I-REC's Roles in Decarbonization in Thailand: Challenges and Opportunities

Suchada Karestree* and Aweewan Panyagometh**

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Abstract

Thailand has electricity from renewable energy resources 13-15% of the total electricity supply, but it comes through the mixed grid with brown energy as The Electricity Generation Authority of Thailand is the single buyer of bulk electricity and distributes it nationwide through one grid. However, those companies can claim the use of renewable energy by purchasing renewable energy certificates. The certificate available in Thailand and acceptable at the international level standards is the Trading of the International Renewable Energy Certificate (I-REC). This research studies I-REC's role in decarbonization in Thailand and its ecosystem by the qualitative method through in-depth interviews. The result shows that I-REC meets the needs of the company that wants to claim its decarbonization at the international level standards and focus on the utilization of renewable energy. However, registration costs and customer acquisition are not easy to make decisions for some small renewable energy power plants. There is a business model that offers support on the registration fee, manages marketing and sale of their I-RECs, and shares profits with the project owners. It will encourage more development of renewable energy and promote more supply of I-REC in the Thai market. Currently, I-REC demand is exceeding the supply. According to the Utility Green Tariff scheme and The Feed-in Tariff (FiT) Scheme for the Period of 2022 to 2030, there can be an impact on the players in the I-REC registry the market, the price, and the demand and supply.

Keywords: i-REC; Decarbonization; Renewable Energy; Net Zero Emission

* International College of NIDA, National Institute of Development Administration (NIDA)
148 Moo 3, Serithai Road, Khlong-Chan, Bangkapi, Bangkok 10240, THAILAND.
E-mail: -

** International College of NIDA, National Institute of Development Administration (NIDA)
148 Moo 3, Serithai Road, Khlong-Chan, Bangkapi, Bangkok 10240, THAILAND.
E-mail: maweewan@gmail.com

บทบาทของไออาร์อีซีในการลดการปล่อยคาร์บอนในประเทศไทย: ความท้าทายและโอกาส

สุชาดา คเรศตรี* และ อาวีวรรณ ปัญญาโกเมศ**

รับวันที่ 22 สิงหาคม 2566 ส่งแก้ไขวันที่ 30 ตุลาคม 2566 ตอบรับตีพิมพ์วันที่ 17 พฤศจิกายน 2566

บทคัดย่อ

ประเทศไทยมีไฟฟ้าจากแหล่งพลังงานหมุนเวียนร้อยละ 13-15 ของอุปทานไฟฟ้าทั้งหมด แต่ทว่ามาจากระบบกริดผสมของพลังงานสีน้ำตาล โดยมีแค่การไฟฟ้าฝ่ายผลิตแห่งประเทศไทยเป็นผู้จัดซื้อและจำหน่ายไฟให้ทั้งประเทศผ่านหนึ่งกริดแต่ เพียงผู้เดียว อย่างไรก็ตามบริษัทต่าง ๆ สามารถอ้างว่าใช้พลังงานหมุนเวียนด้วยการซื้อใบรับรองการผลิตพลังงานหมุนเวียน ซึ่งใบรับรองดังกล่าวในประเทศไทยนั้นเป็นที่ยอมรับตามมาตรฐานสากล โดยการซื้อใบรับรองการผลิตพลังงานหมุนเวียนสากลหรือ ไออาร์อีซี (I-REC) งานวิจัยนี้ศึกษาบทบาทของไออาร์อีซี ด้านการลด การปล่อยคาร์บอนในประเทศไทยและระบบนิเวศ ทั้งนี้ด้วยวิธีวิจัยเชิงคุณภาพผ่านการสัมภาษณ์เชิงลึก ผลการวิจัยแสดงให้เห็นว่า ไออาร์อีซีตอบสนองต่อความต้องการของบริษัทที่ประสงค์จะอ้างการลดการปล่อยคาร์บอนตามมาตรฐานสากล และมุ่งมั่นต่อการใช้ประโยชนีจากพลังงานหมุนเวียน อย่างไรก็ตามต้นทุนการจดทะเบียนและการได้มาซึ่งลูกค้าใหม่เป็นสิ่งที่ยากต่อการตัดสินใจสำหรับโรงงานผลิตไฟฟ้าหมุนเวียนขนาดเล็ก ทั้งนี้มีโมเดลธุรกิจที่นำเสนอการสนับสนุนค่าจดทะเบียนจัดการการตลาดและการซื้อไออาร์ซี ตลอดจนการแบ่งปันกำไรกับเจ้าของโครงการ ซึ้งเป็นการสนับสนุนให้มีการผลิตพลังงานหมุนเวียนเพิ่มขึ้น ประกอบกับส่งเสริมอุปทานไออาร์ซีในตลาดไทย โดยปัจจัยมีอุปสงค์ไออาร์ซีเกินกว่าอุปทาน ทั้งนี้ข้อมูลจากมาตรการไฟฟ้าสีเขียวและการรับซื้อไฟฟ้าจากพลังงานหมุนเวียน (FiT) ช่วงปี 2022 ถึง 2023 แสดงให้เห็นว่าอาจมีผลกระทบต่อผู้มีส่วนได้ส่วนเสียในตลาดการจดทะเบียนไออาร์ซี ราคาอุปสงค์และอุปทาน

คำสำคัญ: ไออาร์อีซี การลดการปล่อยคาร์บอน พลังงานหมุนเวียน การปล่อยก๊าซเรือนกระจกเป็นศูนย์

* วิทยาลัยนานาชาติ สถาบันบัณฑิตพัฒนบริหารศาสตร์
เลขที่ 148 หมู่ที่ 3 ถนนเสรีไทย แขวงคลองจั่น เขตบางกะปิ กรุงเทพฯ 10240
อีเมล: -

** วิทยาลัยนานาชาติ สถาบันบัณฑิตพัฒนบริหารศาสตร์
เลขที่ 148 หมู่ที่ 3 ถนนเสรีไทย แขวงคลองจั่น เขตบางกะปิ กรุงเทพฯ 10240
อีเมล: aweewan.m@nida.ac.th

1. Introduction

1.1 Background

Climate change has become a worldwide issue since the Paris Agreement, a legally binding international treaty on climate change, was adopted by 196 countries including Thailand at the 21st UN Climate Change Conference or COP21 in Paris in December 2015. It focuses on strengthening the response to the threat of climate change by limiting the average global temperature increase in this century to less than 2 degrees Celsius compared to pre-industrial times and trying to maintain the global average temperature increase of no more than 1.5 degrees Celsius. It covers the areas of greenhouse gas reduction (Mitigation), climate change adaptation (Adaptation), financial structure (Climate Finance), building mechanisms transparency (Transparency), and review of global operations (Global Stock). It also supports various fields in both the development and transfer of technology as well as capacity building of developing countries including financial. The participating countries must have a proposal of action called the Nationally Determined Contribution (NDC) every five years.

Thailand is one of the top ten countries in the world most affected by climate change with the proportion of greenhouse gas emissions from the transport and energy sectors accounting for 74.35% and the agricultural sector at 15.98% (Action for Climate Empowerment Thailand, 2021). At the 26th UN Climate Change Conference or COP26 in Glasgow in November 2021, Prayut Chan-ocha – the Prime Minister announced Thailand's aim to reach carbon neutrality by 2050, and net zero greenhouse gas emission by or before 2065.

To align with the country's goal, the Ministry of Energy enacted the National Energy Plan to achieve carbon neutrality in 2065-2070. This roadmap will shape the direction of the country's energy development in 4 aspects 1) Electricity – Increase renewable energy to more than 50% of the total production by promoting electric vehicles, accelerating grid technology to grid modernization and microgrid, and relaxing power purchasing agreement and prosumer 2) Natural Gas – Balance domestic and imported liquid natural gas (LNG), and aim to be a hub of LNG trading 3) Oil – Adjust

energy plan for transportation and balance between biofuel and EV users 4) Renewable Energy and Energy conservation – Promote production and consumption of renewable energy as well as enhance energy efficiency in all sectors.

Despite Thailand's commitment to the decarbonization goal, Thailand does not have any regulation or tax system to regulate greenhouse gas emissions or carbon footprint for manufacturing at this moment. In March 2022, Carbon Border Adjustment Mechanism (CBAM) is approved by the Council of the EU to be an EU legislation for businesses importing products into the EU (Deloitte, 2022).

As a transitional period from January 1, 2023, it requires EU importers to report the embedded emissions of imported products and implement the purchase of a CBAM certificate upon embedded emissions amount starting from January 1, 2026. Accordingly, being aware of the climate change issue and business sustainability in line with the commitments made by governments in various countries under the Paris Agreement, many multinational companies commit to achieving net zero or carbon neutrality. Decarbonization has also become a priority for businesses in Thailand especially those who are doing global business. Riding with the global trend, the country's commitment, and upcoming unavoidable legislation, a number of big companies in Thailand have announced their carbon neutrality and net zero goal as an ambition of voluntary emission reduction (Bangkokbiznews, 2021).

Carbon emissions from purchased electricity or scope 2 (see figure 1) are unavoidable for almost every company in Thailand. According to Energy Policy and Planning Office, Ministry of Energy (2022), the average carbon emission amount from electricity generation from 2017 to 2021 was 92.44 million tons of CO_2. To reduce carbon emissions from purchased electricity, we need to transition to renewable energy like solar, wind, thermal, hydro, and biomass because it generates electricity without producing greenhouse gas. However, at present, according to the Electricity Generation Authority of Thailand (EGAT) (2021), Thailand still mainly uses electricity from fossil power plants which are lignite power plants At Mae Moh mine around 10%, imported coal 10%, natural gas 55-57%, domestic hydropower 3%, imported from Lao PDR around 7%, and the rest is renewable energy which is only 13-15%

(Electricity Generation Authority of Thailand, 2021). Electricity supply in Thailand is based on a state-owned enhanced single-buyer scheme. The EGAT is the single buyer of bulk electricity and distributes it nationwide through one grid. Therefore, electricity from every source is mixed in the grid. The consumer cannot choose the source of energy. However, on November 7, 2022, The National Energy Policy Council approved the Utility Green Tariff scheme to set the electricity tariff from renewable energy resources and deliver electricity produced from renewable resources through separate power transmission lines directly to the businesses or manufacturers who require renewable energy and sell REC in a bundle with the electricity. This scheme is expected to be implemented in 2024 (Royal Thai Government, 2022).

It brings the question of how those companies that commit to net zero or carbon neutrality achieve the target because no matter how they put effort to reduce carbon emissions in the company-owned area and controlled resources or scope one, they would not be able to reduce carbon emission in scope 2 (purchased electricity) due to the condition mentioned above at this moment. Shall they wait until the Utility Green Tariff scheme is implemented or do they have other choices to contribute to their commitment?

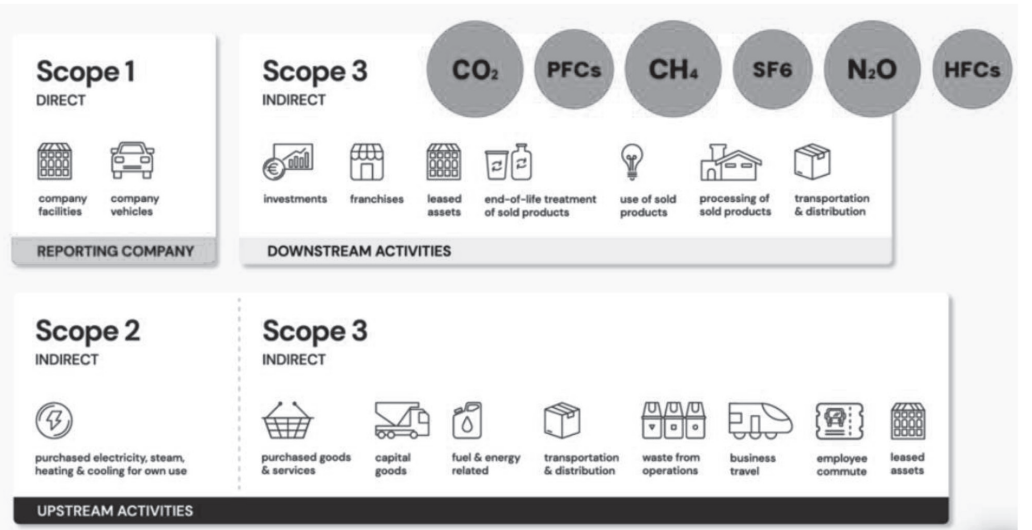

Figure 1: Scope of Carbon Emissions Based on GHG Protocol (Bernoville, 2022)

The EGAT suggests guidelines for carbon emission control for businesses as follows; 1) Carbon credit trading 2) Thailand Voluntary Emission Reduction Program (T-VER) which is a mechanism that aims to encourage all sectors to participate in reducing greenhouse gas emissions in the country and can trade carbon credit. 3) Trading of the International Renewable Energy Certificate (I-REC) to promote electricity production from renewable energy to reduce greenhouse gas emissions. 4) Carbon neutrality to encourage using clean energy innovations such as solar cells.

1.2 Research Objectives

As electricity in Thailand is a mixed grid of brown and green energy, the consumer cannot choose to use only renewable energy, purchasing I-REC tends to be the only choice of businesses that have net zero or carbon neutrality goals to reduce carbon emission in scope 2 at this moment. The objectives of this study isto understand I-REC's role in decarbonization in Thailand and its ecosystem on various aspects e.g. 1)Awareness of I-REC in Thailand. 2) How the companies in Thailand that have net zero or carbon neutrality goal position and utilize I-REC to achieve the goal. 3) Comparison of I-REC and T-VER from the user's and seller's perspectives. 4) What encourages renewable energy power plants to be players in the I-REC registry. 5) I-REC market and the demand and supply. 6) I-REC price mechanism. 7) Impact of The Feed-in Tariff (FiT) Scheme for the Period of 2022 to 2030.

Furthermore, according to Halt (2011), REC affects the decision of the project owner to build renewable energy projects in the compliance market in the United States. If the project is very cost-competitive, the importance of REC revenue may be diminished in the build versus no-building decision, but if the project is small, lacks economies of scale, relies on more expensive technologies, or faces other cost challenges, REC will be more important in the project decision. This research would also study the impact of I-REC on the acceleration of renewable energy projects in the voluntary market in Thailand and whether the expected revenue from I-REC affects the decision of the project owner to build renewable energy projects. To answer these objectives, qualitative methods have been applied in this research.

The findings of this research will be a case study for entrepreneurs who are interested in I-REC no matter to utilize them to achieve net zero or carbon neutrality goal, claim in a sustainability report, or apply it to report to CBAM, and will be a guide for entrepreneurs in energy sectors about the I-REC registry, the trend of consumer's demand and business chances on the I-REC. It also provides information for those who look for new business models and opportunities in the I-REC registry e.g. brokers or banks. Besides, it can be a reference for the government sectors related to energy policy to understand the current I-REC market, develop the utility green tariff scheme and the Fit scheme into action without causing damage to businesses, and initiate some incentives that would benefit both businesses and the country.

2. Literature Reviews

2.1 What is a Renewable Energy Certificate (REC)?

A renewable Energy Certificate or REC is a market-based instrument that represents the property rights to the environmental, social, and other non-power attributes of renewable electricity generation. RECs are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy resource. RECs include data attributes such as certificate date and type, tracking system ID, renewable fuel type, renewable facility location, project name, the capacity of the project, and emission rate of the renewable resource (United States Environmental Protection Agency, 2022).

RECs play an important role in accounting, tracking, and assigning ownership to renewable electricity generation and use because the physical electricity we receive through the electricity power grid comes and mixes from many different resources which are fossil-based power plants, solar farms, etc. Each REC represents a specific amount of electricity produced and delivered to the power grid by a renewable resource such as wind or solar. RECs are the instrument that electricity consumers must use to substantiate renewable electricity use claims. For example, in the case of the wind turbine, for every megawatt hour of electricity it produces, the turbine's owner generates a REC that they can either keep or sell. If a company

buys the REC, the company is now the owner of that green power and is allowed to claim that the electricity the company uses came from a renewable resource with low or zero carbon emission.

RECs allow organizations to choose a cleaner source of energy and reduce their carbon footprint. They give organizations the flexibility to support renewable energy even if they cannot generate it themselves or if the local utility does not provide green power. By purchasing RECs, organizations are providing revenue to support renewable energy projects. When enough people buy RECs, these purchase growth in green power development and help to avoid greenhouse gas emissions across the country.

2.2 The International Renewable Energy Certificate Standard (I-REC)

Developed countries like the United States or European countries have had their own REC schemes which are US RECs and EECS-GO relatively. The International REC Standard Foundation (I-REC Standard) is a non-profit organization headquartered in Netherland that provides a robust standard for developing attribute tracking systems globally, especially in developing countries. The I-REC Standard is accepted by major reporting frameworks such as Greenhouse Gas Protocol (GHGP), Carbon Disclosure Project (CDP), and RE100 as a reliable backbone for credible and auditable tracking instrument (The I-REC Standard, 2022).

Countries participating in The I-REC Standard

1.	Argentina	14.	Dominican Republic	27.	Laos	40.	Saudi Arabia
2.	Australia	15.	Ecuador	28.	Lebanon	41.	Singapore
3.	Bangladesh	16.	Egypt	29.	Malaysia	42.	Somalia
4.	Brazil	17.	El Salvador	30.	Mauritius	43.	South Africa
5.	Brunei	18.	Ghana	31.	Mexico	44.	South Sudan
6.	Burkina Faso	19.	Guatemala	32.	Morocco	45.	Sri Lanka
7.	Cambodia	20.	Honduras	33.	Namibia	46.	Taiwan
8.	Chad	21.	India	34.	Nigeria	47.	Thailand
9.	Chile	22.	Indonesia	35.	Oman	48.	Turkey
10.	China	23.	Israel	36.	Pakistan	49.	UAE
11.	Colombia	24.	Japan	37.	Panama	50.	Uganda
12.	Costa Rica	25.	Jordan	38.	Peru	51.	Vietnam
13.	Democratic Republic of the Congo	26.	Kazakhstan	39.	Philippines	52.	Zambia

As of 2021, there are 51 active I-REC participating countries, 19 accredited I-REC issuers and more than 70 terawatt-hours (TWh) I-REC were issued (see Figure 2). Figure 3 is a sample of I-REC certificate. The beneficiary is an end-user to which the I-RECs are redeemed.

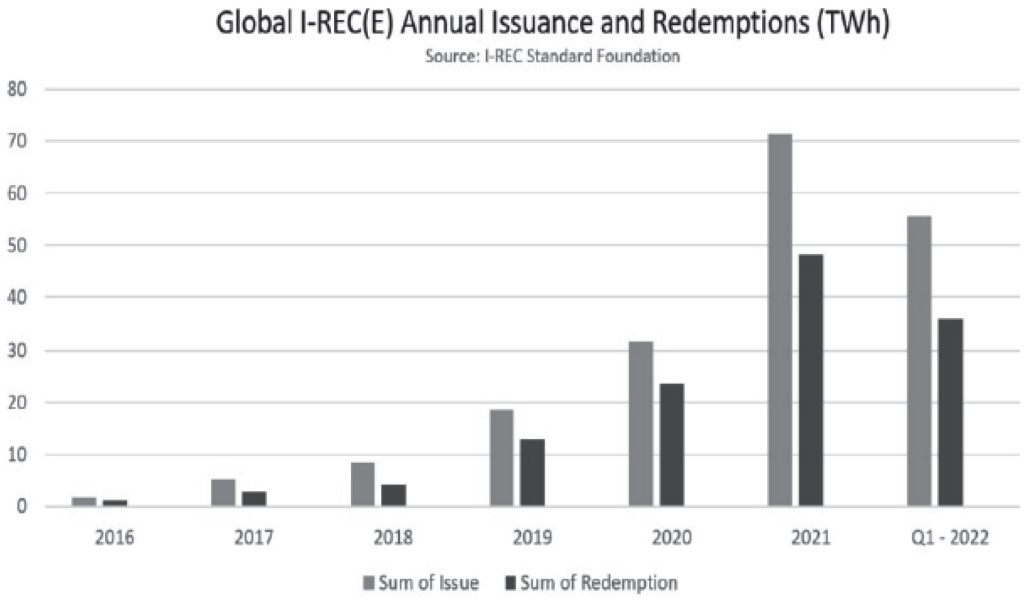

Figure 2: Global I-REC Annual Issuance and Redemption (TWh) from 2016-Q1 2022 (The I-REC Standard Foundation, 2022)

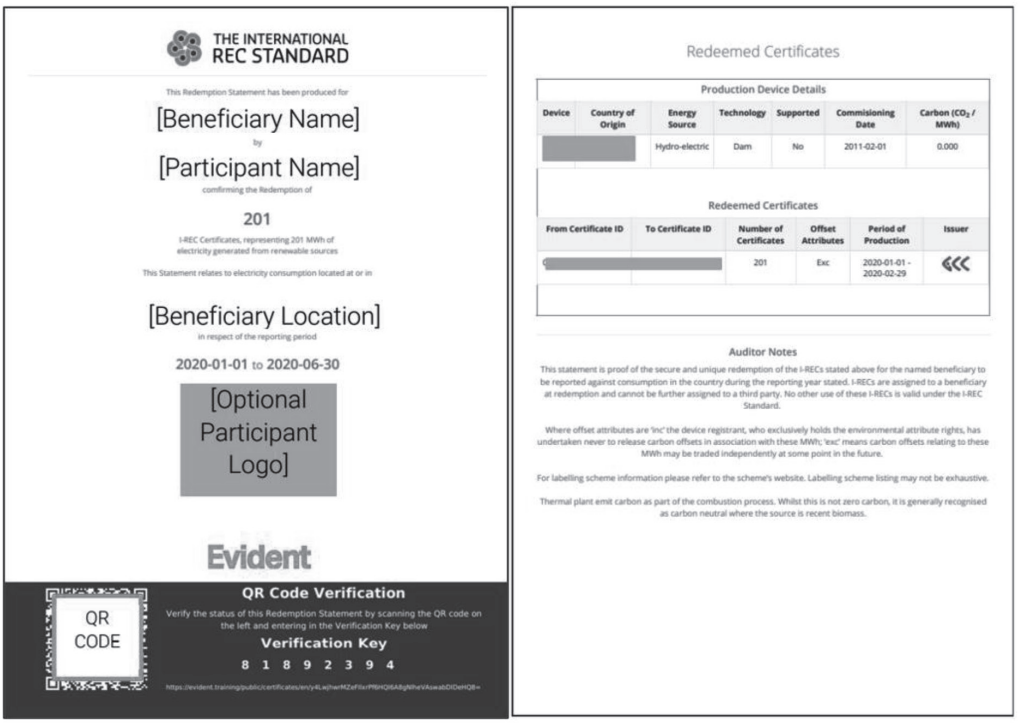

Figure 3: Sample of I-REC Certificate. (Greenyellow, 2022)

2.3 Role in the I-REC Registry

There are main 3 roles in the I-REC Registry

2.3.1 Issuer – The issuer controls the registration of renewable energy generating facilities, oversees and verifies the reporting of generation data, and issues I-RECs based on reported generation. There is usually one issuer for a country which can be a government agency or an independent entity. Thailand's local issuer is the EGAT. However, registration and I-REC issuance can be done through the I-REC central issuer "GCC" which can support worldwide.

2.3.2 Registrant – The registrant is the renewable energy generating facilities that want to have their own devices certified and request I-REC issuance on their behalf to be able to claim for themselves or sell to participants or end users. However, the facility's owner can be both a registrant and a participant.

2.3.3 Participant – The participant can be anyone who wants to trade or hold I-REC to claim their contribution to renewable energy. It can be the renewable energy power plant owners themselves, I-REC brokers, or end-users. However, end-user can buy I-REC from a participant by getting I-REC redemption to their name without registering to be a participant (see Table 1).

Referring to Table 1, the participant will have to bear an account opening fee and the annual fee which is a relatively high cost. Therefore, some renewable energy power plant owners also register as participants to bear that cost and redeem RECs in the name of the buyer. In this case, the buyer does not need to have an account in the I-REC registry, but the price of RECs may be quoted based on the cost of the seller's participant account fee and redemption fee.

Table1: Fee for Registrant and Participant in the I-REC Registry

Registrant (Pay to EGAT)		**Participant (Pay to the I-REC Standard)**	
1. Registrant application fee	-	1. One-time trade account opening fee	EUR500
2.One-time device registration fee (5-year validity)	THB38,000	2. Annual trade account fee	EUR2,000
3. Device renewal fee after 5-year validity	THB15,200	3. Additional redemption account fee	-
4. Issuance fee (per MWh)	THB0.95	4. Redemption fee (per MWh)	EUR0.06

Source: Electricity Generation Authority of Thailand (2022)

2.4 REC Market in Thailand

The I-REC registry was brought into Thailand in 2017. EGAT registered and had a contract with the I-REC organization as a Thai local issuer in 2020. The First I-RECs were issued 62,747 RECs which is equal to 62,747 MWh in 2017 and it has grown double digits every year to 2,166,164 RECs in 2021 from solar, hydro, wind, and thermal resources (see figure 3). However, these I-RECs were redeemed 334,696 I-RECs in 2020 and 757,001 I-RECs in 2021 to participants or end-consumers in Thailand to claim their renewable energy contribution (see figure 4). The redemption rate grew 126% over a year (The International REC Standard, 2022).

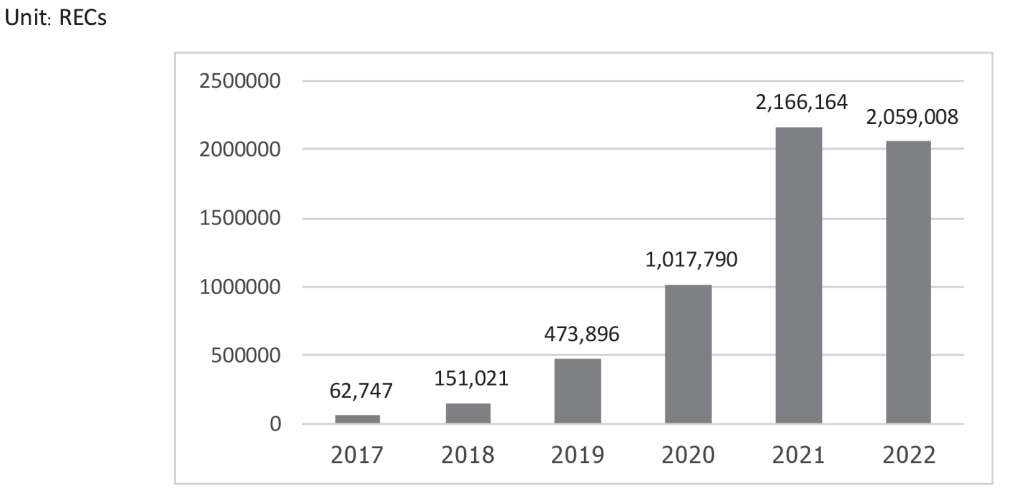

Figure 4: I-RECs Issued in Thailand from 2017 to 2021 by the I-REC Standard as of September 2022

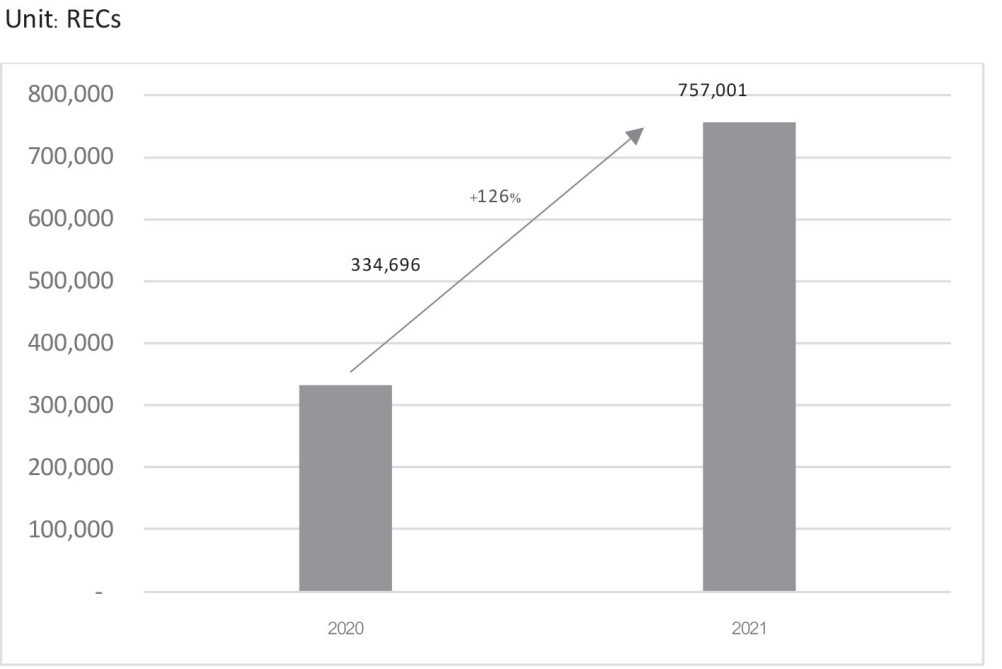

Figure 5: Redemption of I-RECs in Thailand from 2020 to 2021 by the I-REC Standard

REC is an important tool of decarbonization in Thailand. World-leading companies set their net zero emission target as well as a 100% renewable energy utilization commitment (RE100) as evidenced by the increasing number of RE100 companies joining in 2019 with 261 companies to 378 companies at the present. At least 50 of these multinational companies are doing business in Thailand, which means there would be a demand for RECs as it is the only way to contribute and claim the renewable energy attribute in Thailand because they cannot buy renewable electricity directly from the renewable power plants.

3. Research Methodology

3.1 Research Method

As REC is a new thing for businesses in Thailand, it is known only among specific groups of people. In order to satisfy the objective of the research, qualitative research will be held through personal interviews with unstructured questions to gain an in-depth understanding of the underlying reasons and motivations. The unstructured interviews offer flexibility and let the interview flows, leaving room to generate conclusions that were not initially meant to be derived regarding a research subject (Gill & Johnson, 2002).

3.2 Research Approach

This research approach is an inductive approach. The researcher begins with an observation, gathers information from interviews, summarizes, and makes a conclusion. The interviewees are informed prior to the interview. The questions are reviewed by 2 experts to ensure validity of the data. Importantly, the questions should not go against privacy or research ethical issues. The interviewees were asked to consent before voice recording.

3.3 Sample Selection

The sample selection is based on their knowledge, position in organizations, relationships, and expertise regarding the research subject. In this study, the researcher targets senior officers, senior managers, or directors of these 3 groups of these companies which are summarized in Table 2.

Table 2: 3 Samples Group

	Sample Groups	
Issure	EGAT and Innopower Co., Ltd	The Electricity Generation Authority of Thailand and its affiliate; Innopower Co., Ltd. The reason for targeting this group is to gain an overview of current I-REC trends in Thailand as they are the only local issuer.
Registrant	Renewable power producer	Renewable energy power plants who also sell I-REC. The reason for targeting this group is to study the awareness of renewable energy facilities owners on I-REC, how they do marketing on their I-REC, whether they register themselves as a participant to facilitate convenience for the buyer, and how revenue from selling I-REC promote the development of renewable energy projects.
Participant	Customer company as a net carbon neutral company	Companies in Thailand that have net zero or carbon neutrality goal and have purchased I-REC. The reason for targeting this group is to study how they make decisions to purchase I-REC, starting from understanding their decarbonization goal or policy, how they utilize I-REC to achieve net zero or carbon neutrality goal, and why they started to purchase I-REC now despite their goal to achieve net zero or carbon neutrality is many years ahead, how they negotiate the price, whether they make an agreement with the seller in long term, whether they register as a participant in the I-REC registry.

3.4 Research Process

The researcher contacted interviewees through e-mail to explain the scope of the study and asking if they would accept to participate in the research. If they respond, the online meeting would be held during November and December 2022. During the interview, video would be asked to record to help the researcher to analyze the gathered data. The respondents are free to express their views even if it is not directly included in the objective of the research. (pls write in past tense ka)

3.5 Ethical Consideration

All participants reported their written acceptance of their participation in this research and e-sign consent to disclose or not disclose their names or company names.

4. Results and Discussions

The researcher interviewed respondents from 7 companies in which they can be separated into 3 groups. The first group is the companies that have carbon neutrality goal and have already purchased I-REC. Company A is a French company that produces and sells industrial gas. Company B and C are Japanese fast-moving consumer goods companies. The second group is EGAT and its affiliate, Innopower Company Limited. The third group is 2 Thai leading companies (Company RE-A and Company RE-B) that are running renewable energy businesses, have renewable power plants, especially solar energy, in Thailand and overseas, and are registrants and participants in the I-REC registry. From these interviews, we understand I-REC roles and ecosystem from all perspectives which are an issuer, buyers, producers, sellers, and brokers.

4.1 Awareness of I-REC in Thailand

The Business Development team of EGAT had studied REC since 2019 and the I-REC and finally registered as Thailand's local issuer in October 2020. It also registered its power plants as registrants and sold I-RECs that were verified and issued by GCC – The I-REC central issuer. Since then, EGAT announced it through

mass media and had been holding seminars in various events that were hosted but EGAT itself and other organizations such as Thailand Greenhouse Gas Management Organization to disseminate the knowledge about I-REC to entrepreneurs. The audience were both those who can buy I-REC to achieve their decarbonization goals and those who are renewable energy power plants that can be I-REC registrants and sell I-REC. Company RE-B, a Thai large renewable energy corporation, firstly knew about I-REC and saw another opportunity for its business from a seminar that EGAT introduced I-REC in 2020. It triggerred the company to study more about I-REC and started to make business plans for it. Company C, a Japanese fast-moving consumer goods manufacturer, also firstly heard about I-REC from a seminar at one of the Prime Minister's Award events related to energy management in 2020. When its Japan parent company announced the Zero Carbon Emission goal and joined RE100 in the following year, Company C seriously studied I-REC and renewable energy, and finally purchased I-REC to align with the parent company's decarbonization direction.

However, Company RE-A, a Thai leading renewable energy business operator in the Asia-Pacific region, took one step ahead of EGAT's announcement on the I-REC business. It had known about the I-REC standard from peer trading and technology partners overseas and registered the first renewable energy project to the I-REC registry by being verified by GCC in 2020 before EGAT announced its local issuer.

2 companies in target group one knew I-REC from information sharing among their group companies. Company A's sister company in Asia bought I-REC to achieve its parent company's decarbonization goal in 2021. Thereby, Company A started to study more information about I-REC. So as Company B. Its sister company is an electricity supplier including electricity from biomass. This company registered in the I-REC registry, started the I-REC business in 2021, and sold its first issued I-REC to Company B.

4.2 I-REC and Organization's Decarbonization Goal

The companies in the first target group have decarbonization goals as shown in the table 3 which are in accordance with their parent companies' goals.

Table 3: Decarbonization goals and I-REC purchases of companies in the first target group

Company	Decarbonization Goal	I-REC Purchase
A	The ultimate goal: Net Zero Emission by 2050. Short-term goal: 1) Reduce CO_2 absolute emission by 33% in scopes 1 and 2 compared to 2020 by 2035. 2) Reduce carbon intensity 30% compared to 2015 by 2025.	Equivalent to 50% the total electricity consumption in 2022
B	The ultimate goal: Net Zero Emission by 2050 and reduce 50% of CO_2 emissions in the product life-cycle by 2050. Long-term goal: CO_2 emissions reduction targets of 55% compared to 2017 by 2030.	Equivalent to 100% of the total electricity consumption of the 2 factories in 2022. (not cover electricity usage at the office.)
C	The ultimate goal: Net Zero Emission by 2040 and Carbon Negative by 2050. Sub-goal: 1) 100% renewable energy for purchased power. 2) CO_2 emissions reduction targets 55% in scope 1 and 2, and 22% in product life-cycle (scope 1-3) by 2030 compared with 2017. 3) Achieve RE100 of electricity usage.	Equivalent to 50% of the total electricity consumption of the factory in 2022. Plan to cover 100% of the total electricity consumption of the factory and every office from 2023.

Companies A and B have been working on various energy efficiency and machinery improvement projects to reduce carbon emissions but with limitation of infrastructure in Thailand, they face many challenges to achieve the goal with these activities, so they have to use carbon offsetting.

> *"We are doing recycling. We upgraded machinery to modern technology to reduce energy consumption and installed solar roof panels with a capacity of 1,800 kilowatts but cannot extend more*

capacities because it is all of our factories' roof area. We also improved the degraded forest area and registered it as a T-VER project and accredited carbon credit equivalent to 6,000 tons CO_2 per year. No matter how hard we try to improve energy efficiency, we cannot reduce carbon emission to zero, so we had to consider offsetting with I-REC or T-VER." Company B interviewee.

"Our company has been doing reforestation for 8 years and conducting many decarbonization activities in the factory such as installing solar roofs, changing light bulbs to LED, replacing the air-conditioning system to inverter type, improving the waste heat recovery system. For the solar panel, it can generate electricity 782 MWh per year which is only 2% of total demand. We cannot achieve 100% renewable energy goal without considering I-REC due to the regulation that does not allow us to directly purchase electricity from renewable energy power plants." Company C interviewee.

"In our factory, we use 2 main sources of energy which are natural gas for the heating process and electricity. To reduce carbon emissions from the heating process, we need to invest in Carbon capture, utilization, and storage technology (CCUS) which would be a large investment and need to handle the captured carbon from CCUS. There, reaching our decarbonization goal with I-REC first is much easier." Company A interviewee.

Despite their ultimate decarbonization goals are in many years ahead they started carbon offsetting from the end of 2021 - 2022 to approach the goal one step at a time and have lessons learned in each step to see if there are any problems in the operation.

"Purchasing I-RECs brought another company expense. We need to consider how to manage this cost and generate benefits for the company. For example, passing this cost to the customers by offering new products as "low-carbon" products as in the process of these

new products we lower carbon by offsetting CO_2 emissions with I-RECs. It will also help the customers who want to reduce CO_2 in scope 3."
Company A interviewee.

Company B and Company C bought I-RECs this time as a pilot case for their group companies, to be their reference about pricing, sellers, how to purchase, and make agreements. Both companies have a similar opinion that the cost of purchasing I-RECs urges employees to pay more attention to energy saving, encourages us to try to reduce the cost, and initiates new projects for carbon reduction. With these efforts, they consider that I-RECs will reach carbon neutral because finally, it will lead to a decrease in energy costs, so the 2 companies do not consider passing this cost to customers. Purchasing I-RECs also brought them indirect benefits, giving them a good image of corporations that care about the environment and climate change. This might benefit those companies when cooperating with government sectors or international business. I-REC is a tool that they can use to achieve their parent company's goal conveniently and can communicate to the public at the international level.

4.3 I-REC and T-VER

When considering decarbonizing instruments in Thailand, the frequently asked question is it should be T-VER or I-REC. T-VER is the GHG emission reduction program, developed by Thailand Greenhouse Gas Management Organization (TGO) to promote and support all sectors to voluntarily participate in the GHG emission reduction program and can sell the reduction unit or carbon credit, which is called "T-VER" under this T-VER program, under voluntary domestic market (Greenhouse Gas Mitigation Mechanism, 2022). However, T-VER does not meet international carbon accounting goals e.g. CDP, TCR, and GRI. Therefore, those who purchase T-VER carbon credits cannot claim their carbon offsets in international standards, unlike I-REC which is accepted internationally. However, it does not mean this program is better than the other, it actually depends on the purpose and the goal of the organization

Table 4: A comparison between I-REC and T-VER

Issues	T-VER	I-REC
Standard Levels	Domestic Standdard	International Standard
Regulation	Voluntary	International Verification
Stackeholder	Unclear	Major partners: Issuer, Registrant and Participant
Price	None	Depend on Market price
Emission Scope	Scope 1, 2 and 3	Scope 2

I-REC meets the needs of those who focus on renewable energy, and carbon reduction in scope 2, and claim their decarbonization in international standards. T-VERis more suitable for those who focus on the domestic market and want to offset carbon in all scopes. Company B gave us a clear picture of this point.

> *"From 2023 onwards we plan to use T-VER instead of I-REC. We feel that I-RECs has low impact in term of domestic public communication. It is more effective for PR at the international level. Our parent company can mention it globally but for our company itself, our products are sold in Thailand. We think supporting T-VER would deliver a better image and communication to the public and our customers. Besides, we have our T-VER project on reforestation which we can expand and use them to offset our carbon emissions unlike I-REC, we have no way to produce it by ourselves because we cannot build our own renewable energy power plants."* Company B interviewee.

Company A and Company C plan to keep purchasing I-REC in the next years. The parent company of company A allows purchasing I-REC only. Company C has a firm intention to continue buying I-REC because of its 100% renewable energy goal.

4.4 EGAT and I-REC

EGAT is the only Thai local issuer of the I-REC standard. It controls the registration of renewable energy generating facilities, oversees and verifies the reporting of generation data, and issues I-RECs but it also sold I-RECs from its renewable energy power plants which were verified and issued by GCC. However, according to the I-REC standard's regulation, the issuer cannot have a trade account. The customer who wants to buy I-RECs from EGAT must register as an I-REC participant and open a trade account to receive the issued I-REC. It means that the customers must bear the cost of the account opening fee of EUR500 and the annual fee of EUR2,000 (see table 1), even though some large corporates, mostly multinational ones, were willing to purchase EGAT's I-REC because of EGAT's reputation.

However, to separate and make it clear between the issuer's role and the seller's role, EGAT restructured and transferred its functions related to I-REC selling and marketing to its affiliate – Innopower Co., Ltd in June 2022. Innopower's business consists of venture builder for startups in Thailand, venture capital, and joint venture or building quick-win strategic partnerships related to clean energy innovations by jointly investing in businesses that are making profits for sure (Electricity Generation Authority of Thailand, 2022). I-REC business became a part of Innopower's business. EGAT's renewable energy generating facilities are transferred to be registered under Innopower's name as their registrant. Innopower is a registrant and also registered as a participant to hold accounts in the system to hold, transfer, and redeem I-RECs for customers. Customer who wants to buy I-RECs representing electricity generated from EGAT's renewable energy facilities can buy them from Innopower without registering to be a participant in the I-REC registry. In another word, one of Innopower's businesses is an I-REC broker but it does not limit to I-RECs representing electricity generated from EGAT's renewable energy facilities. Innopower is also buying I-REC from other I-REC registrants for trading.

4.5 What Encourages Renewable Energy Corporations to be Players in the I-REC Registry?

Renewable energy power plants can choose to register in either the I-REC registry or T-VER but REC and carbon credit must not be double counted. This research studies how renewable energy corporations decide to be a player in the I-REC registry. The research target second group, Company RE-A, and Company RE-B, both gave the same opinion. they did not even need to do a deep market research before making the decision to register in the I-REC registry because there was a trend of Net Zero from multinational companies before Thailand announce the country's decarbonization goal in COP26. They were quite confident that I-REC would be demanded. Besides, It did not take them long to consider registering in the I-REC registry because the registration process is convenient and user-friendly, does not require too many documents, and device registration fee and renewal fee are not expensive unlike carbon credit project registration e.g. Verra, Gold Standard, and T-VER. The I-REC itself market is wider even though it can use only for scope 2 but it is internationally accepted.

> *"As our company is positive to try new things that tends to be valuable in value chain, we had no hesitation to make a trial in the I-REC registry. The first project we registered was a small project. It was to study the process and expense. We did not expect the market or profits at the moment. After that we could see increasing of demand from multinational companies in Thailand and with the reasonable cost of registration and liquidity in trading as it is acceptable at international level standards, we decided to register all of our project in the I-REC registry. We had registered T-VER projects before. It is not accepted by big global companies. The process is much more complicated and requires a lot of documents. T-VER has a higher cost than I-REC while I-REC has higher demand in the market as Thailand is a voluntary market. Companies are not forced to reduce carbon that they need to buy carbon credit to offset. We had issued*

T-VER 5-6 years ago, but it started to be sold in 2021 according to COP26." Company RE-A Interviewee.

I-REC also triggered Company RE-B to do organizational restructuring to liquidate the business.

> *"After we studied more about the I-REC standard, we processed to registered big 10 facilities first. Thanks to its user-friendliness, straightforward of verification and usage, and affordable and convenient registration process, it's easy for us to decide to be a play in the I-REC registry. Besides, I-RECs are our by-product. The cost of registration to sell this by-product is not high. Even if it cannot be not sold, this loss is acceptable. On the other hand, if we did nothing with it, it would be like we are throwing it away. After COP21 around the end of 2021, as we could see the trend and demand of volume inquiry from multinational companies, we register the rest of our facilities to the I-REC registry. Furthermore, we reorganized work functions related to I-REC and carbon credit trading to another affiliate company to take this business seriously and meet the trend and demand."* Company RE-B Interviewee.

4.6 I-REC Marketing

As renewable energy certificate is still quite a new decarbonization tool in Thailand. It is important to make people understand what it is. Therefore, EGAT started by communicating through mass media, exhibiting academic booths in events, and holding seminars by collaborating with other organizations such as the Thailand Greenhouse Gas Management Organization, the Federation of Thai Industries, and other renewable energy corporations including Company RE-A.

Company RE-A also has a similar strategy to EGAT. It held seminars and also approached potential customers, which are multinational companies in Thailand especially RE100 members, to ask them about their decarbonization policy and introduce I-REC. One thing that Company RE-A did as a pioneer in Thailand is creating

an online marketplace and community platform for T-VER and I-REC call the Carbon Markets Club (www.carbonmarketsclub.com). It was established together with other alliances that care about environments and are interested in decarbonization including EGAT. The Carbon Markets Club offers free membership to corporate and individuals. The member will receive e-newsletters of seminars and can post to sell their T-VER or I-REC on Webboard. It holds seminars and webinars related to decarbonization, environment, and energy which are very educational and informative.

4.7 I-REC Demand and Supply

For the supply side, it grew obviously from 2019-2021 since EGAT became the I-REC local issuer, considering from the number of registrants, device, and I-REC issued. EGAT has a big role to this growth as it has been educating people about I-REC through various events and seminars. Having EGAT as a local I-REC issuer makes it easier for players to access. It also creates more opportunities for the investors who need to invest in green energy.

However, there is high demand of I-REC from domestic and overseas, especially Singapore because it has carbon tax and is carbon trading hub in Asia. I-REC can be claimed internationally in case the country that generates the electricity has grid connection with the buyer's country.

> *"Secondary data that can explain the demand of I-REC is I-REC issuance and redemption report announced on the website of the I-REC standard and the report from RE100 website that shows that movement of renewable energy demand in each country. For primary data, we approach potential corporates to ask about their needs and direction to achieve their clean energy goal. Since our operation in June 2022, we realized that I-REC demand has grown up a lot and caught more attention from businesses. I-REC from some energy resources is starting to short. I-REC from wind energy is very few."*
> Innopower interviewee.

> *"We do not really focus on marketing activities. We only join the Federation of Thai Industries' events such as exhibition booths, seminars, and roadshows. Customers knew us from these events and approached us by themselves. We have 2 groups of customers which are corporates that want to buy I-RECs for themselves and brokers that want to buy I-RECs to service their customers or speculation. Now the demand that has come to us is already higher than we can supply."*

This research studies further the number of I-REC registrants in Thailand. EGAT disclosed the number of I-REC registrants as of November 2022 is 96 registrants with approximately 200 renewable energy generating facilities while there are 1,048 renewable electricity projects with total capacity 4,025 MW that already has commercial operation date (COD) or started selling electricity to EGAT and already distributed electricity to the grid (Energy Regulatory Commission, 2022). Therefore, there is big room for supply to grow in the future. However, new projects that applied for electricity selling under the Feed-in Tariff (FiT) Scheme for the Period of 2022 to 2030 for power plants with no fuel costs will not be able to sell I-REC or carbon credit because it is regulated that any renewable energy certificates (RECs) or carbon credit derived from the projects operating under the New RE Quota Regulations must belong to state utilities or government agencies (Baker & McKenzie, 2022).

4.8 Innopower's Business Model to Support VSPP and Renewable Energy Promotion in Thailand

Even though the I-REC registration costs and participant's trade account fees are not a big cost for Company RE-A and Company RE-B, they matter for some other smaller energy corporates, especially Very Small Power Producers (VSPP). Some small power plants hesitate to register their projects to the I-REC registry as they are not certain if they can acquire customers and if the device registration fee will be worth it, especially for solar projects that VSPP usually has small capacity projects in more than one location. (In the case of registering solar devices in a group, one group can register solar devices in a bundle of up to 5 MW.) The estimation of I-REC generated from solar project with 1 MW capacity is around 1,400 I-RECs per year.

For example, if a group project has a 2 MW capacity, it will generate around 2,800 I-RECs. In case 1 I-REC is 50 baht, this project will generate an income of 140,000 baht. This project owner will have costs of the device registration fee paid to EGAT 38,000 baht, verification fee for the third party in case it is needed, and participant's trade account opening fee and annual fee of 2,500 euro (2,000 euro annual trade account fee + one-time trade account opening fee) in case it wants to service customers in certificate redemption. It would be a hard decision for this company to be a player of the I-REC registry.

Innopower knows these pain points, so it offers VSPP companies support on facilities registration fee, manage marketing and sale of their I-RECs, and share profits with them. This business model is one of Innopower's quick-win strategic partnership buildings that brings promising profits to its stakeholders. It encourages small power plant operators to develop more renewable energy and encourage more supply of I-REC in the Thai market. It would attract investors that look for clean energy to meet their decarbonization goals and increase the country's potential in promoting business that greener and cleaner in Thailand.

4.9 Price Mechanism

There is no standard price for I-REC. On the Carbon Markets Club website, I-RECs from every sellers are offered at the same price at average 50 baht but the actual price depends on bilateral negotiation between the seller and the buyer e.g. vintage year, type of resource, volume, long-term agreement, etc. However, buying big volume does not promise a discount because the demand is higher than the supply. Usually, the price agreed between the seller and the buyer is confidential.

> *"The price depends on the market mechanism. Since Innopower's one of the shareholders is EGAT which is a state enterprise, we need to make a reasonable price for the benefit of the state as well. We also inquire about pricing from buyers, other sellers, and brokers to set suitable pricing. As of 2022, our I-RECs pricing is approximately 45-70 baht, different for each type of energy, contract period, and purchasing volume. However, it does not follow the economy of scale*

as it is an over-demand market now." Innopower interviewee.

"Our average price is 1.35-1.65 USD but I-REC produced in the vintage year 2023-2024 are expected to be over 1.75 USD. We do not offer discounts for big lot purchases because it's exceeding demand now. We accept longest agreement at 3 years and it would be step up price 10%-25% per year. We keep only 20% of our I-RECs for future contracts because it is difficult to predict the price. We prefer to keep the rest 80% of I-REC for spot trading." Company RE-B interviewee.

"The price shown on the Carbon Markets Club website is an average price. It can be varied by volume and contract period. We make pricing by hearing from brokers that have business with us and also sharing with other sellers. At this moment, it is an excess-demand market. We accept the longest contract period at 5 years." Company RE-A interviewee.

4.10 I-REC and Acceleration of Renewable Energy Projects

Despite in the compliance market in the US, expected revenue from REC affects to the decision of developing a new renewable energy project, it is different in voluntary market in Thailand.

"I-REC price in Thailand is not high enough to generate revenue to consider in feasibility model to make a new project. It is not a factor that can tell if a project is feasible or not. However, it does promote renewable energy projects as the profits from I-RECs were reinvested in various renewable energy projects including digital solutions and energy optimizations" Company RE-A interviewee.

"The profit from I-REC is very small compared to our investment in renewable energy projects, so I-REC does not have a direct effect on the acceleration of renewable energy in my opinion. However, we are doing this business because we would like to promote awareness about renewable energy to the society and be a total solution

provider of renewable energy." Company RE-B Interviewee.

Even I-REC does not have a direct impact on acceleration of renewable energy projects in Thailand, it promotes renewable energy in indirect ways by encouraging renewable energy corporates to develop initiatives related to renewable energy, promote awareness of renewable energy, and attract more global investors to Thailand, leading to Thailand's economy stimulation.

4.11 The Feed-in Tariff (FiT) Scheme for the Period of 2022 to 2030

As the Feed-in Tariff (FiT) Scheme for the Period of 2022 to 2030 for power plants with no fuel costs announced by the Energy Regulatory Commission (ERC) has a condition for the renewable energy producers that applied for electricity selling to the state that any renewable energy certificates (RECs) or carbon credit derived from the projects operating under the New RE Quota Regulations must belong to state utilities or government agencies, this research studied if it impacts or demotivates energy corporate to develop renewable energy projects.

> *"I will have no right to claim REC or carbon credit from new projects applied to the scheme. If the state claims these energy attribute certificates for the country's decarbonization goal, it will not affect I-REC supply in the market while demand would be higher. On the other hand, if the state claims them as I-REC and sells them in a bundle with electricity, it will affect supply in the market. At this moment, I think it would not impact our company much because it still seems to be an excess-demand market, but it is pity that we lost the opportunity to have more I-RECs to sell. Investing in renewable energy projects would be a bit less appealing. However, it would be acceptable for us if we receive the proper compensation for losing I-REC's right from feed-in tariff (FiT)." Company RE-A interviewee.*

5. Conclusion and Future Studies

The objective of this research was to study I-REC's role in decarbonization in Thailand and its ecosystem by researching secondary information and interviewing companies that purchased I-REC, EGAT which is the I-REC issuer in Thailand, and Innopower, its affiliate company, and renewable energy power plants that sell I-REC, to understand about I-REC from all of I-REC stakeholders' perspectives.

I-REC was widely known when EGAT announced it is a local issuer and started the I-REC business in 2020. However, its I-REC business function was transferred to Innopower in June 2022 to separate the issuer role and the commercial role. It makes I-RECs business became more liquidity. Those who want to buy I-RECs generated from EGAT'a facilities no longer need to register as I-REC participant. It saves the cost of registration and account annual fee.

The companies that are interested in I-REC are mostly multinational companies that have net zero carbon emission goals and need to use I-REC to achieve their goals at the international level. On the other hand, companies that focus on the domestic market may prefer T-VER as it is more effective in delivering the company's environment-caring image to their customers. Purchasing I-REC gives the buyers indirect benefits as it urges people in the organization to be more aware of energy saving and stimulates them to initiate energy efficiency or carbon reduction projects.

Renewable energy power plants can choose to register in either the I-REC registry or T-VER but they tend to prefer the I-REC registry because the registration process is easy and convenient, the registration fee is not expensive, and it can be claimed and accepted at the international level standards. Besides, increasing announcements of global companies' net zero goal and Thailand's pledge at COP26 confirmed their confidence that there would be market and demand for I-REC. The market did go as they expected as it is an excess-demand market currently. Marketing for I-REC is in the form of an academic approach. The pioneer players introduce I-REC to the market through mass media, seminars, and an online community for information sharing. There is no standard price for I-REC. To offer or to buy, the seller and the buyer should observe by asking directly to counterparts

and compare the price. Currently, purchasing at a big volume does not give the buyer economy of scale because I-REC demand is exceeding.

However, currently, there are approximately 200 renewable energy generating facilities registered in the I-REC registry while there are 1,048 renewable electricity projects with a total capacity of 4,025 MW in Thailand, meaning that 80% of renewable electricity projects have not joined the I-REC registry yet. What holds them from registering is considered to be a concern on the cost and market acquisition. To solve this concern, encourage more development of renewable energy and promote more supply of I-REC in the Thai market, Innopower offers VSPP companies support on the facilities registration fee, manages marketing and sale of their I-RECs, and shares profits with them.

As Thailand is a voluntary market, the I-REC price in Thailand is relatively cheap compared to the compliance market in the US. Revenue from I-RECs does not accelerate the development of new renewable energy projects but it does promote renewable energy in indirect ways. However, considering revenue from I-REC from the new renewable energy project that applies to sell the electricity to the state after 2022, it may become less appealing to invest because the Energy Regulatory Commission regulated that any RECs or carbon credit derived from the projects operating under the New RE Quota Regulations must belong to state utilities or government agencies.

In sum, I-REC seems a promising mechanism to promote decarbonization on the utilization of renewable energy at the national and international levels. However, registration costs and customer acquisition are not easy to make decisions for small scale renewable energy power plants. For this reason, a business model that offers support on the registration fee, manages marketing and sale of their I-RECs, and shares profits with the project owners should be developed. This will encourage more development of renewable energy and promote more supply of I-REC in the Thai market.

There are limitations on this research. First, a few number of interviewees who might not be representatives of all aspects. The results, however, can provide information for those who are interested to use I-REC as their decarbonization tools, renewable energy companies who are looking for business opportunities in I-REC, and brokers. This research suggests other studies to deepen and broaden these findings to further understand I-REC's role in decarbonization in Thailand by collecting data or interviewing Thai companies that purchased I-RECs, renewable energy power plants who are not in the I-REC registry or chose to do T-VER. Besides, currently, it is a transition period to renewable energy that the government is changing the regulations to make entrepreneurs can access renewable energy resources, not just the certificate, e.g., the Utility Green Tariff scheme and The FiT Scheme for the Period of 2022 to 2030. It can further study how the government takes these schemes into action, and how it will affect current players in the I-REC registry, the market, the price, and the demand and supply.

6. References

Action for Climate Empowerment Thailand (2021). *Thailand was ranked among the top 10 most affected countries*. Retrieved from https://actionforclimate.deqp.go.th/news/2790/

Baker & McKenzie (2022). *Thailand: The wait is over! New round of renewable energy auctions have officially been launched - Bidding ends in November 2022*. Retrieved from https://insightplus.bakermckenzie.com/bm/projects/here

Bernoville, T. (2022). *What are Scopes 1, 2, and 3 of Carbon Emissions?.* Retrieved from https://plana.earth/academy/what-are-scope-1-2-3-emissions

Deloitte (2022). *EU Carbon Border Adjustment Mechanism (CBAM): The state of play and ways forward*. Retrieved from https://www2.deloitte.com/nl/nl/pages/tax/articles/eu-carbon-border-adjustment-mechanism-cbam.html

Electricity Generation Authority of Thailand (2021). *renewable energy future electricity generation trends.* Retrieved from https://www.egat.co.th/home/พลังงานหมุนเวียน-เทรนด์

Electricity Generation Authority of Thailand (2022). *"Innopower" from EGAT Group.* Retrieved from https://www.egat.co.th/home/20220923-art01/

Energy Policy and Planning Office, Ministry of Energy (2021). *National Energy Plan*. Retrieved from http://www.eppo.go.th/index.php/en/component/k2/item/17093-nep

Energy Policy and Planning Office, Ministry of Energy (2022). *The situation of carbon dioxide emissions from the energy sector in 2021.* Retrieved from http://www.eppo.go.th/index.php/th/component/k2/item/17963-annually-2021

Energy Regulatory Commission (2022). *Database of SPP/VSPP*. Retrieved from http://www2.erc.or.th/ERCSPP/default.aspx?x=0&muid=23&prid=41

Gill, J. & Johnson, P. (2002). *Research Method for Managers*. Sage.

Greenhouse Gas Mitigation Mechanism (2022). *What is T-VER?.* Retrieved from https://ghgreduction.tgo.or.th/en/t-ver-en/16-t-ver-en/about-tver/47-what-is-t-ver-en.html

Greenyellow (2022). *International REC Standard - How it works & I-REC registry in Vietnam.* Retrieved from *https://www.greenyellow.vn/en/how-irec-works-irec-registry-in-vietnam/*

Royal Thai Government (2022). *Reduce energy imports from abroad*. Retrieved from https://www.thaigov.go.th/news/contents/details/61349

The International REC Standard (2022). Retrieved from https://www.irecstandard.org/

United Nation Climate Change (2022). *The Paris Agreement*. Retrieved from https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

United States Environmental Protection Agency (2022). *Renewable Energy Certificates (RECs)*. Retrieved from https://www.epa.gov/green-power-markets/renewable-energy-certificates-recs

Bangkokbiznews (2021). *500 Carbon Reduction Organizations Drive renewable energy.* Retrieved from https://www.bangkokbiznews.com/business/974021