in the process. A wide range of experts includes Academic (Wang H.-W. , Personal Communication, 2019; Dodd A. , 2019), NGO researchers (Tsai, 2019; Chung, 2019), environmental groups' organizers (Lai R.-H. , 2019; Lin K.-H. , 2019; Liu S.-S. , 2019), fishery group organizer (Wang C.-M. , 2019), politicians (Hung, 2019) were interviewed. The expert-guided standard for adaptation plan utilizes stricter conservation standards and impact aggregation to achieve the standard-based zoning. The conservation measures include the inclusion of expert-identified wetlands, utilization of wetland buffer, and wetland compensation. These areas are shown in green. The impact aggregation standards utilize infrastructure adjacency, including roads and residentials, to aggregate surrounding impact. The level of adjacency utilizes 120 meters in 2040 and 360 meters in 2060 as the standard to aggregate solar development. This standard layer will further be used as the standards for the adaptation plan.

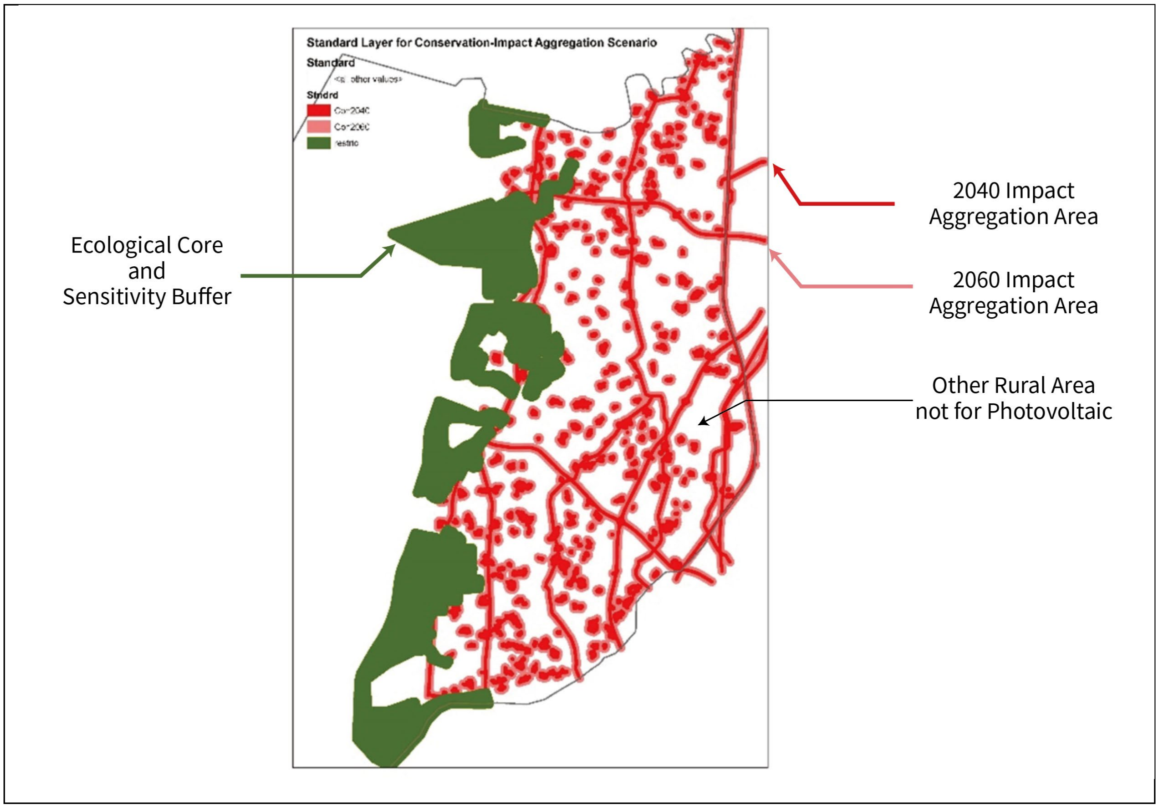


Figure 4-5 Experts-Guided Standards for Adaptation Scenarios

4.2 SCENARIO DEVELOPMENTS

The scenario development of solar zoning is as follows. Four maps are produced from the trajectories specified. They are Business-as-Usual 2040, Business-as-Usual 2060, Adaptation 2040, and Adaptation 2060

Developing Business-as-Usual Scenario

The Business-as-Usual scenario is guided by the continuation of current policies and business-as-usual. Spatially it appears that the growth of the scenario is affected by the increased flooding area. It also appears in the concentrated growing area on the coast, to where wetlands are adjacent, and where aquaculture buffers exist.

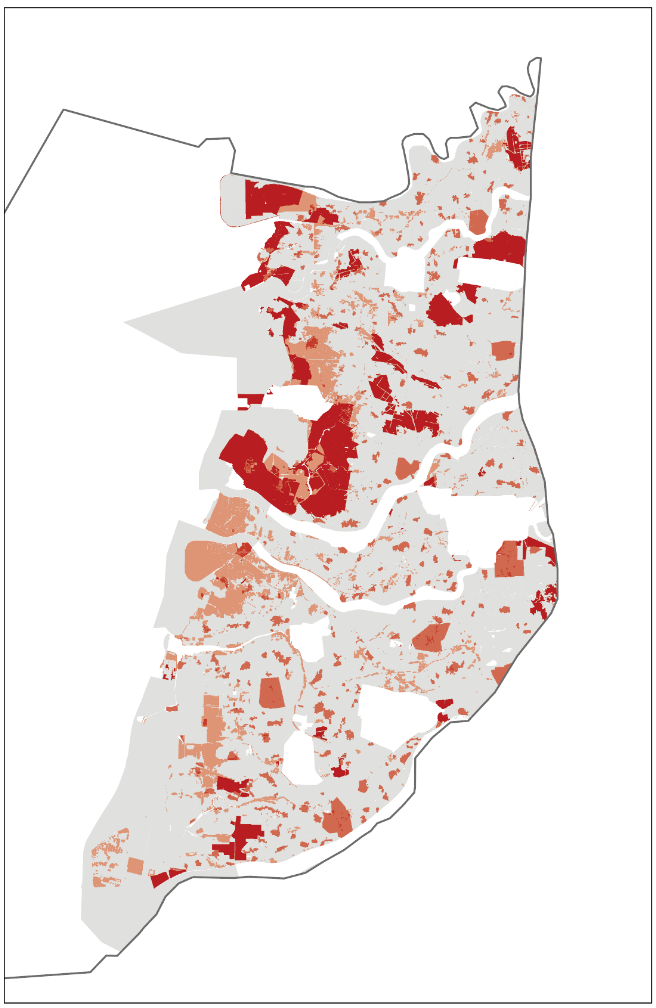
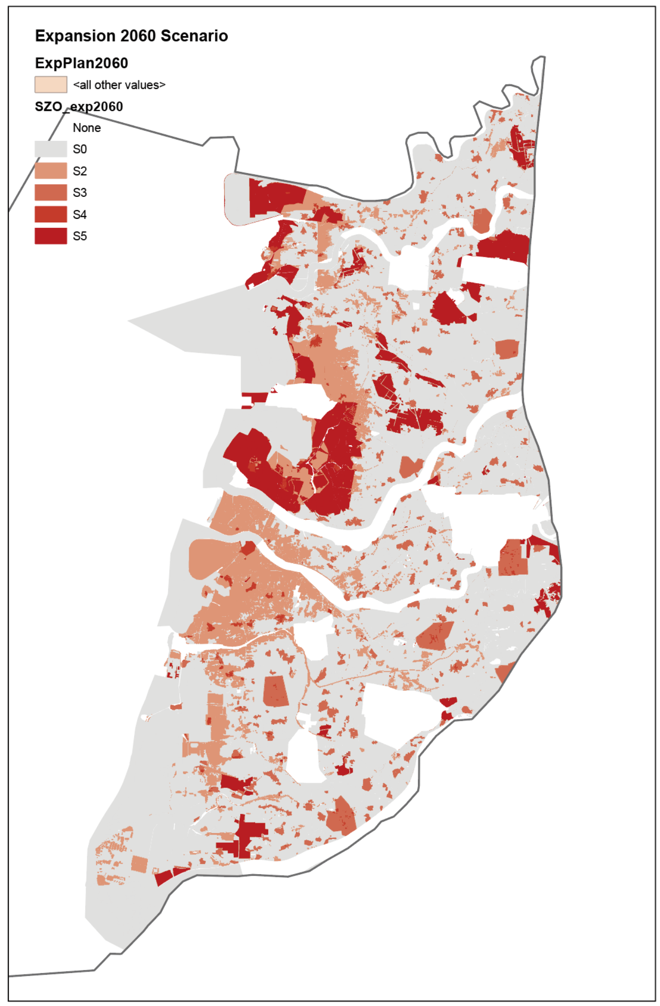
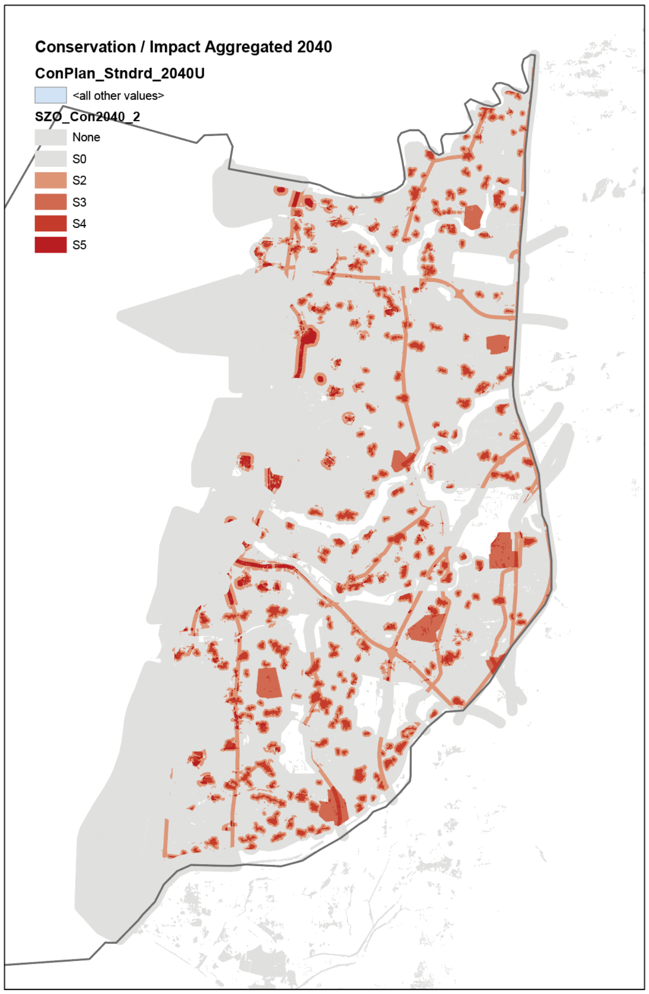
Business-as-Usual 2040	Business-as-Usual 2060
	

Figure 4-6 Business-as-Usual Scenario

Developing Adaptation Scenario

The adaptation scenario is guided by the standard created by the input of experts. Spatially, adaptation scenario appears to growth around existing infrastructures and conserving coastal areas.

Adaptation 2040



Adaptation 2060

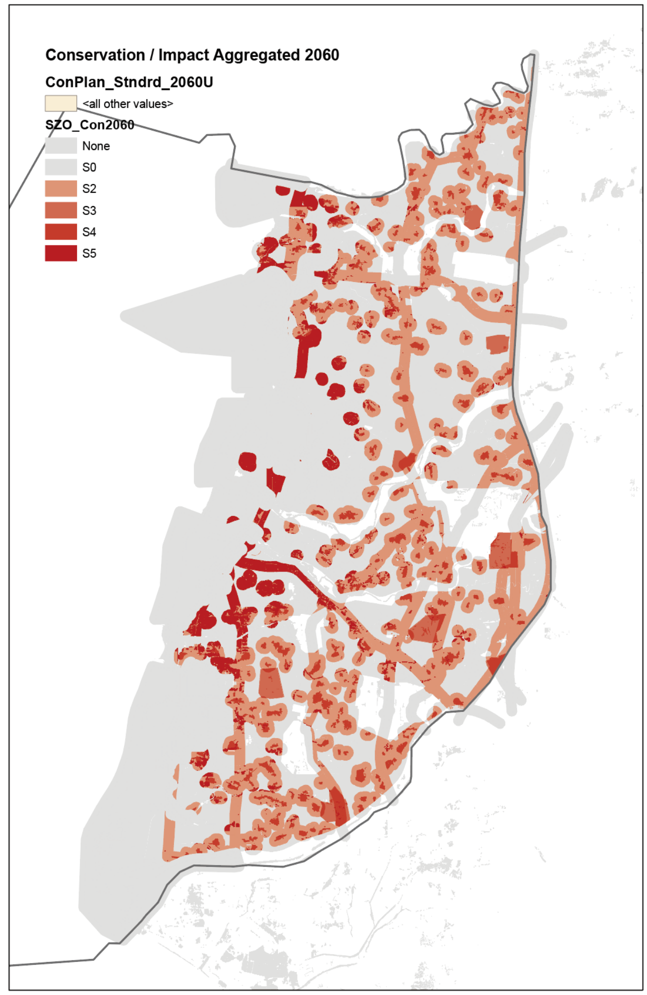


Figure 4-7 Adaptation Scenario

4.3 ENVIRONMENTAL PERFORMANCE EVALUATION FOR SCENARIOS

The overall land-use change will be assessed in this subsection. In order to communicate the opportunity; cost, agriculture, and aquaculture area loss and gain will be measured to understand what the landscape change would take from the different sectors. The carbon emission avoided will also be an essential part of the cost benefits assessment since climate change mitigation is the initiative of the renewable energy facility implementation. This will help readers to understand how much carbon emission will be avoided in each scenario while knowing how much resources it cost.

Wetland and Flooded land Functions and Services

Wetland areas in the Business-as-Usual scenario will lose significantly, while those in the adaptation plan will be compensated. This difference affects the flood detention capacity of the landscapes in each plan.

PERFORMANCE	Wetland Area Change	Wetland Carbon Sequestration Capability Change (Marshes)	Wetland Carbon Sequestration Capability Change (Mangrove)	Flood Detention Capacity Change	Flooded Area Change
UNIT	Hectare	Ton-CO2e / year	Ton-CO2e / year	Ton	Hectare
DESCRIPTION	Wetlands on land area would be Permanently flooded.	Changes in capability of wetland sequestrating carbon dioxide equivalent per hectare per year	Changes in capability of wetland sequestrating carbon dioxide equivalent per hectare per year	Volume capacity change due to permanent flood of all land-use types	Area impacted by permanent flood, unless managed as artificial wetland.
Business-as-Usual 2040	-4740.09	-472744.59	-101327.24	-106,977,451.00	17,495.44
Business-as-Usual 2060	-5500.16	-548549.17	-117575.06	-262,824,532.00	25,563.19
ADAPTATION 2040	0.00	0.00	0.00	-50,435,818.54	12,755.36
ADAPTATION 2060	0.00	0.00	0.00	-206,282,899.54	20,063.03

Figure 4-8 Table of Wetland and Flooded Land Performance

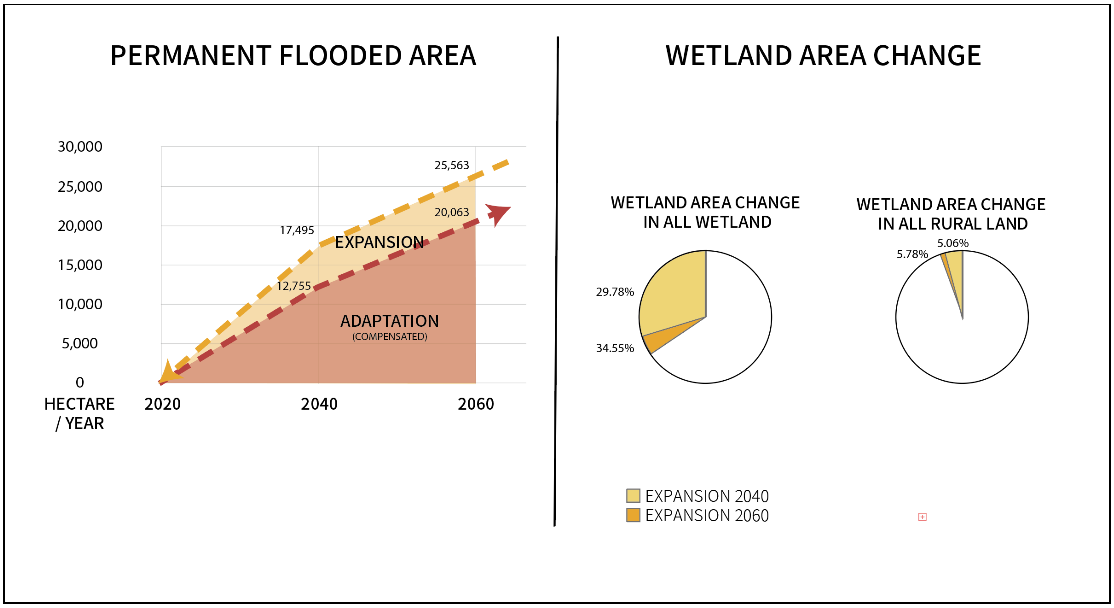


Figure 4-9 Land Area Comparison Wetland and Flooded Land

Energy Sector

Energy sector growth in Business-as-Usual scenario shows that wetland areas in the Business-as-Usual scenario will lose significantly, while those in the adaptation plan will be compensated. This difference affects the flood detention capacity of the landscape in each plan.

PERFORMANCE	Land Area Impacted by photovoltaic	Actual photovoltaic taking place	Electricity Generation Capacity	Electricity Generation per year	CO2 equivalent emission avoided from energy compare to natural gas	CO2 equivalent emission avoided from energy compare to coal
UNIT	Hectare	Hectare	GW capacity	kWh / year	Ton CO2e/kWh/ year	Ton CO2e/ kWh/ year
DESCRIPTION	Area impacted by PV implementation including adjacent mix use.	Actual area impacted by PV implementation excluding adjacent mix use	Capacity of potential total solar developmental rights	Potential amount of energy produced from total solar developmental rights	Amount of the CO2 equivalent as gas powerplant emission	Amount of the CO2 equivalent as coal powerplant emission
Business-as-Usual 2040	21,916.26	15,507.80	13.57	16,961,675,000	6,326,704.78	13,959,458.53
Business-as-Usual 2060	25,984.71	17,180.15	15.03	18,790,775,000	7,008,959.08	15,464,807.83

ADAPTATION 2040	17,495.00	9,112.26	7.97	9,966,538,000	3,717,518.67	8,202,460.77
ADAPTATION 2060	34,064.02	17,621.18	15.42	19,273,161,605	7,188,889.28	15,861,812.00

Figure 4-10 Table of Energy Sector Performance

Township	Electricity Consumption in 2018 (khw)	Electricity Consumption in Jul&Aug 2018 (khw)
東石 Dong-Shi	28,593,631	5,730,764
布袋 Bu-Dai	34,768,527	6,989,438
北門 Bei-Men	13,451,331	2,706,819
學甲 Hsue-Chia	38,248,831	7,852,697
將軍 Chiang-Chung	25,060,929	5,075,545
佳里 Chia-Li	91,862,783	18,930,817
七股 Chi-Gu	26,660,184	5,378,237
Total of Seven County	**258,646,216**	**52,664,317**
		(With daily capacity factor of 3.5 kWh/day/kWp, Approximately 246 MWc is required for self-sufficient in house-hold energy)

Figure 4-11 Energy Consumption of Seven Counties of the Study Area (Taipower, 2017)

County	Electricity Consumption in 2018 (khw)	Cf. ADAPTATION 2040 (khw)
Tainan County	3,674,231,701	
Chia-Yi Metro	498,983,734	
Chia-Yi County	868,716,524	
Total	5,041,931,959	9,966,538,000

Figure 4-12 Energy Consumption of Three Counties Compared to Adaptation 2040 Scenario (Taipower, 2017)

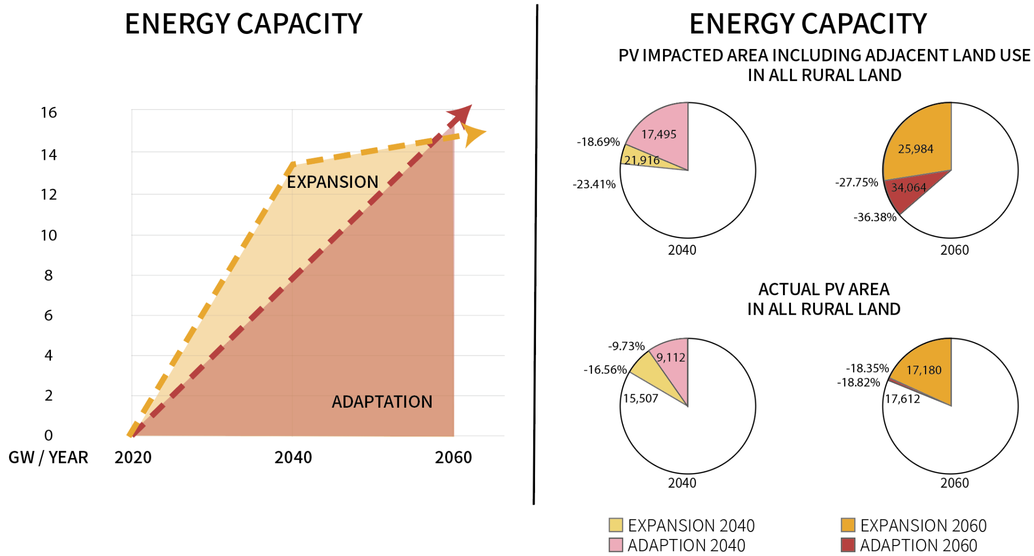


Figure 4-13 Land Area Comparison of Energy Sector

Agriculture and Aquaculture Sector

Agricultural land-use includes two land-use types: farmland, and aquaculture. In the land-use change parameter, farmlands become permanently flooded would be converted to aquaculture land. The results show that the adaptation plan preserves more agricultural land overall.

PERFORMANCE	Farmland Area Change	Farmland Carbon Change	Aquaculture Area Change	Aquacultural Carbon Change	Agricultural Sector Land Area Change
UNIT	Hectare	Ton CO2 equivalent / year	Hectare	Ton CO2 equivalent / year	Hectare
DESCRIPTION	Actual area of farmland land use no longer farmable due to photovoltaic or flood	Carbon sequestration change from Farmland every year	Actual area of Aquacultural land-use changes due to flood. Assuming all flooded agricultural land will convert to aquacultural land	Carbon sequestration change from aquacultural sector every year	Area changes of agricultural sector land-use, including farmland and aquacultural land
Business-as-Usual **2040**	-10285.50	-1414348.95	1857.63	-14935.31	-8427.87

Business-as-Usual **2060**	-19138.90	-2631771.43	3962.11	-31855.33	-15176.79
ADAPTATION 2040	-8727.37	-1200091.74	3816.48	-30684.53	-4910.88
ADAPTATION 2060	-19454.49	-2675168.60	6169.47	-49602.54	-13285.02

Figure 4-14 Table of Agriculture and Aquaculture Sector Performance

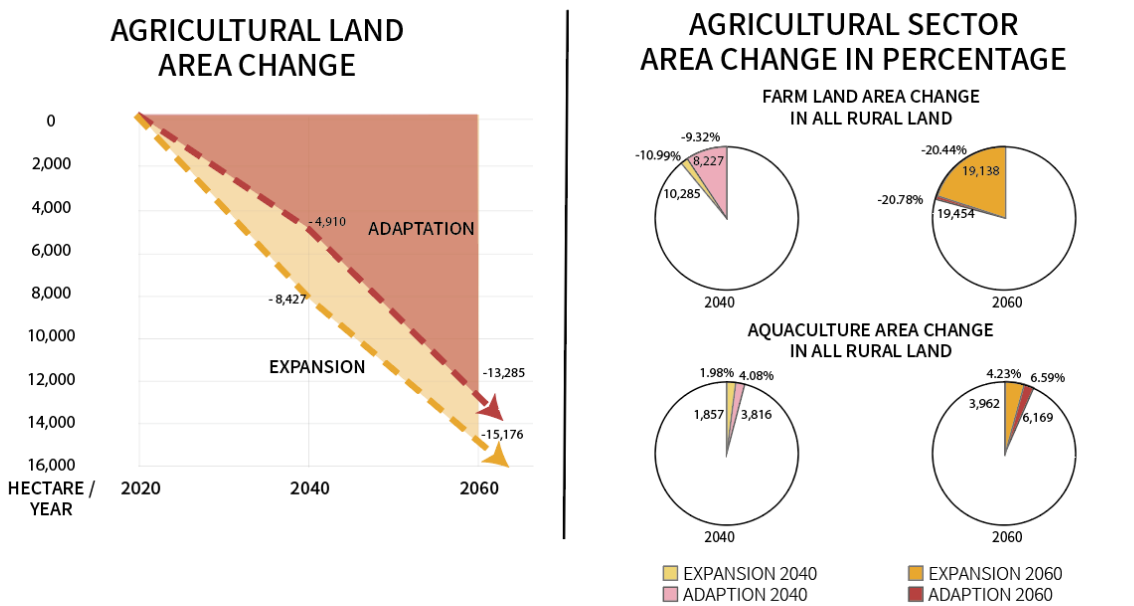


Figure 4-15 Land Area Comparison of Agriculture and Aquaculture Sector

Overall CO2 equivalent emission avoided

The overall CO2e emission avoided is the indicator to understand the performance of the scenario in saving carbon compared to the current condition. Notably, the energy carbon emission avoided and wetland carbon emission avoided can differ according to the condition that is compared. Energy carbon emission avoided can be compared to the gas powerplant or the coal powerplant, while wetland carbon emission avoided can be compared to marshes or mangrove ecosystems. Based on the current study area context, this project recommends the plan be compared with gas and marshes for discussion.

PERFORMANCE	Total Carbon emission avoided compared to gas energy when wetland managed as mangrove	Total Carbon emission avoided compared to coal energy when wetland managed as mangrove	Total Carbon emission avoided compared to gas energy when wetland managed as marshes	Total Carbon emission avoided compared to coal energy when wetland managed as marshes
UNIT	Ton CO2 equivalent / yr	Ton CO2 equivalent /year	Ton CO2 equivalent / yr	Ton CO2 equivalent /year
DESCRIPTION	ΔC-energy(gas) + ΔC-wet(mangrove)+ ΔC-aqua + ΔC-agri	ΔC-energy(coal) + ΔC-wet(mangrove) + ΔC-aqua + ΔC-agri	ΔC-energy(gas) + ΔC-wet(marshes)+ ΔC-aqua + ΔC-agri	ΔC-energy(coal) + ΔC-wet(marshes)+ ΔC-aqua + ΔC-agri
Business-as-Usual **2040**	4,796,093.28	12,428,847.03	4,424,675.93	12,057,429.68
Business-as-Usual **2060**	4,227,757.25	12,683,606.00	3,796,783.14	12,252,631.89
ADAPTATION 2040	2,486,742.41	6,971,684.51	2,486,742.41	6,971,684.51
ADAPTATION 2060	4,464,118.15	13,137,040.87	4,464,118.15	13,137,040.87

Figure 4-16 Table of Overall Carbon Performance

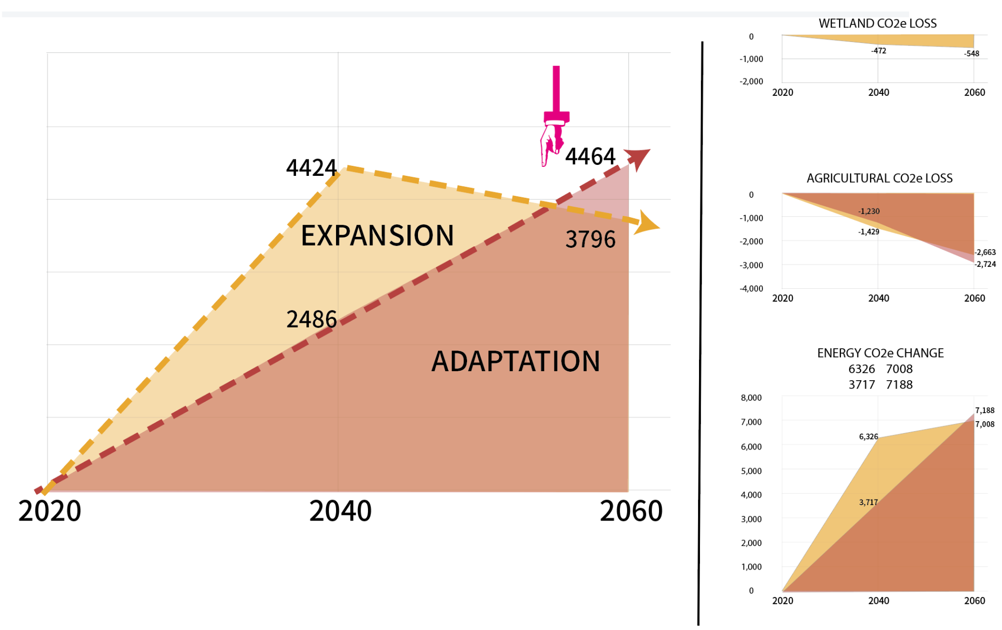


Figure 4-17 Overall Carbon Performance of Two Scenario

5 REPRESENTATION OF LAND USE CHANGE TYPES

The purpose of this chapter is to offer a visualization of land-use changes and related information. This will include identification of the types of land-use change, illustration of the dynamics of the coastal changes, and the rendering of perspective views of selected types.

5.1 IDENTIFYING TYPES

The dynamics of land-use change types will be seen in a longer temporal scale, and are not one-directional. The identified types, including original land-use and land-use with solar energy colocation, are in figure 5-1. This diagram reinforces the idea that humans in this landscape (re) industrialize and (re) naturalize the landscape in a complex manner. It is critical for designers and planners to utilize the intentional landscape changes critically and creatively to enhance the wellbeing of the people who rely on this landscape, as well as preserve its ecological health.

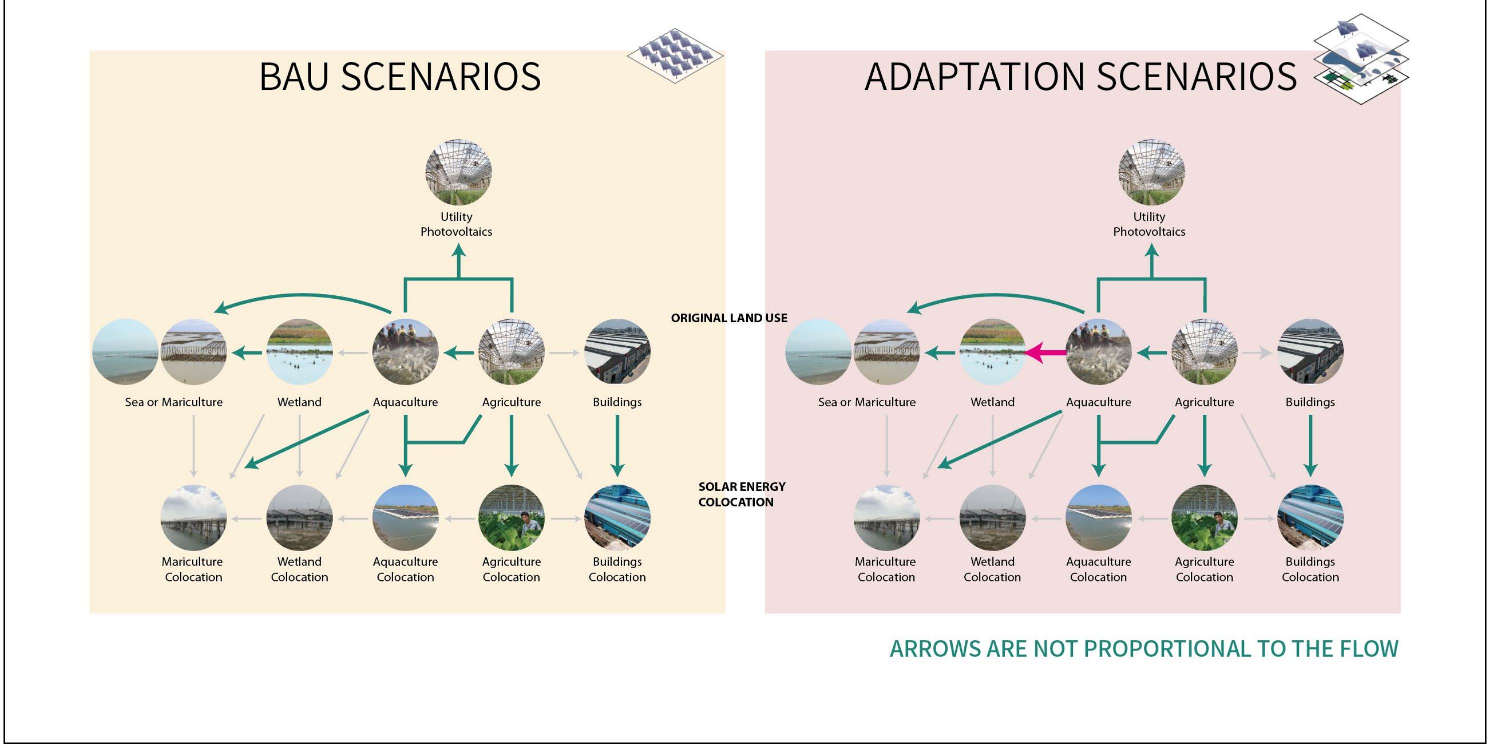


Figure 5-1Types of land-use changes in Business-as-Usual Scenario 2060

5.2 COLOCATION DYNAMICS STUDIES

Two colocation dynamics in this study are worthwhile in illustrating the section view; they are the inland retreat model, and the impact aggregation model.

Inland Retreat Model

The inland retreat model constitutes a dynamics of land uses moving inland, which includes mariculture, aquaculture, and agriculture. This model diagram attempts to ignite the following questions:

1. From Aquaculture (mostly milkfish) to mariculture (mostly oyster) colocation: in future flood conditions, mariculture, mostly occurring in the tidal zone, would retreat inland. Many colocation opportunities for the mariculture would appear. What would these fields look like with specific solar zoning overlay?
2. Agriculture (lowland paddy fields) to aquaculture (mostly milkfish) colocation: in future flood conditions, some agricultural land, mostly lowland paddy fields, would be permanently flooded. What would these fields look like with specific solar zoning overlay?
3. Non-flooded Agriculture colocation: what would these fields look like with specific solar zoning overlay?

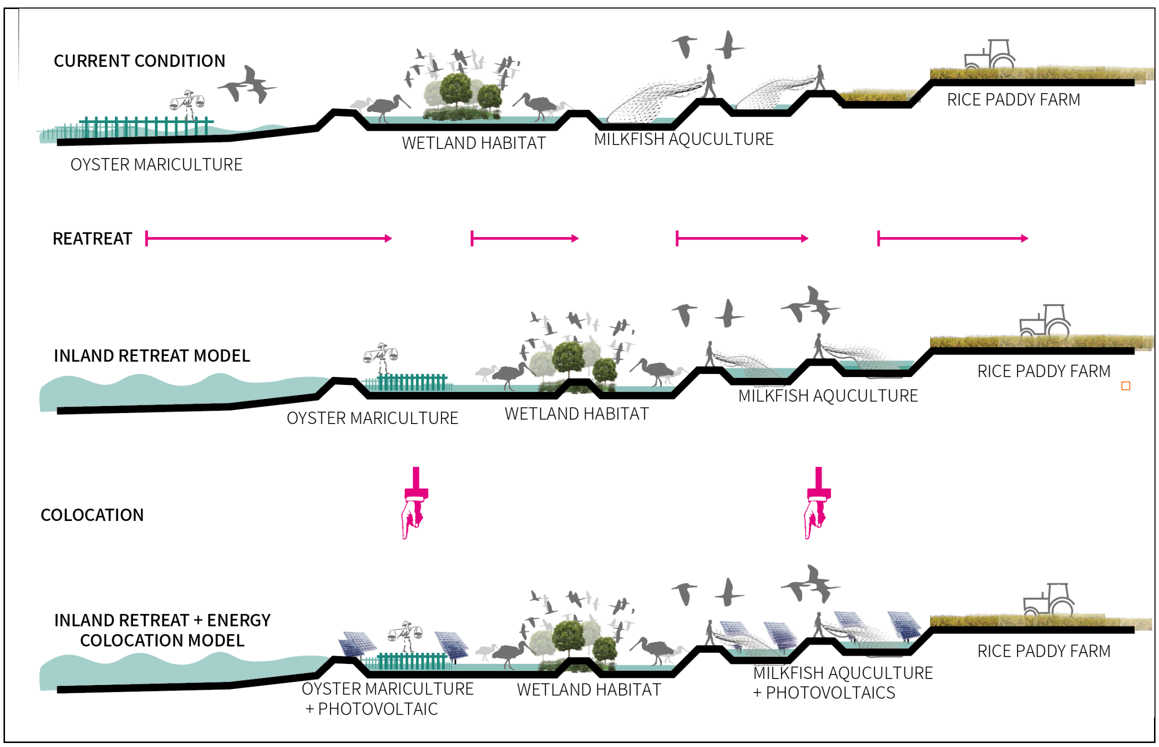


Figure 5-2 Inland Retreat Model Diagram

Impact Aggregation Model

The impact aggregation model constitutes of existing rural infrastructure, which includes highways, residential, and agriculture. This model diagram attempts to ignite the following questions:

1. Flooded coastal villages: what would flooded coastal villages look like with certain solar zoning overlay?
2. Flooded roadsides and transportation corridor: what would flooded roadsides and transportation corridor look like with certain solar zoning overlay?

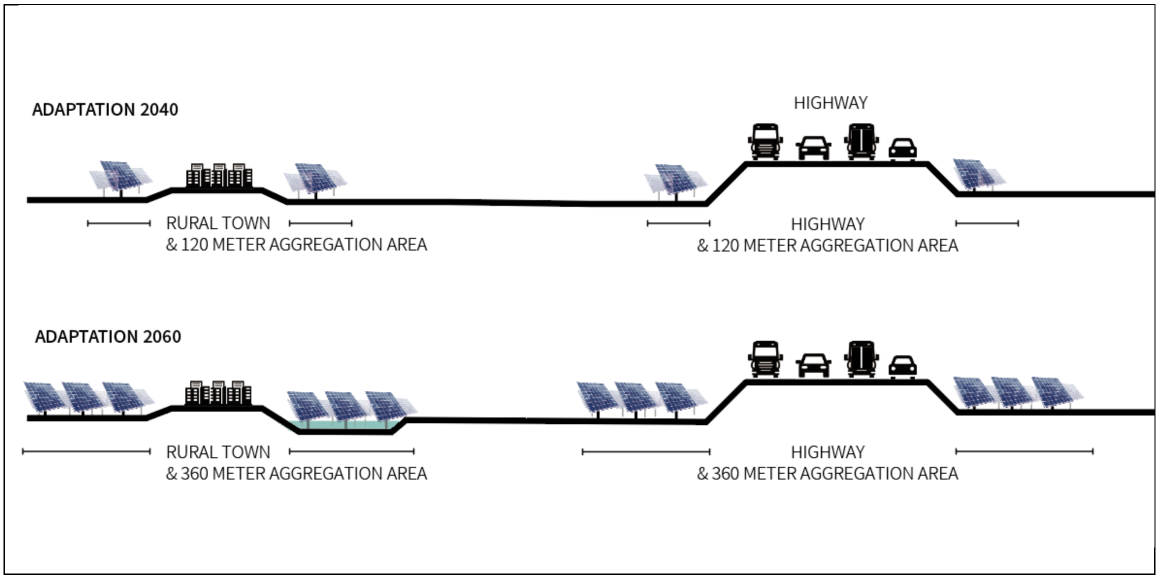


Figure 5-3 Impact Aggregated Model Section

5.3 REPRESENTATION OF LANDUSE TYPES

The representation of each type would be represented with the solar zoning overlay.

Figure 5-4 Mariculture Land Use Change

Figure 5-5 Aquaculture Land Use Change

Figure 5-6 Coastal Roadside Land Use Change

Figure 5-7 Rural Residential Land Use Change

6 CONCLUSION

Given the scope and significance, study area context, project framework, planning analysis, and site representation, this project developed the solar zoning overlay, scenario guide, land-use change parameter, and environmental performance evaluation. They offer quantification of the intensity of the development, spatialization of the potential development area, and evaluation of the performance of the plan.

6.1 RESEARCH FINDINGS

This project utilizes the alternative future method to study the intentional landscape change with solar zoning overlay to understand the land use growth and its impact in southwest coastal Taiwan in a climate-changing condition. The business-as-usual scenario utilizes a large area of coastal aquaculture land. However, it is clear that these aquacultural areas, serving as forage ground and buffer zone from disturbance, have a tremendous contribution to the black-faced spoonbills' life cycle. The adaptation scenario allows a different means of photovoltaic development by avoiding implementation in coastal areas and aggregate the development around existing infrastructure, such as highways and rural towns.

It cannot be emphasized more than the attempt to conduct alternative future studies is not to come up with a conclusion of "good plan" or "bad plan." Dialectic and conversational approaches are much suitable when dealing with a changing landscape with multiple levels of uncertainty. Therefore, a landscape approach to the conflicts of greens, using the alternative future method, offer a tool in evaluating green approaches. With trajectories extracted from the government plan and guided by experts, this project visualizes how the landscape changes of the systematic green approach and segmented green approach would look like. The two approaches have significant differences in their environmental performance: one boosts the electricity generation and carbon emission avoided rapidly, while the other allows constant growth and multifunctionality of the landscape to exist. However, if one acknowledges the approaches and thoughts, such as "system of sacrifice," "paradigm shift," "proactive adaptation," and "distributional justice," one can make judgments on the consequences of the trajectories to people.

	Business-as-Usual Scenario	**Adaptation Scenarios**
Zoning Method	**Map-based**	Expert-guided **Standard-based**
Green Approach	**Segmented Green** Approach: Maximization of photovoltaic development	**Systematic Green** Approach: Considering wetland protection and Aggregating impact
Pros	More overall carbon emission avoided	Constant growth Critical habitat preserved and compensated Better land-use efficiency
Cons	Reach capacity margin Critical habitat loss Worse land-use efficiency	Less overall carbon emission avoided

Figure 6-1 Pros and Cons of Two Scenarios

6.2 CHALLENGES

There are a few limitations to this project, which also provides the opportunity for further studies. These limitations and challenges are assumptions made in the research process, emphasis on quantity over quality, scopes, or objective left out in the process, and the democratization of the decision process.

This project relied on heavy assumptions and was limited by the uncertainty of the data projections in the research process. However, the GIS layers and map data are the best available data accessible to the project. With the limited human power and time, this project makes the best-educated assumptions at the moment in order to make further decisions in the uncertainty. The flood layer is specifically the one piece that uncertainty has a big part in. Most of the hydrological studies deal with the uncertainty of the future and changes. This is also true to the nature of the landscape system. If there were to be more resources to put into hydrological studies related to the multiplier effect of sea-level rise, land subsidence, and extreme rain events, the result of the future trajectories would be more credible for the public to understand the trend to plan with uncertainty. Future projects should work with other experts to better understand the landscape changes.

This project focuses on calculating the quantities of land area changes rather than the quality of the ecological services and functions when evaluating environmental performance. This is true and common to a lot of alternative future studies with a limited amount of research power to investigate the quality of the land. However, in Willamette River Basin Atlas, researchers spent efforts in developing models to assess habitat quality, quantity, the pattern on species' survival rates, reproductive output, and movement patterns. Notably, thirty researchers conducted the project in five years periods, which allows them to have time and resources for assessing the environmental quality of the project. As to photovoltaic production, this project calculated land areas with solar zoning overlay as a rough estimate while disregarding its visual quality and efficiency in a different area. Given the time and scale, this project is working within limited resources and reduced framework, and it would worth layering other criteria to better zone for photovoltaic development. Future projects should also utilize in-depth system modeling and identify the environmental qualities of the landscapes.

This project is also blind to a particular scope in order to meet specific goals. Goals such as minimal farmland area redline and efficiency considerations were not considered in this project. Farmland area baseline is a minimum area of 740 to 810 thousands hectare of farmable land that the Department of Interior and the Council of Agriculture should maintain in Taiwan regulated by the *Spatial Planning Act*. Taiwan only has 684 thousand hectares of farmable land (CoA, 2017) , according to the investigation in 2017. Future studies should also consider the balance between renewable energy goals, wetland conservation, and maintaining the area of aquaculture and agriculture pond. In practice, adding another parameter to set a scenario guide for farmland and evaluating the results would complicate the project, but making the project more comprehensive. Also, some considerations, such as financial cost, visual quality, and transmission efficiency, were not considered in this project.

Other alternative future studies utilize expert-input, citizen participation, or mixed approaches. Given the limited timeframe and resources, this project utilizes an expert-based approach to develop trajectories. The further studies on southwest coastal landscape photovoltaic development should utilize the result of this project to ignite communication. It is critical to acknowledge that each approach has its own strength. The worst condition we should all avoid is the expert-authoritarian in the "black box." Instead, if we are envisioning a world of ecological democracy, experts' opinions, stakeholders' input, and citizen participation in all stages of the process would be critical and fundamental.

7 APPENDICES

7.1 BIBLIOGRAPHY

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7.2 CODE AND PROCESS

Getting Study Boundary

1. Study Boundary: Create a new feature, draw polygon following the Zengwen River on the southside, coastline on the westside, Beigang River on the northside, and Taiwan Highspeed rail on the east side.

Create Current Land Use Map

1. Land-use zoning: MERGE rural land use and all urban boundaries
2. Organize land use field with FIELD CALCULATOR:

Define and Execute update function to update fields with urban boundaries	def update(ds, fx, fy): ... with arcpy.da.UpdateCursor(ds, [fx, fy]) as rows: ... for row in rows: ... if row[0] == None: ... row[0] = row[1] ... rows.updateRow(row)

	... return ds update("LUP_whole", '計畫_12', '使用分')
Reclassify and update land-use zoning as code with FIELD CALCULATOR	def update(row): if row == u'\u4e00\u822c\u8fb2\u696d\u5340': row = "genAg" elif row == u'\u570b\u5bb6\u516c\u5712\u5340': row = "NationPark" elif row == u'\u5c71\u5761\u5730\u4fdd\u80b2\u5340': row = "SteepConsrv" elif row == u'\u5de5\u696d\u5340': row = "Industrial" elif row == u'\u5e02\u93ae\u8a08\u756b': row = "UrbanPlan" elif row == u'\u68ee\u6797\u5340': row = "Forest" elif row == u'\u6cb3\u5ddd\u5340': row = "River" elif row == u'\u7279\u5b9a\u5340\u8a08\u756b': row = "Dsgntd" elif row == u'\u7279\u5b9a\u5c08\u7528\u5340': row = "rrlDsgntd" elif row == u'\u7279\u5b9a\u8fb2\u696d\u5340': row = "DsgntdAg" elif row == u'\u9109\u6751\u5340': row = "rrlResidn" elif row == u'\u9109\u8857\u8a08\u756b': row = "rrlTown" elif row == u'\u98a8\u666f\u5340':

	row = "Scenery" else: row = "error" return row
Organizing Land use zoning map with	CLIP [LUP_whole] by StudyBound, named as [LUP_2cnty]

Update Land Use Map with Ecological Information

Union habitat layers into one map	UNION layers including national parks, the protected wetlands of importance, and the expert identified wetlands without legal status
Update field for further processing	Using FIELD CALCULATOR to update the classification of protection status.
Combined Land use layer with habitat information.	UNION habitat layers with Land use zoning layers

Generating Flood Layers

1. Using 5m x 5m resolution DTM of Chiayi and Tainan County as the current DTM
2. Preparing for the DTM layer in 2040 and 2060 with the impact of sea-level rise. Based on the estimation of the Source, sea-level rise for this research is set as 40 cm and 80 cm accordingly.

Using the MINUS function to create update DTM	MINUS 40 cm for 2040 DTM MINUS 80 cm for 2060 DTM

3. Using the rain event data of 150mm/6hr representing the frequent flood and 650mm/24hr representing the extreme flood.

Updating frequent rain event data	Using FIELD CALCULATOR to update rain event data for further process
Combining extreme and Rain event	UNION rain event data of 150mm/6hr with data of 650/24hr
Updating field	Using FIELD CALCULATOR to update fields representing area being "frequently flooded" or "rarely flooded"

4. Using land subsidence data to map out the area with high land subsidence risk and their level of subsidence in 2040 and 2060.

Drawing land subsidence area polygon	Using EDIT and DRAW tool to create polygons from original data
simplify the layer	Using UNION to eliminate the duplicated areas.
Updating level of subsidence	Using the EDIT tool to edit fields manually to update the annual average level of subsidence
Getting 20 years and 40 years land subsidence	Using FIELD CALCULATOR to update the level of future land subsidence for 20 years and 40 years.
Turning the layer into raster.	Using POLYGON TO RASTER to extract the shape of the raster.
Update the level of land subsidence	Using RASTER TO FLOAT to update the level of future land subsidence for 20 years and 40 years.

5. Overlaying the three layers and organize it for further usage.

Get the preliminary 2040 flood layer	Using the PLUS tool to add 2040DTM and 20 years land subsidence.

Get the preliminary 2060 flood layer	Using the PLUS tool to add 2060DTM and 40 years land subsidence.
Using the SET NULL function to get permanently flooded area	Selecting area under sea-level which is 0 with SET NULL function to get the area under sea level in the 2040 DTM and 2060 DTM
Extract flooded area	Using FLOAT TO RASTER to reclassify the permanently flooded area and using RASTER TO POLYGON to turn it into polygons
Get flood layer	Using UNION to overlay flooded areas. Update with the classification of permanently flooded, frequently flooded, rarely flooded, and no flood risk.
Reclassify to Boolean with major flood risk.	Update reclassification with FIELD CALCULATOR as 1(Yes) or 0(No) to major flood risk. **Code** update flood: def updare(row): if row == 0: return 0 else: return 1

Developing Business-as-Usual Scenario

Preparing Conservation scenario.	UNION flood layer, and land use layer.
Preparing for the	Using FIELD CALCULATOR to generate solar zoning overlay and land-use change scenario. **Solar Zoning Overlay Field**

```
def update( LU, Fld ):
  if LU == "Dsg":
   return "S5"
  elif LU == "Res" and Fld == 0:
   return "S3"
  elif LU == "Res" and Fld == 1:
   return "S4"
  elif LU == "genAg" and Fld == 0:
   return "S0"
  elif LU == "genAg" and Fld == 1:
   return "S2"
  elif LU == "PrimeAg" and Fld == 0:
   return "S0"
  elif LU == "PrimeAg" and Fld == 1:
   return "S2"
  elif LU == "ECO" and Fld == 1:
   return "S0"
  elif LU == "ECO" and Fld == 0:
   return "S0"
  else:
    return "None"
```

Land Use Change Field

```
def update( LU, Fld ):
  if LU == "Dsg" and Fld == 1:
   return "F_Dsg"
  elif LU == "Dsg" and Fld == 0:
```

	return "Dsg" elif LU == "Res" and Fld == 0: return "Res" elif LU == "Res" and Fld == 1: return "F_Res" elif LU == "genAg" and Fld == 0: return "genAg" elif LU == "F_genAg" and Fld == 1: return "lostGenAg" elif LU == "PrimeAg" and Fld == 0: return "PrimeAg" elif LU == "PrimeAg" and Fld == 1: return "F_PrimeAg" elif LU == "ECO" and Fld == 1: return "F_ECO" elif LU == "ECO" and Fld == 0: return "Eco" else: return "None"

Developing Conservation - Impact Aggregated Scenario

Preparing Conservation scenario.	UNION Standard layer, flood layer, and land use layer.
Assign standard to layers	Update land use layer with FIELD CALCULATOR **SOLAR ZONING OVERLAY**

	`` def update(F, LU, S): if LU == "ECOallexp" and F == 0 and S == "Con2040": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "Con2040": return "F_Wetland " elif LU == "ECOallexp" and F == 0 and S == "restric": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "restric": return "F_Wetland" elif LU == "ECOallexp" and F == 0 and S == "other": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "other": return "F_Wetland" elif LU == "GenAg" and F == 0 and S == "Con2040": return "GenAg" elif LU == "GenAg" and F == 1 and S == "Con2040": return "F_GenAg" elif LU == "GenAg" and F == 0 and S == "restric": return "GenAg" elif LU == "GenAg" and F == 1 and S == "restric": return "F_GenAg" elif LU == "GenAg" and F == 0 and S == "other": return "GenAg" elif LU == "GenAg" and F == 1 and S == "other": return "F_GenAg" elif LU == "PrimeAg" and F == 0 and S == "Con2040": return "PrimeAg" ```

	<pre>elif LU == "PrimeAg" and F == 1 and S == "Con2040": return "F_PrimeAg" elif LU == "PrimeAg" and F == 0 and S == "restric": return "PrimeAg" elif LU == "PrimeAg" and F == 1 and S == "restric": return "F_PrimeAg" elif LU == "PrimeAg" and F == 0 and S == "other": return "PrimeAg" elif LU == "PrimeAg" and F == 1 and S == "other": return "F_PrimeAg" elif LU == "Res" and F == 0 and S == "Con2040": return "Res" elif LU == "Res" and F == 1 and S == "Con2040": return "F_Res" elif LU == "Res" and F == 0 and S == "restric": return "Res" elif LU == "Res" and F == 1 and S == "restric": return "F_Res" elif LU == "Res" and F == 0 and S == "other": return "Res" elif LU == "Res" and F == 1 and S == "other": return "F_Res" else: return "None"</pre> **LAND USE CHANGE SCENARIO 2040**

```
def update(F, LU, S):
  if LU == "ECOallexp" and F == 0 and S == "Con2040":
    return "S0"
  elif LU == "ECOallexp" and F == 1 and S == "Con2040":
    return "S0"
  elif LU == "ECOallexp" and F == 0 and S == "restric":
    return "S0"
  elif LU == "ECOallexp" and F == 1 and S == "restric":
    return "S0"
  elif LU == "ECOallexp" and F == 0 and S == "other":
    return "S0"
  elif LU == "ECOallexp" and F == 1 and S == "other":
    return "S0"
  elif LU == "GenAg" and F == 0 and S == "Con2040":
    return "S2"
  elif LU == "GenAg" and F == 1 and S == "Con2040":
    return "S5"
  elif LU == "GenAg" and F == 0 and S == "restric":
    return "S0"
  elif LU == "GenAg" and F == 1 and S == "restric":
    return "S0"
  elif LU == "GenAg" and F == 0 and S == "other":
    return "S0"
  elif LU == "GenAg" and F == 1 and S == "other":
    return "S2"
  elif LU == "PrimeAg" and F == 0 and S == "Con2040":
    return "S2"
```

	elif LU == "PrimeAg" and F == 1 and S == "Con2040": return "S5" elif LU == "PrimeAg" and F == 0 and S == "restric": return "S0" elif LU == "PrimeAg" and F == 1 and S == "restric": return "S0" elif LU == "PrimeAg" and F == 0 and S == "other": return "S0" elif LU == "PrimeAg" and F == 1 and S == "other": return "S2" elif LU == "Res" and F == 0 and S == "Con2040": return "S4" elif LU == "Res" and F == 1 and S == "Con2040": return "S5" elif LU == "Res" and F == 0 and S == "restric": return "S0" elif LU == "Res" and F == 1 and S == "restric": return "S0" elif LU == "Res" and F == 0 and S == "other": return "S3" elif LU == "Res" and F == 1 and S == "other": return "S4" else: return "None" **LAND USE CHANGE SCENARIO 2060**

	def update(LU, S, F): if LU == "ECOallexp" and F == 0 and S == "Con2060": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "Con2060": return "F_Wetland " elif LU == "ECOallexp" and F == 0 and S == "restric": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "restric": return "F_Wetland" elif LU == "ECOallexp" and F == 0 and S == "other": return "Wetland" elif LU == "ECOallexp" and F == 1 and S == "other": return "F_Wetland" elif LU == "GenAg" and F == 0 and S == "Con2060": return "GenAg" elif LU == "GenAg" and F == 1 and S == "Con2060": return "F_GenAg" elif LU == "GenAg" and F == 0 and S == "restric": return "GenAg" elif LU == "GenAg" and F == 1 and S == "restric": return "F_GenAg" elif LU == "GenAg" and F == 0 and S == "other": return "GenAg" elif LU == "GenAg" and F == 1 and S == "other": return "F_GenAg" elif LU == "PrimeAg" and F == 0 and S == "Con2060": return "PrimeAg"

	`` elif LU == "PrimeAg" and F == 1 and S == "Con2060": return "F_PrimeAg" elif LU == "PrimeAg" and F == 0 and S == "restric": return "PrimeAg" elif LU == "PrimeAg" and F == 1 and S == "restric": return "F_PrimeAg" elif LU == "PrimeAg" and F == 0 and S == "other": return "PrimeAg" elif LU == "PrimeAg" and F == 1 and S == "other": return "F_PrimeAg" elif LU == "Res" and F == 0 and S == "Con2060": return "Res" elif LU == "Res" and F == 1 and S == "Con2060": return "F_Res" elif LU == "Res" and F == 0 and S == "restric": return "Res" elif LU == "Res" and F == 1 and S == "restric": return "F_Res" elif LU == "Res" and F == 0 and S == "other": return "Res" elif LU == "Res" and F == 1 and S == "other": return "F_Res" else: return "None" ```

Solar Zoning

<table>
<tr><td>Calculation for developmental rights</td><td>CODE
def update(SZO):
  if SZO == "S0":
    return 0
  elif SZO == "S1":
    return 0.2
  elif SZO == "S2":
    return 0.4
  elif SZO == "S3":
    return 0.6
  elif SZO == "S4":
    return 0.8
  elif SZO == "S5":
    return 1
  else:
    return 0</td></tr>
<tr><td>Calculation for actual photovoltaic coverage</td><td>def update(SZO):
  if SZO == "S0":
    return 0
  elif SZO == "S1":
    return 0.14
  elif SZO == "S2":
    return 0.28
  elif SZO == "S3":
    return 0.42
  elif SZO == "S4":
    return 0.56</td></tr>
</table>

	elif SZO == "S5": return 0.7 else: return 0