Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition Road Map for Chiang Rai Province, Thailand

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

NEXSTEP
National Expert SDG Tool for Energy Planning

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Developed using National Expert SDG7 Tool for Energy Planning (NEXSTEP)

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*The shaded areas of the map indicate ESCAP members and associate members.**

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The principal authors and contributors of the report were Anis Zaman, Charlotte Yong, and Muhammad Saladin Islami. A significant contribution to the overall work was from Munlika Sompranon, Director of Policy and Strategy Section, Strategy and Planning Division, the Department of Alternative Energy Development and Efficiency, and Kamol Tanpipat, Deputy Managing Director, BRIGHT Management Consulting Co. Ltd.

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Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

UNITED NATIONS ESCAP
Economic and Social Commission for Asia and the Pacific

Foreword

The Ministry of Energy is well aware that Thai quality of life can be better via effective energy policy implementation and support, especially for the community. The National Energy Plan (NEP) 2022 is being drafted with the objectives to drive the economic and social development for better life quality for people and to achieve the carbon neutrality target by 2050 from the commitment at COP26 and meet the Sustainable Development Goals (SDGs). Consequently, the Alternative Energy Development Plan (AEDP) and Energy Efficiency Plan (EEP) are also being formulated as parts of NEP which aim to increase the share of renewable energy and alternative energy over 50% and reduce Energy Intensity (EI) more than 30% by 2050.

The excellent cooperation from the Economic and Social Commission for Asia and the Pacific (ESCAP) on the project **"Renewable Energy Technologies in Cities and Urban Planning for Renewable Energy Applications in Thailand"**, started in the early year 2021, aims to develop the SDG7 roadmap for 3 pilot provinces (ie. Surat Thani, Udon Thani and Chiang Rai) along with capacity building programme for the policymakers in targeted areas. This project can help the local energy authorities to assess locally available renewable energy options and energy efficiency measures for their own drawing roadmap in the future.

With full and continued support from ESCAP, Provincial Energy Office and other related both local and central departments. The outcome shall provide high-level technological and policy recommendations on achieving SDG7, responding to climate change goals, and also improving the life quality at a community level. I do hope that the SDG7 roadmap could guide local authorities to pave their ways to the sustainable energy transition and help achieve Thailand's Carbon Neutrality Goal.

On behalf of the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, Thailand, I would like to express my sincere appreciation for ESCAP's efforts and support so far. I would also like to thank all the people and organizations involved in this project for their excellent cooperation and contributions. I look forward to continuing this great collaboration in the near future.

Dr. Prasert Sinsukprasert
Director – General
Department of Alternative Energy Development and Efficiency (DEDE),
Ministry of Energy, Thailand

Foreword

The guidelines of Chiang Rai Province development plan are to achieve the goals of Creative Tourism City by making the city clean, safe and attractive to visitors. The city development plan is necessary for driving creative economy, creative environment and creative society to achieve balance across all dimensions. There are five development aspects including; 1) Creating value-added through creative tourism by upholding Lanna culture, 2) Promoting production and developing innovations to upgrade creative agricultural products under the sustainable development guidelines, 3) Developing creative economy in trade, investment, services, and logistics, 4) Managing natural resource and environment to maintain integrity and sustainability, and 5) Developing quality of life, human resources, and security to promote creative society, respectively.

According to the city development aspects mentioned above, Chiang Rai should apply clean energy, and environmental promotion to accelerating the city's efforts to achieve the development targets. Therefore, Chiang Rai is developing the project of Chiang Rai Sustainable Energy Transition Roadmap in collaboration between Chiang Rai Province, Economic and Social Commission for Asia and the Pacific (ESCAP), and Department of Alternative Energy Development and Efficiency (DEDE). The roadmap will be applied as a guidance to promote provincial policies, measures, programs to achieve the Sustainable Development Goals and National Greenhouse Gas Reduction Goals (NDCs). The starting point might focus on three approaches including 1) rapidly increasing the use of electric vehicle (EV) to support low carbon transportation, 2) promoting decarbonization in energy sector (i.e., installation of solar rooftop PV), investment in renewable energy (RE) for electricity generation, and 3) raising target ambition of decreasing the consumption of electricity and promoting Net Zero Carbon in energy sector, respectively. These three approaches will enhance the potentials of the city's development policy.

For the success of the city's roadmap development, we would like to express our gratitude to the Provincial Energy Office of Chiang Rai who is the key focal agency to create a collaboration framework and perform consultation activities to develop the Chiang Rai Sustainable Energy Transition Roadmap for the benefits of the Chiang Rai community.

Paskorn Boonyalug
Governor of Chiang Rai Province

Foreword

Energy transition is critical to reduce the impact of the current energy crisis due to the COVID-19 pandemic, the rising geopolitical conflicts that are causing supply and price shocks to energy resources, as well as the impacts of climate change. Energy Division of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) is pleased to partner with the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy and Chiang Rai province as one of the three pioneer regions in Thailand to have developed a Sustainable Energy Transition Road Map using the National Expert SDG Tool for Energy Planning (NEXSTEP).

The NEXSTEP methodology has been applied in several countries, to support national policymaking to achieve the SDG 7 targets and emissions reduction through Nationally Determined Contributions (NDCs). Efforts at a sub-national level are also equally important in realizing the global goals on sustainable energy and the objectives of the Paris Agreement on climate change.

The province of Chiang Rai, as the economic and tourism hub of Northern Thailand, faces several challenges concerning energy use and environmental sustainability. in the development of a sub-national Sustainable Energy Transition Road Map supports the region's endeavour in becoming a low-carbon region.

This Road Map takes a holistic approach to Chiang Rai's energy system. It evaluates the region's current progress towards the SDG7 targets, identifies the priorities for action, and suggests opportunities for improvement. For instance, the Road Map highlights the current gap in universal access to modern energy in the region and proposes the appropriate long-term solutions to close this gap, which also enhances socio-economic development.

The Road Map also details a range of technical opportunities and policy options for reducing emissions and saving energy across the whole economy that provides multi-fold benefits. Sustainable mobility options, particularly electric vehicles, shall redefine the means for region dwellers' mobility and travel, whilst reducing energy demand and related air pollution. The industrial sector also offers a notable energy-saving potential. The Road Map also suggests a substantial increase in the share of renewable energy in the electricity supply chain by, for example, implementing renewable energy auctions, to achieve the emissions reduction target while paving the way towards a net-zero society.

I would like to thank DEDE, the province of Chiang Rai, and other stakeholders for their continuous support and contributions, without which the development of this Sustainable Energy Transition Road Map would not have been possible. I look forward to the province of Chiang Rai's continuing progress in building a sustainable energy future.

Hongpeng Liu
Director, Energy Division, ESCAP

Abbreviations and acronyms

ADB	Asian Development Bank
BAU	business-as-usual
CBA	cost benefit analysis
CDP	Comprehensive Development Plan
CES	clean energy scenario
CLUP	Comprehensive Land Use Plan
CO_2	carbon dioxide
CPS	current policy scenario
DOE	Department of Energy
DPS	decarbonization of power sector
EE	energy efficiency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt-hour
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ktoe	thousand tonnes of oil equivalent
kWh	kilowatt-hour
LCOE	Levelized Cost of Electricity
LEAP	Long-range Energy Alternatives Planning
LPG	liquified petroleum gas
MCDA	Multi-Criteria Decision Analysis
MJ	megajoule
$ktCO_2$-e	thousand tonnes of carbon dioxide equivalent
MTF	Multi-Tier Framework
MW	megawatt
MWh	megawatt-hour
NDC	nationally determined contributions
NEXSTEP	National Expert SDG Tool for Energy Planning
RE	renewable energy
REF	reference scenario
SDG	Sustainable Development Goal
SET	sustainable energy transition
TFEC	total final energy consumption
THB	Thai Baht
TGFA	total gross floor area
TNZ	towards NetZero
TPES	total primary energy supply
TWh	terawatt-hour
UNEP	United Nations Environment Programme
UNSD	United Nations Statistics Division
US$	United States Dollar
WHO	World Health Organization

Executive Summary

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure sustained economic growth as well as respond to increasing energy demand, reduce emissions and, more importantly, consider and capitalize on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection, ESCAP has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as emission reduction targets in Nationally Determined Contributions (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9, which endorsed its outcome. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

Recognising the imperativeness of subregional efforts in supporting the achievement of the 2030 Agenda for Sustainable Development and the national commitment towards the Paris Agreement, this initiative has been applied to several cities and subregions. ESCAP and Thailand's Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, have collaborated to support three provinces of Thailand in developing their Sustainable Energy Transition (SET) road maps using the NEXSTEP tool. This SET road map, developed for Chiang Rai province, identifies the technological options and policy measures that will help the province to navigate the transition of its energy sector in line with the 2030 Agenda for Sustainable Development, national targets and commitment towards the Paris Agreement.

A. Highlights of the roadmap

Chiang Rai is the Thailand's northernmost province. It is distinguished by its remote hilltribes who live in mountainous terrain accessible by trekking. Chiang Rai city, on the Mae Kok River, has a well-known night market and the White Temple, a modern Buddhist shrine with quirky modern sculptures and murals. With a total land area of 11,678 km^2, Chiang Rai had a population of around 1.3 million in 2018. The gross provincial product (GPP) in 2018 was baht 107.3 billion and the GPP per capita was around baht 93,000.

This SET road map has two main objectives. First, it aims to establish a scenario baseline for 2019-2030, considering the current policy settings. Second, it identifies the measures and technological options that could raise Chiang Rai's efforts to align with the SDG 7 targets, national targets as well as achieving deep decarbonization of its energy system. The four scenarios that are presented in detail in this road map are:

- The Current Policy scenario (CPS), which has been developed based on existing policies and plans and used to identify the gaps in existing initiatives in aligning with the SDG 7 targets and national targets and commitment towards the Paris Agreement;
- The Sustainable Energy Transition (SET) scenario, which presents technological options and policy measures that will help the city to align its development with the SDG 7 targets and national targets;
- The Sustainable Transport strategies (STS) explore how the province can further transition its transport sector through a greater degree of mass public transport and electric vehicles usage.
- The Towards Net Zero (TNZ) scenario, the most ambitious scenario, looks at a pathway for moving towards a net zero society in the near future, through decarbonizing the electricity supply, fuel substitution and more ambitious electrification.

An additional scenario – business as usual (BAU) – has also been modelled to provide a BAU baseline where no enabling policies/initiatives are implemented, or where, the existing policies/initiatives fail to achieve their intended outcomes. This scenario helps to identify specific national targets e.g., the emission reduction target.

B. Aligning Chiang Rai's energy transition pathway with the SDG 7 targets and national commitments

1. Access to modern energy

Chiang Rai has already achieved universal access to electricity, while the clean cooking access rate was estimated to be 5.6 per cent in 2018. This included the 8.9 per cent of households that do not conduct cooking at home. The remaining 24.4 per cent of the population, which corresponds to approximately 136,300 households, relied on traditional charcoal stoves which contributed significantly towards indoor air pollution and associated health impacts. The national clean cooking access rate improved to an annual rate of 0.6 per cent during 2015-2019. Assuming the same rate, the access to clean cooking in Chiang Rai is expected to reach 81 per cent in 2030. To align with the SDG 7.1.2 target. NEXSTEP suggests that Improved Cooking Stoves (ICSs) may be promoted to losing the clean cooking gap.

2. Renewable energy

The share of renewable energy (RE) in the total final energy consumption (TFEC) was 9.6 per cent in 2018. This low share was due to very high petroleum fuel consumption in the transport sector amounting to about 72.6 per cent of the entire energy demand. This RE share is far below the national renewable energy target, 30 per cent of TFEC, set for 2037. Under the CPS, the share of RE will increase to 12.5 per cent by 2030. The increase in the RE share under the current policies is driven by the high growth of renewable energy share in grid electricity, which is projected to increase from 17.8 per cent in 2019 to 24.6 per cent in 2030, and a slight increase in biofuel usage in the transport sector. In the SET scenario, the RE share in TFEC will decrease slightly to 12.2 per cent due to reduced biomass consumption for cooking in the urban areas and reduced biofuel consumption in the transport sector. The RE share will increase to 12.9 per cent in the STS scenario due to reduced petroleum consumption in the transport sector.

The RE share in TFEC for the TNZ scenario is expected to be high as a result of a decarbonized electricity supply. Apart from a decarbonized electricity supply, the TNZ scenario also aims to increase the pace towards net-zero carbon through fuel substitution and a higher rate of electrification, reaching a RE share of 47.4 per cent in 2030. As described later in this road map, there are several pathways to achieving a decarbonized electricity supply, with the most promising and cost-effective one being through renewable energy auction.

3. Energy efficiency

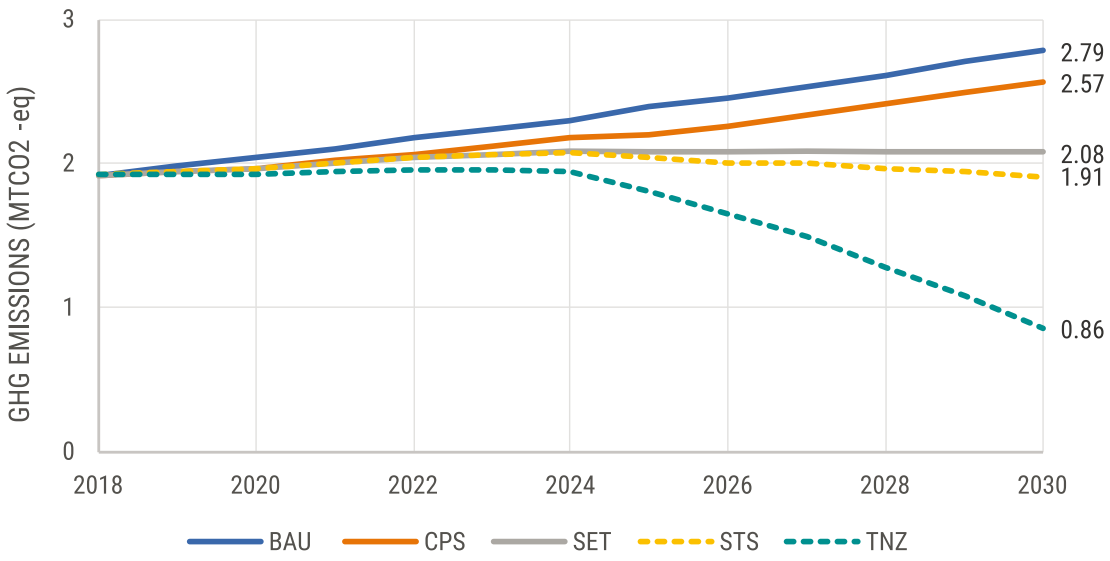
Chiang Rai's energy Intensity was estimated to be 6.12 ktoe/billion baht$_{2010}$ (in terms of TFEC) in 2018. It is expected to decline to 5.83 ktoe/billion baht$_{2010}$ by 2030 in the CP scenario, as GDP growth outpaces the growth in energy demand. With this reduction, Chiang Rai will have achieved the national energy efficiency target of 5.98 ktoe/billion baht$_{2010}$ by 2037. The SET scenario proposes several energy efficiency interventions across the demand sectors, which further decreases the energy intensity to 4.55 ktoe/billion baht$_{2010}$ by 2030, helping Chiang Rai achieve the energy efficiency target for SDG 7. The transport sector accounted for 72.6 per cent of the total energy demand in 2018 and is expected to be 75 per cent in 2030. This points to the need for adoption of energy efficiency measures across the sector. NEXSTEP proposes an increase of the electric vehicle share in the transport fleet to between 25 -50 per cent, by 2030. This will result in a reduction of 174 ktoe in energy demand from the CPS due the high efficiency of electric vehicles. Energy savings can also be sought from the residential and commercial sectors. The proposed measures are detailed further in chapter 4.

The energy demand reduction could be remarkable, should Chiang Rai consider a higher ambition for its transport sector, specifically, expanding mass public transport and electric vehicle adoption. The energy intensity of the STS scenario is projected to decline to 4.08 ktoe/billion $baht_{2010}$. The energy intensity of TNZ scenario is projected to be 3.5 ktoe/billion $baht_{2010}$.

4. GHG emissions

The GHG emissions in 2018 were estimated to be 1.92 $MTCO_2$-e, which considers the direct fuel combustion from the demand sector and emissions attributable to the grid electricity. Figure ES 1 shows the GHG emission trajectories for the different scenarios. The GHG emissions from the CPS are projected to reach 2.57 $MTCO_2$-e, while it decreases further to 2.08 $MTCO_2$-e in the SET scenario. The latter corresponds to a 25 per cent reduction from a BAU baseline, aligning the province's GHG emission reduction with the unconditional NDC target. More ambitious sustainable transport strategies further reduce the emissions to 1.91 $MTCO_2$-e in the SET scenario, while a drastic decrease is observed in the TNZ scenario – only 0.86 $MTCO_2$-e with a fully decarbonized electricity supply.

Figure ES 1. **Comparison of emissions by scenario, 2018-2030**



C. Key policy recommendations

As described above, there are ample opportunities for Chiang Rai to transform its energy system in alignment with the national targets and commitment towards the Paris Agreement. The key policy recommendations to help Chiang Rai in its sustainable energy transition, include:

1. **Sustainable transport strategies should be pursued, including the expansion of mass public transport and transport electrification.** This will bring a multitude of benefits, such as reduction of road traffic congestion (by mass public transport), energy demand and GHG emissions. More can be done to encourage such a transition, e.g., expanding EV charging and public transport infrastructure;
2. **Decarbonization of the power supply provides the highest potential in GHG emission reduction.** Several pathways can be considered, such as solar rooftop and RE auction, which may be the most cost-effective and efficient solutions. Chiang Rai's provincial government should consider working with the Government to identify modalities for implementing RE auction at the local level;
3. **Raised ambitions, particularly a higher level of electrification and a net-zero power sector, will put Chiang Rai on the path to a net-zero trajectory.** The national Government should support this direction by introducing enabling policy measures, e.g., mandating development and implementation of provincial net zero plans.

บทสรุปผู้บริหาร

การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (หรือ Sustainable Energy Transition: SET) มีวัตถุประสงค เพื่อส่งเสริมให้สามารถบรรลุเป้าหมายการพัฒนาอย่างยั่งยืน (หรือ Sustainable Development Goals 2030) ได้ในปี พ.ศ. 2573 ประกอบกับเป้าประสงค์ภายใต้ความตกลงปารีส (หรือ Paris Agreement) มีความยากและซับซ้อนสำหรับผู้พัฒนานโยบาย ด้วยเหตุนี้ เพื่อให้การเจริญเติบโตด้านเศรษฐกิจมีความยั่งยืน, สามารถตอบสนองต่อความต้องการด้านพลังงาน ที่เพิ่มมากขึ้น และลดปริมาณการปล่อยก๊าซเรือนกระจก ไปจนถึงเกิดความตระหนักและการใช้ประโยชน์จากการเชื่อมโยงระหว่างเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และข้ออื่น ๆ โดยการเชื่อมโยงนี้ ESCAP ได้ดำเนินการพัฒนาเครื่องมือ "National Expert SDG7 Tool for Energy Planning" (หรือ NEXSTEP) ซึ่งเป็นเครื่องมือที่มีส่วนช่วยให้ผู้พัฒนานโยบายสามารถสร้างแบบจำลองสถานการณ์สำหรับประกอบการตัดสินใจเกี่ยวกับนโยบายเพื่อให้บรรลุเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และเป้าหมายการลดก๊าซเรือนกระจกของประเทศ (NDCs) โดยการดำเนินการนี้ได้จัดทำขึ้นเพื่อตอบสนองต่อปฏิญญารัฐมนตรีที่มีต่อการประชุม Asian and Pacific Energy Forum ครั้งที่ 2 (เมษายน พ.ศ. 2561 กรุงเทพฯ) และได้มีมติคณะกรรมการ 74/9 นอกจากนี้ NEXSTEP ยังได้รับการสนับสนุนจากคณะกรรมการด้านพลังงานในสมัยที่ 2 ด้วยคำแนะนำในการขยายจำนวนประเทศที่ได้รับการสนับสนุนจากเครื่องมือนี้

โดยการสนับสนุนนี้ได้มีการนำไปประยุกต์ใช้กับเมืองและอนุภูมิภาคในหลายแห่ง เพื่อก่อให้เกิดความตระหนักถึงความจำเป็นของความพยายามในระดับอนุภูมิภาคอันจะมีส่วนช่วยสนับสนุนให้เป้าหมายการพัฒนาอย่างยั่งยืนประสบความสำเร็จตามที่กำหนดไว้ในปี พ.ศ. 2573 และความมุ่งมั่นระดับชาติที่มีต่อความตกลงปารีส ในการนี้ ESCAP และกรมพัฒนาพลังงานทดแทนและอนุรักษ์พลังงาน (พพ.) กระทรวงพลังงาน ประเทศไทย ได้ประสานความร่วมมือกันเพื่อสนับสนุนสามจังหวัดของประเทศไทยในการพัฒนาแผนงานการเปลี่ยนผ่านด้านพลังงานอย่างยั่งยืน (หรือ Sustainable Energy Transition: SET) โดยใช้เครื่องมือ NEXSTEP ทั้งนี้ แผนงานการเปลี่ยนผ่านด้านพลังงานอย่างยั่งยืน (SET) ได้พัฒนาขึ้นสำหรับจังหวัดเชียงราย ซึ่งได้กำหนดตัวเลือกเทคโนโลยีและนโยบาย/มาตรการ ที่เป็นทิศทางในการพัฒนาของจังหวัดให้สอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในปี พ.ศ. 2573, เป้าหมายการพัฒนาประเทศและความมุ่งมั่น ต่อความตกลงปารีส

แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน

จังหวัดเชียงราย เป็นจังหวัดที่อยู่เหนือสุดของประเทศไทย มีความโดดเด่นด้วยลักษณะภูมิประเทศที่เป็นภูเขาและแม่น้ำกกที่เป็นแม่น้ำสำคัญของจังหวัด ประกอบกับวัฒนธรรมดั้งเดิมที่ยังคงผสมผสานกับวิถีชีวิตในปัจจุบัน จังหวัดมีพื้นที่ 11,678 ตารางกิโลเมตร มีประชากรประมาณ 1.3 ล้านคนในปี พ.ศ. 2561 ผลิตภัณฑ์รวมของจังหวัด (GPP) ในปี พ.ศ. 2561 อยู่ที่ 107.3 พันล้านบาท และผลิตภัณฑ์มวลรวมของประเทศ (GDP) ต่อหัวอยู่ที่ประมาณ 93 พันบาท ตามลำดับ

แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) นี้ ประกอบด้วยวัตถุประสงค์ 2 ประการ โดยประการแรกมีเป้าหมายเพื่อจัดทำกรณีฐาน (Scenario Baseline) ระหว่างปี พ.ศ. 2562 – พ.ศ. 2579 พิจารณา ถึงการกำหนดนโยบายในปัจจุบัน และประการที่สอง คือ เพื่อกำหนดตัวเลือกมาตรการ และเทคโนโลยีซึ่งมีส่วนช่วยส่งเสริมให้การพัฒนาจังหวัดเชียงรายมีความสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7, เป้าหมายการพัฒนาประเทศ และลดการปล่อยก๊าซเรือนกระจกในภาคพลังงาน โดยแบบจำลองสถานการณ์ (Scenario) ทั้งหมด 4 แบบจำลองภายใต้ แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) มีรายละเอียด ดังต่อไปนี้

- แบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (Current Policy Scenario: CPS) ซึ่งได้พัฒนาขึ้นตามนโยบายและแผนที่มีอยู่ในปัจจุบัน และนำมาใช้เพื่อวิเคราะห์ช่องว่างสำหรับนโยบายและแผนที่มีอยู่ โดยสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7, เป้าหมายการพัฒนาประเทศ และความมุ่งมั่น ต่อความตกลงปารีส
- แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ได้นำเสนอตัวเลือกเทคโนโลยีและนโยบาย ซึ่งจะมีส่วนช่วยให้การพัฒนาจังหวัดเชียงรายมีความสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และเป้าหมายการพัฒนาประเทศ
- แบบจำลองสถานการณ์การพัฒนาระบบขนส่งอย่างยั่งยืน (Sustainable Transport Strategies: STS) ได้

นำเสนอแนวทางการปรับเปลี่ยนด้านการขนส่งผ่านการประยุกต์ใช้ระบบขนส่งสาธารณะในระดับที่สูงขึ้นและยานพาหนะไฟฟ้า (EV)

- แบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (Towards Net Zero: TNZ) โดยเป็นสถานการณ์ที่มีความท้าทายมากที่สุด และมุ่งเน้นแนวทางไปสู่การบรรลุการปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ในอนาคตอันใกล้ผ่านการลดปริมาณการปล่อยก๊าซเรือนกระจกจากแหล่งจ่ายไฟฟ้า การทดแทนเชื้อเพลิงและความมุ่งมั่นในการใช้พลังงานในรูปแบบของพลังงานไฟฟ้าที่มีมากขึ้น (Electrification)

นอกจากนี้ แบบจำลองสถานการณ์แบบเป็นไปตามปกติ (BAU) ได้มีการจัดทำขึ้นเพื่อแสดงถึงกรณีฐาน ในกรณีที่ไม่มีการประยุกต์ใช้นโยบาย/การริเริ่มใด ๆ หรือ ในกรณีที่นโยบายและแผนที่มีอยู่ในปัจจุบันไม่สามารถบรรลุผลลัพธ์ได้โดยสถานการณ์นี้มีส่วนช่วยให้สามารถระบุเป้าหมายของประเทศได้ เช่น เป้าหมายการลดการปล่อยก๊าซเรือนกระจก เป็นต้น

การเชื่อมโยงแนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืนของจังหวัดเชียงราย เข้ากับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และเป้าหมายการพัฒนาประเทศ

การเข้าถึงพลังงานสมัยใหม่ (Modern Energy)

จังหวัดเชียงรายได้บรรลุเป้าหมายสำหรับสัดส่วนการเข้าถึงพลังงานไฟฟ้าแล้ว ในขณะที่ปี พ.ศ. 2561 ประชากรประมาณร้อยละ 75.6 มีการใช้เทคโนโลยีสำหรับการประกอบอาหารที่สะอาด ซึ่งรวมไปถึงร้อยละ 8.9 ของครัวเรือนทั้งหมดไม่ได้ประกอบอาหารเองในครัวเรือน และร้อยละ 24.4 ที่เหลือ (หรือ ประมาณ 136,300 ครัวเรือน) ยังคงใช้เทคโนโลยี ที่ประสิทธิภาพต่ำซึ่งไม่เป็นมิตรต่อสิ่งแวดล้อมและอาจก่อให้เกิดผลกระทบด้านสุขภาพ ทั้งนี้ การเข้าถึงเทคโนโลยีสำหรับการประกอบอาหารที่สะอาดของประเทศมีอัตราเพิ่มขึ้นร้อยละ 0.6 ต่อปี ในระหว่างปี พ.ศ. 2558 - พ.ศ. 2562 โดยคาดว่า จะบรรลุสถานการณ์ที่ครัวเรือนร้อยละ 81 สามารถเข้าถึงเทคโนโลยีสำหรับการประกอบอาหารที่สะอาดได้ในปี พ.ศ. 2567 โดยเครื่องมือ NEXSTEP เสนอให้มีการปรับปรุงประสิทธิภาพเตาสำหรับประกอบอาหาร (หรือ Improved Cook Stoves: ICSs) อาจสามารถช่วยสนับสนุนให้ครัวเรือนสามารถพลังงานสะอาดได้

พลังงานทดแทน (Renewable Energy)

สัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (Total Final Energy Consumption: TFEC) ในปี พ.ศ. 2561 มีการใช้พลังงานทดแทนเพียงแค่ร้อยละ 9.6 เปรียบเทียบกับการใช้พลังงานขั้นสุดท้าย ซึ่งพิจารณาว่าเป็นสัดส่วนที่ค่อนข้างต่ำเนื่องจากความต้องการใช้เชื้อเพลิงปิโตรเลียมในปริมาณสูงสำหรับภาคการขนส่ง (หรือ ร้อยละ 72.6 ของความต้องการใช้พลังงานทั้งหมด) ด้วยเหตุนี้ ส่งผลให้จังหวัดมีส่วนช่วยผลักดันสำหรับการบรรลุเป้าหมายด้านพลังงานทดแทนของประเทศที่ร้อยละ 30 ของ TFEC ที่กำหนดไว้สำหรับปี พ.ศ. 2580 ได้ไม่มาก ทั้งนี้ สัดส่วนการใช้พลังงานทดแทนภายใต้แบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) ที่ขับเคลื่อนโดยการเพิ่มสัดส่วนการใช้พลังงานทดแทนในโครงข่ายไฟฟ้า ซึ่งคาดว่าจะเพิ่มขึ้นจากร้อยละ 17.8 ในปี พ.ศ. 2562 เป็นร้อยละ 24.6 ในปี พ.ศ. 2573 และการใช้เชื้อเพลิงชีวภาพในภาคขนส่งเพิ่มขึ้นเพียงเล็กน้อย โดยสัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (TFEC) ในแบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) จะลดลงร้อยละ 12.2 เนื่องจากการใช้เชื้อเพลิงชีวมวล ที่ลดลงสำหรับประกอบอาหารในเขตเมือง และการลดการใช้เชื้อเพลิงชีวภาพในภาคการขนส่ง ทั้งนี้ สัดส่วนการใช้พลังงานทดแทนจะเพิ่มขึ้นเป็นร้อยละ 12.9 ภายใต้แบบจำลองสถานการณ์การพัฒนาระบบขนส่งอย่างยั่งยืน (STS) เนื่องจาก การลดการใช้เชื้อเพลิงปิโตรเลียมในภาคการขนส่ง

สัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (TFEC) สำหรับแบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) คาดหวังว่าจะอยู่ในระดับสูง ซึ่งมุ่งเน้นไปที่การจ่ายไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจก นอกจากนั้นแบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) ยังมีเป้าหมายที่จะบรรลุการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (Net-Zero Carbon) ผ่านการใช้เชื้อเพลิงเพื่อทดแทนเชื้อเพลิงเดิมและอัตราการใช้ไฟฟ้าที่สูงขึ้น โดยสัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (TFEC) บรรลุ ร้อยละ 47.4 ในปี พ.ศ. 2573 ทั้งนี้ แนวทางต่าง ๆ เพื่อให้บรรลุการจัดหาไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจก โดยวิธีที่มีประสิทธิภาพและคุ้มค่าที่สุด คือ การประมูลพลังงานหมุนเวียน

การปรับปรุงประสิทธิภาพการใช้พลังงาน (Energy Efficiency)

ความเข้มข้นการใช้พลังงาน (Energy Intensity: EI) ของจังหวัดเชียงราย ได้รับการประเมินอยู่ที่ 6.12 ktoe/ ล้านบาท2553 (ในแง่ของสัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย TFEC) ในปี พ.ศ. 2561 โดยคาดว่าจะลดลงอยู่ที่ 5.83 ktoe/ล้านบาท2553 ในปี พ.ศ. 2573 ภายใต้แบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS)

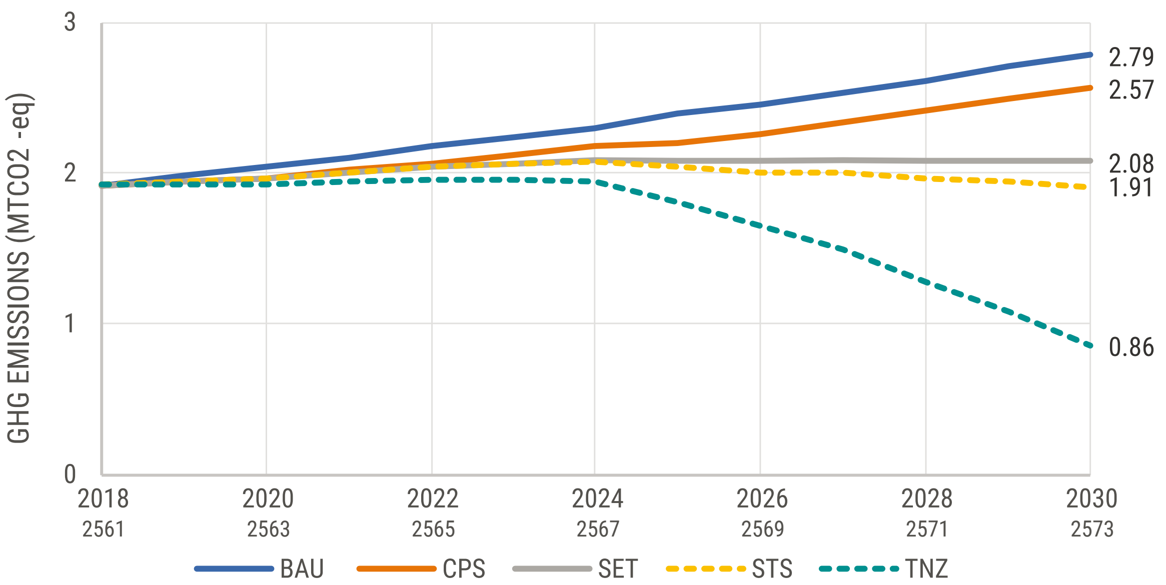
เนื่องจากการเติบโตของผลิตภัณฑ์รวมของประเทศ (GDP) จะเพิ่มขึ้นมากกว่าการเติบโตของความต้องการพลังงาน จากแบบจำลองนี้ส่งผลให้จังหวัดเชียงรายสามารถเป้าหมายการปรับปรุงประสิทธิภาพการใช้พลังงานของประเทศที่ 5.98 ktoe/พันล้านบาท2553 ได้ภายในปี พ.ศ. 2580 ทั้งนี้ แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) เสนอให้มีการประยุกต์การปรับปรุงประสิทธิภาพการใช้พลังงานในภาคที่มีความต้องการใช้พลังงาน ซึ่งสามารถส่งผลให้ความเข้มข้นการใช้พลังงานลดลงเหลือ 4.55 ktoe/พันล้านบาท2553 ภายในปี พ.ศ. 2573 อันจะมีส่วนสนับสนุนให้จังหวัดเชียงรายสามารถบรรลุเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 ประกอบกับ ความต้องการใช้พลังงานในภาคการขนส่งคิดเป็นสัดส่วนประมาณร้อยละ 72.6 ของความต้องการพลังงานทั้งหมดในปี พ.ศ. 2561 ซึ่งคาดว่าจะเพิ่มขึ้นเป็นร้อยละ 75 ในปี พ.ศ. 2573 ด้วยเหตุนี้ จึงจำเป็นต้องมีการนำมาตรการประหยัดพลังงานไปประยุกต์ใช้กับหลายภาคส่วนต่าง ๆ โดยเครื่องมือ NEXSTEP ได้เสนอให้เพิ่มสัดส่วนการใช้ยานพาหนะไฟฟ้าในภาคการขนส่งให้ครอบคลุมร้อยละ 25 ถึงร้อยละ 50 ภายในปี พ.ศ. 2573 ด้วยเหตุนี้ ผลลัพธ์ที่คาดการณ์ไว้ความต้องการพลังงานจะลดลง 174 ktoe จากแบบจำลองสถานการณ์สำหรับนโยบาย ในปัจจุบัน (CPS) อันเป็นผลจากจากประสิทธิภาพของยานพาหนะไฟฟ้า นอกจากนี้ การลดการใช้พลังงานสามารถส่งเสริม ในภาคที่อยู่อาศัยและภาคพาณิชยกรรมได้ด้วยเช่นกัน

ความต้องการพลังงานที่ลดลงจะสามารถประสบความสำเร็จได้สูง หากจังหวัดเชียงรายพิจารณาถึงความทะเยอทะยานที่เพิ่มขึ้นสำหรับภาคการขนส่งของจังหวัด ซึ่งสามารถทำได้โดยการเพิ่มประสิทธิภาพระบบขนส่งสาธารณะ และเพิ่มสัดส่วนการใช้ยานพาหนะไฟฟ้า ทั้งนี้ ความเข้มข้นพลังงานภายใต้แบบจำลองสถานการณ์การพัฒนาระบบขนส่งอย่างยั่งยืน (STS) คาดว่าจะลดลงเหลือ 4.08 ktoe/พันล้านบาท2553 ความเข้มพลังงานภายใต้แบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อย ก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) คาดว่าจะอยู่ที่ 3.5 ktoe/พันล้านบาท2553 ตามลำดับ

การปล่อยปริมาณการปล่อยก๊าซเรือนกระจก (GHG emissions)

การปล่อยก๊าซเรือนกระจกในปี พ.ศ. 2561 อยู่ที่ 1.92 $MTCO_2$-e ซึ่งพิจารณาครอบคลุมถึงการเผาไหม้เชื้อเพลิงโดยตรงจากภาคที่มีความต้องการใช้เชื้อเพลิง และการปล่อยก๊าซเรือนกระจกที่เกิดจากไฟฟ้าในสายส่ง โดย ES 1 แสดงถึงระดับการปล่อยก๊าซเรือนกระจกจากสถานการณ์ต่างๆ โดยการปล่อยก๊าซเรือนกระจกจากแบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) คาดว่าจะเพิ่มถึง 2.57 $MTCO_2$-e ในขณะที่แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ลดลงอยู่ที่ 2.08 $MTCO_2$-e โดยลดลงร้อยละ 25 จากกรณีฐาน (BAU) ซึ่งสอดคล้องกับเป้าหมายการลดการปล่อยก๊าซเรือนกระจกของจังหวัด และเป้าหมายการลดก๊าซเรือนกระจกของประเทศ (NDC) แบบไม่มีเงื่อนไข ทั้งนี้ ความทะเยอทะยานในภาคการขนส่งจะส่งผลให้สามารถลดการปล่อยก๊าซเรือนกระจกได้ 1.91 $MTCO_2$-e ภายใต้แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ในขณะที่ เป็นที่น่าสังเกตว่า ภายใต้แบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) จะสามารถลดการปล่อยก๊าซ เรือนกระจกได้เพียง 0.86 $MTCO_2$-e ในกรณีที่มีการจ่ายไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจกทั้งหมด

ตัวอย่าง เปรียบเทียบการปล่อยก๊าซเรือนกระจกในแต่ละสถานการณ์ ระหว่างปี พ.ศ. **2565 – พ.ศ. 2573**



ข้อเสนอแนะเชิงนโยบาย

ตามที่ได้นำเสนอไว้ข้างต้นนั้น จังหวัดเชียงรายยังมีโอกาสมากมายที่จะปรับเปลี่ยนระบบพลังงานให้สอดคล้อง กับเป้าหมายของประเทศและความมุ่งมั่นต่อความตกลงปารีส ทั้งนี้ ข้อเสนอแนะเชิงนโยบายที่สำคัญเพื่อมีส่วน ช่วยให้ จังหวัดเชียงรายสามารถมุ่งไปสู่การเปลี่ยนแปลงด้านพลังงานอย่างยั่งยืน ประกอบด้วย

1. การเพิ่มสัดส่วนการใช้ยานพาหนะไฟฟ้าอย่างรวดเร็วเพื่อสนับสนุนการขนส่งแบบคาร์บอนต่ำ ด้วยการดำเนินการนี้จะสามารถนำมาซึ่งประโยชน์มากมาย เช่น ลดความแออัดของการจราจรบนถนนผ่านการใช้ระบบขนส่งสาธารณะ ลดความต้องการใช้พลังงานและลดปริมาณการปล่อยก๊าซเรือนกระจก เป็นต้น ทั้งนี้ จังหวัดสามารถดำเนินการเพิ่มเติมเพื่อสนับสนุนให้เกิดการเปลี่ยนแปลงดังกล่าว ได้โดยการเพิ่มจำนวนสถานีชาร์จสำหรับยานพาหนะไฟฟ้า และโครงสร้างพื้นฐานการขนส่งสาธารณะ
2. การใช้พลังงานที่ไม่ทำให้เกิดคาร์บอนไดออกไซด์ (Decarbonization) ในภาคผู้ผลิตพลังงานถือได้ว่ามีศักยภาพในการลดการปล่อยก๊าซเรือนกระจกสูงสุด ซึ่งสามารถดำเนินการได้โดยการติดตั้งระบบโซลาร์เซลล์บนหลังคา (Solar Rooftop) และการประมูลพลังงานทดแทน (RE Auction) โดยเป็นแนวทางดำเนินการที่มีการลงทุนน้อยที่สุด ทั้งนี้ หน่วยงานราชการในระดับจังหวัดอาจพิจารณาถึงการดำเนินงานร่วมกับหน่วยงานกลาง เพื่อกำหนดแนวทางการประมูลพลังงานทดแทนในระดับจังหวัด
3. เพิ่มความท้าทายโดยมุ่งเน้นไปที่การเพิ่มระดับของการใช้พลังงานไฟฟ้า และการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ในภาคพลังงานซึ่งทำให้จังหวัดเชียงรายอยู่บนเส้นทางของการขับเคลื่อนการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ ทั้งนี้ หน่วยงานกลางควรสนับสนุนเพื่อขับเคลื่อนแนวทางนี้ เช่น การมอบหมายให้จังหวัดดำเนินการพัฒนาได้ และดำเนินการตามแผนการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ของจังหวัด

1. Introduction

1.1. Background

Transitioning the energy sector to achieve the 2030 Agenda for Sustainable Development and the objectives of the Paris Agreement presents a complex and difficult task for policymakers. It needs to ensure a sustained economic growth, respond to increasing energy demand, reduce emissions as well as consider and capitalise on the interlinkages between Sustainable Development Goal 7 (SDG 7) and other SDGs. In this connection. The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) has developed the National Expert SDG Tool for Energy Planning (NEXSTEP). This tool enables policymakers to make informed policy decisions to support the achievement of the SDG 7 targets as well as emission reduction targets – Nationally Determined Contributions (NDCs). The initiative has been undertaken in response to the Ministerial Declaration of the Second Asian and Pacific Energy Forum (April 2018, Bangkok) and Commission Resolution 74/9 which endorsed its outcomes. NEXSTEP also garnered the support of the Committee on Energy in its Second Session, with recommendations to expand the number of countries being supported by this tool.

The NEXSTEP tool has been specially designed to support policymakers in analysing the energy sector and developing an energy transition plan in the context of SDG 7. Further details of the NEXSTEP methodology are discussed in the next chapter. While this tool has been designed to help in developing the SDG 7 road map at the national level, it can also be used for subnational energy planning.

1.2. SDG 7 targets and indicators

SDG 7 aims to ensure access to affordable, reliable, sustainable and modern energy for all. It has three key targets, which are outlined below.

- Target 7.1. "By 2030, ensure universal access to affordable, reliable and modern energy services." Two indicators are used to measure this target: (a) the proportion of the population with access to electricity; and (b) the proportion of the population with primary reliance on clean cooking fuels and technology.
- Target 7.2. "By 2030, increase substantially the share of renewable energy in the global energy mix". This is measured by the renewable energy share in total final energy consumption (TFEC). It is calculated by dividing the consumption of energy from all renewable sources by total energy consumption. Renewable energy consumption includes consumption of energy derived from hydropower, solid biofuels (including traditional use), wind, solar, liquid biofuels, biogas, geothermal, marine and waste. Due to the inherent complexity of accurately estimating traditional use of biomass, NEXSTEP focuses entirely on modern renewables (excluding traditional use of biomass) for this target.
- Target 7.3. "By 2030, double the global rate of improvement in energy efficiency", as measured by the energy intensity of the economy. This is the ratio of the total primary energy supply (TPES) and GDP. Energy intensity is an indication of how much energy is used to produce one unit of economic output. As defined by the International Energy Agency (IEA), TPES is made up of production plus net imports minus international marine and aviation bunkers plus stock changes. For comparison purposes, GDP is measured in constant terms at 2017 PPP.

2. NEXSTEP methodology

The main purpose of NEXSTEP is to help design the type and mix of policies that would enable the achievement of the SDG 7 targets and the emission reduction targets (under NDCs) through policy analysis. However, policy analysis cannot be done without modelling energy systems to forecast/backcast energy and emissions, and economic analysis to assess which policies or options would be economically suitable. Based on this requirement, a three-step approach has been proposed. Each step is discussed in the following sections.

2.1. Key methodological steps

(a) Energy and Emissions Modelling

NEXSTEP begins with the energy systems modelling to develop different scenarios to achieve SDG 7 by identifying potential technical options for each scenario. Each scenario contains important information including the final energy (electricity and heat) requirement by 2030, possible generation/supply mix, emissions and the size of investment required. The energy and emissions modelling component use the Long-range Energy Alternatives Planning (LEAP). It is a widely used tool for energy sector modelling and for creating energy and emissions scenarios. Many countries have used LEAP to develop scenarios as a basis for their Intended Nationally Determined Contributions (INDCs). Figure 1 shows the different steps of the methodology.

(b) Economic Analysis Module

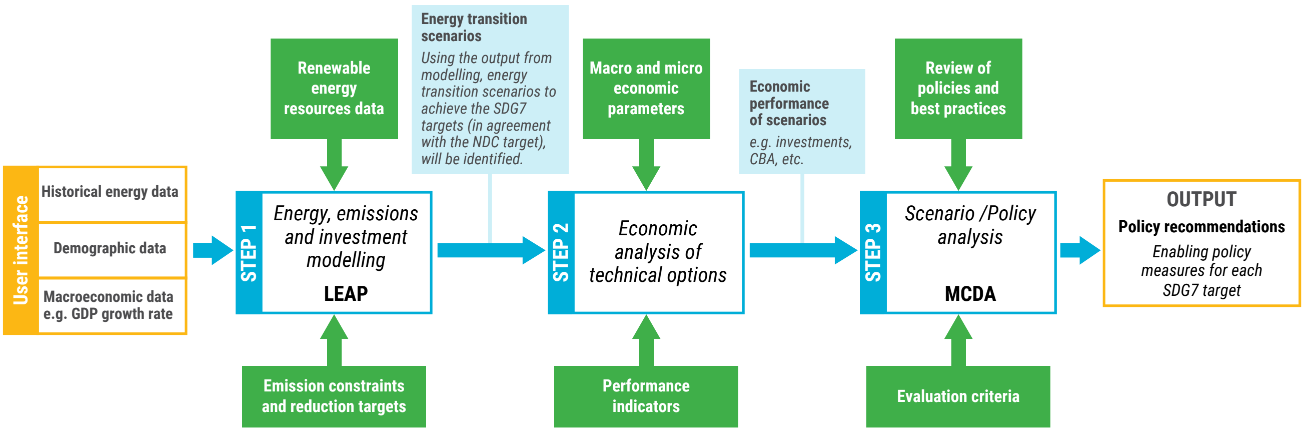
The energy and emissions modelling section selects the appropriate technologies, and the economic analysis builds on this by selecting the least cost energy supply mix for the country. The economic analysis is used to examine economic performances of individual technical options identified and prioritize least-cost options. As such, it is important to estimate some of the key economic parameters, such as net present value, internal rate of return and payback period. A ranking of selected technologies will help policymakers to identify and select economically effective projects for better allocation of resources.

The economic analysis helps present several economic parameters and indicators that would be useful for policymakers in making an informed policy decision.

(c) Scenario and policy Analysis

Using Multi-Criteria Decision Analysis (MCDA) tool, this prioritised list of scenarios is assessed in terms of their techno-economic and environmental dimensions to convert to a policy measure. The top-ranked scenario from the MCDA process is essentially the output of NEXSTEP, which is then used to develop policy recommendations.

Figure 1. Different components of the NEXSTEP methodology



This tool is unique in a way that no other tools look at developing policy measures to achieve SDG 7. The key feature that makes it outstanding is the backcasting approach for energy and emissions modelling. This is important when it comes to planning for SDG 7 as the targets for the final year (2030) are already given; thus the tool needs to be able to work its way backward to the current date and identify the best possible pathway.

2.2. Scenario definitions

The LEAP modelling system is designed for scenario analysis, to enable energy specialists to model energy system evolution based on current energy policies. In the NEXSTEP model for Chiang Rai province of Thailand, three main scenarios have been modelled: (a) BAU scenario; (b) Current Policy scenario (CPS); and (c) Sustainable Energy Transition (SET) scenario. In addition, two ambitious scenarios, the (d) Sustainable Transport scenario (STS) and (e) Towards Net Zero (TNZ) scenario, have been modelled for exploring how Chiang Rai may adopt more vigorous sustainable transport strategies and move towards a net zero future:

(a) BAU scenario – this scenario follows historical demand trends, based on simple projections, such as using GDP and population growth. It does not consider emission limits or renewable energy targets. For each sector, the final energy demand is met by a fuel mix reflecting the current shares in TFEC, with the trend extrapolated to 2030. Essentially, this scenario aims to indicate what will happen if no enabling policies are implemented or the existing policies fail to achieve their intended outcomes;

(b) CPS scenario – inherited and modified from the BAU scenario, this scenario considers relevant local and national policies and plans in place. For example, the recently adopted building energy code and Thailand's Power Development Plan, 2018-2037;

(c) SET scenario – this scenario aims to align the province's energy transition pathway with the national energy intensity and renewable energy targets as well as the unconditional NDC target;

(d) STS scenario – this scenario explores how the province can further transition its transport sector through a greater degree of mass public transport and electric vehicles usage;

(e) TNZ scenario – this is the most ambitious scenario of all, as it considers several ambitious measures to realise a more rapidly decline in the GHG emissions reduction trajectory, paving the way towards achieving net zero in the near future.

2.3. Economic analysis

The economic analysis considers the project's contribution to the economic performance of the energy sector. The purpose of a Cost-Benefit Analysis (CBA) is to make better informed policy decisions. It is a tool to weigh the benefits against costs and facilitate an efficient distribution of resources in public sector investment.

2.3.1. Basics of economic analysis

The economic analysis of public sector investment differs from a financial analysis. A financial analysis considers the profitability of an investment project from the investor's perspective. A project is financially viable only if all the monetary costs can be recovered in the project lifetime. Project financial viability is not enough in an economic analysis, and contribution to societal welfare should be also examined. For example, in the case of a coal power plant, the emissions from combustion process emit particulate matter which is inhaled by the local population, causing health damage and accelerated climate change. In an economic analysis a monetary value is assigned to the GHG emission to value its GHG emissions abatement. This is done in the scenario analysis, discussed in subsection 2.3.3.

2.3.2. Cost parameters

The project cost is the fundamental input in the economic analysis. The overall project cost is calculated using the following two parameters:

(a) Capital cost – capital infrastructure costs for technologies, which are based on country-specific data to improve the analysis. They include land, building, machinery, equipment and civil works.

(b) Operation and maintenance cost consists of fuel, labour and maintenance costs. Power generation facilities classify operation and maintenance costs as fixed ($/MW) and variable ($/MWh) cost.

2.3.3. Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the Multi-Criteria Decision Analysis (MCDA) tool, with a set of criteria and weights assigned to each criterion. Ideally, the weights assigned to each criterion should be decided in a stakeholder consultation. If deemed necessary, this step can be repeated using the NEXSTEP online portal in consultation with stakeholders when the participants may wish to change weights of each criterion and where the total weight needs to be 100 per cent. The criteria considered in the MCDA tool can include the following – however, stakeholders may wish to add/remove criteria to suit the local context:

- Access to clean cooking fuel
- Energy efficiency
- Share of renewable energy
- Emissions in 2030
- Alignment with Paris Agreement
- Fossil fuel subsidy phased out
- Price on carbon
- Fossil fuel phase-out
- Cost of access to electricity
- Cost of access to clean cooking fuel
- Investment cost of the power sector
- Net benefit from the power sector

This step is generally applied to all countries utilizing NEXSTEP in developing the national SDG 7 or the subnational SET Road map, as a means to suggest the best way forward for the countries or cities by prioritising the several scenarios.

3. Overview of the Chiang Rai province energy sector

3.1. Overview of the Chiang Rai province

Chiang Rai lies in upper northern Thailand and is Thailand's northernmost province. Covering a total area of 11,503 km2, Chiang Rai is a mountainous province with an average elevation of 580 metres. While the eastern part of the province is characterized by relatively flat river plains, the northern and western part consists of the hilly terrain of the Thai highlands. Chiang Rai province is intersected by Asian Highway 2 – which runs for more than 13,000 kilometres from Denpasar in Indonesia to Khosravi in the Islamic Republic of Iran – and by Asian Highway 3 – which runs for more than 7,000 km from Kengtung in Myanmar to Ulan-Ude in the Russian Federation. The surrounding mountainous region of Chiang Rai has a historic orientation to the north, which was somewhat altered by the completion of the southern highway in the 1920s. Chiang Rai is one of Thailand's significant provinces that drive the country's economy, especially cross-border trading between northern Thailand and eastern Myanmar.

Today, Chiang Rai is a traveller's paradise, as it is endowed with abundant natural tourist attractions and antiquities; in fact, the province itself is evidence of past civilization. Attractions range from magnificent mountain scenery, ruins of ancient settlements, historic sites, Buddhist shrines as well as ethnic villages as the province is also home to several hilltribes who maintain fascinating lifestyles.

The province is subdivided in 18 districts (Amphoe). These are further subdivided into 124 subdistricts (tambon) and 1,510 villages (mooban).

3.2. Provincial energy profile

(a) Access to modern energy. The population of Chiang Rai province in 2018 was reported to be 1.3 million, while the number of households stood at 558.800 households. Chiang Rai has already achieved universal access to electricity, while the clean cooking access rate is estimated to be 75.6 per cent. This also includes the 8.9 per cent of households that did not conduct cooking at home. The remaining 24.4 per cent of the population relied on inefficient and unclean technologies such as charcoal/wood stoves and kerosene stoves as their primary cooking technology. Overall, liquefied petroleum gas (LPG) cooking stoves are the most dominant primary clean cooking technology, with an estimated share of 74 per cent. This is followed by electric cooking stoves, estimated at 1.7 per cent.

(b) Modern renewable share in TFEC. Modern renewable energy delivered approximately 9.6 per cent of TFEC in 2018, contributed by renewable electricity, biofuels usage in the transport sector and a substantial biomass consumption in the industrial sector, as further explained below. The electricity requirement of the region is fulfilled almost exclusively by electricity from the central grid. The percentage share of renewable energy considers the share of renewable electricity of the central grid, which is estimated to have been 17.8 per cent in 2018.[2] Other usage of renewable energy includes a small amount of biofuel consumption in the transport sector (34.6 ktoe). The national biodiesel mandate in 2018 was 7 per cent, while several blend rates are available in the market, according to the United States Department of Agriculture (USDA, 2021). NEXSTEP modelling assumes an average blend rate of 13 per cent for transport petroleum usage. Petroleum fuel consumption in the transport sector is the most substantial, at 400.5 ktoe (90 per cent of transport sector's TFEC) in 2018.

(c) Energy intensity. The energy intensity in 2018, calculated in accordance with the SDG 7.3 target (total primary energy supply per GDP) (in terms of PPP2017), was 2.9 MJ/US$2017. In terms of total final energy consumption per GDP2010, it is estimated to have been 6.12 ktoe/billion baht.[3]

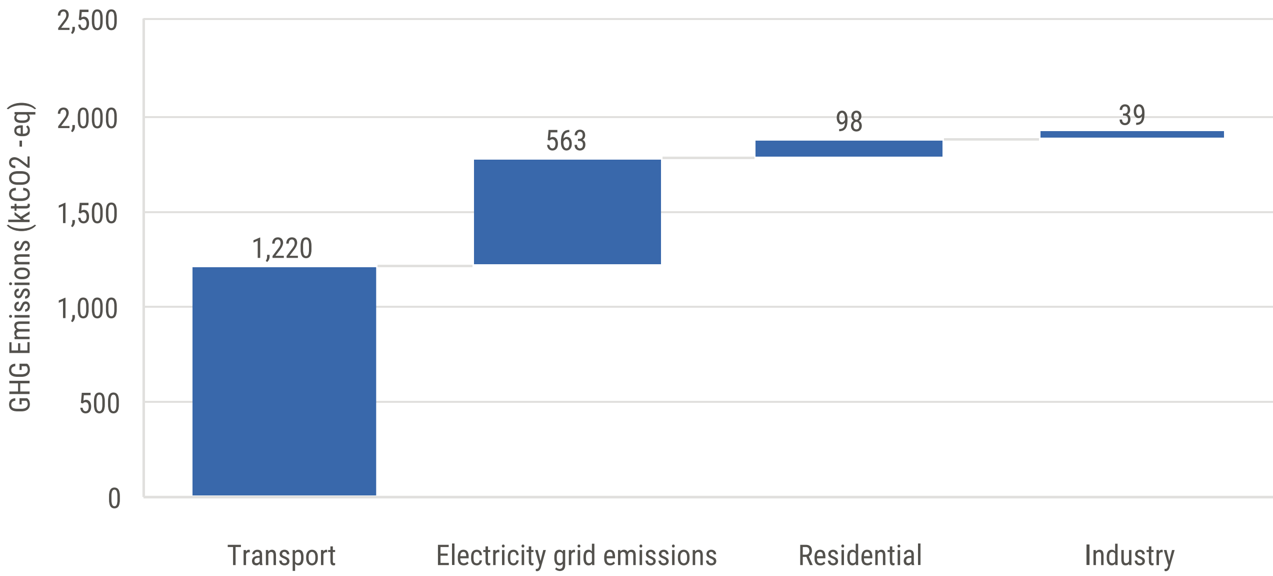
(d) GHG emissions. The GHG emissions from the energy sector is estimated at 1.9 MTCO$_2$-e in 2018. The GHG emissions breakdown is shown in figure 2. The emissions from the transport sector were the largest at 1.22 MTCO$_2$-e, arising from direct fuel combustion in internal combustion engines. Emissions related to electricity usage are not

2 Based on the Power Development Plan 2018-2037.

3 The provincial GDP was registered at 206.9 billion baht in 2018. Considering a CPI of 112.47 for 2018 and CPI of 100 for 2010 (from the World Bank database), the GDP 2010 for 2018 is estimated at 183.9 billion baht.

attributable to the electricity-consuming demand sectors but are attributable to the supply side, i.e., purchased grid electricity. As electricity is the only energy supply in the commercial, agriculture and non-specified sectors (see figure 3), emissions attributable to these sectors are already accounted for in the electricity supply category. The grid emission factor considered for base year 2018 is 0.413 tCO_2/MWh. The total emission attributable towards overall electricity usage is estimated at 0.56 $MTCO_2$-e. Direct combustion of fuels is also relevant to the industrial and residential sectors, which emit around 39 $ktCO_2$-e and 98.4 $ktCO_2$-e, respectively. Considering emissions both from direct fuel combustion and electricity usage, the emission profile is as follows – transport, 64 per cent; residential, 17 per cent; industry, 12 per cent; commercial, 6 per cent; and non-specified, 1 per cent. industry 12 per cent, commercial 6 per cent and non-specified 1 per cent.

Figure 2. GHG emissions in 2018



The current progress of Chiang Rai's energy sector in accordance with the SDG indicators are summarized in Annex I.

3.3. Provincial energy balance, 2018

This subsection describes the estimated energy consumption built up by using data collected with a bottom-up approach, based on data for such as activity level and energy intensity. The majority of the following 2018 energy data has been collected from various sources in consultation with the Chiang Rai Provincial Authority and DEDE, unless stated otherwise. Further details on the data and assumptions used can be found in Annex II.

The TFEC in 2018 was 599 ktoe. The largest energy-consuming sector is the transport sector, consuming 435 ktoe (72.6 per cent of the TFEC) in 2018. Of this share. 98.4 per cent is attributable to road transport and the remaining 1.6 per cent is attributable to aviation transport. In terms of fuel, the largest share comes from diesel (74 per cent), followed by gasoline (14.8 per cent) and biofuel (7.9 per cent).

The second-largest demand was from the residential sector, at 82 ktoe (13.7 per cent) in 2018. About 59 per cent of the energy consumed was in the form of electricity to power electrical appliances, while LPG (38.8 per cent) and charcoal (2.7 per cent) were used for residential cooking purposes.

The industrial sector's consumption in 2018 was 53 ktoe (8.9 per cent of TFEC). The largest demand in this sector came from the other (miscellaneous) industries (62 per cent), followed by the food and beverages industry (30.6 per cent), and cement and non-metallic industry (4.7 per cent). The majority of the energy supply came from electricity (76 per cent).

The energy consumed in the commercial, non-specified and agricultural sectors is exclusively electricity, at 25.3 ktoe (4.2 per cent), 2.3 ktoe (0.4 per cent) and 1.2 ktoe (0.2 per cent), respectively.

Figure 3 shows the fuel demand from the demand sectors in 2018, while figure 4 shows the TFEC breakdown by fuel type in 2018.

Figure 3. TFEC breakdown by sector and fuel type, 2018

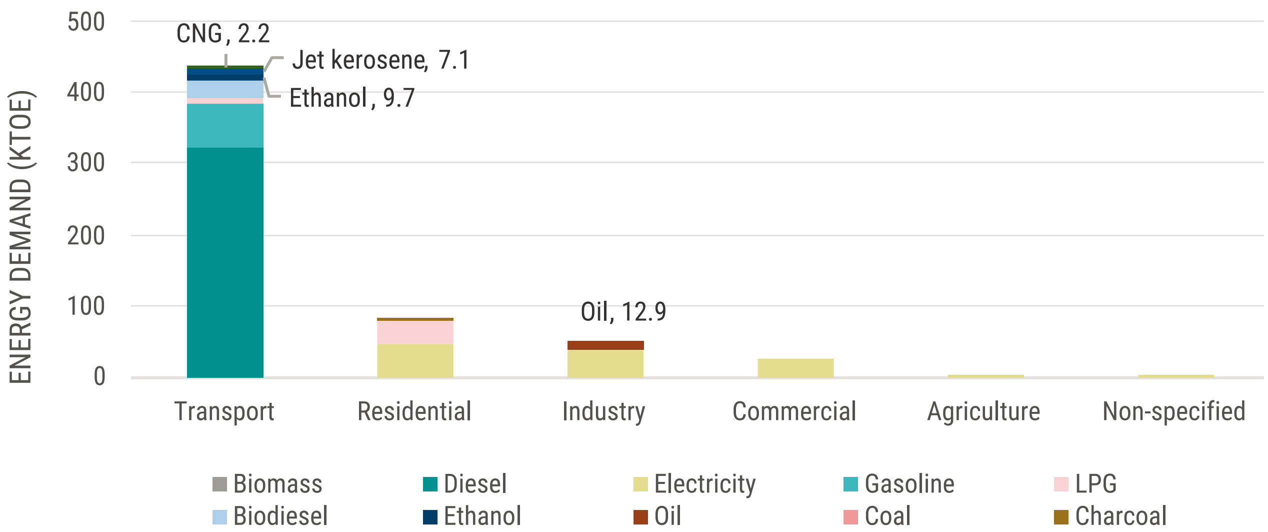
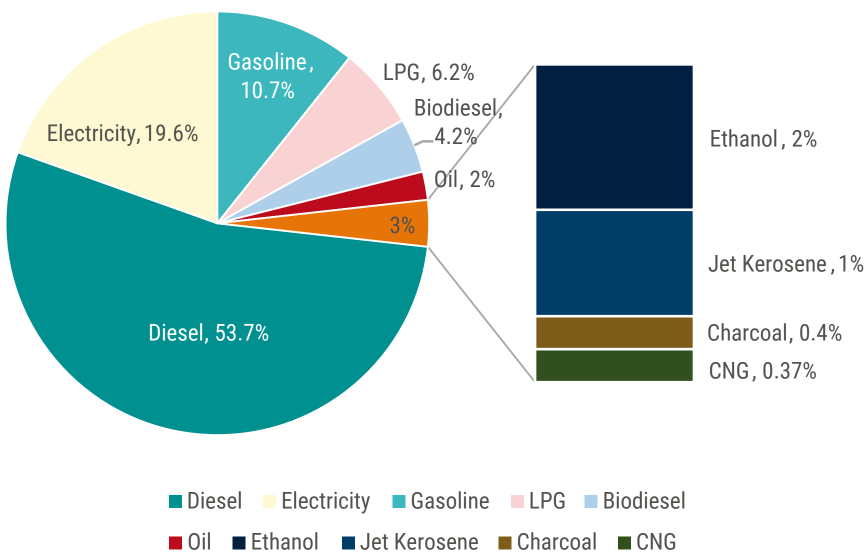


Figure 4. TFEC breakdown by fuel type, 2018



The total primary energy supply in 2018 was 599.2 ktoe. As mentioned above, the province meets almost all of its electricity requirements from the central grid.

3.4. Energy modelling projections

The future energy demand is projected based on a bottom-up approach, using activity levels and energy intensities, with the LEAP model. The demand outlook throughout the NEXSTEP analysis period is influenced by factors such as annual population growth, annual GDP growth as well as other demand sector growth projections. The assumptions used in the NEXSTEP modelling are further detailed in Annex II, while table 1 provides a summary of the key modelling assumptions for the three main scenarios (i.e., BAU, CPS and SET scenarios).

Table 1. Important factors, targets and assumptions used in NEXSTEP modelling

<table>
<tr><th>Parameters</th><th>Business as usual scenario</th><th>Current policy scenario</th><th>Sustainable energy transition scenario</th></tr>
<tr><td>Economic growth</td><td colspan="3">3.63 per cent per annum.</td></tr>
<tr><td>Population growth</td><td colspan="3">0.22 per cent per annum.</td></tr>
<tr><td>Urbanization rate</td><td colspan="3">33.7 per cent in 2017, growing to 45.7 per cent in 2030.[4]</td></tr>
<tr><td>Commercial floor space</td><td colspan="3">- Designated buildings: Total commercial floorspace of 0.74 million m^2 in 2018. The commercial floorspace is projected to grow at an annual rate of 3.63 per cent.
- Non-designated buildings: No floorspace data available. The electricity consumption was 19.66 ktoe in 2018 and the activity is projected to grow at an annual rate of 3.63</td></tr>
<tr><td>Industrial activity</td><td colspan="3">Industrial activity is projected to grow at an annual rate of 3.63 per cent.</td></tr>
<tr><td>Transport activity</td><td colspan="3">- Road transport: Passenger transport activities were estimated at 3.21 billion vehicle-kilometres and freight transport activities at 1.9 billion vehicle-kilometres, in 2018. These are assumed to be growing at a rate similar to the growth in GDP per capita.
- Air transport-related energy consumption is estimated at 7.13 ktoe for 2018. This is assumed to be growing at a rate similar to the growth in GDP.</td></tr>
<tr><td>Residential activity</td><td colspan="3">The ownership of electrical appliances is projected to grow at a rate similar to the growth in GDP per capita, until reaching a 100 per cent saturation.</td></tr>
<tr><td>Access to electricity</td><td colspan="3">100% access rate has been achieved.</td></tr>
<tr><td>Access to clean cooking fuels</td><td colspan="3">Projected based on the national historical improvement rate of 0.6 per cent, during the 2015-2019 period. Clean cooking access rate is projected to reach 81 per cent in 2030.</td></tr>
<tr><td>Energy efficiency</td><td>Additional energy efficiency measures not applied</td><td>Additional improvement based on implemented policy measures.</td><td>Energy intensity is 4.55 ktoe/billion baht. All scenarios to meet the national energy intensity target of 5.98 ktoe/billion baht by 2037</td></tr>
<tr><td>Power plant</td><td>Considers the 2018 RE share in power generation and grid emissions</td><td colspan="2">Considers the increasing RE share and decreasing grid emissions, in accordance with the Power Development Plan 2018</td></tr>
</table>

3.5. Energy policies and targets

Chiang Rai's energy sector development is guided by several national policies and legislations. These policies have been used as guiding references for the NEXSTEP modelling, to better understand the country context and to provide recommendations in adherence to the national Government's overarching direction. Where applicable, the currently implemented and adopted policies or

4 This assumes that the urbanization rate grows with an annual rate of 2.5 per cent, with reference to the national historical urbanization growth from 43.9 per cent in 2010 to 51.4 per cent in 2020.

regulations are considered in the current policy scenario, in order to identify gaps in achieving the SDG 7 targets.[5] The following policies or strategic documents have been consulted:

- **Thailand's Nationally Determined Contribution** – Thailand intends to reduce its GHG emissions unconditionally by 20 per cent from the BAU baseline by 2030. The conditional target is 25 per cent from the BAU baseline by 2030, subject to adequate and enhanced access to technology development and transfer, financial resources and capacity building support;
- **Thailand's Power Development Plan, 2018-2037 (PDP, 2018)** aims to improve energy efficiency and enhance energy security in Thailand, while setting goals for new power production capacity;
- **Thailand's 20-year Energy Efficiency Plan, 2018-2037 (EEP, 2018)** sets out an energy intensity reduction target of 30 per cent by 2037 compared with the 2010 baseline, reaching an energy intensity (in terms of final energy consumption) of 5.98 ktoe/billion baht. It sets out several compulsory measures and voluntary measures in achieving this target;
- **Thailand's Alternative Energy Development Plan, 2018-2037 (AEDP, 2018)** aims to promote the development of renewable energy production in the country and sets a goal to increase the share of renewable energy and alternative energy in total final energy consumption (TFEC) to 30 per cent by 2037;
- **The Thailand biofuel mandate** stipulates a minimum biodiesel blending of 7 per cent from 2014 onwards, which was increased to 10 per cent in 2020 (for compatible vehicles) (USDA, 2021);[6]
- **The Ministerial Regulation Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation, B.E. 2563 (2020)** mandates an energy-efficient design for all new buildings with a total floor area in all stories of 2,000 square metres or more;[7]
- **Minimum Energy Performance Standards (MEPS)** have been implemented for refrigerators and air conditioners since 2005 and 2011, respectively (IEA, 2017 and 2020). MEPS for washing machines was recently announced in August 2021. In addition, voluntary certification is available for several types of electrical equipment through the Energy Efficiency Labelling No. 5 Programme and for several types of non-electrical equipment through the Energy Efficiency Labelling Programme.

3.6. Chiang Rai's energy system projections in the current policy settings

The Current Policy Scenario (CPS) explores how Chiang Rai's energy system may evolve under the current policy settings. It takes into account initiatives implemented or scheduled for implementation during the analysis period, 2018-2030. Several high-level strategies have been outlined in national policies (i.e., energy efficiency measures outlined in the Energy Efficiency Plan, 2018-2037); however, NEXSTEP modelling only takes into account policy measures that have come into force or already have a concrete implementation timeline within the analysis period. Otherwise, the energy intensities from the different demand sectors are assumed constant throughout the analysis period, with demand growth as detailed in table 1. The policies/initiatives considered in the modelling of CPS are:

- The **Power Development Plan (PDP), 2018-2037**

  The PDP, 2018-2037 is considered in modelling the share of RE electricity and the emission factors of the central grid. In accordance with the expansion plan stipulated in the PDP, an increasing share of RE electricity and a decreasing grid emission factor are expected;
- **Thailand biofuel mandate**

  The biodiesel mandate was 7 per cent in 2018.

5 Only policies with concrete and implemented measures are considered in the scenario modelling for the current policy scenario. Measures mentioned in strategy policy or planning documents that are yet to be enforced or implemented prior to October 2021 (i.e., plans stipulated in the Energy Efficiency Plan) are not considered in the modelling of the current policy scenario.

6 It is noted that there is no bio-ethanol mandate in Thailand, although several blend rates are available in the market (USDA, 2021). NEXSTEP modelling assumes an average blend rate of 13 per cent for transport gasoline usage.

7 The 2009 ministerial regulation is applicable to nine types of new or renovated government buildings, while for private buildings it is on a voluntary basis.

This has been increased to 10 per cent from 2020 onwards.

- **Implementation of the Ministerial Regulation (2020)** which mandates an energy-efficient design for all new buildings with a total area in all stories of 2,000 square metres or more. NEXTEP modelling assumes the following:
  (a) The energy savings shall take effect in buildings completed in 2023 and onwards, considering the grace period and construction time required;
  (b) The energy saving is assumed to be 36 per cent, compared to the baseline intensity (EEP 2015);
  (c) All new designated buildings are assumed to meet the minimum floorspace requirement;
  (d) 50 per cent of new designated buildings (in terms share of electricity consumption) are assumed to meet the minimum floorspace requirement.

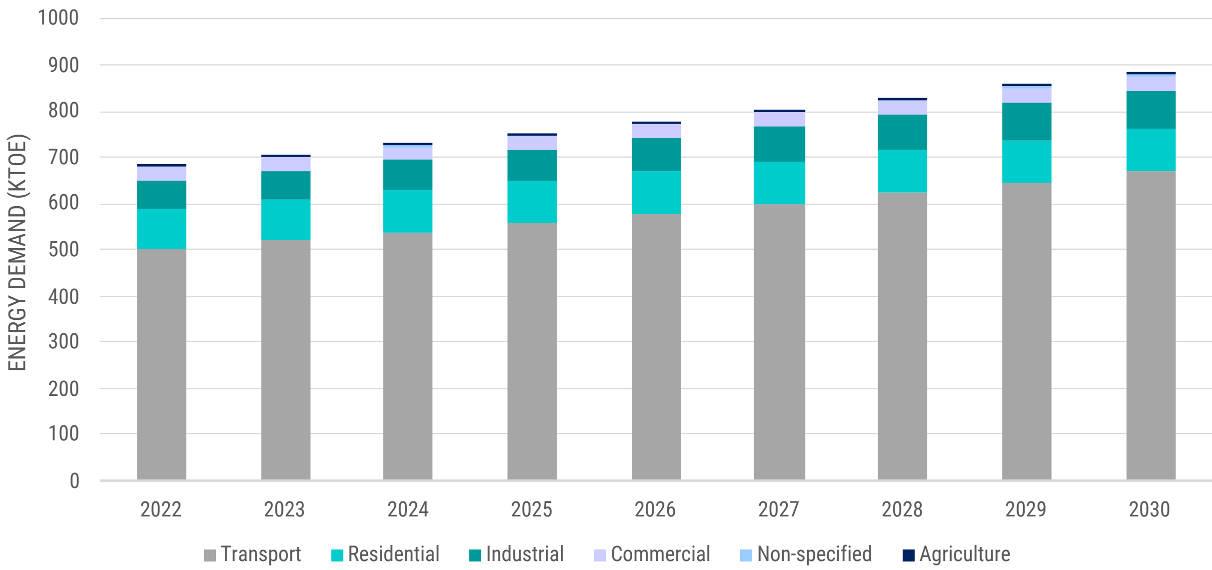
The following section describes further the energy and emission outlook in the current policy settings.

3.6.1. Energy demand outlook

In the current policy settings, TFEC is projected to increase from 599.2 ktoe in 2018 to 881.5 ktoe in 2030. The transport sector consumption will remain the largest at 667.6 ktoe (75.7 per cent), followed by the residential sector at 95.7 ktoe (10.9 per cent), the industrial sector at 81.4 (9.2 per cent), the commercial sector at 31.4 ktoe (3.6 per cent), non-specified at 3.6 ktoe (0.4 per cent) and the agricultural sector at 1.8 ktoe (0.2 per cent).

The sectoral overview of energy demand in the CPS is discussed below and is shown in figure 5.

Figure 5. Chiang Rai's energy demand outlook, CPS 2022 – 2030

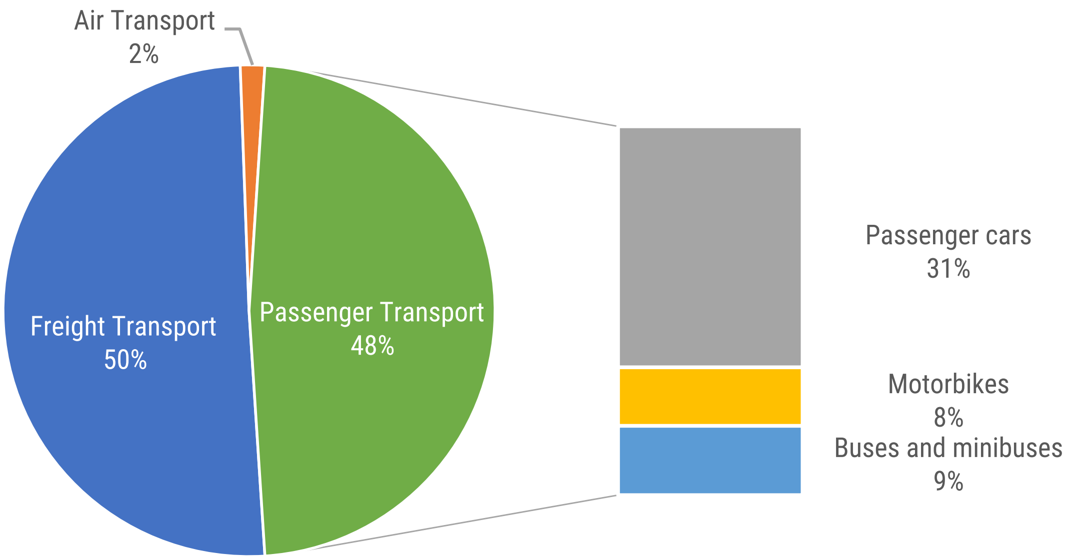


(a) Transport sector

The transport sector energy demand will continue to dominate Chiang Rai's TFEC, and is projected to increase from 435 ktoe in 2018 to 667.6 ktoe in 2030. In 2030, the subsector share of transport energy demand is projected to be road passenger transport at 320 ktoe (47.9 per cent), road freight transport at 337 ktoe (50.5 per cent) and air transport at 10.7 ktoe (1.6 per cent).

Road passenger transport is subdivided into three sub-categories, i.e., passenger cars, motorcycles, and buses and minibuses, while freight transport consists of trucks. The demand share in 2030 by road transport subcategories is shown in figure 6. The first chart shows the share of freight transport (i.e., freight trucks) and passenger transport, while the second chart provides the demand breakdown of passenger transport subcategories. As observed, 31.8 per cent of the road transport energy demand is expected to come from passenger cars.

Figure 6. **Energy demand distribution by transport sector sub-categories, CPS in 2030**



(b) Residential sector

The residential sector energy demand is projected to increase to 95.7 ktoe by 2030, compared with 82 ktoe in 2018. Residential cooking is projected to take up around 37 per cent of TFEC, with the remaining 63 per cent contributed by various electric appliances, e.g., air conditioners, refrigerators.

(c) Industry sector

The industry activity in Chiang Rai is relatively small; there are mainly three categories – other industry, food and beverages, and cement and non-metallic. The modelling of CPS assumes that the energy intensity of the industrial sector remains constant throughout the analysis period, while industrial energy productivity increases by 3.63 per cent annually. Table 2 shows TFEC and share of TFEC by industry subcategories.

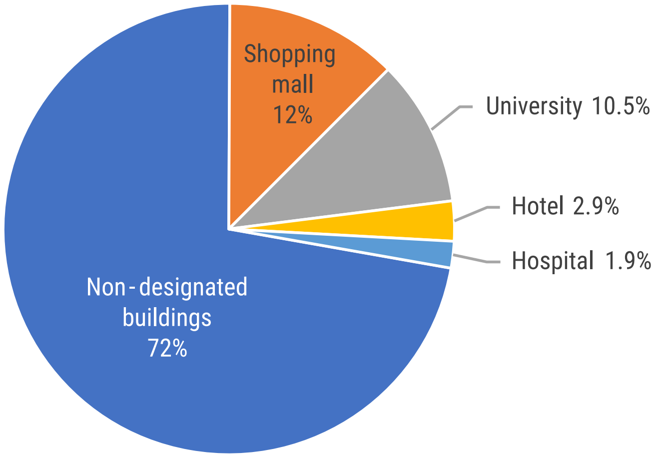
Table 2. **TFEC and share of TFEC by industry subcategories**

Branch	TFEC in 2030 (ktoe)	Share of TFEC (%)
Other industry	50.5	62.0
Food and beverages	24.9	30.6
Cement and non-metallic quarry products	3.8	4.7
Machinery and transportation tools	0.8	1.0
Fertilizer, chemical, and rubber products	0.5	0.7
Wood and other products	0.3	0.3
Iron and steel	0.3	0.4
Pulp and paper	0.3	0.3

(d) Commercial sector

The commercial sector energy demand is projected to increase from 25.3 ktoe in 2018 to 31.4 ktoe in 2030. The implementation of the Ministerial Regulation (2020) that mandates an energy-efficient design for all new buildings with a total area in all stories of 2,000 square metres or more. The energy demand distribution in 2030 is shown in figure 7.

Figure 7. Energy demand distribution by commercial subcategories, CPS in 2030



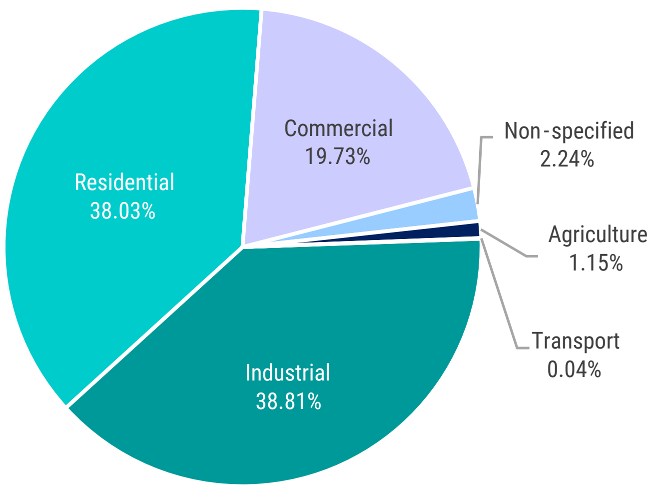
(e) Non-specified sector and agriculture sector

The energy demand from the non-specified and agricultural sectors is relatively insignificant at only 0.6 per cent, in total, in 2030. The energy demand for these two sectors is expected to increase from 3.5 ktoe to 5.4 ktoe by 2030.

3.6.2. Electricity generation outlook

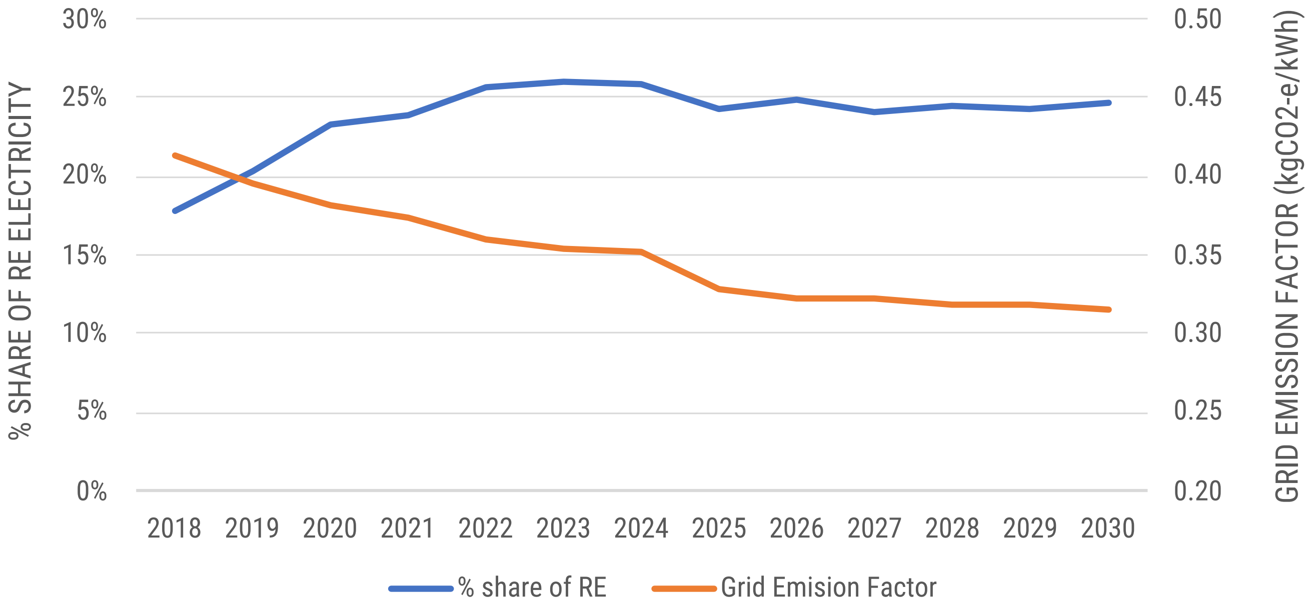
The 2030 demand for electricity in the current policy scenario is projected to be 1,848.6 Gigawatt-Hours (GWh), an increase from 1,362.8 GWh in 2018. The demand will be the highest in the industrial sector at 717.4 GWh (38.8 per cent) followed by the residential sector at 702.9 GWh (38 per cent), the commercial sector at 364.8 GWh (19.7 per cent), non-specified sector at 41.4 GWh (2.2 per cent) and agriculture sector at 21.2 GWh (1.1 per cent).

Figure 8. Electricity demand distribution by demand sector in 2030, CPS



The electricity required to fulfil the demand in Chiang Rai is almost exclusively purchased from the grid, while generation for self-use is limited in the province. As stipulated in Thailand's Power Development Plan, 2018-2037, the central grid electricity is expected to have a decreasing emission factor, as the percentage of renewable energy increases.

Figure 9. Percentage share of renewable electricity and grid emission factor of central grid, 2018-2030



3.6.3. Energy supply outlook

In the CPS, TPES is projected to increase from 599.2 ktoe in 2018 to 881.5ktoe in 2030. Figure 10 shows the TPES breakdown further by fuel type, while figure 11 shows the energy flows in 2030.

Figure 10. TPES breakdown by fuel type, CPS in 2030

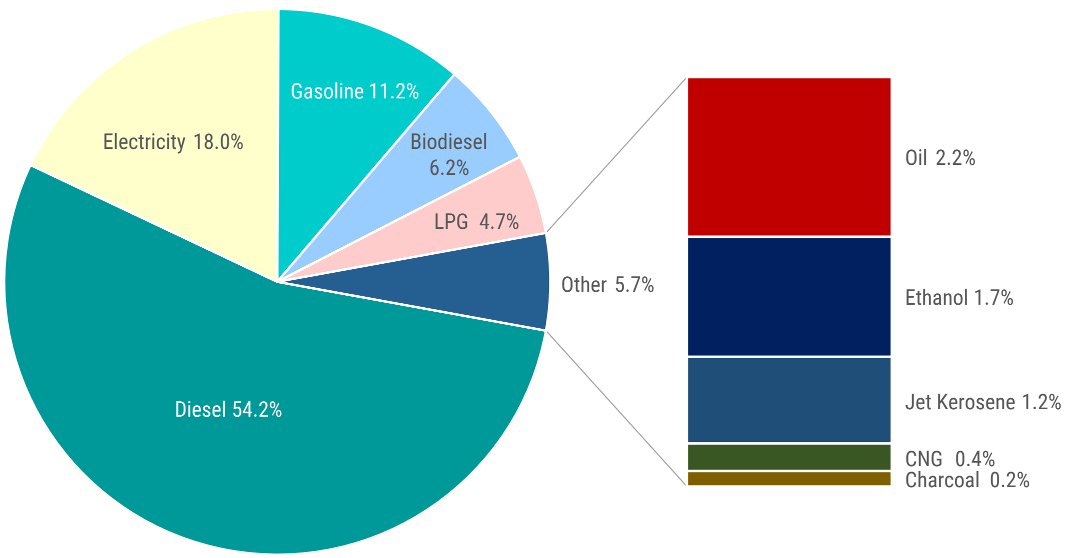
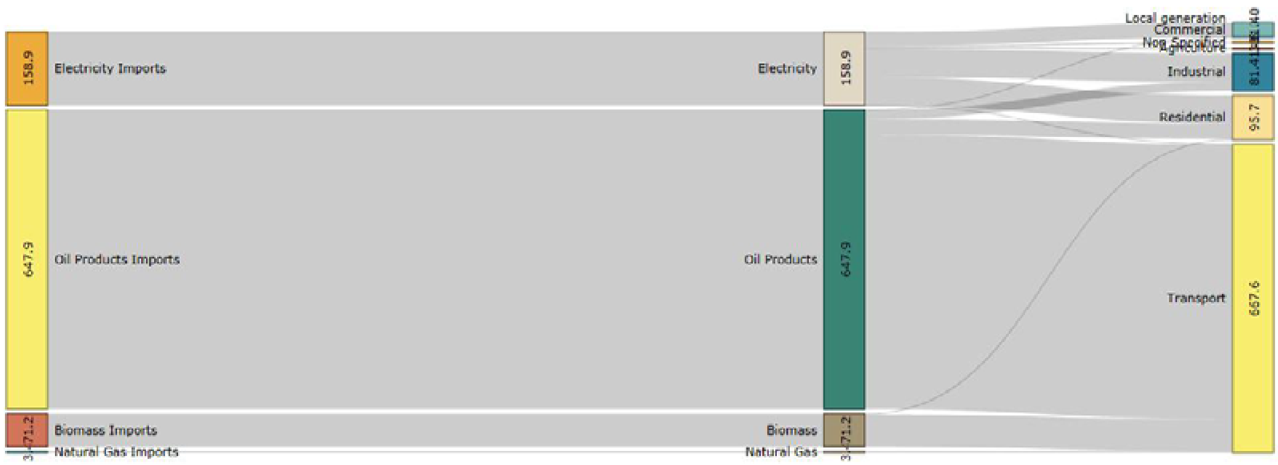


Figure 11. Sankey Diagram, CPS in 2030 (unit: ktoe)



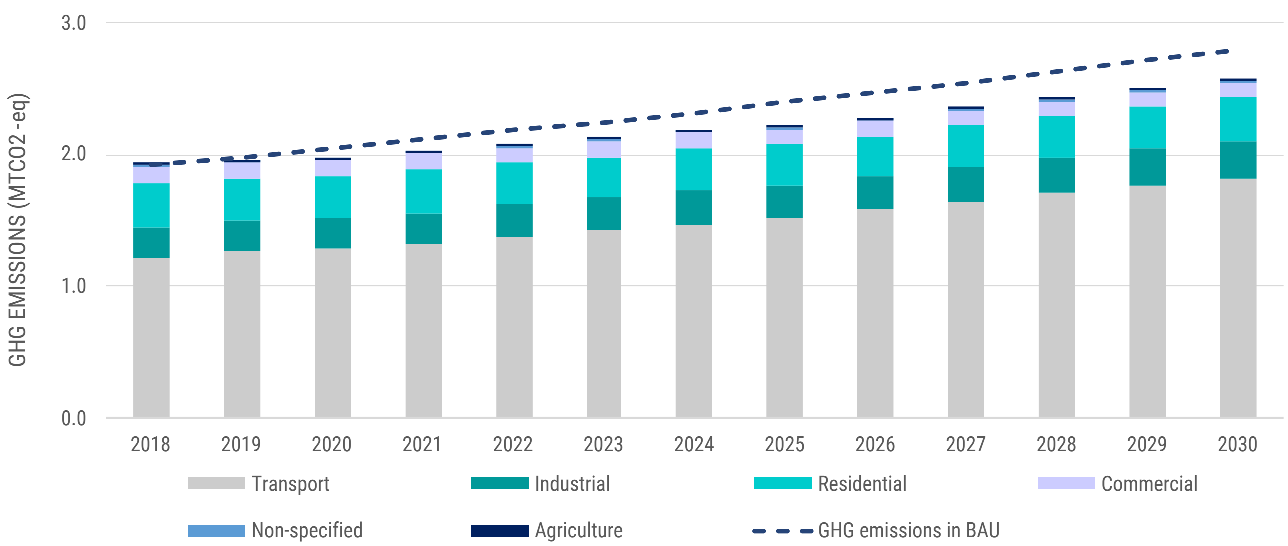
3.6.4. Energy sector emissions outlook

The energy sector emissions, from the combustion of fuel, is calculated based on the IPCC Tier 1 emission factors assigned in the LEAP model. The combustion of biomass products (i.e., biodiesel and ethanol) is considered carbon neutral. The emissions attributable to grid electricity have been included, while considering the projected decrease in grid emission factor during the analysis period (figure 9).

In the CPS, the total GHG emission from the energy sector increases from 1.9 $MTCO_2$-e in 2018 to 2.6 $MTCO_2$-e (figure 12). The largest contributor of GHG emissions in 2030 is the transport sector (65.3 per cent), followed by the residential sector (11.6 per cent), industrial sector (10.2 per cent), commercial sector (4.1 per cent), non-specified sector (0.5 per cent) and the agricultural sector (0.2 per cent). These consider emissions from both the direct fuel combustion and electricity usage.

The emission reduction is 8 per cent, relative to the BAU scenario. The decreasing emission factor of the central grid electricity is the major contributing factor to the emission reduction. Notwithstanding this, in the event that the share of RE in the electricity mix increases less rapidly than modelled, the emission reduction will be much less substantial.

Figure 12. Chiang Rai's energy sector emissions outlook, CPS, 2018-2030



4. SET scenario – sustainable energy transition pathway for Chiang Rai province

Both subnational and national efforts are imperative in achieving the 2030 Agenda for Sustainable Development and Paris Agreement on climate change. Not only that, countries, too, require subnational co-operation in order to reach the national targets. This chapter provides details of the SET scenario, exploring how economy-wide efforts may improve the energy and climate sustainability of the Province of Chiang Rai, in alignment with the national targets. Table 3 shows a summary of the targets considered in the SET scenario.

Table 3. Targets considered in the SET scenario

Indicator	National target	Comparative SDG 7 target
Access to modern energy	No set target.	7.1. By 2030, ensure universal access to affordable, reliable, and modern energy services.
Renewable energy	30 per cent by 2037.	7.2. By 2030, increase substantially the share of renewable energy in the global energy mix.
Energy efficiency	30 per cent energy intensity reduction by 2037, compared to the 2010 baseline: • NEXSTEP considers an energy intensity target of 6.64 ktoe/billion baht by 2030.[8]	7.3. By 2030, double the global rate of improvement in energy efficiency.
GHG emissions reduction	20 per cent GHG emission reduction compared to the BAU baseline in 2030, as per Thailand's unconditional NDC target.	n/a

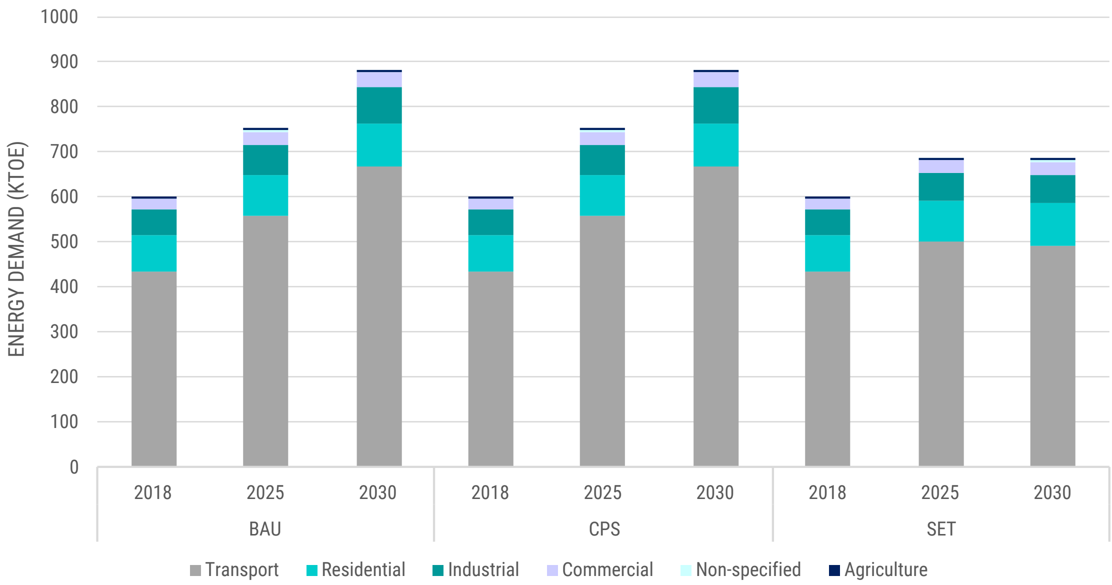
The following subsections discuss the energy system trajectory under the SET scenario in relation to the different indicators.

4.1. SET energy demand outlook

In the SET scenario, TFEC increases at a much slower pace than CPS, from 599.2 ktoe in 2018 to 684.6 ktoe in 2030. The reduction of 197 ktoe in TFEC in this scenario, compared with the CPS, is due to the improvement in energy efficiency across the demand sectors. The proposed energy efficiency interventions are further described in 4.2.3. In 2030, the transport sector will still have the largest share of TFEC at 494 ktoe (72 per cent), followed by the residential sector at 94.7 ktoe (14 per cent), industrial sector at 61.8 ktoe (9 per cent) and commercial sector at 28.8 ktoe (4.2 per cent). Figure 13 shows TFEC by scenario in 2030.

8 As interpolated using energy intensity target (in terms of final energy consumption) of 5.98 ktoe/billion baht in 2037 and a 2010 baseline of 8.54 ktoe/billion baht.

Figure 13. Projection of TFEC by sector, 2030



4.2. SET progress towards main sustainable energy indicators

4.2.1. Access to modern energy

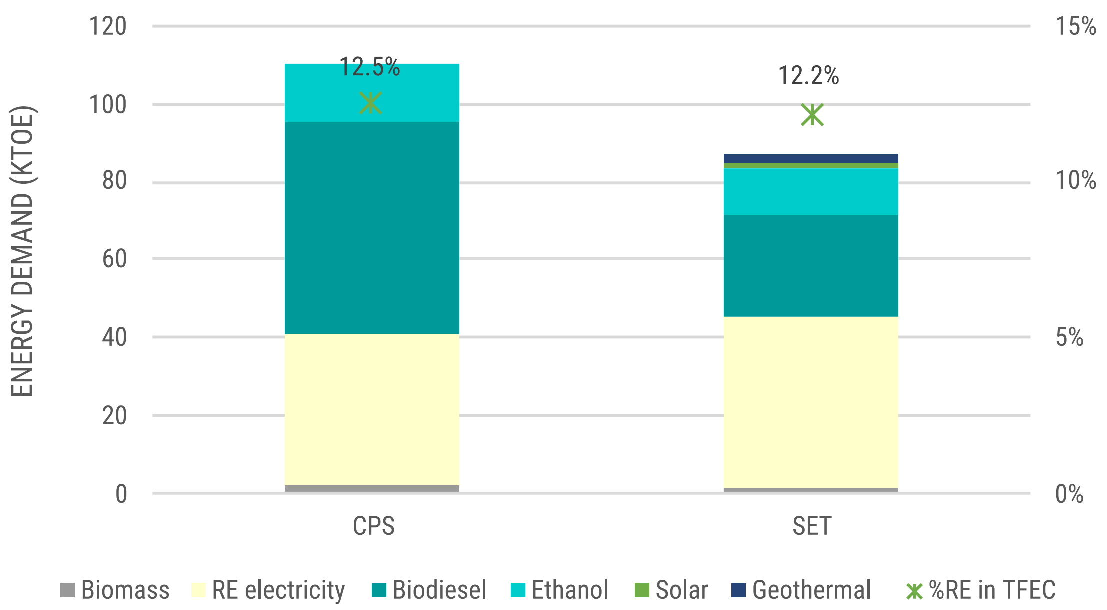
Chiang Rai has already achieved universal access to electricity. In 2018, the clean cooking rate was estimated at 75.6 per cent. Projected based on a national historical improvement rate of 0.6 per cent, during 2015-2019,the clean cooking access rate can be expected to reach 81 per cent in 2030. More needs to be done to achieve the SDG 7.1.2 target. NEXSTEP suggests that ICS may be promoted to households to close the clean cooking gap.

4.2.2. Renewable energy

Thailand's Alternative Energy Development Plan, 2018-2037 (AEDP, 2018) has set forth a renewable energy target of 30 per cent by 2037. On the other hand, SDG 7.2 does not have a quantitative target, but requires a substantial increase of the renewable energy share in TFEC. The RE share in TFEC was estimated at 9.6 per cent in 2018, excluding a small amount of traditional biomass usage in the residential cooking sector. This low share of RE is mainly because the bulk of the energy demand is in the transport sector (about 75 per cent), which is fossil fuel. In addition, the use of biomass in this province is minimal. Therefore, none of the scenarios are expected to meet the national target of a 30 per cent RE share as set forth in AEDP, unless a drastic transformation of the energy sector is implemented. This is discussed in the ambitious scenario (Towards Net Zero).

In the SET scenario, the RE share in TFEC is projected to be 12.2 per cent by 2030. The slight decrease in the RE share in TFEC compared with both the CP scenarios is mainly due to the reduced use of biomass in the residential sector by some households switching to electric cooking stoves and some adopting efficient improved cooking stoves. In addition, switching internal combustion engine vehicles to electric vehicles reduces the biodiesel and ethanol needs. It also assumes a 24.6 per cent share of RE electricity in the central grid, the same as the CP scenario. Figure 14 compares RE shares in the CP and SET scenarios in 2030.

Figure 14. Renewable energy shares in the CP and SET scenarios, 2030



4.2.3. Energy efficiency

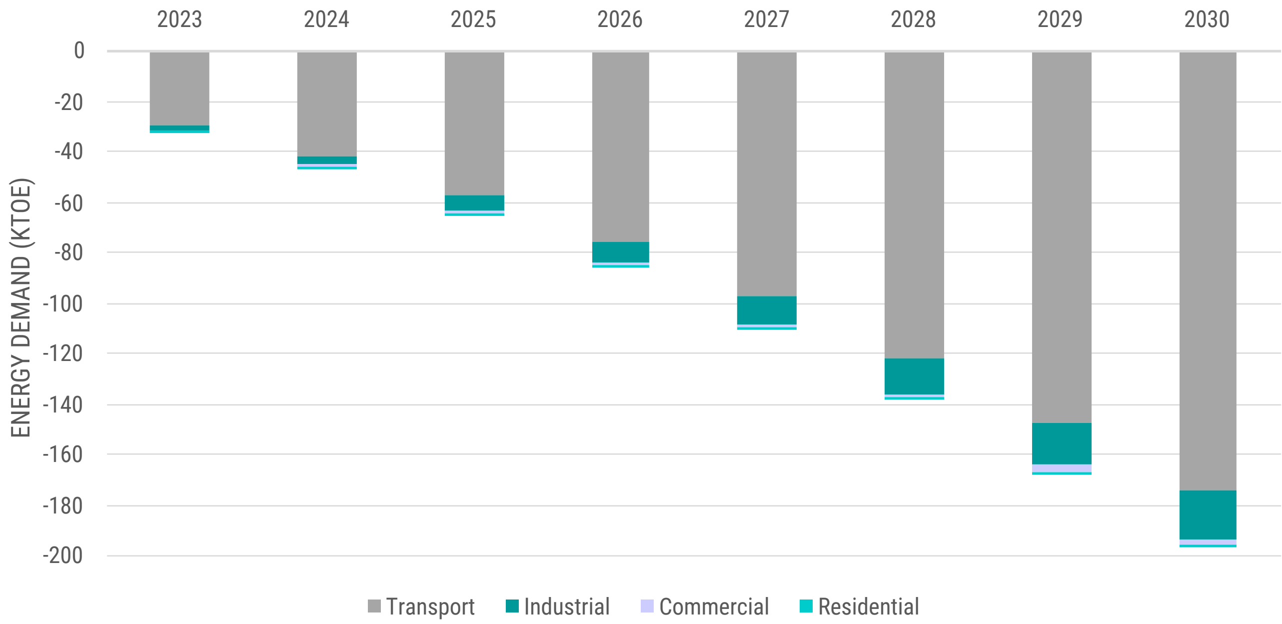
The energy intensity is projected to reach 4.55 ktoe/billion baht$_{2010}$ in 2030, considering the energy efficiency measures proposed for the SET scenario. As it is in the BAU and CP scenarios, this meets the energy intensity set out for 2030[9] in accordance with the national energy intensity target of 5.98 ktoe/billion baht$_{2010}$ by 2037. The energy efficiency measures proposed for the SET scenario are constrained by aligning Chiang Rai's GHG emission reduction with the national unconditional target of 20 per cent, relative to a BAU baseline.

Figure 14 shows the energy savings that may be achieved through the implementation of energy efficiency measures across the demand sectors, compared with CPS. The transport sector is the largest energy-consuming sector in Chiang Rai, which can also be expected to make the largest contribution (173.7 ktoe in 2030), through the increased adoption of transport electrification for such as buses, cars and motorcycles. In addition, measures can be sought from the residential and commercial sectors, albeit with a smaller energy savings potential.

Further details of the energy efficiency measures, and their impacts are provided below.

9 The energy intensity target is 6.64 ktoe/billion baht by 2030, as interpolated using the energy intensity target (in terms of final energy consumption) of 5.98 ktoe/billion baht in 2037 and the 2010 baseline of 8.54 ktoe/billion baht.

Figure 15. Energy savings in the SET scenario, compared to CPS



4.2.3.1. Transport sector

The current share of electric vehicles in the existing fleet is very low. However, the promotion of electric vehicles is an effective way of reducing demand consumption in the transport sector as well as GHG emissions. In the SET scenario, NEXSTEP proposes that the uptake of electric vehicles can be promoted across the different vehicle categories, reaching a considerable share of the transport fleet by 2030. Further details and the estimated annual savings are shown in table 4.

Table 4. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the transport sector

Subcategory	Energy efficiency measures	Annual saving in 2030 (ktoe)
Passenger cars	Increase the share of electric passenger cars to 50 per cent by 2030	81
Buses and minibuses	Increase the share of electric buses to 50 per cent by 2030	14.2
Motorcycles	Increase the share of electric motorbikes to 25 per cent by 2030	12.7
Freight vehicles	Increase the share of electric freight vehicles to 25 per cent by 2030	65.9
Total		**173.7**

4.2.3.2. Industrial sector

The potential savings in the industry sector, as modelled in the SET scenario (table 5), references the energy conservation potential assessment findings in MOE (2011), with the exception of the cement and non-metallic quarry products industry.

The energy savings potential in MOE (2011) is roughly assessed by comparing Thailand's average specific energy consumption (SEC) in 2009, with the best SEC in other countries or within Thailand. On the other hand, the economic potential of the cement industry is assumed to be 25 per cent (ADB, 2015).

Table 5. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the industrial sector

Subcategory	Potential savings compared to BAU baseline	Annual saving in 2030 (ktoe)
Food and beverages	28 per cent [a]	6.98
Other industry	22 per cent [b]	11.10
Wood and wood products		0.6
Machinery and transportation tool		0.19
Textile and leather		
Fertilizer, chemical and rubber products	44 per cent [c]	0.24
Iron and steel	11 per cent [d]	0.04
Cement and non-metallic quarry products	25 per cent [e]	0.95
Total		**19.6**

Note:

(a) Based on energy savings potential for "food and beverage" category (MOE, 2011).

(b) Based on energy savings potential for "others" category (MOE, 2011).

(c) Based on energy savings potential for "chemical" category (MOE, 2011).

(d) Based on energy savings potential for "basic metal" category (MOE, 2011).

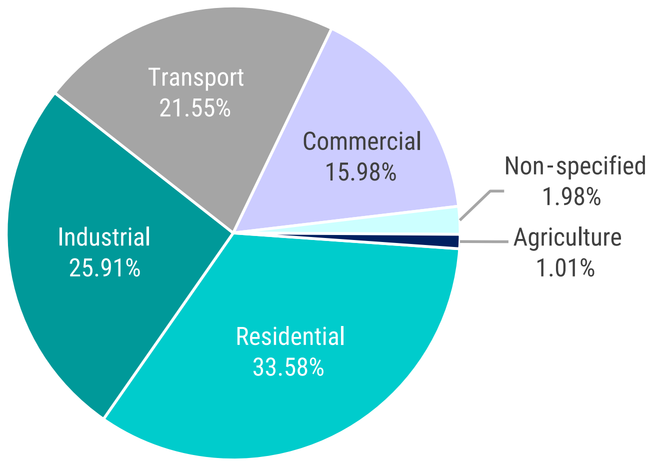
(e) Assumes the economic potential savings of 25 per cent for the cement industry (ADB, 2015).

4.3. Electricity supply and demand in the context of sustainable energy transition

The demand for electricity in 2030 is projected to be 2,093.5 GWh in the SET scenario, an increase of 245 GWh compared with the CPS. This increase in electricity demand is mainly from the transport sector, by 450.3 GWh, due to widespread adoption of electric vehicles.

The largest electricity demand can be expected from the residential sector, at 703 GWh. This is followed by the industrial sector at 542.4 GWh, transport sector at 451 GWh, commercial sector at 334.4 GWh, non-specified sector 41.4 GWh and agricultural sector at 21.2 GWh (figure 16).

Figure 16. Electricity demand in 2030, by sector, SET scenario



4.4. Energy flows and balance, 2030

In the SET scenario, TPES is forecast to increasing from 599 ktoe in 2018 to 684.6 ktoe in 2030.

Figure 17 shows further the TPES breakdown by fuel type, while figure 18 shows the energy flows in 2030.

Figure 17. TPES breakdown by fuel type, SET in 2030

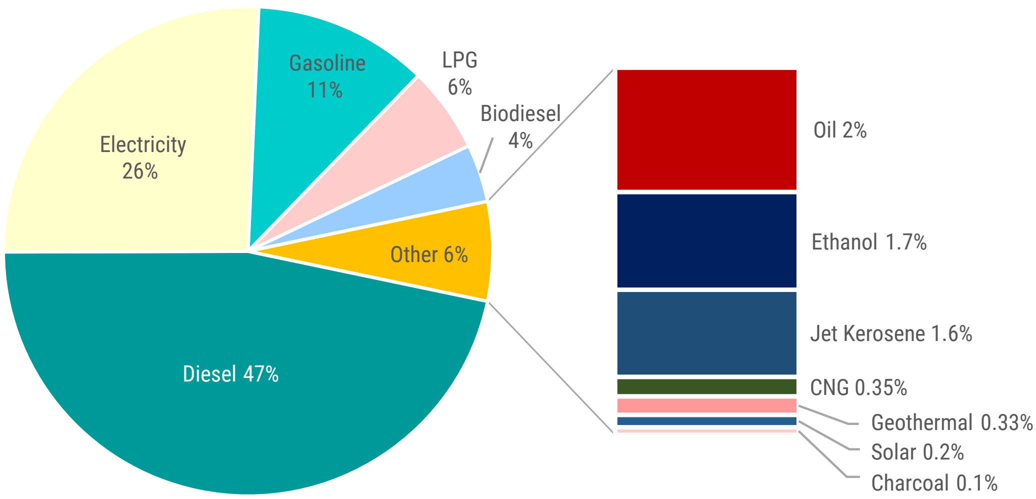
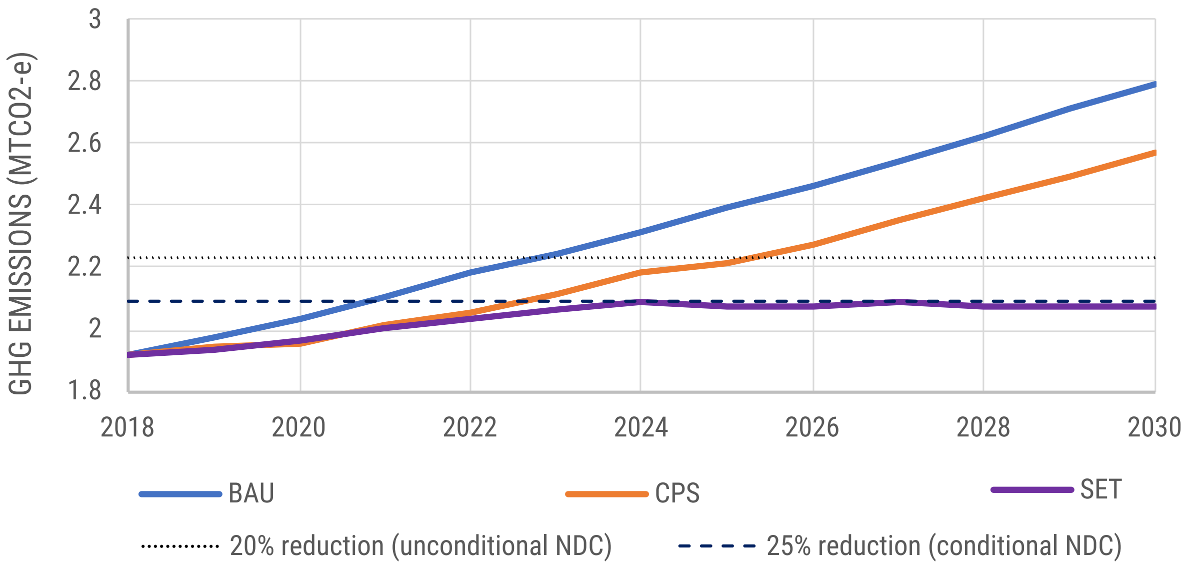


Figure 18. Sankey Diagram, SET in 2030 (unit: ktoe)

4.5. GHG emission reduction with sustainable energy transition

The GHG emission in 2030 is projected to be 2.08 $MTCO_2$-e, a reduction of 490.5 ktCO2-e from CPS. This corresponds to a 25 per cent reduction from the BAU scenario, or a 19 per cent reduction from the CPS (figure 19).

Figure 19. GHG emission trajectories, 2018-2030, by scenario



The net GHG emissions reduction by demand sectors, relative to CPS, in 2030 is further summarised below. The emissions reduction from the residential, industrial and commercial sectors are due to the reduced direct fuel combustion and/or electricity usage. The GHG emission reduction due to a decrease in direct fuel combustion by the transport sector is significant. However, this is slightly compensated for by the emissions associated with the increased electricity demand.

Table 6. Net GHG emissions reduction by demand sectors, relative to CPS, in 2030

Sector	Measure	Net GHG emission reduction (ktCO2-e)
Residential	Adoption of efficient household appliances	0.6
Industrial	Adoption of energy efficiency measures (assuming 100 per cent adoption rate)	13.9
Transport	Increase the share of electric buses to 50 per cent by 2030	80.7
	Increase the share of electric passenger cars to 50 per cent by 2030	283.5
	Increase the share of electric motorbikes to 25 per cent by 2030	32.1
	Increase the share of electric freight vehicles to 25 per cent by 2030	157.2
Sub-total		567.6
Power	Increased emissions due to the increased demand for electricity	-77.1
Total		**490.9**

The SET scenario sets out various strategies in facilitating an economy-wide energy efficiency improvement in alignment with the national targets and commitment towards the Paris Agreement. Notwithstanding that, Chiang Rai province may consider more ambitious pathways, moving towards a net zero society.

Substantial energy demand and emission reduction have been achieved in the SET scenario through energy efficiency improvement measures. These measures have allowed energy demand reduction of 196.9 ktoe and emission reductions of 490.9 $ktCO_{2-e}$, (18 per cent) relative to CPS. This also corresponds to a 25 per cent reduction from the BAU scenario, aligning with the national conditional NDC commitment. Two ambitious scenarios have been modelled to further explore how Chiang Rai may adopt more vigorous sustainable transport strategies and realise a steeper GHG emission reduction trajectory, moving towards a net zero energy system in the near future.

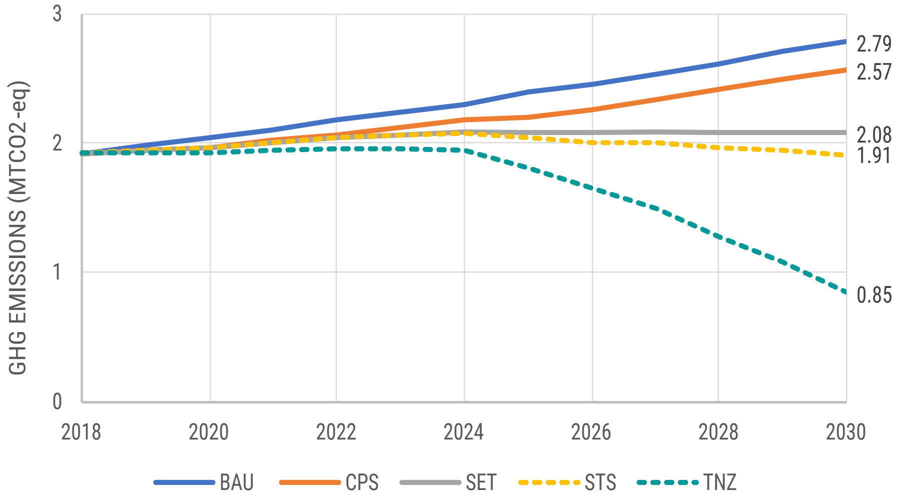
The Sustainable Transport Strategies (STS) scenario focuses on the opportunities in transition of the transport sector through a greater degree of mass public transport and electric vehicles usage, realising a significant energy demand and GHG emissions reduction. On the other hand, the TNZ scenario – the most ambitious scenario – aims to pave the way towards achieving net zero in the near future. The measures proposed are decarbonizing the province's power supply and fuel/clean technology substitution.

The GHG emissions reduction that may be achieved with the two ambitious scenarios are shown in

figure 20. The two ambitious scenarios are further described in the following sections.

5. Raising ambitions with sustainable transport strategies and moving towards a net zero society

Figure 20. GHG emission trajectories, 2018-2030



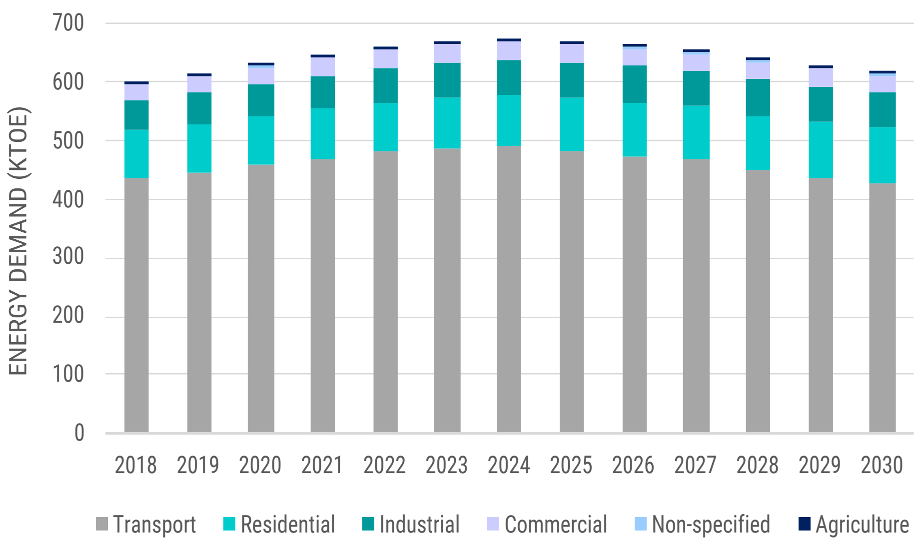
5.1. Ambitious scenario 1: Sustainable Transport Strategies (STS) scenario

Building on the SET scenario, the STS scenario further explores how the province can further transition its transport sector through a greater degree of mass public transport and electric vehicles usage. It also allows the GHG emission reduction to exceed with the national conditional target (31 per cent compared to the BAU baseline). The energy demand reduction and GHG emission reduction are as further explained below.

5.1.1. Energy demand outlook

The total final energy consumption is expected to increase from 599 ktoe in 2018 to 616.8 ktoe in 2030, a reduction of 67.7 ktoe compared to the SET scenario. The transport sector still has the largest share, at 68.8 per cent, followed by residential sector 15.6 per cent, residential sector 10 per cent and commercial sector 4.7 per cent. Figure 21 shows the projected TFEC by sector under the STS scenario.

Figure 21. Projection of TFEC by sector, STS scenario, 2018-2030



5.1.2. GHG emission reduction and energy savings

The measures considered in the STS scenario and the respective energy demand and GHG emission reductions (compared to the SET scenario) are summarized in table 7.

Table 7. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to SET)

Sector	Measure	Energy demand reduction (ktoe)	GHG emission reduction (ktCO2-e)
Residential	Increase the share of electric cooking stove to 22.5 per cent by 2030	-1.6	0.1
Road - Passenger	Reduces vehicle-km travelled in passenger cars by 20 per cent compared to BAU baseline, through a greater adoption of public mass transport (i.e., buses and minibuses) Increase the share of electric buses to 100 per cent by 2030	3.4	86.0
	Increase the share of electric passenger cars to 50 per cent by 2030	53.1	116.9
	Increase the share of electric motorcycles to 50 per cent by 2030	12.7	32.1
Sub-total		67.7	235.5
Power	Increased emission due to increased demand for electricity	0	73.4
Total		**67.7**	**161.7**

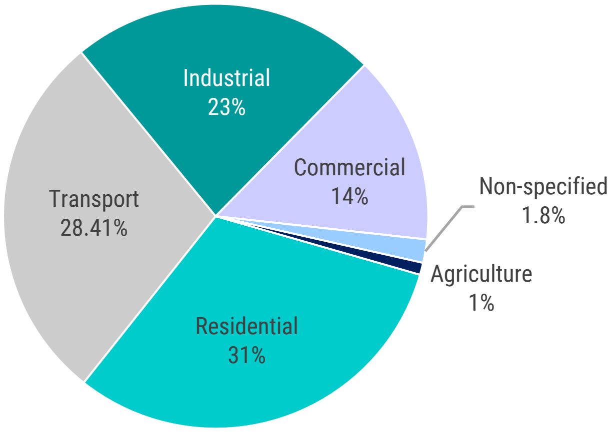
The GHG emission reduction is significant, particularly with a simultaneous increase in public transport usage and ambitious electric buses and cars adoption. This, however, requires extensive coordination from the public and the private sector in expanding public transport reach and charging facilities, while providing incentives for electric vehicle adoption to the general public.

The travelled-kilometres by minibuses and buses are projected to be more than doubled from 2018. In addition, a 100 per cent electric bus fleet requires a vigorous adoption from early years onwards and early retirement of internal combustion engines. The yearly sales share of electric-type motorcycles and passenger cars should aim to start from 5 per cent in 2023, rising to 50 per cent by 2030. Freight trucks may, on the other hand, take a more conservative approach as options are currently less abundant – starting from a yearly sales share of 1 per cent in 2023, rising to 25 per cent by 2030.

5.1.3. Electricity demand and supply in 2030

The demand for electricity in 2030 is projected to be 2,326.5 GWh in the STS scenario, an increase of 233 GWh compared with the SET scenario. Such an increase is solely due to the proposed increase in the share of electric vehicles across the vehicle subcategories. As shown in figure 22, the transport sector has a 28.4 per cent share of electricity demand in the STS scenario, compared to none in the CP scenario.

Figure 22. Electricity demand in 2030 by demand sector, STS scenario



5.1.4. Energy flows and balance, 2030

In the STS scenario, TPES is forecasted to increase from 599 ktoe in 2018 to 616.9 ktoe in 2030.

Figure 23 further shows the TPES breakdown by fuel type, while figure 24 shows the energy flows in 2030.

Figure 23. TPES breakdown by fuel type, STS in 2030

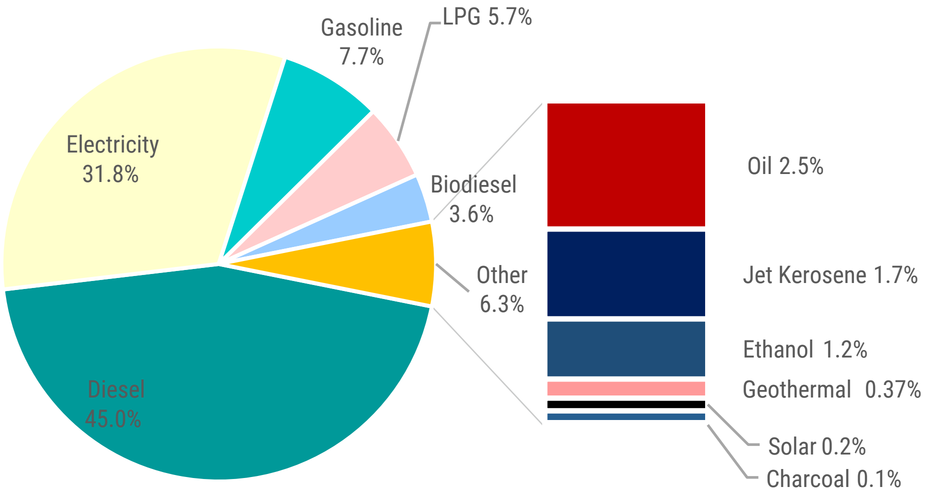
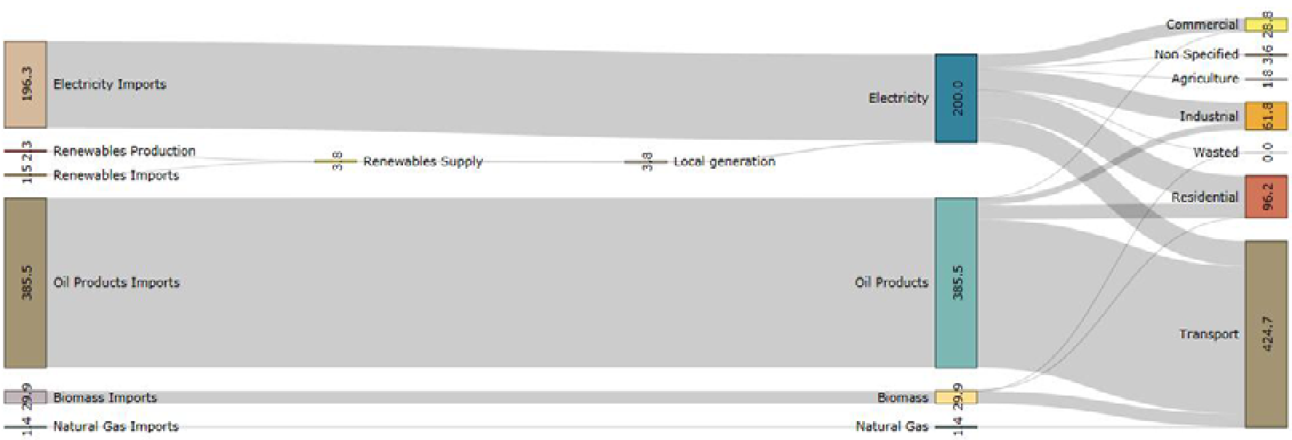


Figure 24. Sankey Diagram, STS in 2030 (unit: ktoe)



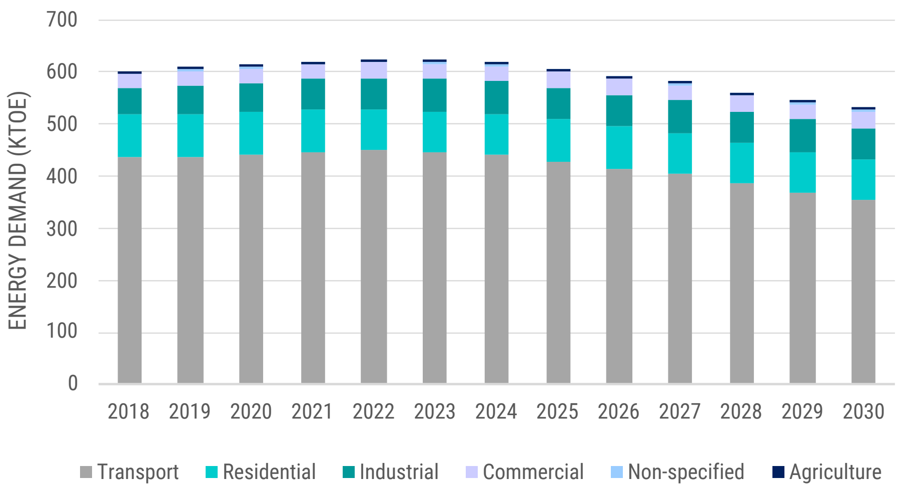
5.2. Ambitious scenario 2: Towards Net Zero (TNZ) scenario

Climate change has become one of the most pressing global issues, whereby a net zero goal within the coming decades is essential to limit the impacts of climate change. Achieving a net zero goal by 2030 is challenging. However, Chiang Rai may consider several ambitious measures to realise a more rapidly decline in the GHG emissions reduction trajectory, paving the way towards achieving net zero in the near future. The measures are, for example, decarbonizing the province's power supply and fuel/clean technology substitution. The measures proposed (in addition to the ones already proposed for the SET and SST scenarios) are further explained in later sections.

5.2.1. Energy demand outlook

The total final energy consumption is expected to increase from 599 ktoe in 2018 to 528.1 ktoe in 2030, a reduction of 88.8 ktoe compared to the STS scenario. The transport sector still has the largest share, at 66.9 per cent, followed by the residential sector at 15 per cent, industrial sector at 11.7 per cent and commercial sector at 5.4 per cent. Figure 25 shows the projected TFEC by sector under the TNZ scenario.

Figure 25. Energy demand by sector, TNZ scenario



5.2.2. GHG emission reduction and energy savings

The measures considered in the TNZ scenario and the respective energy demand and GHG emission reductions (compared to the STS scenario) are summarized in table 8.

Table 8. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to STS)

Sector	Measure	Energy demand reduction (ktoe)	GHG emission reduction (ktCO2-e)
Power	Achieving a 100 per cent decarbonized power supply by 2030	-	732.9
Transport	Replacing all ICE passenger transport vehicles with EVs by 2030	71.7	224.5
Residential	Increase the adoption **of electric cooking stoves** to 100 per cent in urban areas by 2030	17.1	102.1
Total		**88.8**	**1,059.4**

The power sector is often regarded as the low-hanging fruit in achieving a net zero energy system, particularly with the competitive cost of renewable electricity. With the emissions associated with electricity usage making up around 54 per cent of Chiang Rai's GHG emissions in 2018, decarbonizing the electricity supply can be a cost-effective and efficient way to achieve a substantial GHG emissions reduction. Other measures are also important to Chiang Rai's net zero endeavour – fuel substitution can be considered in the industrial sector, while electrification can be further promoted, such as in the transport and residential sectors.

5.2.3. Energy flows and balance, 2030

In the TNZ scenario, TPES is forecast to increase from 599 ktoe in 2018 to 528.1 ktoe in 2030. Figure 26 further shows the TPES breakdown by fuel type, while figure 27 shows the energy flows in 2030.

Figure 26. TPES breakdown by fuel type, TNZ in 2030

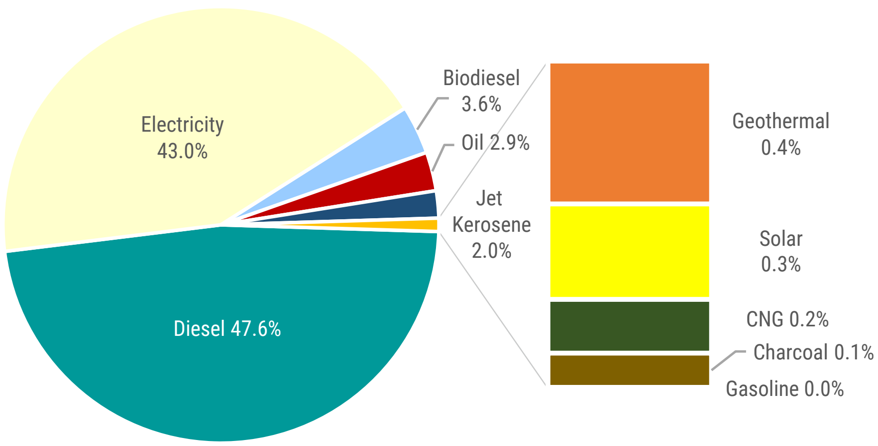


Figure 27. Sankey Diagram, TNZ in 2030 (unit: ktoe)

5.2.4. Pathways in decarbonizing Chiang Rai's electricity supply

The electricity demand is projected to be 2,682 GWh in 2030. Chiang Rai currently fulfils almost all its electricity requirements with electricity from the central grid. Significant challenges exist for the province to increase the share of renewable energy in its electricity supply, as the province currently does not have direct control of the central grid, either in the RE share or the grid emissions. Nevertheless, there are a few pathways that the province can explore, in collaboration with the citizens and/or private investors, in order to achieve a net-zero carbon power supply objective:

(a) Rooftop solar PV installation can be promoted for both new and existing buildings. Incentivising rooftop solar PV installation provides two benefits to the province – (i) a reduction of the financial burden on the city for establishing the province's own utility-scale solar PV system, and (ii) reduced land-use requirement from ground-mounted PV. The provincial government may consider offering incentives to increase the uptake of solar PV rooftop systems (see figure 28 for LCOE comparisons). Nevertheless, maintenance of solar panel is important due to the PM2.5 issue. As a result, the city should provide capacity building, especially on proper cleaning of these systems;

(b) Establishing a power purchase agreement (PPA). The province can enter into a special renewable energy power purchase agreement with interested RE suppliers. In turn, the suppliers will supply Chiang Rai with an agreed RE share electricity (solar, wind, biomass etc.) at an agreed price. However, this may not allow the province to take advantage of the lower generation costs available, such as through renewable energy auction;

(c) Lowering cost through renewable energy auctions. A more workable solution and a recent policy instrument is the renewable energy auction. This approach is likely to substantially decrease the cost of electricity supply through competitive pricing bidding and therefore, return a greater net benefit. The recent auctions, e.g., the 60 MW solar PV auction in Cambodia, has achieved $0.0387 per kWh (ADB, 2019). Further details about renewable auctions can be found in box 1;

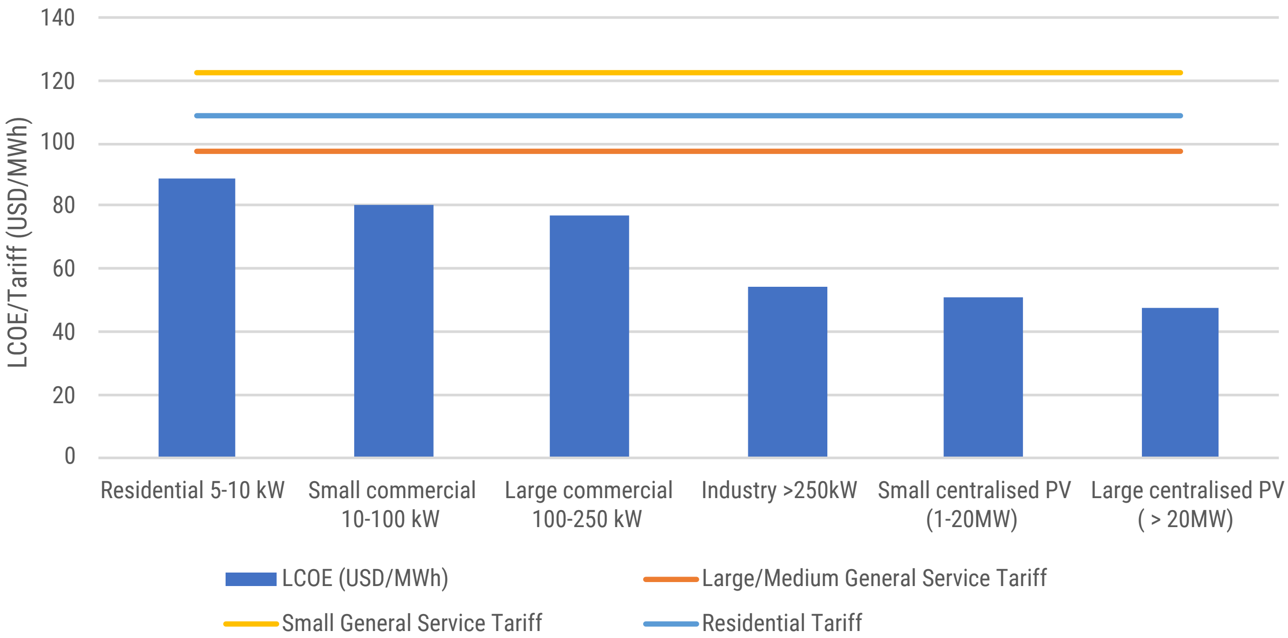
(d) Promotion of geothermal power generation; Local power generation using geothermal is possible on a very small scale. The provincial geothermal resource potential is around 4 MW. The current investment cost for a geothermal power plant is between US$ 2 million and US$ 7 million per MW (IRENA, 2021). However, the 300 kW geothermal power plant installed by EGAT in Fang district of Chiang Mai found that the quality of heat was not sufficient for suitable electric power generation, and that the cost of construction was extremely high. This is because of the larger well-depth requirement, which eventually increased the cost of power generation.

(e) Waste-to-Energy in the form of Residual Derived Fuel (RDF). Around 430,828 tonnes of waste are generated annually. Organic waste accounts for 40 per cent while the remaining 60 per cent is from general waste materials. The general and recyclable wastes could be converted to energy as refuse-derived fuel 2 (RDF-2 or coarse RDF). The estimated average heating value of this RDF-2 is 23.56 MJ per kilogram (Suma and others, 2019).

The above options are five different pathways (including the BAU scenario) that the province may pursue. A combination of one or more of the pathways, specifically with urban solar PV and renewable energy auction, may be a good solution. Figure 28 shows that the LCOE of solar PV systems[10] are cheaper in comparison with the different tariff categories. The cost assumptions are included in the annex.

10 This considers only CAPEX, and fixed O&M and assumed discount rate of 5.37 per cent.

Figure 28. LCOE of solar PV systems on different scales, in comparison to the average tariffs[11]



11 The different tariffs are averaged tariffs with reference to the data provided on the Metropolitan Electricity Authority website.

6. Policy recommendations for a sustainable energy transition

Chapter 4 demonstrates how sustainable energy transition can be accelerated to progress Chiang Rai's development in line with the national targets and commitment towards the Paris Agreement. Chapter 5 provides achievable low carbon transition pathways for Chiang Rai, with the most ambitious pathway reaching a GHG emission as low as 0.85 $MTCO_2$-e by 2030. This chapter presents several policy recommendations, which further elaborate on the interventions proposed.

6.1. Sustainable transport strategies to realise a low-carbon transport sector

Chiang Rai's transport sector accounted for about 72.6 per cent of the total energy demand and contributed 64 per cent of the province's GHG emissions in 2018. Hence, ambitious policy actions for the transport sector are critical for Chiang Rai to realise substantial GHG emission reduction, aligning with the national NDC commitment, specifically, through the adoption of transport electrification.

Electric vehicles have garnered great interest globally, growing exponentially during the past decade. Electric car sales passed 2 million globally in 2019, with a projected compound annual growth rate of 29 per cent through to 2030 (Deloitte, 2020) . Various government policies have been introduced that directly or indirectly promotes the adoption of electric vehicles as a means to achieve environmental and climate objectives. Thailand similarly has a grand plan for e-mobility, targeting 50 per cent zero-emission vehicles (ZEVs) of its domestic vehicle production by 2030, and an ambitious target for the registration of new cars to be 100 per cent ZEVs by 2035 (Ministry of Foreign Affairs, 2021). The SET scenario targets a 50 per cent electric share for passenger cars, 25 per cent electric share for motorcycles, a 50 per cent electric vehicle share for buses and minibuses and a 25 per cent electric vehicle share for freight transport. These, altogether, are projected to be reduced by 173.7 ktoe of energy demand and 553.5 ktCO2-e of GHG emissions in 2030.

Promoting the use of public transport, specifically buses, can effectively reduce fuel consumption from the transport sector. It is also a means of reducing traffic congestion – a major problem in many cities. With the urbanization rate expected to rise over the coming years, without intervention traffic congestion is likely to worsen. In addition, air pollution can be substantially decreased by taking cars off the road. The impact of increased mass public transport adoption on GHG emissions and energy demand is further examined in the STS scenario, simultaneously with a higher ambition for transport electrification. The current development of "a double-track rail route"to facilitate goods distribution, enhance tourism significantly and promote energy efficiency in the transport sector.

Several potential technical barriers to the widespread adoption of electric vehicles including an increase in demand for grid electricity, and the lack of charging facilities. A close collaboration between the province and power development agency should be fostered to carefully deliberate the potential impact on the power and grid infrastructure. In addition, the provincial government should take a lead in establishing an extensive charging infrastructure and expanding public transport infrastructure.

6.2. Pursuance of high renewable power share through cost effective pathways

Renewable energy capacity has increased significantly across the globe amid climate change concerns. The decarbonization of the power sector is generally regarded as low-hanging fruit, as the cost of renewable power technologies decreases rapidly over the past decade. With the electricity constituting around 20 per cent of the total fuel consumption and more than 29 per cent of the GHG emissions in 2018, decarbonizing the electricity supply provides a quick decarbonization pathway, reaching a substantial GHG emissions reduction, while providing financial benefits. NEXSTEP proposes four different pathways that may be considered in decarbonizing the electricity supply, as described in 5.1.1. A combination of these four pathways can be adopted.

Renewable energy auctions may be the most cost-effective and efficient option, whereby contracts and agreements are awarded through competitive bidding. While the renewable energy auction mechanism and its associated standards are set at the national level, Chiang Rai can work with the central Government to implement RE auctions at the city level. Box 1 explains on the renewable energy auction in more detail.

Box 1. Mechanism of renewable energy auction

A renewable energy auction, also known as a "demand auction" or "procurement auction", is essentially a call for tenders to procure a certain capacity or generation of renewables-based electricity. The auction participants submit a bid with a price per unit of electricity at which they are able to realize the project. The winner is selected on the basis of the price and other criteria, and a power purchase agreement is signed. The auctions have the ability to achieve deployment of renewable electricity in a well-planned, cost-efficient and transparent manner. Most importantly, it makes the achievement of targets more precise than would be possible by other means, such as a Feed-in-Tariff (FiT). Auctions are flexible and they allow Governments to combine and tailor different design elements to meet deployment and development objectives. Unlike FiTs, where the Government decides on a price, auctions are an effective means of discovering the price appropriate to the industry, which is the key to attracting private sector investment. In addition, an auction provides greater certainty about future projects, and is a fair and transparent procurement process. However, the administrative and logistic costs associated with auctions are very high unless multiple auctions are undertaken at regular intervals.

It is imperative that an auction be appropriately designed to (a) avoid the risk of underbuilding and project delays, and (b) allow sufficient competition among different levels of bidders in order to drive down the cost. IRENA suggests the following key design elements:

- Auction demand. Governments need to clearly indicate the scale or size of each auction, the preferred technology (technology neutral of a specific technology), auction frequency, and the upper and lower limits of projects size and price;

- Pre-qualification. A strict or high pre-qualification for bidders will leave out the smaller entities, while a relaxed pre-qualification may undermine the quality of the project and increase the administrative costs. Governments need to make a trade-off, depending on the project size and other development objectives;

- Selection criteria. Commonly two selection criteria are used: (a) the lowest bid where only the lowest bidder will win; and (b) lowest bids plus other objectives where in addition to the price, other objectives such as local content and jobs are taken into consideration;

- Payment modalities. The pay-as-bid model is good to minimize the cost; however, the marginal cost payment model, where the same price (selected based on the highest cost winner) is paid to all winners, is also practised;

- Penalties for non-compliance. There could be cases where the developer either delays the project or fails to complete it. To avoid such cases, penalties should be set. There are two modes of penalty. In the monetary penalty, money will be deducted from bidder's "bond" or the price of energy will be reduced for a delayed completion. A form of non-monetary penalty can be the exclusion of the bidder from future auctions.

6.3. Moving towards NetZero Carbon

Limiting temperature rise to 1.5°C requires climate mitigation efforts on an unprecedented scale and speed in order to reduce GHG emissions by about 45 per cent from 2010 levels by 2030, reaching net zero around 2050 (IPCC, 2018). Failing to act on this currently most pressing issue may lead to catastrophic impact on human livelihoods. Thailand is highly vulnerable to the impacts of climate change, with the greatest impacts likely to come from flooding events. Thailand's agricultural sector could be significantly affected, whereby the productivity decreases with the warming climate (World Bank and ADB, 2021).

The energy system of Chiang Rai is well positioned for an accelerated decarbonization effort as the required net-zero technologies in decarbonizing its energy systems are readily available and matured, namely electric vehicles, electric cooking stoves and renewable power technologies. As detailed in section 5.2, decarbonizing its electricity supply is key for deep decarbonization as it contributed around 29 per cent of the total GHG emissions in 2018. A decarbonized electricity supply is also required to complement the hastened adoption of electricity-based technologies, such as electric vehicles and electric cooking stoves, in order to realise the greatest potential of electrification.

Efforts by all levels and sectors are imperative in the emission race to net zero. These include a clear and well-guided transition plan from the provincial and national governments as well as citizens' participation. The latter is often a challenge due to barriers such as low climate consciousness and low purchasing power to transition to a more sustainable lifestyle. Thus, an energy conservation awareness programme and easier access to sustainable choices are a key to encouraging widespread adoption of efficient technologies, such as electric vehicles. In addition, financial incentives can aid the transition, particularly during the early stage.

7. Conclusion

The 2030 Agenda for Sustainable Development and Paris Agreement provide a common goal in achieving sustainability and climate objectives. While achieving the SDG 7 targets is principally a national effort, it requires combined contributions from stakeholders at various levels, such as subnational jurisdictions and cities. Recognising this, ESCAP and Thailand's Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy, further expanded the NEXSTEP initiative to develop a Sustainable Energy Transition (SET) road map for Chiang Rai province, as part of the DEDE "Energy for All" programme focusing on sustainable energy planning for cities.

Chiang Rai is the northernmost province of Thailand. The GDP of Chiang Rai is projected to grow at 3.63 per cent per annum, while the population is expected to increase by 0.22 per cent annually. Under the current policy settings, the overall energy demand is projected to rise by an annual average rate of 3.3 per cent, to 881.5 ktoe. Considering the increasing renewable energy generation share as per Thailand Power Development Plan, 2018-2037, GHG emissions are projected to be 2.6 $MTCO_2$-e, a GHG emission reduction of 0.25 $MTCO_2$-e, compared to a business-as-usual baseline.

The SET scenario proposes an energy transition pathway that strategically allows Chiang Rai to align its energy sector performance with the national targets and the national unconditional NDC commitment. It suggests several energy efficiency opportunities that would lead to energy savings and GHG emission reduction, across different demand sectors. The industrial sector is relatively small in Chiang Rai but it is the third highest sector in terms of energy demand. With limited energy saving options across different subcategories, the energy demand reduction is projected to be 13.8 ktoe, if best practices are adopted widely. Energy conservation awareness should be further strengthened among the industrial business owners, while financial incentives may be provided to assist overcoming the financial hurdles for small and medium-sized enterprises (SMEs).

The transport sector is the largest energy-consuming sector, and therefore has a substantial energy saving potential. Electric vehicle adoption is critical to achieving a 25 per cent GHG emissions reduction, aligning with the national conditional NDC commitment. The SET scenario realises an energy demand reduction and GHG emission reduction of 173.7 ktoe and 553.5 $ktCO_{2\text{-}e}$, respectively. More can be done, such as greater adoption of public mass transport and electric vehicles, as further examined in the STS scenario. These, however, require a concerted effort by the public and private sectors, such as establishing an extensive network of charging stations and public transport routes.

Climate change is one of the most pressing issues of this century, requiring hastened and widespread climate mitigation from all sectors. Chiang Rai may play its part by raising its decarbonization effort to realise a more rapidly declining GHG emissions trajectory, particularly, through decarbonizing of its electricity supply. This road map further explores several pathways that the province may undertake in decarbonizing its electricity supply. Renewable energy auctions stand out as the cheapest option at the same time, without the operational burden from the provincial government. In combination with a high transport electrification ambition and energy efficiency measures as already proposed for the SET and STS scenarios, the GHG emissions is projected to reduce to 0.86 $MTCO_2$-e in 2030, a 70 per cent reduction from the BAU baseline.

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Annexes

Annex I. Key assumptions for NEXSTEP energy modelling

(a) General key assumptions:

Annex table 1. GDP and GDP growth rate

Parameter	Value
GDP (2018, current Thai baht)	110.8 billion
GDP (2018, current US dollar)	3,429.7 million
PPP (2018, constant 2017 US dollar)[12]	17.6 billion
GDP growth rate	3.63%

Annex table 2. Population, population growth rate and household size

Parameter	Value
Population (2018)	1,295,026
Population growth rate	0.22%
Number of households (2018)	558,825
Household size (constant throughout the analysis period)	2.3

(b) Demand analysis and growth projections, by sector

Residential:

- The residential sector is further divided into urban (33.7 per cent) and rural (66.3 per cent) households.
- The clean cooking access rate is estimated as 75.6 per cent in 2018. The cooking distribution and assumed energy intensities are as estimated in annex table 3.

12 he GDP in 2018 (in terms of local currency) is converted into PPP (current US dollars) with a conversion factor of 12.723 (see https://data.worldbank.org/indicator/PA.NUS.PPP?locations=TH) and adjusted to 2017 US dollars based on the consumer price index (CPI) provided in https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator/consumer-price-index-1913-

Annex table 3. Cooking distribution for 2018

Stove type	Distribution [13]	Energy intensity (GJ/household)
LPG stove	73.95%	4.17
Electric stove	1.66%	1.77
No cooking	8.9%	-
Charcoal stove	15.49%	6.58

- The residential appliance ownership data are based on ownership database from National Statistical Office. The appliance ownership is projected to grow at a rate similar to the growth in GDP per capita, up till reaching a saturation of 100 per cent.
- The average electrical intensities per owning household for the different appliances are as estimated based on assumed appliance wattage and operating hours/year, constrained by top-down measured residential electricity consumption data. The energy intensities are assumed constant throughout the analysis period.

Annex table 4. Residential appliance baseline assumptions for 2018

Category	Appliance	Ownership (%)	Electricity intensity (kWh/HH/year)
Lighting	Fluorescent	94.4	108.9
	Compact fluorescent	42.5	58.6
	LED E27	7.6	53.25
-	Air conditioner	25.7	1075.1
-	Refrigerator	92.30	163.21
Television	LCD/LED/plasma	40.38	44.81
	Common	59.62	48.88
-	Water heater	30.50	359.53
-	Electric stove	1.66	475.08
-	Electric fan	96.9	163.38
Washing machines	Top loading	97.7	17.32
	Front loading	2.3	96.81
-	Water pump	11.5	167.52
-	Electric iron	71.6	117.7

13 Cooking distribution is based on a 2019 survey by the National Statistical Office – percentage of households classified by type of fuel for cooking in the southern region.

Transport:

- The land transport sector consumption is estimated using the vehicle-km statistics and assumed fuel economy, as shown in annex table 5. The vehicle statistics and vehicle-km statistics were compiled by the local consultant, while fuel economy assumptions are based on numbers referenced in several studies conducted for Thailand.
- Transport activities in 2018 are estimated to have been 3.24 billion vehicle-kilometres for road passenger transport and 1.9 billion vehicle-kilometres for road freight transport. The growth in both passenger transport and freight transport activities is assumed as growing at the same rate as the GDP, i.e., 3.63 per cent per annum.

Annex table 5. Transport sector baseline assumptions for 2018

Passenger transport	% share of vehicles by fuel type	Travelled mileage in 2018 (million km)	Fuel consumption	% share of passenger-km
Passenger car	Gasoline – 32.78%	1,925	12.5 km/l	59.87%
	Diesel – 64.42%		11.1 km/l	
	Hybrid – 0.28%		20 km/l	
	LPG – 1.9%		2.7 MJ/km	
	CNG – 0.62%		2.7 MJ/km	
	Electric – 0%		5 km/kWh	
Motorcycle	Gasoline – 100%	1,068	25.5 km/l	33.21%
Bus and minibus	Gasoline – 1.41%	222	5.15 km/l	6.91%
	Diesel – 89.20%		5.15 km/l	
	CNG – 1.53%		7.3 MJ/km	
	LPG – 7.63%		7.3 MJ/km	
Freight transport	No. of vehicles	Travelled mileage in 2018 (million km)	Fuel consumption	% share of tonne-km
Freight truck	Diesel – 99.54%	1,709	9.29 km/l	90.60%
	Gasoline – 0.01%		9.29 km/l	
	CNG – 0.52%			
Trailer	Diesel – 100%	177	3.00 km/l	9.40%

Industry:

- The industrial sector is further differentiated into seven sub-categories. The fuel consumption by industrial sub-categories is as detailed in annex table 6, as provided by the local consultant.
- The industrial activities are assumed to be growing at an annual rate of 3.63 per cent, similar to the provincial GDP growth rate.

Annex table 6. Fuel consumption by industry sub-categories in 2018

Industry	Fuel consumption (ktoe)					
	Coal	Oil Products	Biomass	Electricity	Biogas	Total
Cement and non- metallic quarry xproducts		-	-	2.47	-	2.47
Iron and steel		-	-	0.21	-	0.21
Fertilizer, chemical, and rubber products		-		0.35	-	0.35
Food and beverages		2.21		14.04		16.25
Machinery and transportation tool	-	-	-	0.55	-	0.55
Wood and other products	-			0.17	-	0.17
Other industry	-	10.67		22.22	-	32.89
Pulp and paper				0.21		0.21

Commercial:

- The commercial sector is differentiated into designated buildings and non-designated buildings.
- The total commercial floorspace of the designated buildings is estimated as 0.74 million m^2 in 2018. They can be further distinguished as six sub-categories. This is projected to grow at an annual rate of 3.63 per cent, a rate similar to the projected growth in provincial GDP.
- There are no floorspace data available for non-designated buildings, but the fuel consumption is measured as 19.66 ktoe in 2018. NEXPSTEP assumes a 3.63 per cent annual growth in fuel consumption, a rate similar to the projected growth in provincial GDP.
- The fuel intensities and consumption data for 2018 are as summarized in annex table 7.

Annex table 7. Commercial sector fuel intensities in 2018

Category	Sub-category	Floorspace (million m^2)	Electricity intensity (kWh/m^2)	Total (ktoe)
	Shopping mall	0.35	83.1	2.52
	Hotel	0.04	171.5	0.59
	Hospital	0.033	140.55	0.39
	University	0.32	79.26	2.16
Non-designated buildings	-	-	-	19.66

Other sectors:

- The remaining demand sectors are (a) non-specified use and (b) agriculture. The estimated energy consumption in 2018 is detailed in annex table 8. The consumption growth is projected to increase at an annual rate of 3.63 per cent, the same as the provincial GDP growth rate.

Annex table 8. Consumption in other sectors in 2018

Sector	Electricity consumption (toe)
Agriculture	1.19
Non-specified use	2.32

Annex II. Power technologies assumptions

Cost assumptions used for calculating the levelized cost of electricity (LCOE) of solar PV systems and biomass power plant are shown in annex tables 9 and 10.

Annex table 9. Capital cost assumptions for solar PV and biomass plant

	Installation cost[14]	
	THB/W	US$/MW
Residential 5-10 kW	52	1,612,000
Small commercial 10-100 kW	47	1,457,000
Large commercial 100-250 kW	45	1,395,000
Industry >250kW	32	992,000
Small centralised PV (1-20MW)	30	930,000
Large centralised PV (> 20MW)	28	868,000
Biomass power plant	-	2,390,000

Annex table 10. Other assumptions

Other general assumptions	Value
Capacity factor[15]	16.5 per cent for solar PV 66.5 per cent for biomass power plant
Fixed O&M (US$/MW)[16]	1.2 per cent of CAPEX for solar PV 6.5 per cent of CAPEX for biomass power plant
Lifetime	30 years
Biomass fuel cost[17]	12.5 US$/ton

14 With reference to the National Survey Report of PV Power Applications in Thailand 2018

15 Averaged capacity factor for Thailand quoted in Levelized Cost of Electricity of Selected Renewable Technologies in the ASEAN member States (2016)

16 Averaged O&M for Thailand quoted in Levelized Cost of Electricity of Selected Renewable Technologies in the ASEAN member States (2016)

17 Averaged fuel cost for Thailand quoted in Levelized Cost of Electricity of Selected Renewable Technologies in the ASEAN member States (2016)

Annex III. Summary result for the scenarios

Annex table 11. Summary result for the scenarios

	BAU scenario	CPS scenario	SET scenario	STS scenario	Towards NetZero
Universal access to electricity	Already achieved				
Universal access to clean cooking	81% by 2030		100% by 2030		
TFEC in 2030	881 ktoe	881 ktoe	685 ktoe	617 ktoe	528 ktoe
Energy efficiency (in terms of TFEC)	5.83 ktoe/billion $baht_{2010}$	5.83 ktoe/billion $baht_{2010}$	4.55 ktoe/billion $baht_{2010}$	4.08 ktoe/billion $baht_{2010}$	3.50 ktoe/billion $baht_{2010}$
Energy efficiency (SDG 7.3)	2.86 MJ/$US\$_{2017}$	2.86 MJ/$US\$_{2017}$	2.22 MJ/$US\$_{2017}$	2.00 MJ/$US\$_{2017}$	1.72 MJ/$US\$_{2017}$
Renewable energy share in TFEC	9.4%	12.5%	12.2%	12.9%	47.4%
GHG emissions	2.79 $MTCO_2$-e	2.57 $MTCO_2$-e (8% from BAU)	2.08 $MTCO_2$-e (25% from BAU)	1.91 $MTCO_2$-e (31% from BAU)	0.86 $MTCO_2$-e (69% from BAU)

Annex IV. Energy balance

Annex table 12. Energy balance of Chiang Rai 2018 (ktoe)

Particulars	Oil products	Biomass	Electricity	Total
Primary production		2.18		2.18
Import	479.79		117.18	596.97
Export				
International marine bunkers				
International aviation bunkers				
Stock change				
Total primary energy supply	**479.79**	**2.18**	**117.18**	**599.15**
Transfers				-
Statistical difference				
Electricity plants				
Oil refineries				
Other transformation				
Energy industry – own use				-
Losses				-
Total final energy consumption	**479.80**	**2.18**	**117.18**	**599.15**
Residential	31.85	2.18	48.1	82.11
Industrial	2.861		40.20	53.08
Commercial	0.00		25.33	25.33
Transport	435.08			435.13
Agricultural			1.19	1.19
Non-specified			2.32	2.32

Figure 29. Energy balance of Chiang Rai, 2018 (ktoe) – Sankey Diagram