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Doctorate Dissertation

An integrated renewable energy and carbon market modeling for climate market mechanism analysis: challenges and opportunities

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論文口試委員審定書

環境科學與工程學系博士班莊昇勳君所提之論文

題目：能源與減碳整合氣候市場機制分析：挑戰與機會

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中華民國107年6月29日

東海大學博士班研究生

論文指導教授推薦書

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係由本人指導撰述，同意提付審查。

指導教授：__________（簽章）

107 年 6 月 29 日

致謝

叩謝我的父母

感謝我的太太

致謝

2007 年在美國工作不順利決定回台時，一度徬徨不知何去何從而想去賣車。後來，經過研究所同學的介紹，進入了碳交易市場，在只有三個人的北京辦公室擔任東亞區總監，開始直航前日夜顛倒四處奔波的日子，而父母親與妻子一直給我無條件的支持。在往後十一年天天靠簽合約做交易過日子才明白，“無條件”的條件只有兩種人會給：傻子跟家人。在七年多前自立門戶後，母親永遠都知道我何時阮囊羞澀，在公司快要週轉不靈發不出薪水時毫不吝嗇的給于協助。爸爸總是在每週四晚上泡好茶等我回去跟他閒聊，離開前在門口一邊抽煙一邊淡淡的給兩句“辛苦了，加油！”

爸爸媽媽，感謝栽培。

這十幾年來我自己的家庭成員從兩個變七個，我的妻子對於我頻繁密集的出差，常常為了國際電話會議以及回覆國外郵件作息日夜顛倒無法兼顧家庭的生活型態從無怨言，總是早上讓我補眠睡到自然醒才去上班，一個人眉頭不皺一下默默的接送小孩上放學一天七八趟，甚至還悄悄的幫我報名健身房，鼓勵我養成運動的習慣，讓我從四十歲開始花了五年的時間，終於學會游自由式了。

太太，謝謝你。

這十一年來，我從被當成台灣第一個碳交易騙子，到第一個把碳權賣到國外，第一個完成碳中和，第一個賣到對岸，第一個在大學教授碳資產管理，從發想到成立與推動 I-REC Standard，全球第一個核發國際再生能源憑證，第一個賣出憑證。。。。。許多的第一個。這本論文總結了過去十一年的氣候變遷生涯的學習。這本論文也總結了許多人一路的支持。為此，要感謝的人還有很多。沒有你們，前面這些第一（包括被當成台灣第一個碳交易騙子）都不會發生。從最初鼓勵我攻讀學位的萬師，一路指導與打氣的鄧老師，亦師亦友同時在最後關頭給了許多寶貴意見的連老師。辦公室裡

不厭其煩又仔細的幫我校稿及調整格式的佳蓉，把我的學位當成自己的一樣緊張又謹慎看待的佩瑄和以婕，以及已有更好發展的老友興中、Mitsuko、珮華和宛蓉過去的協助，沒有你們我只得望洋興嘆了。

最後，再一次謝謝我的傻子家人：爸爸、媽媽，還有辛勞的太太與乖巧的孩子們。

『感謝上帝，爸爸終於畢業可以跟我玩 UNO，不用再寫論文了。』小女兒鬆了一口氣說。

莊昇勳 謹誌於

東海大學環境科學與工程學系

中華民國一零七年八月

Abstract

The ultimate goal of this study is to put forward a policy analytical tool for climate (carbon and green power) market review and design. Chapter 1 elaborates with international roadmap and progress so far to expend common objectives and the foundation for future global discussions. The drawbacks observed in various adopted approaches have been highlighted in this chapter in-order to advance the use of renewable energy and to cut down Green House Gas (GHG) emissions. Chapter 2 proposed an integrated model of market mechanisms consist of potential policy tools for renewable energy development i.e. Consolidated Climate Market Mechanism Analysis (CCLIMMA) which could potentially and simultaneously lead to GHG emission reduction management. A comprehensive literature review has been summarized in chapter 3 to identify and compare the current research. This extensive study provides detailed investigations of existing policy for renewable energy development and also reveal the deficiencies often seen internationally. Chapter 4 introduces the existing situations and difficulties for Taiwan based on internationally consolidated localized market design. Two innovative cases studies were carried out to propose unprecedented applications of market instruments in chapter 5. The study is concluded with CCLIMMA model building and analytical application in three selected markets (in chapter 6. Chapter 7 is concerning the future prospect of such policy designs.

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Chapter 1. Introduction

1.1 Climate Change

Climate change is now the buzzwords of the Green movement. The realistic threat of global warming in the last few decades has spearheaded a global effort to accelerate the attempt to reduce the emission of greenhouse gases (GHGs) into the atmosphere. The escalating demand of energy, most of which is still generated by coal combustion as of today, only exacerbates the situation of CO_2 emission during power generation. Very few carbon capturing and sequestration or utilization technologies are matured enough to reduce the CO_2 emission at an economically competitive scale. Electricity production from renewable energy sources, primarily wind and solar power, is weather-dependent and typically entails high capital investment, thereby keeping them from being competitive in the energy marketplace. Figure 1 shows the annual global average temperature rising yearly.

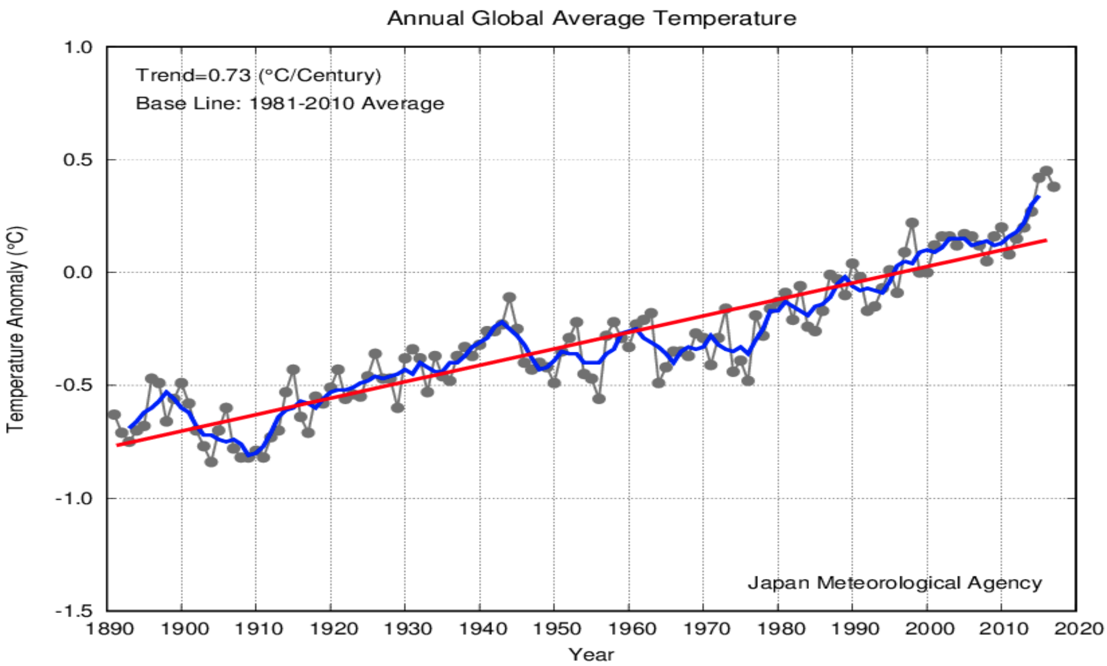


Figure 1. Annual global average temperature (Japan Meteorological Agency, 2018)

The volume is addressed to the delineation of the ways and means of using technology, economics and policy to provide clean, reliable, secure and competitive energy supply. Each country has to figure out its own energy portfolio, consistent with its endowment of energy resources, and employing technologies, which are economically viable and socially equitable, and have minimal adverse impacts.

Climate-Change Index provides a snapshot of global climate change. It highlights the general trend with which the temperature increases globally. According to this index by the Climate Change Performance index 2018, Taiwan (Chinese Taipei stands 54nd place globally, shown in Figure 2).

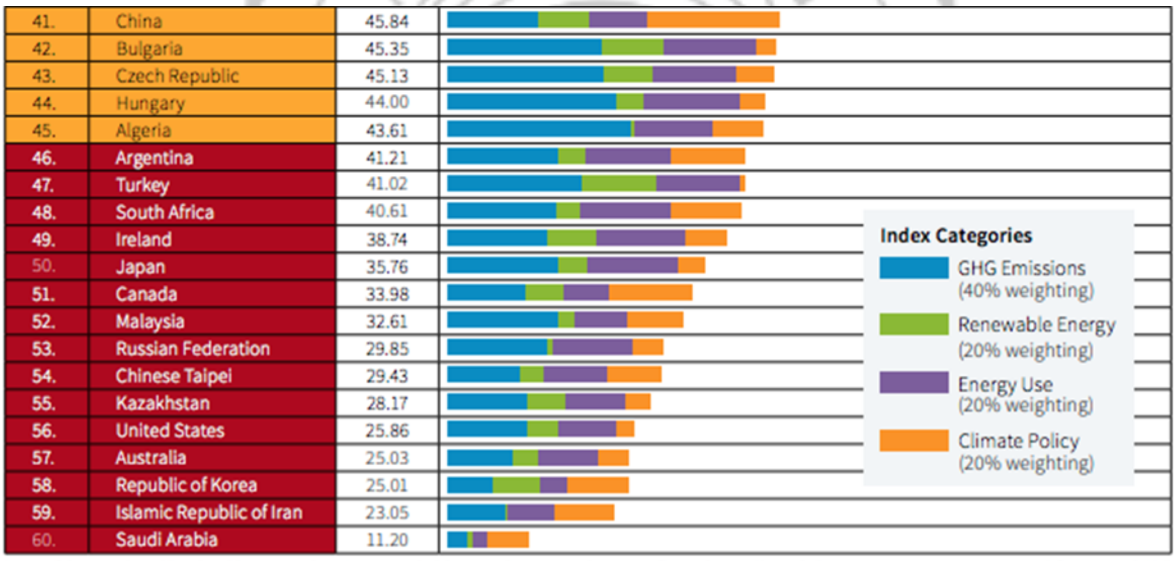


Figure 2. The climate change performance index results 2018 (The Climate Change Performance Index of Germanwatch, 2018)

The unacceptable degradation of the environment could only be mitigated by the decoupling of economic growth from energy demand and reduction in the use of fossil fuels. Due to the demand of large scale energy systems, it is necessary to establish a reliable and efficient electricity supply system, as a first step. The relatively smaller number of power stations in each country makes it easy to legislate for particular environmental measures. The future electricity supply system which evolves minimum environmental impacts, both in construction and operation must be affordable to all users. The virtues of a clean fuel has been the great resurgence of interest in biogas capture i.e., methane capture to reduce the rapidly growing danger of global warming.

1.2 Historical review of emerging challenges on human sustainability

The ozone layer depletion and global warming are two global environmental issues that pose a threat to humanity from the last decade, e.g. In 1995, Roland, Moreno and Cruzan were awarded the Nobel Prize in Chemistry following their discovery of the harmful effects of the fluorocarbons on the ozone layer. This, not only led to the formulation of 'Montreal Protocol' in 1987, but also confirmed its (Montreal Protocol) success in effectively controlling fluorocarbons, and thus mitigating the problem of ozone layer depletion. In 1988, the United Nations Environment Program (UNEP) in conjunction with the World Meteorological Organization (WMO) founded the Intergovernmental Panel on Climate Change (IPCC) to slow down the effects of global warming. In 2007, IPCC and Al Gore, the former Vice President of the United States, were jointly awarded the Nobel Peace Prize in recognition of their efforts to build up and disseminate knowledge about climate change and global warming and to lay the foundations for the measures needed to diminish such change.

In 1992, the United Nations Commission on Environment and Development (UNCED) held the Earth Summit in Rio De Janeiro, Brazil, and passed the United Nations Framework Convention on Climate (UNFCCC), which sets global regulatory objectives in relation to greenhouse gas (GHG) emissions generated from human activities. Since then, an annual conference has been held each year to discuss issues regarding the global approach concerning climate change and global warming. In 1997, the third conference of UNFCCC (COP 3) was held in Kyoto, Japan. The 'Kyoto Protocol' was adopted to commit state parties to reduce GHG emissions. The protocol was subsequently entered into force in 2005.

When comparing the fluorocarbons objectives of the former Montreal Protocol and the Kyoto Protocol, the latter can be deemed to be more comprehensive in terms of its impact and influence on the GHG emissions. This is because the six main categories of gases classified as GHG emissions are not only limited to a specific single industry or a product. They also take into account the output of all by-products on many other different levels, including political, economic, social, etc. As a result, it has garnered more widespread attention internationally.

In light of global warming issues, international government organizations have initiated dialogue to advocate for strategic carbon reduction measures, by means of carbon credits and renewable energy certificates (RECs). However, as Taiwan is not a member of the UN, it has still yet to engage in the development and transactions of carbon credits of the Kyoto Protocol. As such, it also lacks an ideal platform for facilitating carbon market trading. On the other hand, however, after the expiration of the first crediting period including an extension to 2015 of the Kyoto Protocol, current trading in the carbon market is not as active as it used to be since the beginning of 2008. Moreover, support for RECs has become a popular alternative to realizing carbon reductions. In other words, the most significant difference for Taiwan with regards to carbon credits and RECs, in this case, is that "Locale" attributes of RECs specific to the region are no longer under the UN regulations.

1.3 Challenges to Taiwan's sustainable developments related to energy

1.3.1 GHG emission reductions

The GHG Reduction and Management Act (GGRMA) was enacted on 1st July, 2015. It also marks a new milestone for Taiwan's global GHG reduction and management initiatives. The GGRMA transpires in allowing Taiwan to achieve its long-term GHG reduction objectives for the first time. In retrospect, the amount of GHG emissions in 2050 should then be reduced, to levels lesser than 50% of the GHG emission figures of 2005.

In 2015, Taiwan's CO_2 fuel combustion figures obtained from relevant departments, showed total emissions amounted to 250.50 million metric tons. Industrial sector emissions, excluding indirect emissions for power consumption, only amount to 39.93 million metric tons (16% of the overall total). The figure adds up to 119.84 million metric tons (47.5% of the total), when power consumption emissions are included, whilst the difference of 79.91 million metric tons (32% of the total) involves indirect emissions classified under Scope 2.

The GHG emissions from high-tech manufacturing industries are primarily from power consumption. Subsequently, Scope 1 emissions merely amount to 370,000 tons, however, while Scope 2 emissions are as high as 26.96 million metric tons. Evidently, in order to achieve the long-term goal of realizing reductions for Taiwan, it is necessary to simultaneously implement CO_2 emission controls, for both Scope 1 and Scope 2. Particularly, more attention needs to be addressed towards crucial IT manufacturing industries in Taiwan, which are excessively dependent on power consumption. Therefore, GHG emissions, can be defined within the GGRMA, as a unit or process that directly or indirectly emits GHGs into the atmosphere, which is also included in both Scope 1 and Scope 2 emissions.

1.3.2 Renewable energy developments

Taiwan's Bureau of Energy (BOE), under the authority of the Ministry of Economic Affairs (MOEA), reported that 75% of total installed capacity of power generation originated from thermal power in 2016 (i.e., coal-fired ~34.7%, gas-fired ~32.3%, oil-fired ~8.1%) and that 82% of total electricity was thermally generated. Additionally, Taiwan's industrial sector was responsible for 47.8% (equivalent to 119.8 Mt CO2e) of total CO2 emissions in 2016. Of these carbon emission sources, 66.7% was attributed to emissions from purchased electricity (79.9 Mt CO2e). The data implies that intensive electricity industrial consumers (primary energy) such as the semiconductor and flat panel fabrication plants),e, s are the major GHG emitters in the Scope 2 category of GHG inventory. In addition, to this power consumption nature, Taiwan also faces several critical challenges with its energy capacity and portfolio, including the growing energy demand, decreasing reserve margin, and an excess dependence on fossil fuel energy. Therefore, increasing installed capacity and transitioning from coal-based to renewable-based energy portfolio have become the primary goals of reforming the energy structure. Taiwan has also committed to phase out all nuclear power plants by 2025, and to achieve a GHG reduction goal of 50% lesser than the emission level in 2005 (baseline year), by 2050. The energy portfolio to be attained by 2025 includes increasing the portion of renewable capacity to at least 20%, reducing the portion of coal-fired capacity to less than 30%, and increasing gas-fired capacity to less than 50%. It is expected that solar energy capacity will be increased from 1.3 GW to 20 GW by 2025 and the wind energy will increase from 0.69 GW to 4.2 GW in 2025. The expected electricity generation by these renewables by 2025 is about 50 TWh. To stimulate renewable energy production, Taiwan has intensified its effort to reform energy structure via both policy amendments and market framework adjustments. For example, new legislative instruments such as the GGRMA, effective since 2015, and amendment of Electricity Act in 2017, have provided the necessary legal framework to enable the transformation of the energy market. The change implies from a monopolized, vertically-integrated supplier model to a market-driven model, which separates the functions of power generation, transmission and distribution, and retailing.

To facilitate the increase of renewable energy sources in the energy mix, Taiwan government implemented its own version of a Feed-in Tariff (FiT) scheme in 2009, followed by the policy-driven programs, such as the Voluntary Green Power Pilot Program (VGPPP) in 2014. Furthermore, in 2017, Taiwan REC (T-REC) system adopted the similar tracking system as the International REC Standard (I-REC). The primary goal is to accelerate the transformation to a renewable-based energy portfolio by providing financial incentives for energy generators, and to reduce CO_2 emissions from the industrial sector purchasing electricity (i.e., Scope 2 emissions). During its implementation between 2014 and 2017, the available total quantity of green power under the VGPPP increased from 4.3 to 100 GWh, whereas the direct purchased quantity only increased from 4.2 to 270 GWh. The lack of interest to purchase green energy is the ambiguity of the policy framework, the definition and use of such green electricity products. For instance, under the existing policy framework, electricity purchased or acquired under GPPP by corporates cannot be adopted in their GHG inventories (Scope 2 emissions) reported to Taiwan’s Environmental Protection Administration (TEPA) and the governing authority of the country for GHG management and reduction policies.

The BOE annually publishes its Emission Factor (EF) of purchased electricity on the basis of the grid's power portfolio. The TEPA, however, does not allow offsetting of corporate GHG emission reporting by acquiring VGPPP, thereby undermining the financial benefit of the VGPPP framework. Figure 3 shows Scope 2 CO_2 emission from different sectors. The T-REC scheme, administered by the Bureau of Standards, Metrology & Inspection (BSMI), under the MOEA, which replaced GPPP starting from 2018, is still in the early stage of development involving governmental agencies (BSMI, BOE, and TEPA) in the aspects of supply, trade, and application.

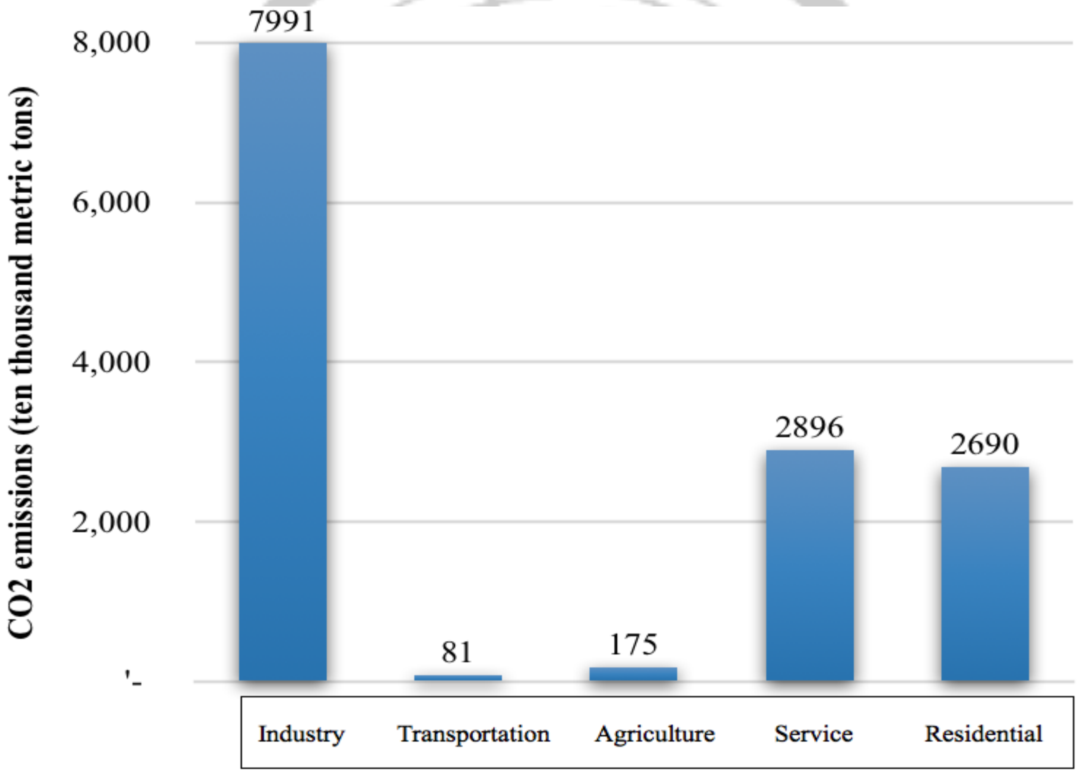


Figure 3. Scope 2 CO_2 emission from different sectors

Among these recently-adopted policies, power market reformation through the amendment in the Electricity Act, allowed green power trading as the greatest impact. The first iteration of the amendment was submitted to the Legislative Yuan in 1995. Since then, it has been reviewed by the legislature and amended many times. It was finally approved by the

Legislative Yuan on the evening of January 11th, 2017. However, the amendment passed is not a one-time comprehensive reform. Instead, it began the first phase of renewable energy (commonly known as "Green Power") "Electricity Generating Enterprise and Electricity Retailing Enterprises," entering the electricity market. It also gave priority grid access to green power sources. Taiwan's state-controlled power company, Taiwan Power Company (Taipower) will then unbundle its operation sectors, maintaining transmission and distribution, and providing access to electricity generating companies and electricity retailers.

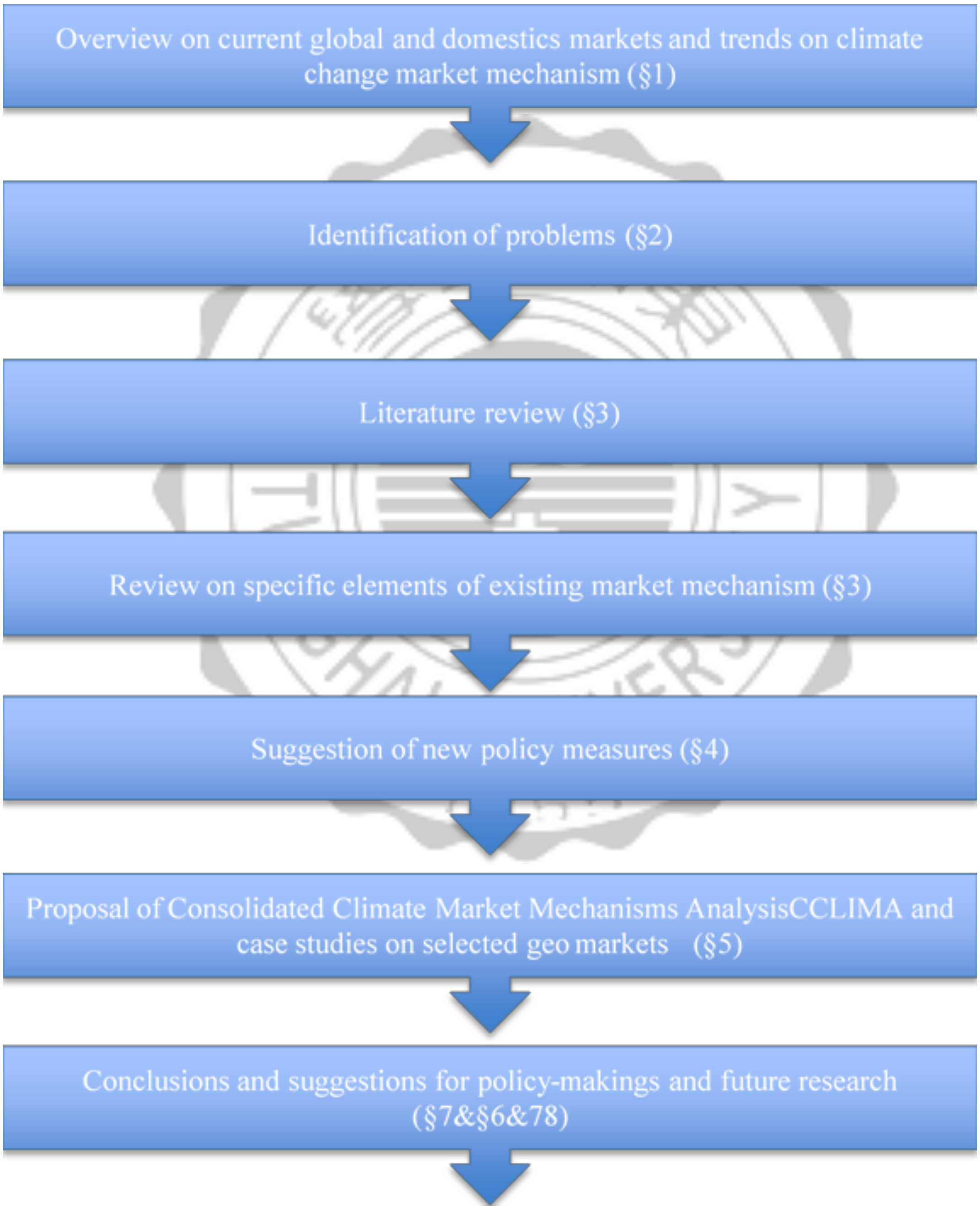
On the other hand, resource allocation efficiency is quite low in a monopoly where there is only one retailer, and there is no price competition. Under these circumstances, it is certain that resources will be misplaced and the price will be too low or too high, resulting in a waste of social resources. In the past, renewable energy options were scarce and expensive, domestic and industrial understanding of renewable energy was limited, and the high construction costs to the electricity industry rendered them unprofitable. This situation, plus the increasing discussions related to the development of renewable energy in the international arena, prompted the *Renewable Energy Development Act* ("REDA") in July of 2009, and increased the government's attention to renewable energy as well as domestic demands for renewable energy. In the amendment of the Electricity Act, the government also made it clear that all nuclear power plants will be decommissioned by 2025, to achieve the vision of a "Nuclear-free Homeland". Through these actions, the government has demonstrated that it is fully committed to the development of renewable energy. At a time, when both the government and the private sector are actively involved, the history of Taiwan's electricity industry would be at a turning point.

In order to realize its goals, the government has actively promoted the use of renewable energy by amending the REDA, aiming to improve environmental quality through the effective use of renewable energy and achieve the goal of a 20% Renewable Portfolio Standard (RPS), by 2025. The government, so far has started the FiT system in 2009, and launched the PGPPPmVGPPP in 2014, as well as the T-REC system in 2017. The challenges of renewable energy certification systems that occur in each country are slightly different. US reported study indicates that Solar Renewable Energy Certificates (REC) has become an important driver for promoting solar photovoltaic (PV) system. Yet, Solar REC price volatility has created a major barrier to popularizing the installation of solar PV system. In Japan, a combination of RPS and FiT schemes has been put into practice from last decade. The output of electricity from renewable energy sources (RES-E) is primarily correlated with the magnitude of the RPS requirement and the fixed tariff. Also, the RPS requirement has a direct impact on the REC price. Non-renewable electricity faces a cost increase to maintain network reliability, because grid-connected RES-E accelerated rapidly under FiT. Government policies, REC systems, and construction and installation costs can all affect the implementation of an REC scheme.

On a regional and national scale, to accelerate the displacement of fossil fuels with renewable energy sources, numerous market-supporting schemes have been devised and implemented in many developed countries. Among these schemes, FiT has been the most commonly practiced market-interfering policy, which requires electricity suppliers to purchase the electricity generated by renewable energy sources at a government-regulated tariff. Often, FiT policy works in conjunction with an emission-cap or a quota obligation scheme whereby a certain fraction of the electricity sold by suppliers has to be generated from renewable energy sources. To quantify and to track renewable energy transactions, many countries have also issued tradable “green certificates”, which also serve the purpose of verifying the compliance of quota obligations by non-renewable energy suppliers. Such systems have been implemented and enforced in most European countries under the European Union’s (EU) supervision, and has now been adapted in some of the states in the United States and also been pioneered in East Asian countries (e.g., Japan, South Korea, China, and Taiwan). It is worth noting, that the ultimate goal of such market-based systems is to stimulate the growth of renewable energy and hence, also reduce CO_2 emissions from fossil fuels via a pathway that can generate a new “carbon” market, drive Carbon Capture and Storage (CCS) technology innovation. As it is designed, many researchers have discussed the pros and cons of the system from economic and financial perspectives to reflect the level of its success as an instrument to reduce carbon emissions.

1.4 Structure of this research

The diagram below shows the structure of this research. Further elaborations will be presented in following chapters.



Chapter 2 Motivations, problems and goals

2.1 Motivations

2.1.1. Impacts and implications learnt from the collapse of international carbon markets

The Kyoto Protocol (KP) mandates three market mechanisms for carbon trading, which are, emissions trading (ET), joint implementation (JI), and a clean development mechanism (CDM). The first two mechanisms were designed to enhance the cooperation between the KP's Annex I (developed) countries, and the third, often referred to with the acronym "CDM" was a cooperation scheme between Annex I and non-Annex I countries.

At the time of the adoption of the KP, Japan was the only Annex I country in Asia, while South Korea, China and Southeast Asian countries were all KY signatory Parties as non-Annex I countries. Due to its unique international status, Taiwan has not been able to take part in any of the KP's carbon markets. Although Taiwan is unable to actively participate in the development of CDM projects, international developments and the trade of voluntary carbon credits has allowed Taiwan to compete worldwide, particularly via the international Voluntary Carbon Standard (VCS) and Gold Standard (GS). The key to carbon reductions is to be able to seek out suitable projects with potential GHG reduction opportunities under the same methodologies set forth by the UNFCCC. Hsikou Hydropower Plant Project, located at Wushantou Reservoir of Jianan Farmland Water Conservancy Association became the first VCS project in Taiwan in 2009.

The first crediting period of the KP expired at the end of 2012. By the end of 2012, it was mandatory for Annex I countries to hand over GHG emission reports to the UNFCCC. Essentially, emitting installations with reduction obligations in Annex I countries, which required emission certificates to secure their purchases prior to this deadline.

Eventually, the demand for carbon certificates started to mature and stopped growing, from 2011. The sharp and rapid decline of Kyoto carbon certificates (both allowances and credits) can be clearly seen as illustrated in Figure 4, with public market data. For example, the price decline of Certified Emission Reduction (CER) certificates was approximately €12 in March 2011 and hit the €10/CER mark by the beginning of July 2011. The decline continued in a flat straight-line. By the end of 2011, the price had already fallen below the €5 mark and the descending trend continued in 2012. The price finally fell below €1/CER before Christmas 2012 and has never recovered since then.

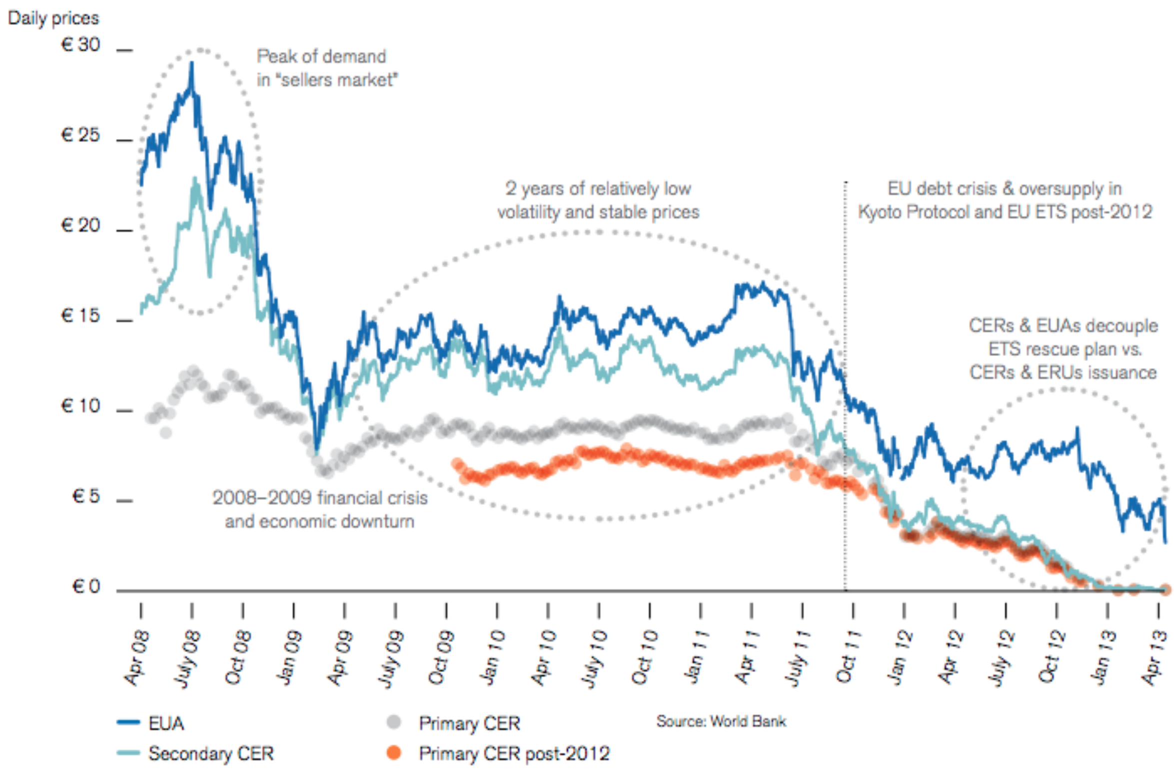


Figure 4. Global CER prices August 2008 - April 2013 (Office of Sustainable Development, Environmental Protection Administration, 2009)

The reasons for the dramatic collapse in carbon prices (over -95% in 2 years) can be summarized as follows:

1. A comparatively definite demand lacking a long-term prospective: while the demand of carbon credits largely relied on the outcome of international negotiations and agreements,

it was capped by the commitment each party (country) made to the Kyoto Protocol. Due to the phased design of the KP market, the demand for carbon credits was only clear and foreseeable until 2012. Further, post-2012, demand was largely dependent upon negotiations among the parties (before 2012), which did not come to an action. This created great uncertainty to carbon credit sellers for their opportunities in the long run.

2. Supply increasing without limitations: project-based carbon credits were generated from projects that met CDM requirements. The market was expected to mature throughout the auto-adjusting mechanism (price), thus leading to the maturation of supply growth. However, the development process involved significantly subjective review procedures, which caused unpredictable timeframes and eventually caused delays in carbon credits generations. Meanwhile, there was no administrative management of the quantity control on the supply side. In reality, not long after the expiration of the first crediting period ending in 2012, the market was flooded with issued carbon credits without any foreseeable buyers. Very similar to every black Friday event in stock markets, panics soon spread across the globe and further deteriorated the outlook of the pricing level.

Based on the collapse of KP international carbon markets, the following lessons can be learnt for market traders as well as international treaty negotiators and policy makers who are designing similar regional or national markets:

1. Complexity of cross-border trading: carbon trading was meant to be international since initiated. Entities from developed countries were supposed to offer funding, technologies and cooperate with entities with comparatively economical reductions potential in developing countries. However, it is very difficult to predict the volume and prices in both the short and long-term under such high international trading. One adjustment often found in new carbon markets for better controlled supply is to tighten the qualification of carbon projects. These are often seen, such as the commission year, locations, ownership (non-foreign owned), maximum percentage of imported credits etc. Examples are China, Korea and potentially Taiwan.
2. Possibility of supply and demand imbalance: Long-term high-level emission reduction targets are usually set by comprehensive economic and scientific analysis. Oftentimes,

public consultations and political negotiations are necessary before the outcome is decided, which could potentially make the conclusions less scientific. Upon implementation, such artificial adjustments could result in imbalanced supply and demand and highly illiquid market. This is not only observable in carbon markets such as in New Zealand and Australia, but also other types of environmental assets such as RECs in China, Taiwan and Japan.

3. UNFCCC held its 21st Conference of Parties in Paris in December 2015. It was considered the turning point of post-Kyoto era. The outcome was summarized in Paris Agreement that was successfully ratified. In its Article 6, a voluntary market mechanism is again being recognized as an important tool for international cooperation among Parties. It is also considered as a form of extension of KP's market mechanisms with more robust and complete consideration, to promote the reduction of GHG emission and to achieve broader sustainability development, for avoiding leakage and enhance international cooperation. The major aspect emerged from the following Paris Agreement in the international business world is the attention and focus on the use of renewable energy.

2.1.2 The rise of international renewable energy markets

In more than two-decade long history of global power market liberalization, two most popular policy models administered to stimulate the deployment of renewable energy are RPS and FiT.

1. RPS: also known as Renewable Electricity Standard (RES) at US federal level and Renewable Obligations in the UK. It is often implemented together with the use of REC and is a mechanism first converting environmental attributes as tradable instruments/certificates. Further, backed by regulatory enforcement of use of such certificates. RPS usually requires electricity suppliers to procure certain percentage of its total supplied power from renewable-based sources. But, recent developments in Asia (China and Taiwan) also started to observe such requirement being placed on large power users.
2. FiT: According to Renewable Energy Source Act 2000, of Germany, the key characteristics of FiT include:

i. Grid access guarantee

ii. Long-term purchase agreements

iii. Cost-based pricing principles

The FiT is a policy mechanism designed to accelerate investment in renewable energy technologies with dedicated resources and support provided by public sector.

2.1.2.1 International renewable energy market developments

While observing the collapse of international carbon market, the majority of professionals in the market started to look for other opportunities. While some brought lessons learnt from such volatilities to traditional financial markets, others remained optimistic and persistent in pursuit of a carbon future.

The EU published the Renewable Energy Directive 2009/28/EC, which could be considered as pan-EU RPS rules. By the time, the carbon market reached its historical low price level in 2012/2013, the development of renewables in the EU had been gaining traction for 3 years. Prior to its publication in April 2009, REC trading had been voluntarily developing since early 2000, started by REC International from the Netherlands. The United States had also been pioneering power market liberalization since mid-1990's, and later included the trading of renewable-based electricity in various forms.

The GHG Protocol, a program co-funded by the World Resource Institute and the World Business Counsel of Sustainable Development based in Washington DC, started to look into amending its context in 2011. This was mainly in response to the diversification and rapid growth of non-utility scale power trading in the western world. Power traded between generators and final users became feasible reform mid-1990s, in selected countries like South America, Western Europe, and certain states in the US. This came in the form of certificate trading (for both renewable and non-renewable), bilateral contracts, suppliers' special rate programs or passively adopting adjusted grid EFs.

In the beginning of 2014, the International REC Standard was founded in the Netherland with the goal to "empower consumers' choice" of power sources around the world. Back then, it was initially considered an alternative for carbon credit sellers with minimal expectations. The major RE100 members are illustrated in Figure 5. For environmental asset traders, it was considered a new battlefield in the continuing the fight against climate changes.

Figure 5. Major RE100 members

Starting from an inquiry email sent by the author to REC International in mid-2013, the International Standard was adopted in 18+ markets, thereby providing an internationally-accepted mechanism including GHG protocol scope 2 guidance and regulation on renewable sourcing by international NGOs such as CDP and RE100 to serve the needs of seller and buyers.

The trend and focus on the environmental asset trading of the world, has also gradually shifted from carbon credits in the past, to the direct use of renewable energy. Based on the different markets, backgrounds and policies, prices can vary by more than 100 times in different markets. In terms of market size, undoubtedly, China is the largest, whilst Brazil is not far behind. Figure 6 shows the international REC standards. It is estimated that the global I-REC certificate usage would be top five billion kilowatt hours by 2018.

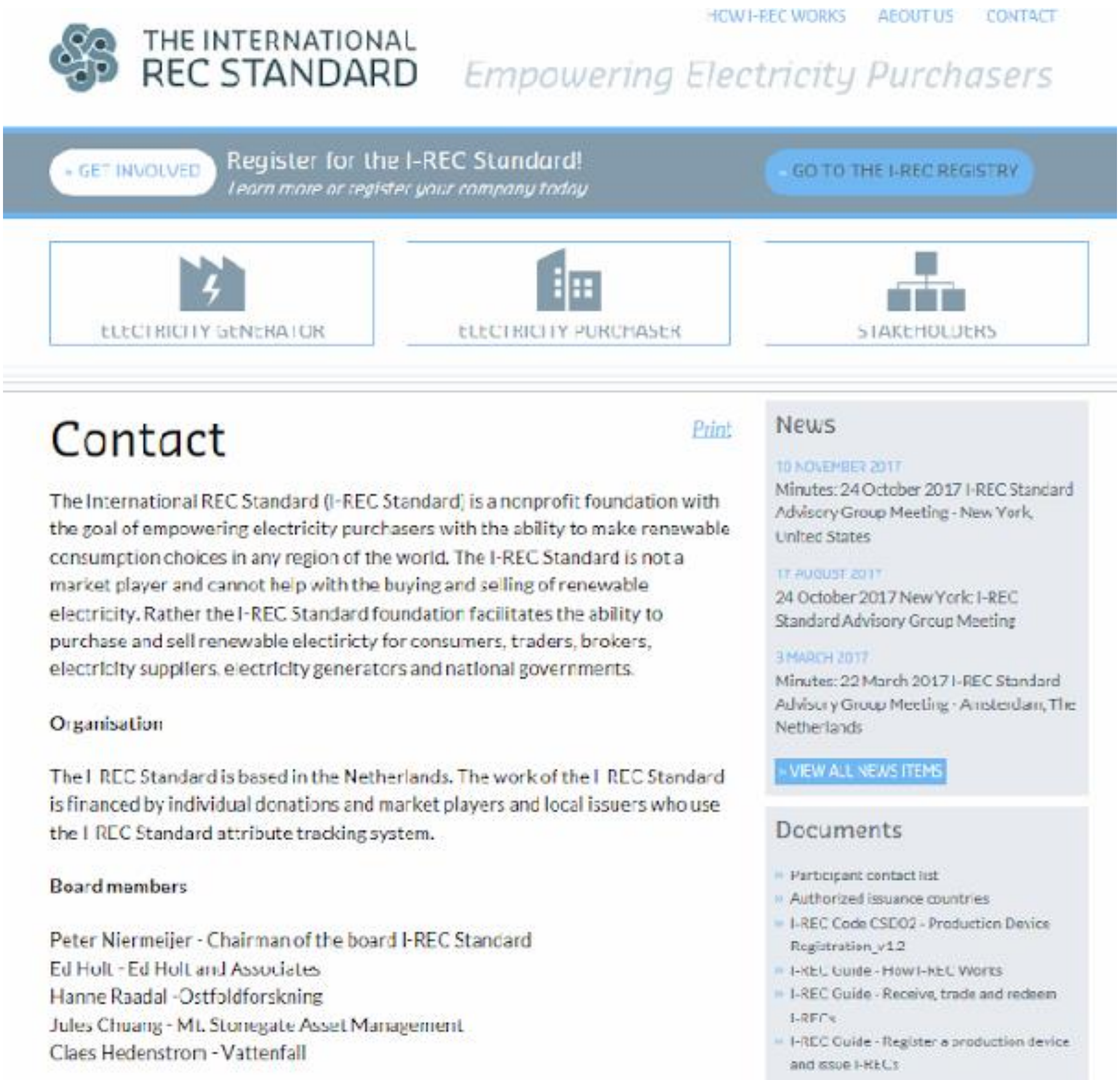


Figure 6. The International REC standard

It is worth mentioning that Taiwan was the first region in the world to successfully pass a resolution from the I-REC Council, to successfully register an I-REC project, to approve and issue I-REC certificates, and also to transact and use I-REC certificates.

2.1.3. Recent RE-related policy development in Taiwan

According to the BO E's statistics on Taiwan's CO_2 emissions from fuel combustion in 2016, Scope 2 CO_2 emissions from the industrial sector in Taiwan in 2015 totaled 119.84 million metric tons. This accounted for 47.84% of the total CO_2 emissions from all sectors, of which CO_2 emissions from electricity generation was 79.91 million metric tons, justifyingr 66.68% of the total CO_2 emissions from the industrial sector (Figure 2). The electricity consumption was mainly for fulfilling the manufacturing needs of Taiwan's high-tech industries such as the semiconductor, TFT-LCD panel, and electronic sectors, where a large part of their production capacities, supported by electricity. Since thermal power is a major power generation source in Taiwan, Scope 2 emissions from the electricity-intensive manufacturing industries have been the primary source of carbon emissions.

Therefore, the government has actively promoted the use of renewable energy by establishing the REDA, aiming to improve environmental quality through the effective use of renewable energy and achieve the goal of 20% by 2025. The government also started the FiT system in 2009, and launched the VGPPP in 2014 as well as the REC system in 2017. Hoping that the development of renewable energy will be spurred through these institutional incentives, a solution to reduce the massive CO_2 emissions from Taiwan's industrial sector, due to purchased electricity, can be worked out while, at the same time, speeding up Taiwan's energy transition.

The BOE launched the three-year VGPPP in the July 2014. The quantities of proclaimed subscriptions and actual subscriptions during the period of 2014–2016 are shown in Table 1.

Table 1. Quantity of subscriptions under the VGPPP

Year	2014	2015	2016
Proclaimed subscriptions	4,345,000 kWh	784,000,000 kWh	1,000,000,000 kWh
Actual subscriptions	4,241,865 kWh	156,369,100 kWh	270,280,400 kWh

Through the three-year VGPPP, the quantity of purchases has increased year by year to 270 million kWh. The industrial sector purchased green power for the sole purpose of reducing CO_2 emissions during the manufacturing process. However, when performing GHG inventory, green power subscriptions could not be used as offsets against Scope 2 emissions. Based on the GHG Inventory and Registration Guidelines, the competent authority believes that the BOE's specified electricity EFs shall be used consistently even for the EFs of the subscribed green power. However, the MOEA's VGPPP states that the green power has a near-zero EF. Therefore, when the REC system is introduced, it will still face the same electricity EF issue.

In order to accelerate the development of the green supply chain as well as achieve the goal of 20% power generation from renewable energy, Taiwan issued the first Taiwan REC (T-REC) in May 2017. There is one cohesion between T-REC and other internationally-issued certificates, the use of a tracking system. During the voluntary purchase of green power pilot program, some foreign companies hesitated to purchase green electricity in Taiwan because it is unverifiable if they were using "purely green" power. However, T-REC solves the problem of untraceable power source. According to the guidelines for pilot implementation of REC, before applying for certification, a power generation equipment check and power generation verification must be conducted. This means that the source of green electricity used (from which renewable energy power plant or facilities) can be identified in the future. As for reductions in Scope 2 emissions, the Environmental Protection Administration (EPA) has also agreed that T-RECs can be used as a tool to calculate end users' indirect emissions from the use of electricity in Taiwan's GHG inventory. When a company holding a T-REC carries out a GHG emission inventory check, the GHG emissions relative to electricity consumption prescribed for the certificate that it holds, can be calculated with the nationally-announced EF for renewable energy. The BOE announced the 2016 electricity EFsF for renewable energy as a note, stating that “for the power generation facilities using renewable energy such as hydropower, solar and photovoltaic power, wind power, and geothermal power, since no fossil fuel is used during the power generation process, resulting in no GHG emission.” Therefore, the T-REC can serve as a proof of the renewable source of electricity used by a company, as well as the corresponding GHG reduction benefits.

Carbon reduction is a policy-driven outcome. While there are companies highly committed to their social responsibilities, the government’s regulations are even more important. If the relevant ministries fail to integrate their interfaces or the regulations are not conducive to reducing carbon emissions, the effectiveness of efforts will be diminished. For example, if the inability to use VGPPP as offsets against CO_2 emissions or the promotion of renewable energy is being held back by the electricity EF, double the efforts will produce half the results in carbon reductions, and even motivated companies would find it difficult to put things into action. This article mainly discusses the challenges and opportunities facing the newly-launched REC system in Taiwan after the adoption of the “Green Power First” policy guide, following the amendment to The Electricity Act. That is, how T-REC focuses on the “self-generate self-use” renewable energy in the first stage, deals with existing regulations such as GHG Reduction and Management Act (carbon credits), REDA (FiT), Electricity Act (REC), and Standard Procedures for Calculating Electricity EFs (electricity EF), etc. This further achieves the intended objective of the T-REC system through the integration of interfaces. In this study, practically feasible operating steps and a suggested timeline are proposed, in the hope that the government will start off on the right track and get connected with the globe, when it launches the policy, thereby constituting an impetus for companies to reduce carbon emissions. Since the success of a REC system is closely related to the electricity EF, this research points out, by means of scenario analysis, the necessity that the T-REC system must be accompanied by the appropriate power EFs (which we call the “residual mix EFs”).

2.2 Summary of problems observed

2.2.1 Unharmonized policies on GHG regulations and renewable energy developments

As discussed previously, Taiwan set its goal for both GHG reduction and renewable energy development. The GHG's ultimate goal, with intermediate milestones, is to achieve a 50% reduction from 2005 by 2050. As a result of the zero-nuclear policy, Taiwan is facing a severe challenge to meet power supply needs. The government, thus started to implement demand-side incentives such as GPPP and RECs. Collectively, policies of GHG reduction and renewable development could contribute to both goals with well-designed interactions. This is currently missing and sometimes creates obstacles for developers.

2.2.2 Conflicts between FiT and REC/RPS

Experiences learnt from mature, liberalized markets in the US and EU show tracking systems with green power certificates are the foundation of a well-functioning liberalized market. Meanwhile, public subsidies (such as FiT) and tax incentives are often regarded as an effective tool in the early stage of market development to boost the installation and power supply. However, as the market gradually moves toward an open and deregulated stage, these incentives will become obstacles to the development of a competitive market.

With the amendment of Electricity Act tin 2017, Taiwan embraced the liberalization of the power market, starting with renewable-based generation. As one can clearly see, T-REC is in its infant stage, while FiT has been used as the main power policy tool in boosting renewable energy development. Since FiT serves to provide highly secure income sources, it is understandable that project developers show high preference toward FiT over a market-based mechanism.

Upon debating policy adjustments, it is unavoidable that there will be many, sometimes competing, interest groups, advocating policies that would serve their interests. Under these circumstances, rational discussions and consensus will be difficult to reach without a clear roadmap for all parties involved, including project developers, power users and policy makers.

2.2.3 Summary

Leading Asian economies such as China (C), Japan (J) and South Korea (K) even Taiwan (T) are at the turning point, where, without justifying action, climate change will become an increasingly difficult challenge. This is not only because local climates are worsening and extreme weather events occur more frequently. There is also pressure from international trading partners, particularly from Europe and the US. This is also closely related to ensuring a sustainable future for people living in these markets.

While restricting GHG emissions, often seen as an effective measure, scaling up renewable energy use at the same time is being regarded as an equally emphasized policy option. In leading Asian economies, renewable energy is becoming more and more important, although reasons differ slightly depending on the country. Ruling out nuclear energy (J and T), reducing fossil fuel dependence, capitalizing on the environmental value of green power (C, J, T) are usually on the top of the agenda in these regions.

As discussed in previous sections, renewable energy has gained momentum since the mid-2010 and could potentially serve as one of the options to reduce GHGs. What has not been widely discussed is the interactions of GHG reduction and renewable energy development policies. Further discussions will commence with literature review and later lead to discussions on issues often seen in the topic. A comprehensive integrated model will then be presented in chapter 6.

Chapter 3 Literature review

3.1. Post 2012 GHG reduction relationship with the Clean Development Mechanism (CDM)

3.1.1 Issue of climate change by CDM

One of the advantages of the CDM is able to simultaneously meet the needs of both developed and developing countries. The CDM encourages developed countries to invest in emission-reduction projects in developing countries and earn CER credits in return. These CERs can be traded and sold, and used by industrialized countries to a meet a part of their emission reduction targets under the KP. In order to utilize global resources for their CDM projects, host countries should participate actively. A host country that pursues more partnership-based projects takes better control of resources and knowledge-flow in the eco-network formed around the country. (Moon Jung Kang et al., 2013)

A large proportion (about 69%) of CDM projects are renewable energy projects. This means that the renewable energy projects are more viable in gaining CDM recognition (Xin-Le Lim et al., 2014). Though the research shows that under some conditions the CDM can truly succeed in suppressing CO_2 emissions and become a second-best measure to mitigate global warming. Nevertheless, it must be clarified that the prices of carbon offsets in advanced economics are not generally sustainable without the help of the outside agencies such as governments, NGOs or market traders. (Morio Kuninori, 2017)

3.1.2 Importance of “additionality” to the development of a CDM project

The main purposes of CDM are GHG reductionss, sustainability for host countries, and cost-effective mitigation for investors. A “net decrease” may or may not be caused by CDM. Additionality plays an important part in CDM. Additionality avoids giving credits to projects that would have happened anyway (Free-Riders) without the presence of CDM. There are specified rules to ensure that the project reduces emissions more than would have occurred in the absence of the CDM. If these projects are truly additional and continue to operate well beyond the credit issuance period, they will decrease global GHG emissions. However, if they are mostly non-additional, as research suggests, they could increase global GHGs. (Peter Erickson et al., 2014)

3.1.3 Corporate Social Responsibility (CSR) as a legitimizing tool in the carbon market

Sustainable development has been incorporated as one of the objectives of CDM. Based on the evaluation of 593 projects registered, it was identified that there are some CSR activities corresponding to the social, environmental and economic indicators in Brazil, Mexico, and Peru. CSR is a business approach that contributes to sustainable development by delivering economic, social and environmental benefits for all stakeholders. CSR activities in most of the cases were implemented as a way to legitimize and as a means to achieve social acceptance. (L.L.Benites-Lazaro et al., 2017)

For example, the Proximus Group has committed to render their operations climate neutral since 2016. The main driving force behind the development of this is the multi-annual “GS” certified climate project. Besides reducing emissions internally, the company offsets emissions cannot yet reduce by supporting international projects aimed at fighting global warming in Africa. For example, in a specific region in Benin, where 69% of the population lives in poverty, 91% of households use wood as an energy source and there is limited access to electricity. These groups have been deploying high-performance stoves in households, on which a thermo-electric generator is installed for charging smartphones and LED lamps. By providing cheaper,e reliable and more sustainable energy, these stoves are not just beneficial for the families (savings on wood, access to electricity and telecoms, fewer respiratory illnesses) but are also good for the planet (fight against deforestation).

Figure 7. The Proximus Group received its first CO_2 neutral certificate. (Proximus, 2017)

3.2. Feed -in Tariffs (FiT) and Renewable Energy Certificates (RECs)/Renewable Portfolio Standard (RPS)

3.2.1 Comparing different renewable energy policies

To examine the effectiveness of RPS and REC trading in China, the development of renewable energy and the environmental and economic benefits under different policies have been quantitatively investigated. tREC trading can efficiently reduce the government's expenditure on subsidies for the development of renewable energy but may not be enough to achieve renewable energy targets, especially when the capital cost is high. In China's renewable energy market, it has been recommended that RPS, REC trade and FiT subsidies should be implemented as complementary policies instead of independently. (Qi Zhanga et al., 2017)

Tradable green certificates can promote investment in large-scale plants. (Anna Darmani et al., 2016) A study using theoretical model with data from the Spanish electricity system for the period 2008–2013 showed that a green certificate scheme could both achieve the 2020 targets for renewable electricity and reduce regulatory costs. However, the role of regulators is still important, since setting the right target for renewable electricity affects the cost burden of the system. (Aitor Ciarreta et al., 2017)

3.2.2 The influence of renewable energy policy in the development of renewable energy

Both South Korea's RPS and FiT can effectively expand electricity generation from renewable energy sources (RES-Es), like solar PV. Under South Korea RPS, higher market risks are a major concern, particularly for smaller suppliers in the solar PV market. (Tae-hyeong Kwon, 2015)

Renewable energy policy indeed influences the development of renewable energy. The Australian clean energy industry is finally “on the verge of a major breakthrough”. According to the Clean Energy Australia Report launched by the Clean Energy Council, which highlighted the industry’s record-breaking 2017 in terms of investment and rooftop solar installations. (Joshua S Hill, 2018) Whether through research or national internal affairs reports or news reports, we can find that renewable energy is increasingly valued and supported by policy implementation. Using market tools for renewable energy, global GHG reductions have been achieved.

3.3. The role of renewable energy in climate stabilization

3.3.1 Rising power supply from renewable energy globally

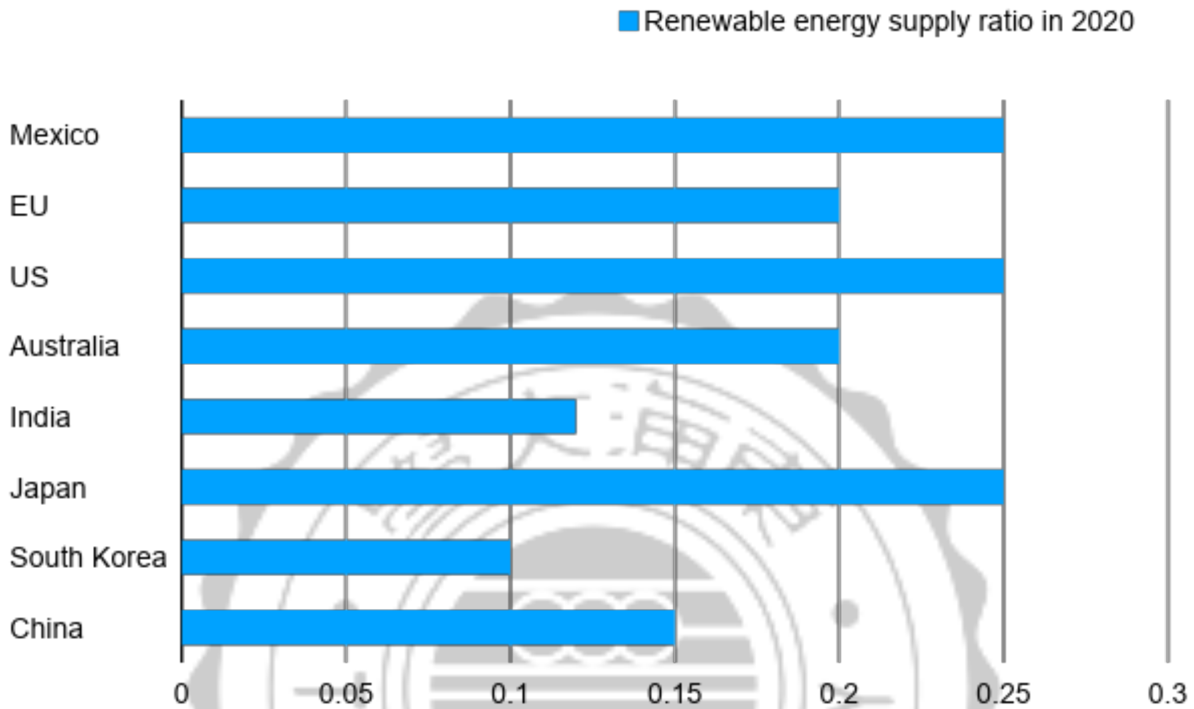


Figure 8. Renewable energy supply ratio by country in 2020

Since the catastrophe in Japan's Fukushima nuclear power plant in 2011, the safety of nuclear power has been strongly questioned, and countries using nuclear energy have re-examined their nuclear energy policies. Germany announced that the operation of all nuclear power plants will cease after 11 years. Prime Minister of Japan announced that they will abolish its plan to increase the proportion of nuclear power generation to 50% before 2030, and will make every effort to increase renewable energy development plans, including solar and wind power.

At present, the proportion of electricity supply from renewable energy sources has been increasing year by year. The German government has set a goal to achieve 30% of electricity generation from renewable energy sources by 2020 and reach 50% by 2050 while, Spain has gone even further by aiming for 100% in 2050.

3.3.2 GHG emission reduction path

Based on a global survey, renewable energy, fuel switching, and efficiency improvements in power generation will account for 45% of the total GHG emission reductions in 2020. Non-energy sectors, namely, fugitive emissions, waste management, agriculture, and fluorinated gases, will account for 25% of the total GHG emission reduction in 2020, while (CCS, solar, wind, biomass, and biofuel together will account for 64% of total GHG emission reductions in 2050. (Osamu Akashi et al, 2012)

Renewable energy consumption contributes around 1/2 less per unit of energy consumed than fossil energy consumption in terms of GHG emissions in EU countries. This implies that a shift in energy consumption mix towards alternative renewable energy technologies might decrease the GHG emissions. (Gülden Bölük et al, 2014)

The Dumitrescu-Hurlin non-causality approach indicates that there is bidirectional causality between renewable energy and carbon emissions, and unidirectional causality running from real income to carbon emissions, from CO_2 emissions to non-renewable energy, and from trade acceptance to CO_2 emissions. (Eyup Dogan et al, 2016)

A study from the US, examines the relationship between renewable energy production and GHG using US state-level data for 2010. After controlling for other sources of emissions, US states that produce a larger share of renewable energy are found to have lower GHG emissions. It is estimated that a 10% increase in the share of renewable energy could decrease CH_4 emissions by ~0.26%. Since the use of renewable energy sources does not release GHG emissions, this effect can be interpreted as stable if renewable energy is added to coal use or as corrective if it replaces coal. (Jay Squalli, 2017)

3.3.3 Renewable energy market tools

As previously mentioned, the CDM is one of the market tools to reduce GHGs. This section will introduce a market tools that could be utilized in addition to national policies to promote the development of renewable energy installations.

RECs are tradable, non-tangible energy commodities in the US, which proves that 1 megawatt-hour (MWh) or 1,000 kWh of electricity was generated from an eligible renewable energy resource and was fed into the shared system of power lines which transmit energy. snory ys RECs provide a mechanism for the purchase of renewable energy that is added to and pulled from the electrical grid. The updated GHG protocol scope 2 guidance lists Guarantees of Origin (GOs), RECs and I-RECs as mainstream instruments for documenting and tracking electricity consumed from renewable sources. These systems were created to be able to meet the identity of electricity sources, including energy type, device capacity, and power plant location, especially for renewable energy.

These certificates can be sold and traded or exchanged, and the owner of the REC can claim to have purchased renewable energy. According to the US Department of Energy's Green Power Network, RECs represent the environmental attributes of the power produced from renewable energy projects and are sold separately from commodity electricity. While traditional carbon ET programs use penalties and incentives to achieve established emissions targets, RECs simply incentivize carbon-neutral renewable energy by providing a production subsidy to electricity generated from renewable sources.

A certifying agency gives each REC a unique identification number to make sure it doesn't get double-counted.

Based on the above discussions, literature shows that the establishment of renewable energy devices, government policies assistance, and market tools can indeed directly or indirectly lead to a reduction in GHG emissions.

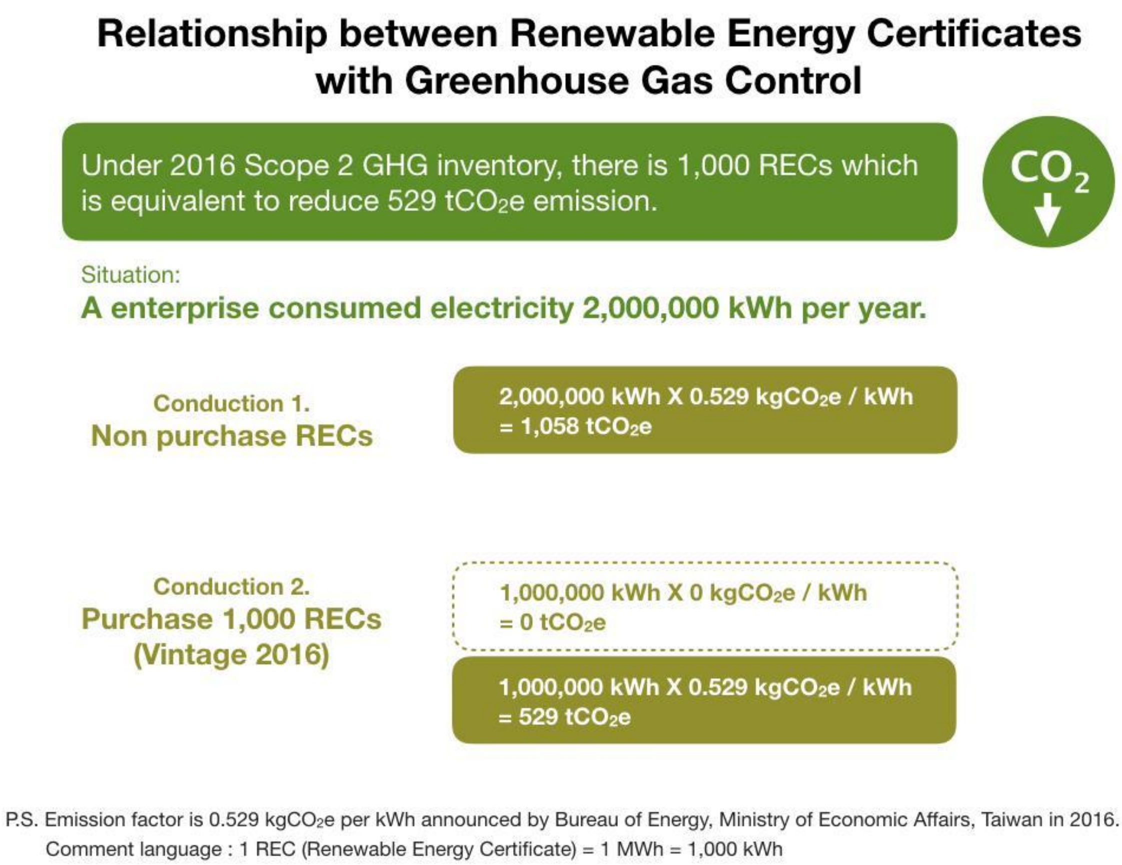


Figure 9. Relationship between RECs with GHG controls

3.3.4 How to use renewable energy certification on GHG Protocol Scope 2 Guidance?

Each unit of electricity consumption should be matched with an EF appropriate for that consuming facility's location or market. For a market-based method, this means choosing a contractual instrument or information source for each unit of electricity. For example, if a company has purchased certificates to apply to half of a given operation electricity use, it will need to use other instruments or information on the EF hierarchy to calculate the emissions for the remaining half. The GHG Protocol provides guidance to clarify how specific sectors can apply GHG Protocol standards.

Chapter 4 Studies of existing market mechanisms

This chapter examines the major market mechanisms of renewable energy and carbon trading. Comparisons among various market instruments and cross-comparisons of RE and carbon markets have been conducted. The conclusions drawn from such studies summarizes, which serve as the foundation of several innovative concepts of market mechanisms advancements.

4.1 Introduction to power market instruments

Global experience has shown that government subsidies are a suitable and effective policy to encourage the development of renewable energy in the early stage. With the gradual maturity of the technology and the sharp decline in costs, subsidy termination and market mechanism initialization would be the key to develop the renewable energy sustainability and transforming renewables into the main source of power in the future.

Various market mechanisms have been launched globally to promote renewable energy development, such as regional RECs, including US-RECs, EU-GOs) and I-RECs, which are briefly described below:

1. REC: Each REC is granted with code and the present REC is distributed into two markets. (1) A compulsory market where it is mandatory for power companies to use a certain allocation of renewable energy. (2) Voluntary market where green power is used by companies or consumers voluntarily, there are third parties (e.g. managers or agents) participating in both of these markets.
2. GO: GOs are applicable in the green power market in Europe where consumers have the right to freely choose a renewable energy power plant, and each GO is granted a code to indicate the source of power.
3. I-REC:C Each 1,000 kWh electricity from renewable energy is certified in accordance with

the I-REC standard and granted an exclusive code to prove its validity, i.e. each 1 MWh is granted a certificate. Figure 10 shows schematic drawing for the generation of green power certificateset. When power is generated by a renewable energy operator, the essential power will be delivered through the nearest electric grid. Meanwhile, the environmental benefit or energy attribute will be certified with an energy attribute certificate in an electronic tracking system, and the certificate, which is convenient to circulate and use, discloses the environmental benefit and energy benefit from the power.

Some of the RECs issued in Taiwan and abroad are introduced as follows:

1. T-REC

   T-RECs are issued by the National Renewable Energy Certification Center in Taiwan. The first batch of certificates were issued in May 2017. A certificate is issued after verification by a third-party notary that an enterprise uses renewable energy equipment and power generation. The objectives are to increase the use of renewable energy and promote GHGs reduction.

2. REC

   The REC system is used in the American renewable energy market. The certificate represents the environmental benefits of electrical power and other non-power-related attributes. Each REC unit represents the environmental benefits created by 1MWh of renewable power. RECs can also be used to track power generation and power sources.

3. GO

   The GO is a voluntary system employed by the EU that a specified quantity of green energy used by the certificate holder comes from renewable power sources. The GO system was formulated by EU Directive 2001/77/EC and certifies information such as the power source, power generation date, and power generation location. EU members are encouraged to set up their GO systems based on this directive.

4. C(I-RECs)

For tradable contractual tools used in regions where no RECs or GO certificates are in place, I-RECs may be used. An I-REC measures the environmental benefits created by 1 MWh of renewable power and is a tool used by consumers as proof that they are using renewable power. A company's renewable power generation and usage data can be traced and verified via an open system.

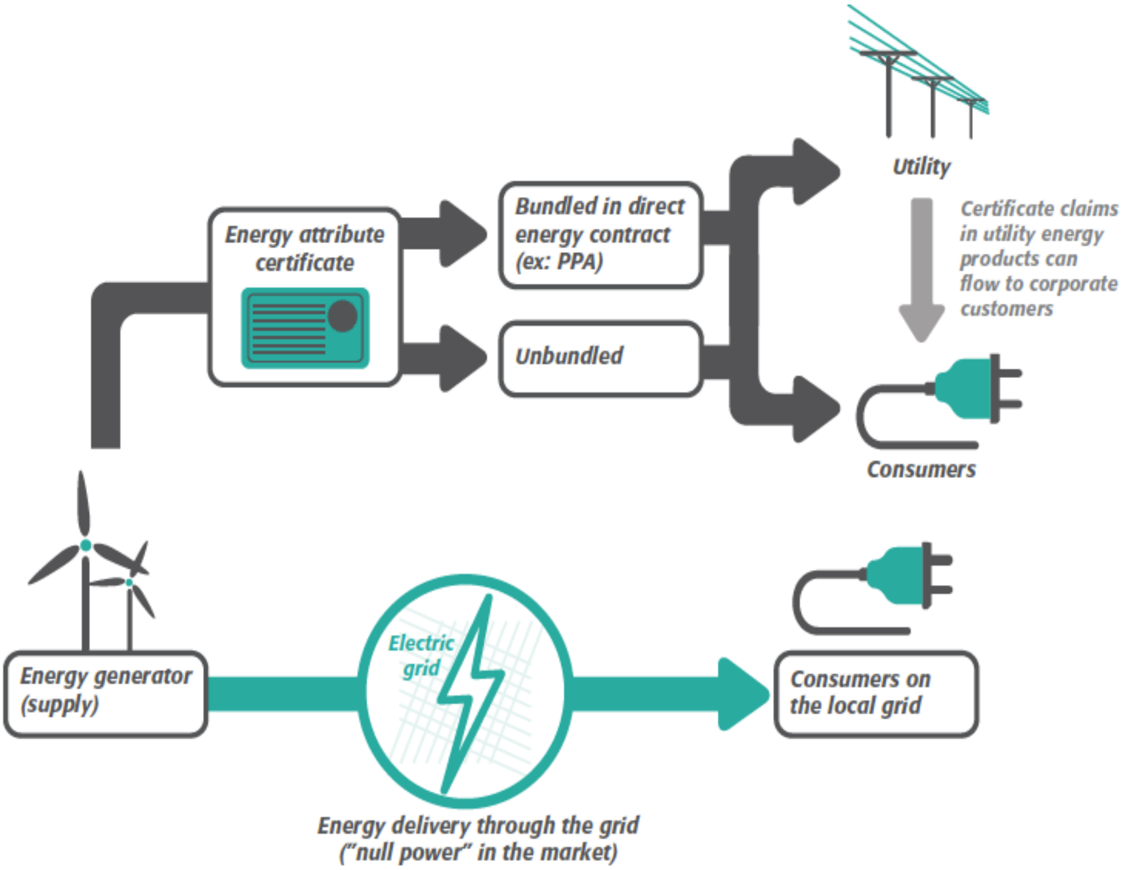


Figure 10. Schematic drawing for the generation of green power certificates (Mary Sotos, 2015)

Compared with the carbon reduction mechanism in the Kyoto Protocol period, the green power (certificates) are now used as a tool of carbon reduction and can be considered as a conservative duplication of the past global carbon trade system. The carbon credit in the carbon trading system can be traded internationally. For example, carbon credits generated from a solar farm from a non-Annex I country can be traded with a purchaser from an Annex I country. Such trading provides benefits for both sides. It helps to develop more power generation facilities in non-Annex I countries with funding and technology provided from Annex I countries. Through in such cooperation, purchasers under reduction regulations could source reduction credits in comparatively economical manner. Green power is restricted by the physical constraints of the power grid and power plants, as well as principles and standards of carbon accounting. REC trading addresses this shortcoming by allowing cooperation and the exchange of funding, technology and environmental attributes without being confined by geographical boundaries. As solar farms are installed and generate power in the same market, where the physical power and associated environmental attributes are traded. The benefits from such certificate trading appear to be much more visible. That is why it is the preferred option that has found mainstream support, encouraged by the GHG Protocol and Carbon Disclosure Project (CDP). The former specifies, the origin of power which cannot be traded cross-borders, while the latter specifies with international green power certificates can confirm actual carbon reductions. This distinction between the use of carbon credits and RECs are among other attributes, the PPPmVGPPP is not able to meet.

Taiwan's VGPPP is a measure to allow power users to voluntarily purchase green power. Although special rate programs offered by suppliers are also considered one of the viable options to provide power to the users in the GHG Protocol Scope 2 Guidance. It also requires such special rates to be backed by the use of RECs with an operational tracking system. There is always a risk of double counting without a certificate tracking system. This is the reason why the GHG Protocol Scope 2 Guidance emphasizes the importance and the use of a tracking system.

Judging from the lessons learnt in Taiwan and experiences accumulated internationally, and guidance provided from GHG Protocol, CDP, and RE100, a feasible green power market mechanism could be established with the following borne in mind: (as shown in Tab. 1):

1. REC based on a tracking system:
    a. Applicable occasion: The purchase of RECs is an economical and simple form of green power consumption. This is the fundamental reason why it has become the

mainstream solution for green power acquisition. With the support of an electronic tracking system, trading can be further simplified and made convenient. A system of REC with tracking not only conveys environmental attributes from the electricity generated from the underlying power plants, but also its location, type (wind, solar PV etc.), generation period and corresponding GHG emission of each unit of renewable energy power. Third-party verification can also be carried out to enhance the credibility and value of the certificate. This is usually accomplished with an eco-label scheme (see Sec. 4.2).

b. Market transaction cost: The cost of renewable energy power certificates is low compared to other forms of green power purchase (direct Power Purchase Agreement (PPA) and on-site installations).

2. Direct power purchases: Power is traded directly between producers and end users. The amount and price of power purchased are fixed between the power generator and the large end consumers by signing a PPA. The power is then transmitted from the power generator to the consumers through wheeling provided by the grid operator.

    a. Applicable market mechanism: The application of direct power purchases is limited to small-scale consumers. When the proportion of power purchased by large consumers becomes substantial, the stability of the power grid will be at risk for all users on the same grid. Developing the mechanism in a regulated market requires excessive legislation and new rule-setting, such as wheeling rates. This type of model is often seen in fully deregulated markets.

    b. Market transaction cost: Cost is even high in liberalized power markets due to legal and transaction costs associated with PPA contractual arrangements.

3. Suppliers' green power rates:

    a. Applicable market mechanism: As direct power purchase with PPA is limited by the scale, the green power rates is suitable for consumers in any scale if it is developed effectively.

b. Market transaction cost: Market transaction cost is low as it is one of fee schedules available to end users. However, since it is still required to obtain corresponding volume of RECs for the quantity of power sold and the convenience provided to end users, the unit price per kWh tends to be higher than that of direct PPA.

4. On-site generation:

   a. Applicable market mechanism: This is considered option that has the most direct positive impact on renewable energy development. There is basically no pre-condition for this option since the users are usually able to consume the power generated from the renewable energy facilities on site compared to the other options mentioned above.

   b. Market transaction cost: There is no market transaction cost as the generated power will be consumer on-site. However, the overall costs are the highest as users will need to invest the capital as well as the construction costs associated with installing the facilities.

Table 2. Comparisons of market instruments

#	Name		Advantages	Disadvantages
1	REC		1. Convenient and easy to obtain 2. Free market mechanism 3. Transparent power source 4. Low transaction costs	1. Market deregulations needed 2. Legislation and administrative resources required. 3. Varying regionally and unable to be used inter-regionally
2	Direct power purchase		1. High security 2. Good reliability	1. Involves complicated laws and policies which are not yet in place 2. Only feasible in less regulated electricity markets 3. Limited by scale (not open to small-scale consumers) 4. High threshold and only available to large-scale consumers
3	Suppliers' green power rates		1. Convenient and fast access for consumers 2. Suitable for consumers on any scale	3. Low transparency of power source if not backed by REC 4. Low flexibility 5. High price
4	Direct investment	Solar energy	1. Easy to realize 2. Generate and use power directly	1. Only applicable for small scale generation 2. Complicated application procedures
		Onshore wind	Mature technology	1. Significant environmental impact 2. Complicated installation process
		Offshore wind	1. Large scale 2. Rich resource	1. High cost 2. High environmental impact 3. Less mature technologies
		Others (biogas)	1. Clean 2. Environmentally friendly	Lack of large-scale applicability

Purchasing green power directly is now possible due to the amendment of Electricity Act in Taiwan. This means that large-scale power consumers can freely choose a renewable energy power plant and purchase the power directly, and power supply can be realized with the transmission by a power grid operator. This was the first step to liberalize the power market in Taiwan, and the REC is a policy instrument to stabilize an immature green power market in the transition period before the establishment of complete green power pricing and direct-purchasing power system. The REC market mechanism coupled with high government subsidies for renewable power, has the potential to not only meet demand for low carbon power sources rapidly and conveniently but also stimulate market development and generate more demand. In the long run, the true green power market can be activated more effectively using the mechanism. Meanwhile, taxpayer-funded government subsidies, can be phased out gradually. As a result, the renewable energy market can become sustainable, and attract more investment in technology, facilities and individuals.

The selections among these different market instruments could be complicated if markets are liberalized and mature. These options are not available to the users in Asian markets at the moment. It is expected, however that the options will increase gradually along with the level of liberalization in the coming years.

Table 3. Market instruments by county

#	Market instruments	China	Japan	Korea	Taiwan
1	REC	Yes	No	No	Yes
2	Direct power purchase	No	No	No	Yes
3	Suppliers' green power rates	No	Yes	No	No
4	On-site generation	Yes	Yes	Yes	Yes

4.2 REC market differentiation with the use of eco-labels

Practices from mature power markets in the US and EU show that a RECs are factual-based certificates. The term "factual" is used to emphasize the importance of objectivity, minimizing the possibility of subjective value judgements. Every REC represents 1 MWh, which means that all certificates are homogenous.

While RECs are considered objective and uniform, when the volume is significant, there is fierce trading competition. In order to partly address the issue of a lack of differentiation, renewable energy quality labels (often referred to as eco-labels), have become popular and common in mature REC trading markets.

Through a visit and an interview with EKO-energy, an eco-label scheme with its secretariat office in Helsinki, Finland, the author summarizes the findings and implications for renewable energy markets in developing economies in this section.

REC schemes serve the purpose of identifying specific data associated with each unit of green power, ensuring that it comes from a particular source of renewable energy generation devices. Such specific information includes, the location of the power generation facility, the owner of the facility, the type of renewable energy, installed generation capacity, the start date of the power generation facility and the time of power generation. Therefore, an REC can also be regarded as an identification measure for renewable power, whilst allowing environmental benefits of zero-carbon emissions from renewable energy sources to then be clearly identified. Renewable energy power plants can facilitate renewable power consumption by everyone, as well as proof of identity via the certification system. Furthermore, because the proof of identity includes certification of environmental benefits at the same time, therefore, within the EU, RECs can be isolated from power, and certificates may be traded independently.

In terms of renewable energy quality labels, it is essentially a qualification scheme with subjective criteria added on top of the factual attributes of RECs. Such labelling system can be considered as a derived instrument, which is attached to the REC and demonstrates additionally-required characteristics by the eco-label operators. It is expected that the differentiation created by such labelling will help to upgrade the quality of the overall REC market. Currently, there are a variety of renewable energy quality labels internationally, including Green-e issued by the Center for Resource Solutions, USA, OK Power issued by the Hamburg Institute, Germany and EKOenergy by the Finland. Renewable energy quality labels are issued by these issuing agencies according to preset guidelines to create additional market value. For example, the EKOenergy quality label, headed by Secretary General Steven Vanholme, is a Finland-based NGO promoting the use of their eco-label to ensure the minimization of environmental impacts caused by underlying renewable energy facilities. In order to obtain an EKOenergy quality label, it is compulsory for applicants to be subjected to a review by local environmental NGO partners in conjunction with EKOenergy. Eco-labels are only issued if review check of the underlying projects have not found major unresolved environmental issues. In other words, addition value is generated through the review process conducted by the partner NGO reviewing the certificate.

As eco-label itself is not a subjective qualification over factual RECs, therefore, the renewable energy quality label must be attached to the REC and cannot exist independently, as shown in the Figure 11 below:

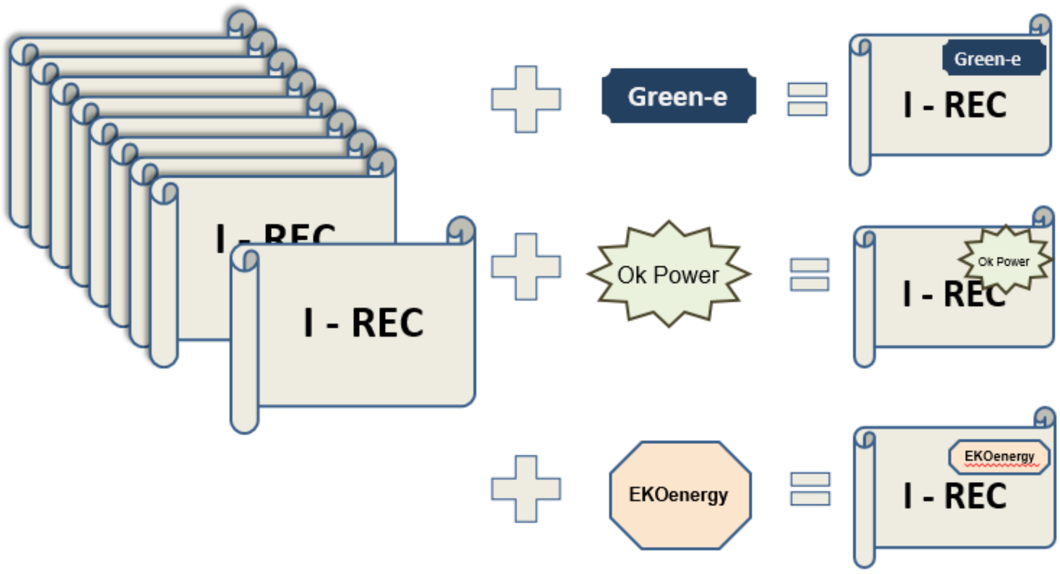


Figure 11. The relationship of eco-label and renewable energy certificates

The following table 4 summarizes the comparison of the REC and the RE quality label:

Table 4. Comparison of REC and RE quality labels

	REC	RE quality label
Nature	Objective fact	Subjective qualification
State	Stand alone	Attached to REC
Timing of existence	Beginning of the market	Upon competition matures
Quantity	Large in quantity	Small in quantity
Market value	Low	High
Transaction costs	Low	High

4.3 Implications for GHG emission reduction control

The issue of global warming and climate change is one of the most critical issues facing the world today. To reduce global carbon emissions, a market mechanism based on carbon credit transactions has been implemented after the Kyoto Protocol took effect in 2008. Later, the Paris Agreement was adopted by consensus during the 21st Conference of the Parties (COP) in 2016. The agreement urged the world to commit for controlling the global temperature increase to less than 2 °C above pre-industrial levels. Although the task is overwhelming, the committed parties have never ceased in their efforts to meet this goal. Over the time, carbon reduction practices have gradually shifted from carbon credits to the use of renewable energy (renewable electricity or green energy). A prominent example is the rise of the RE100 initiative proposed and formulated by the climate group during the 2014 climate week event in New York City. The initiative encourages participating companies to commit to the use of 100% renewable energy. Currently, over 100 major global enterprises have joined the coalition, including Google, Apple, Facebook, Coca-Cola, Nike, and Starbucks. Environmental sustainability and economic sustainability are two major cornerstones underpinning the framework of sustainable development (with a third being social sustainability). It is vital that enterprises commit to fulfilling their CSR to reduce carbon emissions in order to achieve both carbon reductions and corporate development objectives.

Companies commit to reduce carbon emissions for a number of reasons. In addition to fulfilling CSR, when reducing carbon emissions reduces corporate spending and enhances competitiveness, enterprises are more willing to embrace such endeavors. We generally consider CSR-related expenses as the tangible costs of an enterprise. One reason for these costs is to gain intangible assets (income) for the enterprise by fulfilling CSR and contributing to the community. This process is beneficial to all parties involved. Specifically, enterprises gain intangible returns (such as improved reputation, which is invaluable) and the parties (e.g., disadvantaged groups) that receive their support gain tangible benefits (e.g., environmental protection). From the perspective of CSR, low-cost carbon reduction tools are not ideal tools for controlling carbon emissions, as such practices violate the fundamental principles of CSR and will not help the enterprise gain its expected intangible returns.

Do carbon reductions reduce corporate costs? Carbon reductions would become extremely popular among enterprises if this expectation could be met. A rational entrepreneur's definition of good energy would include the expectation of stability, affordability, and environmental friendliness. Among these expectations, stability would be the principal factor, followed by price, and then environmental friendliness. A comparison of the energy qualities of fossil fuel and renewable power generation is tabulated in Table 5. The biggest advantage of fossil fuels is stability. Their primary disadvantage is carbon emissions. The opposite is true of renewable energy. Nonetheless, both forms of energy require appropriate supporting measures to overcome their flaws. Currently, wind generation is slightly cheaper than fossil fuel generation. Although the average price of renewable energy is presently higher than that of fossil fuels, solar power will inevitably become more affordable than fossil fuels as the relevant technologies continue to advance and the size of the market grows. In other words, the low-cost, clean energy sources long anticipated by enterprises are already available. The preparation of sufficient reserve capacity and the development of large-scale storage facilities are essential to the growth of renewable energy. From this perspective, we can optimistically anticipate that promoting carbon reduction will not only improve enterprises' corporate reputations; it will also reduce operating costs and enhance corporate competitiveness.

Table 5. Evaluation and comparison of the energy qualities of fossil fuel vs. renewable power generation

Priority	Evaluation item	Fossil fuels	Renewables
1	Stability	Excellent	Poor
2	Price	Poor long-term competitiveness	Poor short-term competitiveness
3	Environmental friendliness (zero carbon emissions)	Poor	Excellent
4	Supporting Measures	Development of CO_2 reduction and capturing technologies	Development of sufficient reserve capacity and large-scale storage systems

Taiwan's high-tech industries, including the semiconductor industry, TFT-LCD panel industry, and electronics industry, are energy-intensive industries. Business entities that emit GHGs as a byproduct of energy consumption or thermal/steam generation are classified as Scope 2 entities in the Guidelines for National GHG Inventories. In 2015, national statistics on carbon emissions from fuel combustion for each scope revealed that 250.5 million metric tons of CO_2 was emitted in 2015. The industrial sector (excluding Scope 1 carbon emissions due to power consumption) produced 39.93 million metric tons, accounting for 16% of overall emissions. When carbon emissions from electric power consumption are included, the figure increases to 119.84 million metric tons, which accounts for 47.5% of overall emissions. The difference of 79.91 million metric tons (32%) is the amount indirectly emitted by Scope 2 entities. (MOEA, 2016) Further investigation revealed that computer, communication, and audiovisual electronics manufacturers, which are the primary carbon emitters due to electric power consumption, only emitted 370,000 metric tons in Scope 1. However, they emitted 26.96 million metric tons in Scope 2. These statistics clearly show that to achieve long-term carbon reduction goals, efforts should be focused on controlling the CO_2 emissions of computer, communications, and audiovisual electronics manufacturers, which are the major sectors in

Taiwan’s industrial chain and electricity-intensive entities.

Therefore, we raised the following fundamental questions: What are the items, Scope 2 enterprises should focus on when endeavoring to reduce carbon emissions? After reviewing existing international specifications and mechanisms, the following items should be considered:

Establishing a renewable, self-sustainable energy generation system (zero carbon emissions).

1. Procuring external carbon credits (e.g., dVCS and GS d).
2. Procuring external RECs (e.g., using green energy).
3. Adopting green building designs, when building warehouses, and implementing department-wide power-saving strategies and energy-efficient equipment (e.g., air conditions and lightings).

For enterprises, establishing renewable power generation systems, adopting green building designs, and implementing department-wide power-saving strategies are tangible operations., are easy to understand. By comparison, carbon credits and RECs are abstract policy instruments. Although the purpose of these instruments is to achieve carbon reductions, but are differed in details and content, and have a competing relationship. For the dedicated personnel within an enterprise have difficulties in distinguishing their differences, and even more difficult to explain to company chiefs, leading to misunderstandings, diminishing enthusiasm, and making it challenging to achieve cost-effective carbon reductions. In this research, we have compared and analyzed carbon credits and RECs to highlight differences, competing relationship, and its practical applications. Thereafter, we presented a situational simulation to serve as a demonstration.

4.3.1 Introduction to carbon credits: The Kyoto Protocol, the CDM, and the VCS

"Carbon credits" is actually a general term for a carbon reduction tool. It refers to the UNFCCC signed by 155 countries during the 1992 UNCED. The UNFCCC quickly became fundamental to the efforts of UN in promoting carbon credits. The Kyoto Protocol was made legally binding in the UNFCCC COP3 in 1997. The Marrakech Documents, a series of decisive documents concerning the Kyoto Protocol, were passed in the UNFCCC COP9 in 2001. These documents became the legal basis of carbon credit-based carbon transactions.

The international carbon transaction market has grown exponentially under the framework defined in the Kyoto Protocol. The agreement proposed three carbon reduction mechanisms, namely the CDM, (JI, and ET. These mechanisms were rooted in cost-effective policies and measures and international cooperation regarding carbon reductions. This also allow the parties who signed the UNFCCC to transfer or acquire carbon credits to or from one another. However, the specific rules and roles of these mechanisms differ (2). JI focuses on joint reductions in carbon emissions by Annex I parties. Emission transactions are based on the acquisition and trading of carbon credits on a regulated platform. Only the CDM allows for the transfer of carbon credits between Annex I parties (developed countries) and Non-Annex I parties. This mechanism currently provides incentives for developing countries to reduce carbon emissions while maintaining sustainable development. Annex I parties can also complete CDM items to receive CERs. One CER unit is equivalent to one ton of CO_2 and can be used to reduce the cost of fulfilling commitments of the country to the UNFCCC.

Based on the aforementioned three mechanisms, carbon transactions can be characterized as allowance-based transactions and project-based transactions. Allowance-based transactions refer to transactions involving emissions reduction units under overall emissions control, such transactions are involving European Union Allowances (EUAs) in the EU Emissions Trading System (ETS). These transactions are largely used for excess ET between Annex I parties in accordance with the Kyoto Protocol and generally entail spot trading. Project-based allowances refer to transactions involving emissions reduction units generated while implementing emissions reduction projects, such as the CER transactions in the CDM and the emissions reduction units in JI. These transactions are largely carried out through international carbon reduction projects and generally entail futures trading. Thus, the advantage of project-based transactions can also be considered as potential drawback.

The CDM allows Annex I parties (developed countries) and Non-Annex I parties to jointly implement GHG reduction projects such as CO_2 emissions reduction projects. The amount of carbon reduced in these projects can count towards the carbon restriction or carbon reduction commitments of Annex I parties. For Annex I parties, the CDM is a flexible compliance mechanism that helps them to realize their commitments. For developing countries, CDM projects provide funding and advanced technologies. This win-win concept allows the CDM to help developed countries to reduce carbon emissions reduction costs. Through project development, developed countries acquire CERs from developing countries to offset their carbon reduction goals. Simultaneously, developing countries receive additional funding to develop advanced green-energy technologies, thereby achieving global carbon reduction and technology transfer objectives. (Stuart, M. et al., 2003) International cooperation is the greatest advantage of the CDM.

CDM project-based transactions are guided by CDM project activity models. Regulations governing CDM projects involve planning specifications, additionality assessments, accreditation of baseline and reduction efficiency calculation methods, accreditation of emissions monitoring methods, accreditation and registration of CDM plans, CER validation, and CER issuance and registration. A comprehensive description is illustrated in Fig. 12. (Stuart, M. et al., 2003)

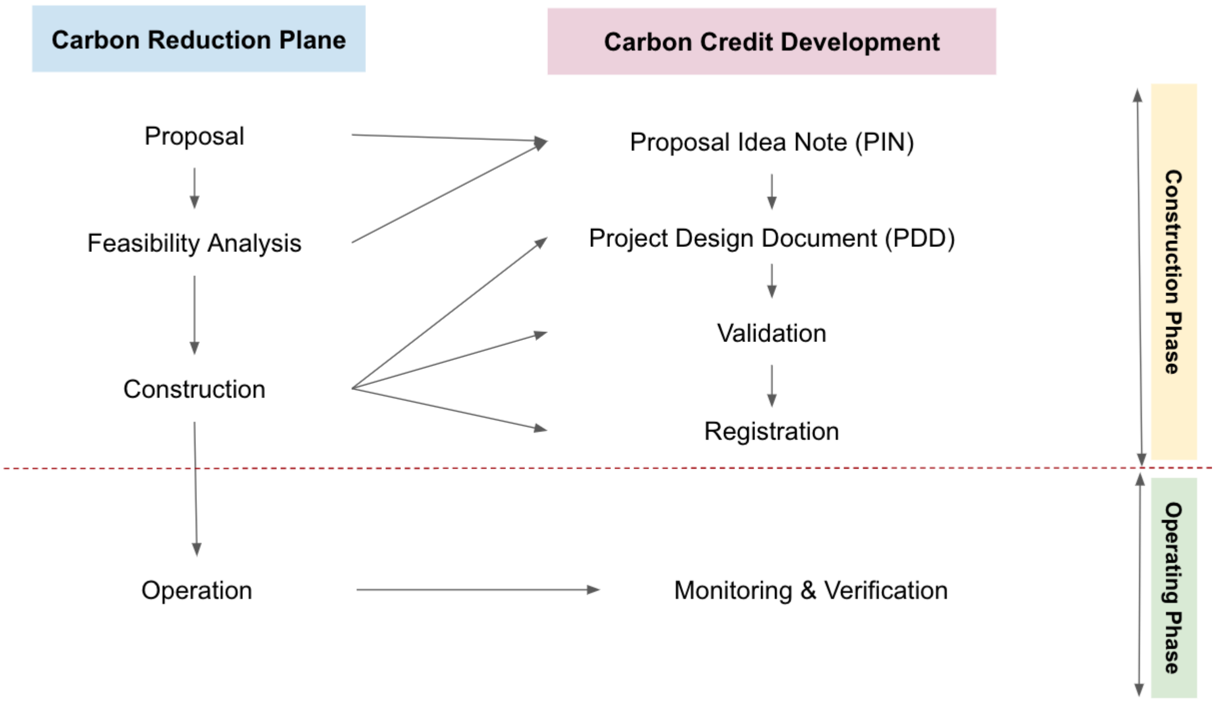


Figure 12. CDM project cycle and procedures

To ensure the effectiveness of CDM projects and to achieve further long-term, measurable carbon reductions, the CDM executive board under the UNFCCC proposed a set of effective and transparent operational baseline and monitoring methodologies to serve as guidelines for project registration and validation during the execution of CDM projects. The CDM methodology includes a total of 15 sectoral scopes and 165 methodologies approved by the CDM executive board. The methodologies themselves are divided into five categories. There are 73 large-scale methodologies (ACM), 59 small-scale methodologies (AMS), 16 consolidated methodologies, 10 large-scale afforestation/reforestation methodologies, and 7 small-scale afforestation/reforestation methodologies. Sectoral scopes refers to the type of carbon reduction project. The fifteen sectoral scopes are: energy industries (including renewable and non-renewable energy), energy distribution, energy demand, manufacturing industries, chemical industries, construction, transport, mining/mineral production, metal production, fugitive emissions from fuels (solids, oils, and gases), fugitive emissions from production and consumption of halocarbons and sulfur hexafluoride, solvent use, waste handling and disposal, afforestation and reforestation and agriculture.

A carbon reduction project in any sectoral scope can be considered either large-scale, small-scale, or consolidated (a mix of large- and small-scale) depending on the size of the project. Table 6 lists all project types. (UNFCCC, 2016)

Table 6. CDM carbon reduction project types

CDM methodologies	Associated project types
Baseline methodologies (AM)	Energy industries; energy distribution; energy demand; manufacturing industries; chemical industries, transport, metal production; fugitive emissions from fuels; fugitive emissions from production and consumption of halocarbons and sulfur hexafluoride; waste handling and disposal; afforestation and reforestation; agriculture
Large-scale methodologies (ACM)	Energy industries; manufacturing industries; chemical industries; transport; mining/mineral production; fugitive emissions from fuels; waste handling and disposal; agriculture
Small-scale methodologies (AMS)	Energy industries; energy distribution; energy demand; manufacturing industries; chemical industries; construction; transport; fugitive emissions from fuels; fugitive emissions from production and consumption of halocarbons and sulfur hexafluoride; waste handling and disposal
Consolidated baseline methodologies (AR-AM)	Afforestation and reforestation
Consolidated large-scale methodologies (AR-ACM)	Afforestation and reforestation
No methodology available	Solvent use

CDM methodologies are complex, and the number of methodologies continues to grow. Generally, the methodologies do not overlap, and a single applicable methodology for each project is typically easy to identify. The success of CDM projects primarily depends on the abundance of project additionality. The UNFCCC provides a robust database on additionality. Its *Tool for the Demonstration and Assessment of Additionality* is a particularly convenient and accurate evaluation tool.

Although the CDM offers potential economic benefits, CDM projects are not without risk. CERs are a form of futures transaction with the deadline in 2012. Since then, project risk has increased in concert with uncertainty. To some extent, risk in CDM projects is associated with project type and the parties involved in the transaction. Risks involved in project execution include registration risks, project establishment and operational risks, policy risks, price risk, financing risks, and legal risks. The presence of such genuine risks are the drawbacks of CDM project. Carbon credits are generated through the successful construction and operation of future projects, actual CERs generated by a project may be less than anticipated, or the delivery of CERs may be deferred if a project lacks reasonable design or monitoring accuracy, resulting in uncertainty risk.

The carbon emissions credits regulated by the Kyoto Protocol belong to a mandatory carbon market. The most widely accepted voluntary markets are the VCS and the GS. The VCS consists of Voluntary Carbon Units (VCU) for voluntary carbon markets jointly proposed by the International Emissions Trading Association (IETA) and the World Economic Forum (WEF). The GS was jointly introduced by the World-Wide Fund for Nature, the South-South North Initiative, and Helio International. Its establishment entailed long-term collaboration between many interested parties, including NGOs, government organizations, environmental institutions, private contractors (investors and project developers), and accreditation entities. These parties collectively formed the Gold Standard Foundation (GSF) in 2003. The VCS and GS provide alternative universal reduction mechanisms that are flexible and affordable and which allow the participation of non-Kyoto states. In other words, while the mandatory carbon market is only open to Kyoto Protocol signatories, voluntary carbon credits differ in that they can be regional (locally produced) or cross-border. Regardless of whether they involve mandatory or voluntary carbon credits, CDM projects ultimately enable parties to gain emissions reduction credits, which are the basic operational framework for carbon credits.

In July 2015, the Taiwanese Government announced the *GHG Reduction and Management Act*, which established adaptation strategies in response to global climate change to reduce and manage GHG emissions. Taiwan has introduced a number of carbon credit reduction methodologies. Approved carbon reduction projects are referred as offset projects, and methodologies for manufacturing industries and waste handling and disposal have been developed. (TEPA) A comparison between carbon credits methodologies in Taiwan and in other countries are shown in Table 7.

Table 7. Carbon credit methodologies in Taiwan and other countries

	Taiwan	Other countries
Carbon credit methodologies	Domestic reduction methodologies CDM methodologies	CDM methodologies VCS methodologies CAR methodologies
Carbon credit certificates	GHG Emissions Reduction Early Action and Offset Program (previously ratified, has since been abolished) Offset projects	GS VCS CDM
Carbon certificate applicability	Only in Taiwan	In all countries recognizing the above carbon credit certificates

As policy-driven incentives have disappeared and transaction prices for carbon credits have dropped exponentially. The 2017 *State of Voluntary Carbon Markets* reported that the average transaction price per ton of CO_2 in Asia was US $0.70 in 2016. By comparison, afforestation and reforestation carbon credits in Africa reached US $6.70, although the average annual price is only US $3.00. (Office of Sustainable Development, Environmental Protection Administration, 2009). It is worth noting that the carbon credit price per metric ton of CO2 emissions differs according to regions and methodologies. These differences can be attributed to the balance of supply and demand within the market mechanism as well as development costs. Moreover, the operational concept underlying CDM carbon credits, assumes cross-border cooperation whereby developed countries provide support to developing countries out of mutual interest (carbon credit additionality). Using voluntary carbon credit markets as an example, the cost of simple carbon reduction methods, such as wind power generation or solar power generation, is generally low. Moreover, these methods create job opportunities and promote biodiverse carbon reduction undertakings by improving forest management. Carbon credits produced using methods with co-benefits are generally more expensive (Fig. 13). Figure

14 shows the cost of carbon credits in Africa, Oceania, and Latin America are comparatively more expensive than in other countries. It reflects the development cost of the projects and assistance and humanitarian support received in developing regions.

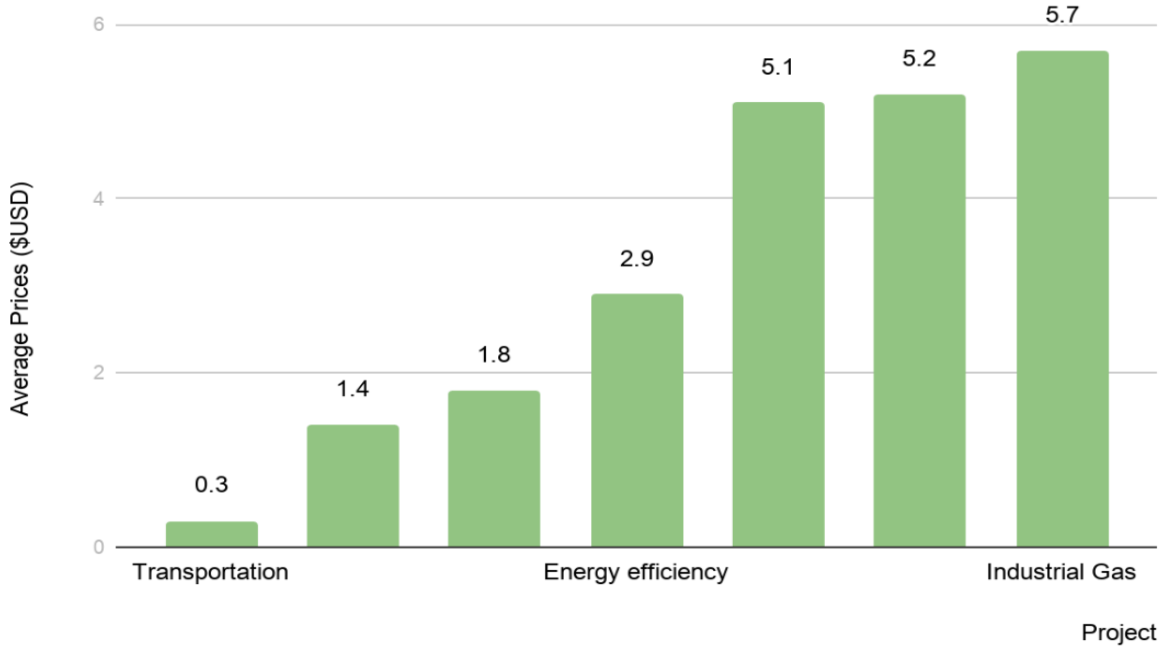


Figure 13. Average prices of voluntary carbon credits based on project type in 2016 (Office of Sustainable Development, EPA, 2009)

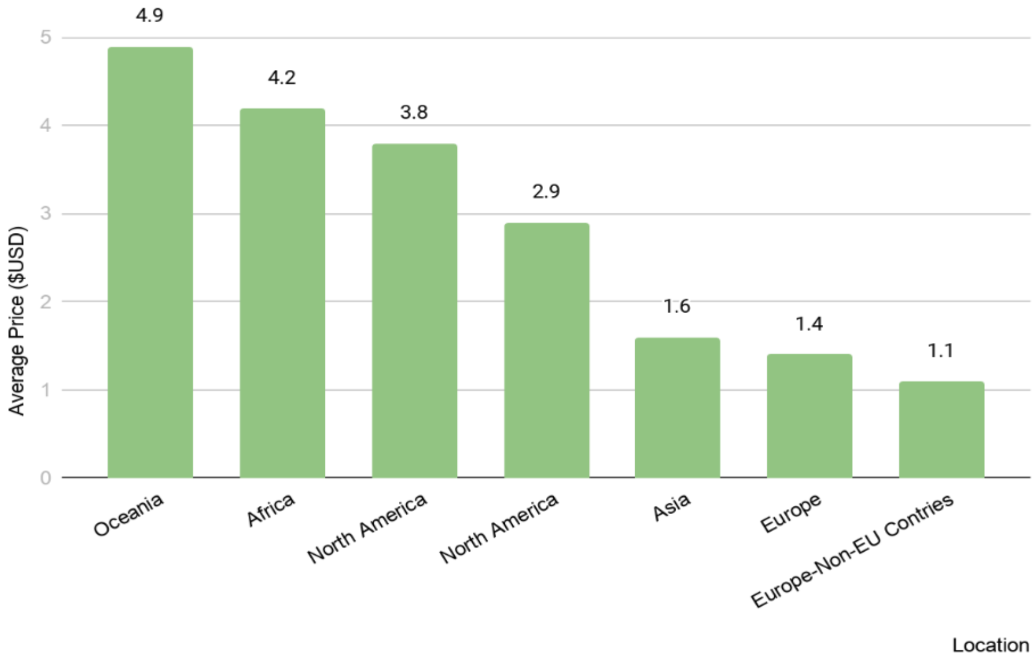


Figure 14. Average voluntary carbon credit prices by region in 2016 (Office of Sustainable Development, Environmental Protection Administration, 2009)

4.3.2 RECs

◆ **What are RECs?**

Power plants were considered as only an electricity supply source in the past. Regardless of plant type (fossil fuel, nuclear, or hydroelectric), the price per kWh of power remained the same. However, fossil fuel power stations has been increased , which produced considerable CO_2 emissions, failed to meet sustainable development goals and make negative impact on the environment, looking for sustainable environmentally benign solution. This subsequently led to the arrival of "post-power era," in which power generation is viewed not only in terms of the power supplied, but in terms of its environmental benefits or lack thereof (Table 8). Power generation methods without CO_2 emissions are devalued as benefitting the environment. Renewable energy is the iconic form of power in the post-power era. Firms are wishing to provide proof that their power is generated from renewable energy sources must obtain RECs.

These certificates signify that a firm's power comes from renewable energy, and the power source generates environmental benefits. Therefore, the REC system involves verification of the equipment used and quantity of power generated. A certificate shows that (a) the power is derived from renewable energy, and (b) the power generation process features environmental benefits. Equation (1) illustrates this relationship:

Power = power (measured in kWh) + environmental benefits (indicated in the REC) (1)

Because fossil fuel power generation has zero environmental benefits, no certification systems are in place for it. There is no certification systems have been developed for nuclear power, though it does not produce sCO_2. The nuclear power remains a highly controversial topic.

Table 8. Power in the post-power era

Power	Features	Measurability	Unit of measure	Policy direction
Electricity	Objective physical existence	Directly quantifiable	kWh	Price/kWh of electricity
Environmental benefits	Subjective consensus	Can be measured indirectly	Corresponds to the amount of CO_2 emissions	Price/kg of CO_2

◆ **Why do we need RECs?**

Power is transmitted through power grids. All power plants, regardless of type, must transmit power through a power grid for public use. As power grids transmit power from a mix of different power sources, an REC system is inevitably the most efficient way to verify that power from a common power grid has been generated using renewable energy. To take an example from another perspective, no complex certification systems are required for biodiesel (a type of renewable energy) used in low carbon transportation. This is because biodiesel is a primary energy form whose quantity can be directly measured. On the other hand, REC system is used for secondary energy whose quantity cannot be directly measured.

The REC system can provide statistical data for specific aspects of renewable power, such as the source of the power (i.e., the power generation facility in which the renewable power is generated), the location of the power generation facility, the owner(s) of the power generation facility, the power generation method, power generating capacity, the first day of operation facility, and power generation time. Therefore, REC can be viewed as statistical proof to use renewable power and an indicator that the renewable energy used produces zero carbon emissions. Renewable energy power plants supply power to the public (the most basic function of all power plants), whereas the REC system provides statistical proof of renewable energy usage (along with verification that the renewable energy features environmental benefits). In the EU, RECs and power certificates may be applied separately.

RECs are linked to the power grid. Thus, they are local and regional-based, and limited by the scope of the power grid. One of the objectives of RECs is to confirm that the power source used is renewable. Therefore, RECs facilitate rapid regional renewable energy development.

1. Who needs a REC?

When government policies involve quantifying via residual mixed power emission coefficients, firms using renewable energy, must obtain RECs. Residual mixed power emission coefficients are explained in detail in the section below. According to GHG Protocol Scope 2 Guidance, the definition of renewable energy is representing the property right to the environmental, social, and other non-power-related properties generated by renewable power. (Mary Sotos, 2015)

4.4 Comparing carbon credits and RECs

A basic understanding of carbon credits and RECs allows us to recognize that both are used as proof of carbon reduction and can be quantified and priced. We compare the carbon credits and RECs by exploring its applicable scope, management of total amount of carbon/renewable energy used, objectives, output/calculation method, pricing methods, certification costs, price, additionality, carbon leakage risk (security), and scale (Table 9).

Carbon credit certificates are made to achieve global carbon reductions goal. Therefore, in designing the CDM, a cross-regional cooperation model was adopted in which actual carbon reductions in a given region might differ from stated goals. RECs can be utilized in conjunction with regional renewable power policies to effect carbon reductions. The introduction of RECs, facilitates the transformation of power generating structure of a country, and inevitable result in carbon reduction.t The fields of applicability of these two carbon reduction tools are even more different. Carbon credits may be transnational (e.g., CDM) or local (e.g., VCS), whereas the scale of RECs is limited to the range of a power grid in a single area.

RECs work to control total carbon emissions via indexing the quantity of renewable energy used against the total amount of power consumed. Because the total amount of renewable energy used in a closed system (e.g., a regional power grid) is quantifiable, carbon reduction management is relatively simple and carbon leakage is less likely to occur. In contrast, carbon credits are not based on the concept of the total amount of carbon used. Instead, they operate in an open system (the world) where the concern is global carbon reductions. Thus, actual carbon reductions (i.e., the physically quantifiable amount) may be lower in a given region than stated. However, this discrepancy can be managed through system design. For example, according to the GHG Reduction Act, Taiwan may offset 10% of its carbon emissions through the purchase of carbon credits from a foreign country via a mechanism such as the CDM. If we assume that Taiwan's CO_2 emissions are 100 units, then the purchase of 10 CDM units from Africa will decrease Taiwan's CO_2 emissions to 90 units (100-10). This is helpful for global carbon reduction but does not change Taiwan's actual carbon emissions. Thus, the public may not have a strong perception that reductions have been achieved.

Previous carbon credit endeavors have mostly been in the form of projects involving scenario-based planning and verification in accordance with baselines to ensure that the planned carbon reduction amounts are achieved. However, this type of approach involves the calculation of anticipated carbon reductions in the future. In fact verification on a regular basis is an important factor in ensuring sustained carbon reductions. Because of the high cost of verification and the complexities involved in differing calculation methods employed for different projects, verification may not be performed regularly and may be implemented incorrectly, leading to carbon leakage risk (because RECs can be indexed, the risk of this scenario is low).

In 2016, the average price of the voluntary carbon credit of one ton of CO_2 equivalent (CO_2e) was US $3.00. According to Taipower's power emission coefficient calculations at that time, one unit of I-REC denoted a reduction of 529 kg in CO_2e. In other words, a reduction of one ton of CO_2e was equal to 1.89 units of an I-REC, which based on an average price of US$5 in 2016, signified a cost of approximately US$9. Therefore, the REC method resulted in a higher market price per ton of CO_2e than the carbon credit certificate method did. It should be noted that the 2016 GHG Protocol Corporate Standard (revised version) stipulated that companies under Scope 2 may use RECs (including RECs, I-RECs, TIGRs, and GOs) with indirect emissions as a measure to offset their CO_2 emissions. In contrast, carbon credits from renewable energy projects cannot be used to offset CO_2 emissions.

Table 9. Comparison of carbon credits and RECs

	Carbon Credit	REC
Type of Certificate	Carbon reduction certificate	Carbon reduction certificate
Scope and Limitations	Transnational (e.g., CDM for Kyoto Protocol participating nations); voluntary carbon credits such as VCS and GS meet transnational and local market demand	Limited to countries with power generating capacity or regions supported by power grids
Management Basis	• Not based on concept of total carbon amount. • Open system; concern is global carbon reduction. • Real/listed regional carbon reductions may differ. • Discrepancies managed through system design.	• Based on total amount of renewable energy used indexed against total amount of power used • Quantifiable closed system (regional power grid) simplifies carbon reduction management • Less carbon leakage
Objectives	To reduce carbon globally (long-term goal)	• To help countries meet their renewable power ratio • To help countries transform their power generating environment (short-term goals)
Output Method	Multiple (methodologies)	Single (renewable energy)

Calculation Method	• Scenario-based comparisons • Future-oriented	Based on actual power generated
Pricing Method	• Differs according to carbon credit source type and location • Determined by market mechanisms	Determined by market mechanisms of country or territory where certificate is located
Certification Cost	High	Low
Price	Approximately US$3/ton (State of Voluntary Carbon Markets, 2017.)	Approximately US$9/ton
Additionality	Normal	High
Carbon Leakage Risk	High	Low
Scale	Transnational: CDM, VCS, and GS Local: VCS and GS	Limited to regional power grids

Power emission coefficients must be used as conversion factors between power and CO_2 when calculating Scope 2 emissions. A simplified equation is provided below:

$$Power\ Emission\ Coeffient = \text{"}Total\ Carbon\ Dioxide\ /\ Total\ Power\ Generated\text{"} \quad (2)$$

In countries that do not promote the REC system, power emission coefficients are the key factors reflecting overall renewable energy ratios. Renewable power increases power without increasing CO_2 emissions, it decreases the power emission coefficient and increases renewable energy ratio. This creates the false impression that carbon reduction has been achieved. An example is provided below using the Scope 2 emissions method with carbon credits, assuming that a region generates power using both fossil fuels and renewable energy, the power thus generated and the resulting carbon emissions will be as shown in Table 10.

Table 10. Data settings and analyses for Scenarios 1 and 2

	Fossil fuel power		Renewable energy		Emissions factor	Residual mixed
	Power generated (unit)	Carbon emissions (unit)	Power generated (unit)	carbon emissions (unit)		
Scenario 1	100	100	20	0	100/120 = 0.83	100/100=1
Scenario 2	100	100	30	0	100/130 =0.77	100/100=1

In carbon credit calculations, the basic assumption is that the use of one unit of renewable power can replace carbon emissions produced by one unit of fossil fuel power, thus achieving the goal of carbon reduction. In Scenario 1, renewable energy produces carbon credits equivalent to the carbon emissions generated by 20 units of fossil fuel power. In Scenario 2, the renewable energy is increased to 30 units without changing the number of units of fossil fuel power (i.e., 100 units). Theoretically, for the substitution effect to occur, fossil fuel power generation should be reduced to 90 units in this scenario (i.e., a total of 120 units of power). Thus, while the 30 units of carbon credits creates the illusion of carbon reduction, actual carbon reduction is not achieved. Herein, lies the problem with using carbon credits, the concept is based on assumptions that are not entirely sound.

Although the emissions coefficient was decreased in Scenario 2, total carbon emissions did not decrease. When economic conditions are kept constant, low electricity prices may result in non-economical and inefficient use of electricity, thereby increasing total carbon emissions. In contrast, if production volume increases but fossil fuel generated power remains constant (i.e., there is only an increase in renewable power), a substitution effect takes place, and the a priori assumptions of carbon credits are satisfied. The 10 extra units (30-20) of carbon credits reflect actual carbon reductions. Unfortunately, because economic conditions are often impossible to confirm, carbon reductions cannot be accurately assessed using only power emission coefficients.

Therefore, when promoting the REC system, the concept of a residual mixed power emission coefficient must also be introduced:

$$Residual\ Mixed\ Power\ Emission\ Coefficient = \frac{Total\ Carbon\ Dioxide\ Emissions}{Total\ Power\ Generated - REC} \quad (3)$$

Where REC = Power generated, corresponding to the annual REC issued

The use of a residual mixed power emission coefficient allows firms with RECs (i.e., those that practice carbon reduction) to be distinguished from those without RECs, and vice versa. For companies without RECs, residual mixed power emission coefficients can be used to share CO_2 emissions. The carbon reduction results of firms with RECs can be quantified, enabling them to possess “real carbon credits” with applicable carbon reduction effects. This is the advantage of the REC system over the carbon credit system. The latter involves calculating carbon reduction based on hypothetical assumptions, resulting in carbon credits that may not accurately reflect actual carbon reductions. Carbon credits can be quantifying if obtained via the REC system. Companies without RECs may only use residual mixed power emission coefficients to calculate their CO_2 emissions. In a country with REC system, power emission coefficients (i.e., no nuclear power) can be completely decoupled from renewable energy to become coefficients based solely on fossil fuel power.

4.4.1 Case scenarios

RECs and carbon credits are the basic tools to quantify carbon reduction and environmental benefits. The environmental benefits of power generated with renewable energy can be indicated via RECs or in the form of carbon credits. However, one of them can be used to avoid the double counting. An electronics industry that generates and uses its own solar energy, has been used to illustrate the relationships between carbon reduction, T-RECs, and carbon credits.

1. **Scenario:**

The manufacturing firm with indirect GHG emissions, possesses its own solar power generation system, which produces and utilizes 100 units of renewable power per year. The power generated is not included in (Taipower's power pricing and purchasing system. Assuming that this firm also produces one unit of fossil fuel power (which would create one unit of CO_2 emissions), would it be considered to have achieved carbon reductions?o Possess carbon credits? Have T-RECs? The answer to all three of these questions is "yes". However, carbon credits and T-RECs cannot both be adopted, and T-RECs may be used to offset Scope 2 GHGs.

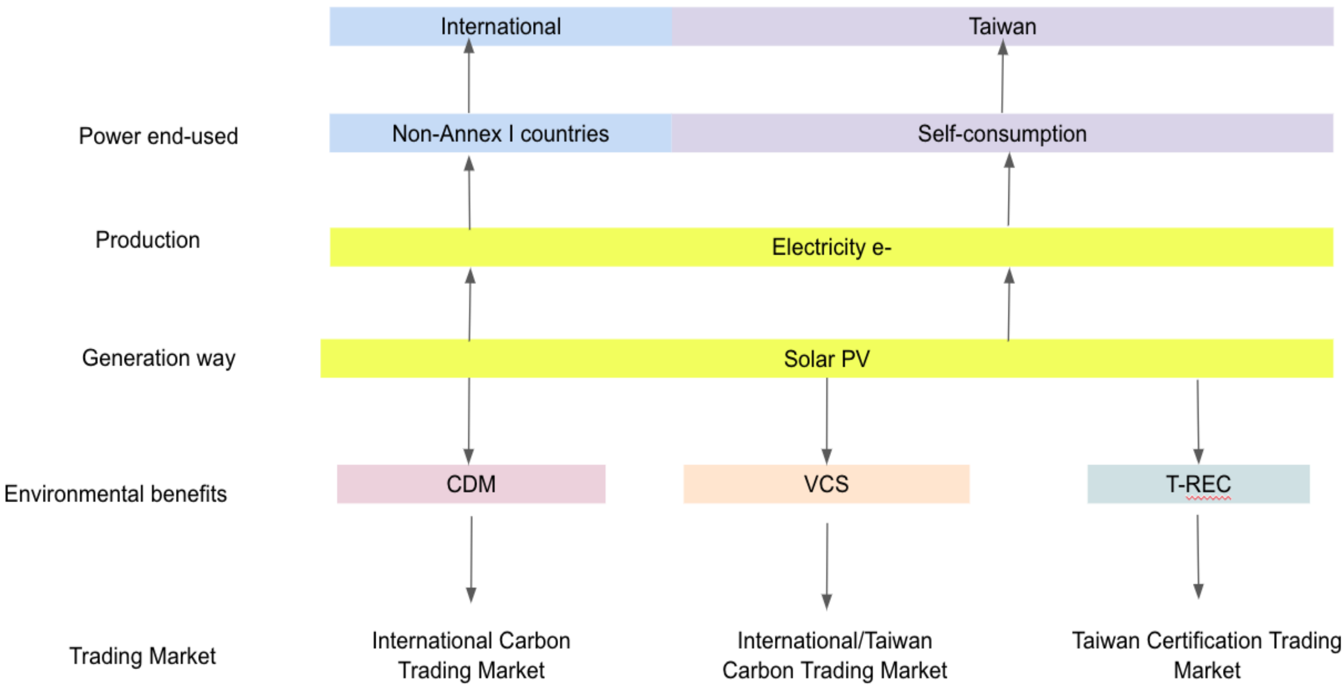


Figure 15. Comparing RECs with carbon credits obtained from power produced with renewable energy

Figure 15 shows that a solar power system may be used to produce CER carbon credits (through CDM transnational mechanisms), VCS or GS carbon credits (through Taiwan's own voluntary carbon credit system), or T-RECs (through Taiwan's T-REC system). Since this company generates and uses its own solar power, it may use its carbon reduction results to obtain T-RECs. This company would be certified with zero carbon emissions industry due to avoiding fossil fuel power. Therefore, its carbon disclosure declaration shows zero carbon emissions from power generation. However, if the company converts its carbon reduction results to T-RECs, it trades away its emissions reductions to the buyers. In other words, the power originally generated and used by the firm is viewed as fossil fuel power rather than renewable power, despite the fact that physically, it was solar power. If the company holds on to its T-REC reserves, it will retain its carbon reductions and environmental benefits.

In Taiwan, most firms that currently generate and use their own power, because they want to reduce carbon. These firms are desired to produce environmental benefits by generating power via renewable energy. As a result, these firms are unlikely to voluntarily trade away their T-RECs. Thus, the liquidity of T-RECs on the market most likely will be very low in the future, because these firms are unable to further reduce carbon emissions and will be unwilling to sell their carbon credits. These firms generate power while retaining environmental benefits, making their personally-owned REC bundles. Nevertheless, should they sell their T-RECs, they would be considered to have forfeited their environmental benefits, thus making their T-RECs typical unbundled RECs.

1. Conclusions

a. To achieve carbon reductions, the Kyoto Protocol stipulated that countries with reduction targets (i.e., developed countries) may purchase CER carbon credits to offset their carbon emissions to meet their quotas. However, policy-induced incentives have evaporated and carbon credit transaction prices have dropped drastically in recent years. In 2016, the average price of voluntary carbon credits in Asia was US$0.7 per ton of CO_2 equivalent. In addition, the average price of carbon credits for afforestation and reforestation in Africa was merely US$3.0, despite a price ceiling of US$6.7.

b. In general, the price of carbon credits awarded to simple carbon reduction endeavors such as wind power or solar power are lower than those provide employment opportunities or increase biodiversity like forest management improvement. This is because the latter include added co-benefits. Carbon credits in Africa, Oceania, and Latin America are higher than rest of the world. Such a phenomenon reflects the costs of carbon credit project development and humanitarian assistance and the support offered to developing regions.

c. The REC system involves assessing the renewable energy equipment used and quantity of power generated. The certificate shows that: (a) the power is derived from renewable energy, and (b) the power generation process features carbon reduction benefits. All power plants, regardless of type, must transmit power through power grids for public use. Because power grids transmit power from a mix of different power sources, the REC system is inevitably the most efficient way to verify that power from a common power grid has been generated using renewable energy. Current major domestic and foreign RECs include T-REC, REC, GO, and I-REC.

d. Carbon credit certificates are in scope globally. Therefore, in designing the CDM, a cross-regional cooperation model was adopted in which actual carbon reductions in a given region might differ from listed reductions. RECs are incorporated into regional renewable power policies to reduce carbon. The two abovementioned carbon reduction tools are used on different scales. Carbon credit certificates may be transnational (CDMs) or locally based (VCS), whereas RECs are used only in countries with power generating capability or regions supported by power grids.

e. RECs adopt the concept of the total amount of renewable energy used compared with the total amount of power consumed as a method of controlling total carbon emissions. The total amount of renewable energy use in a closed system (the power grid of a region) can be quantified, carbon reduction management is relatively simple and carbon leakage is rarely occurred. Carbon credit certificates do not reflect the total amount of carbon used. They operate in an open system (the world) where the concern is global carbon reductions. Physically quantifiable carbon reductions may be less in a particular region than is recorded.

f. Previous carbon credit activities have mostly been in the form of projects, involving scenario-based planning and verification in accordance with baselines to ensure that the planned carbon reduction amounts have been achieved. The high cost of verification and the complexities involved in differing calculation methods employed for different projects, verification may not be performed regularly and may be implemented incorrectly, leading to carbon leakage risk (because RECs can be indexed, their risk is low).

g. When promoting an REC system, residual mixed power emission coefficients must be introduced to replace the simple average power emission coefficients of the past. The use of residual mixed power emission coefficients allows firms with RECs to be distinguished from those without, and vice versa. The carbon credit system may not accurately reflect companies' carbon reduction, but the REC system does. In a country with an REC system, power emission coefficients (i.e., no nuclear power) can be completely decoupled from renewable energy to become coefficients based solely on fossil fuel power.

4.5 Summary of findings

4.5.1. Taiwan's green power purchase system vs. international standards

In response to the domestic demand for green power, the BoE, began a trial of the Green Power Purchase System on July 1, 2014, but due to high cost, only 4.24 million kWh of green power sold in the first year, and 73% was purchased by the same corporation. However, most of the domestic demand for renewable energy come from businesses. In 2015, the government began the vigorous promotion of green power purchases to businesses, and thus, the sales of green power in the following years rose steadily. However, there is a hidden dilemma that leaves each of the green power purchasing corporations helpless.

The 21st COP to the UNFCCC was held in Paris and the Paris Agreement was achieved before the conclusion of the meeting. Once again, this raised the issue of climate change to its highest point of attention in the international community. To meet the world's trend and the stakeholders' expectations, corporations from all countries are investing in the reduction of carbon emissions and/or the use of renewable energy, in order to get a high CSR or CDP score. Taiwan's local corporations are no more exception. Corporations are actively participating in ISO-14064-1, which is commonly known as the Organization's GHG Inventory, to understand the various types of carbon emissions made at the organization level. Many corporations are also voluntarily participating in the CDP and filling out an annual questionnaire, disclosing information such as the corporation's internal carbon emissions, their renewable energy consumption, and their strategies for dealing with climate change. Conducting the organization's GHG inventory or filling out CDP questionnaires are both becoming a trend. The well-known international companies already implemented these practices as part of their annual routines. In addition, customers have already started to ask companies to require those suppliers within their upstream and downstream supply chains that have not yet disclosed their carbon emissions to voluntarily take the initiative of filling out the CDP questionnaires. As an OEM export-oriented country, Taiwan also has some companies that have already been asked by downstream customers to make concrete, follow-up steps in combating climate change.

In Taiwan, the electricity used by corporations is their main source of carbon emissions. For instance, companies in the electronics industry started taking their organizations' GHG inventory recently and they found that 90% of their internal carbon emissions come from their electricity consumption. Therefore, they started to look for available green energy sources to reduce their carbon emissions. The VGPPP of the MOEA naturally became one of their options to fulfill those purchases. However, many corporations that purchased green power from the MOEA expressed that the green power they purchased could not be recognized by their organization or could not be accredited as green power by a third-party inspection agency. As a consequence, they could not effectively declare their carbon emission reductions, such as the

CDP questionnaire in international meetings.

Corporations may have purchased from “green energy” sources approved by the government, but they cannot declare the use of “green energy” internationally. Why? The main reason why the green power of MOEA cannot be accredited internationally is that the details of each kWh generated and used are not properly documented. In order to be accredited internationally, companies must comply with the specifications of GHG Protocol Scope 2 Guidelines, which indicate that the green power must have a tracking system. That is why the energy source of the power plant shall be identified for each kWh of green power generated, and distinguished from other power sources to avoids circumstances such as the selling of electricity that has not been generated or double counting. However, once the corporations purchased green power from the MOEA and received green power purchase certificates issued by Taipower, they discovered that besides the total kWh purchased, there was no other information on the certificates. Therefore, it is not possible to identify which renewable energy plant produced the green power, or to prove the repeated purchases.

4.5.2. Trends of green power consumption internationally: Bundled and unbundled

Consuming green power does not mean the electricity has to be directly transmitted to the end users through a wire. In practice, the international trends of green power can be generally divided into two types: bundled and unbundled.

“Bundled” is referred as “wheeling” or “direct purchase” in the market. It is the combination of the electricity itself and all the environmental benefits of green energy (such as zero carbon emissions), represented in each transaction. Operationally speaking, when a user purchases environmental benefits from a power plant, at the same time he/she pays the power plant for the power purchased, the transactions between the user and the power plant are direct. However, the electricity consumed by the user is still transmitted through the power grid. The costs and other details of transmission are negotiated between the power plant and the transmission and distribution companies. Thus, the user does not need to conduct transactions with the power grid. The more mature the electricity free market is, the more likely it is to have these type of power transactions. The EU's electricity market is an example of a market with a more complete system.

An "unbundled" situation is when the user purchases green power but the electricity is purchased apart from its environmental benefits. The user pays the transmission and distribution companies to purchase the electricity, and pays the power plant to purchase the environmental benefits. These two transactions combined also achieve the goal of purchasing green power. In the case of unbundled, electricity is still purchased in the traditional way, but the environmental benefits of the transactions are mostly presented as REC. Ownership of this certificate can be used to declare the environmental benefits of a certain amount of electricity that has been purchased. Therefore, the unit of the certificate is an electric quantity (such as kWh, MWh, etc.), and the certificate will specify the number of each kWh, the type of electricity source such as wind power or solar energy, etc., to avoid the double counting problem on different types of certificates. Regarding the method of purchasing RECs, it is usually the product that first appears in the emerging electricity market to satisfy the green power requirements of consumers before the unbundled transaction mechanism is established.

4.5.3. Bringing Taiwan's green power certificate system in line with international standards

As mentioned above, REC separates the environmental benefits from renewable energy, so that users can purchase the environmental benefits directly and declare as per their wish. For example, a corporation can purchase RECs directly when doing their inventories, and even if the actual used power was gray electricity (i.e., it is uncertain that it came from a renewable source), the corporation can declare that they have paid the costs of purchasing green energy with REC. In addition, the REC will clearly mention the selling power plant, serial number of power generation, type of power generation, the emission coefficient, and other relevant information about the total amount of green power purchased by the corporation. Therefore, if necessary, it will be possible to trace the electricity's origin, production and double counting.

Currently, most of the RECs in the world are set by governments, and are only used in specific regions, such as the RECs of the United States, GOs of the EU, and GECs of Japan, etc. Taiwan still does not have a national REC that is legally regulated and in compliance with the international standards that can be used for carbon inventory deduction. At present, the I-REC standard can be used by a country or region that has not yet established a REC System. This standard has also been approved by the GHG Protocol and CDP calculation guidelines. Taiwan is in the process of establishing a certificate system for green power or renewable energy, and the international REC can serve as reference.

4.5.4. Gradually moving toward liberalization of the electricity industry

The REC is only tool to catalyze the liberalization of the electricity market buts not the ultimate goal. In terms of the voluntary purchase of green power, a sound certificate system should not only satisfy the buyer's demand for green power, but also avoid double counting. In order to create a competitive market for electricity liberalization, the government should not only continue to refer to the sustainable development goals and regulations issued by the UN, but also create domestic policies that comply with international standards. It also will need to separate the electricity generation and retail industry from the transmission and distribution industry, and manage the dispatch mechanism of the transmission and distribution sector. Moreover, the government should provide an effective coordination mechanism for electricity transmission and distribution companies, and safeguard free competition among the electricity generation companies and electricity retailing companies. It should no longer hinder the free market with existing "electricity retailing utility companies (or electricity generation utility companies)." On top of these points, the timing of market liberalization measures must also be carefully considered. Passing the third reading of Amendment to the Electricity Act Phase I was only the beginning. We are still waiting for the enforcement rules for the Electricity Act to be promulgated. In order to achieve the sustainable goals of the country and businesses, the government and the private sector must work together in order to be prepared for the global environmental crisis that we will soon face, and lay the proper foundation for the energy sector before the impacts are felt.

Chapter 5 Innovative applications of market instruments

Renewable energy development often needs support from the public sectors in the early stage, as discussed in previous chapters. This chapter will discuss and present the use of RECs in two occasions and the impact on the policy implementations of renewable energy development. The first section is to examine the interaction of REC with power grid EF, followed by the discussion on the necessity of grid connectivity of RE devices from which RECs are generated. The second section is to explore the potential and possibility of the utilization of RECs as a mean of (BAT).

5.1 Impact of RECs on electricity EFs

The algorithm of electricity Emissions Factor (EF) calculations are based on the 2006 IPCC guidelines for national GHG inventories and the fourth assessment report. For example, Taiwan's 2016 electricity EF is 0.529 kg-CO_2e/kWh according to the BOE. In extreme cases, if a country supplies its entirely electricity by renewable energy, there will be no CO_2 emission resulting in zero EF. In general, a reduction in a country's electricity EF often means increased use of renewable energy. The electricity EF also represents indirect CO_2 emission intensity from the use of electricity. The following is a simplified formula of the algorithm:

$$Electricity\ Emissions\ Factor = \frac{Total\ Carbon\ Dioxide\ Emissions}{Total\ Power\ Generation} \qquad (1)$$

Total power generation = thermal power + nuclear power + power from renewable sources sold in that year.

This chapter aims to use scenario-based calculations to demonstrate loopholes in the existing T-REC framework that could cause reverse incentive and policy failure through "free-rider effect" (i.e., people taking advantage of a common resource without paying for it) and "outsider effect" (i.e., value changes in a market caused by unrecorded or excluded outside factors). We also provide recommendations on how the ambiguity could be corrected through simplified scenario-based demonstrations. To focus solely on the problem, this article does not discuss the effectiveness of renewable energy certification system in reducing GHG emissions.

5.1.1 Parameters and condition setting

In order to illustrate the use of RECs and its impact on changes of EF calculation, the power market in Taiwan is simplified and the following simulation and analysis are performed. The three scenarios include:

- Scenario I: REC scheme is not in place, therefore the volume of REC applied is 0;
- Scenario II: REC system is in place;
- Scenario III: RECs from off-grid devices are included.

For the simplicity of analysis, the following terms are assumed:

1. Upon the achievement of the Nuclear-free Homeland goal by 2025, the sharing of nuclear power in the primary energy will be 0. The remaining will be total power generation = thermal power + power from renewable sources.
2. Composition of total power generation in Taiwan is 80% thermal power and 20% power from renewable energy. Each unit of thermal power corresponds to one unit of CO_2 equivalent, and the CO_2 emission from renewable energy is zero.
3. Each unit of power from renewable energy can generate 1 REC unit.
4. Taiwan's annual power generation totals 100 units of power. The total CO_2 emissions and total units of REC are summarized in Table 11.
5. Taiwan's total power generation are provided to five companies, namely A, B, C, D and E, for production purposes. The companies have the same power consumption of 20 units.

Table 11. Basic parameters of scenario analysis

	Unit of power generation	CO_2 emission equivalent	Available RECs
80% thermal	80	80	0
20% renewable	20	0	20
Total	100	80	20

5.1.2 Scenario analysis

Scenario I. Taiwan does not implement an REC system, and REC units = 0

Taiwan's electricity EF can be calculated as 0.8 from Equation (1) and Table 12.

$$Residual\ Mix\ EF = \frac{Total\ Carbon\ Dioxide\ Emission}{Total\ Power\ Usade\ with\ RECs} = \frac{80}{100} = 0.8$$

Therefore, the CO_2 emission of each company is the individual electricity usage multiplied by the EF.

Table 12. CO_2 emission analysis for each company in Scenario

Company	Unit of power usage (A)	Electricity factor (B)	CO_2 emission equivalent (C = A×B)
A	20	0.8	16
B	20	0.8	16
C	20	0.8	16
D	20	0.8	16
E	20	0.8	16
Total	100		80

Although Taiwan has just implemented the T-REC system, the actual effect has not yet shown up (to be further explained in the analysis of Scenario III). Therefore, Scenario I is similar to the current situation in Taiwan. That is why, all companies use the same electricity EF. The carbon reduction effect of the 20 units of electricity from renewable energy is shared evenly by all companies. This gives rise to several questions worth pondering. First, what is the major source of renewable energy power? It is the high-cost green power purchased by Taipower at FiT rates? In other words, the carbon reduction effect is subsidized by taxpayers. Is it fair that businesses gain the carbon reduction benefits without any effort? On the other hand, the green electricity tariff is intended to prove the renewable sources of electricity consumed by a company through the purchase of green power. It is in fact a counteraction against the aforesaid unfair practice. However, the current situation is that buyers cannot reap the benefits of the carbon reduction by using them as the basis for offsetting the company's CO_2 emissions, resulting in another kind of injustice.

Scenario II. Taiwan implements an REC system

RECs represents renewable energy power certification, which allow their holders to use them as offsets against carbon emissions. Therefore, when calculating the total power generation, the REC units purchased by a company must be deducted first. This concept is called the "residual mix power" in the GHG Protocol Scope 2 Guidance, which is the "residual" electricity in the power grid not allocated to specific end customers and not used up by other renewable energy customers. If the source of electricity purchased by a customer is not certified by a reliable tracking certificate, the power purchased is the residual mix power. Therefore, adjustments have to be made in the calculation of the electricity factor, and this is called the residual mix EF.

$$Residual\ Mix\ EF = \frac{Total\ Carbon\ Dioxide\ Emission}{Total\ Power - Total\ Usage\ with\ RECs} \qquad (2)$$

Where REC represents the renewable power certificates issued in the year.

Taiwan's electricity EF can be calculated from Equation (2) and Table 12. The figure can be obtained in the annual settlement.

$$Residual\ Mix\ EF = \frac{Total\ Carbon\ Dioxide\ Emission}{Total\ Power - Total\ Usage\ with\ RECs} = \frac{80}{100-20} = 1.0$$

This result shows that when an REC exists and is held by a company, the electricity EF will increase because the REC holder has obtained the corresponding offsets against the CO_2 emissions from thermal power generation. Consequently, those who do not hold a REC have to bear the carbon emissions from thermal power generation.

Assuming that Company A has purchased all 20 REC units, the companies' CO_2 emissions are then calculated by multiplying their respective power consumption by the residual mix EF and then deducting the REC value, as shown in Table 13:

Table 13. CO_2 emission analysis for each company in Scenario II

Company	Original power usage (A)	No. of RECs (B)	Adjusted residual mix electricity (C, C=A-B)	Residual mix EF (D)	Renewable electricity factor (E)	CO_2 emission equivalent (F=(B×E)+(C×D))
A	20	20	0	1	0	0
B	20	0	20	1	0	20
C	20	0	20	1	0	20
D	20	0	20	1	0	20
E	20	0	20	1	0	20
Total	100	20	80			80

Comparing the results of Scenario I and Scenario II, it can be seen that:

1. The total CO_2 emissions are a physical fact. It will not change because of the design of

the system (with or without RECs). Therefore, the total emissions are 80 units of CO_2e.

1. The design of the system affects the value of the electricity EF. An REC system can substantially reflect the CO_2 emissions from thermal power generation. Withoutn REC system, the electricity EF is diluted by the zero emissions from renewable energy and cannot accurately reflect the actual carbon reduction effect, attributable to thermal power generation. It means, thermal power can also achieve the effect of CO_2 reduction by adopting appropriate reduction technology or enhancing energy efficiency, but this effect cannot be directly reflected in the electricity EF unless the contribution of renewable energy is deducted.
2. Through REC system, companies that are willing to contribute to carbon reduction rather than being free riders, can be identified.
3. In the absence ofn REC system, the more power generated from renewable energy, the lower the electricity EF. As far as the companies are concerned, a lower electricity EF is more favorable for their carbon disclosure report. However, the government and taxpayers at the current stage are concerned, more renewable electric power means more FiT subsidies. That is why, all taxpayers are footing the bill. Businesses enjoy the environmental benefits of using electricity without having to bear the cost of subsidizing the renewable electricity. This unfair phenomenon is called the Free Rider Effect.
4. A relatively fairer practice is adopting the user-pay principle, without requiring the government to subsidize renewable energy. In other words, through REC system, users announce their use of renewable electricity by purchasing RECs. For those who have not purchased RECs (i.e., who are not willing to bear the cost of environmental benefits), their CO_2 emissions are calculated using the residual mix EF which deducts the power generated from renewable energy. The higher factor reflects their higher CO_2 emissions. Therefore, under the same conditions, the users of green power have a lower figure in their carbon disclosure report, while those who do not use green power have a higher reported value, reasonably reflecting the actual situation.

Scenario III. Issues relating to the self-generate self-use approach to T-REC

The current T-REC adopts the self-generate self-use approach or non-FiT subsidized electricity, i.e., companies build their own renewable energy power facilities to meet their own electricity needs, and convert them into certificates. Such power sources show the power generated from renewable energy by the companies, which is not incorporated into Taipower's power grid, and so not recorded in Taipower's total power generation. These are independent power systems. Here, we assume that Company B has a self-generate self-use electric power system with a capacity of 10 electric power units. Therefore, it can generate 10 government-accredited T-RECs, which can be used as offsets against CO_2 emissions, as shown in Table 14.

Table 14. Basic parameters of scenario analysis when there is an independent electricity system outside the Taipower grid

Capacity	Unit of power generation	CO_2 emission equivalent	Available RECs
80% thermal	80	80	0
20% renewable	20	0	20
Total	100	80	20
Company B, self-generate self-use	10	0	10 (T-REC)

The self-generate self-use electricity is not included in Taipower's capacity, and the calculation data for the residual mix EF does not include the self-generate self-use electricity:

$$Residual\ Mix\ EF = \frac{Total\ Carbon\ Dioxide\ Emissions}{Total\ Power\text{–}Power\ Usage\ with\ RECs} = \frac{80}{100-20} = 1.0$$

Assuming that Company B sells its 10 units of T-REC to Company C, then the CO_2 emissions of the companies are shown in Table 15. Company B's number of RECs is zero, and

Company C has its carbon emissions reduced because of the purchased T-RECs.

Table 15. CO_2 emission analysis for each company in Scenario III (bias due to neglect of the outsider effect)

Company	Original power usage (A)	No. of RECs (B)	Adjusted residual mix electricity (C=A-B)	Residual mix EF (D)	Renewable electricity factor (E)	CO_2 emission equivalent (F=(B×E)+(C×D))
A	20	20	0	1	0	0
B	20*	0	20	1	0	20
C	20	10	10	1	0	10
D	20	0	20	1	0	20
E	20	0	20	1	0	20
Total	100	30	70			70

*This is Company B's original power usage, purchased from Taipower, not including the self-generate self-use electricity.

As mentioned above, the amount of Taiwan's total emissions is a physical objective fact, that does not change because of the system design. However, we can see here Taiwan's total CO_2 emissions being reduced by 10 equivalent units to 70 equivalents from the original 80 equivalents. This is obviously erroneous (or illusionary). It is the Outsider Effect, which means that when there is no proper verification mechanism, the calculation of the total CO_2 emissions will be distorted by the RECs, outside the power grid due to double counting.

Table 16. The correct CO_2 emission analysis for each company in Scenario III: assuming Company B sells the T-RECs to Company C

Company	Original power usage (A)	No. of RECs (B)	Adjusted residual mix electricity (C=A-B)	Residual mix EF (D)	Renewable electricity factor (E)	CO_2 emission equivalent (F=(B×E)+(C×D))
A	20	20	0	1	0	0
B	20*	0	20	1	0	20
B (Self-generate self-use)	10	0	10	1	0	10
C	20	10	10	1	0	10
D	20	0	20	1	0	20
E	20	0	20	1	0	20
Total	110	30	80			80

The truth is that the self-generate self-use renewable electricity does not use thermal power, and thus has zero carbon emissions. Therefore, the carbon emissions from this part of electricity consumption is zero in the carbon disclosure report. However, a company's environmental benefits from emission reduction (relative to thermal power) will be traded out to the purchaser together with the T-RECs when the carbon reduction benefits are translated into T-RECs. Therefore, the true carbon balance analysis should look like the one shown in Table 16, where the original self-generate self-use electricity from renewable energy is regarded as thermal power (as shown in the "B self-generate self-use" row in Table 17). On the other hand, if Company B keeps its T-RECs, the environmental benefits will remain with Company B, while the carbon emission remains zero, and the result will look like the one shown in the "B self-generate self-use" row in Table 17.

Table 17. The correct CO_2 emission analysis for each company in Scenario III: assuming Company B keeps the T-RECs

Company	Unit power usage (A)	No. of RECs (B)	Adjusted residual mix electricity usage (C, C=A-B)	Residual mix EF (D)	Renewable energy factor (E)	CO_2 emission equivalent (F=(B×E)+(C×D))
A	20	20	0	1	0	0
B	20*	0	20	1	0	20
B (Self-generate self-use)	10	10	0	1	0	0
C	20	0	20	1	0	20
D	20	0	20	1	0	20
E	20	0	20	1	0	20
Total	110	30	80			80

From the analysis of Table 16 and Table 17, the following can be concluded:

1. Correctness of this analysis is dependent upon the premise that there is a self-generate self-use independent power system outside Taipower's grid system, i.e., the mutual verification of the REC issuing authority and the competent authority in charge of calculating the electricity EFs, is of critical importance.
2. If a company's self-generate self-use electricity is intended for carbon reduction, i.e., for acquiring the environmental benefits of renewable energy power generation, then the "willingness to trade" the self-generate self-use T-RECs will be very low, or the T-RECs will have very low market liquidity in the foreseeable future. The reason is simple, why would a company want to sell the hard-won CO_2 emission offsets that are hardly enough for its own use? In this circumstance, the original T-REC holders (proprietors with self-generate self-use electricity) not only use the self-generated electricity, but also keep their

environmental benefits. The T-RECs owns are actually an “exclusive” bundle of RECs.

3. If an original holder (proprietor with self-generate self-use electricity) is willing to sell its T-RECs, it means that the electricity generated from renewable energy is used, but its environmental benefits are given up, and the T-RECs are typically unbundled RECs in this case.
4. To create the market liquidity for T-RECs, the source holders shall have no need to retain their environmental benefits. If the source holders are in the manufacturing industry, they need to reduce carbon emissions themselves, and hence will have a very low desire to trade the T-RECs even if they can generate them. Therefore, source holders having no need to retain the environmental benefits, do not come from the manufacturing industry, but mainly from the energy industry. At this stage, the easiest targets in the energy industry are the power plant owners who have not enjoyed FiT subsidies or whose subsidies are lower than the current average power price.
5. Currently, the T-REC system adopts a self-generate self-use approach that does not affect the calculation of the electricity EF. Although the trade of self-generate self-use T-RECs is feasible (despite their extremely low liquidity), a verification system for the T-REC transaction records should be established with the EPA (the authority in charge of GHGs) to avoid misleading data due to the outsider effect, that results in double counting in the national total capacity.

In particular, the current T-REC system adopts a self-generate self-use approach that does not affect the calculation of the electricity EF. A simple interpretation is given below:

When there is a verification system, the BOE can predict the capacity of self-generate self-use electricity and the number of RECs issued, and so the residual mix EF can be calculated as follows:

$$Residual\ Mix\ Emission\ Factor = \frac{Total\ Carbon\ Dioxide\ Emissions}{Total\ Power\text{–}Power\ Usage\ with\ RECs} = \frac{80}{110-30} = 1.0$$

The result is exactly the same as in the case without taking into consideration the self-generate self-use electricity. This is not hard to understand are the self-generate self-use electricity from renewable energy is not included in the total power generation of Taipower, the increase in total power in the denominator is 0 when calculating the electricity EF, and the increase in total CO_2 emissions in the numerator is also zero since there are no carbon emissions. Consequently, the electricity EF is not at all affected by the users of self-generate self-use electricity.

5.1.3 Recommended steps to promote an REC system in Taiwan

Since REC system involves the calculation of the electricity EF, where the residual mix EF shall be derived, and the integration of interfaces required for the subsequent reporting of carbon offsets by companies, we hereby recommend three processes and steps to promote T-REC system in Taiwan:

1. Self-generation and self-use (completed). This is a good start with the lowest barrier of entry, and is a substantially feasible step. The key lies in proclamation and education to convince people that the government is indeed implementing its renewable energy policies, and educating people about the use and purpose of the REC throughout the whole process. The advantages of taking this step includes: the fact that it has no impact on the electricity EF and causes minimal resistance. It also presents an excellent demonstration of bundled and unbundled RECs. Nonetheless, there must be a verification platform for sale and purchase of RECs (to avoid the outsider effect). The disadvantage is the lack of market liquidity.
1. Select the subjects of renewable energy that can create market liquidity for implementation of the T-REC system. To create the market liquidity for T-RECs, the source holders should have no need to retain their environmental benefits. If the source holders are in the manufacturing industry, they need to reduce carbon emissions themselves, and hence will have a very low desire to trade the T-RECs even if they can

generate them. These source holders, who have no need to retain their environmental benefits, are mainly energy suppliers. At this stage, the easiest targets in the energy industry are the power plant owners who have not enjoyed FiT subsidies or whose subsidies are lower than the current average power price. By certifying the electricity generated by these power plants with RECs, the system brings extra revenue for power suppliers on one hand, and provides T-RECs with high market liquidity on the other hand. The target at this stage is to vitalize the REC market and it is a transition period towards a mature market.

2. Through the establishment and stable development of the REC market, the FiT mechanism shall be gradually withdrawn, so that the free rider effect can be eliminated. Under the current FiT system, more renewable electric power means more FiT subsidies, and all taxpayers are footing the bill. Business enjoys the environmental benefits of using electricity without having to bear the cost of subsidizing the renewable electricity. For the government and the taxpayers, this is relatively unfair. Therefore, when the REC market matures, the government should replace the subsidized FiT with the market mechanism of REC pricing. By that time, a stage of Taiwan's electricity liberalization can be considered accomplished.

5.2 Use of market instruments as BAT in GHG emission reduction control

The GGRMA was enacted as a control mechanism that was introduced in 1st July 2015, to realize its objectives of reducing GHG emissions effectively, in an economically-efficient manner. This includes allocating an emission allowance for the supervision of businesses in the form of free form allocations, auctions or placements. In accordance with the laws and regulations concerning GHG emission reductions, the central authorities shall allocate allowances for businesses involved in industrial development based on Taiwan's economic development needs, and for the implementation of Best Available Technology (BAT) for emission sources of the business. The main purpose of the BAT is to control and reduce CO_2 emissions. The scheme is applicable for industries that fall under Scope 1, involved with direct emission discharges. The companies in class of Scope 2, involved with indirect emission discharges, notably the emission of GHGs resulting from electric application usage. Consequently, enforcement officials may be faced with difficulties posed by Scope 2 businesses for the implementation of BAT, in accordance with Article 20 of the GGRMA. Current research shall investigate the BAT concept for Scope 2 companies. A white certificate system introduced for the reduction of energy wastage (or provisions of energy conservation), while a green certificate system encourages the reduction of CO_2 emissions by means of adopting and using renewable energy as a power source.

In compliance with the ISO 14064-1 and the GHG Protocol, GHG emissions of companies are mainly classified into Scope 1 and Scope 2. Among them, Scope 1 involves direct GHG emissions. GHG emissions directly held or controlled from the company and Scope 2 involves indirect gas emissions. Indirect GHG emissions from the production of purchased energy, for instance heating or steaming, yet the industries that use or require electricity for production/ manufacturing, including the semiconductor industry and electronics industry. Taiwan's CO_2 fuel combustion figures obtained from relevant departments, showed total emissions accounted for 250.50 million metric tons, in 2015. Industrial sector emissions excluding electrical consumption emissions (Scope 1) amounted to 39.93 million metric tons (16% of overall total). The figure adds up to 119.84 million metric tons (47.5% of the total), when electricity consumption emissions are included, while the difference of 79.91 million metric tons (32% of the total) involves indirect emission classified under Scope 2.

Further examination has identified consumer electronic product manufacturing industries, where electrical consumption is the main source of CO_2 emissions. Subsequently, Scope 1 emissions merely amount to 370,000 tons. However, Scope 2 emissions are as high as 26.96 million metric tons. Evidently, to achieve the long-term goal of realizing reductions for Taiwan, it is necessary for the simultaneous implementation of CO_2 emission controls, for both Scope

1and Scope 2 emissions. In particular, more attention needs to be paid to crucial consumer and audio-visual electronic product manufacturing industries in Taiwan that are excessively dependent on electricity consumption. Therefore, GHG source emissions (hereinafter abbreviated as GHG source emissions), can be defined within the GGRMA, as a unit or process that directly or indirectly emits GHG into the atmosphere, included in both Scope 1 and Scope 2 category industries.

This goal-oriented concept acts as the fundamental regulatory mechanism that allows the volume of emission sources to be controlled. Simultaneously, the promotion of the control of volume in an economically efficient manner for Taiwan's implementation for GHG reductions, includes allocating an emission allowance for the supervision of businesses in the forms of free form allocations, such as auctions or placements. According to the GGRMA, a portion of the allocation allowance has to be retained, while certain business with new or altered industrial emission sources shall abide by the implementation of BAT for such emission sources. Therefore, in terms of managing GHG reductions, Central Authorities shall allocate allowances to business for industrial development in accordance with the economic development needs of Taiwan, while also ordering the implementation of BAT on emission sources of the business. BAT refers to the assessment of technologies to commercially minimize emissions, after taking into account energy, economic and environmental impacts.

5.2.1 Best Available Control Technology (BAT)

Slightly different from that of Taiwan’s GGRM Act, is the Taiwan EPA’s definition of BAT, which also incorporates a case-by-case basis. In other words, BAT for (A) industry is not entirely applicable for (B) industry. In most cases and in general, any technology that increases energy efficiency is considered as BAT. As for the deciding factor concerning technologies that are BAT applicable, the US EPA utilizes these five evaluation steps:

Step 1: Confirmation of all current and available control technologies

Step 2: Removal of technically infeasible options

Step 3: Remaining technologies are sorted based on CO_2 emission control effectiveness

Step 4: Assessment of economic, energy, and other environmental impacts

Step 5: Analyzing the best options for BAT

The evaluation steps of EPA reveal that the concept of BAT is applicable to Scope 1 industries with direct emissions sources. For business entities producing direct emissions, BAT can be defined separately in accordance with the relevant business category. For example, in Taiwan, iron & steel, cement, chemical and petroleum, pulp and paper making and aluminum production industries are all considered to be energy-intensive. Currently, CO_2 emissions from five industries account for 75% of total emissions. BAT within these industries include, improving the energy efficiency of equipment, Combined Heat and Power (CHP), higher efficiency for motor and steam systems, waste heat recovery and reuse. In terms of fuel and feed conversions, the widespread utilization of biomass will become an important measure. CCS is an important option for realizing substantial CO_2 reductions within the steel sector, in the future. Interestingly, most energy consumption within the aluminum industry comes from the electrical consumed during smelting. The benefits of applying the aforementioned BAT is still limited with only a 12% potential to reduce energy consumption compared to current levels. The main reason is the aluminum production process, which consumes a lot of power and emits a considerable amount CO_2. Therefore, in the long run, the combined usage of zero-carbon electricity, such as wind or solar energy, offers the largest potential to reduce CO_2 emissions from the aluminum production sector. (Xi-Ming Lu, 2011)

5.2.2 BAT Assessment for Scope II emissions

The aforementioned carbon reduction approach for the aluminum production industry actually poses an apparent dilemma for Scope 2 companies, involved with indirect carbon emission sources, when interpreting BAT definitions. Currently, it seems to be ambiguous way to reduce the GHG emissions of Scope 2 companies, since their emissions are mainly derived as a result of electricity usage. However, in contrast, Scope 1 involving direct emission sources. BAT is defined as the device used to control and reduce CO_2 emissions, which in this case, is feasible. Seemingly, plugs to the grids are the only practically available option to address indirect emission sources caused by electricity use. Hence, when enforcement officials require Scope 2 companies to abide to BAT in accordance with Article 20 of the GGRM Act, there may be dilemmas involving implementation.

Currently, GHG and energy management in Taiwan are two separate entities under the same body. Therefore, in order to meet the government's long-term strategic goal of reducing GHG emissions, the "Four Energy Laws (carbon reduction)" are taken into account. These four laws include "Energy Management Law," "Regulations on Renewable Energy Development," "GHG Management and Reduction Law" and "Energy Tax Regulations" (draft). The coordination of the four laws would allow energy security to be taken into consideration, improve energy efficiency, develop renewable energy and create green initiative business opportunities, thus helping to realize the goal of comprehensively reducing GHG emissions.

Based on existing regulatory framework of Taiwan, current research proposes that BAT for Scope 2 emission sources should consider the two following points:

1. According to the relevant provisions stipulated in the 'Energy Management Law,' power plants should improve efficiency using electricity-saving and energy-saving equipment (lighting, air conditioning, etc.). Alternatively, this law could be implemented as a separate option for BAT. The aim of the practice would to reduce energy consumption (or to offer energy-saving efficiency), with regards to the concept of the White Certificate system. This includes the Energy Savings Certificate (ESC), or Energy Efficiency Credit (EEC), etc. (Irene Beucler, 2016)
2. According to the 'Regulations on Renewable Energy Development,' companies using renewable energy as a power source should reduce CO_2 emissions by improving the usage of renewable energy to realize their emissions goals in relation to BAT. This would fall under the concept of the Green Certificate scheme. Also, this is the current T-REC policy mechanism being promoted by the National REC Center.

The two points are discussed in detail in the following.

Firstly, the government has managed to carry out positive promotions with laws and regulations. The MOEA has established the “Regulations on Energy Users' Setting Energy Saving Targets and Implementation Plan” according to Articles 8, 9 and 12 of the Energy Management Law, which was announced on 1st August, 103 as Economic Energy No. 10304603580 notice and became effective on the same day. Methods for the implementation of the “Standardization of energy-saving targets for large industrial energy users” include:

1. Setting energy saving targets for large industrial energy users. The average yearly economic power saving rate is estimated to be at 1% in the next five years (2015 - 2021).
2. Strict implementation. Failure to accomplish the target set out by the economic power savings rate, would require companies to submit a report and improvement plan for MOEA approvalA. Moreover, failure to achieve one hundred percent of the target without justification, would subject the company to an implementation plan introduced by the central authorities.
3. Energy users should select high efficiency equipment during the updating or renewing process, such as high-efficiency motors. The term "Large Industrial Energy Users" within this regulation, include large energy users of both production industries (such as chemistry, iron and steel, textiles, papermaking, cement, electronics, etc.) and non-productive industries (such as business office buildings, hospitals, stores, hypermarkets, transport warehousing and communications, etc.).

However, in terms of the concept of additionality, the White Certificate system is already established as a regulatory government requirement. Hence, the related companies (i.e. large energy users) have no other choice but to comply. Subsequently, there is no additionality in allowing practices to improve energy efficiency or power-saving facilities, while further discussion is needed to comprehend its suitability as options for BAT. Instead, it should be viewed as the basic requirement companies should satisfy before seeking BAT. Nevertheless, if companies set the goal of increasing average annual economy power savings rate at higher than the statutory requirement of 1% between 2017 and 2021, the surplus portion is subject to additionality, which is reasonable to be identified as BAT. In terms of how much the emissions target should be exceeded before being able to have equal effects of BAT requires further insight.

Secondly, using renewable energy as a power source is essentially an active way to reduce CO_2 emissions. As enterprises invest in renewable energy power generation equipment, carbon emissions from the use of fossil fuels to generate electricity can be reduced by producing their own power. Hence, there is a scientific basis for using renewable energy power generation equipment of BAT Scope 2 companies as a consideration of the BAT assessment criteria. Simultaneously, another additional benefit arises, since the reduction of carbon stemming from the use of renewable power will showcase the company's performance when calculating reduction results. In other words, it is a win-win result for companies. As to the appropriate proportion of renewable energy of a power source, to conform the concept of BAT, the industry, government and academia need to conduct further analysis before reaching conclusions. However, when enterprises limited by plant space or environmental conditions (such as sunshine, air volume, etc.) have difficulties in establishing renewable energy generation facilities by themselves or can only provide very limited power generation, whether there is an alternate assisting approach is another issue that will be encountered in practice. Currently, in order to encourage the promotion of renewable energy, the government has set up the National REC Center and established the T-REC system, so that the use of renewable energy and the environmental benefit of renewable energy equipment and electric quantity can be verified and proven by certificates. Questions as to whether company purchases of T-RECs act as a basis for carbon reduction can be calculated via the proportion of the power sources. It is debatable whether companies are allowed to purchase T-RECs as a partial replacement of BAT etc., and even a key issue about the competition and cooperation relationship between carbon rights and RECs are worth further analysis. The environmental benefits of GHG management law is based on carbon rights, while that of an REC system is based on certificates, the commonality of the two lies in the simple fact of "carbon reduction".

5.2.3 Conclusions

This chapter discusses the method of defining BAT under Article 20 of the "GHG Reduction and Management Law", "Central Authorities retain a portion of the allocation allowance, while certain businesses with new or altered industrial emission sources shall abide to the implementation of BAT for such emission sources"- and how it applies to Scope 2 industries involving indirect emissions. As Scope 2 industries mainly use electricity as the basis for generating GHG emissions, no appropriate technologies currently exists for realizing direct CO_2 reduction goals. This chapter proposes the concept of using the White Certificate scheme, which aims to reduce energy wastage (or offer energy conservation), while the Green Certificate scheme aims to reduce CO_2 emissions by using renewable energy as a power source, in an attempt to discuss BAT for Scope 2 enterprises. In consideration of the principle of additionality, Taiwan has stipulated that large industrial energy users to set power-saving targets by means of the "Energy Management Law", which specifies an average power saving economy rate of 1% from 2017 - 2021. Therefore, within the legal validity period, unless large energy users voluntarily increase economy power savings rate by more than 1%. The White Certificate scheme may only be suitable as a basic requirement for enterprises, before seeking BAT. On the other hand, it is reasonable at the current stage to adopt REC scheme using renewable energy as power source to reduce CO_2 emissions and BAT for Scope 2 companies, by simultaneously using renewable energy power equipment. The only issue to address would be to specify the proportion of renewable electric power that is appropriate to conform to the concept of BAT. This still needs further discussion.

Chapter 6. Proposal for CCLIMMA model and case studies

In previous chapters, this research conducted a standard literature review on the policy tools of GHG reductions and RE developments and their effectiveness around the world. It was followed by decade-long industry-level insights (Chap 4) gained by the author to point out the deficiencies often seen in the implementations of these policies. Two innovative suggestions were then presented in Chapter 5 trying to address issues found in Chapter 4. In the following discussion, the author presents an integrated analytical model that could be used to address policy deficiencies and point out more effective directions.

Figure.16 contains all commonly used policy tools regarding indirect emissions reductions. It is a generic model which objectively plots the relations, direct and indirect, among important factors related to these policies. Not all markets have all the relationships developed or implemented.

6.1 Introduction of CLIMMA model

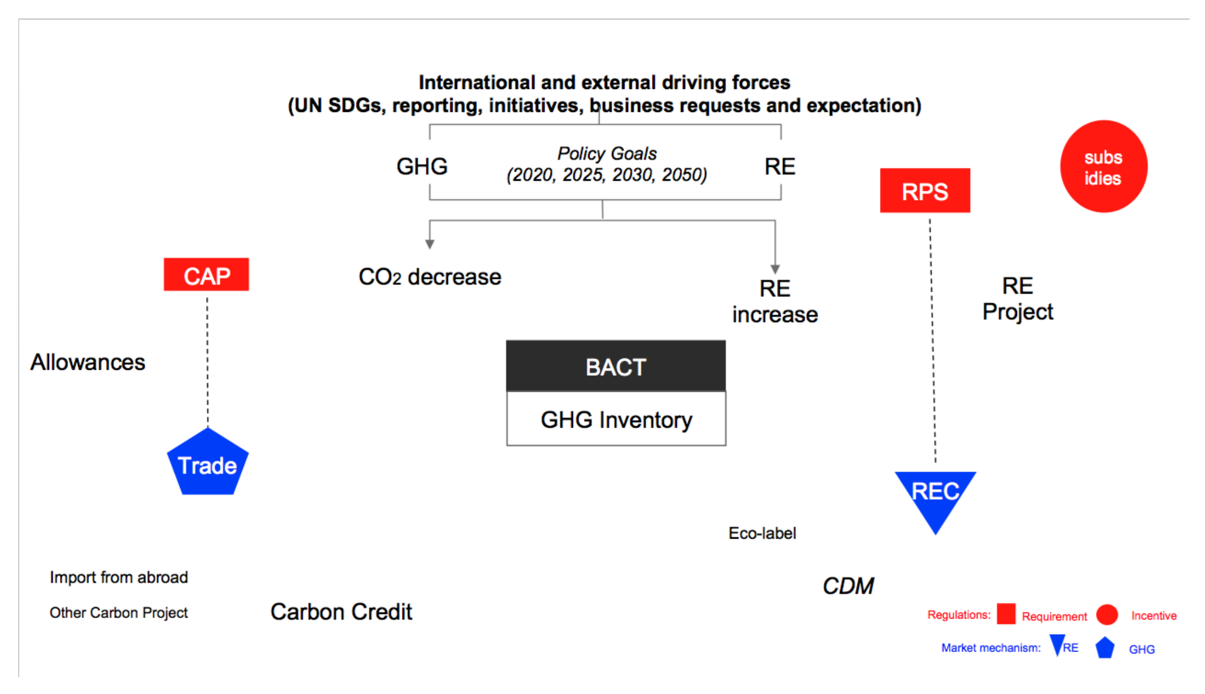


Figure 16. Consolidated climate markets mechanism analysis (CCLIMMA)

The top part of the diagram represents the international driving forces. This includes the top level UN sustainable development goals, the national policies, NGOs' initiatives and international agreements. These pursuits collectively lead to energy-related policies in two areas, GHG reductions and renewable energy developments (e.g. in Taiwan, 20% renewable energy in total primary energy supply by 2025; phased GHG reductions in 2020, 2025 and 2050). Directly underneath these top-level pursuits at the core of the entire scope is two main policy goals, GHG reductions and renewable energy development.

On the right-hand side, there are two main policy tools for renewable energy development, RPS and subsidy. Subsidies come in several forms. One of the most widely use is a FiT. FiT is a price guarantee scheme offered by the government. It can be a fixed pricing schedule with periodical review or a top-up floating scheme referring to selected benchmarks (e.g. average fossil-fueled generation costs) or market prices in liberalized markets. Experience gleaned from markets such as China reveals that price guarantees are not adequate to assure revenue streams for project developers, where curtailment is a severe issue. Other forms of subsidies also include investment tax credits and production tax credits, which are often seen in markets such as the United States.

RPS, on the other hand, empowers authorities to impose a minimum supply of green power onto the users. This can be in the form of a requirement imposed on operators of fossil-fueled generators, utilities and suppliers (supply side), or major power users (demand side). While it is more common for the supply side to be subjected in such requirements (certain states in the US, China, Korea, major EU countries, Australia and India for example), Taiwan elected to impose such requirement on end-user demand in the amendment draft (currently being reviewed by the Legislative Yuan (as of June 2018)) of its REDA.

Meanwhile, renewable energy power plants will generate electricity and contributing to GHG reductions either in the form of (1) substituting the existing output of fossil-fuel power plants and/or (2) replacing the expansion of future fossil-fuel power plants. (1) is often presented in the form of an REC, while (2) is termed as carbon credits under carbon schemes such as CDM.

The left-hade side of the diagram represents the standard cap and trade mechanism of carbon markets. Where caps are often imposed by state laws, mostly after national ratification of international protocols such as the Kyoto Protocol, domestic trading schemes (such as those in China and South Korea) usually the mimic the KP's ETS.

It is now standard practice that the use of renewable energy is regarded as a form of low GHG energy consumption, would be revealed as low GHG inventory. This is gaining wide interest internationally, particularly with the publication of GHG Protocol's Scope 2 Guidance and guidance from other major international NGOs, which have initiatives focusing on energy uses.

In the following section, CCLIMMA will be used to examine the effectiveness of GHG and RE related policies in selected markets (Taiwan, Japan, and China).

6.2 Review of selected power markets using the CCLIMMA mode

Different markets have their own energy requirements due to varied and distinct energy characteristics and socioeconomic development. Electricity is deemed one of the most fundamental needs in the livelihood of a person, playing a role in the social development, perceptions and technological advances that coherently influences transformations within the market. For comparative purposes, this section focuses on three specific Asian economies in terms of highlighting the cause and effect of difficulties that includes REC requirements and market instruments within the electricity market. We shall conduct a comparative overview of the electricity markets and RECs for the respective areas, whilst also proposing solutions to the problems arising from recent reforms and market predicaments.

6.3 Historical evolutions of power market reforms

European electricity market, started reforming in the early 1990s and began to take root to eliminate the barriers among the member states. The EU Council continuously advocated for the liberalization of the electricity markets through legislation and constructing systems. Currently, all member states are required to lift restrictions within local electric power industries, and to concurrently open up their electrical power networks in an impartial manner to power plant operators, power distribution companies and users. Member states are also required to supervise the cost and management of these underlying projects. Moreover, the EU implemented reforms that give individuals more choices to purchase electricity. By the July 2007, the majority of EU member states already had established electricity markets, providing most electricity users with options for purchasing electricity.

6.3.1 Taiwan

Before the amendments of the *Electricity Act* in 2017, the electricity market in Taiwan mainly comprised of "Synthesis Electric Power Industry", "Private Power Plants" and "Self-powered Electricity Equipment." Although the government allowed private enterprises to set up electric power generation plants, Taipower has remained the single largest independent entity in the "Synthesis Electric Power industry" with integrated electric power generation, transmission and distribution. Surplus electricity can only be sold to Taipower and not directly to consumers, highlighting the 'rigid' stance consistently maintained in the electricity market. In 1995, the Executive Yuan submitted the 6th draft of the Electricity Act to the Legislative Yuan, following liberalization trends in international electricity markets. After more than 20 years of deliberations and revisions, in response to the "Nuclear-Free Homeland" and an electricity shortage crisis, the government finally decided to pass the amendment to the *Electricity Act* in early 2017. The basis for the amendment is the "Green Electricity Initiatives" that introduces measures such as priority power network and dispatch for renewable energy, discounts for electricity transmission and distribution, and allowing direct electricity sales. Moreover, there is also strong interest and anticipation of private investment in the renewable energy industry, which would simultaneously bolster transformations within Taiwan's energy framework. Figure 17 shows the electricity market framework following Taiwan's amendment of *Electricity Act*.

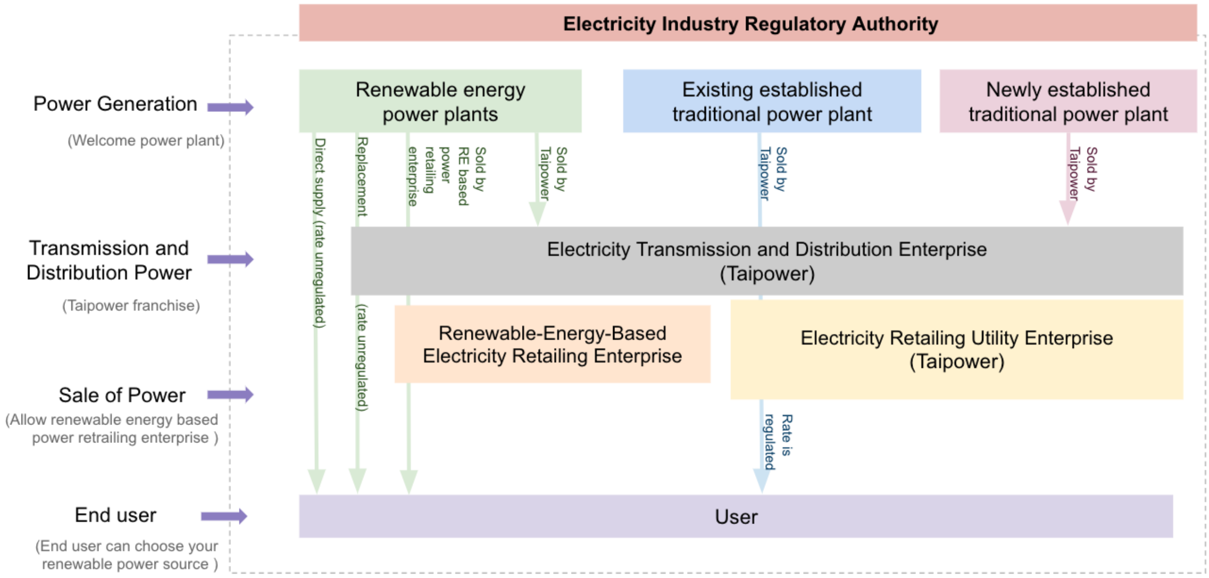


Figure 17. The electricity market framework following Taiwan's amendment of *Electricity Act*

6.3.2 Japan

Japan has 10 integrated electric power companies that offer vertically-integrated electricity generation, transmission, and distribution. In addition to these, there are also new electric power and independent generation industries, supply electrical power to the whole nation. The electric utilities in the eastern regions of Japan are Hokkaido Electric Power Co., Tohoku Electric Power Co., and Tokyo Electric Power, while the system operates with a frequency of 50HZ. Utilities in the western region are Kansai Electric Power Co., Shikoku Electric Power Co., and Okinawa Electric Power Co, using a frequency of 60HZ). Figure 18 shows the geographical locations, interconnecting system capacity and maximum load of the 10 major electricity companies of Japan.

Reforms in the electric power industry which occurred 4 times in 1995, 1999, 2003 and 2008, respectively in response to pressure from international trends, and excessively high electricity prices in Japan. In 2011, Regional blackouts caused by the earthquakes and the tsunami that hit the Fukushima Nuclear Power Plant in Eastern Japan, exposed the limitations and complications faced by Japan's electric power system, and prompted Japan's government to introduce a new round of reforms in 2013. This subsequent round of reforms set the objectives of ensuring the stability in electricity supply in Japanoy, setting a maximum ceiling price for rising electricity prices, increasing the viable options to the users and to open more developmental opportunities for related companies. (Chen Youjun, 2016)

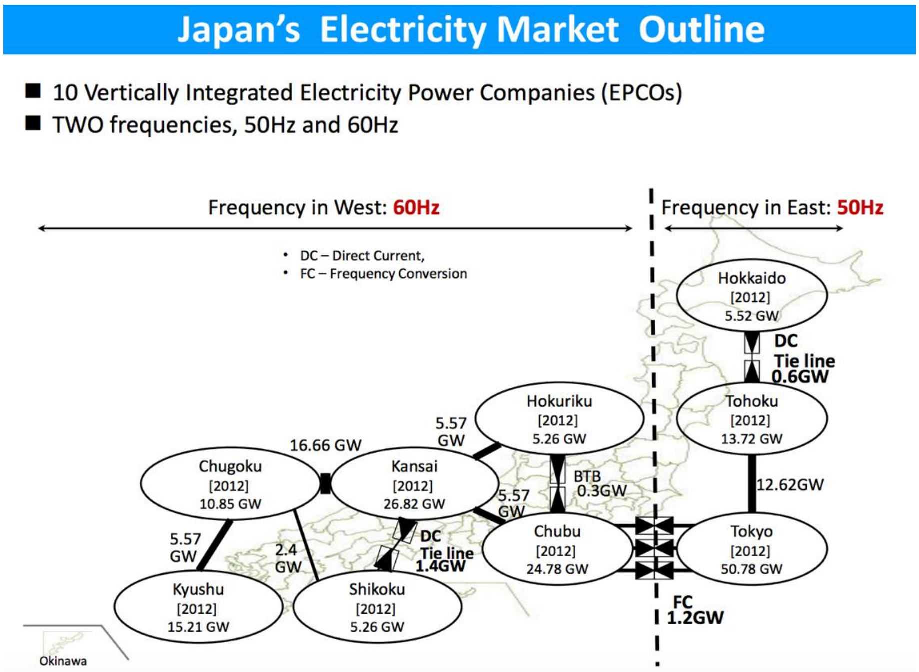


Figure 18. The geographical location, interconnecting system capacity and maximum load of the 10 major electricity companies of Japan. (Japan's Ministry of Economy, Trade and Industry, 2015)

6.3.3 China

Figure 19 shows the reform timeline for the electricity sector in China , categorized into three stages). The first of these reforms began in the 1980s. In order to alleviate electricity shortage issues, China allowed investors from both the public and private sectors to access the electricity generation industry, which led to an increase in private investment in the industry. In February 2002, the State Council released the Electric Power Systems Reform Program, which separated electricity generation from electricity transmission or sales sites, plants with electric power grids, main plants with auxiliary plants, and finally electricity transmissions with electricity distribution entities. td These electricity generation companies are devided into five major electricity generation groups: China Huaneng Group, China Datang Group, China Huadian Corporation, China Guodian Corporation and China Electric Power Investment Group.

The State Grid Corporation of China and the China Southern Power Grid Company were established to cover the areas of Yunnan, Guizhou, Guangxi, Guangdong and Hainan. Also, the State Electricity Regulatory Commission (SERC) was set up to act as the regulatory body for electric power. This change signified the most important structural adjustment in the modernization of the electric power industry. However, reforms at this stage reached a deadlock in 2007, with electricity transmission, distribution and sales, all undergoing total integration. The state council released the “Issues on the Further Deepening of Reforms for the Electricity System” in March 2015, to further encourage competition among the wholesale electricity providers and the retailers. Thereafter, a series of complementary measures and policies were introduced that shifted focus to include the development of renewable energy, reforms for electricity transmission and distribution, electric consumption plans, construction of an electricity market, improving trading institutes, and introducing reforms for electricity sales. During the “13th Five-year Plan,” the electricity industry in China, experienced a drastic transformation shifting from a state controlled towards a market-oriented model.

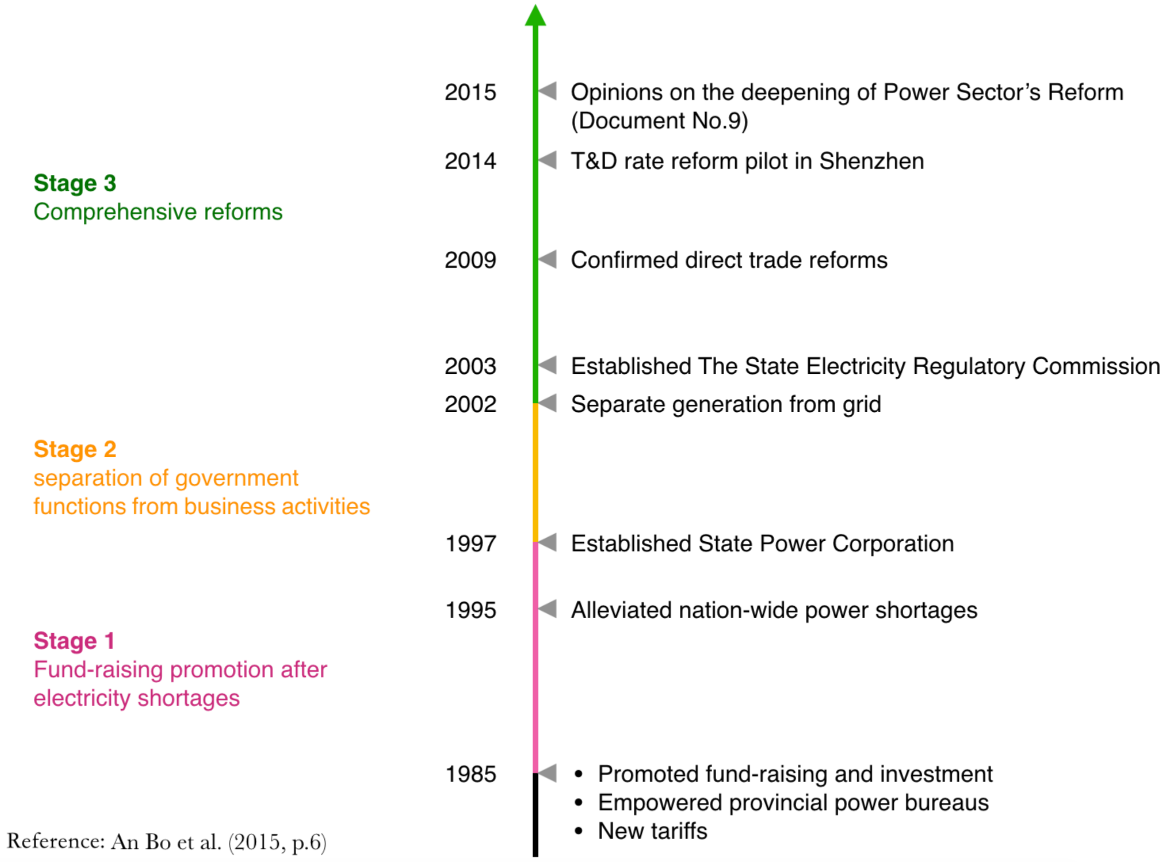


Figure 19. Reform timeline for the electricity sector in China[5]

6.4 Renewable energy demand, government policies and market regulators

International renewable energy development has been driven by climate change, environmental protection and energy security. Equally important, are the international conventions and initiatives introduced, such as the *Kyoto Protocol* and *Paris agreement*.

6.4.1 Taiwan

In order to develop renewable energy electricity in early 1992, TEPA and MOEA developed a succession of subsidy schemes for methane, solar-powered electricity, and wind-generated electricity. Currently, newly set up renewable energy electricity generated would be purchased at a price of NTD$2.00/kWh, which duly encouraged more investments in renewable energy projects. Thereafter, the Legislative Yuan passed the *Articles for Renewable Energy Developments* in 2009, which boosted renewable energy developments, and adopted FiT system, that would ensure that renewable energy was being purchased. The FiT in accordance with the *Articles for Renewable Energy Developments* obligates the Taipower to purchase renewable energy electricity at prices publicly quoted during the year. The relevant authorities are required to take into account renewable energy equipment aspects such as technology, cost, policies, etc., and to convene a meeting to review and determine prices on yearly basis. Moreover, rates are not allowed to be lower than the average cost of generated electricity via fossil fuels, while Taipower applies the relevant FiT buying rates in accordance with the year in which the renewable energy generating equipment is setup for application.

Currently, Taiwan's total installed renewable energy capacity is 4.7GW, which accounts for 9.43% of the total installed capacity. The total capacity for generated renewable energy accounts for 4.77%. In 2016, the government proposed a "Nuclear-free Homeland" plan, estimated by 2025. Taiwan's national electric grid structure is expected comprise a renewable energy generating capacity of about 20%, while coal would fall to 30%, and natural gas would be increased by 50%. By that time its target is for solar-powered electricity installed capacity to reach 20GW, whilst offshore wind turbine capacity would reach 3GW. In June 2017, the Executive Yuan passed a "4-year plan for wind generated electricity". It estimates that in 2020 land-based wind generated electricity would top 814MW and offshore wind generated electricity would amount to 520MW. Moreover, the GHG Reduction and Management Act stipulates that GHG emissions in 2050 should be reduced to 50%. When selecting market regulators to aid in the liberalization of the electricity industry in the country, the MOEA issued the MOEA VGPPP for setting up voluntary green electricity application subscription channels, accessible to the general public. The green electricity revenue accumulated from this by Taipower is then channeled back into a renewable energy development fund for FiT renewable energy expenditures and reward schemes. Although the plans for renewables energy only amount to 20% of capacity, in terms of large scale multinational companies, with the consolidation of Taiwan's power grid, green electricity and traditional electricity would combined into a unified power grid to be used. However, the "green electricity" that was being offered by Taipower for purchase was unable to satisfy the requirements of companies who are legally required to purchase green electricity. Thus, after 3 years of its trial implementation, the plan was duly abolished. In order to satisfy the pressing demands concerning certification from the different stakeholders, the inspection bureau of the MOEA began to consider its existing system for international renewable energy certification. In 2017, MOEA established the renewable energy certification system, and also the first T-REC was rolled out, with each certificate representing a value of 1,000 kWh of renewable electricity. According to Taiwan's REC center for statistics, as of 31st May 2018, a total of 29,339 T-RECs have been issued, while only 448 certificates has been traded.

6.4.2 Japan

Japan introduced the RPS in order to better promote the development of renewable energy in early 2003. RPS means that a country or a region, by law, has to account for mandatory proportional provisions for renewable energy electricity amongst its total electricity generation. The utility is required to fully acquire later, while those responsible (who fail to meet portfolio requirements) would be fined accordingly. On 11th March 2011, when the Fukushima Nuclear Power Plant incident occurred, Japan made substantial changes to its energy policies, and to also promote renewable energy industrial development. In July 2012, via the *Renewable Energy Special Measures (FiT) Act,* for buying and selling renewable energy was introduced. It also specified that the government is required to buy renewable energy electricity for the next 20 years at a fixed rate. Moreover, a tax would be levied on electricity to provide a source of funds to reallocate funds for purchasing electricity. In April 2017, Japan began implementing the *Amendments to Renewable Energy Special Measures (FiT) Act*, which is essentially the new FiT law. The main changes in the new law included: application of a new system that verifies that operators would be able to actually implement power generation activities. Further, a new method for determining changing purchase prices, building a system that ensures the long term stability of electric power generation, revising the tax exemption system for large consumption users, such as manufacturers. Besides, FiT electricity procurement obligations were altered to change the status of traditional retail operators to electricity transmission and distribution operators. (Lin Xianghui, 2017)

Currently, the total installed capacity of Japan's renewable energy is 9.8GW, which accounts for 3.6% of totally installed generation capacity. The total output of renewable energy accounts for 13.2% in 2016. (Natural Resources and Energy Agency, Japan, 2017.) In light of the initiatives from climate change conferences, Japan imposed a national target for 2030 that would reduce GHG emission by 26% compared to the levels of 2013, that is a reduction of 25.4% compared to 2005. The long-term energy supply and demand expectation for 2030 is for total generating capacity of renewable energy to account for 22% to 24% of the total, and for nuclear energy to account for 45%. Out of the three markets discussed in the paper, Japan was the earliest to adopt an REC system. In November 2000, a private company called 'Japan Natural Energy Company Limited, proposed the establishment of a commercial green electricity certificate system. By 2008, the Green Energy Certification Center, Japan (GECCJ) was established as a branch for economic energy research, a separate entity independent from electricity companies, owners and buyers. Its main responsibilities are for the management, verification and developmental planning for Green Energy Certificates, Japan (GECJ). The GECCJ has issued 2,732,000MWh worth of GECJs, and accumulated trade amounting to 2,630,019 MWh from 2008 to 2017. (The institute of Energy Economics, Japan)

6.4.3 China

In 1995, the Chinese government enacted the Electricity Law signaling its intention to encourage and support the development of renewable energy. In 2005, the Renewable Energy Law was passed, addressing specific issues such as the total targeted figures, grid connectivity for electric power generation, formulation and finalizing technical aspects with product specifications, industry guidance and technical support, electricity price management and cost apportionment. This helped to boost renewable energy development drive of China. Moreover, the Renewable Energy Law obligates grid operators to link renewable energy generating equipment to the grid. They are also required to purchase all renewable energy electricity that is produced. In August 2007, the Chinese National Development and Reform Commission (NDRC) released the renewable energy medium to long-term development plan, aimed to renewable energy development durations and objectives, which is inclusive of hydroelectric power, biomass energy, wind power and solar energy. Alternatively, each government department and committee encapsulating the renewable energy medium to long-term development plan is required to formulate a plan accordingly for their various projects, highlighting clearly, the developmental objectives. By means of both discount pricing policies and mandatory market sharing policies, market demand should be fully sustained. Improving the conditions within the market also ensures that renewable energy is being purchased. In addition, prices and cost-apportioning policies were also introduced, coupled with increasing financial investments, and tax incentives. According to statistics from 2016, total renewable energy installed capacity in China, amounted to 570 million kW, which accounts for the 34.6% of the nation's total. Renewable energy electric power generation capacity amounts to 1.45 trillion kWh, accounting for 24.2% of the sector's total. (Development Department of China Electricity Enterprise Union, 2017) China has been taking a hardline approach towards combating climate change by setting 2030, as the year when carbon emissions will peak, after which the government has set a goal of reducing CO_2 emissions per unit of GDP by 60-65% compared to 2005 levels, and to take a step further in strengthening the demand for renewable energy within the country. In March 2012, China's Finance Ministry, in conjunction with the NDRC and the National Energy Administration (NEA) issued "Interim Measures for the Management of Additional Subsidies for Renewable Energy Electricity Price" (NDRC, 2012), implementing an on-grid FiT subsidy policy. From 2012 until 2017, there have been a total of 7 reported additional subsidies for renewable energy. Subsidy standards for renewable energy electricity generation projects and FiT volumes are determined by the NDRC in relation to factors consisting of renewable energy FiT electricity prices, and desulfurized coal standard electricity pricing.

In recent years, with the increasing financial pressure posed by electricity pricing subsidies, the NDRC proceeded to repeatedly lower the FiT of renewable energy such as wind power and solar power (Figure 20 and Figure 21). Currently, the subsidy funds for renewable energy electricity generation in China all originate from a single source, renewable levies imposed on end users. It is predicted that with the Chinese current subsidy system and by year

2020, the subsidy gap for renewable energy will have surpassed 300 billion yuan. In order to mediate the widening subsidy gap, in January of 2017, three of Chinese bureaus jointly issued the *Notice for the Trial Implementation of the Renewable Energy Electricity Green Energy Certificate Approval and Issuance Voluntary Subscription Trading System*. Since July 2017, the system has been trialed throughout the China. It is widely expected that in 2018 China is predicted to start conducting a renewable energy quota review and to enforce restrictions on green electricity certificates trading. The said policy specifically highlights the "Two Parts" of electricity pricing; whereby "Electricity Pricing Subsidies" can be in the form of "Green Certificates," thus making prices within the market more competitive. By the end of November 2017, about 8 million green certificates were issued, and about 21,000 certificates were traded, accounting for less than 0.03%. (China Green Electricity Certificate Subscription Trading Platform) In terms of the green certificate prices, the average price of each green certificate ranged from CN¥157 to CN¥686, from October to November of 2017. This represents a significant difference when compared to other certificates circulating in the market, such the I-RECs.

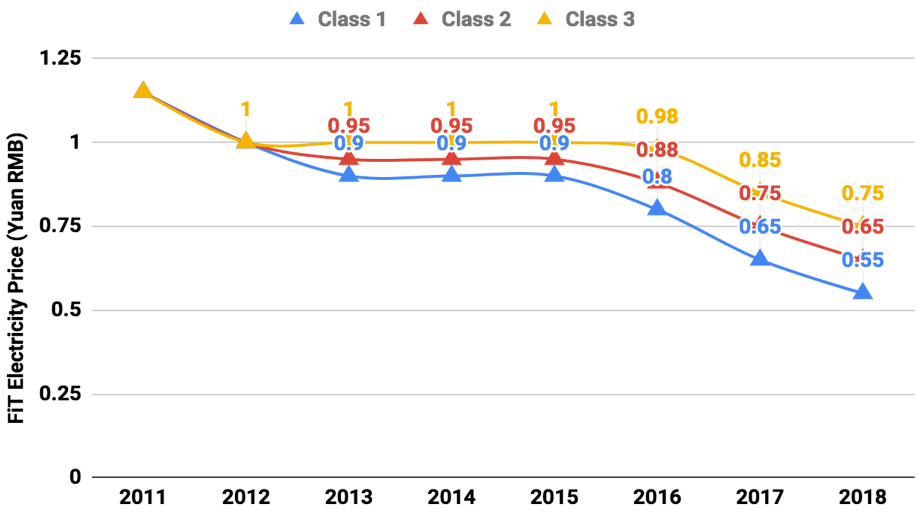


Figure 20. FiT electricity price trends in the Chinese solar energy power industry

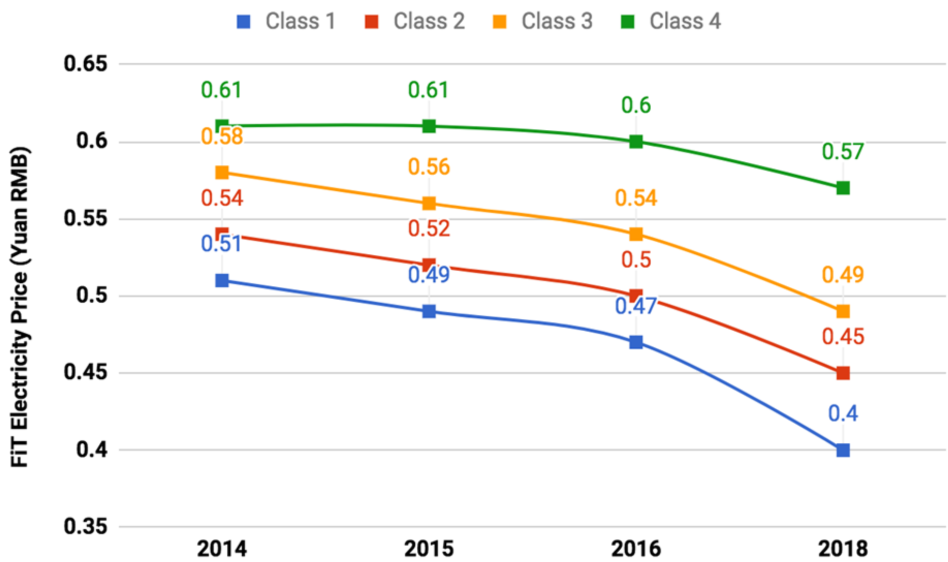


Figure 21. FiT electricity price trends in the Chinese wind power industry

Table 18. The division of the solar power and wind power resource areas in China

Resource Areas	Solar Power Resource Areas	Wind Power Resource Areas
Class 1	Ningxia; Haixi (Qinghai); Jiayuguan, Wuwei, Zhangye, Jiuquan, Dunhuang, Jinchang (Gansu); Hami, Tacheng, Altai, Karamay (Xinjiang); Inner Mongolia except Chifeng, Tongliao, Hinggan League and Hulun Buir.	The Inner Mongolia Autonomous Region except Chifeng, Tongliao, Hinggan League and Hulun Buir; Urumqi, Yili Kazakhstan Autonomous Prefecture, Karamay and Shihezi (the Xinjiang Uygur Autonomous Region)
Class 2	Beijing; Tianjin; Heilongjiang; Jilin; Liaoning; Sichuan; Yunnan; Chifeng, Tongliao, Hinggan League and Hulun Buir (Inner Mongolia); Chengde, Zhangjiakou, Tangshan and Qinhuangdao (Hebei); Datong, Shuozhou, Xinzhou and Yangquan (Shanxi); Yulin and Yan'an (Shaanxi); Qinghai; Gansu; Xinjiang except areas of Class 1	Zhangjiakou and Chengde (Hebei); Chifeng, Tongliao, Hinggan League and Hulun Buir (the Inner Mongolia Autonomous Region); Jiayuguan and Jiuquan (Gansu); Yunnan

Class 3	Areas except Class 1 and Class 2	Baicheng and Songyuan (Jilin); Jixi, Shuangyashan, Qitaihe, Suihua, Yichun, and Greater Khingan Range (Heilongjiang); Gansu Province except Jiayuguan and Jiuquan; The Xinjiang Uygur Autonomous Region except Urumqi, Yili Kazakhstan Autonomous Prefecture, Karamay and Shihezi; the Ningxia Hui Autonomous Region
Class 4	No	Areas except Class 1, Class 2 and Class 3

6.5 Comparison with proposed market modeling

In this section, three Asian major economies are selected for in-depth analysis using the CLIMMA model as presented in Chapter 4. A shoulder-to-shoulder comparison will be presented as a summary in this section.

6.5.1 Taiwan

Taiwan has undergone major reform of its legal frameworks for sustainability in the last 3 years. With enactments of laws and regulations on GHG reductions, renewable energy developments, and power sector liberalization, Taiwan is set to enter a new era of climate market mechanisms.

While related legislation is in place, implementations and integrations within and among related governmental agencies will still need substantial efforts. Each regulation is established through comprehensive consultations and debate inside and outside parliament, it is unavoidable to see bias and emphasis on certain aspects. The long-term goal is to reach a regulatory framework which enforce to create broad synergy and also ensures that no regulations are reinforced in a way that diminishes or undermines other policy goals.

1. Carbon market: imbalanced supply and demand and delayed schedule

Due to its unique diplomatic position in international society, not being the UN member, Taiwan is not able to participate in the CDM carbon market. For this reason, the EPA started a voluntary carbon scheme 2010 aiming to establish a voluntary domestic carbon market. At the time the GGRMA was enacted in 2015, there was almost no activity in the market. The review procedure for project registry had been lengthy due to the unfamiliarity with CDM protocols. This in turn increased the development costs and further worsened the prospective profitability.

Even after its enactment in 2015 with long-term goals set under Clause 4, the GGRMA hasn't been able to speed up the timeline of achieving reduction targets, resulting in a very limited progress towards reaching reduction goals by 2020. The left-hand side of the Figure 22 shows the proclaimed cap is not able to contribute to GHG reductions, as explained above. The dotted line shows the insignificant trading due to the limited supply of carbon projects. Clearly, the trading for allowances is not in the picture as it has been in other carbon markets such as EU and China.

2. Renewable energy market: time to phase out of FiT in favor of market liberalization enhanced by RPS

The enactment of REDA, the economic and financial incentives available to renewable energy project developers has been limited to FiT. FiT have served the purpose of spurring the development of renewable power generation vastly in the past decade since mid-2000s.

After the amendment of the Electricity Act in 2017, the power evolution is set to take on a liberalization path and start with green power. Access requests for green power from international business which have operations and supply chains in Taiwan, contributed to not only the realization of the amendment but also demand for access to green power. The introduction of T-REC in 2017 is intended to meet such demand in line with international practices. T-REC is designed in a way that allows electricity with the underlying RECs to be traded simultaneously among the same parties, also known as "bundled" transactions. Further, T-RECs cannot co-exist with FiT for the same unit of underlying green power. This is to say, project developers/operators will have to choose either T-REC or FiT.

Liberalized market is always a painful process if it involves ending subsidies without imposing restrictions of any kind in the market. Project developers tend to rely on subsidies for higher financial revenues and oftentimes, better risk management in terms of prospective revenue streams. After more than a decade of subsidies and with the partial liberalization of the market, it is essential to end the government's interventions in order to ensure healthy market development, even though the interventions in this case are subsidies rather than limitations.

Taiwan should phase out FiT (containing subsidies) to ensure the liberalization of green power market. Meanwhile, it is also important to monitor developments to ensure that the market evolves as intended by supporting policies to ensure the public resources (budget and environment benefits of renewables) are not being distorted due to market malfunctions. The revision of the REDA, currently under review in the Legislative Yuan, includes a clause to introduce the renewable portfolio standard. Such a design not only allows the government to keep a handle on the renewable energy and its future development in the long term, but also leaves a policy instrument for the government to fine-tune the market mechanism for optimal performance.

3. Interaction between carbon and renewable energy market mechanisms

The Figure 22 represents the current status of the climate markets in Taiwan. It clearly points out the deficiencies discussed above. On the left-hand side, the goal to the cap is clearly defined in the long run but poorly executed (-2% by 2020), which won't contribute significantly to the building of the carbon market nor induce self-driven reductions from emitting installations to meet the long-term cap designated in the GGRMA. The missing link between the cap and CO_2 reduction goal represents this failure.

In reality, Taiwan is a very small market in terms of carbon market operation. Due to missing linkage with the international carbon market, the learning curve of the entire Taiwan market has turned out to be flat and expensive. All parties from authorities to project proponents market players, certification and accreditation, face the same challenge owing to a lack of scalabilities and efficiencies. The lack of economical scale has led to slow and uneven carbon market development. That is why, the entire carbon market on the left-hand side of the diagram looks very vague with missing links and dotted lines.

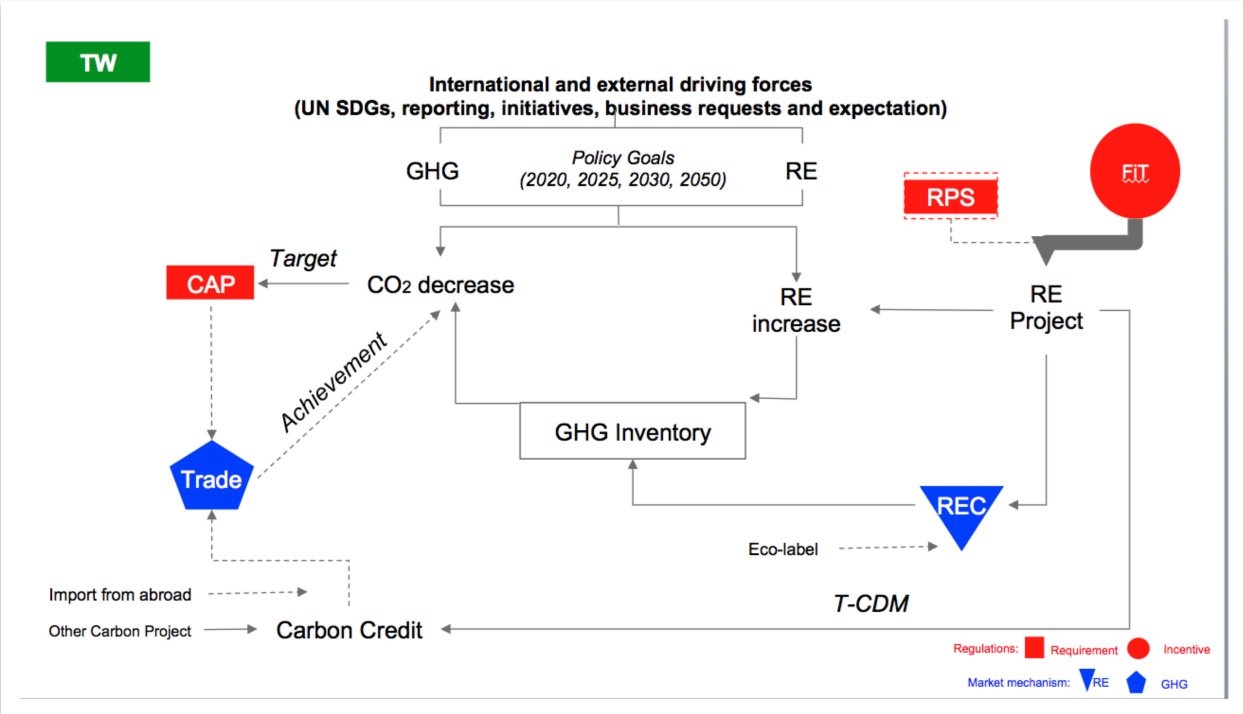


Figure 22. CCLIMMA model of Taiwan as of June 2018

The energy market on the other hand has been observing healthy development with the support of FiT. The immediate challenges that lies ahead is the next stage of market-oriented developments, as previously mentioned, the replacement of subsidies by RPS.

Most importantly, the more liberalized energy market, the more benefits it could lead to in terms of GHG reduction through GHG inventory (i.e. lower emissions from power generation and grid EF). This is particularly important for developed economies like Taiwan. Significant GHG reductions are unlikely through technological advances and facility upgrades. This also implies that, to meet the GHG reductions goals, a shift is needed away from a direct-emitting industry structure (mostly heavy and energy-intensive industries) towards high add-value manufacturing.

6.5.2 Japan

1. Carbon market: weak with mandatory cap missing

Japan is the only Annex I country in Asia with a reduction goal commitment to the Kyoto Protocol dating back to the mid-1990s. Since the ratification of KP in February 2005, Japan has never implemented mandatory reduction measures domestically. It also has never transferred the commitment to the KP on to the private sector. Japanese government purchases AAU (Assigned Allowance Units) to meet this goal, mainly from Eastern European countries. These countries had substantial surpluses of AAUs due to the collapse of USSR and subsequent economic downturn. Japan was also one of the major CDM credit purchasing countries in the world. The large arrow of "import from abroad" in the Figure 23 represents, measures taken by Japan which eventually helped achieve the goals under the Kyoto Protocol.

Such public and private resources dedicated to credit imports, Japan was on the track to meet the commitment by 2012. However, the Fukushima crisis which occurred in March 2011 turned such planning upside down and made the achievement of Japan's reduction goal under the Kyoto Protocol a seemingly impossible mission. With the shutdown of all nuclear power plants in the following months, Japan's total emissions in 2011 rose by 6% compared to 2010. Japan was one of the first counties to announce its withdrawal from the joining Kyoto Protocol after UNFCCC's Convention of Party in Cancun Mexico in December 2010. The Fukushima crisis put Japan in a very tough position to keep its commitments to the Kyoto Protocol.

Domestically, Japan initiated several GHG reduction cooperation schemes regionally, nation-wide, and even bilaterally internationally with some 20 countries. But, to date, none of these efforts have been scaled up.

Under the Paris Agreement, Japan has an NDC (national determined contribution) of a 25% reduction from 2013 to 2030. Japan is expected to meet this goal through its internal cooperation scheme (Joint Crediting Mechanism). It is clear that in a mature and developed economy likes Japan, the reduction opportunities at home will be technically difficult and economically expensive. It is also expected that the missing link between reduction and cap will continue to be missing, while the reduction goal will have to largely rely on credit imports, either through international cooperation or direct purchase.

2. Renewable energy market: regaining momentum with FiT but lacking a market mechanism

For island countries such as Japan with an indigenous scarcity of fossil fuel, nuclear power has been the best compromise option for power generation. However, the Fukushima crisis completely overturned this preference. Japan had launched FiT scheme in 2012, one of the last OECD countries adopting such a policy while Germany already started to phase it out. Japan's renewable energy installations, especially solar PV, tripled from 2013 to 2017 under a very solid FiT scheme.

Observing the issues such as the growing financial burden from accumulating the required budget for FiT through the lives of projects, Japan just launch its RPS+REC scheme in May 2018, aiming to ensure a market-oriented approach for sustainable renewable energy development. While, it will be subjected to further examine, such market approach sets Japan on track to private sector inclusion for financial support and aligns the interests of various industries.

3. Interaction between carbon and renewable energy market mechanisms

Following the dip caused by the 2008 financial crisis, Japan's emissions had risen steadily until 2012. However, following the introduction of FiT schemes (in 2012), Japan started to witness a decrease in GHG emissions, even though there was no domestic enforcement mechanism.

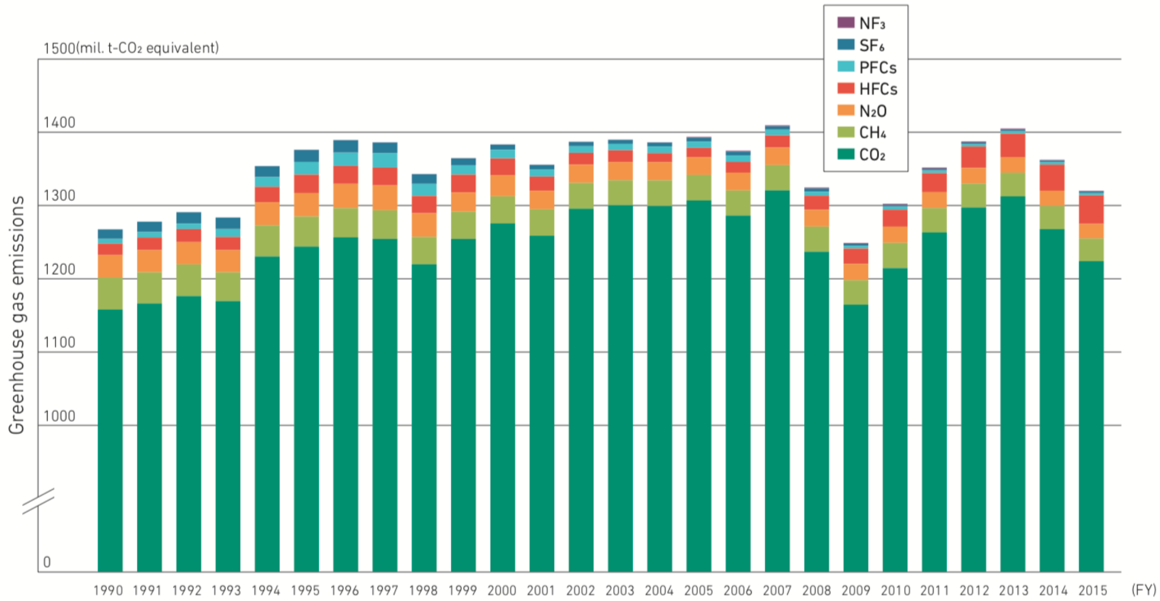


Figure 23. Japan GHG emission from 1990 to 2015 (Ministry of Environment, Japan)

The case in Japan proved again that FiT schemes are an effective policy tool in boosting the development of renewable energy. In the Figure 24, the grey arrows in the middle indicate the achievement of renewable energy development into GHG reduction, measured through GHG inventory, FiT could potentially build into a serious fiscal burden for the decades following their implementation. The weak links between renewable markets and carbon markets also indicate the untapped market mechanisms that could be adopted for economic efficiencies.

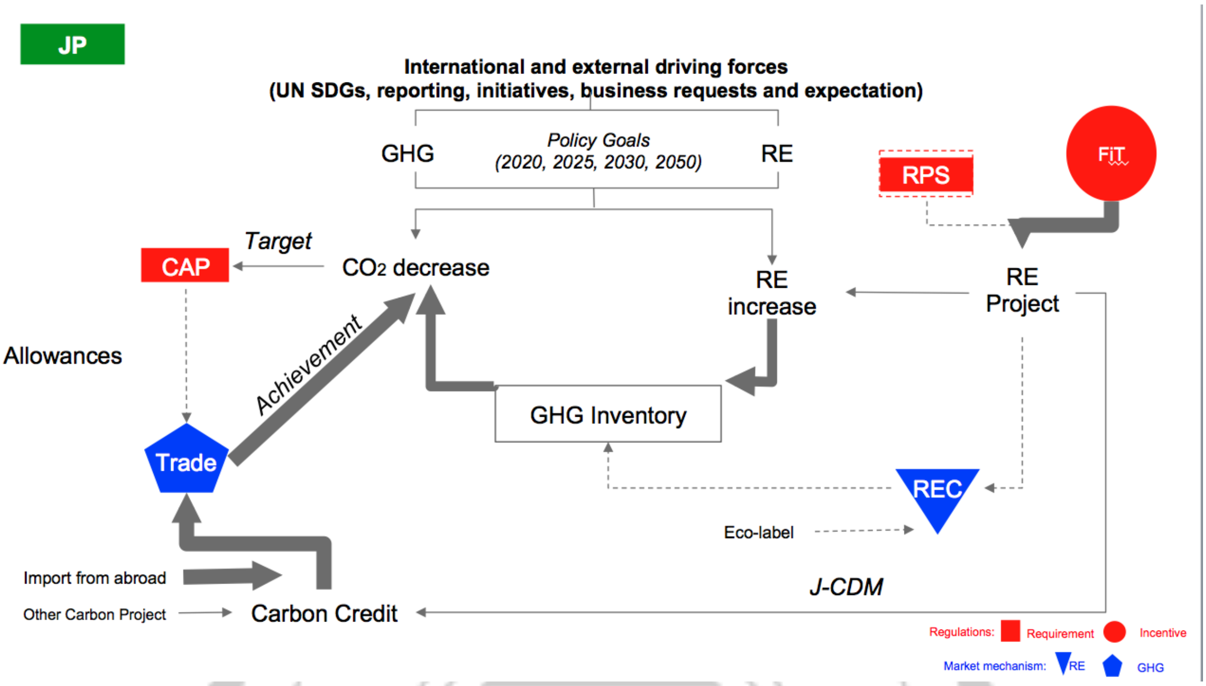


Figure 24. CCLIMMA model of Japan as of June 2018

One unique difference from other major OECD and neighboring economies is that Japan only started its FiT in 2012. This made a difference in the tariff setting and is worth for further research and observation, if Japan faces fiscal challenges in fulfilling long-term FiT subsidy commitments.

6.5.3 China

Under the proclaimed policy goals of GHG reductions and renewable energy development, China launched its pilot domestic carbon scheme starting with 7 regional markets in 2014. Meanwhile,, China also started to subsidize the development of renewable energy, mainly for onshore wind and solar PV in past decade. Through the years up until today, China has developed into the largest renewable consuming country in the world, with the largest installed capacity and output on the back of the steepest growth rate by far.

1. The stagnating carbon market

Under the cap-and-trade scheme, emitting installations receive allowances at zero cost at the volume equal to the total emissions in previous year after subtracting required reduction. Emitting installations are expected to put in the effort to reduce emissions either through facility upgrades and improvements, production reduction, and purchase of allowances and reductions credits.

China does not allow credit imports, partially owing to the collapsing international market for which it was once the largest credit export country. Under the CCER pilot scheme, it was also expected to take replace the EU's ETS and become the largest carbon market on the planet but this has not yet happened.

In addition, there is no clear sign of the way forward. The Chinese government announced its ambition to create a national carbon market from 2018. Experiences learnt from pilot regional markets give mixed signals and do not bode well for a Chinese carbon market. Looking ahead, there is no clear sign showing GHG reductions are likely to advance substantially in the foreseeable future.

2. Energy market facing development hurdles

China started its subsidies in the form of floating FiT (premium on top of fossil fuel generation costs as a benchmark) since late 2000's. The development of modern renewable energy (mainly onshore wind, solar PV and recently offshore wind) under such monetary incentive scheme resulted in a record-breaking growth rate and a world-leading status in terms of total installed capacity. By the end of 2017, China has 619 GW of total installed capacity of renewable energy power plants, the largest of any country in the world and 2.7 times bigger to the 2nd place country the US (with 229GW).

The inherent vulnerability of FiT is the financial burden of subsidies building up through time and the excessive length of commitment timeframes. Standard PPAs with FiT range from 10 to 20+ years (projects around the globe last for at least 20 years on average). The expanding and long-term financial burden of subsidies further pushed down the level FiT and potential disincentive further development.

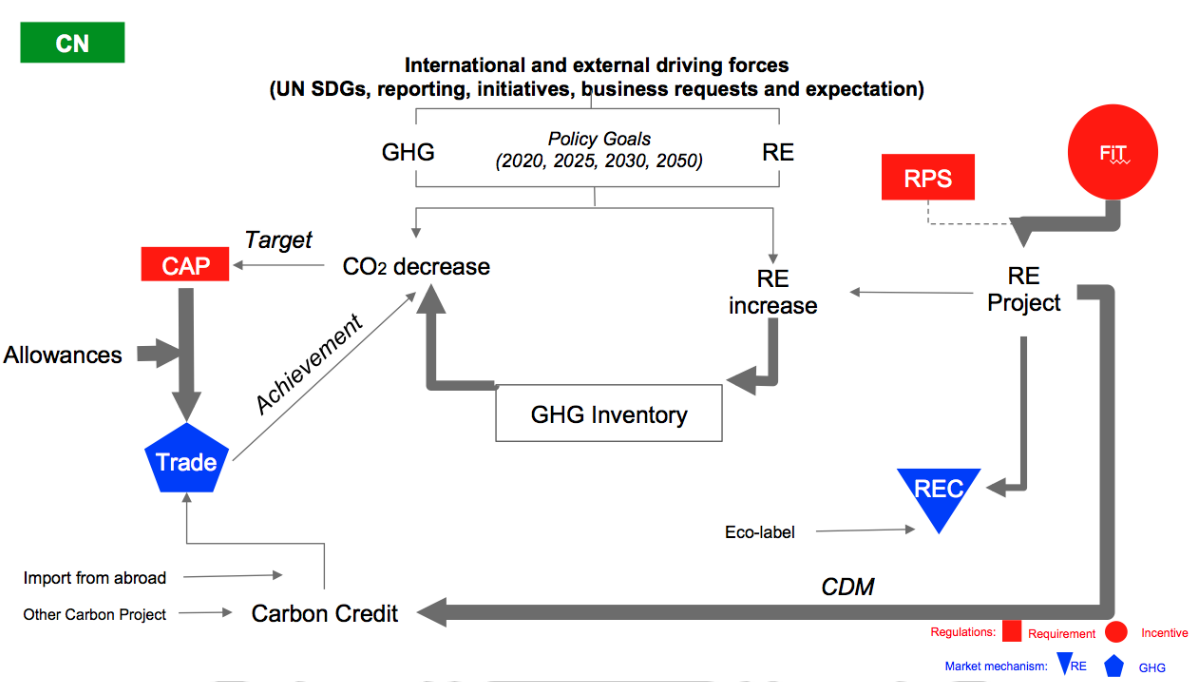


Figure 25. CCLIMMA model of China as of June 2018

Along the progress of renewable development, the adjacency of generation and consumption started to face geographical segregations. Naturally, renewable energy resources are mostly likely located in remote regions from densely populated metropolises. Due to this, electricity generated by renewable energy, faces severe market barriers for wheeling and cross-region trading from incomplete and biased market conditions. Incomplete refers to the way that cross-provincial trading is not possible with a few exceptional cases in Southwest provinces and demonstration projects. Biased market conditions refer to the sense the grid operators (State Grid and South Grid) have not been focused on reform since 2002. China, as the largest renewable energy market, also faces the highest curtailment of generated green power in the world.

The Chinese government launched pilot Green Electricity Certificate scheme in July 2017 and a draft of RPS for public consultation in March 2018. The goal is to launch RPS/REC to gradually replace FiT. The purpose is to shift the financial burden from taxpayers to large and actual users of green power. The shortfalls in subsidies will climb to US$30.2 billion by 2020. Meanwhile, delays in receiving subsidies are also exceeding 12 months. This is the reason why the government launched the REC market mechanism last year, in the hopes of diverting the financial burden to power users.

1. Interaction between carbon and energy markets

The following diagram is based on the carbon-energy market model presented in Chapter 4 and tailored based on China's current realistic circumstances.

On the right-hand side, the large red bubble indicates that the scale of subsidies is substantial. Subsidies have served as an effective policy tool to boost the growth of renewable energy installations. The left-hand side of the diagram shows the current status of carbon market in China. The pilot carbon markets learnt the experiences of market operations with cap and trade primarily on allowances. The cap has not been very aggressive and the feasibilities of CCER are fairly inconsistent each year, it has been fairly successful overall and effective in reducing GHGs.

6.6 Conclusions

In conclusions, we found that the three Asian markets possess common characteristics in the process of electricity development: (1) The promotion of the renewable energy development via FiT system, albeit experiencing heavy financial pressure burdens; (2) The implementation of FiT system is being followed by the REC system which then faces the difficulties of failure within the certificate market. The current status of renewable energy development in the three markets are illustrated in Table 19.

FiT systems implemented in Taiwan, Japan and China are all faced with the same problem. The lack of FiT subsidy resources entails huge economic and financial burdens for the respective governments. Taiwan's funds for renewable energy electricity procurement are derived from a renewable energy development fund. Japan raises funds through the collection of additional electricity charges to the general public, apportioning some of the cost to users. In terms of the long-term energy supply and demand outlook, a clear objective highlighting a makeup of 45% of nuclear energy is to be realized by 2030. The Japanese government is attempting to restart nuclear energy plants in the aftermath of the Fukushima events. China's source of funds is similar to Japan; relying on collections from additional charges levied upon renewable energy electricity to end-users for maintaining its FiT system operations.

Other than capital problems, FiT system also impedes the liberalization of the electricity market. China has inherent laws, regulations and policies that do not clearly correlate with the environmental benefits associated with renewable energy electricity generation. Moreover, the FiT system combines electric power and environmental benefits, when, in fact, they are both substantially different, and thus should not be made to compete in the same market. In the long run, FiT system will be a hindrance to the liberalization of the electricity market.

In Taiwan, the prior voluntary subscription plan for green electricity is similar to the existing T-REC. However, due to the lack of strong economic incentives, its implementation effects are not very significant. Currently, T-REC, which is a result of the measures for the implementation of voluntary REC regulation, limits applicants to either renewable energy electricity generation operators, or to the users with renewable energy equipment termed "self-consumed". However, renewable energy that is "self-consumed" is very limited, and is entirely unable to meet the T-REC market supply and demand requirements. Moreover, most of the "self-consumed" users demand green electricity. Therefore, they possess little interest in offering up T-RECs to be traded on the market. At present, both the supply volume (only about 26,000 certificates) and the trading volume (only 448 certificates) are very low. Hence, the certificate system is likely to face a dead-end if a more circulative REC market is not established soon.

The existing trading difficulty of green certificates in China also highlights that it is impossible to replace subsidies with green certificates in the short run. The high price of green certificates is the underlying reason for poor market performance and the low incentives for the consideration of electricity consumers. Simultaneously, with reference to the *Notice on the Trial Implementation of Issuance and Voluntary Subscription Trading of Green Energy Certificate for Renewable Energy Electricity*, it clearly stipulates that green certificates are not allowed to be resold. Thus, green certificates are not able to convey the role or value associated with a commodity within the certificate market. If T-REC or Chinese green certificates persist as a voluntary subscription mechanism without the corresponding regulatory policies to enforce it within the market, such as introducing RPS of renewable energy regulations, the current predicament will continue to prevail. However, in terms of China's up and coming carbon market, green certificates can be utilized as an alternative market instrument for energy savings and carbon reductions to mitigate existing adverse factors such as the grave imbalance between renewable energy electricity generation regions and electricity consumption regions. A defective market adjustment mechanism, the shortage of transmission facilities, and the lack of flexibility within the electric power system that have already contributed to the abandonment of wind power and solar power in the western regions.

As per EU's experience, the existing FiT system for renewable energy electricity subsidies will experience a year on year decline until it is eventually eliminated. However, in order to truly realize the liberalization of electricity market in the process of shifting towards electricity liberalization, the market can be supplemented via certificates.

The existing problems regarding self-consumed generation in Taiwan can be rectified with the introduction of electricity generation certificates. The discrepancy between Japan's electricity system and market can be improved by the means of market integration, optimizing resource allocations. With regards to China's gigantic geographical landscape, and the imbalance of development in differing regions, most wind power and solar power equipment resides in massive and sunny regions of the northwest and southwest of China. This includes Xinjiang, Gansu, Ningxia and Qinghai. Many recent energy plants with newly installed equipment become stagnant, as electricity generated is unable to be transferred out. Therefore, work was discontinued, as it is likened to electricity being discarded, called "Abandonment of

Wind Power" or "Abandonment of Solar Power". However, these problems can be resolved using green certificates.

In terms of the three specific markets discussed within this paper, I-RECs are issued and circulated as REC market commodities. Furthermore, I-RECs are flexible in price and are not restricted by transaction frequencies. Moreover, they are representative of the environmental benefits, and compete independently within the certificate market. Thus, they should help shape the formation of a liberalized electricity market. In short, based on the experience of the European Union and other advanced nations, it is clear that the key deciding factor for FiT moving towards electricity liberalization is for electricity and the environmental benefits to be segmented into two separate markets, to improve market transaction mechanism and establishing liquidity.

Table 19. Comparison of the current situation of renewable energy development in Taiwan, China and Japan

	General situation of Renewable Energy		Taiwan	Japan	China
Current situation	Supply	Installed capacity(GW)	4.7	9.8	570
		Installed Capacity Ratio	9.43%	3.6%	34.6%
		Generating Capacity (GWh)	12.6	138.7	1,450
		Generation Ratio	4.77%	13.2%	24.2%

Demands	Objectives	- In 2025, generating capacity of renewable energy will account for 20% - The installed capacity of solar power devices will reach 20GW - The installed capacity of offshore wind power will reach 3GW - GHG emission in 2050 will be reduced to 50% of that in 2005	- GHG emission in 2030 compared to 2013 will decrease by 26%. - The generating capacity of renewable energy will account for 22% to 24%	- Before 2020, 40GW of hydroelectricity will be added, Totaling 340GW - 79GW of wind power will be added, 210GW in total, of which hydroelectric + wind power is 5GW - 68GW of solar power generation will be added, 110GW totally - 15GW of biomass in total. - Carbon emissions peaking in 2030 - Decrease of CO2 emissions per unit of GDP by 60%-65% as compared to 2005

Policies and regulations	**Policies**		*Renewable Energy Development Act* Amendments to *Electricity Law*	*Renewable Energy Special Measures Act*	*Renewable Energy Law*
	Regulations	Early stage Electricity market reform, supply side	Private power plants introduced late 1990s.	small scale power sector reform from 1995/1999/2003/2008; Private organizations initiating RECs	Separating government functions from enterprise management, separating power plants from power grid, separating electricity transmission from electricity distribution
		Current stage Renewable energy arises; FiT system	Fixed FiT rate, long term contract, and annual price review	The combination of RPS and GECJ is too slow; FiT arises	FiT subsidies without time limits = FiT - the standard electricity price of desulfurized coal benchmark electricity prices

	Attribution of environmental benefits and its tools	Ambiguous - Voluntary green electricity price - T-REC, 26,070 certificates approved and issued, 448 certificates traded.	Belong to grid operators/the public - GECJ, certification 2.73 million certificates issued, 2.63 million certificates traded - Non-fossil power electricity certificate	Ambiguous - Green electricity certificate, about 8 million certificates issued, 21,000 certificates traded
The emergence of the certificate system		2017	2000, Voluntary/private 2008, Official	2017

Chapter 7. Policy suggestions and suggested future research

7.1 Policy suggestions

The generic CCLIMMA model presented in Chapter 6 was used to examine three Asian energy marketer. The conclusions drawn from such analysis were presented at the end of Chapter 6. While each market has its own specific historic and dynamic characteristics, the following conclusions can be drawn as references for further policy-making:

1. FiT are effective at igniting renewable energy development. But long-term sustainable development still relies on market mechanisms guided by non-subsidy policies such as renewable portfolio standards (RPS). It is suggested to have a roadmap migrating from subsidy-based FiT to an RPS/REC market mechanism.
2. While cap-and-trade could serve as an enforceable policy instrument, renewable energy growth would bring definite and direct GHG reductions by reducing grid EFs in the short term and replacing fossil-fueled power generation in the long term. It is suggested to allow and realize GHG reductions through consuming green power in GHG inventory.
3. Adoption by law for recognizing consuming green power as measures of BAT for power-intensive industries would directly change the power consumption profiles and result in lower GHG emissions.
4. The co-existence of REC and carbon credits for the same unit of electricity often causes confusion and conflicts. Many believe such co-existence will cause double counting of the underlying environmental attributes. Whether or not there is double counting would strictly rely on the designs or definitions of these policy measures. Examples allowing such co-existences include such as the GO and ELCert markets in Norway and Sweden, RPS in Korea which co-exist with K-CER or CDM, and Green Certificate Scheme in China co-existing CDM or CCER. Examples that do not allow such co-existence are the GO under the German FiT, Japanese renewable PPAs under FiT and Renewable PPAs under FiT. It is suggested to first define the policy goals rationally before the justification of allowing such co-existence/double claims or not.

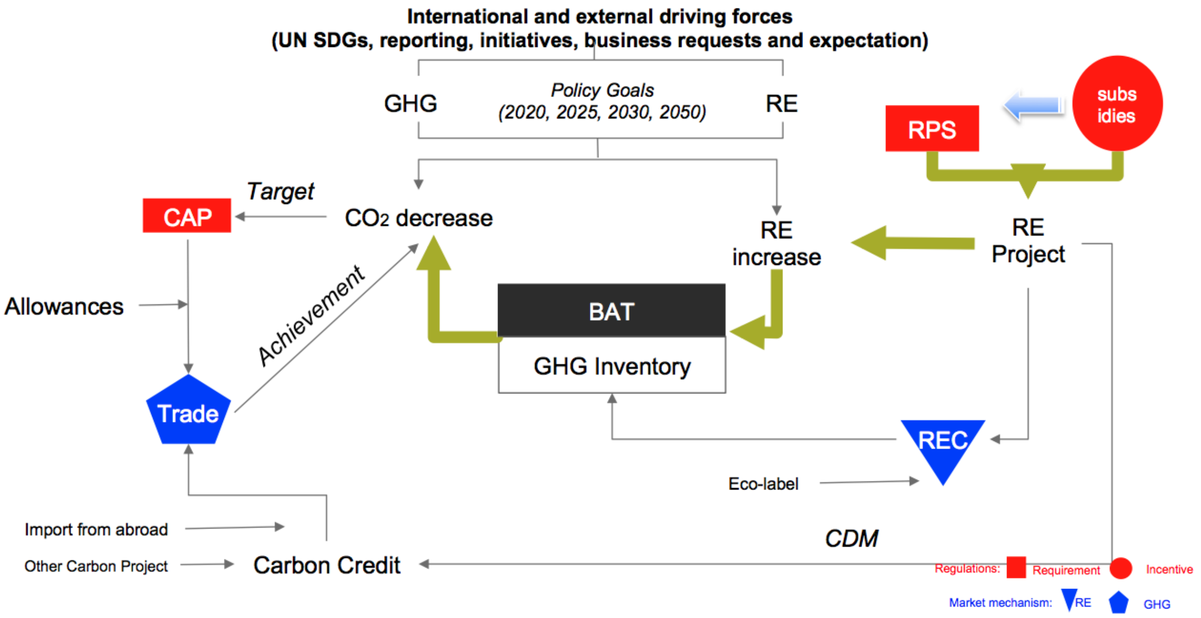


Figure 26. CCLIMMA model of suggested climate market

7.2 Suggested further research

1. Integrating carbon and renewable energy policies for synergies: the synergetic effect of carbon and renewable energy policies in quantitative manners in total fiscal budget spent to reduce GHGs.
2. Phasing out FiT for selected renewable types gradually: governmental guaranteed purchase is always one of the factors regarded as hurdles of market liberalizations. Further research could be conducted on simulations of subsidy phase-outs and their impact on further GHG reduction and renewable energy developments.
3. Innovative technology of trading market infrastructure: facilitating market developments by cutting-edge market tools such as distributed ledgers, smart contracts, and block chains.

Glossary

Terms	Definition
Climate markets	Carbon markets and green power markets
Carbon markets	Marketplace where carbon market instruments are traded
Carbon market instruments	Allowances and carbon credits
Allowances	Emission permits granted by authorities under can-and-trade scheme
Cap and trade scheme	Regulatory scheme emission targets and carbon market instruments
Carbon credits	Offset credits generated from project-based emission reduction activities
Green power markets	Marketplace where renewable-based power being traded

Abbreviations

AAU	Assigned Allowance Units
ACM	Large-scale methodologies
AM	Baseline methodologies
AMS	Small-scale methodologies
AR-ACM	Consolidated large-scale methodologies
AR-AM	Consolidated baseline methodologies
BAT	Best Available Control Technology
BSMI	Bureau of Standards, Metrology & Inspection
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CER	Certified Emission Reduction
CHP	Combined Heat and Power
COP	Conference of the Parties
CSR	Corporate Social Responsibility
EEC	Energy Efficiency Credit
EF	Emission Factor
ESC	Energy Savings Certificate
ET	Emissions trading
ETS	Emissions Trading System
EUA	European Union Allowances
FiT	Feed-in Tariff
GECCJ	Green Energy Certification Center, Japan
GECJ	Green Energy Certificates, Japan
GGRMA	Greenhouse Gas Reduction and Management Act

GHG	Greenhouse Gas
GO	Guarantee of Origin
GS	Gold Standard
GSF	Gold Standard Foundation
IETA	International Emissions Trading Association
IPCC	Intergovernmental Panel on Climate Change
JI	Joint Implementation
MOEA	The Ministry of Economic Affairs
MWh	Megawatt-hour
NDRC	Chinese National Development and Reform Commission
NEA	National Energy Administration
PPA	Power Purchase Agreement
PV	Photovoltaic
REC	Renewable Energy Certificate
RPS	Renewable Portfolio Standard
SERC	State Electricity Regulatory Commission
Taipower	Taiwan Power Company
UN	United Nations
UNCED	United Nations Commission on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate
VCS	Voluntary Carbon Standard
VCU	Voluntary Carbon Units
VGPPP	Voluntary Green Power Pilot Program
WEF	World Economic Forum
WMO	World Meteorological Organization

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