Renewable Energy Transition towards Krabi's Sustainable Energy

Miss Chariya Senpong

A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Environment, Development and Sustainability
Inter-Department of Environment,Development and Sustainability
GRADUATE SCHOOL
Chulalongkorn University
Academic Year 2021

การเปลี่ยนผ่านพลังงานหมุนเวียนสู่พลังงานยั่งยืนจังหวัดกระบี่

น.ส.จริยา เสนพงศ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรดุษฎีบัณฑิต
สาขาวิชาสิ่งแวดล้อม การพัฒนา และความยั่งยืน สหสาขาวิชาสิ่งแวดล้อม การพัฒนาและความยั่งยืน
บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	Renewable Energy Transition towards Krabi's Sustainable Energy
By	Miss Chariya Senpong
Field of Study	Environment, Development and Sustainability
Thesis Advisor	Associate Professor DAWAN WIWATTANADATE, Ph.D.

Accepted by the GRADUATE SCHOOL, Chulalongkorn University in Partial Fulfillment of the Requirement for the Doctor of Philosophy

.... Dean of the GRADUATE SCHOOL
(Associate Professor THUMNOON NHUJAK, Ph.D.)

DISSERTATION COMMITTEE

.... Chairman
(Associate Professor VITHAYA KULSOMBOON, Ph.D.)

.... Thesis Advisor
(Associate Professor DAWAN WIWATTANADATE, Ph.D.)

.... Examiner
(Associate Professor Narumon Arunotai, Ph.D.)

.... Examiner
(Assistant Professor Suthirat Kittipongvises, Ph.D.)

.... External Examiner
(Associate Professor Chalie Charoenlarpnopparut, Ph.D.)

จริยา เสนพงศ์ : การเปลี่ยนผ่านพลังงานหมุนเวียนสู่พลังงานยั่งยืนจังหวัดกระบี่. (Renewable Energy Transition towards Krabi's Sustainable Energy) อ.ที่ปรึกษาหลัก : รศ. ดร.ดาวัลย์ วิวรรธนะเดช

งานวิจัยฉบับนี้มีวัตถุประสงค์เพื่อศึกษาภาพรวมพลังงานไฟฟ้า ช่วงเวลาการเปลี่ยนผ่านพลังงานหมุนเวียน ศักยภาพพลังงานหมุนเวียน ปัจจัยขับเคลื่อน อุปสรรคและความท้าทายสู่พลังงานยั่งยืนจังหวัดกระบี่ รวมทั้งการจัดทำแนวทางและข้อเสนอแนะเชิงนโยบายเพื่อไปนำไปสู่ความสำเร็จในการพัฒนาพลังงานหมุนเวียนของจังหวัดกระบี่ จากการศึกษาพบว่า ความต้องการใช้พลังงานไฟฟ้าของจังหวัดกระบี่เพิ่มสูงขึ้นอย่างต่อเนื่องตั้งแต่ปี 2538 และมีแนวโน้มที่จะเพิ่มสูงขึ้นเป็น 320 เมกะวัตต์ในปี 2580 ในขณะที่จังหวัดกระบี่ยังคงพึ่งพาการผลิตไฟฟ้าจากสายส่งกลาง แม้ว่าจังหวัดกระบี่จะมีศักยภาพพลังงานหมุนเวียนสูงและมีการผลิตไฟฟ้าจากพลังงานหมุนเวียนตั้งแต่ปี 2550 ยังคงผลิตไฟฟ้าได้เพียงกว่าร้อยละ 50ของความต้องการใช้ไฟฟ้าสูงสุดรายปีของจังหวัด ในขณะที่แผนงานกระบี่โกกรีนของจังหวัดมีเป้าหมายที่จะทำให้จังหวัดกระบี่สามารถพึ่งตนเองได้ในการผลิตไฟฟ้าและมุ่งสู่จังหวัดพลังงานหมุนเวียนร้อยเปอร์เซ็นต์ภายในปี 2569 เป้าหมายดังกล่าวจึงท้าทายอย่างยิ่งและจำเป็นต้องลงมือปฏิบัติการ

แผนพัฒนาพลังงานทดแทนและพลังงานทางเลือก (AEDP) และแผนงานกระบี่โกกรีนเป็นปัจจัยขับเคลื่อนหลักของการเปลี่ยนผ่านพลังงานหมุนเวียนสู่พลังงานยั่งยืนจังหวัดกระบี่ จากการศึกษาพบว่าจังหวัดกระบี่มีศักยภาพพลังงานหมุนเวียนสูงแต่กำลังผลิตติดตั้งยังคงจำกัดเนื่องจากอุปสรรคหลายประการ การรวบรวมความคิดเห็นจากผู้มีส่วนได้ส่วนเสียจากการสัมภาษณ์เชิงลึกและการสัมภาษณ์กลุ่มเล็กพบว่า นโยบายและแนวทางปฏิบัติว่าด้วยการรับซื้อไฟฟ้าจากพลังงานหมุนเวียนเป็นอุปสรรคสำคัญที่จะส่งผลต่อความสำเร็จหลักของพลังงานหมุนเวียนแต่ละชนิด ดังนี้ ปัจจัยที่จะนำไปสู่ความสำเร็จของโรงไฟฟ้าชีวมวลและก๊าซชีวภาพคือการทบทวนนโยบายการรับซื้อไฟฟ้า โดยเฉพาะอย่างยิ่งก๊าซชีวภาพซึ่งเป็นเชื้อเพลิงที่เป็นมิตรกับสิ่งแวดล้อม ลดการปล่อยมลพิษทางอากาศ รวมทั้งการลดสัดส่วนการปล่อยก๊าซเรือนกระจกจำนวนมาก ในขณะที่ปัจจัยที่จะก่อให้เกิดความสำเร็จของพลังงานแสงอาทิตย์คือการทบทวนระบบโควต้ารับซื้อไฟฟ้าจากพลังงานแสงอาทิตย์บนหลังคา ซึ่งเป็นพลังงานที่ปราศจากการปล่อยมลพิษทางอากาศจากการเผาไหม้ในกระบวนการผลิตไฟฟ้าและไม่มีความจำเป็นที่จะต้องมีมาตรการจูงใจเนื่องจากราคาแผงโซลาร์เซลล์และอุปกรณ์การติดตั้งลดลงอย่างรวดเร็ว นอกจากนี้ผลการศึกษายังพบว่า ปัจจัยที่จะผลักดันความสำเร็จของโรงไฟฟ้าขยะมาจากปริมาณขยะที่มีศักยภาพจำนวนมากและกำลังส่งผลกระทบต่อสิ่งแวดล้อมและสุขภาพ การบูรณาการแผนงานการจัดการขยะของหน่วยงานและภาคส่วนที่เกี่ยวข้อง การชดเชยชุมชนรอบโรงไฟฟ้าขยะและพื้นที่ฝังกลบขยะที่มีอยู่หลายพื้นที่ของจังหวัดกระบี่

สาขาวิชา	สิ่งแวดล้อม การพัฒนา และความยั่งยืน	ลายมือชื่อนิสิต ....
ปีการศึกษา	2564	ลายมือชื่อ อ.ที่ปรึกษาหลัก ....

6087820420 : MAJOR ENVIRONMENT, DEVELOPMENT AND SUSTAINABILITY

KEYWORD: RENEWABLE ENERGY, SUSTAINABLE ENERGY, ENERGY TRANSITION, KRABI PROVINCE, DRIVERS, BARRIERS, CHALLENGES

Chariya Senpong : Renewable Energy Transition towards Krabi’s Sustainable Energy. Advisor: Assoc. Prof. DAWAN WIWATTANADATE, Ph.D.

The present study was conducted with an aim to investigate Krabi's electricity outlook, renewable energy transition timeline, and potential of renewable energy resources, key drivers, barriers, and challenges towards Krabi's sustainable energy. Guideline as well as policy recommendation for successful renewable energy transition was also developed. The study found that Krabi's electricity demand has continuously increasing and tends to increase up to 320 MW by the year 2037. Meanwhile, electricity supply has still relied on national grid since 1995. Meanwhile, Krabi Goes Green which is a provincial roadmap has set a target to be self-reliance and all electricity supply would be 100% renewable energy by 2026. This target is challenging and need actively implementation.

National Alternative Energy Development Plan (AEDP) as well as Krabi Goes Green Roadmap are key drivers for Krabi's renewable energy transition towards sustainable energy. Even though high potential of renewable energy resources has been reported, the domestic installed renewable energy power plants, gradually installed since 2007, can supply only about half of its annual demand. This is due to various barriers and obstacles to be overcome. Challenges or key success recommendation for each RE are briefly described. In case of biomass and biogas power plants, reconsideration of power purchasing policy is recommended which is green energy without combustion pollutants and also contributes large opportunity for GHGs mitigation. The solar PV case, revision of quota for solar rooftop equipment is highly recommend due to green energy without combustion pollutants and no more incentive need due to disruptive factor on rapidly price lowering of solar panel and equipment. By the way, the study found that waste-to-energy (WtE) power plant would be the first priority due to high potential and severe impacts on both environment and human health. Policy integration among relevant agencies as well as fair compensation for community around waste landfill sites and the WtE power plants should be sincerely consideration.

Field of Study:	Environment, Development and Sustainability	Student's Signature ....
Academic Year:	2021	Advisor's Signature ....

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my thesis advisor Assoc.Prof.Dawan Wiwattanadate, Ph.D., a former director of Environment, Development and Sustainability Program and a lecturer at Faculty of Engineering, Chulalongkorn. Her patience, enthusiasm, co-operations and suggestions made me present this research work to produce in the present form. Her brilliant, skillful supervision enriched this study higher than my expectation.

This research work would not be possible without hit stimulation, inspiration and cooperation. Sincere thanks are also express to my thesis committees, Assoc.Prof Vithaya Kulsomboon,Ph.D., Assoc.Prof.Narumon Arunothai,Ph.D., Assist.Prof.Suthirat Kittipongvises,Ph.D. and Assoc.Prof Chalie Charoenlarpnopparut, Ph.D. for their valuable comments and suggestion. This thesis work could not be possible without stimulation, inspiration, and cooperation from all stakeholders in Krabi province, officers from Provincial Electricity Authority (PEA), Krabi Provincial Administrative Organization, Krabi Municipality, Provincial Cooperative Office, Krabi Tourism Association, Agriculture and Cooperatives network, Provincial Strategic Office, Krabi Goes Green network , Provincial Industry Office, renewable energy power producers and South Solar Cell Co.,Ltd. and are thankful for their kind information support and shared their thoughtfulness. Thanks are also expressed to all interviewers for their valuable time, information, and opinions.

I also would like to thank all my respected professors in the Program of Environment, Development and Sustainability and Prapassorn Siriwichai, Bantika Jaruma, Akanat Boonyoung, Tara Buakamsri, Wisut Thongyoi, Wiwat Lertwilaisak and all friends who have been spending our time for years, and memories to Inda Fitryarini our classmate, deserve my thanks who directly and indirectly provide me with inspirations and valuable suggestions during the course of this study. I would to thank to the Doctorate Scholarship Program “The 100th Anniversary Chulalongkorn University Fund for Doctoral Scholarship”, in the Environment, Development and Sustainability international program, Graduate School of Chulalongkorn University and funding support from Program of Environment, Development and Sustainability.

Finally, yet importantly, a sense of respect goes to my mother, husband and family for their strong support as well as regular encouragement in every step to make me in the present stage. Similarly other relatives are also subject to special thanks for their inspiration and cooperation in my study.

Chariya Senpong

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I
Introduction

Energy, especially electricity is the one priority for economic development and improves quality of life. In the past, electricity was mainly generated from fossil fuels like coal, oil and natural gas that accumulate emissions of both local air pollutants and greenhouse gases (GHGs), causing greenhouse effect and global climate change. A global scenario on climate change mitigation indicates that renewable energy is a solution to reduce greenhouse gas emissions and climate change impacts (IPCC, 2021). Growing renewable energy is not only challenging environmental benefits but also the aspect of economic and energy security. Energy market and policy-driven energy transition is emerging to nations, which targets to achieve sustainable energy. The challenge is the transition from fossil fuels to renewable energy electricity generation as an alternative plan for a country and a master plan of regional planning on energy and its management. Even though the global price of renewable energy facilities continue decreasing, high renewable energy target in national policy and implementation are still limited. The ambitious scenario needs to increase the effectiveness of economic, energy and environmental cost.

Growth of population and urban places in the world is also challenging to government and policymakers for smart city planning and shifting to sustainable development goals (Nurtaj 2017). Simultaneously, urbanization and regional development would generate unexpected environmental and ecological damage. A shortage of resources as well as biodiversity reduction is facing in national, regional and global levels that governments have already been encouraging to diverse to sustainable investment for reducing the impacts. Sustainability and security in regional development is a strategy proposed for a harmonious city (Feng and others 2009) and the integration within nations is an essential requirement for energy sustainability strategies (Osamah, A., et al, 2018). A global trend of renewable energy has directly affected to ASEAN's energy policy. ASEAN Power Grid as a master plan of ASEAN countries has been one of the intergovernmental targets of efforts and activities to get a closer reach to agree with aspiration goal on reducing regional energy intensity of at least 8% by 2015 (based on 2005 levels), and the collective target of 15% of total installed power capacity from renewable energy sources by 2015. The ministers have also agreed to consider a higher level of commitment in terms of energy intensity reduction and installation of renewable energy beyond 2015 in reference to other international and regional commitments (ASEAN, 2021). On the other hand, the ASEAN power grid has not been addressing much on applying a policy to achieve the target and it significantly seems that the supply of national grid is the priority on fossil fuel generating as a concept and mindset of energy security in the region.

The increase demand for regional and urban drives to reach a sufficient supply chain on resources, especially energy resources, which might affect the quality of life. A trend of regional transition towards renewable energy to reduce the climate change crisis is a key factor to turn people in nations aware of the measurements of climate change mitigation and adaptation. National energy policy aims to increase the share of renewable energy on the grid, which depends on its potential, regulation enforcement, and political will. A smart plan for a renewable energy city is emerging decentralization of electricity generation and the solution of climate change. In-country level, Thailand would harvest the potential renewable energy transition to balance dependency on fossil fuel for electricity generation, especially the provinces having continuously increasing electricity demand. Therefore, renewable energy transition has become important, especially the provinces having continuously demand increasing like Krabi. Krabi province is the one famous destination place for tourism and the growing of amount and income annually has led high electrical consumption. As Krabi Goes Green vision is the top of the policy implementation and renewable energy supply is being potential to fulfill those demand, so renewable energy transition in a province is priority to study. As Krabi is one of the provinces having remarkable demand to increase and fulfil the growth of tourism, this study aims to investigate the potential to transition towards sustainable energy in the province. The study begins with briefly reviewing key aspects of the direction of national energy policy, provincial energy implementation, and the transition capacity related to policymakers, institutions, public acceptance, and so on.

Krabi province is the research case study with the purpose of renewable energy investment, starting with biomass supply as the main internally raw energy sources and the first province initiated the provincial master plan of “Krabi Vision 2020” and “Krabi Goes Green” concept including green tourism and green development. In 2015, the government plans to increase the energy supply for the national southern grid, passed the green light of the new coal power plant project. During that period, the first proposal by Save Andaman from Coal Network submitted the Krabi 100 percent renewable energy plan to the government and the feasibility study about the potential of renewable energy supply before approving that new coal project. Krabi is continually increasing the renewable energy installation such as biomass, biogas, solar and waste-to-energy to feed the electricity‘s demand growing annually.

As mentioned above, Krabi Goes Green has set target to generate electricity from 100% renewable energy and maximize utilization of domestic energy resources for electricity generation. However, installed renewable energy power plants in the province are still limited. What are the problems or limitation has become questions for this research. The research aimed to investigate key drivers, barriers, and challenges to overcome the barriers in order that guideline and policy recommendation towards successful renewable energy transition would be developed. Research question, research objectives, and scope of the present research are described below.

1.1 Research questions

1) How could Krabi province fulfill the increasing electricity demand and maximize of domestic energy resources for electricity generation

2) What would be key drivers, barriers and challenges for transition towards sustainable renewable energy in Krabi province?

3) How could institutions and stakeholders take accountability on sustainable energy transition?

1.2 Research objectives

1) To study electricity outlook of Krabi province and the potential for electricity generation from renewable resources.

2) To study key drivers, barriers and challenges for the renewable energy transition towards Krabi's sustainable energy.

3) To develop guideline or policy recommendation for the renewable energy transition process from the policy makers and relevant stakeholders.

1.3 Scope and limitation

1) This research collected the potential of renewable energy, energy supply and demand on grid connection as secondary data from Provincial Electricity Authority (PEA), Municipality and Krabi Goes Green report.

2) This research focused on the primary data from in-depth interview, on-site observation and group discussion to answer the drivers, barriers and challenges to overcome barriers.

3) This research developed the guidelines for the transition of Krabi's sustainable energy including stakeholders, institutions and the roles of that relevance from the in-depth interview.

4) Due to the research was conducted during COVID19 pandemic, focus group discussion could not be conducted, just only small group interviews instead. Revisit or re- interview for clarification was also limited, just only phone calls or group line calls were used instead, especially during discussion about guideline and policy recommendation. These are key limitations of the present study.

CHAPTER II
Literature Reviews

This chapter describes the importance of renewable energy (RE) transition, whether it hurts the economy, why RE is the cornerstone of the global energy transition, RE transition in some countries and relevant studies, and RE transition, including Krabi Goes Green Vision and the RE target.

2.1 The importance of RE transition and experiences in some countries

Until the 20th Century, fossil fuels like coal, oil and gas have been major supplies for electricity generation which was not only import dependency and high risk, but also accumulated both GHGs and local air pollutants. According to Renewable Energy Policy Network for the 21st Century, it is presented that renewable energy transition, shifting from fossil fuels to RE, is on-going (REN21, 2021).

Global RE transition has grown rapidly in the power sector during recent years. Approximate 26.4% of total capacity of more than 200 GW are renewable energy share, and solar PV is expected to reach approximately 107 GW by the year 2020 even uncertain energy policy in some Asian countries. The solar PV is the largest share of RE installed in many countries due to effective incentive measures like feed-in-tariff for the long term power producer agreement (PPAs), the net metering for the solar rooftop, public utility policy and the intensive regulatory for decentralized system pathway (Renewables, 2020). Corporates and prosumers are driving the energy storage technologies.

RE plays important roles on environmental protection, climate change impacts mitigation, and air pollutants reduction in energy sector (Simionescu, M., et al.). Implementation of RE innovation and investment could support the three pillars of sustainable development, which are economic, social and environment. To achieve the Sustainable Development Goals (SDGs), systematic policy development plan, the role of social innovations (UN, 2030), community involvement and social acceptance (Marquardt, J. and Delina, L. L., 2018.). RE transition has become an important energy policy around the world since the 20th century. Experiences of RE transition in some countries are described below.

Xiangchengzhen and Yilmaz, 2020 (Xiangchengzhen and Yilmaz, 2020) studied Northeast Asia like China, Mongolia, Japan, Russia, Democratic People's Republic of Korea and South Korea to overcome challenges the traditional energy supply by investing to RE. The research illustrated the existing problems of energy in this region and energy consumption and supply in those countries and analysis the mechanism, incentive and prospects of energy cooperation in the region. The study found that energy has become the high politics on energy security and risk that needed to be priorities on their nations. The concept of energy security was generally accepted on availability, accessibility, acceptability and affordability and of course RE transition offered challenges on those. The research considered the potential of RE and dimension of importers and exporters. Reasonable price was connected to the technological market competitive and low social and environmental cost that advantage to a framework of climate change agreement. The study analyzed the challenges for clean energy and mentioned about the potential of national and transnational power grid was underdevelopment, small fraction of clean energy mix of the total electricity generation and supply and geopolitical intervention challenges. RE investment, smart grid technologies for storage and transmission, and financial capabilities would overcome the challenges.

RE transition has also improved the accessibility to electricity generation especially in rural locations and rare to connect grid transmission. Developing remote rural areas required the potential of RE and investment. Some forms of RE has been gradually decreasing and provide the households and industries action to reduce their relying on fossil fuels and saving money from electrical bill. Stimulating growth of RE investment has supported from several of the effective policies.

Mah and Cheung (2021) studied policy mixes and the policy learning process of energy transitions and urban community solar in Hong Kong. The paper reviewed the timeline of the government's RE policy development between 2002 and 2019 and the scheme of Control Agreement in 2033. The major types of RE policy instrument effectively in promoting the expansion of RE such as RE feed-in-tariff (FiT) to guarantee the long term 25 years of energy purchasing, net metering is that the utilities purchase electricity from prosumers (Daphne Ngar-yinMahabAltair T.F.Cheungc, 2021). The studies found the barriers in various aspects to overcome such as technical, internal institutional and social barriers etc. as shown in figure 1. Part of technical barrier was about the capacity of solar panel to natural disaster such as typhoons and structural loading. In term of financial aspect was the absence of direct subsidies and long payback period and the institutional barriers of the approval procedure that took many months since the application process to permission etc.

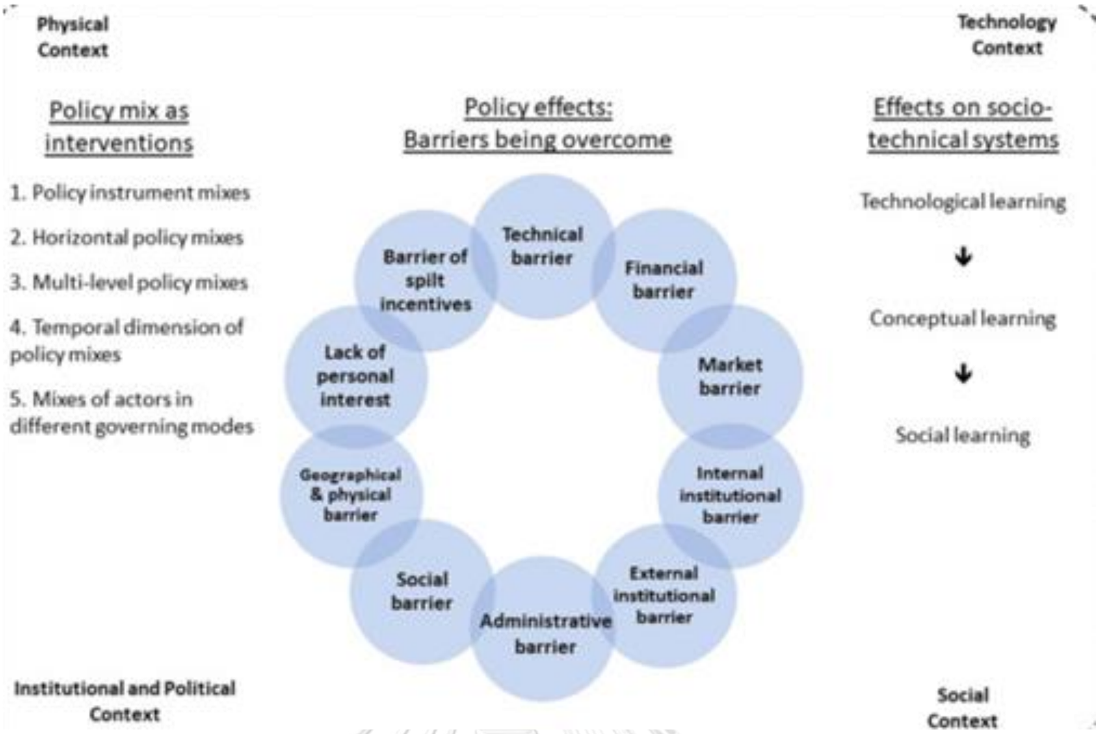


Figure 1 Policy mix approach for energy transition
Source: Mah D.N. and Cheung A.T.F. (2021)

Moreover, Lindberg, B.M., et al. (2019) positioned in the literature the existing policy process of EU and explored the analysis dimension of instructional structures, technologies and actors. EU electricity has driven by a various policies and politics that affects to wide energy intensive industries. EU energy transition drives internal market, security supply and set a target to achieve by European Council. EU Energy policies agenda are the important elements to deploy energy transition including UN Framework Convention on Climate Change and Kyoto Protocol, EU emission trading system (ETS), Climate and Energy package for 2020, Energy and Climate policy framework etc. EU energy policy has mix centralization and decentralization system operation and the different positions and roles of energy incumbents, and continually adapt new technology and process among the different policy negotiations (Lindberg, B.M., et al, .2019).

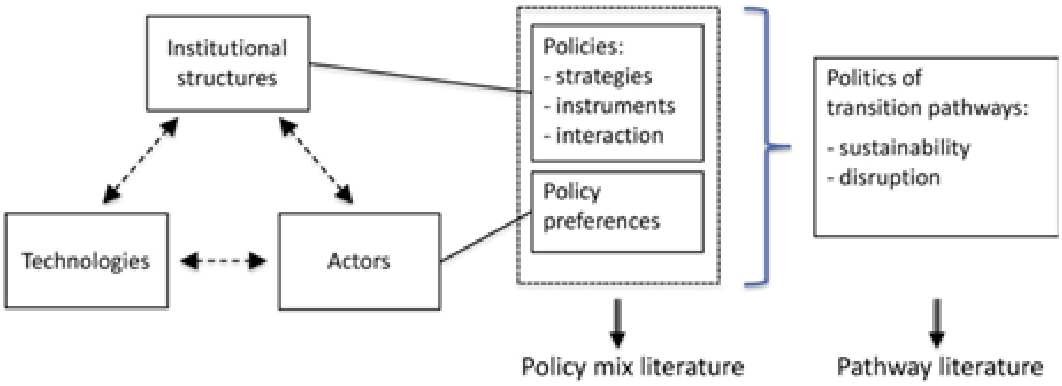


Figure 2 Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix
Source: Lindberg, B.M., et al. 2019.

Energy sector has also a concretely economic contributor of investment and job creation in global. Ram and Breyer (2021) studied the direct job creation of a global energy transition across the power sector by 2050, found that it estimated to be increased global jobs of the energy sector from 57 million in 2020 to 134 million positions in 2050 and nearly 75% driven from RE. In Germany, as Energiewende had discuss the employment trends and studied the impact of the quantity of energy employment changing in energy sector. Jobs are significant impacts to function economy to reduce the rate of global unemployment rate that increasing during Covid-19 pandemic. Jobs creation of energy transition sector has also affected to social impact and advocate to green jobs as sustainable energy transition. The challenges are to skill-sets, training and education or even reskilling of those employment and to design the policy, regulation and investment strategies to harvest the potential of RE (Ram, M., and Breyer, C., 2021).

The sustainable energy transition has a trend continually in diverse geographical areas and particularly actors of the change. The case studies of different stakeholders including national and local energy policymakers, private sectors would lead the assessment of energy transition master plan. In 1990, Birmingham City Council of England has Green Commission Vision 2027 as a roadmap to lead a green city and set an ambitious to reduce 60% of carbon dioxide emission by 2027 (Birmingham, 2012). Green growth agenda covered the benefits and opportunities for social, economic, improve the better air quality including the quality of health and climate regulation. The roadmap opened space for the various partnership such as business, academic research and citizen in a city to participate delivering the journey of change. The roadmap proposed the alternative plans challenging those scenario to business as usual, business as usual plus national efforts, and the carbon roadmap scenario. In a part of energy resources that aims to generate more low and zero carbon energy. A city has dominated electricity consumption from natural gas, waste-to-energy and coal. RE supported job creation around 35,000 jobs nationally.

In Germany, energy transition framework was called “Energiewende” has a target to reduce greenhouse gas emission in a 2020 and 2050 (Global Energiewende. 2012). In 2008, Frankfurt City, the Municipality’s Energy Agency in Frankfurt am Main and the Department for Climate Change and the Environment planed towards 100% RE instead of importing approximate 95% of their consumption in 2010. By 2050, Master plan for 100% Climate Mitigation aims to drive energy consumption of 100% local and regional RE source and energy efficiency. Their scenarios had been conducted by research institution to analysis on an hourly basis and the potential of RE demand, and saving energy strategies and implementation. Since 2013, participatory process has been started and applied top-down and bottom-up approach and working more than a hundred of institutions, experts and various stakeholders to be a part of city’s transition plan. Climate change fighting has committed and leaded by Frankfurt city council and initiated projects (Frankfurt, 2018).

In Spain, Iñigo Capellán-Pérez and JonTerés-Zubiaga (2018) also studied the RE cooperatives as an instrument towards the energy transition, and found that current economic-political context was the main barrier and conductive legislative framework. The last decades of the 20th century, when the impact of global financial crisis impacted to the country and social awareness about energy issues happening that modified the regulation to allow cooperatives to retail electricity and innovated “energy-shares” for 3,500cooperative members to make the solar energy investment since 2016 (Global Status, 2021).

In 2021, global overview of renewables in cities illustrates that more than 1 billion people who live in over 1,300 cities having the RE policies or targets. As of the end 2020, at least 799 cities had RE policies which driven by air pollution crisis and better quality of life. The report shown the drivers and opportunities for RE depends on the local context such as climate change declaration and mitigation and adapting to resilience, supporting local economic development and jobs creation, reducing the cost of electrical supply with cheaper some RE investment, security energy supply and independence, and supporting energy justice and democracy (IRENA, 2018).

2.2 Thailand's electricity outlook, PDP and RE transition

Integration of sustainable development and energy transition is an indicator to express how a country embarks on an ambitious journey to expand renewables and energy security. Thai government and energy agencies has committed to transit towards a low carbon country with focusing on power and transportation sectors, of which the highest GHGs emissions. Hence, the RE transition has become a pathway of energy reform as well as acknowledge the growth of disruptive technologies such as smart grid and decentralization systems to support the growth of electricity generation from RE as shown in figure 3.

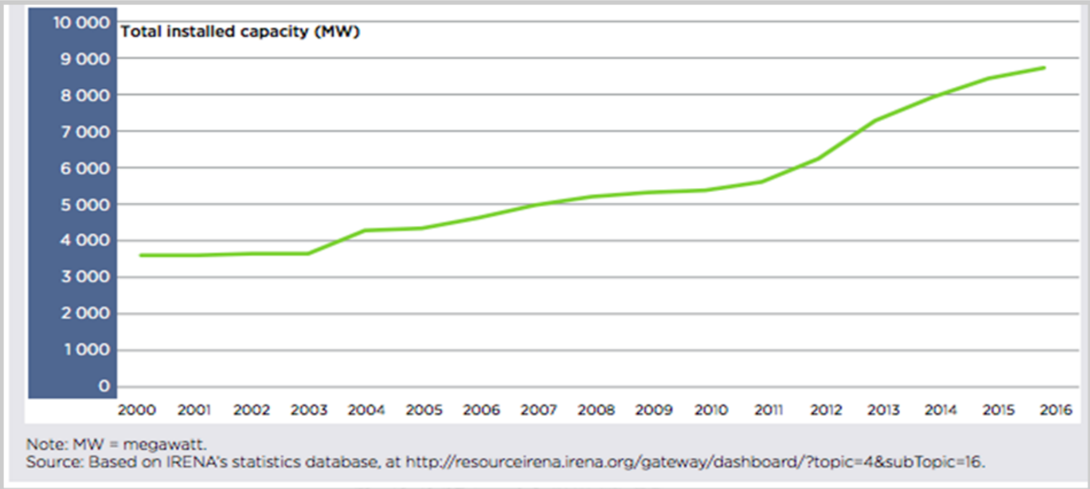


Figure 3 Thailand's total renewable electricity generating capacity in 2000-2016

Source: Energy Policy and Planning Office, Ministry of Energy, 2020

The most recent Power Development Plan (PDP 2018-2037) set a target of 20,766 MW RE projects compared to a total capacity target of 56,431 MW for new installation in the next 20 years. Thailand's current electricity generated from RE was approximately 1 0 percent of its total installed capacity. Decentralization on RE investment leaded a government to target its pilot project such as solar rooftop purchasing with around 100 MW in 2019 and the disruption in the business sector and properties companies joint benefit on block chains technology allowing electrical users to become “prosumers" that generate electricity with their own capacity and traded to small neighboring markets in the city. The phenomenon was widespread when RE became the household and institution economic driver including city, peri-urban and rural development. The evolution of energy transition, in terms of traditional to technological development shifted from fossil fuel dependency to decarburization initiatives.

The PDP addressed the target to increase electricity installation up to 77,211 MW in a year of 2037 which required to raise the potential of energy supply at 56,431 MW and the decommission target at 56,431 MW Smart Grid energy transmission was transferred to secure the future energy system and management. In terms of the Southern energy plan, the platform of public participation held by the Ministry of Energy had been prioritizing energy security, affordable price, and environmental concern. Energy security was planned to secure the regional energy supply and serve the disruptive energy from RE and fed to the regional grid. The trend of disruptive technology had an influential impact on the energy system from centralization to decentralization, replacing the main power plants and creating flexibility with smart grid and its storage system for RE. As PDP was the national energy policy driver to sustainable energy however, the barriers were about its flexibility and capacity to invest in smart grid and energy storage systems.

The energy transition in Thailand has been emerged since 1750 which experienced technology development from coal to natural gas, and then RE, related to market instruments and policy drivers. The ongoing energy transition towards sustainable energy city covered the integrated dimension of geographical, deployed policy and adopters. The disruption took place in residential, business and governance models that also approached the justice procedures and transition management, improved a level of public participation and increased the engagement groups to create the public acceptance of changes (Epaminondas, B., 2018). Energy sustainability covered main aspects of energy security consisting of availability, accessibility, affordability, and acceptability; however, the process of transition management refers to energy justice and just transition (Jeffrey, B. K. and Hironobu. U., 2018). The balances of the internal economy, which relied on tourism, fishery, and agriculture and the external economy concerning an environmentally friendly dimension that was targeting to reduce emissions from point sources were very challenging. The transition process was linked to institutional policies representing key organizations and structural reforms for a fundamental change of energy creativity and was participatory to drive the transition direction and initiated the pattern of sustainable energy pathway (Michael, G., 2018).

Transition thinking was to frame the evolution of energy changing in terms of traditional to technological development from dependable fossil fuel to decarburization initiatives (Philip, A., 2016). The energy transition could be conceptualized as a socio-technical defining the relative formal and informal of institution development and policy paradigm (Aleh, C., et al., 2018). The multi-level perspective was disrupted in terms of structure and demographics of economy, environment and social, depending on various factors of legislation, technology and innovation etc. The unexpected phenomena required understanding the adaptive transition that relies on knowledge, skill and capacity experiencing across the initiative. The interconnection of energy transition involves socio-technical, techno-economic, and political actions emerging to deal with complicated contexts of occurrence requiring the challenge of effective management. This transition process was the challenge of the uncertain context society which experiences key connection factors remaining flexible (Jorge, B., et al., 2018).

The pattern of the energy transition was based significantly on the potential of RE to be adopted for energy demand and consumption, enabling in various countries to move forward technology, infrastructure and institution practices relevant to stakeholder perspective in the various states including adopters, non-adopters and potential adopters. RE market prices reduction, a higher rate of return investment, feed-in-tariff agreement policy etc. were the potential factors shifting to its transition (Ping, H. and Vanesa, C. B., 2018). Reduction of environmental impact led to the challenging interactions and role of climate change mitigation. Energy transition became the main dimension of city management to deploy its scale of RE utilization. The potential of RE was the interconnection of landscape, management, investment to secure and sustainability. City planning priority coordinates with energy transition that illustrates the strategy and indicator to create its long-term. The pathway of energy transition related to social-spatial in context of distance, which referred to the cluster and location of land use management (Nancy, O., 2006).

The sustainable energy transition would cover the interdisciplinary triangle of sustainable development and the energy transition governance and also an analysis of the sustainable policy, participatory and planning of energy security. The direct relevance was that the environmental impacts concern drivers, pressure, state of natural capital and response framework to local and national policy-decision (Georges, A. T., et al., 2010). Also the frequency of using indicators like economic, environmental and institutional, and environmental aspects as a tool to approach sustainable creation with the indices for the public, policymakers and scientists to integrate a plan and practice (Meg, H., 2006). Ultimately, to process and deliberate a transition towards a sustainable energy was that engaging the kinds of people experiments from a diverse perspective to participate with and understanding its energy transition values (Enayat, A. M. and Shirin. M., 2018). Participatory planning defined organization and individuals in combination with transition dynamics pathways (George, G. and Megan, A. F., 2018). The transition towards a sustainable energy covered the integrated dimension of geographical, deployed policy and adopters. The disruption took place in residential, business and governance models that also approached the justice procedures. Transition management improved a level of public participation and increased the engagement groups to create the public acceptance of the change. The emergence of the energy transition was from the bottom as a social movement under informal, pluralistic and political drivers (DEDE, 2013).

2.2.1 Thailand RE and alternative energy transition

Thailand's Power Development Plan 2015 indicated the pathway of a country's energy planning for 20 years targets; mainly dependent on fossil fuel supply

70% natural gas baseload. In 2018, the Ministry of Energy and energy agencies had proposed the revised power development plan 2018 upon the reasons of the derails of Independent Power Producer (IPP) investments and behaviors of energy consumption changing to more RE increasing, self-generating and peak load at the night time. Energy consumption peak load in 2019 up to 32,273 MW and gradually drop in the first quarter of 2020 as the first phase of Covid-19 epidemic crisis approaches as shown in figure 4.

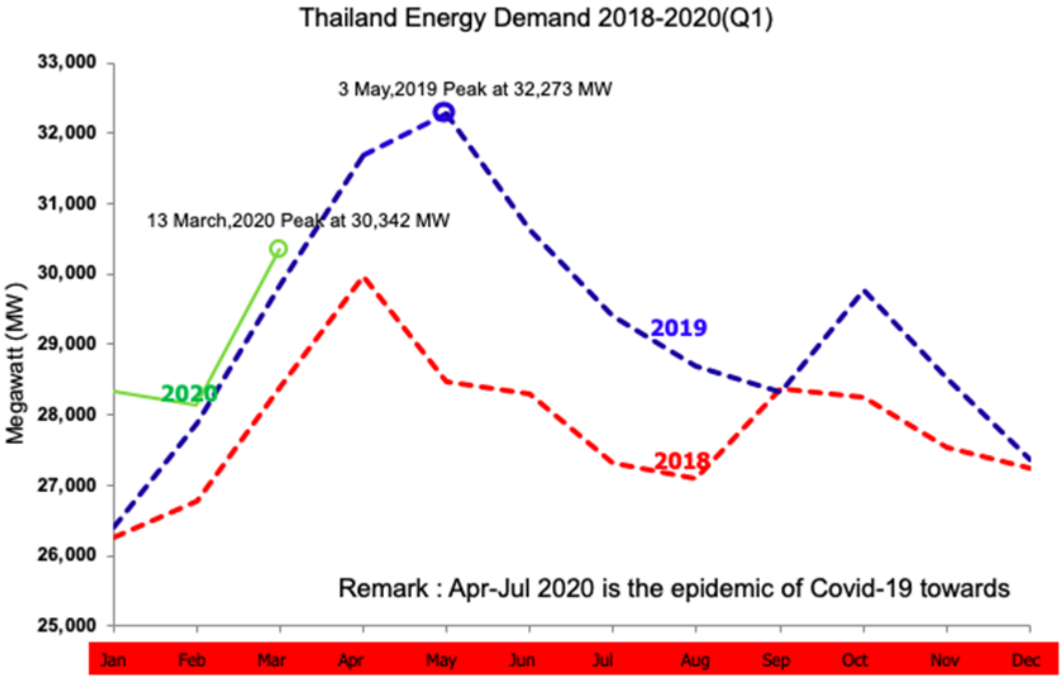


Figure 4 Thailand energy demand 2018-2020 (Q1)
Source: Energy Policy and Planning Office, Ministry of Energy, 2020

With the noting that potential of RE in Thailand as a top of RE investment in Southeast Asia and a relevant policy had been endorsed to unlock the limited regulation. Since 1994, RE installation in the country had expanded its capacity growing to 1,000 MW in 2006, and stable increasing to 2,000 MW in 2010 with the latest in 2016 it was generating up to more than 5,000 MW. The majority of the possibility of supporting initiative of RE city was to endorse the first draft of RE Act and implementing effectively in the country to encourage the province to research and develop on RE investment plan as a very small, small and independent power producer such as highlight the potentials of producing solar energy from the rooftops of urban homes and rural area, visible institution-building and communities in country [DEDE, 2012]. It would be empowering the capacity of the energy transition on the energy revolution, increasing RE and energy efficiency implementation in a country.

These features would create the perception that producing the right of residential own electricity from RE with the main message of energy security and energy independence. Since 2013, Thailand had been raising the subject of the RE Act to the public and later pushing on policy work to the Department of Alternative Energy Development and Efficiency and finally ending at the Ministry of Energy drafting and National Legislative Assembly (Amornrat, L., 2011). In March 18, 2015 the Committees of the National Legislative Assembly had officially announced to open the platform of RE Law Drafting Public Hearing for RE alignments including RE experts, RE policy working group, RE investors, civil society and people to raise the last comments to final that work under the law procedure.

In 2014, the National Reform Council had passed the resolution on “solar rooftop” expansion scheme expecting that in the first 5 years (2015-2019) there would be about 100,000 solar rooftop module (not exceed 10 kilowatts) for household with total installed capacity of 500 MW and in the next 20 year about one million solar rooftops with installed capacity of 5,000 MW If the Thai government was aggressively promoting the investment of the solar energy industry including solar PV module production Thailand was expected to be a winner in this area of RE in the next 10 year[EPPO, 2018]. Next step as policy expectation, for Thailand NRC, was to push for RE law to be passed by the parliament to ensure a proper, just, fair, and sustainable supporting mechanism for clean RE development. In terms of RE policy, Thailand’s Alternative Energy Development Plan (AEDP 2012-2022) had promoted production and consumption of RE by setting a challenging target of increasing alternative energy share up to 25 percent by the year 2022. The national energy planning obviously indicated that the increasing electricity demand would be secured with additional fossil fuel power plants installation as baseload even fulfilled the implementation of the national energy efficiency strategy.

Thailand’s Power Development Plan 2018, targeted RE to supply on the grid for the next 20 years at 20,766 MW was expected to reach grid connection from 2019 to 2026 with opening a quota of 100 MW solar rooftop transmission and later intensive growth after 2027 (ERC, 2021). Beside that plan indicated the Southern Energy System covers electricity installation of 2,164 MW while its demand was 2,624 megawatt. Additional supply from central energy transmission led to energy policymakers and agencies promoting new power plants in the southern area to secure the increasing demand in the long term with public debate on kinds of energy sources and benefits. However, the energy agencies had a plan to revise the new National Power Development Plan in 2020 as expected due to the epidemic Covid-19 crisis. The Gross Domestic Product (GDP) had declined by approximately 5-8 percent and the tourism estimates to drop to 1 of 5 of the year 2019 which connected to the low public consumption and investment across the country. This situation would affect the provincial and national energy plan as a long term of Covid-19 epidemic and economic recovery plan.

In a country, the barriers of RE installation and its supply on the grid were distributing arguments on policymakers and the public. Not only lacking sufficient support of RE law and regulation but also there was a variety of technology transfer, grid transition system, technical development and value of the investment. To lead urban and regional RE implementations required investigating the potential of RE supply and integrated on-grid into the remaining energy infrastructure and further invest in grid expansion. The potential of RE in a country was increasing in a proportion of total power generation which was different in each regional geographical area including solar, biomass, and wind energy to be harvested and more development. However, the dependable capacity to secure its supply was obviously low compared to an advanced RE investment in developed countries and fluctuating flowing supply in some conditions. The implementation of regional RE was not just a part of the potential of RE; planning on energy, environment, and economic aspects were the keys for achievement.

2.2.1.1 Biomass and biogas transition

The feasibility of biomass and biogas depended on site selection of its power plant that related to the potential and investment cost as the priority. The cost of collective, process and transportation within 100 kilometers however, was dependent on the competitive price of palm at that time. Southern Thailand was abundant with palm and rubber trees. In 2010, adder was the key intensive policy supporting RE investment. Biomass and biogas was calculated at 0.50 baht (about 0.016 USD) of the installation less than 1 MW and 0.3 baht (about 0.0096 USD) for 7 years support. Regarding the Power Development Plan (PDP) 2018, the installation of biomass energy was targeted at 3,376 MW and biogas 546 MW by 2037.

In 2019-2022 Regional Energy Development Plan pointed out that the potential of biomass in the southern part of Thailand was about 50 percent. Site selection of biomass was impactful to the effectiveness of the monitoring system and impact to communities and environment nearby the project. Local people had opposed those projects across the country. In 2021, ERC declared the new regulation for Very Small Power Producer (VSPP) as “Community Power Plant for Grassroots Economy” with the officially opened quota 150 MW as follow by total 75 MW of biomass and feed-in-tariff purchasing contract 4.85 baht/kWh and 4.26 baht per kWh for less than 3 MW and up more than 3 MW respectively. Biomass aimed to generate bio-energy to reach feed in tariff about 75 MW with the purchasing price at 4.73 baht (about 0.15 USD) for 20 year support [ERC, 2019].

2.2.1.2 Solar energy transition

The first solar energy investment in Thailand was installed in 1987 by the governmental policy support Adder scheme was applied to encourage RE investment during 2007-2013, since then a feed-in-tariff scheme has been applied instead. The earlier phase of the adder program applied in 2007 to benefit the start-up RE investor in a country and its systematic model was very much attractive for solar farm grid connection streamline application generating electricity to the grid. This initiative program was drafted by the Ministry of Energy (MoE) and proposed to the National Energy Policy Commission (NEPC).

The attractive adder rate raised the capacity in the pipeline and targeted a country to further establish the formulation and regulation of RE. The NEPC continually promoted solar energy purchasing policy in 2007 with a total target of 500 MW according to AEDP and planned for the next 10 years, to reach the total target 3,000 MW under AEDP. The price of energy purchasing in 2013, was high at the beginning of solar energy development as high as 8 THB (about 0.26 USD) per kWh of VSPP and SPP for the long term support of 7 years and extended to 10 years.

In 2010, the adder deduction policy was forced down to 6.50 THB (about 0.21 USD) per kWh by NEPC and transmitted to FiT policy. Adder intensive policy was distributed with a huge budget as the beginning to encourage the new international and national solar energy investors and at the turning point, when the solar energy's market was competitive reflecting the dropped solar energy cost. The later adopted policy in 2013 was feed-in tariff (FiT) for solar PV rooftop and the effectiveness of this program depended on the rate of energy price, design and implementation details. In 2014, the business model of solar power was growing capacity mainly from utility-scale installation of the solar farms investment distributed location in the central and northeast of a country with a high concentration factor. Price of its purchase was 5.66 THB (about 0.18 USD) per kWh within the 25 years contract period for governmental agencies and agricultural cooperatives. Moreover, the specified price for the household sector was 6.96 THB (about 0.22 USD) per kWh, 6.55 THB (about 0.21 USD) of its small business and 6.16 THB (about 0.20 USD) per kWh of the medium and large business scale.

The country's pilot phase of solar rooftop applied during 2019 officially opened the quota for 100 MW household sector and the additional 100 MW for the business and industrial sector with the FiT long term contract (Thongsopit, S., et al., 2019). A pilot project of solar rooftop had mainly created the household target to self-energy generating supporting their consumption and sold the left to the grid system, the total installation capacity not exceeding 10 kilowatts per each and totally less than 100 MW across the country and reaching a 10 years purchasing agreement of net billing measurement (ERC, 2019). In 2019, Solar for All projects were announced by the Energy Regulatory Commission of Thailand (ERC) opening the quota of solar rooftop for the household sector for the 10 years power purchasing contract under the net billing measurement, separately the quota 30 and 70 MW for Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority(PEA) respectively (Thailand Solar Fund, 2019).

In November 2019, Thailand Solar Fund had solidarity with the 15 wider networks including environmental, consumer and green development groups raising crowdfunding across the country to support the solar rooftop installation as the initiative solar hospital and technician schools projects (Eskew, J., et al., 2018). Although a country could deliver the generated solar energy on grid the remaining barriers of solar power purchasing agreement (PPA) was unclear status of a third-party developer could sell electricity to the consumer as a scale up business model, the sizing of solar rooftop system was limited and not allowing the excessing energy production flow to the grid, the potential policy of net metering regulatory has not been yet implemented even the customer’s bill saving are loading benefits, the financial scheme and business model had less support to motivate solar rooftop market and prosumers and the mindset of solar e-waste and requires the plan to offset environmental burden even solar energy created the less impact compared to fossil fuel based electricity life cycle assessment (Krabi Provincial Administrative Organization, 2014)

2.2.1.3 Waste-to-energy transition

The National Thailand Waste Management Roadmap 2016-2021 (PCD, 2016) presented the amount of total solid waste was 27.93 million tons in 2018, up around 2.05 percent compared to the previous year. The expansion of urban and peri-urban across the country and growth of tourism in a year drove the amount of waste 1.15 kilograms per capita per day, up from 2017 about 1.13 kilograms per capita per day. Solid waste of Bangkok was about 4.85 million tons, 17 percent of the country and the rest was around 23.10 million tones. Besides that, Chonburi province and Pattaya city was 2,519 tons per day, followed by 2,480 tons per day of Nakhon Ratchasima and the 2,449 tons per day of Samutprakarn province respectively.

Waste disposal was estimated at the landfill across the country in 2018 at about 10.85 million tons, about 38.85 percent of total waste. Those reduced from the previous year point at 11.69 million tones. Non-waste disposal was at 7.32

million tons, 26.21 percent of its total waste and increased about 2.09 percent compared to data in 2017, which was about 7.17 million tons. Waste reuse was about 9.76 million tons, about 34.94 percent of its total waste and increased about 14.69 percent compared to year 2017, which was about 8.51 million tons, the amount of solid waste reached 28.7 million tons in 2019 and 2 million tons of that was plastic waste. Waste disposal was just 25 percent of total and the rest was limited to access the right way to eliminate waste, and waste per capita was 1.1. kilogram per day. Alternative Energy Development Plan (AEDP) 2018-2037 (AEDP, 2018) addressed the increased quota of waste to energy at 400 megawatts, raising from the existing quota to 500 megawatts. The total 900 megawatts of waste to energy power plants projects are directed to the authority of the District Administration and Ministry of Interior.

2.3 Krabi's energy transition

Krabi became the significant province to drive the energy transition since 2007 and called to the government for 100% RE province when their citizen has opposed the new coal project according to the target of PDP. One of the component of that transition was provincial and vision plan. Green Tourism has been a fundamental plan and vision and of Krabi province since 1987 aimed to guide a sustainable local tourism that benefits economic and environmental aspects in the long term. The majority of stakeholder was private sector mainly, tourism association network, tourism supply chain of services. In 2020, according to PDP 2010 Revision 3 had a plan to build the new coal power plant projects totally 4,400 MW across the country and one of that target was in Krabi province covering 800 MW. Krabi province generated the electricity from the first coal power plant in 1964 and decommission in 31 years later. The existing power plant has been generating the electricity from oil instead, with 340 MW installation.

Since 2012, Electricity Generating Authority of Thailand (EGAT) has continually proposed the new coal project to Krabi province and still having a people resistance. Save Krabi from Coal, Hug Krabi and Save Andaman from Coal campaigns had been launched to public and called to the government transiting to Krabi 100% RE. Until now, the Prime Minister Prayuth Chan-o-cha has accredited the new committees to study the potential of energy supply in southern of Thailand. From now on, a concept of Krabi Goes Green had been raised to their citizen and public to direct a provincial plan for sustainable energy. Since 2014, Krabi Vision 2020 had been implemented by Head of Provincial to set a core team to develop that plan and collaborated with the various group of Krabi citizen to strategy the future resources management, sustainable tourism development plan and local and national tourism roadmap including provincial RE plan and biodiesel extension for alternative energy

[Ministry of Tourism and Sports, 2015]. The strengthen drivers of RE transition connects to the movement to withdraw a new coal project and the participation and ownership of the provincial plan as Krabi Vision 2020 (Krabi Provincial Administrative Organization, 2014).

2.4 Krabi Goes Green Vision and RE target

In 2018, Krabi Goes Green had been studied the potential of RE, grid management and the future city model of 100% RE [Krabi Goes Green Network, 2018]. The study had been conducted by Krabi Goes Green network, academic partnership and civil society. In 2018, Krabi Goes Green network worked with the private sector of tourism representative of six Andaman provinces to sign the MOU of Andaman Goes Green that aims to generate the sustainable economic growth and environmental conservation. These policies in couple with national energy policy on RE are the key factors leading to Krabi's RE transition which is the main purpose of the present study.

Krabi province proposed the concept of Krabi Goes Green that include the green electricity suppling to the grid, besides of the potential of RE. Krabi province is facing overwhelming challenges to solid waste management for municipal solid and other districts across the province. In 2020, waste-to-energy (WtE) is the initiative plant as a solution to reduce landfills contaminations and conflicts between provincial agencies and communities due to the limited of land, the lasting of toxic leaking and health impacts that becoming the citizen's argument to find out the solution of the proper management. Green tourism declaration is the direction of the provincial government, private sectors and networks ambitious to reduce foam, plastic waste and well management of solid waste on land and islands. Green tourism is connected to how citizen and tourists change their mindset of consumption and also drive the provincial policy makers to well management for sustainable municipal solid waste (MSW) management to minimize environmental impacts from overload amount of MSW. To achieve Krabi Goes Green as well as Green Tourism, MSW problems must be one of priorities to be implemented.

WtE is a win-win option that not only to minimize MSW but also increase RE for electricity generation. Green tourism is not even reducing the environmental impact but also encouraging the facilitation of waste separation at source for tourists including campaigning to reduce using single-use plastic bag, beverage cups and straws. Income from tourism forces a city to sustain tourism and energy even if the annual consumption has been increasing. As a top tourism destination, millions of visitors come to Krabi province every year (Ministry of Tourism and Sports, 2015). Before COVID-19 Pandemic, numbers of visitors have been increasing year by year, followed by an increasing trend of MSW as well as electricity demand. Waste-to-energy plan and implementation in Krabi province is disrupted by the Section 44 of the Interim Constitution of Thailand (Thailand Government, 2016) to green light the project to generate electricity to the national grid for 25 years of feed-in-tariff purchasing agreement. RE transition towards sustainable energy has become an important strategy to fulfill the Krabi Vision 2020. Meanwhile, waste-to-energy is expected to be alternative energy and an option to eliminate the problem of MSW management as well as to provide a sustainable source for electricity supply in the province.

Due to the RE transition of Krabi province was significantly outstanding both the potential of RE, relevant policy process and maybe others therefore, the transition towards more RE would accelerate achieving the Krabi Goes Green target of 100% RE by the year 2026.

CHAPTER III

Research Design and Methodology

This chapter presents research site description, research conceptual framework, research design and methodology for the present study. Data collection and analysis to identify key drivers, barriers and challenges to overcome the barriers are also described in this chapter.

3.1 Research site description

Krabi Province was selected as a case study because the province is one of tourism destinations having remarkably increasing of tourists, especially foreigners as well as income from tourism during recent years prior COVID19 Pandemic (data.Krabi.go.th, 2021). Electricity demand of the province has been continuously increasing and its peak load was forecasted to increase up to 320 MW by 2037 (PEA, 2020). Meanwhile, domestic electricity generation can supply only nearly half of its annual demand, and the rest must be imported from southern national grid. In addition, the province has clear visions on green economy and green tourism, which is so-called "Krabi Goes Green" with targeting to be self-reliance on electricity generation from 100% renewable energy by the year 2026, which has become encouraging to explore how the province could achieve such a challenging target. Research site in this study covers all 8 districts, with 53 sub-districts, of the province, as shown in figure 5.

Figure 5 The area of study, Krabi province, 2020
Source: Google and https://ofomaps.com

3.2 Conceptual framework and research design

Global SDGs and Climate Change issues, as well as the needs of economic and human well-being development and also environment and ecosystem concerns are key drivers towards sustainable energy development. These drivers are leading to national policy on low carbon nation and energy security. Meanwhile, all province must initiate provincial policy to implement the national policies. To achieve target on low carbon city as well as energy security, Krabi initiated "Krabi Vision 2020" as well as "Krabi Goes Green" and "Green Tourism" as a provincial roadmap towards Krabi's Sustainable Energy. "Green Tourism" was firstly developed as a provincial roadmap to secure natural resources for tourism sustainability. "Krabi Vision 2020" was then developed by collaboration of diverse stakeholders to provide strategic plan for the province, and "Krabi Goes Green" was thus developed to drive renewable energy transition in the province.

In addition, all implementation should fulfill community satisfaction. However, to implement these policies would face various barriers and challenges to overcome these barriers. All these concerns have been identified in the conceptual framework of the present study as summarized in figure 6. The study started with data collection from secondary sources, followed by surveys on information about barriers and challenges and how to overcome the barriers. The primary information was collected by in-depth interviews, group interviews, site observation and then analyzed by keyword grouping as well as descriptive analysis as shown in figure 7. List of key stakeholders and key information for the present study are shown in Tables 1 and 2.

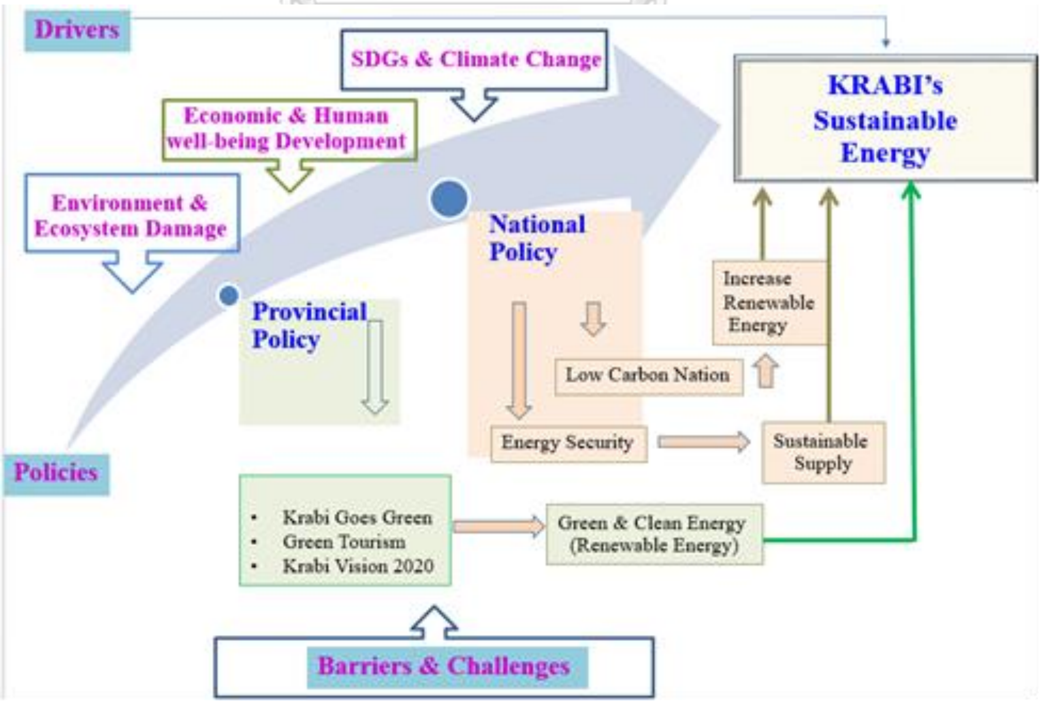


Figure 6 Conceptual framework towards Krabi' sustainable energy, 2020

3.3 Data Collection and analysis

The present study used a qualitative approach. Information from secondary sources was compiled from energy and agricultural waste relevant agencies like Energy Policy and Planning Office (EPPO), Provincial Electricity Authority (PEA) and Krabi Provincial Administrative Organization etc. Information from primary sources was collected by conducting in-depth interviews, small group interviews, and on-site observation. All primary data collection was conducted during July-September 2020. The interview process consists of mixing among structured questions, semi-structured questions, and natural conversation to seek in-depth thought from the interviewees. Most of the questions are open-ended in order to give opportunity for the interviewees' opinions and thought expression. Examples of the question are shown in appendix 1.

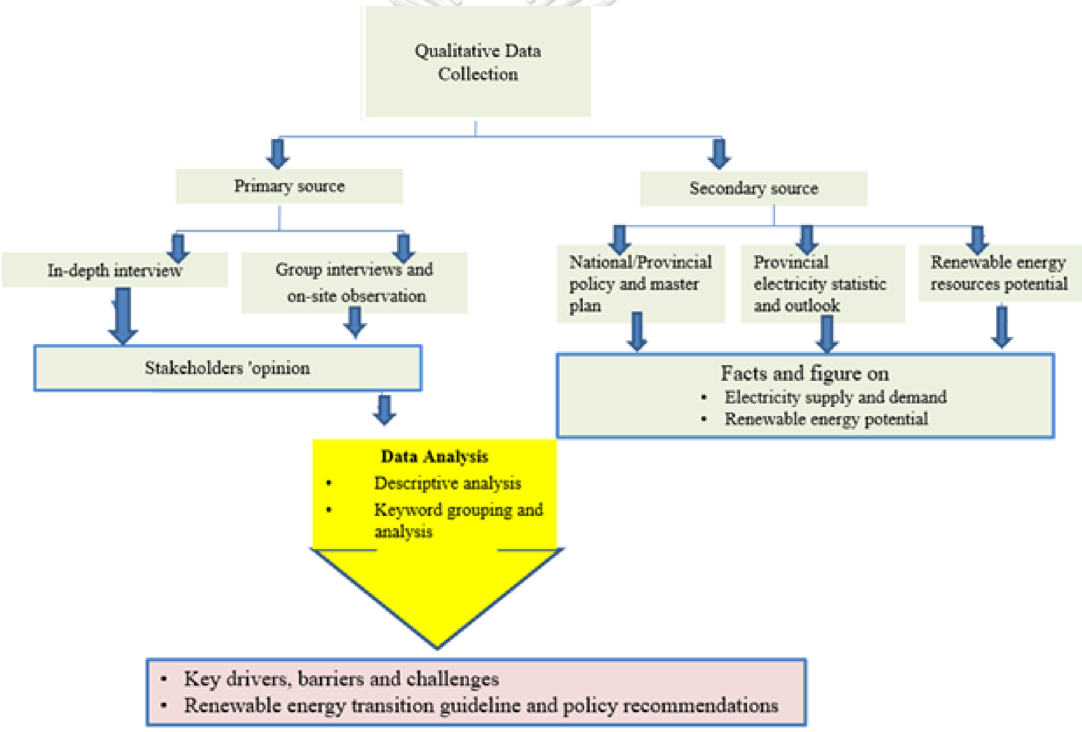


Figure 7 Research design and methodology, 2020

The study process started with searching for both national and provincial organizations having authorities and take responsibility on information, policy and regulations related to each RE and power plant investment. Then, stakeholders and key informants related to each RE investment were identified. Some information were collected from organization's websites, networks and reports publicly available (see also Table 2). While some information which are not publicly available were requested from each relevant organization, including Krabi Goes Green network (see also Table 3).

After gathering all relevant secondary information, the researcher prepared list of key informants and drafted outline for in-depth interviews. All collected secondary information were descriptive analyzed and presented in graphical chart, map, and Table forms for easily understanding. Most of which are outcomes for research objective 1: Krabi's electricity outlook and RE resources potential.

Table 1 List of key stakeholders of Krabi renewable energy transition, 2020

Key stakeholders	Responsibility	Policy/ regulation authority
Energy Policy and Planning Office, Ministry of Energy (EPPO)	Implementation the National energy policies	National Power Development Plan
National Energy Policy Commission	Approving the National energy policy plans	National Power Development Plan
Department of Alternative Energy Development and Efficiency(DEDE)	Planning and implementation the National alternative energy and energy efficiency policy	National Alternative energy and energy efficiency plan
Energy Regulatory Commission(ERC)	planning/implementation of energy purchasing policies and regulations	National Power purchasing policies / power plant fund regulation
Ministry of Agriculture and Cooperatives	Collaboration with Ministry of Energy to promote biomass, biogas and solar energy	National agricultural and cooperative regulations
Ministry of National Resources and Environment	Approval and monitoring the relevant energy projects and environmental impact factors	Environmental Impact Assessment regulations / pollution control regulations
Provincial Administrative Office	Planning for Krabi’s development and investment	Krabi strategic and development plans
Provincial Strategic Office	Strategic planning of Krabi province	Krabi strategic plan
Provincial City Planning Office	A part of the energy projects approval of Krabi province	Krabi city planning and land use regulations

Key stakeholders	Responsibility	Policy/ regulation authority
Provincial Environmental Office	A part of the energy projects approval of Krabi province	Krabi natural resources and conservation regulations
Provincial Industry Office	A part of the energy projects approval of Krabi province	Krabi industry and green tourism plan
Provincial Cooperative Office	A part of the bio-energy projects and agricultural solar farm approval of Krabi province	Agricultural cooperative regulations
Agricultural and Cooperative Association	Implementation the relevant energy projects of Krabi province	Agricultural cooperative regulations
Provincial Electricity Authority (PEA)	Planning and approval the energy purchasing of Krabi's energy projects	Regional power purchasing policies
Energy power producers	Development and investment the energy projects	National energy policies and provincial strategy
Prosumer	Development and investment the energy projects	National energy policies and provincial strategy
Communities	A part of public hearing process for Krabi's energy projects	National impact assessments/ provincial environmental regulation
Banks / financial agencies	Supporting funding for energy projects investment	Loan policy and regulations
Ministry of Interior	Collaboration with Ministry of Energy to support waste-to-energy power plant project	Public health and waste regulations
Krabi Municipality	Planning and being the project's owner of waste-to-energy power plant	Municipal waste management regulations

Table 2 List of key information from organization websites and network

Key information	Publicly source
VSPP of renewable energy	http://www.erc.or.th/ERCSPP/default.aspx?x=0&muid=23&prid=41
Southern electricity supply of PDP 2018	http://www.eppo.go.th/images/POLICY/PDF/PDP2018.pdf
Palm planting production of Krabi province	http://123.242.168.130/krabisys/produce_agriculture/graph/b31
Krabi stragical plans	http://www.krabi.go.th/krabi2015/m_plan.php
Krabi Green Toursim	http://www.krabi.go.th/krabi2015/m_decla.php
Krabi Vision 2020	http://www.krabi.go.th/krabi2015/m_file/KrabiVision2020.pdf
Krabi 100% renewable energy proposing	https://greennews.agency/?p=10250
Krabi Goes Green report	https://www.greenpeace.org/thailand/publication/2953/krabi-goes-green/

Table 3 List of organization providing key information relevant to RE investment, 2020

Information	Organization / Source
Very Small Power Producer (VSPP)	Energy Regulatory Commission (ERC)
Annual electricity demand and supply	Provincial Electricity Authority, Krabi province
Statistic of Krabi electrical demand by sector	Provincial Electricity Authority, Krabi province
Monthly peak demand of Krabi province	Provincial Electricity Authority, Krabi province
Krabi's electrical peak load	Provincial Electricity Authority, Krabi province
Krabi electrical stations	Provincial Electricity Authority, Krabi province
Renewable energy installation	Provincial Electricity Authority, Krabi province
Potential of renewable energy	Provincial Electricity Authority, Krabi province
Solar farms installation	Provincial Electricity Authority, Krabi province
Solar energy development of Krabi province	Provincial Electricity Authority, Krabi province
Biomass and biogas energy development of Krabi province	Provincial Electricity Authority, Krabi province
Krabi's VSPP solar farms installation	Provincial Electricity Authority, Krabi province
Krabi's electrical load forecast	Provincial Electricity Authority,

Information	Organization / Source
	Nakhon Si Thammarat province
Southern electricity supply of PDP 2018	Energy Policy and Planning Office (EPPO)
Krabi's VSPP solar farms installation	Solar farms of agricultural cooperatives
Solar energy investment	Solar South Company
Solar energy development of Krabi province	Solar South Company
Solar Street Light development of Krabi province	Krabi Provincial Administrative Organization
Krabi Goes Green report	Krabi Goes Green Network, Thammasart University, Public Health Policy Foundation, Greenpeace
Palm planting production of Krabi province	Krabi Provincial Administrative Organization Krabi Provincial Commercial Office
Palm price of Krabi province	DumDee Biodiesel Public Learning Center, Krabi Province
Solid waste of Krabi Municipality	Krabi Municipality
Solid waste forecast of Krabi Municipality	Krabi Municipality
Waste-to-energy and waste cluster of Krabi province	Krabi Municipality
Waste-to-energy power plant of Krabi province	Krabi Municipality
Potential of waste-to-energy	Krabi Municipality
Krabi strategical plans	Krabi Provincial Administrative Organization
Krabi Vision 2020	Krabi Provincial Administrative Organization
Krabi Green Tourism	Krabi Tourism Association,
Krabi 100% renewable energy target	Krabi Goes Green Network

Table 4 List of organization providing key information of each RE, 2020

Informant groups	Numbers
Government / provincial governmental agencies (8)	
Provincial Electricity Authority, Krabi province	1
Krabi Provincial Administrative Organisation	1
Krabi Municipality and waste cluster	3
Krabi Provincial Cooperative Office	1
Krabi Provicial Industry Office	2
Tourism /network (6)	
Tourism industial and administrative of Krabi province	2
Krabi Goes Green network	2
Prosumer	2
Power producers (8)	
Biomass/ Biogas Power Producer and Investors	3
Solar energy power producers and investors (solar farm)	4
Solar energy power producers and investors (solar rooftop)	1
Total	**22**

In case of primary information collection, the researcher started with preparing list of key interviewees from relevant stakeholders as shown in Table 4, then making appointments for either in-depth interviews or small group interviews. Some were repeat interviewed after data analysis.

All recorded information from the in-depth interviews, group interviews, and on-site observation was typed in MS word. Keywords were manually selected based on answers related to each category of drivers, barriers, and challenges. The keywords of each category were typed in MS Excel program, for further frequency counting using key word clarity program from the online tool at https://keywordclarity.io. An example of keyword counting outcome is shown in figure 8, and the others are shown in appendices 2-3.

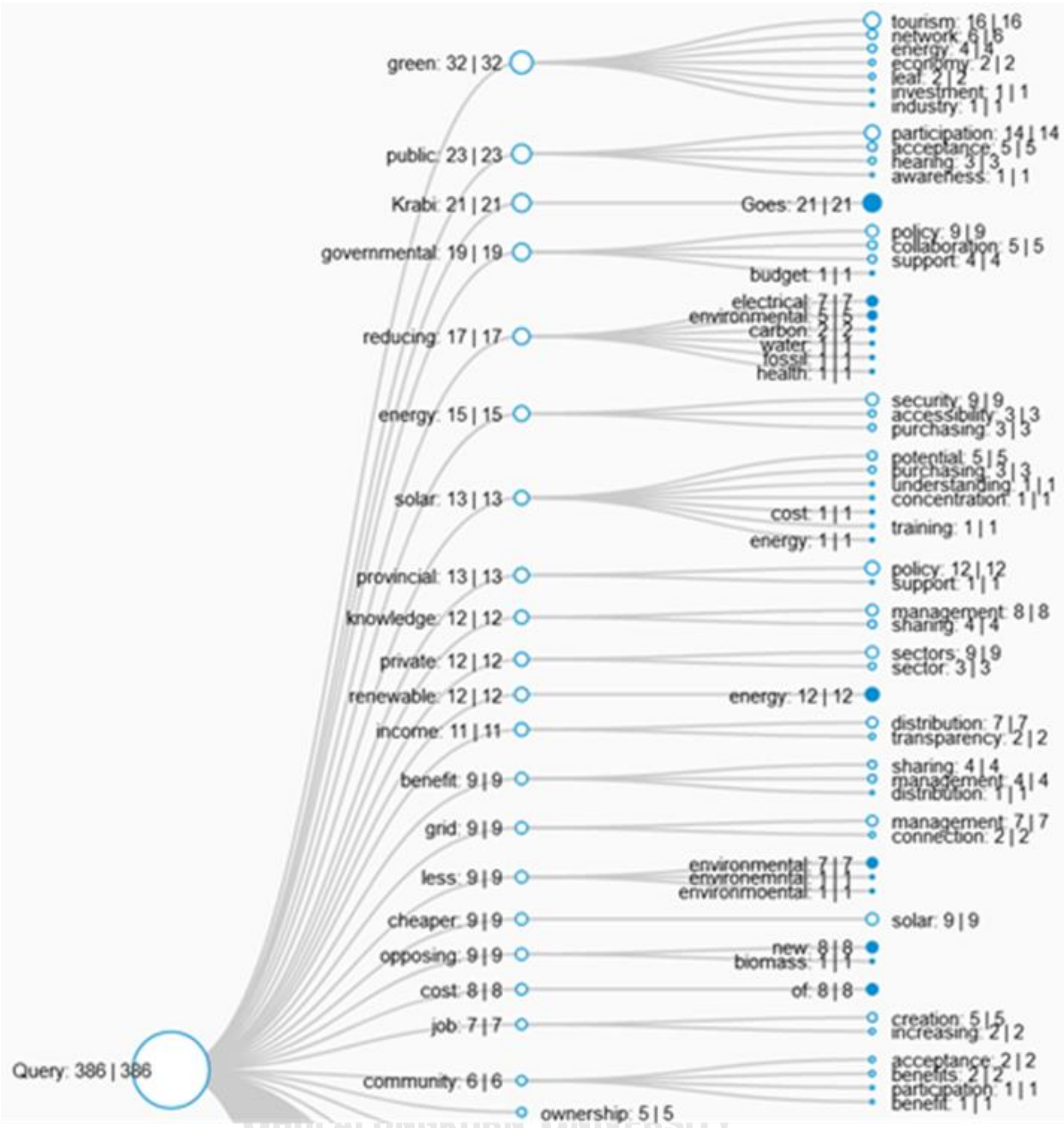


Figure 8 Example of keywords grouping outcome from the in-depth interview, 2020
Source: https://keywordclarity.io, 2020

After frequency counting, each high frequency keyword was manually checked its relation with each RE from the recorded interview information before summarizing key drivers, barriers, and challenges to overcome barriers of each RE. Upon intensive analysis of all information from the interviews and on-site observation, key drivers, barriers, and challenges to overcome the barriers of each RE were summarized to achieve objective 2 of the study. Then, all information both from primary and secondary sources were integrated to formulate guideline and policy recommendations towards Krabi's sustainable energy, which is objective 3 of the study. By the way, before finalized formulation of the guideline and policy recommendations, some of which were brought to re-interview with some stakeholders to ensure acceptable of the guideline and policy recommendation.

CHAPTER IV

Results and Discussion

This chapter presents results of the present study which aimed to answer how Krabi province would fulfill the increasing electricity demand and maximize utilization of domestic RE resources for electricity generation and what would be key drivers, barriers, and challenges towards RE transition for Krabi's sustainable energy. The presentation starts with Krabi's electricity outlook consisting of statistic of electricity consumption and supply, electricity consumption by sectors, demand forecast, RE transition in the province and followed by potential of each RE in the province, key drivers, barriers, and challenges to overcome the barriers of each RE power plant investment. Finally, guideline and policy recommendation for provincial RE transition are briefly described.

4.1 Krabi's electricity outlook

Electricity transmission system in the province belongs to EGAT (Electricity Generation Authority of Thailand), whereas, the electricity grid is managed by Provincial Electricity Authority (PEA) to balance distribution of electricity demand and supply among 10 stations across the province, consisting of 2 center stations, 4 branch stations, and 4 sub-stations, as shown in figure 9. It is clearly observed from the figure that electricity stations are fairly distributed throughout the whole province.

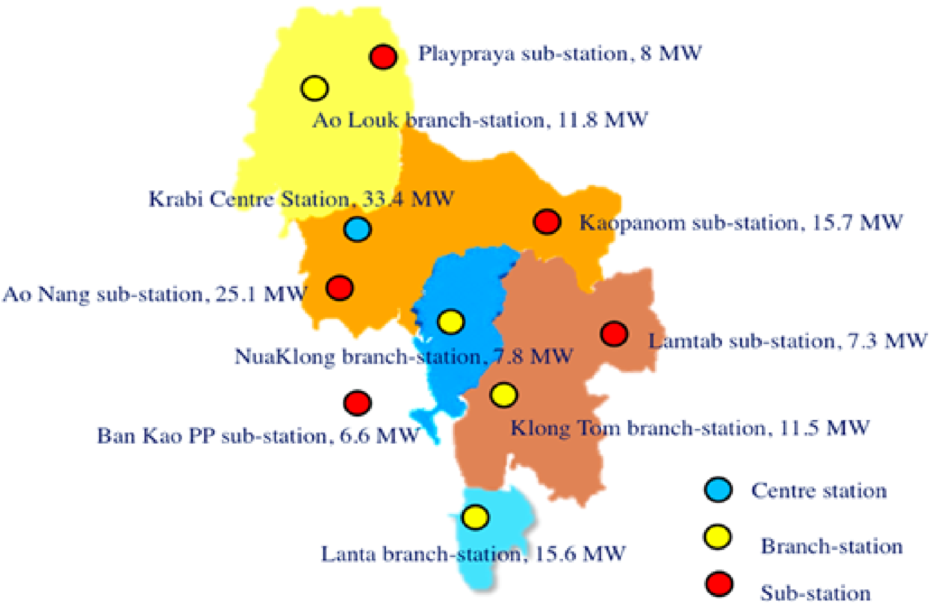


Figure 9 Electricity stations in Krabi province
Source: Provincial Electricity Authority (PEA), 2018

According to information provided by PEA (2018), Krabi's electricity demand and supply during 1964-2020, as shown in figure 10, illustrate that during 1964-1985, the domestic supply from a 60 MW coal fired power plant fulfilled its annual demand until decommissioning in 1995. Since then, electricity supply in the province has mainly relied on national grid from power plants in the southern part of Thailand until nowadays. Even though a 340 MW oil fired power plant was installed in 2004, its role is just for standby during high peak load because of high oil price. RE transition at Krabi was started in 2007 with a 9.5 MW biomass power plant, followed by biogas power plants since 2008. Solar PV farms and solar rooftops have been installed since 2018. While only one WtE power plant (6 MW) was installed in 2020 (see also Table 5 and Appendix 5). By the way, total RE power supply still could not meet its annual demand. More than half of Krabi electricity demand is still relying on national grid

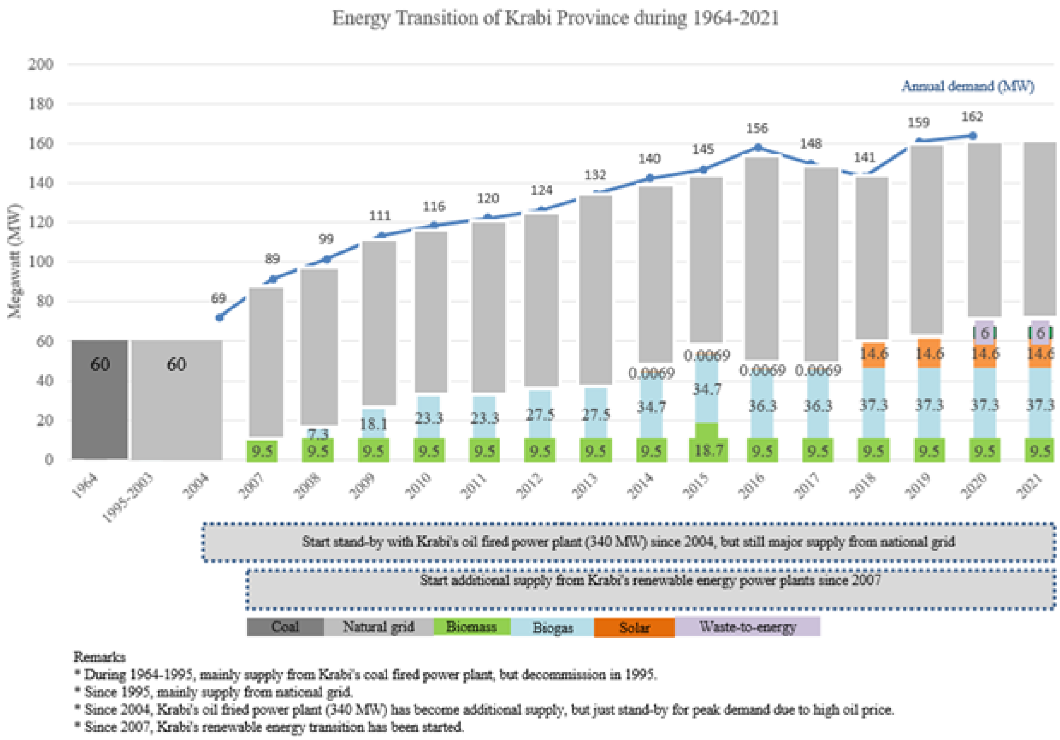


Figure 10 Krabi's electricity supply and demand during 1964-2021
Source: Provincial Electricity Authority (PEA), 2021

Table 5 Krabi's power plant installation as of June 2020

Company	Plant	Fuel	Installation capacity	Actual grid supply
			Megawatt (MW)	Megawatt (MW)
Crude oil	Krabi power plant	Crude oil	340	340 Only peak load)
Fossil fuel total			**340**	**340**
Wanna Chaideker	Solar PV	Solar	0.007	0.007
Thai Green Co., Ltd.	Solar PV	Solar	5	5
Klongya Agricultural Cooperative	Solar PV	Solar	4.16	N/A*
Smart Solar Power Co., Ltd.	Solar PV	Solar	4.64	4.64
Mar Solar Co., Ltd.	Solar PV	Solar	5	5
Solar PV total	**Solar PV**	**Solar**	**18.81 (26.1%)**	**14.65 (26.0%)**
Krabi Waste to Energy Co., Ltd.	Gas engine	Biogas	1.616	1.5
Clean Power Associate Co., Ltd.	Gas engine	Biogas	1.021	0.99
Sarab Biogas Energy Co., Ltd.	Gas engine	Biogas	2	2
Thai Integrate Palm Oil Co.Ltd.	Gas engine	Biogas	0.95	0.95
Thai-Indo Palm Oil Factory Co., Ltd.	Gas engine	Biogas	3.2	1
Namhong Power Co., Ltd.	Gas engine	Biogas	3.189	3

Company	Plant	Fuel	Installation capacity	Actual grid supply
			Megawatt (MW)	**Megawatt (MW)**
Modern Green Power Co., Ltd.	Gas engine	Biogas	3.189	3
Univanit Palm Oil Co., Ltd.	Gas engine	Biogas	2.856	2.856
Sri Chareoun Palm Oil Co., Ltd.	Gas engine	Biogas	3.189	3.093
ASEAN Palm Oil Co., Ltd.	Gas engine	Biogas	1.65	1
Univanit Palm Oil Co., Ltd.	Gas engine	Biogas	5.516	2.856
Multi-industry Palm Oil Co., Ltd.	Gas engine	Biogas	2	1.9
Biogas total			**30.38(42.2%)**	**24.14(42.9%)**
Multi-industry Palm Oil Co., Ltd.	Steam turbine	Biomass	4.05	1
Sarab Energy Co., Ltd.	Steam turbine	Biomass	9.5	8.5
Thai Sri Tong Co., Ltd.	Steam turbine	Biomass	9.24	8
Biomass total			**22.79 (31.7%)**	**17.5 (31.1%)**
Grand total			**71.98 (100%)**	**56.29 (100%)**

Source: Provincial Electricity Authority, 2020

*Remark: The 4.16 MW solar farm at Klongya Agricultural Cooperative has been installed, but not yet grid connection due to ongoing process of justice.

According to information reported in PDP2018, all southern power plants installed as of March 2017 can supply totally 2,164 MW, while the southern total demand was 2,624 MW, additional 460 MW must be imported from central national grid. Therefore, it is not sustainable practice if Krabi electricity supply still relies on the southern national grid. In order to achieve Krabi's sustainable energy, maximize domestic electricity generation from RE sources has become important to ensure supply security and mentioned clearly in both Krabi Vision 2020 and Krabi Goes Green Roadmap. It is noticed that only the 340 MW oil fired power plant is a large scale, the others (biomass, biogas, solar PV, and waste to energy) are either small (capacity less than 100 MW) or very small (capacity less than 10 MW) power plants.

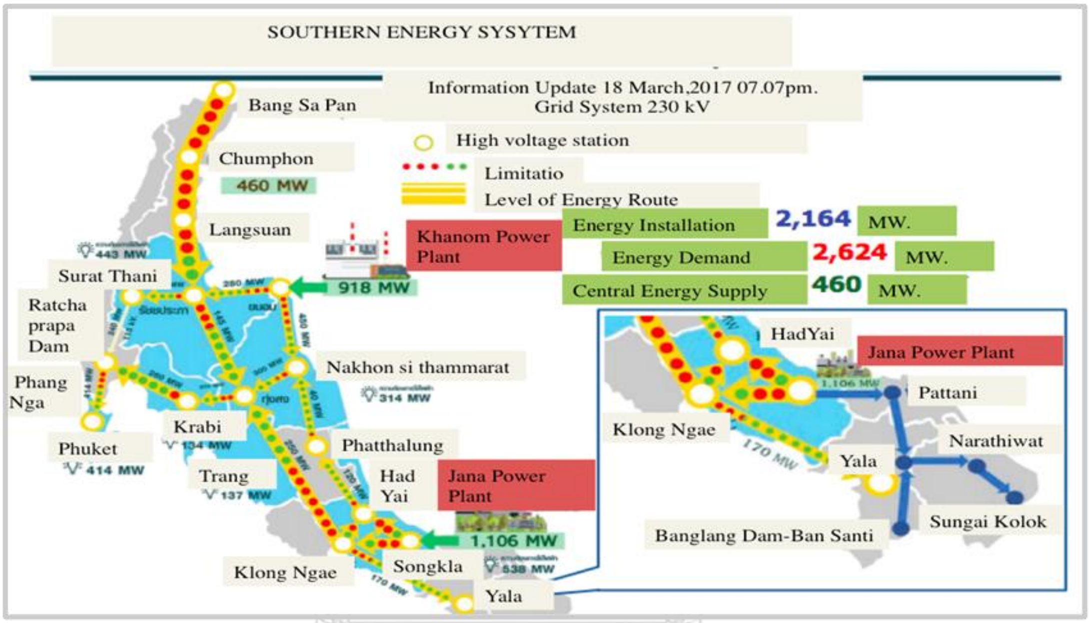


Figure 11 Electricity supply in southern part of Thailand according to the revised PDP2018

Source: EPPO 2018

According to statistic information (as of 2018) provided by PEA, as shown in figures 12-13, it is observed that electricity consumption in Krabi during 2008-2017 had increasing trend in all sectors and residential sector has been the biggest consumer. Whereas the tourism related electricity consumption, such as hotels, resorts, restaurants and souvenir shop are included in the medium and small businesses, which were the second and third biggest consumers respectively.

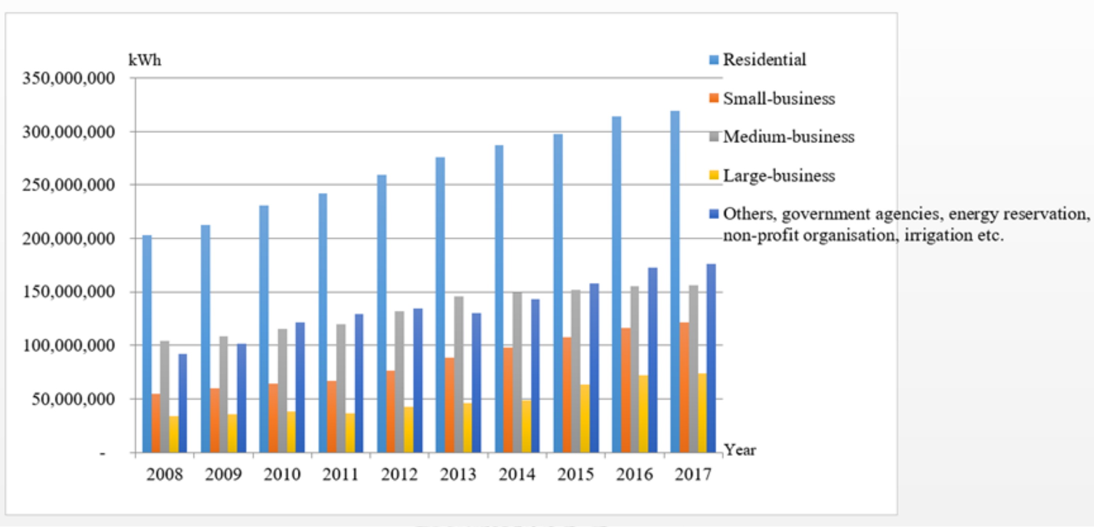


Figure 12 Statistic of Krabi electrical demand by sector during 2008-2017 (kWh)
Source: Provincial Electricity Authority (PEA), 2018

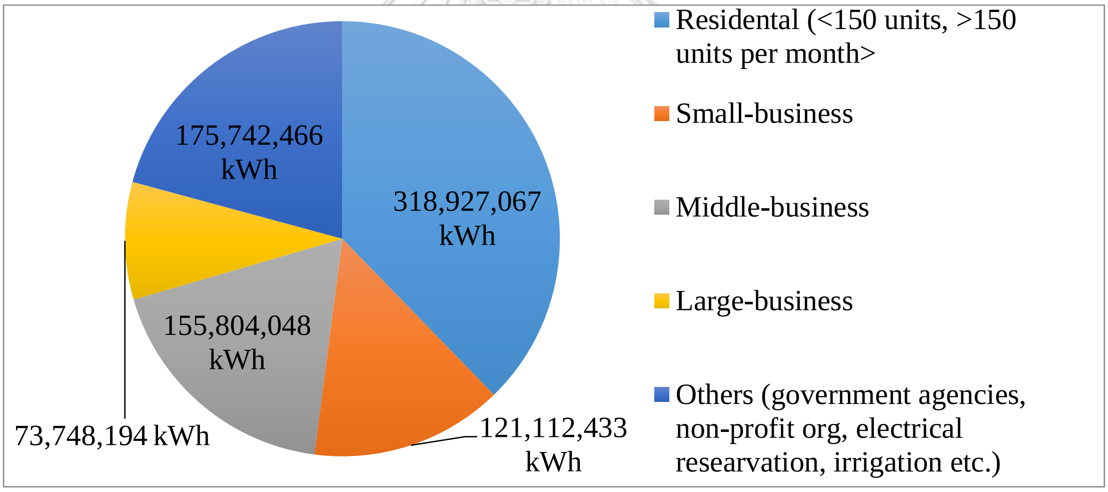


Figure 13 Krabi's electricity demand by sector in 2017 (kWh)
Source: Provincial Electricity Authority (PEA), 2018

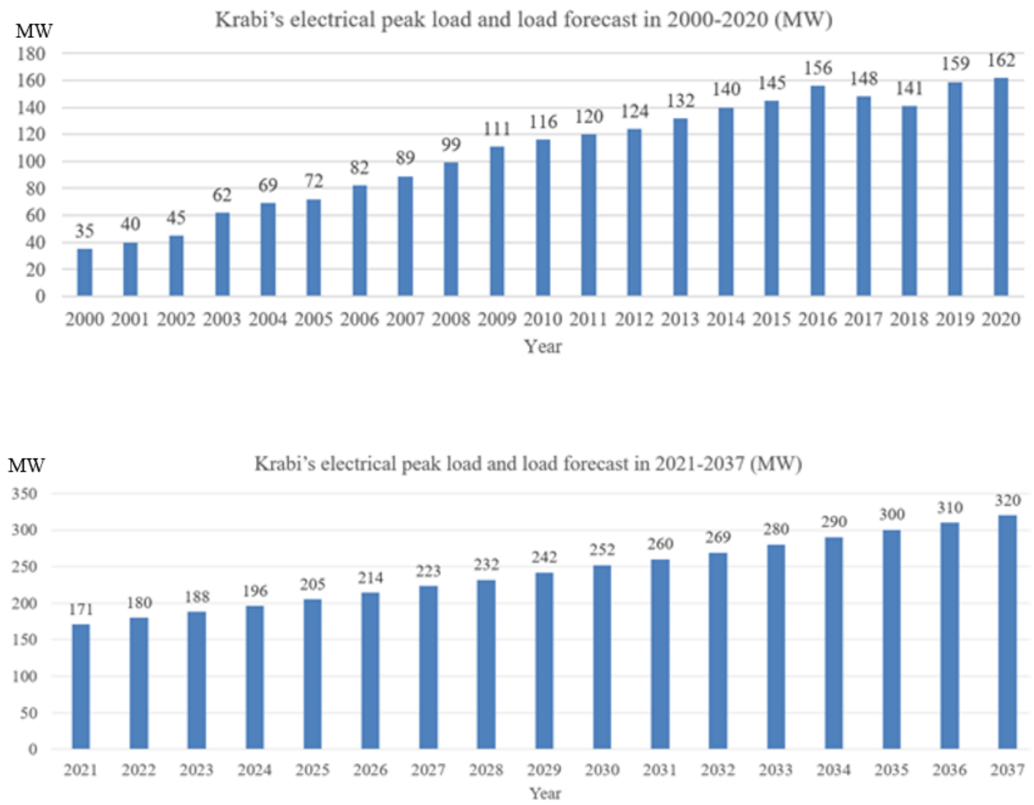
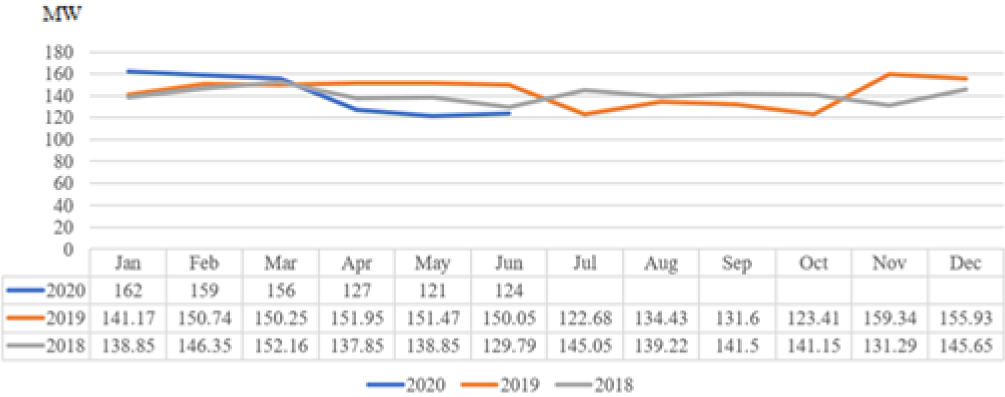


Figure 14 Monthly peak demand of Krabi province in 2018-2020
Source: Provincial Electricity Authority, 2020

According to information provided by PEA (2020), it is observed from Krabi's peak load statistic during 2000-2020 and load forecast during 2021-2037, as shown in figure 14 that peak load demand in the province has continuously increasing from 35 MW in 2000, up to 159 MW in 2019, and tends to increase up to 320 MW in 2037. Meanwhile, the monthly peak load during 2018-2020 (PEA, 2020) as shown in figure 15 illustrates that electricity consumption in the province reached the peak load between 130-160 MW almost every month and exhibited similar trends in 2018, 2019, and 2020. This monthly peak load seems to be different with national peak load which tends to reach high peak during summer season due to increasing utilization of air conditioner, while the tourism related activities always using air conditioner.

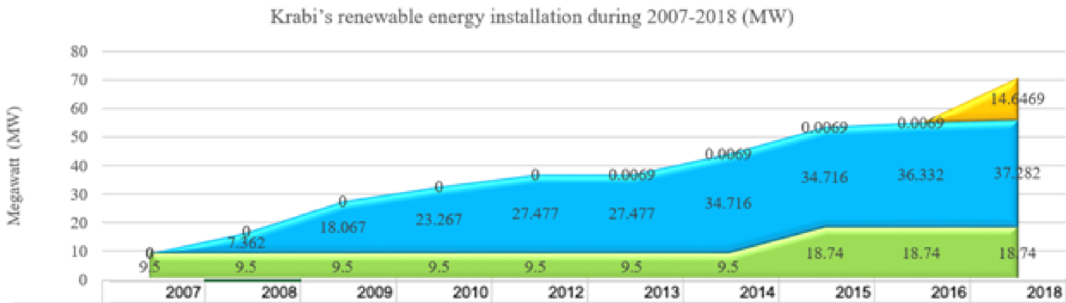


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2020	162	159	156	127	121	124						
2019	141.17	150.74	150.25	151.95	151.47	150.05	122.68	134.43	131.6	123.41	159.34	155.93
2018	138.85	146.35	152.16	137.85	138.85	129.79	145.05	139.22	141.5	141.15	131.29	145.65

Figure 15 Monthly peak demand of Krabi province in 2018-2020 (MW)
Source: Provincial Electricity Authority (PEA), 2020

4.2 Krabi's RE transition

As mentioned above, Krabi started domestic electricity generation from coal fired power plant in 1964 and fulfilled the demand in the province until decommissioned in 1995 due to depletion of domestic coal resource. During 1995-2004, electricity supply relied only on the southern national grid until EGAT installed a 340 MW oil filed power plant for additional supply. However, the oil fired power plant is just stand-by for high peak demand because of high oil price. RE transition in Krabi province has started since 2007 with 9.5 MW biomass (palm oil waste) VSPP, followed with 10 biogas VSPPs having total installation capacity of 27.48 MW during 2008-2012, Solar PV rooftop (0.0069 MW) in 2013, biogas VSPPs (3.189 MW) in 2014, biomass VSPPs in 2014 (4.05 MW) and 2015 (9.24 MW), and then two biogas VSPPs and three Solar PV farm during 2016-2018 (see also figure 16). Then, an additional 6 MW waste-to-energy VSPP was installed in 2020 (see also figure 10). As of December 2020, RE power plants achieved COD (commercial operation date) were reported to be totally 59.06 MW from biomass, 44.4 MW from biogas, and nearly 15 MW from solar meanwhile total electricity consumption in the province was approximately 162 MW (PEA,2020).



	2007	2008	2009	2010	2012	2013	2014	2015	2016	2018
Solar						0.0069	0.0069	0.0069	0.0069	14.6469
Biogas		7.362	18.067	23.267	27.477	27.477	34.716	34.716	36.332	37.282
Biomass	9.5	9.5	9.5	9.5	9.5	9.5	9.5	18.74	18.74	18.74

Figure 16 Krabi's RE installation during 2007-2018 (MW)
Source: Provincial Electricity Authority (PEA), 2019

4.3 Krabi's RE potential

Detail information about each RE resource in Krabi province is briefly described as follow.

1) Biomass and biogas energy

Bio-energy is escalating the potential of RE supply to generate electricity on the grid including biomass waste abstraction (Alhazmi, H. and Loy, A. C. M., 2021). Supply chain of the investment had the inherent ability to grow the local economy on a small scale of that investment including planting, transportation, direct and indirect job creation etc. (Ahl, A., et al., 2018) Small scale biomass and biogas energy development was the harvest benefit of palm, rubber and agricultural productivity of peri-urban and rural communities and sustain people's local livelihoods (Romijn, H., et al., 2010). Supply chain of these resources obtained the intermediate storage, transportation, processing operation and solid fuels production (Nunes, L. J., et al., 2020). Quantity and quality of collected bio-energy related to temperature, moisture content such as straw, grass, palm etc. (Alfonso, D., et al., 2009) Biofuel significantly focused on the availability security supply and the impact from land use change that connected to the cost of investment and high competition. Biomass life cycle covered the environmental impacts including global warming potential, particulate matter, land use and biodiversity, water scarcity etc.(Lee, M., et al., 2020) Cultivating bio-energy sites and locations could influence profitability, competitive cost of investment and economy of scale (Jin, S.J. and Alvaro, R.G., 2018). Operation system required energy storage energy and designed grid transition as an energy management system (Zheng, Y., et al., 2018). Energy policy framework, the feed-in-tariff advocacy and transferred technological development were useful to be implemented (Hansen, E. U. and Ivan, N., 2014).

Referring to data from Krabi Goes Green report, potential of RE in the province as of June 2020 as shown in figure 17 and Table 6, is 1,676 MW, where 1,162 MW of which from solar PV, 249 MW from palm oil biomass, 200 MW from wind, 60 MW from biogas, 32 MW from rubber tree biomass, and 10 MW from mini-hydro power plants. Most RE power plants in Krabi are very small power producers (capacity not exceed 1 MW), and the location of each power plant across the province shown in figure 18. Furthermore, the VSPP of southern Thailand has been installation approximately 289 MW (see the Appendix 4)

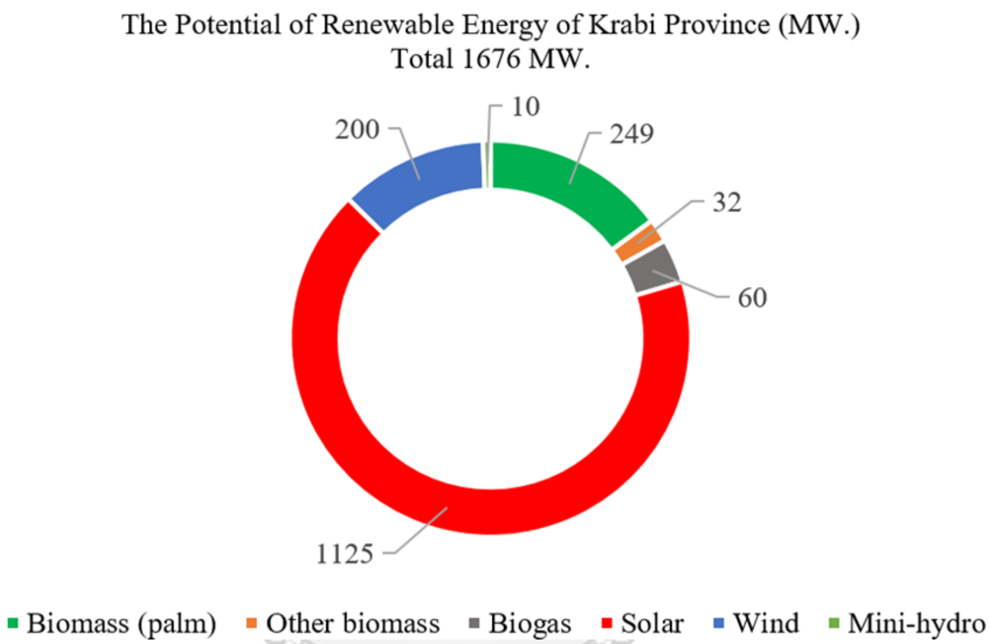


Figure 17 Potential of RE of Krabi province in 2027
Source: Krabi Goes Green, 2018

Table 6 Potential and installation of Krabi's RE (MW), 2019

Potential and installation of Krabi's renewable energy (MW)		
	Potential	**Installation**
Biomass (palm)	249	9.5
Other biomass	32	0
Biogas	60	37.3
Solar	1125	14.6
Wind	200	0
Mini-hydro	10	0
Waste-to-energy	0	6
Total	**1676**	**67.4**

Source: Krabi Goes Green, 2018 and Provincial Electricity Authority (PEA), 2019

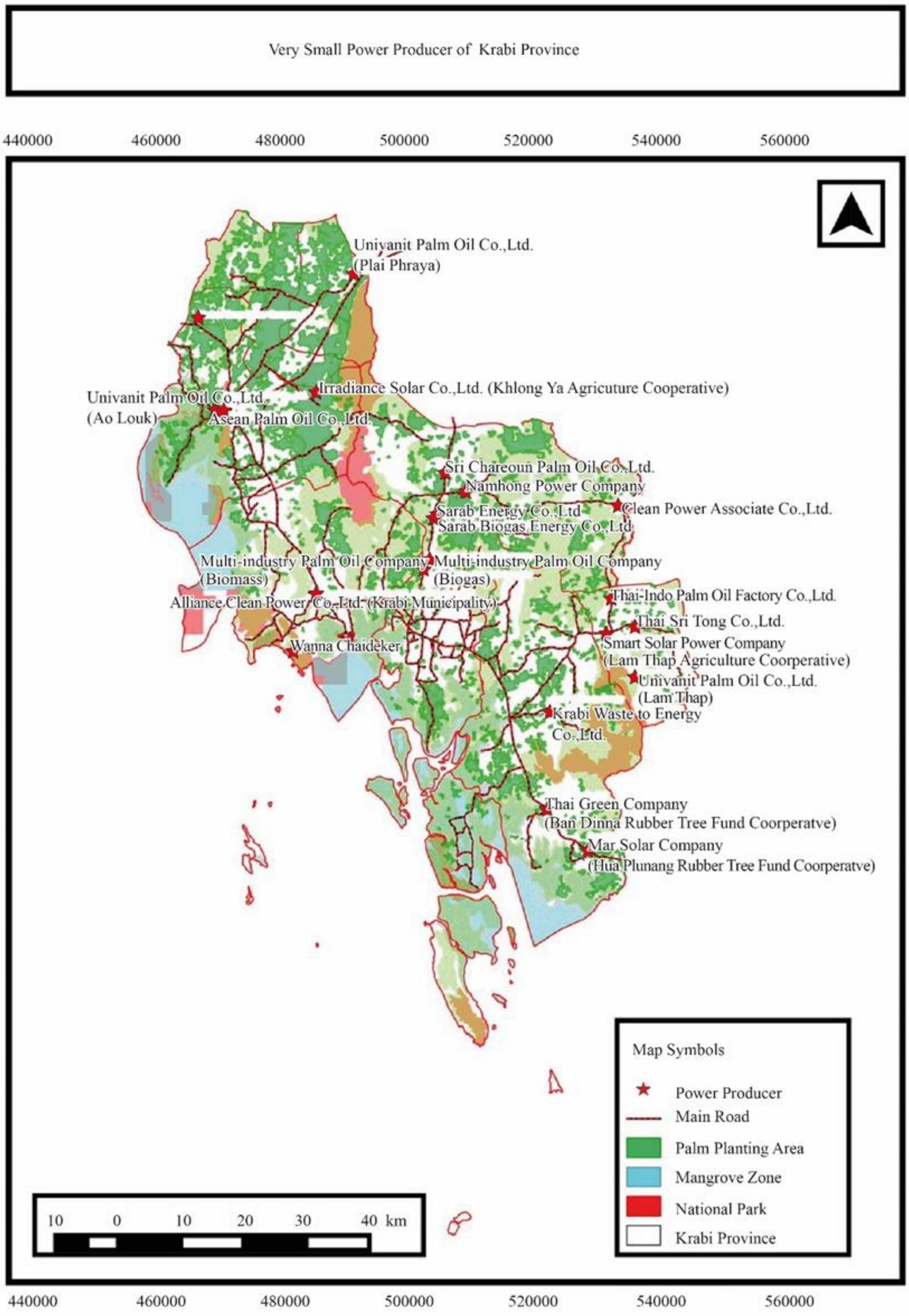


Figure 18 Very Small Power Producer (VSPP) of Krabi Province
Source: Provincial Electricity Authority, 2020

Biomass and biogas energy has played important role in Krabi's RE transition since 2007. Source of biomass and biogas energy at Krabi province mainly comes from palm oil industry, where about one million rai are used for palm tree plantation in the province. Average production of palm tree is more than 3,000 tons per rai each year, as shown in Table 7. Most of solid waste from palm oil industry, as summarized in Table 8, can be used for biomass power plant. While waste water from the palm oil industry can be treated with anaerobic digestion to produce biogas which mainly consists of methane gas having global warming potential as high as 21 times compared to carbon dioxide. Therefore, biogas is not only clean and green energy, but also high contribution to greenhouse gas mitigation. There is no report on the biogas potential because of self-utilization in the palm oil mill industry, both for heating in the process and for electricity generation. However, the biogas potential would be increasing with the production capacity of palm oil in the province. Regarding potential of biomass in the province, it was found to be 249 MW from palm oil tree, 32 MW from rubber tree, and 0.2 MW from coconut tree.

Table 7 Palm planting production of Krabi province in 2013-2018

Year	Household	Planting/Rai	Production/Rai	Production	
				Total (ton)	Avarage(tonne/Rai)
2013	23,079	992,885	864,285	2,858,354	3,307.00
2014	24,507	984,694	950,447	3,320,117	3,493.00
2015	23,079	985,285	920,307	3,221,172	3,495.00
2016	25,726	1,043,700	965,942	3,293,458	3,338.00
2017	25,850	1,119,597	1,058,176	3,309,166	3,127.00
2018	31,063	1,138,323	1,086,190	3,383,122	3,115.00

Source: Provincial Administrative Office, 2020

Table 8 Heat capacity and the potential of biomass power generation from different types of biomass in Krabi

Type of biomass	Heating value	Power generation rate	Potential of biomass
	(MJ / kg)	(MW/ton/year)	(MW)
Palm trunk	7.54	52.89	52.8
Palm leaves and fronds	1.76	12.35	97.8
Palm empty fruit bunch	7.24	50.79	39.1
Palm Fibre	11.4	79.97	39.2
Palm shell	16.9	118.55	20.7
Total			**249.6**

Source: Krabi Goes Green, 2018

However, palm production in Krabi province fluctuated in January, February and the middle of the year in July, August and September as shown in figure19. Advance palm stocking was managed in each supply chain of the power producers. Price of palm has been related to the high and low season of palm production in each period since 2011-2021 and biomass and biogas installation as shown in figures 20 and 21.

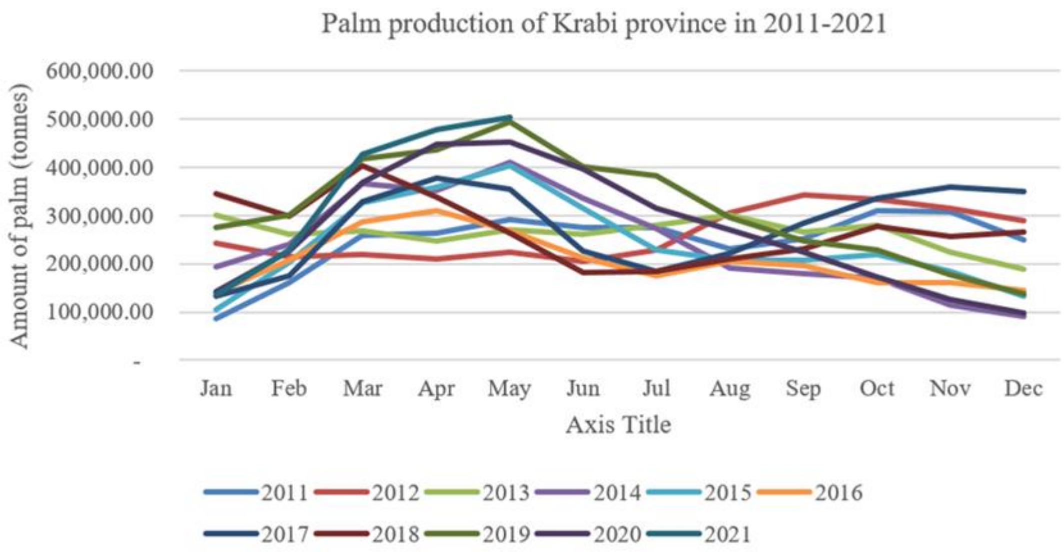


Figure 19 Palm production of Krabi province in 2011-2021
Source: Krabi Provincial Commercial Office, 2021

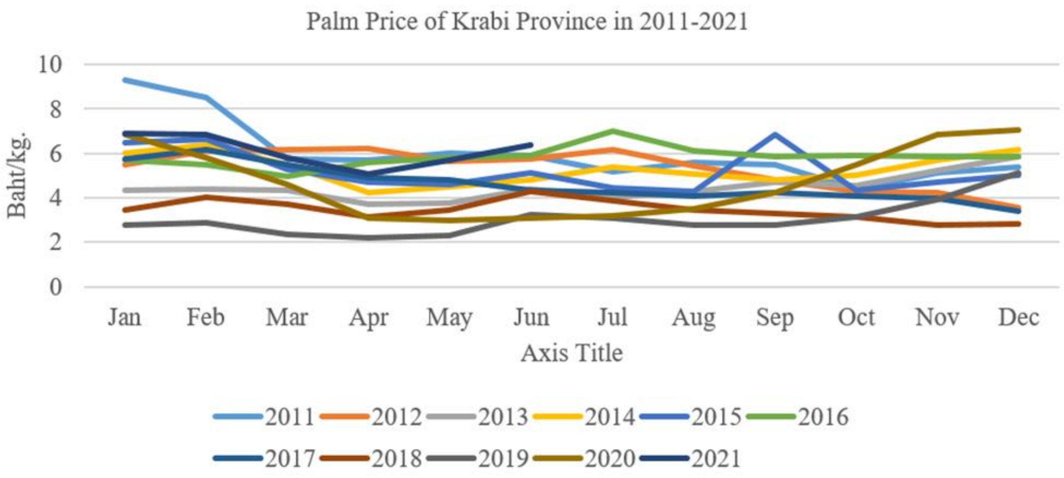


Figure 20 Palm price of Krabi province in 2011-2021
Source: DumDee Biodiesel Public Learning Center, Krabi Province, 2021

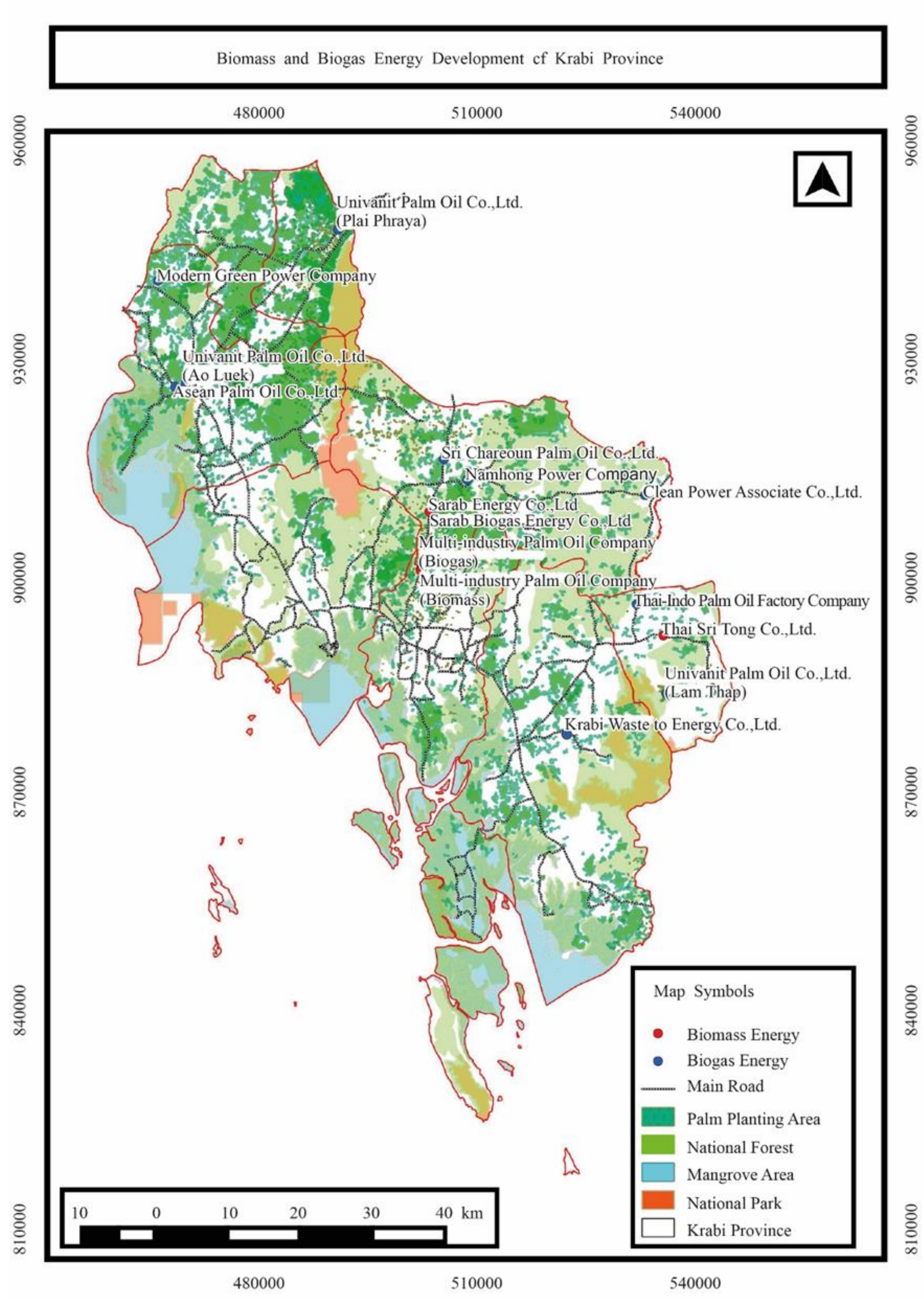


Figure 21 Biomass and biogas energy development of Krabi province, 2020
Source Modified from Provincial Electricity Authority (PEA), 2020

2) Solar energy

Solar PV is clean and green energy with almost unlimited potential in a country likes Thailand. By the way, Krabi province has land limited for solar farm, except shifting from lands of rubber and palm oil tree plantation. Therefore, solar PV to be promoted in the province should be solar rooftop. Experiences from some success projects reveal that national policy on solar PV, especially the quota system and purchasing price, should be reconsidered to encourage more solar rooftop investment in the province. In 2018, a study found Krabi has a number of solar rooftop potential to be installed on rooftops of residential, hotels and business buildings, prioritizing reducing electrical bill and transition loss for the long distance and to benefit the ownership of the decentralization system (PEA, 2020).

The study calculated the capacity of Krabi’s rooftop for the household sector, business SMEs and large building sectors with a total capacity of 1,125 MW. The 91,362 households in the province were calculated with the roof area at average 20 sq.m. and the result with the housing potential was 634 MW. The small, medium and specialized businesses were for the average 50 kW per unit with the potential total of 468 MW. The large building sector averaged 1,000 kWh per place and 23 MW potential. However, as of 2020 the installed grid connected solar rooftop reported by PEA was found to be totally 2.23 MW. In addition, solar street lights have been installed by Krabi Provincial Administrative since 2019.

The first and only one solar rooftop of 0.069 MW was installed on grid from household sector by Wanna Chaideker's home. Then, rapidly increasing installed up to almost15 MW since 2018 due to national attractive policy and measures, but much more installation is expected for the households, tourism business and relevant services and other governmental officer buildings etc. if overcoming many barriers which will be described later. Furthermore, local governmental administration and private sectors continually generated electricity from solar energy including schools, marine tourism port, governmental building, supermarket and another project is street solar light bulbs installed by Krabi Provincial Administrative Organization as shown in figure 22, 23.

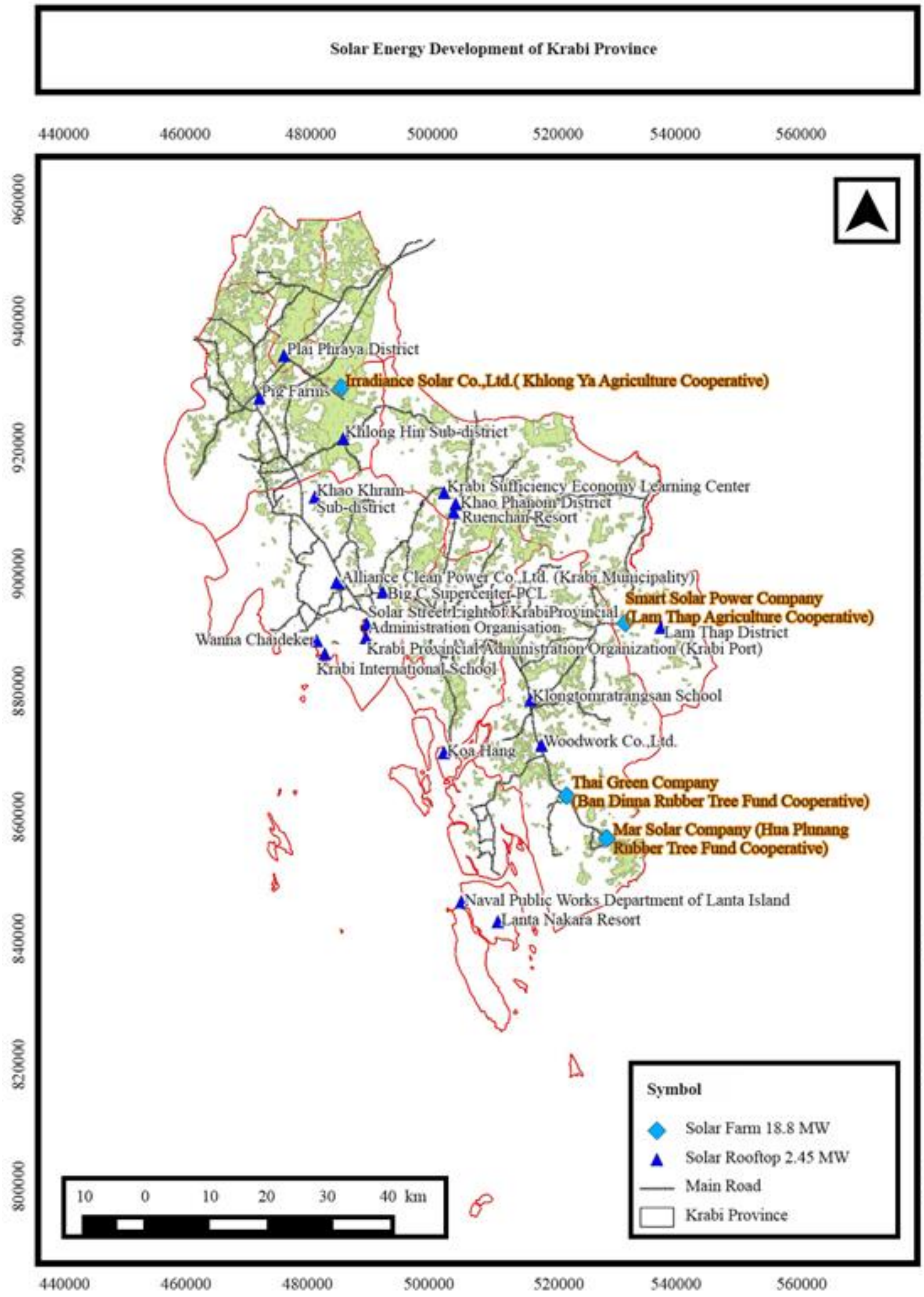


Figure 22 Solar energy development of Krabi province, 2020
Source Modified from Provincial Electricity Authority (PEA) and Krabi solar power producers, 2020

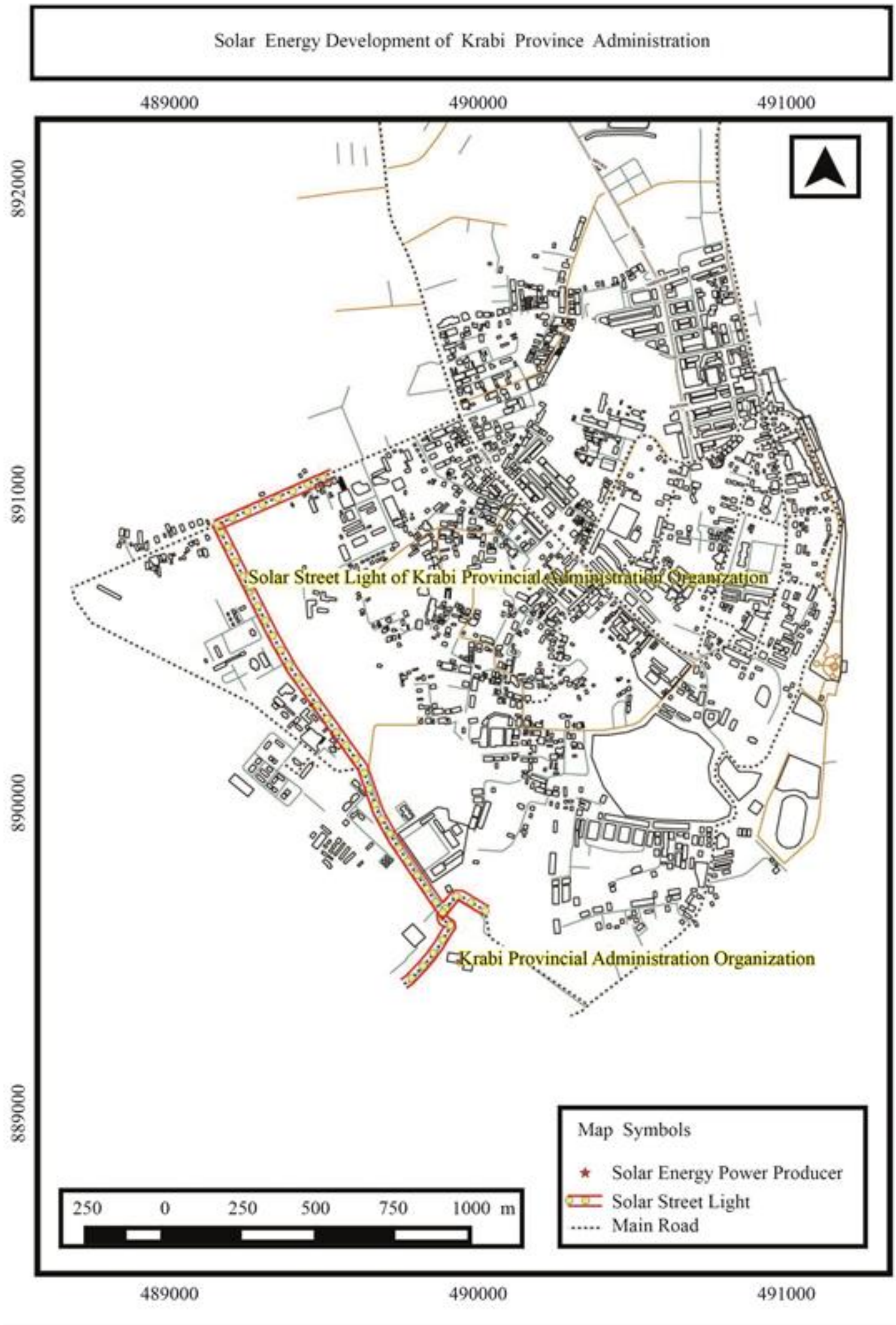


Figure 23 Solar Street Light development of Krabi province, 2020
Source Modified from Krabi Provincial Administrative Organization, 2020

Since 2017, solar farms for agricultural cooperative have been prioritized for joint venture investment between the Ministry of Energy, Ministry of Agriculture and Cooperative (ERC, 2017) and solar energy business sectors. This phenomenon concretely changed solar energy investment in Krabi province and people's mindset when benefits sharing was the priorities proposing. The selected projects gained land use for solar farm installation, the income of electricity purchasing was agreement between the investors and each agricultural cooperative, and the right to sell electricity and the fines if the investors break the contract was under the agricultural cooperative authorized under the 25 years feed-in-tariff long term agreement. Two main regulatory enforcement to manage the solar farm projects were the agricultural cooperative management fund and agricultural cooperative welfare fund. And the additional qualification for solar farm agricultural cooperative was under the conditions of ERC regulation. In Table 9, the capacity of solar energy production has been quite stable and slightly decreasing during the heavy raining season as usual.

Table 9 Krabi's VSPP solar farms installed during 2018-2020

Name	Year	COD (kWh/Month)			
		Jan	Feb	Mar	Apr
Mar Solar Company (Hua Plunang Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	-
	2019	877,680	944,580	986,280	840,240
	2020	928,980	866,040	1,040,460	844,440
Smart Solar Power Company (Lam Thap Agricultural Cooperative)	2018	-	-	-	-
	2019	653,985	661,185	732,060	703,665
	2020	787,815	739,800	874,215	661,725
Thai Green Company (Ban Dinna Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	-
	2019	636,840	678,360	764,220	690,840
	2020	741,840	667,680	790,020	620,100

Name	Year	COD (kWh/Month)			
		May	Jun	Jul	Aug
Mar Solar Company (Hua Plunang Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	-
	2019	781,860	710,820	751,020	660,600
	2020	790,740	643,200	700,620	729,780
Smart Solar Power Company (Lam Thap Agricultural Cooperative)	2018	-	-	-	-
	2019	631,485	600,885	648,720	592,740
	2020	627,615	557,910	589,905	633,330
Thai Green Company (Ban Dinna Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	-
	2019	622,800	551,280	565,620	555,060
	2020	583,140	492,720	535,440	552,900

Name	Year	COD (kWh/Month)			
		Sep	Oct	Nov	Dec
Mar Solar Company (Hua Plunang Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	95,760
	2019	694,200	683,520	697,080	807,300
	2020	-	-	-	-
Smart Solar Power Company (Lam Thap Agricultural Cooperative)	2018	-	-	-	93,105
	2019	567,630	541,665	545,940	653,040
	2020	-	-	-	-
Thai Green Company (Ban Dinna Rubber Tree Fund Argricultural Cooperative)	2018	-	-	-	134,520
	2019	602,100	572,940	591,540	664,500
	2020	-	-	-	-

Source: Provincial Electricity Authority of Thailand, 2020

3) Waste-to-energy

Waste-to-Energy (WtE) has been considered as an option to eliminate the problems of municipal solid waste (MSW) management as well as to be an abundant renewable source for electricity generation across the country. A survey on potential, drivers, barriers and challenges of WtE at Krabi Province was conducted in this study and found that MSW, especially landfill sites, of Krabi Municipality have considerable potential for electricity generation and are driven by national and provincial authority's collaboration under the national waste management roadmap. Drivers of WtE have been connected to the disruptive effects of the Section 44 of the Interim Constitution of Thailand, Krabi Goes Green Vision and the protest of new solid waste landfills extension.

As one of the top tourism destinations, millions of visitors come to Krabi province every year. Before COVID-19 pandemic, numbers of visitors have been increasing year by year, followed by an increasing trend of Municipal Solid Waste (MSW) as well as electricity demand. Improper waste dumping creates both environmental and health impacts (Ahmad, B., et al., 2020). Decay of organic wastes increases methane emission, which is a greenhouse gas having high global warming potential (Paes, X. M., et al., 2020). Meanwhile plastic wastes are non-biodegradable and exhibit high impacts to the ecological system especially impacts to marine animals (Abraham, A., et al., 2021). Fortunately, plastic wastes are combustible and can be used to replace fossil fuels for electricity generation. Hence, electricity generation from waste incineration, so-called waste-to-energy, has been considered as an appropriate option to eliminate impacts of MSW, while increasing renewable sources for electricity supply.

Another option to convert wastes to energy is sanitary landfill which creates landfill gas for electricity generation. However, most cities, especially Krabi, are facing a problem of land limitation and public acceptance of landfill operation (Siddiqi, A., et al., 2020). The citizen's awareness and mindset are difficult to transition to a recycling society, the national waste policy, legislation and the various elements including energy, environmental, economic and water systems (Kudela, J., et al., 2020). Waste is a burden of land use, carbon footprint and sustainable development (Hammond, P. G., et al., 2019). Limitation of lands is a factor to drive a city towards landfill reduction and a zero waste city (Sharma, S., et al., 2020). The facility location of waste to energy demands on energy purchasing agreement and the project needs to identify the strategies of management modelling and analysis from the current practices, challenges and future opportunities (Zhao, R., et al., 2021). Therefore, a systematic integrated waste management coupled with waste-to-energy power plant operation would be the most appropriate option for a big city like Krabi. To maximize waste utilization as a renewable source for electricity generation at

Krabi, a survey on drivers, barriers and challenges to achieve Krabi's sustainable waste-to-energy was conducted and described in this article.

The study found that Krabi province had experienced waste management problems for more than 20 years up to the present (PCD, 2021). Municipality gained some budget support from the Ministry of Science and Technology. It was approximately 24 million baht (about 765,795 USD) to buy 251 rai of land for waste dumping in the city. However, the increase of solid waste and others from especially the high season of tourism, more than 800,000 tons (PCD, 2017). Landfills reservoirs were not enough for the continually growing waste across the province especially in urban areas and the famous island for tourism. Upon considering Krabi' s energy transition during 1964-2012, it is found that Krabi has initiated RE transition nearly 15 years ago, starting with biomass since 2007, followed with biogas since 2008, solar since 2014, and lastly waste-to-energy since 2020 (PEA, 2021). Share of electricity generated from MSW is still low and just started in 2020 although the province has potential outside municipality clusters of approximately 147 tons per day to generate more electricity. Waste to energy tends to be an important alternative energy source for electricity supply in Krabi province.

As mentioned above, Krabi is one of top 5 tourism destinations of Thailand, there are millions of tourists coming to Krabi province each year, in couple with 400,000 citizen in the province would generate huge amount of MSW. Impacts from the accumulated MSW put pressure for the provincial government to manage the MSW more properly, and waste-to-energy power plant is considered to be the most appropriate option.

Furthermore, it was found that more than 800,000 tons of MSW were accumulated in the province, and more than 150 tons of new wastes were generated per day of the municipality's cluster. If improper management, these huge amounts of wastes would create severe impacts to both environment and human health. In particular, plastic wastes have become a part of marine waste transboundary from other both internal and external countries during monsoon. Fortunately, major portions of MSW are combustible and can be incinerated to recover heat energy. If converting the wastes into energy, it would benefit the environment, human health, and sustainable source of electricity supply.

It was also found that MSW generated in the province is seasoning and tends to be the highest in October every year. The amount of MSW is expected to be continuously increasing year by year and it is forecasted to be as high as more than 438 tons per day in the year 2045, as shown in Table 10.The criteria waste has been separated into a group of general waste, organic waste, recycle waste, hazardous waste, industrial waste, infectious waste and electronic waste. The main problem is that waste is not completely pre-separation to remove recyclable and hazardous waste in some clusters.

Table 10 Solid waste of Krabi Municipality in 2015-2020

Solid Waste of Krabi Municipality in 2015-2020 (tons)						
Year	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
January	4,825.79	5,272.45	5,758.50	5,956.11	6,047.24	5,886.46
February	4,333.76	4,938.30	4,977.81	5,558.31	5,462.73	5,086.71
March	4,548.20	4,873.53	5,266.58	5,721.67	5,719.63	4,771.72
April	4,447.70	4,529.53	5,206.82	5,564.28	5,426.90	3,510.47
May	4,708.60	4,874.28	5,422.16	5,813.17	5,356.91	3,924.58
June	4,690.66	4,945.14	5,054.21	5,415.83	5,122.70	3,820.07
July	5,130.27	4,785.75	5,464.33	5,758.73	5,725.16	4,362.04
August	5,262.53	4,977.54	5,698.49	5,897.58	5,656.64	4,492.39
September	4,594.86	4,819.87	4,775.08	5,021.55	4,908.69	4,294.56
October	4,428.80	4,804.62	4,998.38	5,297.96	5,350.49	5,306.46
November	4,429.28	4,835.61	4,821.61	5,217.98	5,343.14	5,283.85
December	4,895.56	5,150.08	5,003.71	5,009.20	5,866.08	5,556.68

Source: Krabi Municipality, 2020

The trend of Krabi's municipal waste explosion in the province is expected to rise every year from nearly 60,000 ton per year in 2021 and peak to more than 160,000 ton per year in the next 25 years as shown in Table 11. However, it will contrast with the vision of Krabi Goes Green aiming to reduce waste from the point source and utilize green tourism to acknowledge the entrepreneurs and consumers to reach the target.

Table 11 Solid waste forecast of Krabi Municipality

Solid Waste Forecast of Krabi Province in 2021-2045		
Year	**Ton/Year**	**Ton/Day**
2021	58,780.32	161.04
2022	61,372.54	168.14
2023	64,079.07	175.56
2024	66,904.95	183.30
2025	69,855.46	191.38
2026	72,936.09	199.82
2027	76,152.57	208.64
2028	79,510.90	217.84
2029	83,017.33	227.44
2030	86,678.39	237.48
2031	90,500.91	247.95
2032	94,492.00	258.88
2033	98,659.09	270.30
2034	103,009.96	282.22
2035	107,552.70	294.66
2036	112,295.77	307.66
2037	117,248.02	321.23
2038	122,418.66	335.39
2039	127,817.32	350.18
2040	133,454.06	365.63
2041	139,339.39	381.75
2042	145,484.25	398.59
2043	151,900.11	416.16
2044	158,598.90	434.52
2045	165,593.11	453.68

Source: Krabi Municipality, 2020

The research found that Krabi province planned for waste management in a concept of waste clusters as shown in figure 24. The clusters of waste management of 62 local administrative in 2019 (tons per day); Krabi Municipality 112.96 tons (cluster 1), Plai Phraya 18.21 tons (cluster 2), Khao Phanom 52.06 tons (cluster 3) and Khlong Thom (South) 76.72 tons (cluster 4). Those clusters had their own landfills dumping and received income from municipalities in a cluster. In

December, 2020 Krabi municipality was the first cluster to transfer waste from landfills to generate electricity. However, the other clusters were facing the limit to extend the new landfills and some were insisting on the new incinerator power plant project. The amount of waste of those clusters had been estimated to grow continually in every year; however, it would be disruptive by green tourism policies and waste reduction implementation. Krabi province had a discussion about the pathway after 10 years of the first waste to energy running that meant it required the imported waste from other clusters and other provinces to supply its plant until the decommission for a total 25 year of COD contract (Krabi Municipality, 2020).

Under the “Waste Management for Clean Communities of Krabi Province 2018 Plan” of Department of Local Administration, Ministry of Interior, waste to energy power plant at Krabi municipality was bidden by the external private sector (Ministry of Interior, 2018). The installation was 6 MW under the feed-in-tariff contract for 25 years to the Provincial Electricity Authority (PEA). The waste plant is planned to eliminate about 65,000 tons per year. It planned to solve the limited landfills of Krabi Municipality that used about 125 rai from total 215 rai and not enough in the long term. The project had a power plant fund to contribute 400,000 baht (about 12,718 US) to impacted communities.

WtE at Krabi was designed to generate electricity from MSW with a main purpose to minimize wastes of landfill cluster. Its first phase was designed for old landfill sites where majority of the remaining wastes are non-biodegradable but combustible; hence, no need for pre-separation before feeding to the incinerator. However, in the future if using daily generated wastes, it is suggested to install pre-separation units to separate recyclable wastes, metals, and wet biodegradable wastes. Equipment and flowchart of the WtE power plant are shown in figure 25 where there is no pre-separation unit, but well equipped with post-combustion waste separation units to ensure environmental friendly process of the WtE power plant. The WtE power plant at Krabi is grid connected and starts selling electricity to PEA in 2020 with feed-in-tariff at 25 year contract.

It is suggested that the design for the new generated wastes would be equipped with pre-separation units to remove recyclable wastes, metals, and other noncombustible wastes before feeding to the incinerator. However, it was well designed for collection of both solid combustion wastes (bottom ash) and air emissions (especially fly ash) to ensure an environmentally friendly process of the power plant. Electricity is purchased to the Provincial Electricity Authority (PEA) grid transmission. Krabi’s waste-to-energy followed the national solid waste management roadmap (Krabi Municipality.2020).

Problem of provincial waste management like Krabi is reflected in the lasting effects of waste impacting a country's waste management significantly. Thailand has experienced a problem of waste management for many years with the internal increasing waste and imported waste. The amount of total solid waste was 27.93 million tons in 2018, up around 2.05 percent compared to the previous year. The expansion of urban and peri-urban across the country and growth of tourism in a year drove the amount of waste 1.15 kilograms per capita per day, up from 2017 about 1.13 kilograms per capita per day. Solid waste of Bangkok was about 4.85 million tons, 17 percent of the country and the rest was around 23.10 million tons. Besides that, Chonburi province and Pattaya city was 2,519 tons per day, followed by 2,480 tons per day of Nakhon Ratchasima and the 2,449 tons per day of Samutprakarn province respectively.

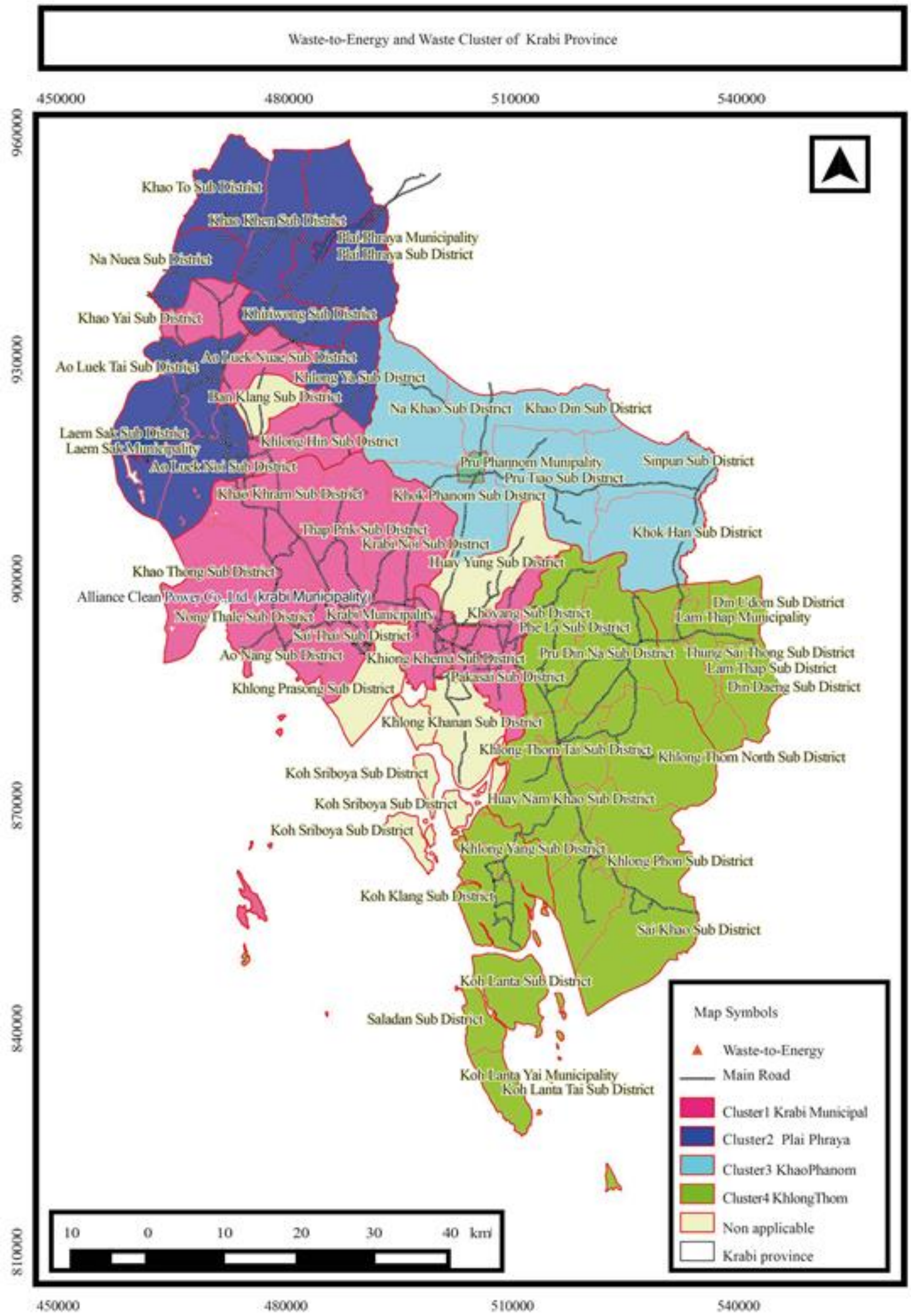


Figure 24 Waste-to-energy and waste cluster of Krabi province
Source Modified from Krabi Municipality, 2020

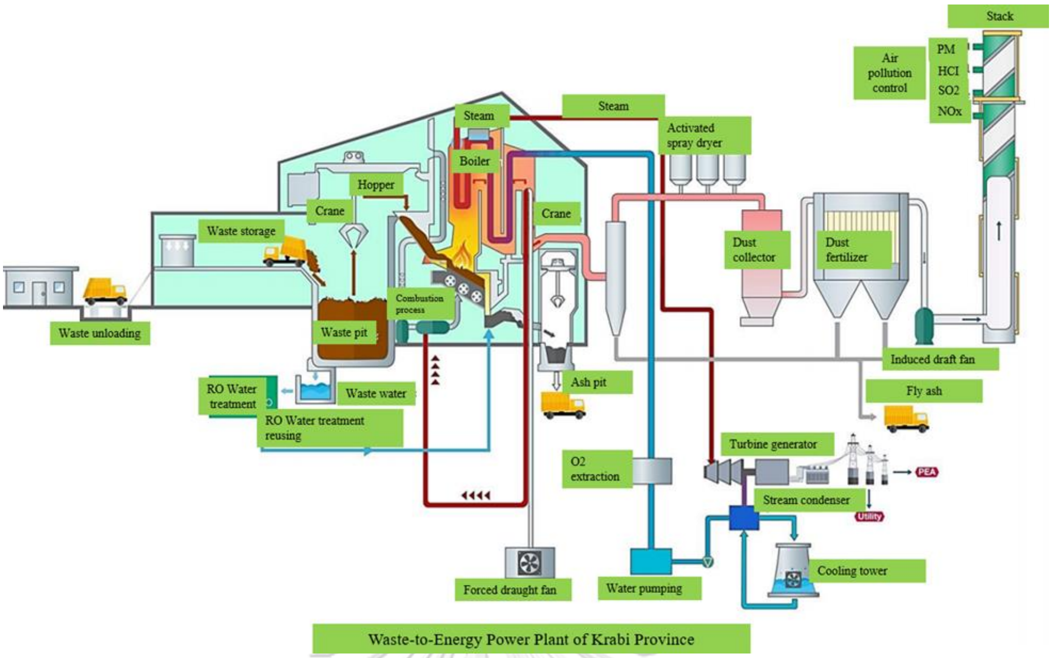


Figure 25 Waste-to-energy power plant of Krabi province
Source: Krabi Municipality, 2020

In 2018, waste disposal was estimated at the landfill across the country at about 10.85 million tons, about 38.85 percent of total waste. Those reduced from the previous year point at 11.69 million tons. Non-waste disposal was at 7.32 million tons, 26.21 percent of its total waste and increased about 2.09 percent compared to data in 2017, which was about 7.17 million tons. Waste reuse was about 9.76 million tons, about 34.94 percent of its total waste and increased about 14.69 percent compared to year 2017, which was about 8.51 million tons.

According to the Pollution Control Department (PCD, 2016), the amount of solid waste reached 28.7 million tons in 2019 and 2 million tons of that was plastic waste. Waste disposal was just 25 percent of total and the rest was limited to access the right way to eliminate waste, and waste per capita was 1.1kilograms per day. The roadmap of waste to energy had been addressed in Alternative Energy Development Plan (AEDP) 2018-2037 to increase the quota of waste to energy at 400 MW, raising from the existing quota to 500 MW. The total 900 MW of waste to energy power plants projects are directed to the authority of the District Administration and Ministry of Interior.

4.4 Drivers, barriers and challenges towards Krabi's sustainable energy

According to information from the interview and on-site observation, the study found that the key words frequency of drivers, barriers and challenges of RE transition towards Krabi's sustainable energy illustrating in Table 12 and some examples of the interviewees' answer in Appendix 6.

Table 12 High frequency keywords from stakeholders interview, 2020

Keyword	Frequency
Drivers	
Krabi Goes Green	21
Green tourism	16
Public participation	14
Provincial policy	12
Renewable energy potential	12
Barriers	
Power purchasing	11
Quota system	8
Energy politics	4
Opposing biomass/WtE	4
Lacking expertise	4
Challenges	
Energy storage	9
Waste management	7
City planning	6
Supply chain management	5
Monitoring system	5

4.4.1 Key drivers

High frequency keywords from interviewees' answer relevant to drivers for Krabi RE transition are Krabi Goes Green, Green Tourism, public participation, provincial policy, and RE potential as describe below.

4.4.1.1 Krabi Goes Green

"Krabi Goes Green" is a provincial vision towards green economy with planning to sustain green tourism, green industry, and green energy with maximizing utilization of domestic renewable resources for electricity generation. It also set a target of 100% RE electricity generation by the year 2026. Most interviewees mentioned that Krabi Goes Green vision is one of key drivers for Krabi RE transition.

4.4.1.2 Green Tourism

Green Tourism Declaration was established with direction towards sustainable tourism in the province. In order to sustain green tourism in the province, green or RE is one priority. Another is to minimize impacts from accumulated MSW, where WtE is an option to be considered. Some districts has adopted zero waste concept under the Green Tourism Declaration. Therefore, green tourism was also mentioned as a key driver for Krabi RE transition.

4.4.1.3 Public participation

It was found that Krabi has very much strength on institution and public participation, which were considered as a key success factor for policy implementation in the province. The clear evident to confirm this strength was well participation in the process of Krabi Goes Green development. Strengthen of RE transition of Krabi province was public participation to endorse the provincial strategic plan since Green Tourism, Krabi Vision 2020 and Krabi Goes Green. Those participations leaded Krabi's citizen to further manage benefits distribution and utilized the potential of RE across the province. There are 6 key stakeholders involve in the public participation on Krabi Goes Green and Krabi's RE transition as summarized below.

1) Government and policy makers: both provincial and national levels

2) Business: both RE power producers and fossil fuel businesses.

3) Community and civil society network: strong network to oppose any new fossil fuel projects.

4) Academia: feasibility study, research, briefing of RE projects support the strong evident of benefits sharing and monitoring the projects.

5) Prosumers: those who switch themselves from electricity bill payer to electricity generation for sale via solar rooftop.

6) Financial institution: loan provider to support investment for both power producers and prosumers.

4.4.1.4 Provincial policy

Krabi provincial strategic plan derived from the various stakeholders from top-down and bottom up process as shown in Table 13. Ownership was heart of provincial planning and affects to the strong direction together and reducing the conflicts. More than ten years those plans had been conducting and implement in every level including governmental agencies, private sectors and communities in the province. Provincial plan and implementation was the important to frame the direction of RE development.

Krabi province has Green Tourism plan, the fundamental strategic plan to lead a green environment balancing tourism growing. Then, the province roadmap on Krabi Vision 2020 and Krabi Goes Green report it is including resources management and green energy development. During that time, the citizen movement to oppose the new coal power plant project has happened as the disruptive momentum for more than 5 years until now. Krabi was at the crossroads to make a decision on provincial development plan and it so far derails coal project mean to the more opportunity for RE investment.

The capacity of RE production, the flow of the implementation plan in the province continually drove to achieve the plan and naturally supported the vision of local governmental agencies and boosting the private sector and investors deciding to agree on the plan. The depth of power analysis, the strong vision and relationship of the leaders, key influencers and private investors in the province motivated the followers to be on a track of the policy implementations..

4.4.1.5 Potential of RE

Abundant of renewable energy resources is one of key 4As (Availability, Affordability, Accessibility, and Acceptability) for energy security and sustainability. High potential or availability of RE resources in the province is sustainable due to it is domestic supply. Therefore, most interviewees mentioned that high potential of RE resources is one of key drivers for Kribi’s sustainable development.

Table 13 Timeline of Krabi RE transition plan, 2020

Krabi Renewable Energy Transition		
Timeline	**Transition**	**Key stakeholder / institution**
1964-2018	*Renewable energy initiative*	
	Increasing renewable energy for internal supply during peak time from 2007-2018	Southern Provincial Electricity Authority Provincial Electricity Authority Biomass power producers and investors Biogas power producers and investors Solar power producers and investors Agricultral and Cooperatives National Biomass Association Energy consumers in each sectors tourism business, governmental office and services entrepreneur Private sector Krabi Provincial Administrative Organisation Local governmental agencies
2012-2020	*Krabi 100% renewable energy proposing*	
	Opposing new coal power plant project and propose to renewable energy investment	Tourism association and network Krabi Provincial Administrative Organisation Krabi fishery network Agricultral and Cooperatives Local governmental agencies Civil society network Agricultral network Private sector Provincial Electricity Authority
2014-2020	*Krabi Vision 2020*	
	Provincial strategy for sustainable future including tourism development master plan in 2013 and local tourism roadmap in 2014 and linked to national strategic plan	Provincial Strategic Office Tourism association and network Krabi Provincial Administrative Organisation Krabi fishery network Agricultral network Local governmental agencies Civil society network Private sector Save Krabi network Local governmental agencies
2018-2020	*Krabi Goes Green*	
	Electricity consumption and generation plans in Krabi province 20 years (2018-2037) Potenrtial of renewable energy in Krabi province	Provincial Electricity Authority Biomass power producers and investors Biogas power producers and investors Solar power producers and investors Agricultral and Cooperatives National Biomass Association Academic network Civil society network Tourism association and network Krabi Provincial Administrative Organisation Local governmental agencies

Apart from high frequency keywords, some keywords are also important drivers even only some interviewees mentioned. Clear vision and strong relationship between leaders, key influencers, and private investors in the province have motivated citizen to be on track of policy implementation. Close relationship of energy investors with tourism. agricultural, and fishery sectors has been driving RE investment in the province even though it took more than 10 years of investment and movement across the province. These are also key drivers for RE transition in the province.

4.4.2 Key barriers

High frequency keywords from interviewees' answer relevant to barriers for Krabi RE transition are power purchasing, quota system, energy politics, opposing biomass and WtE and lacking expertise.

4.4.2.1. Power purchasing

Power purchasing is a key barrier to block the potential to generate electricity on the grid. It is really impact to RE power producer in the province including biomass, biogas and solar energy. Both biomass and biogas power plants are facing with a big barrier of unsecure power purchasing agreement because the both are classified as non-firm system. PEA can deny purchasing if over-supply from other sources, especially during daytime supplied from Solar PV. In case of biogas, the producers still have their choice by converting to use for heat in their process, but quite big barrier for biomass power producers. Another barrier of the biomass power plants are seasoning supply of the biomass. Importing from other provinces and storage for securing supply is an option to solve the problem.

The fluctuated power purchasing policy is the key barrier to restrict the potential of those production, some power plants burned out the biogas during the closed quota of those. Some power plants shifts biogas energy that is planned to be sold on the grid to internal use in the palm industry instead. As VSPP biogas and biomass are non-firm power purchasing system, the power producers will generate electricity to supply grid only during high purchasing price, and sometime PEA denies to purchase electricity from VSPP which leading to high conflict among PEA and VSPP investors.

4.4.2.2 Quota system

Solar energy is unlimited resources in Thailand, including Krabi province. However, the province has land limited for solar farm. Therefore, solar rooftop is suggested to be promoted in the province with quite high potential if not facing with the biggest barrier of quota system. Some interviewees suggested the quota system should be unlocked in order to encourage much more installation in all sectors, including the residential sector which is the biggest electricity consumer.

4.4.2.3 Energy politics

Investment in energy projects must depend on long-term policy and approval politics from the energy related central government agencies, while the provincial agencies have less authority. Most interviewees suggested that the approval process would be transparent and more systematic to encourage successful implementation of AEDP.

4.4.2.4 Opposing biomass and WtE

Even high potential of biomass from palm oil industry and huge amount of MSW in the province, both biomass and WtE power plants are opposed by community because the both power plants must incinerate the solid fuels (biomass or MSW) to generate heat and emit combustion pollutants, especially dust from fly ash. In case of WtE, there are not only impacts from combustion pollutants, but also bad smell of accumulated MSW. Most people do not want to have either the waste landfill site because of less “public trust”. This would be one of the biggest barriers for both biomass and WtE power plant implementation.

4.4.2.5 Lacking expertise

Energy technology, especially electricity generation, requires expert engineer to design, construct and operate. The most difficult and really need various expertise is WtE because the MSW must be manage properly in order not to create impacts to people nearby. It also needs pretreatment or preparation before feeding the waste to the incinerator. In case of solar PV, even no combustion, it still requires expertise. Therefore, most interviewees agree that lacking expertise for RE technology is one of the biggest barriers for RE power plant investment in the province..

4.4.3 Key Challenges

High frequency keywords from interviewers’ answer relevant to challenges to overcome barriers for Krabi RE transition are energy storage, waste management, city planning, supply chain management and monitoring system.

4.4.3.1 Energy storage and supply chain management

Energy storage mentioned by interviewees here does not mean investment of such high technology energy storage system, but referring to storage or stock management to secure fuel supply. This is quite important for biomass power plant where the biomass is seasoning supply. Having supply contracts from other sources or other provinces nearby are suggested as an option to secure the biomass supply. Construct a biomass storage facility is one more option suggested by interviewees. The energy storage mentioned here also means electricity supply management to fulfill its demand without any blackout. Domestic grid extension, smart grid, and decentralization are suggested by some interviewees.

Regarding MSW importing from other provinces, it is possible in term of waste supply because many provinces are facing with big problem of huge accumulated MSW, and still no WtE power plant in the provinces. However, transportation cost must be well consideration.

4.4.3.2 Waste management

The province has a burden of waste management for many years, especially the growing of waste parallel with tourism blooming. Land limitation for waste landfill is a driver for WtE power plant investment. An environmental aspect connected to the mission of low carbon city to deduct greenhouse gas emission, the waste incineration to produce heat or waste-to-energy has become accepted as an alternative solution to reduce methane emission at the landfill site. However, the investor must face with various barriers like negative mindset (not in my yard) of community, high investment and need technology to solve the problem island having sand contamination, insufficient provincial budget, and restrict waste purchasing legislation. Integrated provincial waste policy is the important direction to implement and practice for all alignment including waste separation at the first stage; reduce, reuse and recycle including curriculum economy. Krabi Goes Green vision unofficially drove waste reduction to waste to energy power plant however, its contract was feed-in-tariff for 25 years generating electricity to the national grid under Power Purchasing Agreement (PPA). Moreover, the other clusters excluding municipality remains the potential of waste to be studied and managed.

Main purpose of WtE power plant installation in Krabi province is to get rid of the accumulated MSW at old landfill sites, but achieving electricity as a by-product. It was calculated that all accumulated MSW would be finished within 10 years if daily new generated MSW is incinerated together with the old MSW. By the way Krabi Goes Green aims to reduce waste at the point source with 3R's approach. If successful, the amount of waste might be insufficient for the WtE power plant in the future. At that time, mixed fuels with other solid wastes including agricultural wastes or importing MSW from other provinces are possible options.

4.4.3.3 City planning

Due to Krabi is a tourism destination, city planning for proper land utilization is an important practice. Any RE power plants are not allowed to be installed in conservation and some restricted areas. Therefore, even high potential and feasible in many aspects, the investor should consult with Krabi's Office of Public Work, Town, and Country Planning. That's why some interviewees mentioned about challenging of the city planning aspect.

4.4.3.4 Monitoring system

Emissions of air pollutants, especially dust and dioxin, from combustion of biomass and MSW are major concerns and opposing by community. In addition, most of biomass and WtE power plants are small or vary small power plants where no need for EIA. Therefore, most interviewees and some stakeholders suggested transparent monitoring system would be challenging to overcome barriers of opposing biomass and WtE power plants.

Apart from the high frequency keywords mentioned above, some keywords with low frequency are important as well. Some interviewees mentioned about bidding system which open for external investors may inhibit domestic investors even they have technology potential but lower negotiation techniques. If small power plants can use internal bidding system, it would encourage more community's acceptance because the power plant is belongs to domestic investor and the community would get more benefit sharing.

4.5 Institutions and stakeholders accountability

Challenging of Krabi RE transition moving towards green economy is collaboration of institutions and stakeholders. The study found that strength and uniqueness of Krabi is that having its own provincial roadmap developed by all stakeholder participation, so that most people have "Krabi Goes Green" in their mind and willing to collaborate as best as possible.

There are 3 main institutions involving in RE investment as follow; Ministry of Energy, ERC and PEA as key governmental institutions of RE policy planning. Krabi Provincial Administrative Organization was the key provincial representative for provincial policy and planning for RE transition whereas the civil society accountability was formed as Krabi Goes Green network.

Apart from the 3 main institutions mentioned above, there are many institutions such as Ministry of Agricultural and Cooperatives, Krabi Provincial Administrative Organization, Krabi City Planning Office, Krabi Provincial Cooperative Office, and power producers taking accountability on solar PV investment in the province (see also figure 26). The Ministry of Energy has signed MOU with the Ministry of Agriculture and Cooperatives to provide land options for solar farm installation. Financial institutions in collaboration with Krabi Provincial Administrative Organization are also taking accountability on providing soft lone for small investors. Krabi City Planning Office is taking accountability on land use licensing approval. While Krabi Provincial Cooperative Office is taking part in approval of cooperatives investment.

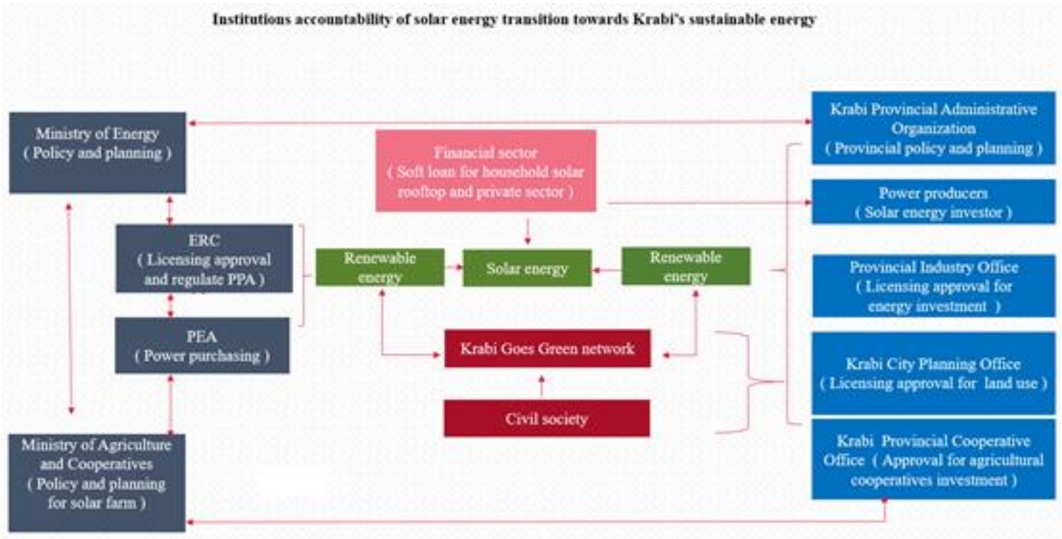


Figure 26 Institutions accountability of solar energy transition towards Krabi's sustainable energy, 2020

In case of biomass and biogas power plant investment, apart from the 3 main institutions mentioned above, Krabi agricultural cooperatives network is also a key institution taking accountability on bio-energy supply chain. Krabi Provincial Administrative Organization, Provincial Industry Office, and Krabi City Planning Office are also key involved institutions (see also figure 27). Financial institutions are also taking accountability on providing soft lone for farmers harvesting either palm oil tree or rubber tree feeding bio-energy supply chain. It is noticed that direction of bio-energy investment has been addressed as a provincial strategic plan.

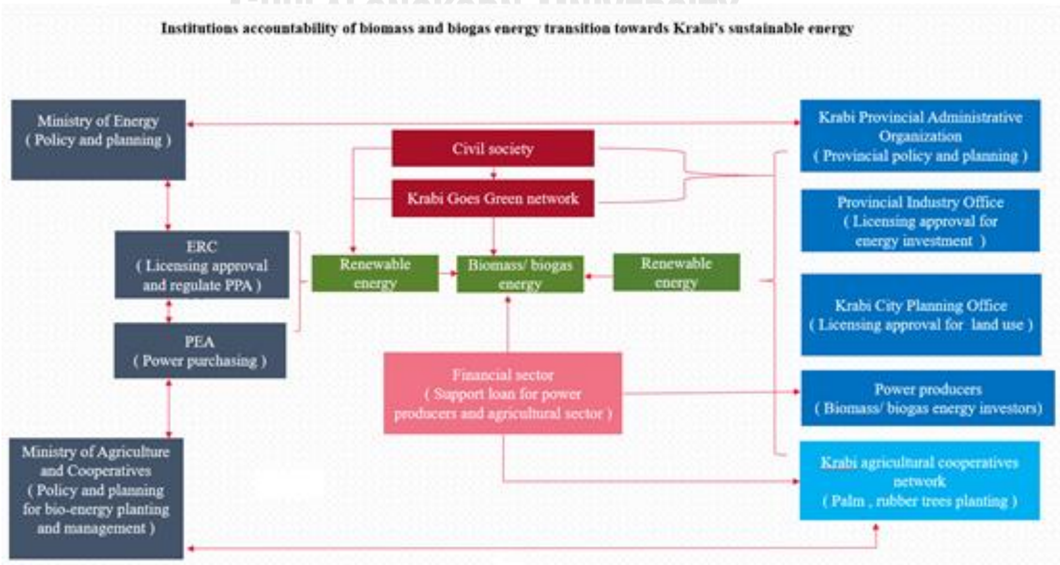


Figure 27 Institutions accountability of biomass and biogas energy transition towards Krabi's sustainable energy, 2020

Regarding WtE, apart from the 3 main institutions mentioned above, Ministry of Interior is a key institute taking accountability on MSW management, either landfill or WtE power plant. The Ministry of Interior established policy and long-term planning for solid waste management and also works closely with Krabi Municipality and provincial solid waste clusters. Even high budget, these institutes has always supported the provincial solid waste management to fulfill the provincial clean and green tourism destination. Krabi Provincial Administrative Organization, the Provincial Industry Office as well as the Krabi City Planning Office are also key involved institutions (see also figure 28).

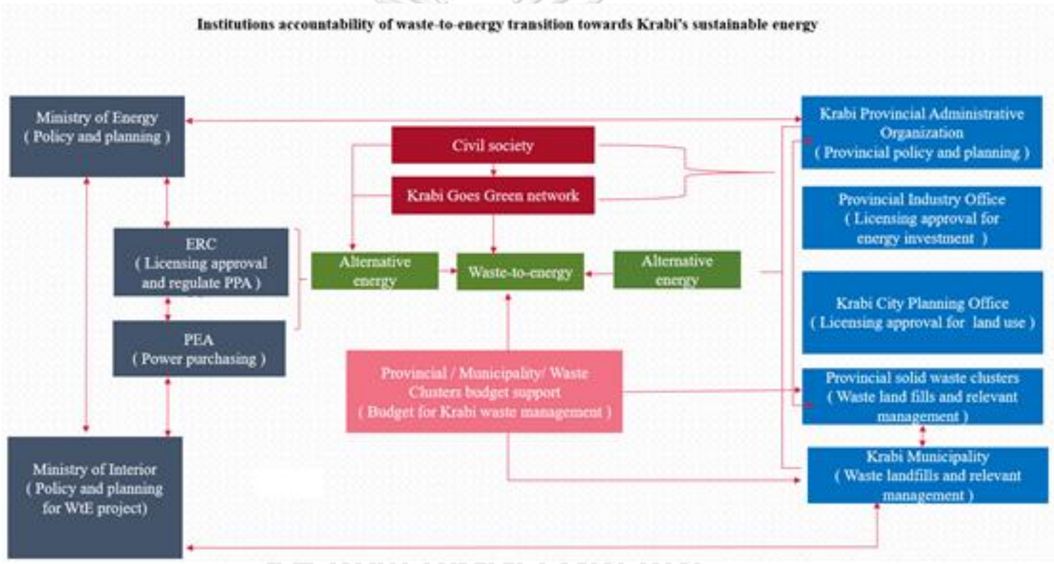


Figure 28 Institutions accountability of waste-to-energy transition towards Krabi's sustainable energy, 2020

4.6 Guideline and policy recommendation

National policy on AEDP and provincial policy on Krabi Goes Green, high solar potential, green energy without combustion pollutants, and community's positive mindset are key factors for solar PV investment. Another disruptive driver is rapidly lowering price of the solar PV panels leading to the shorter return on investment, especially solar rooftop with 5 -6 years return on investment. This disruptive driver encourages both household, business, hospitals and schools are interested to install the solar rooftop to reduce electricity bills. However, they are facing with the quota system, randomness process and politic aspects. More transparent and systematic processes are recommended. Solar farm is also high potential, but facing with land limitation and high price. Therefore, solar rooftop tends to be higher successful if no quota limited. The open mind consultation among relevant agencies are recommend in order to achieve both AEDP and Krabi's sustainable energy.

However, both biomass and biogas power plants are facing with a big barrier of unsecure power purchasing agreement because the both are classified as non-firm system. PEA can deny purchasing if over-supply from other sources, especially during daytime supplied from Solar PV. In case of biogas, the producers still have their choice by converting to use for heat in their process, but quite big barrier for biomass power producers. Meanwhile, Krabi Goes Green has set target to maximize utilization of domestic RE resources to produce electricity in the province. Therefore, all relevant agencies should open mind discussion and solve the problem together to fulfill both provincial and national policy on AEDP. Another option to solve biomass supply is imported from other provinces and well storage. Furthermore, Community Power Plant concept should be thought framed by Ministry of Energy and Ministry of Interior. Whereas biomass and biogas has experienced the long term barrier of power purchasing policy, that is directly to the authority of PEA to revise the one price measurement of time use and invest energy storage. Challenging of Krabi’s RE transition is to collaborate the relevant energy policies and implementation with the key responsible agencies. Public participation and guideline for all renewable development should be standardized by national and formal and informal provincial institutions.

Guideline and policy recommendations for each RE as shown in Table 14 are summarized below.

Table 14 Guideline and policy recommendation for renewable energy transition towards Krabi's sustainable energy, 2020

Option	Potential advantages	Things to consider	Policy recommendation	Responsible agencies and roles
Solar rooftop	Reduce electricity bill Grow jobs creation Earning inclome from PPA ((Power Purchasing Agreement) or Net metering system (If any)	How citizen can get softloan for household solar rooftop and also technical support? How to unlock the quota system? How to deduct electricity bill from generated electricity	Collaboration governmental agencies and financial institutes to establish policy support Educate and train for solar cell installation Revise or reconsider the power purchase policy for solar rooftop Revise Cooperative's investment legislation Reconsider the quota system Regulate net metering measurment of solar rooftop	Financial sector Educational institutions Krabi Provincial Administrative Organization Energy Regulatory Commission (ERC) Provincial Electricity Authority (PEA) Agricultural cooperative
Solar farm	Job creation Earning income from PPA Benefit sharing	How to solve the problem of land limitation? How to get approval more transparent?	Increasing solar rooftop installation instead of new solar farm Revise or reconsider the power purchase policy for solar farm	Energy Regulatory Commission (ERC) Provincial Electricity Authority (PEA)
Biomass / biogas	Utilize domestic agricultural wastes as domestic energy resources Benefit sharing Reduce smell and methane emission from biomass decay	How to secure biomass supply? How to promote public acceptance ? How to reduce conflicts among PEA and power producers?	Install stockpile facility Sign contract with other palm oil industry or industry in other provinces Use fuel mixed with other biomass likes rubber tree or coconut tree Intall high efficiency end-of-pipe treatment equipment with real-time monitoring system Polluters Pay Principle Pollutant Release and Transfer Register (PRTR) of biomss power plant Revise or reconsider the power purchase policy for biomass and biogas power plants	Provincial Electricity Authority (PEA) Energy Regulatory Commission (ERC) Ministry of Energy Krabi Provincial Administrative Organization Provincial Industry Office Krabi Goes Green network Civil society Power producers
Waste-to-Energy	Reduce new landfill Reduce accumulated MSW at old landfill sites Reduce bad smell and methan emission at the landfill sites Gain electricity as by-product Zero waste target	How to reduce negative mindset (NIMBY) ? How to promote public acceptance ? How to promote sense of belonging? How to get budget for investment? How can WtE become first priority because its main purpose is to get rid of accumulated MSW?	Reducing at source together with well treatment at the end-of-pipe are highly recommended * provide separated bins for waste disposal at the point source (reduce at source) * install high efficiency end-of-pipe treatment equipment with real-time monitoring system Install equipment for waste separation to remove incombustible components from the waste before incinneration is also recommended Benefit sharing or fair compensation Community power plant model allowing community members to become share holders Polluters Pay Principle Pollutant Release and Transfer Register (PRTR) Provincial Administrative budget support Consultation and policy integration among relevant government agencies	Krabi Provincial Administrative Organization Power producers Krabi Municipality Ministry of Interior Pollution Control Department Ministry of Public Health Ministry of Industry Krabi Goes Green network Civil society

Solar rooftop is clean and public acceptable. Each household can become a power producer to reduce electricity bill without any impacts to other houses. By the way, electricity generated from each rooftop is not much enough to qualify with the PPA (power purchasing agreement) for VSPP. Therefore, net metering system is recommended for household solar rooftop. In addition, some households still lack of budget and skill for either installation are maintenance, a soft lone system initiated by government as well as technical training is recommended. Regarding the barrier of quota system, unlocking the quota is recommended; however, this may affect the whole country and needs policy reconsideration at both national and policy level. Ministry of Energy, ERC, and PEA should take accountability on these issues, including the net metering system. Meanwhile, the technical training and the soft lone system can be implemented at the provincial level.

Solar farm is also clean, public acceptance, and very high resource potential, but facing with the barrier of land limitation. Most agricultural cooperatives would like to switch their land from palm oil tree plantation to invest solar farm. If too much switching, it might create food security impacts. Therefore, the provincial government should keep balance of food and electricity. Another barrier for solar farm is the lucky draw approval process. More transparent and systematic approval process is recommended. This can be implemented at the provincial level.

In case of biomass power plants, there are much enough resources potential due to a lot of palm oil industries in the province. However, burning solid biomass to produce steam for electricity generation usually emits air pollutants, especially dust of fly ash so that most of biomass power plants are facing with public opposing. Compulsory to install high efficiency end-of-pipe treatment together with real-time monitoring system is recommended. This can be implemented at the provincial level. Another barrier of biomass is unsecure supply due to seasoning available. Installation of stockpile facility and/or signing contracts with other palm oil industries either in the province or other provinces is recommended. This can be also implemented at the provincial or industrial level. By the way, both biomass and biogas power plants are facing with a big barrier of unsecure power purchasing due to non-firm type of PPA. Reconsidering the PPA is recommended, but this requires consultation both at the national and provincial level, especially the Ministry of Energy, ERC, and PEA.

As Krabi has land limitation for waste landfill and most people are opposing more new landfill site. While huge amount of many years accumulated MSW as well as continuously increasing daily generated MSW needed to be eliminated and waste-to-energy (WtE) power plant has been considered as a win-win option. Therefore, WtE is supposed to be the highest RE potential in the province. Unfortunately, most people concern about dioxin from waste incineration and also air pollutants from solid waste combustion. To prevent dioxin emission, some interviewees suggested high temperature incineration would eliminate dioxin and high efficiency end-of-pipe treatment installation would prevent air pollutant emissions. Real-time monitoring system was also suggested to build public trust and well acceptant. These measures can be developed and implemented at the provincial level but needs all stakeholder consultation and policy integration among relevant government agencies like Ministry of Interior, Ministry of Public Health, PDC, Krabi Municipality and Krabi Provincial Administrative Organization should revise the impacts of contamination and pollution that require Polluters Pay Principle, PRTR regulations and installation equipment for waste separation to remove incombustible components from the waste before incineration. Krabi Provincial Administrative Organization, Krabi Municipality, Krabi Goes Green network and civil society should collaborate the fundamental waste management plan and provide separated bins for waste disposal at the point source and the less waste is ended at WtE. ERC, PEA, Krabi Provincial Administrative Organization, Krabi Municipality, Krabi Goes Green network should consult the benefit sharing or fair compensation and community power plant model initiative as the new concept of energy investment also needs various public participation

Some interviewees also suggested to build sense of belonging for all community. A community power plant model having community become shareholders and receive benefit sharing from the WtE power plant was recommended. Polluter pay principle was also suggested to get budget from waste collection fee. All of these recommendation can be implemented at the provincial level.

Finally, it is noticed from the present study that Krabi has strength and uniqueness driving the province developed on track of green economy and RE transition towards provincial sustainable energy where other provinces could use for guideline as summarized below.

* Krabi is a famous tourism destination with continuously increasing numbers of tourists, especially foreigners. Development moving towards green tourism is a key provincial strategy for economic development.

* Krabi used to be land of palm oil tree and rubber tree plantation. Solid waste of both palm oil industry and rubber industry can be used for biomass power plants. In addition, waste water of the both industries has high potential for biogas power plants. If these sold wastes cannot be used for electricity generation, accumulation of these wastes would generate high global warming potential of methane gas from organic decay. Therefore, any provinces having either palm oil or rubber industries should promote both biomass and biogas power plant investment.

* Krabi is an island so that having land limitation for both solar farm and MSW landfill implementation. Therefore, solar rooftop should be implemented instead of solar farm, and waste-to-energy power plant should be implemented instead

of MSW landfill; however, an appropriate technology including high efficiency end-of-pipe treatment facilities must be installed to ensure zero pollutant emissions.

* Krabi has Krabi Goes Green as a provincial roadmap which developed by all stakeholder participation so that most or all people in the province have Krabi Goes Green in their mind and willing to cooperate as best as possible. Therefore, it is highly recommended that all provinces should develop their own provincial roadmaps having all stakeholder participation since the beginning in order to encourage public participation as well as public acceptance in any projects to be developed.

CHAPTER V

Conclusion and Recommendation

This chapter presents conclusion of results from the study on RE Transition: Drivers, Barriers, and Challenges towards Krabi's Sustainable Energy. To explore how Krabi province could fulfill the increasing electricity demand and maximize domestic RE resources for electricity generation. The study was started with reviews of Krabi's electricity demand and supply as well as electricity demand forecast, and also searching for potential of each RE resources in the province. The study found that Krabi's domestic electricity supply could fulfill its annual demand just during 1964-1995 where a 60 MW coal fired power plant was operated. Since decommissioning the coal fired power plant in 1995, Krabi has relied on electricity from southern national grid until nowadays. Even domestic RE power plants have been gradually installed since 2007, all power plants could supply only nearly half of its annual demand, while more than half must rely on the supply from national grid.

How Krabi province could fulfill the increasing electricity demand and maximize utilization of domestic energy resources for electricity generation is challenging. To achieve sustainable energy, it should be sustainable both consumption (demand side) and production (supply side) or SCP (sustainable consumption and production) according to SDG12. The most common practice for energy demand side management is energy efficiency and some organizations has initiated switching to high efficiency LED bulb reducing energy consumption. Therefore, energy efficiency is recommended to be implemented as well.

Upon considering domestic RE resources reported by Krabi Goes Green 2020, it was found that total potential would exceed the demand forecast. However, total installation of RE power plants in the province, as of July 2020, was only 67.4 MW which is only nearly half of its annual demand. What would be key barriers and challenges to overcome the barriers has become the second question to be explored in the study. If most or all of the barriers could be overcome, Krabi could fulfill the increasing electricity demand with high potential of domestic RE resources.

Regarding what would be key drivers, barriers, and challenges for RE transition towards Krabi's sustainable energy. The study found that key drivers for the RE transition in Krabi provinces were both national policy towards low carbon city as well as energy security and provincial policy towards green economy with a target of 100% RE electricity generation by the year 2026. In addition, Krabi has land limitation for waste landfill and waste transportation due to an island area so that huge amount of MSW accumulation needs to be eliminated; hence, a key driver for waste-to-energy power plant investment.

By the way, investment of RE power plant must face with various barriers, but different barriers for each RE. Barriers and challenges to overcome the barriers of each RE as well as policy recommendations are summarized as follow.

(*)In case of solar PV, even though solar energy is almost unlimited, the solar farm investment is facing with a barrier of land limitation and high land price. One challenging approach is switching from palm oil tree planting areas, but too much switching would lead to a new problem of food security. Therefore, consultation in the province to set priority is recommended. Meanwhile the higher potential and rapidly price lowering of solar rooftop has encouraged various sectors like residential, commercial, schools, and hospitals interested in solar rooftop investment, but facing with a barrier of quota system. Unlocking the quota system is recommended, but quite challenging.

(*)The biomass and biogas power plants are also high potential due to a lot of palm oil tree plantation and palm oil industries in the province, huge amount of biomass from palm oil tree solid waste, and also huge amount of biogas from waste water treatment in the industry are high RE potential in the province. By the way, due to most biomass and biogas power plants are small or very small scale, where power purchasing agreement (PPA) is a non-firm type so that their generated electricity sometime are rejected if over supply from solar PV during daytime.

Regarding the unsecured power purchasing of electricity from biomass and biogas power plants, most power producers want to be firm-type PPA where they must guarantee their supply as the signed contract. Most of interviewees recommended reconsidering and/or revising the PPA to become firm-type would secure both electricity supply for buyer (PEA) and electricity selling for power producers. By the way, even revising the PPA, it would enforce only the new power plants. The existing power plants should accept conditions as their already signed contracts. This is to confirm that both institutions and stakeholders should take their accountability for sustainable energy in the province.

One more barrier of the biomass power plant is public opposing due to emissions of air pollutants from solid fuel combustion. Mandatory to install high efficiency end-of-pipe treatment facilities as well as real-time monitoring system is recommended.

(*) According to Krabi Municipality information, waste-to-energy (WtE) seems to be the high resources potential due to huge amount of many years accumulated MSW and also continuously increasing amount of new generated MSW. However, the WtE investment is facing a big barrier of public opposing due to concerning air pollutants from solid waste combustion, especially dioxin. High temperature combustion of the waste as well as mandatory measure to install high efficiency end-of-pipe treatment together with real-time monitoring system is recommended. One more barrier of the WtE investment is insufficient budget. Community power plant model having community members as shareholders and receive fair benefit sharing is recommended to solve both the budget barrier and public acceptance. By the way, open mind consultation as well as policy integration among relevant government agencies is highly recommended.

Another issue being explored in the present study is how institutions and stakeholders could take accountability on RE transition towards sustainable energy in the province. The study found that institutions involving in the RE power purchasing from private small and very small power producers are the following 3 main institutions: Ministry of Energy with authority on policy and planning development, Energy Regulatory Commission (ERC) with authority on licensing approval and issuance process for new RE power producers, and Provincial Electricity Authority (PEA) taking accountability on power purchasing from the licensing power plants. By the way, all new power plant must receive a license of factory operation from Ministry of Industry.

In addition the Ministry of Energy has signed MOU with Ministry of Agricultural and Cooperatives to provide land use options for solar farm investment. Meanwhile, the case of WtE, Ministry of Interior would take key accountability due to MSW management is the Ministry's responsibility. Most organizations at the provincial level also involve in the RE power plant investment. Detail of institutions and stakeholders taking accountability in each RE was mentioned in Chapter 4 . Therefore, institutions and stakeholders collaboration as well as policy integration among all relevant government agencies would be one of key challenges for successful RE transition towards Krabi’s sustainable energy.

Finally, it is noticed from the study that a key driver for Krabi's RE transition towards sustainable energy is the strength of Krabi Goes Green which is a provincial roadmap developed by all stakeholder participation. All people has Krabi Goes Green in their mind. Even though there are still many barriers to be overcome, most people are willing to support any activities moving towards Krabi Goes Green. Therefore, starting with a provincial roadmap developed by all stakeholder participation can be suggested as a guideline for other provinces.

REFERENCES

2016 Water treatment and waste monitoring management report, Pollution Control Department (PCD), Ministry of Environment and Natural Resource, 2017. Available from http://waste.onep.go.th/images/file/1500538739.pdf [Accessed May 30, 2020].

2020 Annual report of Pollution Control Department (PCD). Ministry of Environment and Natural Resource, 2021.

Abraham, A., et al. *Anaerobic co-digestion of bioplastics as sustainable mode of waste management with improved energy production- A review,* pp 1-15, 2021.

Ahl, A., et al. *Balancing formal and informal success factors perceived by supply chain stakeholders: A study of woody biomass energy systems in Japan* pp 50-59, 2018.

Ahmad, B., et al. *Integrated bio refinery approach to valorize winery waste: A review from waste to energy perspectives* pp 1-14, 2020.

Aleh, C., et al. Integrating techno-economic, socio-technical and political perspectives on national energy transitions: a meta-theoretical framework. *Energy Research & Social Science 37* pp 175-190, 2018.

Alfonso, D., et al. *Methodology for optimization of distribution biomass resources evaluation, management and final energy use* pp 1070-1079, 2009.

Alhazmi, H. and Loy, A. C. M. *A review on environmental assessment of conversion of agricultural waste to bio-energy via different thermochemical routes: Current and future trends* pp 1-14, 2021.

Alternative Energy Development Plan (AEDP) 2018-2037. Ministry of Energy, 2018. [online] Available at https://www.dede.go.th/download/Plan_62/20201021_TIEB_AEDP2018.pdf [Accessed May 30, 2020].

Amornrat, L. *Thailand PV Status Report by Solar Club Thailand, Alternative Energy Development Plan 2012-2022.* Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy. pp 21-23, 2011.

Birmingham's Green Commission Carbon Roadmap, Making Birmingham a Leading Green City. pp.1-58. Available at https://www.birmingham.gov.uk/download/downloads/id/2012/exam29_carbon_roadmappdf.pdf.

Community Power Plant for Grassroots Economy. *Energy Regulatory Commission, 2021.*Available from https://www.erc.or.th/ERCWeb2/Front/News/NewsDetail.aspx?rid=86277&CatId=1&&muid=36.

Daphne Ngar-yinMahabAltair T.F.Cheungc. Policy mixes and the policy learning process of energy transitions: Insights from the feed-in tariff policy and urban community solar in Hong Kong, *Energy Policy, Volume 157,* October 2021.

Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy. *The First Draft of Thailand Renewable Energy Law*, 2013.

Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, *Thailand Alternative Energy Development Plan 2012-2022*, 2012.

Enayat, A. M. and Shirin. M. *A participatory exploratory modelling approach for long-term planning in energy transitions* pp 205-216, 2018.

Energy Policy and Planning Office of the Ministry of Energy. The new version of the Thailand Power Development Plan, 2018.

Epaminondas, B. Sustainable energy development: How can the tension between energy security and energy transition be measured and managed in South Africa? *Journal of Cleaner Production* pp 738-753, 2018.

Eskew, J., et al. *An environmental Life Cycle Assessment of rooftop solar in Bangkok, Thailand* pp 781-792, 2018.

Feng, L., et al. Measurement indicators and an evaluation approach for assessing urban sustainable development: A case study for China's Jining City. *Landscape and Urban Planning* 90 pp 134-142, 2009.

George, G. and Megan, A. F. *Just transition management: Balancing just outcomes with just processes in Australian renewable energy transitions* pp 110-123, 2018.

Georges, A. T., et al. Measuring the sustainability of cities: An analysis of the use of local indicators. *Ecological Indicators* 10 pp 407-417, 2010.

Global Transition, the Global Energiewende. 2012. Available at https://energytransition.org/

Hammond, P. G., et al. *Environmental and resource burdens associated with low carbon, more electric transition pathways to 2050: Footprint components from carbon emissions and land use to waste arisings and water consumption* pp 28-43, 2019.

Hansen, E. U. and Ivan, N. *Sustainable energy transitions in emerging economies: The formation of a palm oil biomass waste-to-energy niche in Malaysia 1990-2011* pp 666-676, 2014.

Innovation driving the energy transition, the Global Innovation Index, International Renewable Energy Agency (IRENA), Chapter 3 pp 97-105, 2018.

Jeffrey, B. K. and Hironobu. U. An institutional analysis of the Japanese energy transition. *Environmental Innovation and Societal Transitions* 29 pp 126-143, 2018.

Jin, S.J. and Alvaro, R.G. *Optimizing the location of a biomass plant with a fuzzy-*

DEcision-Making Trial and Evaluation Laboratory (F-DEMATEL) and multi-criteria spatial decision assessment for renewable energy management and long term sustainability pp 509-520, 2018.

Jorge, B., et al. The renewable energy policy Paradox. *Renewable and Sustainable Energy Reviews* 82 pp 1-5, 2018.

Krabi Goes Green: Towards A Model Town, With More Than 100% Renewable Energy Report, 2018. *Krabi Goes Green Network, 2018*. [online] Available from https://www.greenpeace.or.th/report/Krabi-goes-green-EN.pdf.

Krabi Vision 2020 plan. *Krabi Provincial Administrative Organization, 2014.* Available from http://www.krabi.go.th/krabi2015/m_file/KrabiVision2020.pdf [Accessed May2020]

Krabi Vision 2020, *Krabi Provincial Administrative Organization, 2014*. [online] Available from: http://www.krabi.go.th/krabi2015/m_file/KrabiVision2020.pdf [Accessed May 30, 2020].

Kudela, J., et al. *Legislation-induced planning of waste processing infrastructure: A case study of Czech Republic* pp 1-14, 2020.

Lee, M., et al. *Environmental and energy assessment of biomass residues to biochar as fuel: A brief view with recommendations for future bioenergy systems* pp 1-12, 2020.

Lindberg, B.M., et al, .2019. *Policies, actors and sustainability transition pathways: A study of the EU's energy policy mix. Research Policy, 2019*, pp 1-15.

Marquardt, J. and Delina, L. L., *Reimaging energy futures: Contributions from community sustainable energy transitions in Thailand and the Philippines* pp 91-102, 2018.

Master Plan for 100 % Climate Mitigation Frankfurt am Main, strengthening local economy through the energy transition, Available at https://energy-cities.eu/best-practice/master-plan-for-100-climate-mitigation/

Meg, H. Urban indicators and the integrative ideals of cities. *Urban indicators and the integrative ideals of cities* pp 170-182, 2006.

Michael, G. Historicizing transitions: The value of historical theory to energy transition research. *Energy Research & Social Science 38* pp 193-198, 2018.

Nancy, O. *Environmental sustainability for urban areas: The role of natural capital indicators.* pp 184-194, 2006.

Nunes, L. J., et al. *Biomass for energy: A review on supply chain management models* pp 1-8, 2020.

Nurtaj, V., et al. Transition to renewable energy and sustainable energy development in

Azerbaijan. *Renewable and Sustainable Energy Reviews* 80, pp 1153-1161, 2017.

Osamah, A., et al. Integrating sustainable energy strategy with the second development plan of Kuwait. *Renewable and Sustainable Energy Reviews* 82 pp 3430-3440, 2018.

Paes, X. M., et al. *Transition towards eco-efficiency in municipal solid waste management to reduce GHG emissions: The case of Brazil* pp 1-13, 2020.

Philip, A. Applying institutional theory to the low-carbon energy transition. *Energy Research & Social Science* 13 pp 2016-225, 2016.

Ping, H. and Vanesa, C. B. *Interdependence between urban processes and energy Transitions: The dimensions of urban energy transitions (DUET) framework. Environmental Innovation and Societal Transitions* 28 pp 35-45, 2018.

Provincial Electricity Authority, Thailand. VSPP-SPP-IPP Status of Krabi Province, 2020.

Ram, M., and Breyer, C., Job creation during a climate compliant global energy transition across the power, heat, transport, and desalination sectors by 2050, *Energy Journal*, 2021.

REN21, *Renewable Energy Policy Network for the 21st Century, renewable 2020 global status report.* Available from https://www.ren21.net/wp-content/uploads/2019/05/gsr_2020_key_findings_en.pdf [Accessed May 2021]

Renewables 2020: Analysis and forecast to 2025 report, International Energy Agency. Available from https://www.iea.org/reports/renewables 2020 [Accessed May 2021]

Renewables in Cities, 2021 *Global Status Report*. Available at https://www.ren21.net/wp-content/uploads/2019/05/REC_2021_full-report_en.pdf

Romijn, H., et al. *Biomass energy experiments in rural India: Insights from learning-based development approaches and lessons for Strategic Niche Management* pp 326-338, 2010.

Sharma, S., et al. *Waste-to-energy nexus: A sustainable development* pp 1-20, 2020.

Siddiqi, A., et al. *Urban waste to energy recovery assessment simulations for developing countries* pp 1-11, 2020.

Simionescu, M., et al. *Renewable energy in final energy consumption and income in the EU-28 countries* pp 1-18, 2020.

Solar energy development for the governmental sector and cooperative of agricultural projects, 2017-2019. *Energy Regulatory Commission, 2017.* Available from http://www.erc.or.th/ERCWeb2/Front/News/NewsDetail.aspx?rid=23719&Cat

Id=1&&muid=36 [Accessed May 2020]

Solar Energy for All projects. *Energy Regulatory Commission, 2019.* Available from https://www.erc.or.th/ERCWeb2/Front/News/NewsDetail.aspx?rid=85397&CatId=1&&muid=36 [Accessed May 2020]

Solar rooftop for household sector project. *Energy Regulatory Commission, 2019.* Available from http://www.erc.or.th/ERCWeb2/Front/News/NewsDetail.aspx?rid=23719&CatId=1&&muid=36 [Accessed May 2020]

Thailand Solar Fund, 2019. Available at https://thailandsolarfund.org [Accessed May 2020]

Thailand Tourism Strategy 2015-2017, Ministry of Tourism and Sports. [online] Available from: http://www.oic.go.th/FILEWEB/CABINFOCENTER3/DRAWER065/GENERAL/DATA0000/00000359.PDF [Accessed May 30, 2020].

The ASEAN Secretariat. Joint Ministerial Statement of the 29th ASEAN Ministers on Energy Meeting (AMEM), Jerudong, Brunei Darussalam, 2011.

The information of Krabi's energy transition during 1964-2021, Provincial Electricity Authority (PEA), 2021.

The information of Solid waste of Krabi Municipality in 2015-2020, Krabi Municipality, 2020.

The Intergovernmental Panel on Climate Change IPCC. *Summary for policymakers in: IPCC special report on renewable*. Chapter 5 pp 459-468, 2011.

The National Thailand Waste Management Roadmap 2016-2021. *Pollution Control Department (PCD), Ministry of Environment and Natural Resource*, 2016. [online] Available from https://www.pcd.go.th/publication/5061/ [Accessed May 30, 2020].

The National Thailand Waste Management Roadmap 2016-2021. *Pollution Control Department (PCD), Ministry of Environment and Natural Resource, 2016.* Available from https://www.pcd.go.th/publication/5061/ [Accessed May 30, 2020].

The Order 4/2016 of Section 44 of the Interim Constitution of Thailand, *Thailand Government 2016.* [online] Available from http://web.krisdika.go.th/data/law/law3/%A4%CA%AA02/%A4%CA%AA02-20-2559-a0007.pdf [Accessed May 30, 2020].

Thongsopit, S., et al. *The economics of solar PV self-consumption in Thailand* pp 395-408, 2019.

United Nations, 2030 Agenda for Sustainable Development. Available from https://sustainabledevelopment.un.org/content/documents/21252030%20Agen da%20for%20Sustainable%20Development%20web.pdf [Accessed May 2021]

Very Small Power Producer and Small Power Producer (COD) of Southern Thailand, Provincial Electricity Authority of Thailand, June 2020. Available from http://www.erc.or.th/ERCSPP/default.aspx?x=0&muid=23&prid=41 [Accessed May2020].

Waste Management for Clean Communities of Krabi Province. *Plan of Department of Local Administration, Ministry of Interior*, 2018. Available from http://www.tako.go.th/news/doc_download/a_070818_161026.pdf [Accessed May 30, 2020].

Waste to energy power plant of Krabi province. Krabi Municipality, 2020.

Xiangchengzhen and Yilmaz, 2020, Renewable energy cooperation in Northeast Asia: Incentives, mechanisms and challenges, *Energy Strategy Reviews*, Volume 29, May 2020.

Zhao, R., et al. *Towards a zero waste city - an analysis from perspective of energy recovery and landfill reduction in Beijing* pp 1-11, 2021.

Zheng, Y., et al. *Optimization of a biomass-integrated renewable energy micro grid with demand side management under uncertainty* pp 836-844, 2018..

APPENDICES

Appendix 1 Example of questions outline

1. Can you describe about renewable energy investment in Krabi province?
2. Have you ever get involve of Krabi provincial planning?
3. Which renewable energy that you invest or get involve?
4. When renewable energy investment has been started? And how?
5. Why renewable energy investment is important for Krabi province?
6. How about the plan of national and provincial energy policy relevant to Krabi province?
7. How about the portion of Krabi's renewable energy supply in the last 3 years?
8. How about renewable energy transition process in the province?
9. How about the renewable energy grid management and planning in the province?
10. How about the vision of the province? And how it links to renewable energy?
11. How about Krabi Goes Green planning? And how is relevant to energy transition?
12. How about the timeline of renewable energy transition?
13. How renewable energy transition is relevant policies and the investment in the province?
14. What are the drivers of renewable energy transition? And how?
15. What are the barriers of renewable energy transition? And how?
16. What are the challenges of renewable energy transition? And how?
17. What are the disruptive of renewable energy transition? And how?
18. What are the most important factors of Krabi renewable energy transition? And how?
19. How about renewable energy benefits and distribution to community and province?
20. How about the public participation of the provincial plan and renewable energy transition?

21. Who are the key stakeholders of renewable energy transition in a province? Institution, role and responsibility?

22. What about the guideline for renewable energy transition in province?

23. Why renewable energy transition is implemented?

24. Where the scope/ area of energy transition?

25. When the renewable energy has occurred?

26. Who is the relevant key person, institutions, organization of renewable energy transition?

27. How about the guideline/ process for renewable energy transition in province?

Example the additional specific questions to the interviewees that straight on their institution and/or responsibility.

Provincial Electricity Authority (PEA)

1. How about the trend of electrical consumption in the last 10 years?

2. How about the load forecast for the next 10 years?

3. How about the trend for electrical demand and supply for the last 3 years in the province?

4. How about the main station and sub-station for energy contribution?

5. How about renewable energy are related to 4As and energy security?

6. What is the non-firm contract and how impacts to energy purchasing?

7. When the renewable energy has been purchasing to the grid?

Power producers / tourism and others

1. How about the potential of renewable energy (solar etc.) in the province?

2. How about the past and current of renewable energy investment?

3. How about public participation of the projects (waste-to-energy etc.)?

4. How about the current situation of renewable energy supply in a province?

5. How about purchasing policy of renewable energy investment?

6. How renewable energy project benefits to tourism and local economy?

7. What is the security supply chain for renewable energy management?

8. What renewable energy policy is the most obstacle?

Krabi's Governmental agencies

1. Can you describe about the timeline of Krabi renewable energy transition?

2. How about the strategic plan of renewable energy investment in a province?

3. How about policy, legal and regulatory of renewable energy transition?

4. How about the policy and/or legal disruptive of renewable energy transition?

5. How about the controvert policy that impacts to renewable energy transition?

6. How about the conflict management of renewable energy transition?

7. How the collaboration of governmental offices, private sectors and communities happening?

Appendix 2 Example drivers' keywords from the interviewees

Category	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5
Drivers					
	cooperative management	cooperative management	transparency management	non-corruption management	opposing new coal project
	energy security	ownership	transition security system	ownership	energy security
	ownership	people mindset	ownership	governmental support	citizen capacity
	governmental support	public participation	provincial support	solar cost reduction	solar potential
	solar understanding	public hearing	public participation	advance techology	public awareness
	public participation	community benefit	public acceptance	public participation	solution finding
	community acceptance	wealfare benefit	solar potential	community acceptance	motivation
	benefit sharing	land rental	member benefit	cooperative benefit	clean energy
	cooperative benefit	city planning	land rental	city planning	knowledge management
	land rental	internal labors	solar purchasing	solar potential	knowledge sharing
	feed-in-tariff	construction labor	city planning	solar purchasing	geen leaf
	community participation	installation labor	grid connection	grid connection	expensive electrical bill
	clean energy	electricial labor	cheaper solar	benefit management	cheaper solar
	internal labors	utility labor	Krabi Goes Green	less environmental impact	green tourism
	construction labor	engineering labor	benefit management	Krabi Goes Green	green network
	installation labor	security labor	green energy	cheaper solar	Krabi Goes Green
	electricial labor	cleaning labor	land permittion		
	utility labor	gardening labor			
	engineering labor	solar potential			
	security labor	solar purchasing			
	cleaning labor	potential grid			
	gardening labor	benefit management			
	solar potential	less environmental impact			
	solar concentration	knowledge sharing			
	local income	land parcels			
	Krabi Goes Green	feed-in-tariff			
	policy support	policy driving			
	grid management	income transparency			
	benefit management	water management			
	reducing water impact	cheaper solar			
	income transparency	Krabi Goes Green			
	less environmental impact	bidding process			
	active learning				
	cheaper solar				
	bidding process				

Appendix 2 Example drivers' keywords from the interviewees (Cont.)

Category	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10
Drivers					
	provincial policy	opposing new coal project	opposing new coal project	opposing biomass waste	renewable energy potential
	citizen capacity	energy security	energy security	energy security	opposing new coal project
	Krabi Goes Green	Krabi Goes Green	provincial policy	governmental policy	provincial policy
	public participation	job creation	governmental support	governmental budget support	ownership
	green tourism	renewable energy potential	citizen capacity	governmental collaboration	governmental policy
	green network	income distribution	prosumer	benefit distribution	governmental collaboration
	private sectors	Krabi Goes Green	public participation	renewable energy potential	public participation
	reducing environmental impact	less environmental impact	private sectors	bio-waste management	energy security
	cheaper solar	knowledge management	investors	job creation	benefit sharing
	renewable energy potential	green tourism	renewable energy potential	grid management	private sectors
	job creation	reducing electrical bill	economic sharing	reducing environmental impact	green tourism
	less environmental impact	green network	income distribution	palm potential	green economy
	knowledge management	private sectors	job increasing	adder value	public hearing
	go green policy		Krabi Goes Green	Krabi Goes Green	less environmental impacts
	investors		knowledge sharing		job increasing
	governmental support		less environemntal impact		income distribution
			go green policy		reducing electrical bill
			green tourism		community benefits
			green network		Krabi Goes Green
					cheper solar
					energy accessibility

Appendix 2 Example drivers' keywords from the interviewees (Cont.)

Category	Interviewee 11 (2 people)	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15 (2 people)
Drivers					
	Krabi Goes Green	governmental policy	energy purchasing	cheaper solar	Krabi Goes Green
	provincial policy	provincial policy	renewable energy potential	knowledge management	maintanance system
	waste cluster	smart city	governmental policy	solar training	provincial policy
	green tourism	low carbon city	private sectors	cost of investment	public participation
	limited landfills	environmental conservation	cost of investment	public participation	private sectors
	energy purchasing	green tourism	less environmental impacts	reducing electrical bill	green tourism
	private sector	public participation	zero waste	governmental policy	knowledge management
	income distribution	knowledge management	circular economy	green energy	technological transferring
	green tourism	clean city	waste of biomass	energy accessibility	green industry
	cost of investment	municipality investment	green network	incresing consumption	WtE purchasing
	environmental impacts	private sectors	public acceptance	opposing new coal project	grid management
	municipality policy	waste potential	green tourism	green tourism	green leaf
	waste water management	Section 44 of the Interim Constitution	energy security	job creation	governmental collaboration
	governmental collaboration	Krabi Goes Green	Section 44 of the Interim Constitution	prosumer	reducing fossil fuel
	public participation	increasing consumption	adder values	provincial policy	green network
	governmental policy		green investment	benefit sharing	training
	Joint Venture Act		Krabi Goes Green	community benefits	waste of biomass
	grid management			renewable energy potential	opposing new coal project
				income distribution	green energy
				knowledge sharing	reducing carbon emission
				Krabi Goes Green	investment cost
					renewable energy potential
					income distribution
					adder values

Appendix 2 Example drivers' keywords from the interviewees (Cont.)

Category	Interviewee 16	Interviewee 17	Interviewee 18	Interviewee 19	Interviewee 20
Drivers					
	Krabi Goes Green	Krabi Goes Green	reducing electrical bill	reducing environmental impacts	energy security
	provincial policy	cost of transportation	provincial policy	reducing health impacts	Krabi Goes Green
	private sector	reducing environmental impacts	governmental policy	governmental collaboration	governmental policy
	cost of investment	cost of investment	carbon credit	income	provincial policy
	reducing electrical bill	energy purchasing	income	benefit sharing	electrical price
	green tourism	renewable energy potential	Krabi Goes Green	green tourism	provincial policy
	renewable energy potential	governmental policy	solar energy projects	clean city	cost of investment
	zero waste	provincial policy	grid management	public hearing	decentraisation system
	green leaf	income distribution	decentraisation system	public participation	knowledge management
	opposing new coal project	job creation	cheaper solar	public acceptance	green tourism
	positive mindset	grid management	reducing electrical bill	private sector	grid management
	knowledge management	decentraisation system	public participation	Krabi Goes Green	renewable energy potentials
	environmental conservation	cheaper solar	public acceptance		opposing new coal project
	reducing environmental impacts	reducing electrical bill	less environmoental impacts		private sectors
	reducing carbon emission	public participation	economic values		adder values
	green economy	public acceptance	renewable energy potentials		green energy
	economic values	private sectors	green tourism		energy accessibility
	diversity	adder values	economic values		incresing consumption
	maintanance system	smart grid			
	Section 44 of the Interim Constitution	green tourism			
		competitive market			
		citizen capacity			
		economic values			
		cost of investment			
		energy security			

Appendix 2 Example barriers' keywords from the interviewees (Cont.)

Category	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5
Barrier	random process energy purchasing quota system internal politics large land	quota system random process	random process energy politics quota system	random process quota system	energy purchasing

Category	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10
Barrier	opposing biomass energy purchasing	energy purchasing lacking expertise	energy purchasing internal politic	opposing biomass energy purchasing	quota system energy purchasing

Category	Interviewee 11 (2 people)	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15 (2 people)
Barrier	land price opposing waste-to-energy municipality budget negative mindset waste transportation high cost of transportation lacking expertise land use less provincial budget land limitation	energy politics waste reducing	quota system energy politics biomass opposing communities opposing	financial support energy purchasing public mindset	technological sharing energy politics nagative mindset lacking of expertise biomass opposing

Category	Interviewee 16	Interviewee 17	Interviewee 18	Interviewee 19	Interviewee 20
Barrier					
	energy politics lack of expertise	public mindset technological transferring quota system	energy purchasing	opposing waste-to-energy land limitation landfills energy purchasing	quota system energy purchasing technological transferring energy regulatory

Appendix 2 Example challenge' keywords from the interviewees (Cont.)

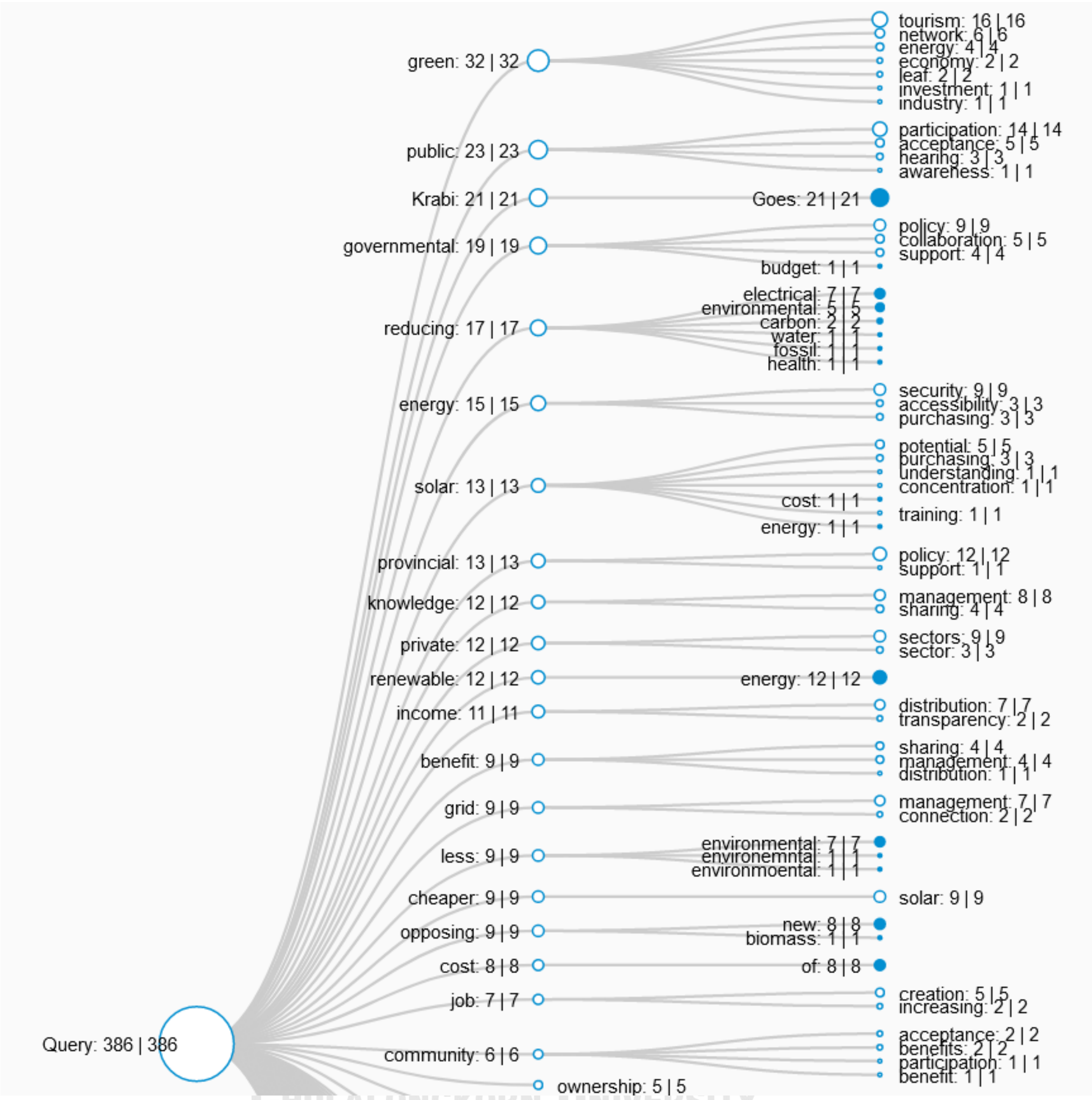
Category	Interviewee 1	Interviewee 2	Interviewee 3	Interviewee 4	Interviewee 5
Challenge					
	financial support energy regulatory city planning non-carbon credit energy storage community concern impact management	energy storage non-carbon credit	non-carbon credit court case energy storage land slide	non-carbon credit energy storage	technology transferring

Category	Interviewee 6	Interviewee 7	Interviewee 8	Interviewee 9	Interviewee 10
Challenge	city planning	financial loan people mindset behavior changing land use technological sharing energy justice	loan accessing	community power plant raw materials management seasonal production price competition	financial support land use permission technological transferring loaning support solar waste

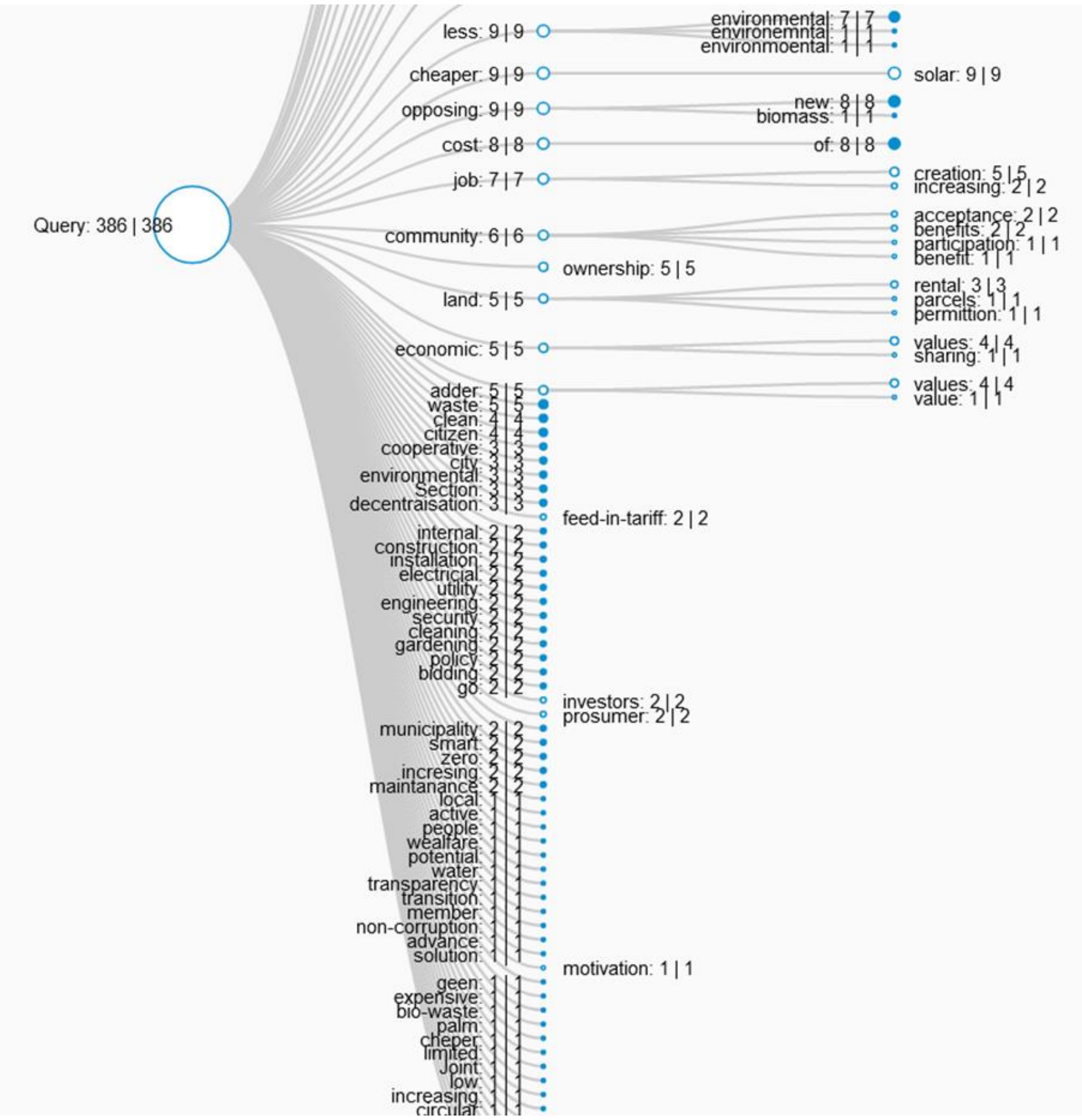
Category	Interviewee 11 (2 people)	Interviewee 12	Interviewee 13	Interviewee 14	Interviewee 15 (2 people)
Challenge	waste management awareness waste seperation technological requirement city planning return on investment polluter pay principle health impact circular economy environmental conservation ownership	waste management waste seperation zero waste city planning controversial policy power plant fund polluter pay principle monitoring system governmental collaboration non-registed population	conflicts management community's power plant ownership power plant fund benefits distribution communities benefits energy storage waste management supply chain management waste transportation monitoring system city planning incresing consumption public participation	technological transferring maintanance system imported tax reduction International privater sector solar waste management monitoring system technological sharing energy storage provincial budget energy security community power plant	diversity models controversial policy health benefits zero waste conflicts management waste management provincial budget communities' benefits supply chain management benefit sharing reducing environmental impacts

Category	Interviewee 16	Interviewee 17	Interviewee 18	Interviewee 19	Interviewee 20
Challenge					
	financial support	waste reducing	provincial budget	waste management	energy storage
	conflicts management	diversity models	energy storage	waste separation	supply chain management
	supply chain management	zero waste	cost of investment	city planning	energy security
	waste management	waste management		zero waste	
	Controversial policy	monitoring system		monitoring system	
		supply chain management			
		energy storage			
		financial support			
		behavior changing			
		carbon credit			

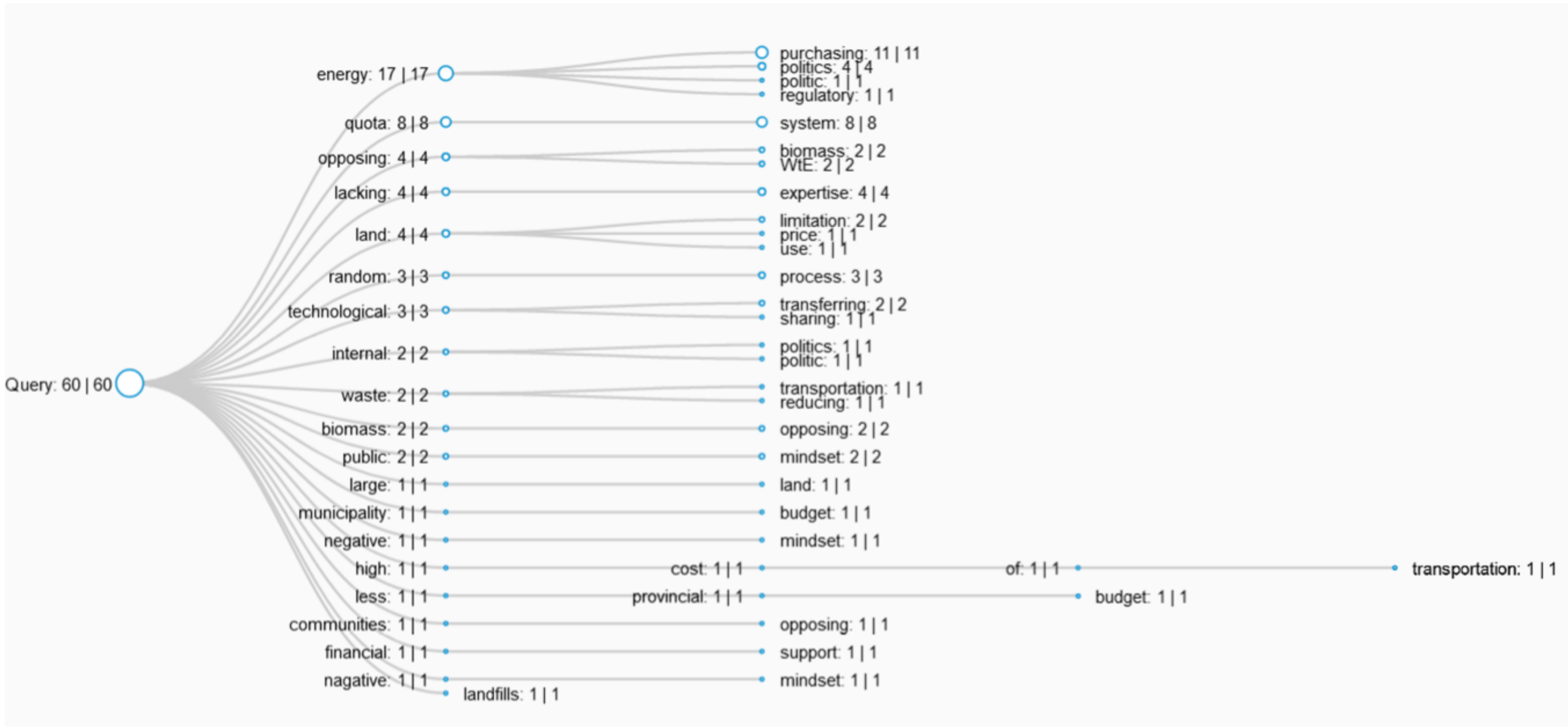
Appendix 3 Example drivers' keywords grouping



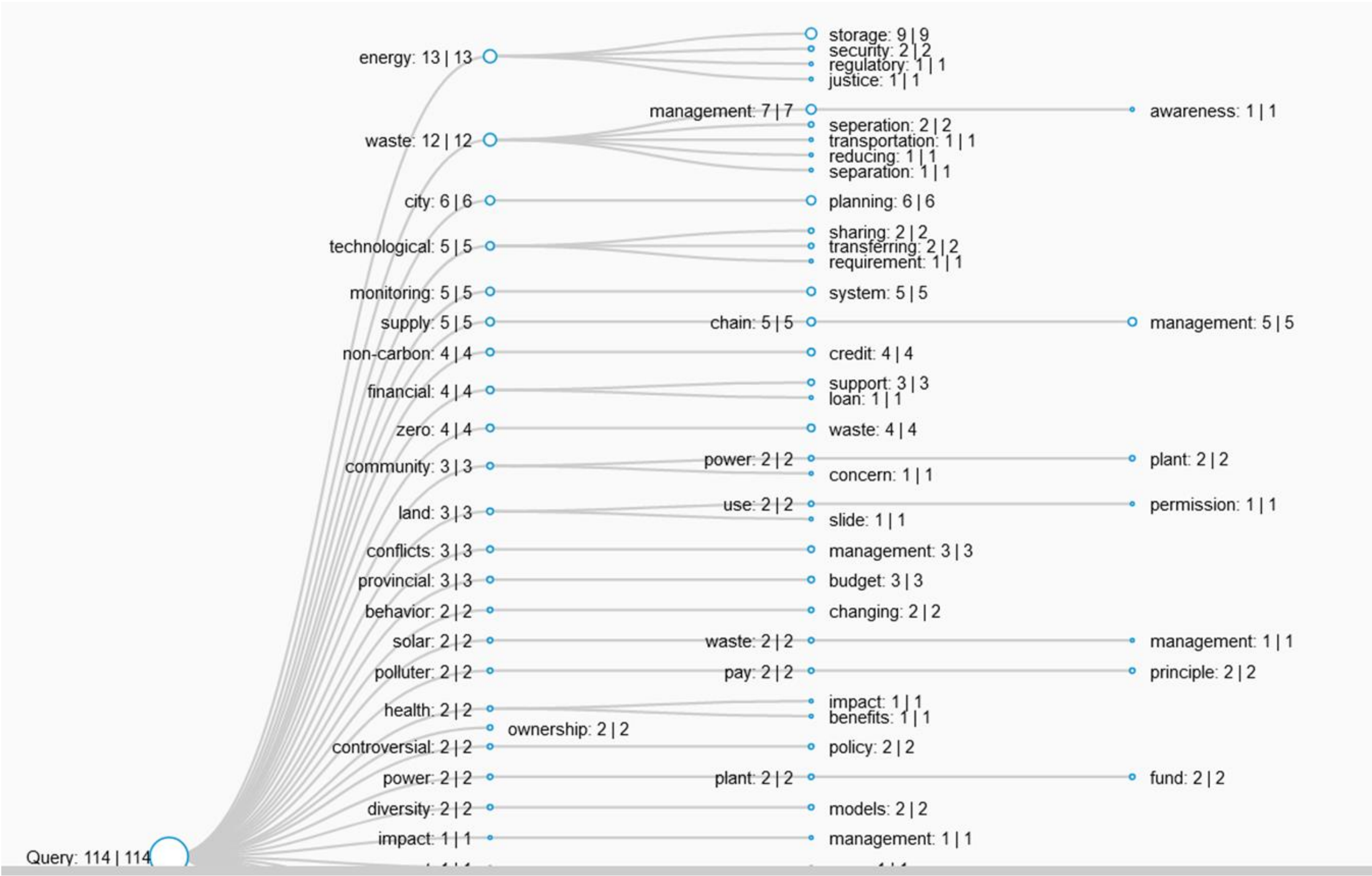
Appendix 3 Example drivers' keywords grouping (Cont.)



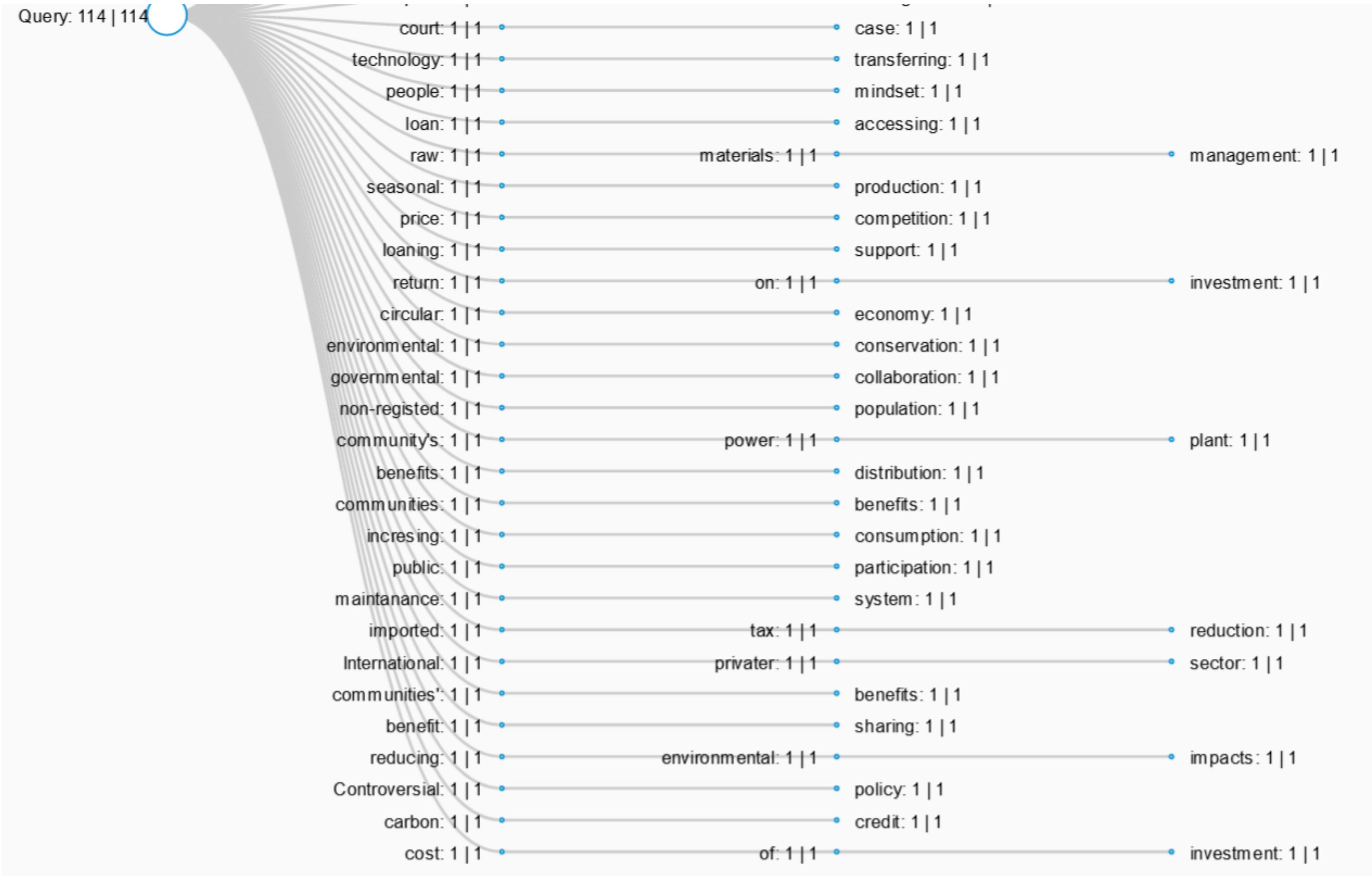
Appendix 3 Example barriers' keywords grouping



Appendix 3 Example challenges' keywords grouping



Appendix 3 Example challenges' keywords grouping (Cont.)



Appendix 4 VSPPs of Southern Thailand

Very Small Power Producer (COD) of Southern Thailand			
Fuel	**Amount**	**COD (MW)**	**Actual Load Total (MW)**
Waste energy	4	16.8000	16.8000
Biogas enegy	44	108.0630	88.9130
Biomass energy	20	113.0780	107.4500
Hydro energy	0	0.0000	0.0000
Wind energy	4	20.7150	20.7150
Solar energy	9	30.8563	30.8563
	Total	**289.5123**	**264.7343**
Very Small Power Producer (PPA) of Southern Thailand			
Fuel	**Amount**	**Power Purchase Agreement (MW)**	**Actual Load Total (MW)**
Waste energy	0	0.000	0
Biogas enegy	0	0.000	0
Biomass energy	3	5.380	0
Hydro energy	0	0.000	0
Wind energy	0	0.000	0
Solar energy	0	0.000	0
	Total	**5.3800**	**0.0000**
Very Small Power Producer (Appealing the cases)			
Fuel	**Amount**	**Power Purchase Agreement (MW)**	**Actual Load Total (MW)**
Waste energy	0	0.000	0
Biogas enegy	0	0.000	0
Biomass energy	3	17.300	0
Hydro energy	0	0.000	0
Wind energy	2	4.850	0
Solar energy	1	4.160	0
	Total	**26.3100**	**0.0000**

Source: Very Small Power Producer (COD) of Southern Thailand, Energy Regulatory Commission, 2020

Appendix 5 Krabi's VSPPs

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wanna Chaideker	2013	-	-	-	-	-	-	-	-	-	-	-	306
	2014	388	378	206	474	347	205	175	131	253	210	119	97
	2015	92	126	62	77	149	101	173	198	153	100	104	113
	2016	129	134	88	100	354	413	229	194	194	163	154	76
	2017	60	15	16	203	220	190	165	127	149	86	51	35
	2018	34	62	115	194	311	221	178	200	261	161	83	64
	2019	32	42	153	286	49	32	30	18	32	27	17	24
	2020	45	24	27	16	12	20	26	1	-	-	-	-
Krabi Waste to Energy	2016	135,630	467,497	569,372	298,640	198,353	159,975	188,975	425,519	300,405	364,869	402,844	292,128
	2017	259,920	383,760	688,227	163,009	150,345	451,222	279,609	283,921	675,798	490,316	755,120	531,586

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Co., Ltd.	2018	849,779	647,325	592,335	389,880	561,362	537,997	565,267	99,481	259,929	468,588	511,777	717,045
	2019	610,497	464,142	786,458	792,617	869,145	704,669	721,443	565,439	517,758	662,234	706,139	574,355
	2020	489,483	836,904	498,870	493,785	427,815	307,620	406,620	822,555	-	-	-	-
	2012	-	-	-	-	-	-	-	-	343,266	466,971	609,857	417,184
	2013	503,607	560,369	356,663	360,123	560,181	394,721	-	428,724	646,704	613,150	400,170	537,060
	2014	463,650	456,225	553,788	248,022	545,702	633,672	230,454	113,814	314,028	378,936	131,436	59,940
Clean Power Associate Co., Ltd.	2015	133,110	373,032	568,458	484,884	429,480	449,910	396,720	373,680	363,276	449,694	253,980	247,302
	2016	253,368	536,994	563,940	57,780	378,090	234,630	32,454	74,808	370,062	240,174	199,206	18,468
	2017	52,524	414	74,826	329,400	550,206	476,226	354,096	61,668	-	115,146	383,364	545,436
	2018	524,880	467,658	569,340	416,772	511,488	19,026	458,650	435,726	350,082	272,664	489,222	96,120

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sarab Biogas Energy Co., Ltd.	2019	-	-	4,518	212,832	465,660	73,170	402,948	59,436	-	-	-	-
	2020	-	-	-	78,030	550,818	37,836	189,108	37,836	-	-	-	-
	2010	-	-	-	-	-	-	-	117,291	19,798	43,161	-	50,752
	2011	96,006	74,261	101,066	76,194	154,095	123,090	103,561	189,682	195,442	327,945	358,097	350,691
	2012	461,819	412,876	397,483	386,825	440,708	470,704	562,857	581,789	479,516	168,366	227,351	422,501
	2013	620,775	597,786	561,429	28,656	547,477	619,381	531,624	665,391	534,534	288,404	457,226	621,883
	2014	239,998	301,778	460,026	318,977	394,990	610,846	686,925	518,625	635,518	486,855	524,338	266,220
	2015	334,440	490,995	626,535	452,467	628,740	305,190	234,900	161,685	186,345	163,665	265,500	399,600
	2016	235,350	271,395	514,774	498,395	327,780	22,995	-	283,275	334,935	350,865	624,510	643,815
	2017	403,650	148,005	190,845	509,445	686,340	632,655	128,790	-	551,205	1,085,220	1,021,815	952,273

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2018	524,880	467,658	569,340	416,772	511,488	19,026	458,650	435,726	350,082	272,664	489,222	96,120
	2019	721,791	862,877	1,286,003	1,250,021	1,225,130	1,175,909	1,400,234	1,327,101	1,328,403	1,298,571	994,063	1,014,348
	2020	951,122	1,081,445	1,290,911	1,333,343	1,239,768	1,254,472	1,234,617	1,295,813	-	-	-	-
	2009	-	-	-	-	-	-	-	-	3,029,983	2,434,140	756,540	1,426,500
	2010	2,219,580	2,127,240	1,318,500	-	206,460	783,900	2,949,855	1,134,857	85,320	62,640	82,260	286,020
Sarab Energy Co., Ltd.	2011	581,760	865,620	1,932,915	2,028,420	1,312,799	2,545,547	2,081,604	3,452,040	2,384,460	3,171,600	2,132,280	2,162,340
	2012	2,573,640	2,369,880	3,202,560	2,416,140	2,703,429	2,148,480	2,116,260	3,035,340	3,034,620	2,944,445	2,554,200	3,271,123
	2013	3,231,295	2,720,720	2,711,796	1,151,640	1,735,380	2,105,820	2,652,660	2,996,100	2,329,560	2,275,653	2,060,561	1,389,420

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2014	1,276,740	1,913,220	1,679,580	1,887,660	1,342,260	350,100	1,163,869	1,352,160	1,076,926	816,660	584,820	512,427
	2015	132,480	-	-	-	-	-	-	-	-	-	133,380	3,355,080
	2016	2,836,574	3,936,419	4,386,810	3,408,033	3,217,360	3,891,549	3,957,977	3,848,897	3,883,468	3,603,697	3,616,472	4,721,857
	2017	2,934,903	283,367	4,255,398	3,680,140	3,290,560	2,002,635	3,729,262	3,787,971	3,811,042	2,551,709	3,036,958	3,774,622
	2018	3,654,792	3,447,832	3,627,934	3,210,404	4,411,098	3,688,455	4,076,095	3,022,374	2,770,997	2,679,040	3,836,692	4,972,939
	2019	4,889,402	4,054,085	4,750,891	3,496,518	3,027,315	4,516,130	5,067,001	4,586,168	3,781,053	3,208,289	3,330,900	4,577,569
	2020	3,839,923	4,758,032	4,922,680	4,618,570	4,766,057	4,439,483	3,978,433	4,473,180	-	-	-	-
Thai Sri Tong	2015	-	-	-	-	404,456	2,952,063	2,483,108	3,151,56	2,647,62	2,470,769	3,155,40	2,652,8

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Co., Ltd.									6	0		0	30
	2016	2,897,065	3,153,433	2,125,525	2,632,500	2,634,300	949,140	1,154,520	3,677,719	3,639,240	2,860,740	3,859,560	3,386,520
	2017	2,226,420	2,473,560	3,863,880	3,477,600	3,607,740	3,650,220	3,055,140	2,178,000	3,387,060	3,542,940	3,362,220	3,516,994
	2018	2,852,121	2,904,840	3,320,280	2,656,434	2,756,160	1,753,560	1,719,360	1,229,040	1,995,840	1,575,180	2,025,900	2,070,360
	2019	1,449,180	1,999,980	3,148,200	2,250,900	3,157,380	2,288,880	2,570,760	1,086,660	1,716,840	1,572,840	1,348,380	309,240
	2020	-	268,020	-	Non-operation	Non-operation	Non-operation	Non-operation	Non-operation	-	-	-	-
Sri Chareoun Palm Oil Co., Ltd.	2009	-	-	-	-	-	-	-	-	-	192,821	511,870	261,912
	2010	277,538	246,255	513,020	485,956	538,955	485,178	482,195	491,331	352,962	560,280	368,209	252,240
	2011	246,540	231,660	459,720	299,220	809,280	960,120	1,092,720	881,940	909,360	1,071,180	1,020,42	606,360

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
												0	
	2012	879,180	909,660	976,020	818,160	848,219	536,160	292,920	429,108	1,066,440	834,720	914,220	688,380
	2013	1,046,460	1,046,040	1,188,120	1,028,760	751,080	609,358	804,060	765,050	546,900	741,900	620,880	452,760
	2014	522,660	403,980	834,960	966,240	605,100	889,740	1,055,220	510,180	260,040	376,740	338,760	238,560
	2015	364,800	246,600	857,580	1,231,560	974,640	811,080	295,380	420,120	423,420	622,560	741,000	24,960
	2016	363,420	490,500	854,820	819,120	672,720	488,280	389,100	509,040	781,740	590,640	588,420	568,740
	2017	448,200	657,480	1,173,120	1,224,840	1,020,540	927,900	601,560	798,540	1,074,600	966,420	1,385,220	957,180
	2018	932,880	740,700	717,120	762,360	697,980	606,360	556,200	652,440	639,540	790,560	867,600	892,980
	2019	1,070,400	654,180	1,045,440	1,032,060	1,055,760	1,450,320	1,052,040	894,660	682,560	632,100	640,200	494,700

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2020	615,180	573,660	1,088,340	1,013,880	974,160	1,486,620	1,083,600	962,640	-	-	-	-
	2009	-	-	-	-	156,240	145,728	91,638	130,590	140,292	180,594	204,966	85,446
	2010	-	95,886	217,242	218,214	269,298	327,114	393,750	281,160	112,086	-	-	-
	2011	-	18	-	1,872	-	99,828	210,474	225,648	380,754	292,932	330,516	373,356
	2012	253,566	316,908	67,140	-	99,486	211,788	250,992	312,660	245,358	267,786	219,186	263,592
ASEAN Palm Oil Co., Ltd.	2013	45,288	-	215,262	273,456	275,328	217,908	250,470	248,436	224,532	243,414	223,200	92,754
	2014	56,538	239,364	269,370	259,794	258,678	241,344	243,576	150,138	73,440	21,060	36	-
	2015	-	5,400	202,680	243,612	109,350	126,468	11,754	-	42,606	76,410	51,030	40,752
	2016	5,202	-	342	18	30,528	216,378	169,794	141,264	155,646	125,568	106,434	89,586
	2017	61,182	59,508	128,646	129,006	77,958	153,090	110,664	112,914	124,992	197,964	173,520	187,920

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2018	47,088	151,362	199,008	166,680	175,986	115,740	46,818	240,282	285,876	204,354	216,414	222,858
	2019	202,104	83,268	161,640	106,182	105,084	31,860	37,350	88,668	14,094	26,046	109,728	63,792
	2020	103,284	92,736	38,214	98,154	132,408	135,702	138,978	131,166	-	-	-	-
	2010	332,100	1,415,580	1,407,540	1,101,000	1,195,800	1,215,240	849,480	547,260	633,900	939,840	981,360	822,420
	2011	186,240	732,540	1,443,300	837,360	1,233,300	1,455,540	1,575,240	1,593,720	1,123,740	1,320,780	1,448,220	1,258,920
Univanit Palm Oil Co., Ltd. (Plai Phraya)	2012	1,569,660	1,513,620	78,060	41,700	835,500	937,080	1,043,040	1,136,580	1,324,680	1,519,620	1,388,760	1,507,800
	2013	1,462,260	1,244,520	919,740	375,540	1,631,820	1,048,680	1,124,340	1,046,040	930,540	957,180	727,200	824,460
	2014	171,540	944,100	1,053,180	685,380	932,400	953,940	911,940	606,960	587,040	667,560	402,300	597,420

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2015	201,420	715,260	1,025,700	1,207,500	1,370,400	1,122,540	650,220	683,880	678,360	776,460	739,560	782,280
	2016	384,600	1,002,420	845,760	1,057,680	654,600	511,860	287,280	412,080	295,560	181,680	490,920	309,900
	2017	515,280	770,760	1,393,020	1,317,000	528,480	816,900	475,080	460,320	627,240	1,336,440	1,463,820	1,358,400
	2018	1,442,940	1,243,680	1,466,340	1,169,520	1,114,800	291,360	405,420	592,800	635,580	871,980	877,440	840,600
	2019	964,260	1,156,980	1,302,060	889,980	1,206,120	1,023,840	975,600	247,140	644,340	583,320	743,400	944,340
	2020	329,640	337,200	766,200	1,112,700	1,336,080	1,021,440	1,002,240	928,440	-	-	-	-
Multi-industry Palm Oil Company	2009	-	-	-	-	-	-	-	-	-	83,754	311,704	219,361
	2010	437,914	248,105	463,029	425,702	455,854	448,520	371,466	204,086	182,545	149,244	76,786	61,785

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(Biogas)	2011	91,485	149,535	366,570	361,215	390,555	305,100	356,535	210,915	41,085	388,260	495,720	400,365
	2012	298,350	417,714	423,045	456,886	65,340	169,470	274,860	269,010	159,030	375,435	374,670	279,045
	2013	280,980	328,500	388,395	307,035	349,650	271,800	359,685	305,595	431,775	450,315	292,545	73,215
	2014	318,735	395,730	525,330	264,510	670,680	566,370	577,305	419,985	460,710	389,835	183,915	143,460
	2015	207,630	345,735	549,990	363,330	619,065	504,630	434,700	363,645	171,270	256,410	219,825	121,500
	2016	122,625	261,045	497,205	304,200	190,665	153,945	34,290	78,570	42,660	15,615	22,410	34,335
	2017	28,260	9,810	328,590	305,100	293,445	133,020	97,290	24,885	17,325	63,180	104,850	81,225
	2018	123,975	15,210	309,420	247,005	115,875	28,575	63,450	61,650	48,420	51,705	113,940	44,415
	2019	86,400	172,485	464,310	275,400	402,570	389,880	185,040	185,805	129,105	115,515	17,550	-
	2020	630	89,955	412,155	257,580	369,090	313,290	145,305	248,490	-	-	-	-

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thai-Indo Palm Oil Factory Company	2010	-	-	-	216,396	144,630	260,424	391,176	280,044	408,762	130,698	74,970	165,852
	2011	94,356	210,996	411,120	349,200	306,342	288,162	244,512	4,032	231,372	428,706	457,650	434,124
	2012	373,698	389,970	315,828	313,866	233,154	211,968	217,386	301,410	364,950	514,314	450,660	398,220
	2013	436,440	262,680	220,860	320,006	281,310	35,190	307,710	379,379	285,180	251,760	224,820	172,170
	2014	173,850	122,370	248,100	230,460	310,470	152,820	225,570	122,520	7,680	9,870	-	-
	2015	-	-	-	37,050	145,410	202,110	101,370	107,340	93,090	46,380	57,420	5,580
	2016	-	37,050	229,680	207,300	161,160	151,380	187,530	208,620	240,090	217,290	254,670	294,750
	2017	282,210	277,740	282,930	200,460	346,140	302,220	259,020	266,610	252,870	328,740	144,000	376,800
	2018	420,510	445,500	267,450	139,590	379,410	339,120	304,200	273,750	290,580	191,460	315,090	301,020
	2019	258,840	287,490	420,600	253,500	310,650	317,490	276,330	306,240	301,320	215,640	225,840	92,550

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	2020	122,610	201,090	312,030	238,740	217,650	224,100	161,130	98,280	-	-	-	-
	2014	137,745	553,354	795,486	821,562	827,638	714,297	968,576	819,367	610,908	659,843	599,985	459,945
	2015	166,455	703,665	1,004,805	980,460	963,315	1,030,482	683,729	613,710	694,737	649,710	689,174	260,278
	2016	178,560	593,576	1,043,820	903,375	866,970	919,934	624,239	790,874	1,010,744	913,002	873,445	294,030
Namhong Power Company	2017	267,390	500,803	823,244	720,122	1,311,743	993,087	530,617	573,390	509,939	805,555	927,590	801,766
	2018	828,011	808,290	1,010,730	998,510	862,442	521,145	405,724	337,454	414,620	880,317	825,501	806,730
	2019	601,113	933,731	1,115,238	1,073,783	1,153,644	1,131,626	1,358,332	1,157,752	805,391	675,225	681,343	746,010
	2020	421,245	439,110	817,504	891,218	1,517,897	1,207,125	1,019,666	674,788	-	-	-	-
Modern Green	2012	-	-	63,135	200,070	197,595	302,985	537,030	546,615	532,440	705,015	591,390	311,445

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Power Company	2013	487,620	355,725	122,400	441,765	465,255	408,150	675,045	632,025	534,825	600,615	567,000	677,385
	2014	333,495	557,280	560,970	298,845	677,565	767,700	409,365	377,280	455,895	531,495	414,630	335,025
	2015	185,355	374,940	515,655	589,365	407,790	340,695	430,875	402,525	410,580	599,445	554,310	397,125
	2016	257,670	359,550	612,450	310,230	388,080	395,190	394,020	566,055	570,510	514,988	608,407	482,417
	2017	292,995	345,420	722,988	872,259	816,480	604,993	678,730	761,702	833,778	897,914	764,130	678,912
	2018	446,670	544,095	771,975	634,590	532,215	546,210	531,090	528,795	505,035	1,007,459	701,775	566,100
	2019	275,535	725,747	765,884	789,244	736,830	705,465	747,788	596,723	542,387	502,397	431,144	410,670
	2020	285,885	559,522	750,605	508,714	586,215	751,095	751,245	777,420	-	-	-	-
Univanit Palm Oil Co., Ltd.	2010	491,346	397,026	508,572	415,692	543,348	285,048	515,016	490,302	435,366	459,432	375,012	127,728
	2011	331,380	330,084	417,708	406,386	477,432	410,742	244,296	262,854	227,088	192,888	237,672	153,936

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(Ao Luek)	2012	-	237,456	416,664	441,072	374,472	466,452	341,208	239,040	391,878	458,928	488,016	379,800
	2013	528,210	421,488	326,124	400,374	178,866	227,700	469,890	403,992	430,200	514,818	437,346	263,898
	2014	336,690	311,472	374,058	477,486	446,760	427,212	393,750	370,440	340,848	321,048	182,880	56,844
	2015	203,544	312,066	501,750	406,314	463,320	492,552	317,358	421,308	307,638	314,892	292,608	197,010
	2016	369,180	54,486	503,442	405,720	467,766	413,028	327,456	367,344	159,714	182,268	252,180	350,298
	2017	83,520	346,518	208,584	220,140	518,706	489,960	404,334	485,046	466,956	434,196	462,726	507,366
	2018	354,474	440,442	415,800	292,986	184,212	434,106	455,994	466,380	488,070	416,250	530,568	372,162
	2019	376,889	367,905	553,388	1,011,900	644,027	791,100	451,560	691,500	451,800	424,320	207,720	235,200
	2020	429,540	762,240	1,150,620	1,206,480	1,470,420	1,245,900	1,140,720	957,480	-	-	-	-
Univanit Palm	2010	700,770	189,300	821,730	802,020	661,920	768,540	1,074,510	178,860	605,070	493,560	338,520	257,910

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oil Co., Ltd.	2011	255,480	168,660	864,450	937,440	828,750	888,720	909,900	638,490	859,110	959,520	710,760	571,650
(Lam Thap)	2012	669,690	257,160	255,810	26,910	233,700	256,500	496,260	501,120	624,450	722,700	765,870	613,140
	2013	721,950	452,310	374,580	330,180	164,310	345,510	292,410	702,420	685,860	704,280	455,640	580,680
	2014	439,800	110,400	615,330	686,280	497,100	356,370	379,980	615,810	516,900	313,500	182,310	205,650
	2015	143,700	131,760	418,680	624,240	695,910	743,940	542,160	652,740	782,730	885,090	766,110	181,650
	2016	131,880	330,870	282,720	565,500	521,010	297,750	361,200	575,850	225,840	267,360	290,730	213,030
	2017	199,740	302,280	556,380	541,830	690,810	504,900	545,550	927,540	819,510	770,250	481,380	343,770
	2018	556,140	725,790	909,150	727,470	484,680	166,530	436,920	695,220	790,590	798,450	736,170	201,030
	2019	-	491,310	602,940	803,610	862,050	728,760	715,020	773,220	445,830	446,850	328,530	185,850
	2020	153,270	273,000	522,930	682,890	618,540	613,860	553,920	202,650	-	-	-	-

Very Small Power Producer of Krabi Province (COD)

VSPP	Year	COD (Kwh/Month)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Thai Green Company	2018	-	-	-	-	-	-	-	-	-	-	-	134,520
(Ban Dinna Rubber Tree Fund	2019	636,840	678,360	764,220	690,840	622,800	551,280	565,620	555,060	602,100	572,940	591,540	664,500
Cooperative)	2020	741,840	667,680	790,020	620,100	583,140	492,720	535,440	552,900	-	-	-	-
Mar Solar Company	2018	-	-	-	-	-	-	-	-	-	-	-	95,760
(Hua Plunang Rubber Tree Fund	2019	877,680	944,580	986,280	840,240	781,860	710,820	751,020	660,600	694,200	683,520	697,080	807,300
Cooperative)	2010	928,980	866,040	1,040,460	844,440	790,740	643,200	700,620	729,780	-	-	-	-
Smart Solar Power	2018	-	-	-	-	-	-	-	-	-	-	-	93,105
Company	2019	653,985	661,185	732,060	703,665	631,485	600,885	648,720	592,740	567,630	541,665	545,940	653,040
(Lam Thap Agriculture Cooperative)	2020	787,815	739,800	874,215	661,725	627,615	557,910	589,905	633,330	-	-	-	-

Source: Status of Very Small Power Producer (COD), Provincial Electricity Authority, Thailand, 2019

Appendix 6 Example of the interviewees 'answers for drivers, barriers and challenges of Krabi's renewable energy transition

Example of drivers' answers as following;

The potential of palm was to directly produce palm oil as the priority of industry investment and the driving factor to value the profit in the long term. In 2007, the first biomass energy power plant was connected to the PEA grid feeding in a small scale of total energy supply. Lots of palm production in a province generated biomass waste in many areas and accelerated the opposition to the palm industry, especially biomass power plants from palm as generated waste water. Opposing biomass waste was a significantly disruptive factor driving the private sector finding a solution of green business and win-win solution.

…Biogas had been invested in a year later, 2008 as the first biogas for electricity generation in a province and then continuing growing without insisting. Waste water transportation from palm industry was under the legal enforcement to inform the local government agencies and find the place of dumping that was the reason of investor to reduce the maximize process and environmental impact to generate biogas instead nearby the biomass power plant. In the social aspect, biomass and biogas energy had been driven by the agricultural and cooperative palm planter that was beneficial for more than 30,000 households in a province and created direct and indirect jobs such as palm collector, technician and power plant workers etc.

…Millions of palm trees were the internal supply by the agricultural households in a province and rank in the top ten provinces of palm highest planting in the country. Besides that, the technological side was the one driver encouraging the investor to develop the biomass and biogas industry. The beginning of biogas energy investment in Krabi province had been transferred from the cassava flour industry to develop the electricity generation and the private sector gradually exchanged those knowledge and developed from the external technologies transferring among their business in national and international levels. National energy policy supported biomass and biogas at the beginning of investment by advocating the funding, adder and budget for the private sector.

…Energy policy and strengthening of the private sector in the province were significantly driving renewable energy investment even though it took more than 10 years of investment and movement across the province. In 2014, Krabi was the first province of a country collaborating with the Krabi Vision 2020 they were working together with different stakeholders in a province such as local governmental agencies, tourism associations, fishery groups, agricultural networks and other communities. Driving the master plan of the province was conducted for years with the eight accreditation of provincial committees in the different responsibilities and roles. Head of the province was the leader of the plan and was responsible for the direction of the long term vision. The first draft of the plan was signed by more than 200 organizations and networks under the Declaration of Green Tourism and completed the full vision of Krabi 2020 to lead the economy, environment and the quality of life. From the green tourism plan to Krabi Vision 2020 plan, Krabi had also studied the feasibility of renewable energy of the province and during the opposition of the new coal power plant project since 2012.

…Aside from the driving of provincial policy planning and people's movement to derail the new plant, the market trend was a disruptive phenomenon that pushed the challenge to a province to make a decision of energy demand and supply shifting. Linked to technological factors, when solar energy had been installed across a country the trend of citizens in the province was interesting so the first local solar company was established in 2015. The potential of solar energy proved energy security and the return of investment shortly at the present within 5-6 years so the household sector, especially tourism business and supermarkets were escalated to save their electricity consumption and the cost of electricity bills. And the governmental agencies projects such as building, schools, tourism pier and street lighting transferred their budget to invest more solar energy. The company also created job opportunities for young graduates from technician schools and people from the local communities by training and knowledge sharing.

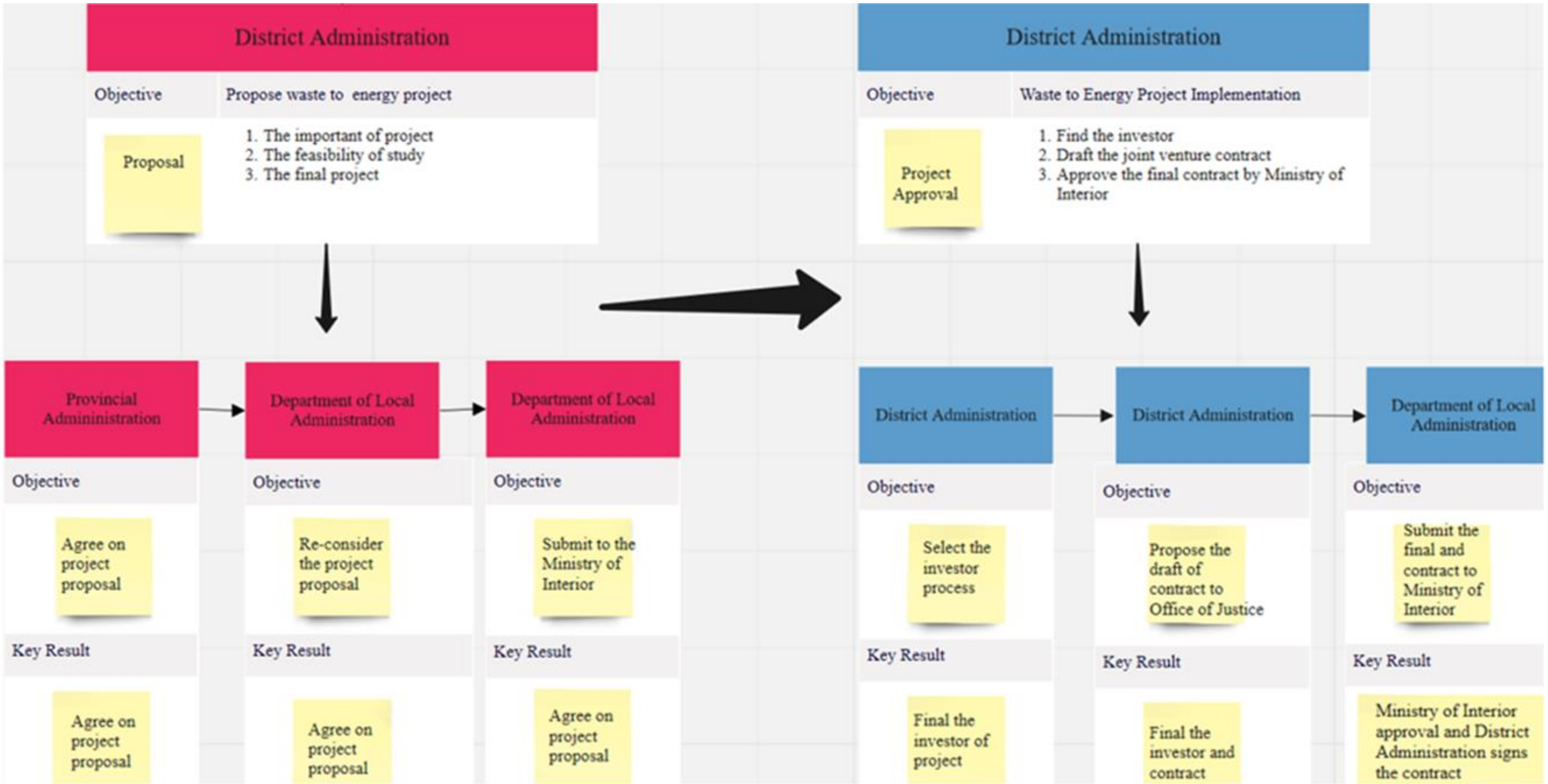
…Solar energy investment initiative was a leading pathway of RE transition towards sustainable energy in Thailand. Krabi province has land limitation for solar farms, except shifting of most lands of rubber and palm oil tree plantation. Whilst a thousand MW potential of solar rooftop has been observed. This potential has become the highest portion among other RE potentials in the province. Challenges of solar rooftop investment experienced from some success projects to overcome the relevant barriers were unlocking the national solar energy policy, the price of solar energy purchasing agreement and motivate measures for investment, such as financial start-up for solar energy's loan for solar rooftop prosumers and the new framework of its contributed to the agricultural cooperative's members to enhance the solar rooftop on their residential. However, supporting policy for solar energy from the government is still necessary. The following key factors to challenge solar energy initiatives at Krabi province needed to be considered: political, legal, economic transition and disruptive phenomenon. Solar rooftop was expected to be further invested depending on RE policy and the potential of electricity generation. In 2018, solar energy had been projected as an official commercial operation date to supply on grid with the following increases in the context of sub-district agricultural cooperative and governmental financial support.

…Political aspect was the important part of the solar energy transition in Krabi province and lifting the potential of its installation to approximately 15 MW in the present. The collaboration between the Ministry of Energy and Ministry of Agriculture and Cooperatives initiated the solar energy project that benefited the grid supply. When the national energy policy unlocked the capacity of solar energy production, the flow of the implementation plan in the province continually drove to achieve the plan and naturally supported the vision of local governmental agencies and boosting the private sector and investors deciding to agree on the plan. And in the depth of power analysis, the strong vision and relationship of the leaders, key influencers and private investors in the province motivated the followers to be on a track of the policy implementations.

…The legal factors had also been released to respond to the energy policy movement, the power purchasing agreement addressed the price per unit of solar energy, the amount of quota in each timeline and feed-in-tariff measurement. In the case of solar energy for cooperatives, the qualification of them was essential to be considered joining a project across the country, especially the transparency management which identified the grade of each cooperatives by internal checks with the Ministry of Agriculture and Cooperatives agencies. Economic factors impacted as a majority subject could build the income and domestic growth in the province. Creating direct and indirect jobs from solar energy investment such as construction, solar cells installation, technician and engineering, gardening, cleaning and security guards. Benefit sharing encouraged the members of cooperatives to make a decision to accept the solar energy project. Those income would be distributed to the cooperative's funding for hundreds members' welfare in each, including the land rental of the project regulated to rent from the members of its cooperatives in the long term period following the solar project contract. The fast track of solar energy investment required the financial support that the party of contract had capacity to deal with.

…Social aspect was much mentioned in the process of energy transition and the way to move the vision of the province to be real practice on the ground. Public participation was the vital process of solar energy investment especially solar farm projects of cooperatives. The process had not just only to know its details but also the members of the cooperative had a right to make their own decision to approve the project. The ownership of the solar farm joint investment would change people's mindset and be aware of their concerns of its impacts during the process of public hearing held by governmental agencies, companies and cooperatives in the community. And the transparency process of bidding that was implemented after the public hearing was important to them because of the benefits and income for the 25 years energy purchasing agreement. The last one was the environmental aspect, the mindset and acceptance of renewable energy were avoiding the opposition to new projects. Solar energy had less impact and green energy, both reasons had been integrated to the vision of the province that priorities on green tourism. At the stage of project consideration, the environmental agencies in the province were required to approve the solar farm project covering the impact assessment, city planning and the risk management such as landslide, water management and land use authority.

…Key drivers of waste to energy transition were political, environmental, legal, economic, social, technological factors including disruptive phenomena. Political aspect was related to the national energy plan addressing the target of waste-to-energy development in the Power Development Plan and Alternative Energy Development Plan. Besides that, the Krabi municipal plan was the one factor that aimed to reduce the existing overloaded waste landfill. More than a year people around the landfill had insisted on the waste dumping at Saithai district of Krabi province. Waste to energy came to the solution of waste management project and Commercial Operation Date (COD) to generate electricity on grid 28 December 2020 towards. The disruptive significance of inventory waste was connected to the Section 44 of the Interim Constitution of Thailand empowered the authority to greenlight those projects without Environmental Impact Assessment (EIA) procedure. According to the new enforcement, an exceptional EIA process would cut the long years of that process and not gain any community concern as usual. The governmental agencies, Ministry of Interior collaborated with the Ministry of Energy to push the waste to energy project within around 2 years to be achieved. The context of governmental partnership would be rushed and easy to be implemented as usual, according to the unlocked policy. The MSW was approved under Code of Practice (CoP), Environmental Safety Assessment (ESA) and Initial Environment Examination (IEE) as shown below.



Source: Waste-to-energy approval, Ministry of Interior, 2020

Krabi municipal and Saithai local authorities agreed to approve waste to energy power plant, the implemented project was thought to be beneficial for the tourism sector as a plan of Green Tourism Vision to reduce the origin waste and well manage the lasting problem and implement the Green Leaf project in 1998, which supported by Mahidol university targeting hotels and resorts group to practice for sustainable tourism management framework. Furthermore, low carbon city implementation in a province had forced the provincial planning on waste management when the landfill option in the past was not the better way of greenhouse gas emission because of the high methane emission. A province had also faced a lasting waste problem from the island such as PiPi and others, they needed to deliver their waste to the main cities on land and somehow those were thrown to the sea and even accidently. Marine waste transboundary was the one difficult problem to manage the collected waste from internal and external countries especially plastic waste.

In terms of legal factor, the Public-Private Partnership Act exposed the opportunity for the private sector to joint venture with local government agencies, a memorandum of understanding (MOU) was signed between the Krabi's municipal and waste to energy company which filled the gap of the limited provincial budget and the governmental agencies could not run their own business competitive with the private sector, according to the law enforcement. Moreover, the benefits from the power plant drove the relevant authorities to agree on the project development.

Waste was the value of energy development, the income of waste trade encouraged the external investor joint venture to make the project possible. Urbanists had paid for waste dumping at the landfill for the Krabi Municipal Administrative and that governmental agency seek for the external investor to get rid of the waste of the city supply chain. Even if the potential of internal investors was less, the bidding process would create the channel for external suppliers to be negotiated. As the overload capacity of waste resources required the private sector to manage, those technical and economic aspects drove the project development pathway.

As waste to energy was directly to the environmental side, the project was concerned about city planning that authorities by Krabi Office Public Work, Town and Country Planning. The location of the waste plant was not constructed in the conservation areas as restricted law enforcement. When the location was not an obstacle the project was approved easier together with the Section 44 of the Interim Constitution of Thailand. An environmental aspect connected to the mission of low carbon city to deduct greenhouse gas emission, the incinerator energy was the solution to reduce methane emissions at the landfills. Considering the social aspect, a province had a burden of waste management for many years, especially the growing of waste parallel with tourism blooming. The Green Tourism concept forces the relevant governmental agencies to seek the existence of those burdens. Ineffective waste management might impact the annual income of tourism such as waste in marine and landfills. Waste to energy had also been driven by the limited land condition as geography of a province with land surrounded by islands, and the protest of people in the province to oppose the extended landfills and the existence of those impacts to communities around experiencing water and soil contamination, smelling, toxic spreading etc.

Example of barriers' answers as following;

Power purchasing policy was the significant barrier relevant to the growth of biomass and biogas energy in the grid system. Intensive return investment encouraged the investors to allocate the money for the bio-energy supply chain that connected from the previous palm oil and potential of palm planting. Biomass and biogas investors were the previous palm oil producers and targeted to extend their own business. The fluctuated power purchasing policy restricted the potential of those production, some power plants burned out the biogas during the closed quota of those. Some power plants shifted biogas energy that was planned to be sold on the grid to internal use in the palm industry instead, such as boilers reducing palm fiber supply and investment cost. Biogas and VSPP of biomass energy relied on the non-firm purchasing system so the investors generated electricity especially during the high cost purchasing. The fluctuated purchasing power affected the biomass and biogas supply that caused the conflict of power producers and PEA.

Krabi province had a capacity to increase more solar energy supply to the grid according to the relevant studies as mentioned above. The quota system was one of the national solar energy policies that blocked the investment potential of both cooperative institutions and the household sector. This policy significantly limited the potential of the cooperative's solar energy projects and solar rooftop because the opening round of promotion was fixed by the number of solar projects and installation's capacity. The limited supply affected the selection process of solar energy for the cooperative group as well, that means the qualified would be eliminated by the randomness process.

A solar farm project to support the cooperative investment required the review of land use permission policy because there was one project of solar energy farm that has been sued to the administrative court. The potential of a solar farm, about 5 MW has not been supplied to the national grid even though the project has been completely installed on the land of cooperative settlement. The loss of energy supply to the grid system and benefits to a company and cooperative was an unexpected policy that significantly impacted the investment. This problem was a conflict between the agencies of the Ministry of Energy and Ministry of Agriculture and Cooperatives. And the unlocked cooperative enforcement was able to grow the potential of solar energy investment for example, the cooperative, as the owner of the project had authority to borrow the money from the financial institution to invest in their own project.

Financial sector has opened the limited opportunities for the customers such as the household sector and cooperative institutions to apply for any financial support implementing solar energy projects. There are some banks exploring the new policy of solar energy loan and mostly service for the private sector such as property owners and tourism associations. Lacking financial flowing, the solar energy investment in both solar rooftop and solar farm has not been growing fast. Finally, the limited internal experts forced the province to seek and import the solar energy professional from the outside and took time to share the relevant knowledge and the effective investment. The growth of prosumer and the potential of solar investment still require fast development and respond to the consumer demands.

Krabi had a long waste problem more than 20 years until the present. Even with the well design of the process, especially the combustion unit and post-combustion waste separation units, communities at municipal clusters still protest and do not allow the WtE power plant at first and are still a problem for other clusters. This is one of key barriers for WtE project implementation. Upon observation and talking with some stakeholders, it is suggested that benefit sharing from the WtE project and raising responsibility as polluter pay principle are challenging for public acceptance. Other barriers for the WtE project implementation are people's mindset and limited land. Therefore, the suggested challenges to overcome the barriers are as follows: economic, political, legal and technological aspects.

Social aspect was one of the barriers on that issue because of people’s mindset and behaviors. Waste was not the priorities management from household sector and policy uptake. Landfill dumping was the responsibility of governmental agencies in each district at the end. Some households took the open burning method to get rid of any wastes and the recycle system was on the middle man management to gain and sell to the center of the unorganized waste system of a province. Social aspect become the root problem of waste management as an ignorance problem and insist on landfills and waste-to-energy power plants in their backyard. Recycle, reuse and reduce waste had not been practiced officially at policy level.

In terms of the economic side, the cost of land in Krabi province was expensive and limited areas to extend more landfills that forced the provincial government to drive a waste power plant instead. Overwhelming waste had impacts not only in the city, peri-urban but also occurring on the islands especially during the high season of tourism. Solid waste on the island was difficult to deliver to the municipality or any main cluster to be managed. The reason was related to the cost of transportation that was burdened to the origin of those municipalities on the island. The provincial budget was not enough to cover and priorities the waste management in each district. It was a political aspect affected to implement on the ground. The provincial budget was generated and distributed to each district across the province and some of that was paid for waste dumping. The key was if each district wanted to eliminate waste that belongs to their border they needed to pay for other districts that were able to take waste for dumping. Garbage management in a province had also contributed to each district authority responsible for public health policy and concerning the restricted location of environmental conservation zones.

According to the garbage purchasing legislation, waste was property of the state and province. Citizens of the province paid to their municipality to clean it, and finally some municipalities paid to the main cluster or waste to energy owners to waste disposal. How to solve this problem was not easy and took time because a province lacked waste experts and human resources to work and analyses specific issues such as waste mixed sand etc. In terms of technological aspect, the limited technology transfer and the return of investment was the important factor for each municipality, especially the island such as Lanta island municipality and Saladan municipality etc. The profit of the waste management project was the top decision to joint venture of each cluster because of the expensive cost of technology as well. The fluctuated solid waste quantity in each season led to the technology adaptation and the point of business returning.

Example of key challenges' answers as following;

In the social aspect, the new and extended biomass and biogas required the concrete public acceptance to increase the investment in Krabi province especially the pollution of biomass as particulate matter and others. Lack of strengthened Environmental Impact Assessment (EIA) monitoring led to those impacts existing. Land grabbing of palm planting was the lasting problem and severely conflicts between communities and palm capitalist and further impacted to the shifting from palm planting to solar energy. In terms of political aspect, land use management was important to be able to sustain the renewable energy raw materials especially bio-energy and it required governmental agencies such as palm agricultural and cooperative, Ministry of Energy, Ministry of Agriculture and Cooperatives etc.

Besides that, the economic aspect, the cost of biomass and biogas investment was connected with transportation cost and price of palm. The seasonal palm production fluctuated and palm production was not stable for some period. The advance stock of palm was competitive among the power plants and raised the high price of palm during the unsecure of its supply chain. Drought was the key factor most impacting the stock of palm production each year. Aside from that, environmental aspect including biomass pollution controls and city planning were to solve the impacts and secure the potential of bio-energy.

The technological challenges were internal private sector capacity to manage the risk of palm production and initiated the development of new technology instead of imported. Secure the electricity generating needed energy storage system to support and the extended decentralization system of provincial utilities. The disruptive of the new power development plan was the community power plant concept, sharing the benefit of investment among private sector and community. However, benefit sharing of biomass and biogas energy was challenging; it was directly advantageous to palm agricultural planting and not sharing the benefit from power plant investment like solar farms of the agricultural and cooperatives in a province. The well management of its supply chain, power purchasing and benefit sharing was able to increase the potential and secure the electricity generating capacity to the grid system.

Krabi is a tourism province of Thailand having continuously invested in electricity generated from renewable sources since 2007. Key drivers for the renewable investment are "electricity demand increasing" to fulfill the tourism sector and the province's Krabi Goes Green vision. While facing various barriers such as the extension of solar farm projects is the challenge and will have a potential effect on the capacity of biomass and biogas energy production because of the collapse of land use management, the requirement of internal grid system extension and management require support for energy security supply and demand sides, the need of smart grid and decentralization implementation plan to invest more budget to feed the renewable energy production and consumption.

Solar rooftop tends to be the highest potential and some drivers like supporting the household’s potential and the pathway of the cooperative's members that urges them to install solar cells reducing the cost of electricity bill and agricultural production cost, wider prosumers will lead the technology knowledge exchanging in the southern and also across the country as the golden opportunity, regulate the intensive cost of solar energy purchasing will be the one factor to fill the gap of renewable energy investment and motivate the internal economy from selling the electricity energy across the province especially in the area of Andaman tourism provinces to value the green tourism and energy, support the decentralization and energy storage will be a priority for the future solar energy transition both on land and the island, must be well considered.

Integrated provincial waste policy was the important direction to implement and practice for all alignment including waste separation at the first stage; reduce, reuse and recycle including curriculum economy. Krabi Goes Green vision unofficially drove waste reduction to waste to energy power plant however, its contract was feed-in-tariff for 25 years generating electricity to the nation grid under Power Purchasing Agreement (PPA). The challenge was that Krabi Goes Green vision meant to reduce trash as the point source and it evaluated the existing dumping waste available for approximately 10 years generating. After 10 years, Krabi waste to energy needed to be supplied from the external sources nearby a province. Solid waste reducing trends will later impact the potential internal waste. Moreover, in case other waste clusters had overloading potential on the island and land required the public monitoring system for the long team project such as air pollution, dioxin, noise and water contamination etc. even the Environmental Impact Assessment had not been implemented under the junta government.

According to the economic aspect, the incinerator power plant was not the sharing benefit directly to the community and less connected to the concept of community’s power plant because the profit of business not directly returning to the community, compared with other renewable energy projects. The imported solid waste in the future from other provinces was the challenge of how benefits could be shared as the long term contract and the impact was accumulated to Krabi's communities. The social factor was about waste separation and sustainable waste management of a province and uptake more public participation to involve in the process of waste-to-energy management.

Krabi' electricity demand and supply, and also potential of waste-to-energy electricity generation at Krabi. The potential of waste is targeted for WtE in Saladan clutter and municipality clusters. Waste management is the significant problem of Krabi province every year parallel with the tourism season and the mountain of garbage in the city and islands. The study found that national and provincial policies were the drivers to shift waste to energy such as the integrated policies of waste management to build WtE power plant, low carbon city and Krabi Vision 2020 implementation plan.

The important barriers were people's mindset, depth of knowledge and behaviors are limited to manage MSW. Less awareness of citizens to criticize the impact of waste problem to the end journey and connected to the pathway of provincial sustainability. Cost effectiveness of its transportation was able to transfer the existing waste from the landfills to the incinerator plant. Technology transferring was suitable and available for the landfilled and municipalities, required the budget to support etc. To overcome those barriers, it needed integrated provincial waste policy, benefit sharing and public monitoring systems etc. and those components would be considered.

VITA

NAME	Chariya
DATE OF BIRTH	20 January 1979
PLACE OF BIRTH	Nakhon Sri Thammarat
INSTITUTIONS ATTENDED	Thammasat University, Thailand, Faculty of Law,LL.B.,2000 Chulalongkorn University, Thailand, MA. of Environment,Development and Sustainability, Interdisciplinary Program, Graduate School,2013 Chulalongkorn University, Thailand, Ph.D candidate of Environment,Development and Sustainability, Interdisciplinary Program, Graduate School, 2018
HOME ADDRESS	9 Soi Chongmechai 6, Chakpra Road, Talingchan District, Bangkok, Thailand
PUBLICATION	1. 6 June,2006: Human in Elephant Track Feature Article on Outlook, The Krungthep Turakit newspaper 2. 29 October,2006: Trap or Answer: The Elephants Feeding on Daily Newspapers 3. February,2007: With Mines, Wildlife Disappear: The Return of Illegal Mines at Tung Yai Wildlife Sanctuary on Feature Magazine 4. April,2007: New Homes for Marine Fish on Nature Explorer Magazine 5. July,2007: Forest Restoration to be Real Forest on Feature Magazine 6. September,2007: From Forest to City, Dichan Magazine 7. April,2011: From Chernobyl to Fukushima, Business Plus Magazine 8. October,2011: Interview on 10 Tips to Energy Efficiency, Marie Claire 9. October,2011: Thailand Needs Energy Revolution, Business Plus Magazine 10. November,2011: The Future Path Way on Coal, Business Plus Magazine 11. June,2011: Inside Out of Thailand's Energy Revolution Report, Writer, Greenpeace Southeast Asia

12. August,2012: Drafting Renewable Energy Framework in Thailand Booklet
13. May,2012: Think Over Than Coal, Business Plus Magazine
14. 6 July,2012: The First Renewable Energy Law in Thailand, Post Today newspaper
15. 7 October,2012: Fish for Life: Food Protection Declaration to Stop Dirty Industrial Development, Thai Post newspaper
16. August,2013 : The Energy Revolution of Nakhon Si Thammarat Province, Greenpeace Southeast Asia
17. 2014: Krabi at the Crossroads Report, Research Consultant, Greenpeace Southeast Asia
18. 2014: Move Beyond Coal on Global Movement , Sierra Club,USA
19. 2015: Move Beyond Coal on Global Movement , Sierra Club,USA
20. 2015: The Human Cost of Coal Power: How coal-fired power plants threaten the health of Thais Report, Greenpeace and Harvard University
21. Oct 2015: Justice denied for murdered Thai activist who defended his community against coal, EcoWatch
22. Mar 23,2016: Coal & Water and People Threaten, Manager newspaper
23. May,2018: Thailand Renewable Job Creation report,Research Associate, Greenpeace Southeast Asia
24. May,2018: Krabi Goes Green report,Research Consultant, Greenpeace Southeast Asia
25. May,2018:CHIA Community Health Impact Assessment of TelukPatani-Sonkla Province of Southern Thailand report,Research Consultant,Greenpeace Southeast Asia
26. April, 2019: Challenge of Renewable Energy Transition towards Krabi’s Sustainable Energy City, ICRMBEE 2019 the 4th International Conference on Research Methodology for Built Environment and Engineering 2019
27. May-September,2019 : CHIA Community Health Impact Assessment of MuakLekSaraburi Province of Central Thailand Research, Research Consultant,Greenpeace

Southeast Asia
28. September, 2019 : Thailand Health Impact Assessment Booklet, Co-writer with
Thailand National Health Commission
29. September2019-March 2020: Thailand Solar Roadmap and Public Policy, Research
Associate, Greenpeace Southeast Asia and Thailand Energy Network
30. 2019-2020: the Mercury Emission of Coal Consumption in Thailand, Research
Associate, Greenpeace Southeast Asia and Thailand Energy Network
31.Sustainable Provincial Power Development Plan, September 2012
https://ejournals.ph/article.php?id=2921
32..Challenge of Renewable Energy Transition towards Krabi's
Sustainable Energy City, Published, 2019
https://iopscience.iop.org/article/10.1088/1755-1315/385/1/012060/pdf

AWARD RECEIVED

1. Foundation for Child Development
August 2004, Projects on behalf of the Foundation for Child Development and was first
out of the 8 finalists' organisations in the NGO Asia Pacific Awards, organised by
Resource Alliance
2. Citizen Base Initiative Prize
November 2004, Child & Shared Card project, winning the National Level Award of the
Citizen Base Initiative Prize from Ashoka Innovators for the public.
3. Ways to Generate Money & Resource Initiative
January 2005, Under the Child & Shared Card project, was first of the 12 recipients out of
99 countries worldwide of the Ways to Generate Money & Resource Initiative prize, from
Ashoka Innovators for the public, www.changemakers.net
4. Research Scholarship of Master degree
November, 2013
Subject of Sustainable Provincial Power Development Plan: Case Study of
Nakhon Si Thammarat Province
MA.of Environment,Development and Sustainability, Interdisciplinary Program, Graduate School, Chulalongkorn University
5. Full Scholarship of 100th Years Anniversary of Chulalongkorn University

Year 2018-2021
Ph.D Candidate of Environment,Development and Sustainability,
Interdisciplinary Program, Graduate School, Chulalongkorn University
6. Regional Campaign Strategy Fellowship, European Climate Foundation,
June-December,2019