Energy Transition Pathways for the 2030 Agenda

Sustainable Energy Transition Road Map for Udon Thani Province of 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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Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

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ESCAP
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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

Udon Thani development plan is guided by a range of long-term strategies including developing infrastructure, improving local production and marketing facilities, developing safe and environment-friendly high-value agriculture systems, and promoting smart agriculture to increase the competitiveness and stability of the fundamental economy. Also, the strength of provincial administration is enhanced through the integration framework between all sectors in accordance with the Smart Province guidelines. Transitioning to low-carbon and sustainable energy future is essential to achieving these outcomes. As such, Udon Thani is committed to applying all aspects of clean energy and environmental enhancement measures to guide the city's development targets.

In this connection, the province of Udon Thani has developed the Sustainable Energy Transition (SET) Road Map which marks the culmination of successful collaboration among the Udon Thani Provincial Energy Office (PEO), the Department of Alternative Energy Development and Efficiency (DEDE) and United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). It has been developed as part of DEDE's Renewable Energy Technologies in Cities and Urban Planning for Renewable Energy Applications in Thailand initiative. The Road Map has examined the socio-economic condition of the province, considered the existing and future plans of energy sector development and identified the best possible pathway for transitioning to a sustainable low-carbon energy future. Recommendations from the Road Map will be applied as a guidance to promote provincial policies, measures, programs to support the achievement of the Sustainable Development Goals 7 (SDG7), the emissions reduction target and the Carbon Neutrality Goal at the national level. I would also like to emphasize that the Road Map supports the Alternative Energy Development Plan (AEDP) and Energy Efficiency Plan (EEP) both of which aim to increase the share of renewable energy and alternative energy over 50 per cent and reduce energy intensity (EI) by more than 30 per cent by 2050, which are a part of the National Energy Plan (NEP).

Key policy recommendations from the Road Map include rapidly increasing the use of electric vehicles (EV) to support low-carbon transportation, and integrating energy efficiency policies at all levels to minimize energy consumption in the industrial sector. The use of clean energy should be promoted across all sectors such as through the installation of solar rooftop PV, investment in renewable energy (RE) for electricity generation, increasing RE share in electricity supply, and moving toward Net Zero Carbon energy system which will allow the province to follow the national Carbon Neutrality and Net Zero Carbon pathway. Additionally, the Road Map serves as a guideline to draw our own energy Road Map in the future.

The Road Map has been developed through an extensive consultative process with key stakeholders of the energy sector including government agencies, private sector and academia to ensure that it adequately reflects the needs and development plans of the province. On the successful completion of the SET Road Map, I would like to express my gratitude to the Provincial Energy Office of Udon Thani which is the key local agency to create this collaboration framework and facilitate consultations to develop the Udon Thani SET Road Map. Our deepest appreciation to ESCAP for their excellent support and guidance to the province of Udon Thani throughout the Road Map development process.

Sayam Sirimongkol
Governor of Udon Thani Province

Foreword

Energy transition is critical to reduce the impact of the current energy crisis due to the COVID-19 pandemic, the 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 Udon Thani 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 Udon Thani, as the commercial centre and transport hub of upper north-eastern Thailand, faces several challenges concerning energy use and environmental sustainability. 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 Udon Thani'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 closing 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 emission reduction targets while paving the way towards a net-zero society.

I would like to thank DEDE, the province of Udon Thani, 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 Udon Thani'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	decarbonisation 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
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 (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 is also supporting the Department of Alternative Energy Development and Efficiency (DEDE), Ministry of Energy in its "Energy for ALL" programme, by furthering the NEXSTEP initiative to three Thailand provinces. This Sustainable Energy Transition (SET) road map, developed for the province of Udon Thani, identifies the technological options and policy measures that will help the province 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 road map

The province of Udon Thani is located on a plateau which is approximately 187 metres above sea level. Most of the area is covered with rice fields, forests and hills; the Phu Pan mountain range and the Songkhram River are the province's two primary natural attractions. It is bordered by the provinces of Nong Khai to the north, Sakon Nakhon to the east, Kalasin province to the south-east, Khon Kaen to the south, and Loei and Nong Bua Lamphu to the west. Udon Thani is also famous for its natural tourist attractions and local products like *Pha Khid* patterned silk weaving. Local communities are also very charming with the simple way of living. The province covers an area of 11,072 km^2. The total forest area is 1,131 km^2, which is 10.2 per cent of the provincial area. Udon Thani had a population of 1.57 million in 2018. The gross provincial product (GPP) in 2018 was Baht 113.9 billion and the GDP per capita was around Baht 72,600.

This SET road map has two main objectives. First, it aims to establish a scenario baseline for 2019-2030, by considering the current policy settings. Second, it identifies the measures and technological options that could raise Udon Thani's efforts to align with the SDG 7 targets, national targets as well as achieving deep decarbonisation of its energy system. The three 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 as well as the 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 Towards Net Zero (TNZ) scenario, the most ambitious scenario, which looks at a pathway of moving towards a net zero society in the near future, through decarbonising 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 the existing policies/initiatives are failing to achieve their intended outcomes.

B. Aligning Udon Thani province's energy transition pathway with the SDG 7 targets and national commitments

Access to modern energy

Udon Thani has already achieved universal access to electricity, while the clean cooking access rate is estimated to have been 62.8 per cent in 2018. This includes the 5.1 per cent of households that do not conduct cooking at home. The remaining 37.2 per cent of the population, which corresponds to approximately 169,599 households, relied on traditional charcoal stoves which contribute significantly towards indoor air pollution and associated health impacts. The national clean cooking access rate was improving with an annual rate of 0.6 per cent during 2015-2019. Continuing on a similar trajectory, it is estimated that Udon Thani will achieve a 67.3 per cent access rate by 2030.

Renewable energy

The share of renewable energy (RE) in the total final energy consumption (TFEC) was 41.5 per cent in 2018. All scenarios are projected to meet the national renewable energy target, 30 per cent of TFEC, set for 2037. Under the CPS, the share of RE will increase to 44.6 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 increase to 44.6 per cent. As described later in this report, the SET scenario proposes several energy efficiency measures in aligning the province's energy demand reduction and GHG emissions reduction with the national targets.

The RE share in TFEC for the TNZ scenario is expected to be high, which is envisioned to be a decarbonised electricity supply. Apart from a decarbonised electricity supply, the TNZ scenario also aims to increase the pace towards net-zero carbon through fuel substitution and higher rate of electrification, reaching a RE share of 64.4 per cent in 2030. As later described in this road map, there are several pathways for achieving a decarbonised electricity supply, with the most promising and cost effective one being through renewable energy auctions.

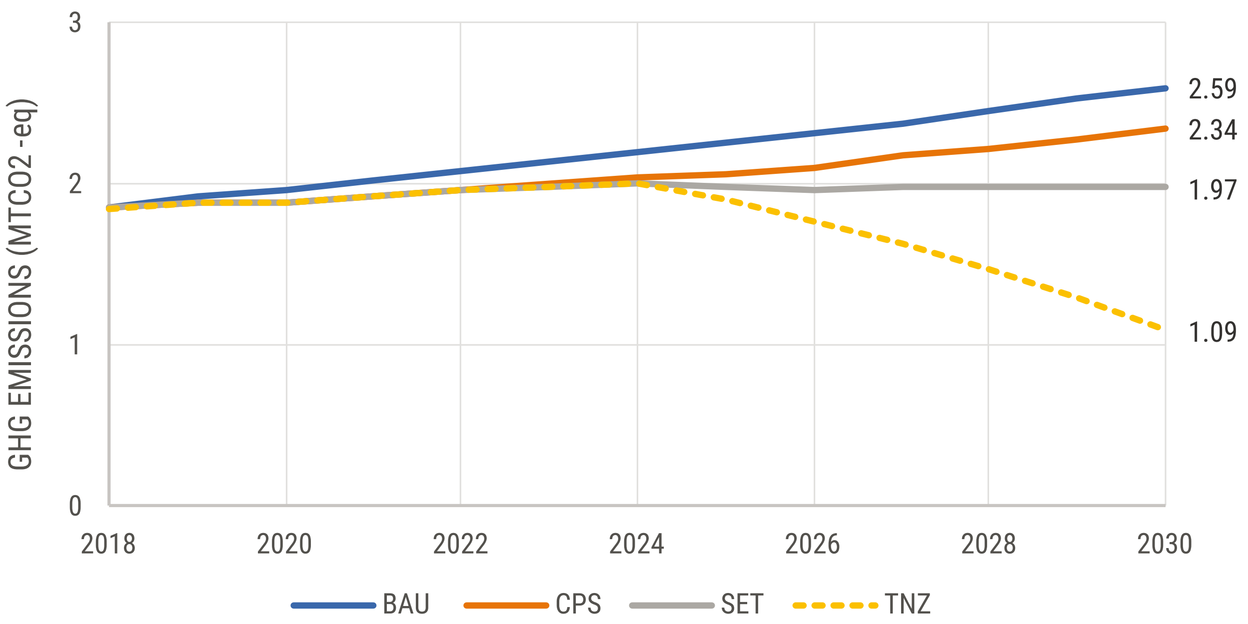
Energy efficiency

Udon Thani's energy Intensity is estimated to have been 8.91 ktoe/billion $baht_{2010}$ (in terms of TFEC) in 2018. It is expected to decline to 8.62 ktoe/billion $baht_{2010}$ by 2030 in the CPS, as GDP growth outpaces the growth in energy demand. This corresponds to an annual improvement rate of 0.26 per cent. The SET scenario proposes several energy efficiency interventions across the demand sectors, which further decrease the energy intensity to 6.6 ktoe/billion $baht_{2010}$ by 2030, putting Udon Thani on a path to meeting the national energy efficiency target of 5.98 ktoe/billion $baht_{2010}$ by 2037. The industry sector made up around 41.9 per cent of the total energy demand in 2018, and adoption of energy efficiency measures across the sector is expected to provide a substantial saving of about 146 ktoe. NEXSTEP proposes an increase of electric vehicle share in the transport fleet to between 15 to 100 per cent, by 2030. The projected result is 128 ktoe reduction 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 further detailed in chapter 4 of this report. The energy intensity of the TNZ scenario is projected to be 6.62 ktoe/billion $baht_{2010}$.

GHG emissions

The GHG emissions in 2018 are estimated at 1.85 $MTCO_2$-e, which considers direct fuel combustion from the demand sector and emissions attributable to grid electricity. Figure ES 1 shows the GHG emission trajectories for the different scenarios. The GHG emissions from the CPS are projected to reach 2.34 $MTCO_2$-e, while they are further decreased to 1.97 $MTCO_2$-e in the SET scenario. The latter corresponds to a 24 per cent reduction from the BAU scenario, aligning the province's GHG emission reduction with the unconditional NDC target. A drastic drop in emissions can be observed in the TNZ scenario – only 1.09 $MTCO_2$-e with a fully decarbonised electricity supply.

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



C. Key policy recommendations

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

1. Rapid adoption of electric vehicles to realise a low-carbon transport sector. The energy consumption of the transport sector is the highest – thus giving a substantial energy savings potential through transitioning to an electric vehicle mobility;
2. Adoption of energy efficiency measures across all industrial subsectors can realise a deep reduction in energy demand. The provincial government may consider providing financial incentives to encourage widespread adoption of industrial best practices;
3. Decarbonisation of the power supply provides the highest potential in GHG emission reduction. Several pathways can be considered, such as solar rooftop and RE auctions, which may be the most cost-effective and efficient solutions. The provincial government should consider working with the national Government to identify modalities to implement RE auctions at the local level;
4. Raised ambitions, particularly a higher level of electrification and a net-zero power sector puts Udon Thani on path of 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) มีวัตถุประสงค์ 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) โดยการดำเนินการนี้ได้จัดทำขึ้นเพื่อตอบสนอง ต่อปฏิญญารัฐมนตรีที่มีต่อการประชุม 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 ได้ประสานความร่วมมือกัน เพื่อสนับสนุนสามจังหวัดของประเทศไทยในการพัฒนาแผนงานการเปลี่ยนผ่านด้านพลังงานอย่างยั่งยืน (หรือ Sustainable Energy Transition: SET) โดยใช้เครื่องมือ NEXSTEP ทั้งนี้ แผนงานการเปลี่ยนผ่านด้านพลังงานอย่างยั่งยืน (SET) ได้พัฒนาขึ้นสำหรับจังหวัดอุดรธานี ซึ่งได้กำหนดตัวเลือกเทคโนโลยีและนโยบาย/มาตรการ ที่เป็นทิศทางในการพัฒนาของจังหวัดให้สอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในปี พ.ศ. 2573, เป้าหมายการพัฒนาประเทศ และความมุ่งมั่น ต่อความตกลงปารีส

แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน

จังหวัดอุดรธานี เป็นจังหวัดที่อยู่บนที่ราบสูงซึ่งมีความสูงจากระดับน้ำทะเลประมาณ 187 เมตร พื้นที่ส่วนใหญ่ เป็นทุ่งนา ป่าไม้และเนินเขา เทือกเขาภูพานและแม่น้ำสงครามเป็นแหล่งท่องเที่ยวทางธรรมชาติที่ได้รับความนิยม โดยทิศเหนือติดต่อกับจังหวัดหนองคาย ทิศตะวันออกติดต่อกับจังหวัดสกลนคร ทิศตะวันออกเฉียงใต้ติดต่อกับจังหวัดกาฬสินธุ์ ทิศใต้ติดต่อกับจังหวัดขอนแก่น ทิศตะวันตกติดต่อกับจังหวัดเลย และจังหวัดหนองบัวลำภู ตามลำดับ จังหวัดอุดรธานี ยังมีชื่อเสียงในด้านสถานที่ท่องเที่ยวทางธรรมชาติและผลิตภัณฑ์ท้องถิ่น เช่น การทอผ้าขิด หรือ การทอผ้าไหมลวดลาย เป็นต้น ชุมชนท้องถิ่นยังคงมีเสน่ห์ด้วยวิถีชีวิตที่เรียบง่าย จังหวัดมีพื้นที่ 11,072 ตารางกิโลเมตร ประกอบด้วยพื้นที่ป่าทั้งหมด 1,131 ตารางกิโลเมตร หรือร้อยละ 10.2 ของพื้นที่จังหวัด จังหวัดอุดรธานีมีประชากร 1.57 ล้านคนในปี พ.ศ. 2561 ผลิตภัณฑ์รวมของจังหวัด (GPP) ในปี พ.ศ. 2561 อยู่ที่ 113.9 พันล้านบาท และผลิตภัณฑ์มวลรวมของประเทศ (GDP) ต่อหัว อยู่ที่ประมาณ 72.6 พันบาท ตามลำดับ

แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) นี้ ประกอบด้วยวัตถุประสงค์ 2 ประการ โดยประการแรกมีเป้าหมายเพื่อจัดทำกรณีฐาน (Scenario Baseline) ระหว่างปี พ.ศ. 2562 – พ.ศ. 2579 พิจารณา ถึงการกำหนดนโยบายในปัจจุบัน และประการที่สอง คือ เพื่อกำหนดตัวเลือกมาตรการ และเทคโนโลยีซึ่งมีส่วนช่วยส่งเสริม ให้การพัฒนาจังหวัดอุดรธานีมีความสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7, เป้าหมายการพัฒนาประเทศ และลดการปล่อยก๊าซเรือนกระจกในภาคพลังงาน โดยแบบจำลองสถานการณ์ (Scenario) ทั้งหมด 3 แบบจำลองภายใต้แนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) มีรายละเอียด ดังต่อไปนี้

- แบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (Current Policy Scenario: CPS) ซึ่งได้พัฒนาขึ้นตามนโยบายและแผนที่มีอยู่ในปัจจุบัน และนำมาใช้เพื่อวิเคราะห์ช่องว่างสำหรับนโยบายและแผนที่มีอยู่ โดยสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7, เป้าหมายการพัฒนาประเทศ และความมุ่งมั่น ต่อความตกลงปารีส
- แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ได้นำเสนอตัวเลือกเทคโนโลยีและนโยบาย ซึ่งจะมีส่วนช่วยให้การพัฒนาจังหวัดอุดรธานีมีความสอดคล้องกับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และเป้าหมายการพัฒนาประเทศ
- แบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (Towards Net Zero: TNZ) โดยเป็นสถานการณ์ที่มีความท้าทายมากที่สุด และมุ่งเน้นแนวทางไปสู่การบรรลุการปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ในอนาคตอันใกล้ผ่านการลดปริมาณการปล่อยก๊าซเรือนกระจกจากแหล่งจ่ายไฟฟ้า การทดแทนเชื้อเพลิงและความมุ่งมั่นในการใช้พลังงานในรูปแบบของพลังงานไฟฟ้าที่มีมากขึ้น (Electrification)

นอกจากนี้ แบบจำลองสถานการณ์แบบเป็นไปตามปกติ (BAU) ได้มีการจัดทำขึ้นเพื่อแสดงถึงกรณีฐาน ในกรณีที่ไม่มีการประยุกต์ใช้นโยบาย/การริเริ่มใด ๆ หรือในกรณีที่นโยบายและแผนที่มีอยู่ในปัจจุบันไม่สามารถบรรลุผลลัพธ์ได้ โดยสถานการณ์นี้มีส่วนช่วยให้สามารถระบุเป้าหมายของประเทศได้ เช่น เป้าหมายการลดการปล่อยก๊าซเรือนกระจก เป็นต้น

การเชื่อมโยงแนวทางการปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืนของจังหวัดอุดรธานีเข้ากับเป้าหมายการพัฒนาอย่างยั่งยืนในข้อที่ 7 และเป้าหมายการพัฒนาประเทศ

การเข้าถึงพลังงานสมัยใหม่ (Modern Energy)

จังหวัดอุดรธานีได้บรรลุเป้าหมายสำหรับสัดส่วนการเข้าถึงพลังงานไฟฟ้าแล้ว ในขณะที่ปี พ.ศ. 2561 ประชากรประมาณร้อยละ 97.3 มีการใช้เทคโนโลยีสำหรับการประกอบอาหารที่สะอาด ซึ่งรวมไปถึงร้อยละ 6.4 ของครัวเรือนทั้งหมดไม่ได้ประกอบอาหารเองในครัวเรือน และร้อยละ 2.6 ที่เหลือ (หรือ ประมาณ 9,600 ครัวเรือน) ยังคงใช้เทคโนโลยี ที่ประสิทธิภาพต่ำซึ่งไม่เป็นมิตรต่อสิ่งแวดล้อม และอาจก่อให้เกิดผลกระทบด้านสุขภาพ ทั้งนี้ การเข้าถึงเทคโนโลยีสำหรับการประกอบอาหารที่สะอาดของประเทศมีอัตราเพิ่มขึ้นร้อยละ 0.6 ต่อปี ในระหว่างปี พ.ศ. 2558 - พ.ศ. 2562 โดยคาดว่า จะบรรลุสถานการณ์ที่ครัวเรือนทั้งหมดสามารถเข้าถึงเทคโนโลยีสำหรับการประกอบอาหารที่สะอาดได้ในปี พ.ศ. 2567 หากอัตราเจริญเติบโตยังคงที่

พลังงานทดแทน (Renewable Energy)

สัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (Total Final Energy Consumption: TFEC) ในปี พ.ศ. 2561 มีการใช้พลังงานทดแทนที่ร้อยละ 41.5 เปรียบเทียบกับการใช้พลังงานขั้นสุดท้าย โดยในทุกแบบจำลองสถานการณ์คาดการณ์ว่าจะบรรลุเป้าหมายด้านพลังงานทดแทนของประเทศที่ร้อยละ 30 ของ TFEC ที่กำหนดไว้สำหรับปี พ.ศ. 2580 ทั้งนี้ สัดส่วนการใช้พลังงานทดแทนภายใต้แบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) ที่ขับเคลื่อนโดยการ เพิ่มสัดส่วนการใช้พลังงานทดแทนในโครงข่ายไฟฟ้า ซึ่งคาดว่าจะเพิ่มขึ้นจากร้อยละ 17.8 ในปี พ.ศ. 2562 เป็นร้อยละ 24.6 ในปี พ.ศ. 2573 และการใช้เชื้อเพลิงชีวภาพในภาคขนส่งเพิ่มขึ้นเพียงเล็กน้อย โดยแบบจำลองสถานการณ์การปรับเปลี่ยน สู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ได้นำเสนอมาตรการปรับปรุงประสิทธิภาพการใช้พลังงานต่าง ๆ ซึ่งสอดคล้อง กับความต้องการใช้พลังงานที่ลดลง และการปล่อยก๊าซเรือนกระจกที่ลดลงที่สอดคล้องกับเป้าหมายของประเทศ

สัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (TFEC) สำหรับแบบจำลองสถานการณ์ที่มุ่งสู่ การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) คาดหวังว่าจะอยู่ในระดับสูง ซึ่งมุ่งเน้นไปที่การจ่ายไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจก นอกจากนั้นแบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) ยังมีเป้าหมายที่จะบรรลุการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (Net-Zero Carbon) ผ่านการใช้เชื้อเพลิงเพื่อทดแทนเชื้อเพลิงเดิมและอัตราการใช้ไฟฟ้าที่สูงขึ้น โดยสัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย (TFEC) บรรลุ ร้อยละ 64.4 ในปี พ.ศ. 2573 ทั้งนี้ แนวทางต่าง ๆ เพื่อให้บรรลุการจัดหาไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจก โดยวิธีที่มีประสิทธิภาพและคุ้มค่าที่สุด คือ การประมูลพลังงานหมุนเวียน

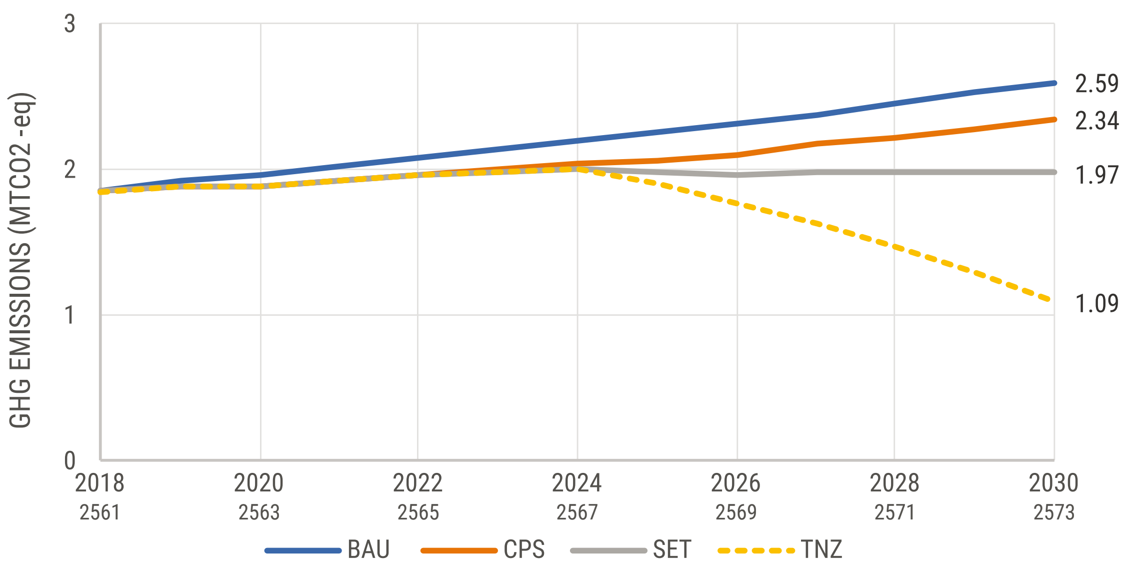
การปรับปรุงประสิทธิภาพการใช้พลังงาน (Energy Efficiency)

ความเข้มข้นการใช้พลังงาน (Energy Intensity: EI) ของจังหวัดอุดรธานี ได้รับการประเมินอยู่ที่ 8.91 ktoe/ ล้านบาท2553 (ในแง่ของสัดส่วนการใช้พลังงานทดแทนในการใช้พลังงานขั้นสุดท้าย TFEC) ในปี พ.ศ. 2561 โดยคาดว่าจะลดลงอยู่ที่ 8.62 ktoe/ล้านบาท2553 ในปี พ.ศ. 2573 ในแบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) เนื่องจากการเติบโตของผลิตภัณฑ์รวมของประเทศ (GDP) จะเพิ่มขึ้นมากกว่าการเติบโตของความต้องการพลังงาน ซึ่งสอดคล้องกับอัตราการปรับปรุงของแต่ละปีที่ร้อยละ 0.26 ทั้งนี้ แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) เสนอให้มีการประยุกต์การปรับปรุงประสิทธิภาพการใช้พลังงานในภาคที่มีความต้องการใช้พลังงาน ซึ่งสามารถส่งผลให้ความเข้มข้นการใช้พลังงานลดลงเหลือ 6.6 ktoe/พันล้านบาท2553 ภายในปี พ.ศ. 2573 ส่งผลให้จังหวัดอุดรธานีมีการดำเนินการที่สอดคล้องกับเป้าหมายการปรับปรุงประสิทธิภาพการใช้พลังงานของประเทศที่ 5.98 ktoe/พันล้านบาท2553 ภายในปี พ.ศ. 2580 ประกอบกับ ภาคอุตสาหกรรมคิดเป็นสัดส่วนประมาณร้อยละ 41.9 ของความต้องการพลังงานทั้งหมดในปี พ.ศ. 2561 และการนำมาตรการประหยัดพลังงานไปประยุกต์ใช้กับหลายภาคส่วนซึ่งคาดว่าจะสามารถ ช่วยประหยัดได้อย่างมากที่ประมาณ 146 ktoe โดยเครื่องมือ NEXSTEP ได้เสนอให้เพิ่มสัดส่วนการใช้ยานพาหนะไฟฟ้า ในภาคการขนส่งให้ครอบคลุมร้อยละ 15 ถึงร้อยละ 50 ภายในปี พ.ศ. 2573 ด้วยเหตุนี้ผลลัพธ์ที่คาดการณ์ไว้ความต้องการพลังงานจะลดลง 128 ktoe จากแบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) อันเป็นผลจากจากประสิทธิภาพ ของยานพาหนะไฟฟ้า นอกจากนี้ มาตรการประหยัดพลังงานในภาคที่อยู่อาศัยและภาคพาณิชยกรรม และความเข้มข้น การใช้พลังงานในแบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) คาดว่าจะอยู่ที่ 6.62 ktoe/พันล้านบาท2553 ตามลำดับ

การปล่อยปริมาณการปล่อยก๊าซเรือนกระจก (GHG emissions)

การปล่อยก๊าซเรือนกระจกในปี พ.ศ. 2561 อยู่ที่ 1.85 $MTCO_2$-e ซึ่งพิจารณาครอบคลุมถึงการเผาไหม้เชื้อเพลิงโดยตรงจากภาคที่มีความต้องการใช้เชื้อเพลิงและการปล่อยก๊าซเรือนกระจกที่เกิดจากไฟฟ้าในสายส่ง โดย ES 1 แสดงถึงระดับการปล่อยก๊าซเรือนกระจกจากสถานการณ์ต่าง ๆ โดยการปล่อยก๊าซเรือนกระจกจากแบบจำลองสถานการณ์สำหรับนโยบายในปัจจุบัน (CPS) คาดว่าจะเพิ่มถึง 2.34 $MTCO_2$-e ในขณะที่แบบจำลองสถานการณ์การปรับเปลี่ยนสู่การใช้พลังงานสะอาดอย่างยั่งยืน (SET) ลดลงอยู่ที่ 1.97 $MTCO_2$-e โดยลดลงร้อยละ 24 จากกรณีฐาน (BAU) ซึ่งสอดคล้องกับเป้าหมายการลด การปล่อยก๊าซเรือนกระจกของจังหวัดและเป้าหมายการลดก๊าซเรือนกระจกของประเทศ (NDC) แบบไม่มีเงื่อนไข ทั้งนี้ ความทะเยอทะยานที่เพิ่มขึ้นสำหรับแบบจำลองสถานการณ์ที่มุ่งสู่การปลดปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ (TNZ) จะสามารถลดการปล่อยก๊าซเรือนกระจกได้อย่างมาก หรือเพียง 1.09 $MTCO_2$-e ในกรณีที่มีการจ่ายไฟฟ้าที่ปราศจากการปล่อยก๊าซเรือนกระจกทั้งหมด

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



ข้อเสนอแนะเชิงนโยบาย

ตามที่ได้นำเสนอไว้ข้างต้นนั้น จังหวัดอุดรธานียังมีโอกาสมากมาย ที่จะปรับเปลี่ยนระบบพลังงานให้สอดคล้องกับเป้าหมายของประเทศและความมุ่งมั่นต่อความตกลงปารีส ทั้งนี้ ข้อเสนอแนะเชิงนโยบายที่สำคัญเพื่อมีส่วนช่วยให้ จังหวัดอุดรธานีสามารถมุ่งไปสู่การเปลี่ยนแปลงด้านพลังงานอย่างยั่งยืน ประกอบด้วย

1. การเพิ่มสัดส่วนการใช้ยานพาหนะไฟฟ้าอย่างรวดเร็วเพื่อสนับสนุนการขนส่งแบบคาร์บอนต่ำ เนื่องจาก ภาคการขนส่งมีสัดส่วนการใช้พลังงานมากที่สุด จึงส่งผลให้การปรับเปลี่ยนไปใช้ยานพาหนะไฟฟ้าสามารถ เพิ่มศักยภาพการประหยัดพลังงานได้
2. การบูรณาการนโยบายเพิ่มประสิทธิภาพการใช้พลังงานที่ครอบคลุมถึงกลุ่มย่อย ๆ จะสามารถลดการใช้พลังงานลงได้ หน่วยงานราชการในระดับจังหวัดอาจพิจารณาถึงการให้งบประมาณสนับสนุน เพื่อกระตุ้นให้เกิดการประยุกต์ใช้นโยบายให้มากขึ้นโดยเฉพาะในภาคอุตสาหกรรม
3. การใช้พลังงานที่ไม่ทำให้เกิดคาร์บอนไดออกไซด์ (Decarbonization) ในภาคผู้ผลิตพลังงานถือได้ว่ามีศักยภาพในการลดการปล่อยก๊าซเรือนกระจกสูงสุด ซึ่งสามารถดำเนินการได้โดยการติดตั้งระบบโซลาร์เซลล์บนหลังคา (Solar Rooftop) และการประมูลพลังงานทดแทน (RE Auction) โดยเป็นแนวทางดำเนินการที่มีการลงทุนน้อยที่สุด ทั้งนี้ หน่วยงานราชการในระดับจังหวัดอาจพิจารณาถึงการดำเนินงานร่วมกับหน่วยงานกลาง เพื่อกำหนดแนวทางการประมูลพลังงานทดแทนในระดับจังหวัด
4. เพิ่มความท้าทายโดยมุ่งเน้นไปที่การเพิ่มระดับของการใช้พลังงานไฟฟ้า และการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ในภาคพลังงาน ซึ่งทำให้จังหวัดอุดรธานีอยู่บนเส้นทางของการขับเคลื่อนการปล่อยก๊าซเรือนกระจกสุทธิเป็นศูนย์ 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 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 (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 that endorsed its outcomes. NEXSTEP has 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 tool NEXSTEP 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 develop 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 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 SDG7 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, 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 for achieving 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.

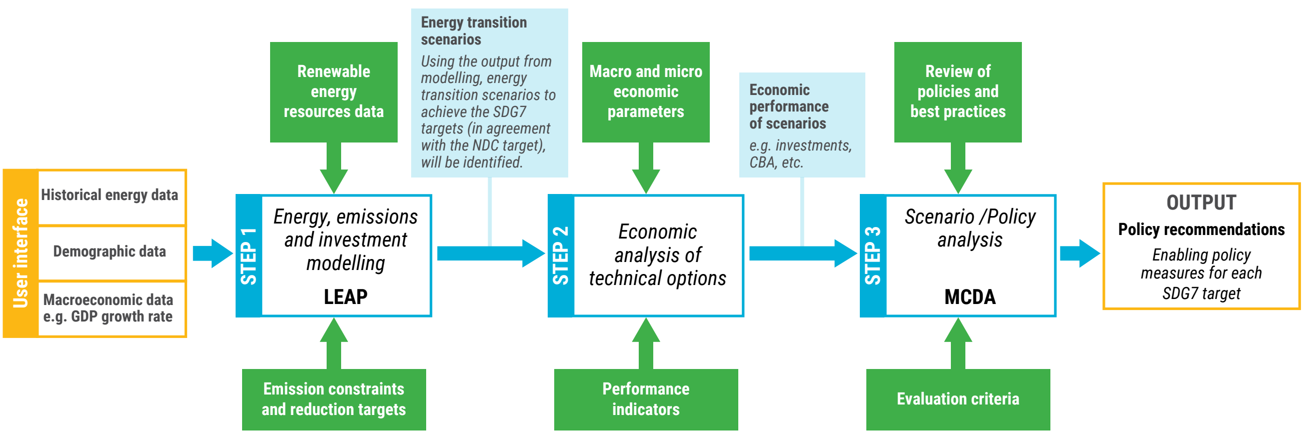
(b). Economic analysis module

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 to 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 the 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 Udon Thani province, three main scenarios have been modelled: (a) BAU scenario; (b) Current Policy scenario (CPS); (c) Sustainable Energy Transition (SET) scenario. In addition, an ambitious scenario (TNZ) scenario, has been modelled, which explores how Udon Thani may move towards a net zero future:

(a). (a)The 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. 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). TNZ scenario. This is an ambitious scenario, which 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 for weighing the benefits against costs and to 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 lifetime. Project financial viability is not enough in an economic analysis; contribution to societal welfare should also be examined. For example, in the case of a coal power plant, the emissions from the combustion process release particulate matter that is inhaled by the local population, causing health damage and acceleration of climate change. In an economic analysis a monetary value is assigned to the GHG emission in order to value its GHG emissions abatement. This is done in the scenario analysis, as 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:

(a) Capital cost – capital infrastructure costs for technologies. These are based on country-specific data to improve the analysis. They include land, buildings, 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;

(c) Decommissioning cost – retirement of power plants costs related to environmental remediation, regulatory frameworks and demolition costs;

(d) Sunk cost – existing infrastructure investments are not included in the economic analysis, since no additional investment is required for the project;

(e) External cost refers to any additional externalities which place costs on society. Use of externalities has been omitted in this road map due to the absence of a well-recognized framework for cost estimation;

(f) GHG abatement – avoided cost of CO2 generation that is calculated in monetary value based on the carbon price. The 2016 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories is followed in the calculation of GHG emissions for the economic analysis. The sectoral analysis is based on the Tier 1 approach, which uses fuel combustion data from national statistics and default emission factors.

2.3.3. Scenario analysis

The scenario analysis evaluates and ranks scenarios, using the 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; the participants may wish to change weights of each criterion, 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 the Paris Agreement;
- Fossil fuel subsidy phase-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 mean to suggest the best way forward for the countries or cities by prioritising the several scenarios.

3. Overview of the Udon Thani province energy sector

3.1. Overview of Udon Thani province

Udon Thani province is located on a plateau which is approximately 187 metres above sea level. Most of the area is covered with rice fields, forests, and hills; the Phu Pan mountain range and the Songkhram River are the provinces two primary natural attractions. It is bordered by the provinces of Nong Khai to the north, Sakon Nakhon to the east, Kalasin province to the south-east, Khon Kaen to the south, and Loei and Nong Bua Lamphu to the west. The total forest area is 1,131 km^2 or 10.2 per cent of provincial area. Udon Thani had a population of 1.57 million in 2018.

With an area of 11,072 km^2, the province is administratively divided into 20 districts, which are further divided into 155 subdistricts and 1,682 villages, subdistrict Administrative Organisations and 40 municipality-level Administrative Organisations.

The province of Udon Thani had a population of 1.57 million in 2018, which translates into a population density of 142 people per km^2. Urban population accounts for 36.8 per cent of the population in Udon Thani. The gross provincial product (GPP) in 2018 was Baht 113.9 billion and the GDP per capita was around Baht 72.6 thousand.

3.2. Provincial energy profile

Access to modern energy. The population of the province of Udon Thani in 2018 was reported to be 1.57 million, while the number of households stood at 528,000. Udon Thani has already achieved universal access to electricity, while the clean cooking access rate is estimated at 62.8 per cent.[1] This also includes the 5.1 per cent of households that do not conduct cooking at home. The remaining 37.2 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, the liquefied petroleum gas (LPG) cooking stove is the most dominant primary clean cooking technology, with an estimated share of 55.5 per cent. This is followed by the electric cooking stove, estimated at 2.2 per cent.

Modern renewable share in TFEC. Modern renewable energy delivered approximately 41.5 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 at 17.8 per cent in 2018.[2] Other usage of renewable energy includes a small amount of biofuel consumption in the transport sector, 45.5 ktoe. The national biodiesel mandate in 2018 was 7 per cent, while several blend rates are available in the market (USDA, 2021). NEXSTEP modelling assumes an average blend rate of 13 per cent for transport petroleum usage. The biomass consumption in the industrial sector was the most substantial, at 209 ktoe (55.4 per cent of industrial TFEC) in 2018, for heating and electricity self-generation purposes.

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 PPP_{2017}), was 4.32 $MJ/US\$_{2017}$. In terms of total final energy consumption per GDP_{2010}, it is estimated at 8.91 ktoe/billion baht.[3]

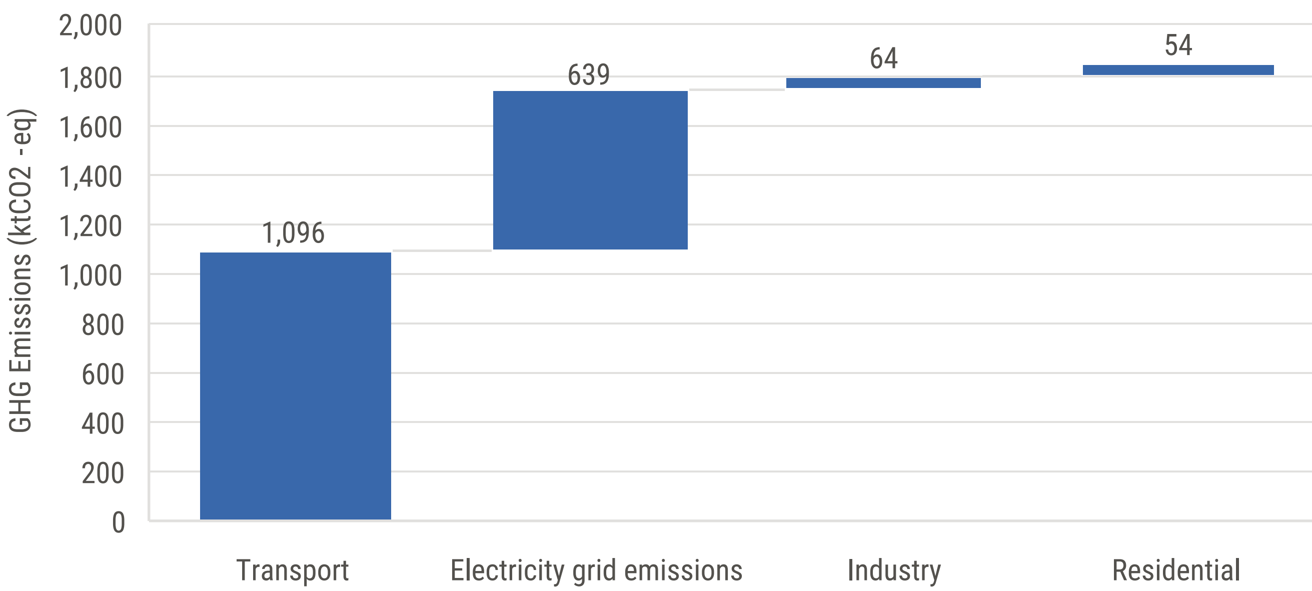
1 As per the definition of the SDG 7, clean cooking refers to fuels and technologies for cooking that do not cause indoor air pollution to the level that can lead to serious health hazards, including immature mortality. According to the World Health Organization (WHO) Guideline, traditional biomass cooking stoves and kerosene are not considered as clean cooking fuels and technologies. Improved Cooking Stoves (ICS) could be regarded as clean as long as they meet the WHO standards for indoor air pollution. More details are available at https://www.who.int/tools/clean-household-energy-solutions-toolkit/module-7-defining-clean

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 World Bank database), the GDP 2010 for 2018 was an estimated 183.9 billion baht.

GHG emissions. GHG emissions from the energy sector were an estimated 1.85 $MTCO_2$-e in 2018. The GHG emissions breakdown is as shown in figure 2. Emissions from the transport sector are the largest at 1.09 $MTCO_2$-e, arising from direct fuel combustions in internal combustion engines. Emissions related to electricity usage are not 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 the base year of 2018 is 0.413 tCO_2/MWh.[5] The total emissions attributable towards to overall electricity usage is an estimated 0.64 $MTCO_2$-e, Direct combustion of fuels is also relevant for the industry and residential sector, which emits around for 63.5 $ktCO_2$-e and 54.1$ktCO_2$-e, respectively. Considering the emissions, both from direct fuel combustion and electricity usage, the emission profile is as follows: transport, 64 per cent; residential ,19 per cent; industry, 15 per cent; commercial, 6 per cent; and non-specified, 0.4 per cent.

Figure 2. GHG emissions in 2018



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

3.3. Provincial energy balance, 2018

The following describes the estimated energy consumption built up using data collected with a bottom-up approach, based on data such as activity level and energy intensity data. The majority of the following 2018 energy data have been collected from various sources in consultation with the Udon Thani 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 902 ktoe. The largest energy-consuming sector was the transport sector, consuming 390 ktoe, around 43.3 per cent of the TFEC in 2018. This can be further categorised into road transport (97.54 per cent) and air transport (2.46 per cent). The industry sector comes second in terms of the final energy consumption, consuming 377.5 ktoe, or 41.9 per cent of Udon Thani's TFEC. The largest demand comes from the food and beverages industry (76.5 per cent), followed by other industries (22.9 per cent).

Residential sector consumption was 108 ktoe (12 per cent) in 2018. About 57.7 per cent of the energy consumed was in the form of electricity; charcoal (28.5 per cent) and LPG (13.8 per cent) were used for residential cooking purposes. The energy consumed in the commercial sector, non-specified sector and agricultural sector was exclusively electricity, at 24.2 ktoe (2.68 per cent), 1.4 ktoe (0.16 per cent) and 0.18 ktoe (0.02 per cent), respectively. Figure 3 shows the fuel demand from the demand sectors, while figure 4 shows the TFEC breakdown by fuel type in 2018.

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

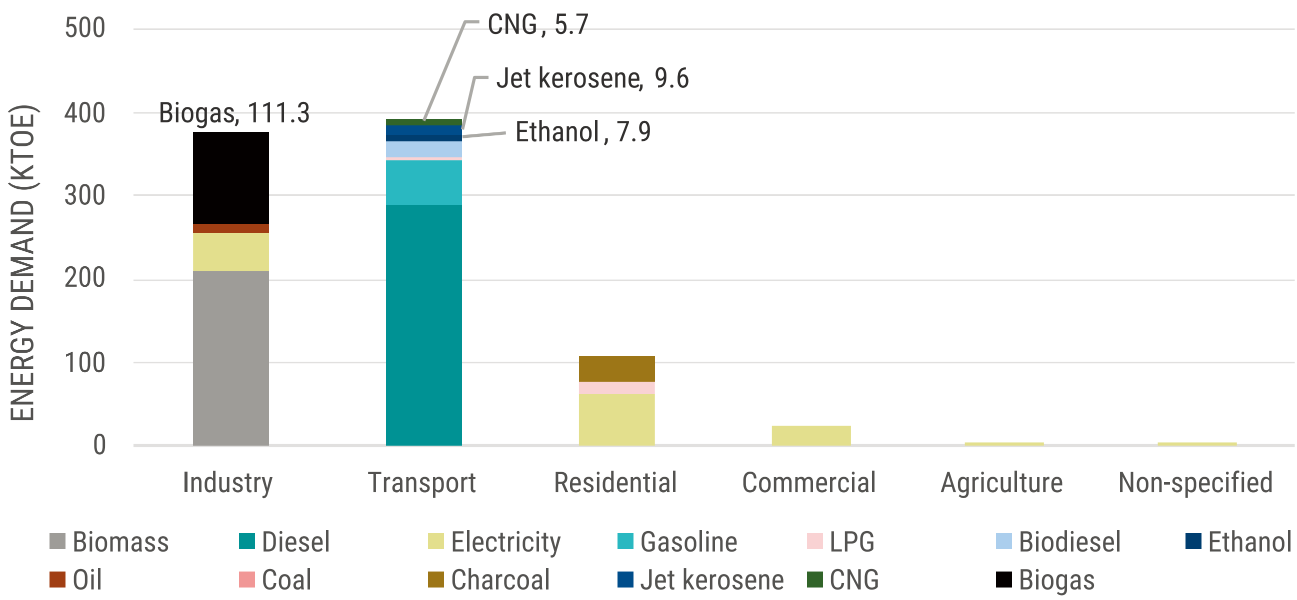
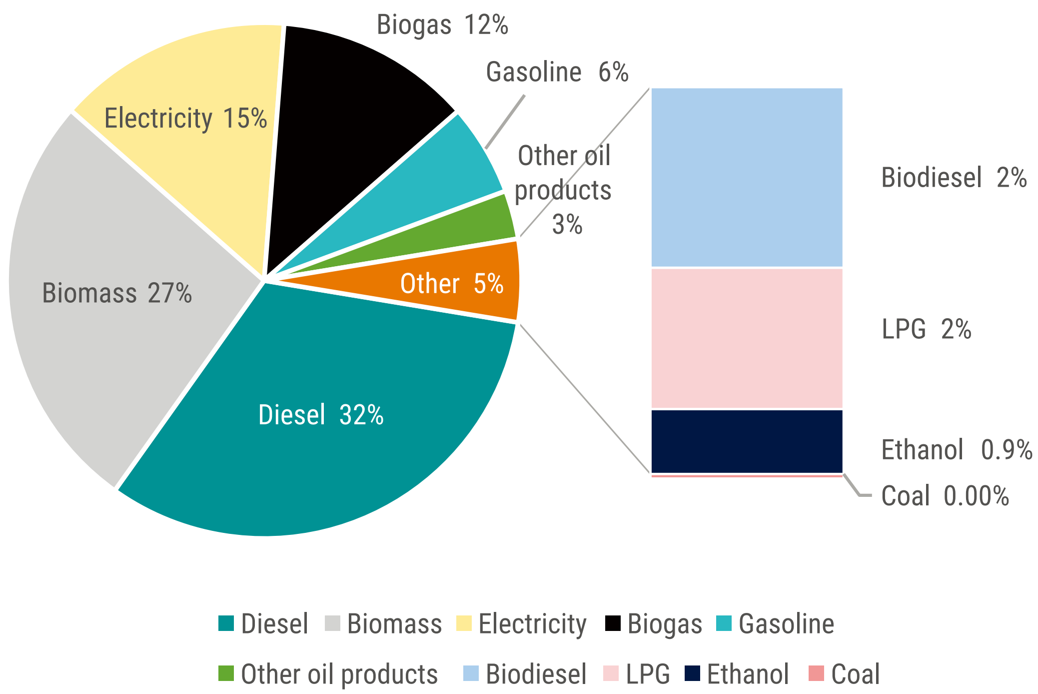


Figure 4. TFEC breakdown by fuel type, 2018



The total primary energy supply in 2018 was 902 ktoe. As mentioned above, the province meets almost all of its electricity requirements with the central grid, while the proportion of self-generation is minimal.

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

Parameters	Business-as-usual scenario	Current policy scenario	Sustainable energy transition scenario
Economic growth	3.17 per cent per annum		
Population growth	Zero per cent per annum		
Urbanization rate	37 per cent in 2018, growing to 44.5 per cent in 2030[4]		
Commercial floor space	- Designated buildings: Total commercial floorspace of 1.13 million m² in 2018. The commercial floorspace is projected to grow with an annual rate of 3.17 per cent. - Non-designated buildings: No floorspace data available. The electricity consumption was 15.55 ktoe in 2018 and the activity is projected to grow with an annual rate of 3.17 per cent.		
Industrial activity	Industrial activity is projected to grow with an annual rate of 3.17 per cent.		
Transport activity	- Road transport: Passenger transport activities were estimated at 2.5 billion vehicle-kilometres and freight transport activities 1.9 billion vehicle-kilometres, in 2018. These are assumed growing at a rate similar to the growth in GDP per capita (3.2 per cent). - Air transport-related energy consumption is estimated at 9.6 ktoe for 2018. This is assumed to grow at a rate similar to the growth in GDP.		
Residential activity	The appliance ownership for the electrical appliances is projected to growth at a rate similar to the growth in GDP per capita, up until reaching 100 per cent saturation.		
Access to electricity	100% access rate has been achieved		
Access to clean cooking fuels	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 67.3 per cent in 2024.		100 per cent clean cooking access rate through the promotion of LPG stoves
Energy efficiency	Additional energy efficiency measures not applied	Additional improvement based on implemented policy measures.	Energy intensity is 6.64 ktoe/billion baht, on track to meet the national energy intensity target of 5.98 ktoe/billion baht by 2037
Power plant	Considers 2018 RE share in power generation and grid emissions	Considers the increasing RE share and decreasing grid emissions, in accordance with the Power Development Plan 2018	

3.5. Energy policies and targets

Udon Thani'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 Government's overarching direction. Where applicable, the currently implemented and adopted policies or 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:

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

5 Only policies with concrete and implemented measures are considered in the scenario modelling for the current policy scenario. To further explain, measures mentioned in strategy policy or planning documents 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.

- **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)** – the Plan 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)** – the plan sets out an energy intensity reduction target of 30 per cent by 2037 compared to 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 for achieving this target;
- **Thailand's Alternative Energy Development Plan 2018-2037 (AEDP, 2018)** – the plan 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 TFEC to 30 per cent by 2037;
- **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]
- **Ministerial Regulation Prescribing Type or Size of Building and Standard, Criteria and Procedure in Designing Building for Energy Conservation B.E. 2563 (2020).** The regulation 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, 2020 and 2017). MEPS for washing machines were announced in August 2021. In addition, voluntary certification is available for several types off electrical equipment through the Energy Efficiency Labelling No. 5 Program and for several non-electrical equipment through the Energy Efficiency Labelling Program.

3.6. Udon Thani's energy system projections in the current policy settings

The Current Policy Scenario (CPS) explores how Udon Thani's energy system may evolve under the current policy settings. It takes into account initiatives implemented or scheduled for implementation during the analysis period of 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 to be constant throughout the analysis period, with demand growth as detailed in table 1. The policies/initiatives considered in the modelling of CPS are:

(1) 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;

(2) Thailand biofuel mandate.

The biodiesel mandate was 7 per cent in 2018. This was increased to 10 per cent from 2020 onwards.

(3) Implementation of the Ministerial Regulation (2020) 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:

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 petroleum usage.

7 **As noted in Invalid source specified.**, the 2009 ministerial regulation is applicable to nine types of new or renovated governmental buildings, while for private buildings they are on a voluntary basis.

(a) The energy savings will 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) A total of 50 per cent of new designated buildings (in terms of share of electricity consumption) are assumed to meet the minimum floorspace requirement.

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

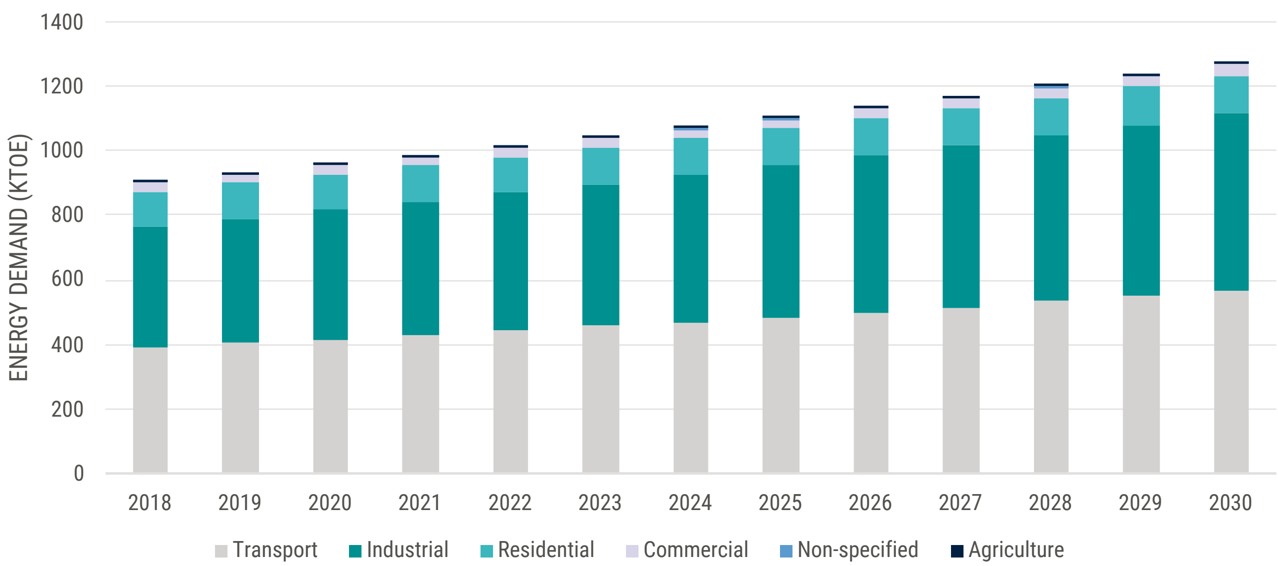
3.6.1. Energy demand outlook

In the current policy settings, TFEC is projected to increase from 902 ktoe in 2018 to 1,269 ktoe in 2030. Slight energy savings of 1.8 ktoe can be expected, relative to the BAU scenario, from the implementation of the new building code, through the Ministerial Regulation (2020).

The transport sector consumption will remain the largest at 567 ktoe (44.7 per cent) in 2030, followed by the industrial sector at 549 ktoe (43.3 per cent), the residential sector at 116.8 (9.2 per cent), the commercial sector at 33.4 ktoe (2.6 per cent), non-specified at 2.04 ktoe (0.16 per cent), and the agricultural sector at 0.26 ktoe (0.02 per cent).

The sectoral overview of energy demand in the CPS is discussed below (see figure 5).

Figure 5. Udon Thani's energy demand outlook, CPS 2018-2030



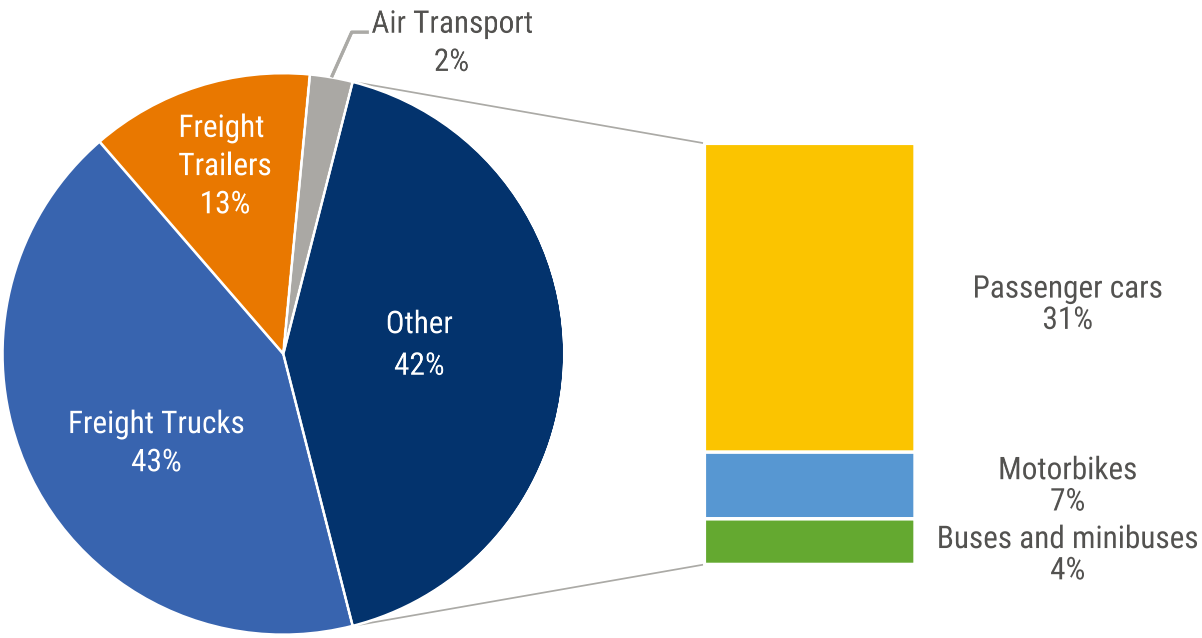
(a) *Transport sector*

The transport sector's energy demand will continue to dominate Udon Thani's TFEC, and is projected to increase from 390 ktoe in 2018 to 567 ktoe in 2030. In 2030, the subsector share of transport energy demand is projected to be: road passenger transport, 238.6 ktoe (42 per cent); road freight transport, 314.8 ktoe (55.5 per cent); and air transport, 13.9 ktoe (2.46 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 and trailers. 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, 42.6 per cent of the road transport energy demand is expected to come from freight trucks.

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



(b) *Industrial sector*

The industrial sector energy demand is projected to increase from 377.5 ktoe in 2019 to 549 ktoe in 2030. The industry activities can be classified into six main categories. 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 3.17 per cent annually. Table 2 shows the TFEC and

Table 2. TFEC and share of TFEC by industry sub-categories

Industry categories	TFEC in 2030 (ktoe)	Share of TFEC (%)
Food and beverages	419.68	76.5
Other industry	125.51	22.9
Cement and non-metallic products	1.04	0.2
Wood and other products	1.04	0.2
Machinery and transportation tools	0.99	0.2
Iron and steel	0.66	0.1

share of TFEC by industry sub-categories.

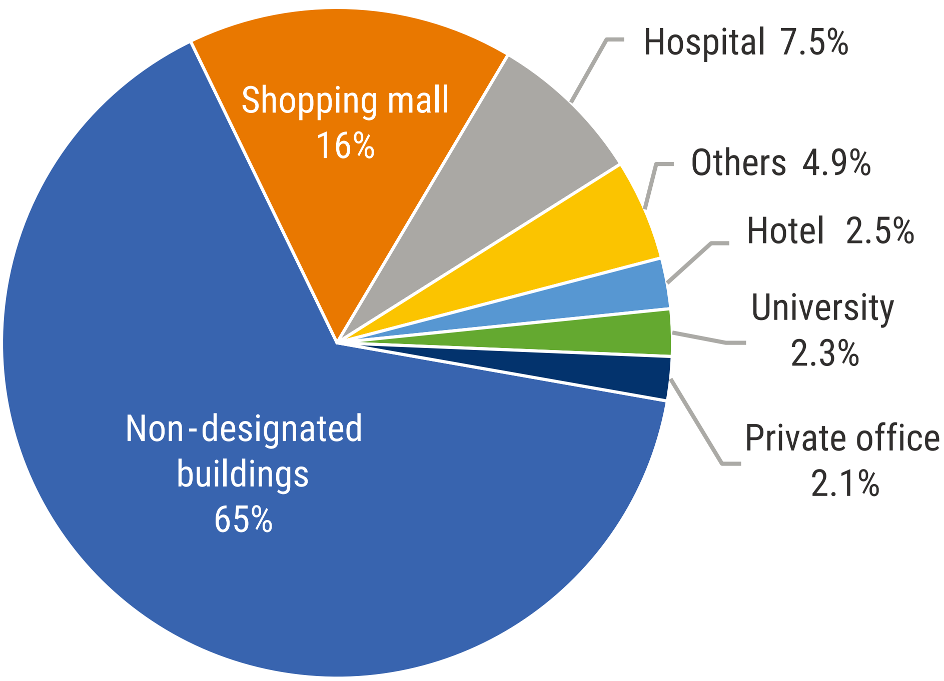
(c) *Residential sector*

The residential sector energy demand is projected to increase to 116.8 ktoe by 2030, compared with 108.5 ktoe in 2018. Residential cooking is projected to take up around 37.8 per cent of the TFEC, with the remaining 62.2 per cent contributed by various electric appliances, i.e., air conditioners and refrigerators.

(d) *Commercial sector*

The commercial sector energy demand is projected to increase from 24.2 ktoe in 2018 to 33.4 ktoe in 2030. The 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 is projected to allow an energy savings of 1.8 ktoe, compared to the BAU scenario. The energy demand distribution in 2030 is shown in figure 7.

Figure 7. Energy demand distribution by commercial sector sub-categories, CPS in 2030



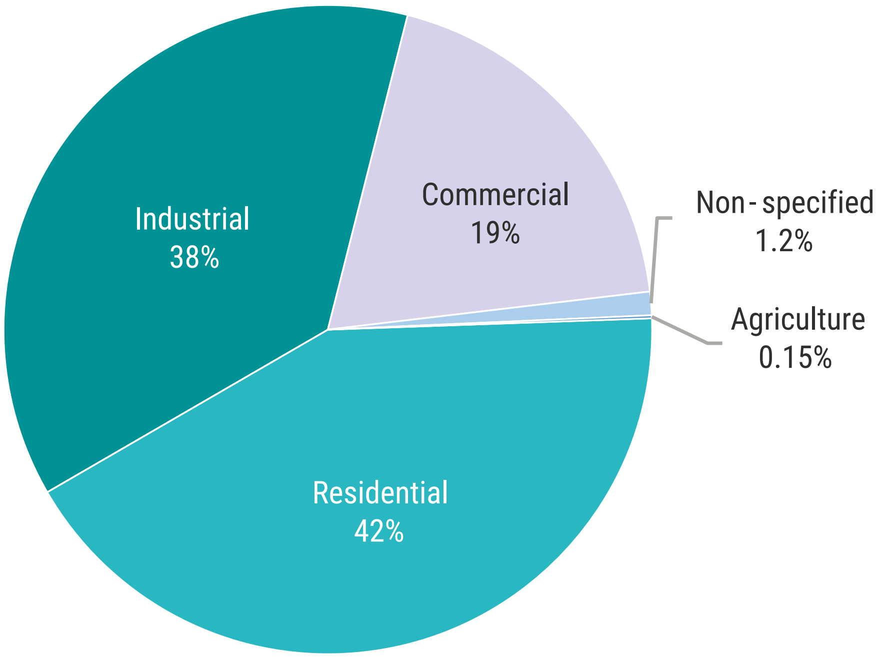
(e) *Non-specified sector and agriculture sector*

The energy demand from the non-specified and agriculture sectors was relatively insignificant, at only 0.18 per cent in total, in 2019. The energy demand for these two sectors is expected to increase from 1.58 ktoe to 2.3 ktoe by 2030.

3.6.2. Electricity demand outlook

The 2030 demand for electricity in the current policy scenario is projected to be 2,026.7 Gigawatt-Hours (GWh), an increase from 1,547.8 GWh in 2019. The demand will be the highest in the residential sector, 855.4 GWh (42.2 per cent), followed by the industrial sector at 756 GWh (37.3 per cent), the commercial sector at 388 GWh (19.2 per cent), non-specified sector at 23.7 GWh (1.2

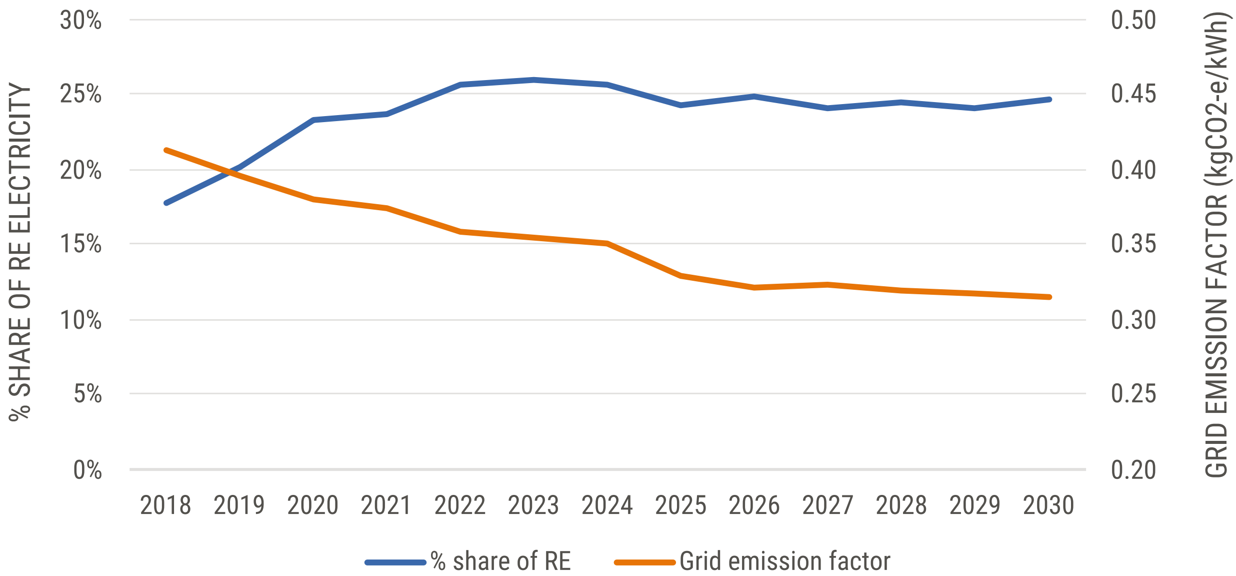
Figure 8. **Electricity demand distribution by demand sector in 2030, CPS**



per cent) and agriculture sector at 3 GWh (0.15 per cent).

The electricity required to fulfil the demand in Udon Thani is exclusively purchased from the grid. As stipulated in Thailand's Power Development Plan, 2018-2037, the central grid electricity is expected

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



to have a decreasing emission factor, as the percentage of renewable energy increases.

3.6.3. Energy supply outlook

In the CPS, TPES is forecast to increase from

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

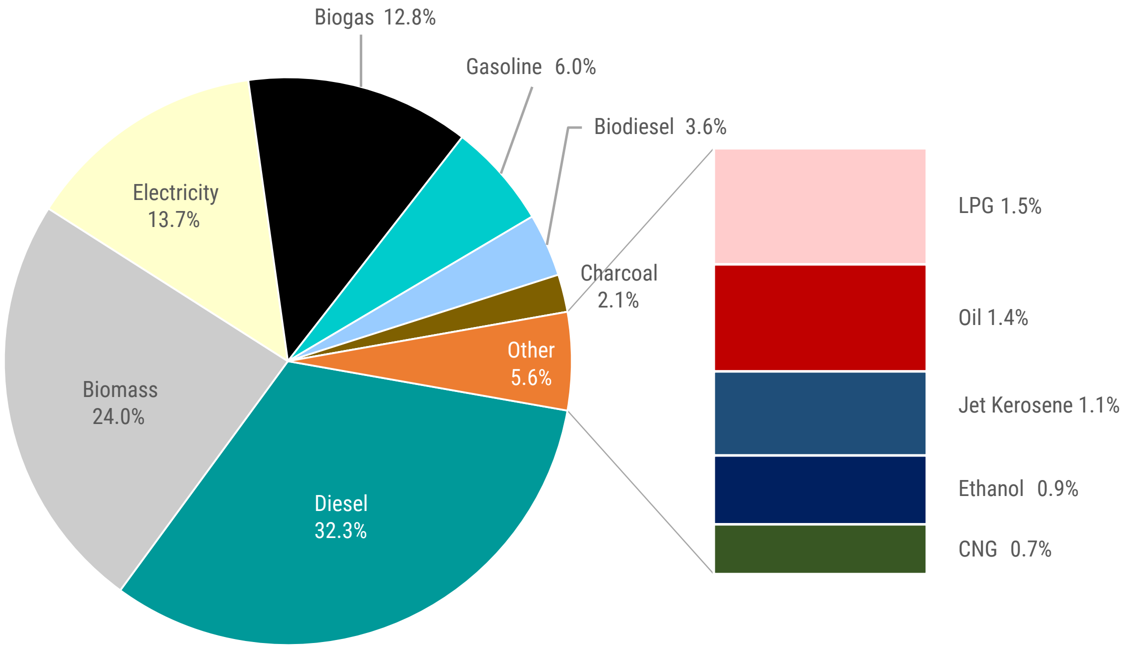
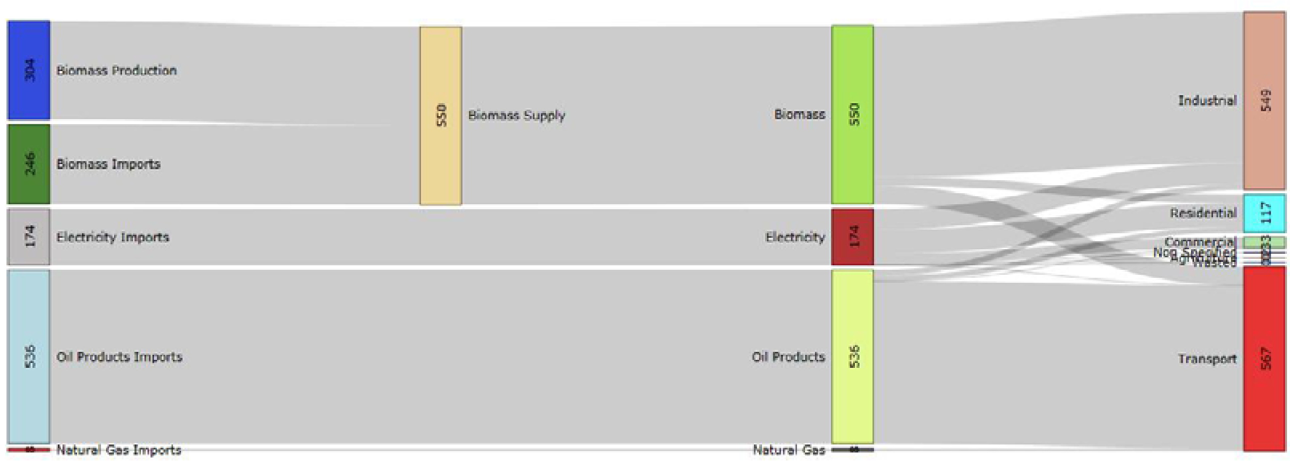


Figure 11. Sankey Diagram, CPS in 2030 (unit: ktoe)



902 ktoe in 2018 to 1,269 ktoe in 2030. Figure 10 shows further the TPES breakdown by fuel type, while figure 11 shows the energy flows in 2030.

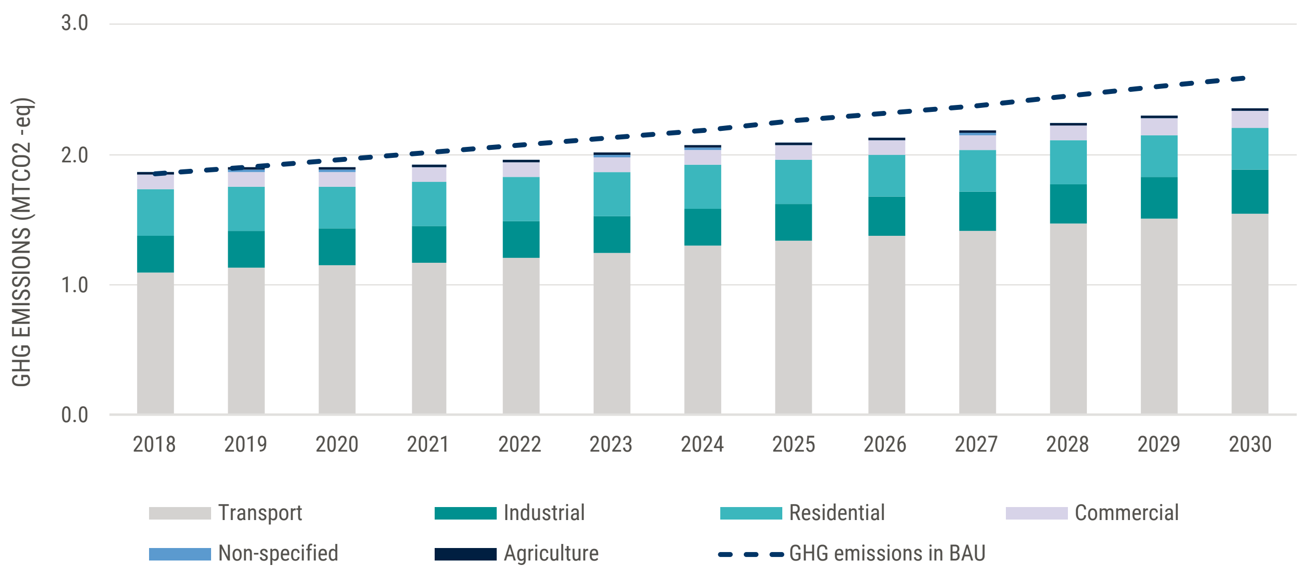
3.6.4. Energy sector emissions outlook

The energy sector emissions, from the combustion of fuels, 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 throughout the analysis period (see figure 9).

In the CPS, the total GHG emissions from the energy sector increase from 1.85 $MTCO_2$-e to 2.33 $MTCO_2$-e (figure 12). The largest contributor of GHG emissions in 2030 is the transport sector (84 per cent), followed by the industrial sector (18 per cent), residential sector (18 per cent), commercial sector (7 per cent), non-specified sector (0.4 per cent) and the agriculture sector (0.1 per cent). These include emissions from both the direct fuel combustion and electricity usage.

The emission reduction is 10 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. For example, total GHG emissions are estimated to be 3.2 $MTCO_2$-e in 2030, if the emission factor remains similar to the 2018 level.

Figure 12. Udon Thani's energy sector emissions outlook, CPS, 2018-2030



4. SET scenario – sustainable energy transition pathway for Udon Thani 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 Udon Thani province, in alignment with the national targets. Table 3 shows a summary of the targets considered in the SET scenario.

Table 3. Summary of the targets considered in the SET scenario

Indicator	National target	Comparative SDG 7 targets
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

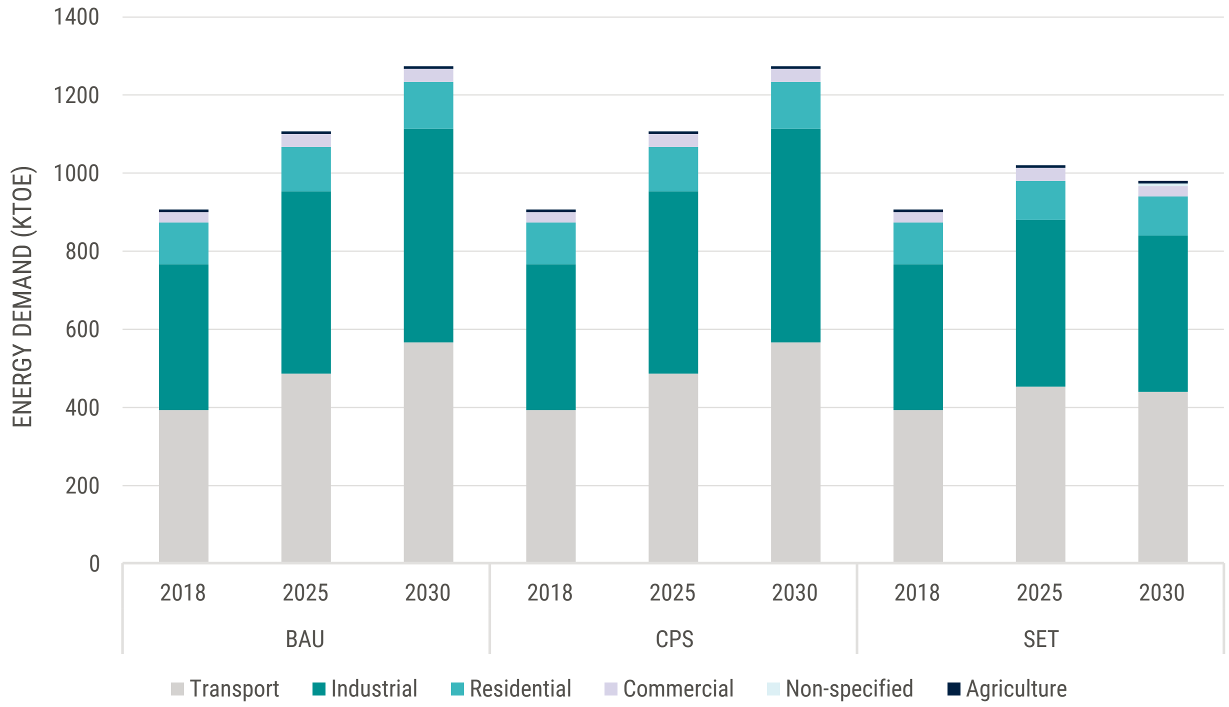
The following subsections discuss the energy system trajectory under the SET scenario in relation to the different indicators.

4.1. SET energy demand outlook

In the SET scenario, TFEC increases at a much slower pace than CPS, from 902 ktoe in 2018 to 971.5 ktoe in 2030. The reduction of 297 ktoe in TFEC in this scenario, compared to CPS, is due to the improvement in energy efficiency across the demand sectors. The proposed energy efficiency interventions are further described in subsection 4.2.3. In 2030, the transport sector will still have the largest share of TFEC at 439 ktoe (45.2 per cent), followed by the industrial sector at 403 ktoe (41.5 per cent), residential sector at 96.6 ktoe (10 per cent) and commercial sector at 30.7 ktoe (3.2 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

Udon Thani has already achieved universal access to electricity. In 2018, the clean cooking rate was estimated at 62.8 per cent. Projected based on a national historical improvement rate of 0.6 per cent, during 2015-2019, clean cooking access rate can be expected to reach 67.3 per cent in 2030.

More needs to be done to achieve the SDG 7.1.2 target. NEXSTEP suggests that LPG stoves should be promoted to the households in closing the clean cooking gap. The benefits of promoting LPG stoves are:

(a) Reduction of indoor air pollution, in comparison to traditional charcoal/wood stoves and improved cooking stoves. This will reduce air pollution-related health impacts;

(b) Minimal follow up requirement, as opposed to improved clean cooking stoves whereby continuous monitoring is required to promote long-term adoption;

(c) Cost effective with low upfront capital cost;

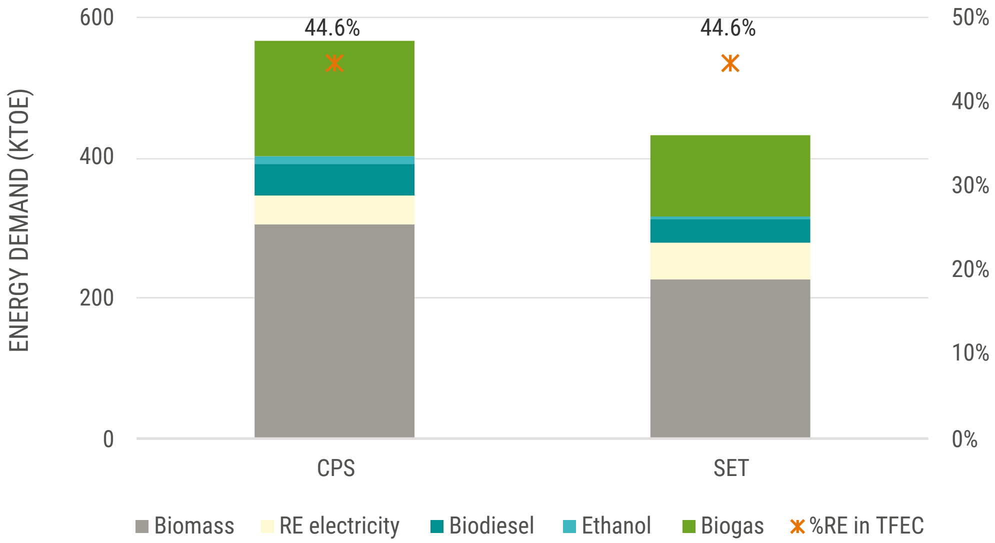
(d) Fuel-efficient, in comparison to traditional charcoal/wood stoves.

In the long term (past 2030), Udon Thani may consider promoting electric cooking stoves, particularly when the power grid is more heavily decarbonised. This will contribute towards a net zero ambition in the long term. A higher penetration of electric cooking stoves within the SDG timeframe (by 2030) is further explored in the ambitious TNZ scenario.

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 renewable energy share in TFEC. The RE share in TFEC was estimated at 41.5 per cent in 2018, excluding a small amount of traditional biomass usage in the residential cooking sector. Such a high percentage usage is attributable to the substantial biomass consumption in the industry sector. Accordingly, the BAU and the CP scenarios are expected to meet the 30 per cent RE target, set forth in AEDP 2018, at 42.6 per cent and 44.6 per cent, respectively. In the SET scenario, the RE share in TFEC is projected to remain the same as in CPS at 44.6 per cent by 2030. Figure 14 compares RE shares in the CPS and SET scenarios in 2030.

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

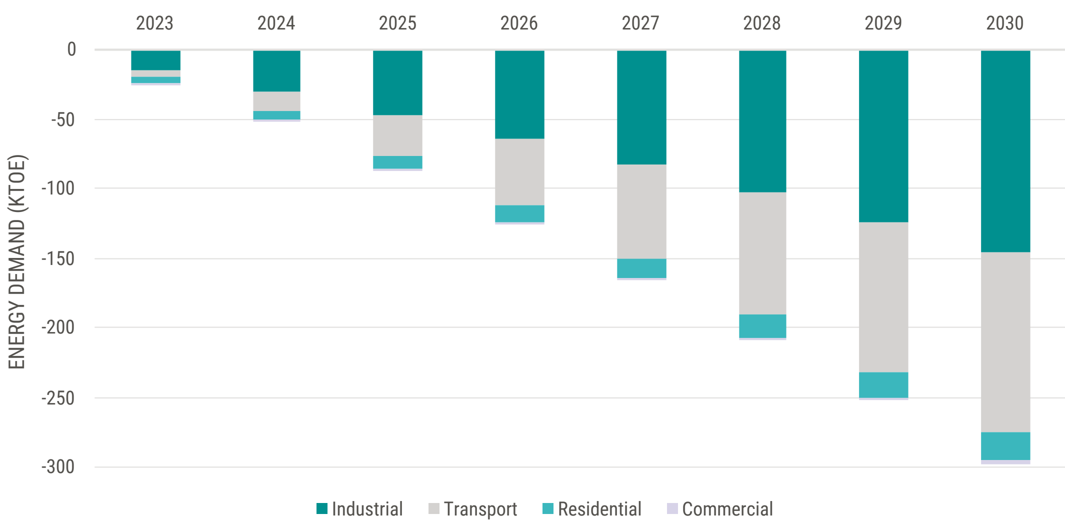


4.2.3. Energy efficiency

The energy intensity is projected to reach 6.60 ktoe/billion baht2010 in 2030, considering the energy efficiency measures proposed for the SET scenario. This meets the energy intensity set out for 2030[9] by a relatively huge margin, while putting Udon Thani on a favourable path to meet the national energy intensity target of 5.98 ktoe/billion baht$_{2010}$ by 2037. The energy efficiency measures proposed for the SET scenario help to exceed h the national unconditional target of 20 per cent, relative to a BAU baseline.

Figure 15 shows the energy savings that may be achieved through the implementation of energy efficiency measures across the demand sectors, compared to CPS. The transport sector is the largest energy consuming sector in Udon Thani, which is expected to contribute 128.4 ktoe energy saving in 2030 through the adoption of electric vehicles, such as buses, cars and motorcycles. In addition, energy savings from the industrial sector are also possible through the increased adoption of energy efficiency measures across the industrial subsectors, estimated at 145.9 ktoe. Further details of the energy efficiency measures and their impacts are provided below.

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



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.

4.2.3.1. Industrial sector

The potential savings in the industrial sector, as modelled in the SET scenario, references the energy conservation potential assessment findings in MOE 2011, with the exception of the cement and non-metallic quarry products industry (table 4). The energy savings potential (MOE, 2011) is assessed approximately 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 4. Energy efficiency measure applied and the estimated annual savings in 2030 (relative to CPS) in the industrial sector

Sub-category	Potential savings compared to BAU baseline	Annual saving in 2030 (ktoe)
Food and beverages	28 per cent [a]	117.50
Other industry	22 per cent [b]	27.60
Wood and wood products		0.23
Machinery and transportation tool		0.22
Iron and steel	11 per cent [c]	0.07
Cement and non-metallic quarry products	25 per cent [d]	0.26
Total		**145.9**

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 "basic metal" category (MOE, 2011).

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

4.2.3.2. Transport sector

Promotion of electric vehicles is an effective way to reduce demand consumption in the transport sector as well as GHG emissions. In the SET scenario, NEXSTEP proposes that 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 5.

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

Sub-category	Energy efficiency measures	Annual saving in 2030 (ktoe)
Passenger cars	Increase the share of electric passenger cars to 20 per cent by 2030	86.3
Buses and minibuses	Increase the share of electric buses to 100 per cent by 2030	3.7
Motorcycles	Increase the share of electric motorcycles to 50 per cent by 2030	16.5
Freight vehicles	Increase the share of electric freight trucks to 25 per cent by 2030	21.9
Total		**128.4**

4.2.3.3. Residential sector and commercial sector

Energy demand reduction can also be realized in the residential sector and the commercial sector (table 6), albeit much less significantly than in the industrial and the transport sectors. Energy savings from the residential sector may come from the adoption of energy efficient appliances, which in the case of Thailand, are promoted through the minimum energy performance standards and voluntary certification for several types of electrical equipment. NEXSTEP suggests the gradual phasing out of non-energy efficient lighting and replacement with light-emitting diode (LED) lighting, realizing an energy savings of around 2 ktoe in 2030. NEXSTEP also suggests that LPG stoves may be promoted to households in closing the clean cooking gap. In addition, potential investment in energy efficiency measures can be promoted through the enforcement of the Energy Conservation Promotion Act for existing designated buildings.[10]

Table 6. Energy efficiency measures applied and the estimated annual savings in 2030 (relative to CPS) in the residential and commercial sectors

Sub-category	Energy efficiency measures	Annual saving in 2030 (ktoe)
Residential	Improving clean cooking access rate to 100 per cent by 2030 - Via promotion of LPG stove	18.3
Residential	Phase out of non-LED lighting	2.0
Commercial	Enforcement of the Energy Conservation Promotion Act for existing designated buildings. - The energy savings potential is assumed to be 28 per cent (EEP 2015).	2.7
Total		**23.0**

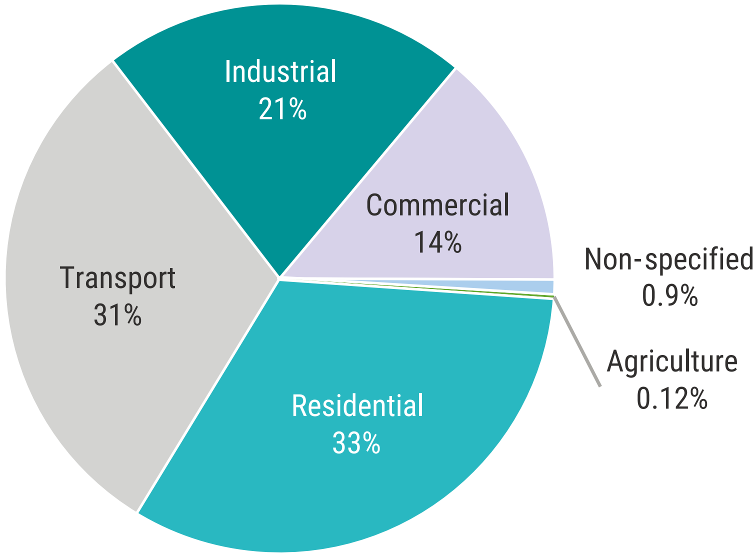
4.3. Electricity supply and demand in the context of sustainable energy transition

The demand for electricity in 2030 is projected to be 2,554 GWh in the SET scenario, an increase of 527 GWh compared to the CPS. Reduction in electricity demand can be expected from the industrial, residential and commercial sectors as energy efficiency measures and energy-efficient appliances are adopted. On the other hand, electricity demand from the transport sectors increases by 788.7 GWh, due to widespread adoption of electric vehicles.

The largest electricity demand can be expected from the residential sector (832.4 GWh). This is followed by the transport sector (789 GWh), industrial sector (549.6 GWh), commercial sector (356.6 GWh), non-specified sector (23.7 GWh) and agricultural sector (3 GWh) (figure 16).

10 According to MOE (2016), this encompasses regulatory approaches for energy management, set and tracked in a systematic way in accordance to standards. It also includes a developing tracking system and database as well as energy efficiency indicators and preparation of a system that will allow special fees to be levied.

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 increase from 902 ktoe in 2018 to 971.5 ktoe in 2030. Figure 17 shows 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

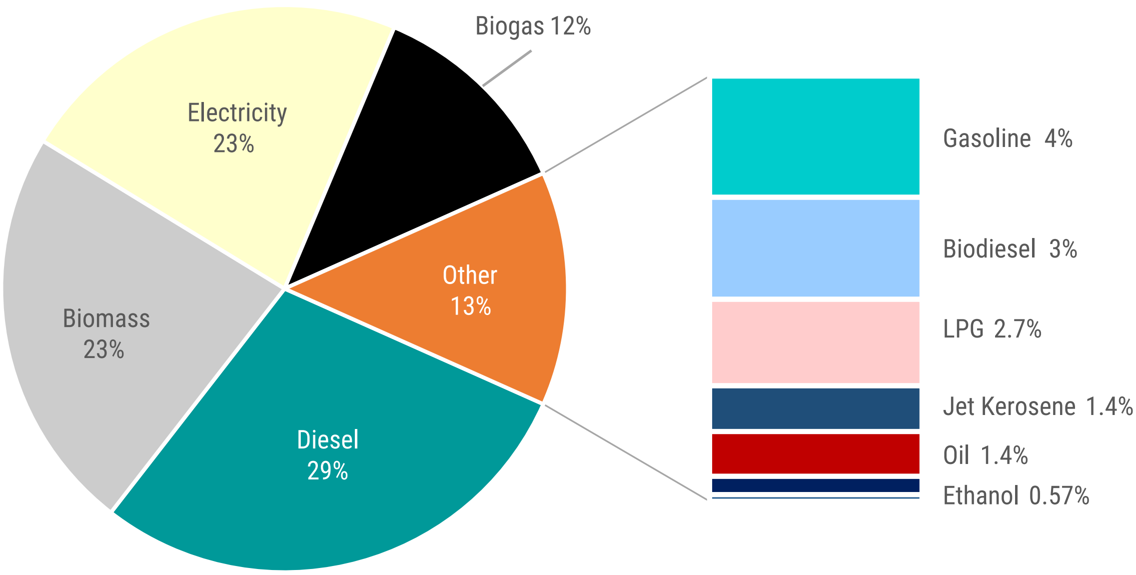
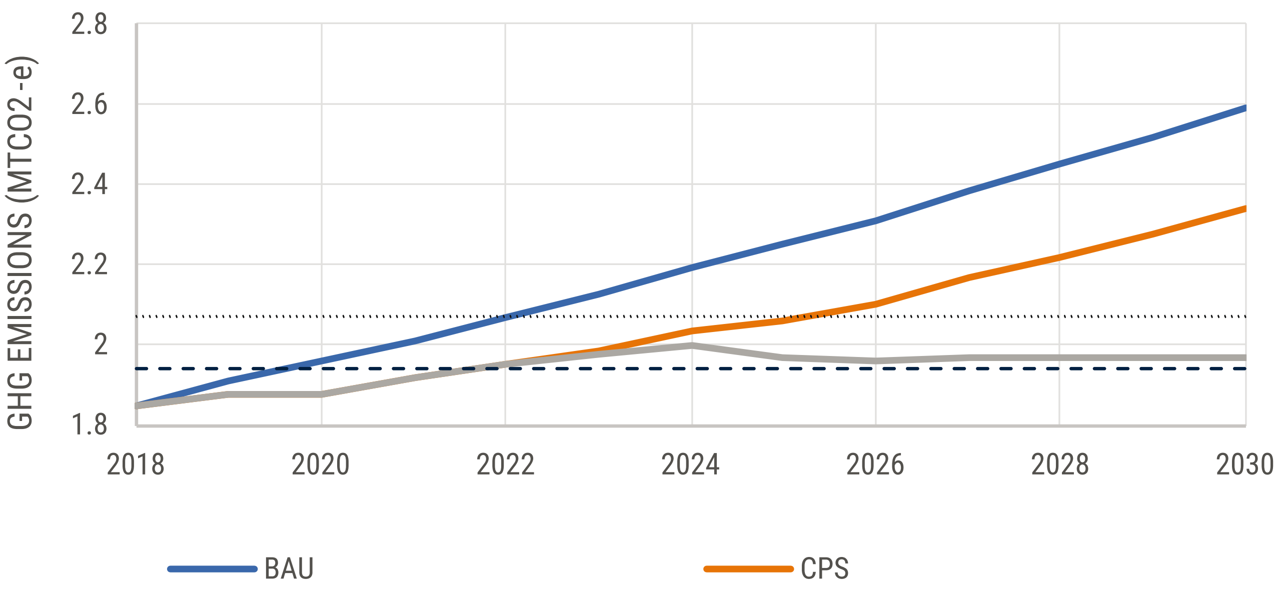


Figure 18. Sankey Diagram, SET in 2030 (unit: ktoe)

4.5. GHG emission reduction with sustainable energy transition

The GHG emissions in 2030 are projected to be 1.97 MTCO$_2$-e, a reduction of 367 ktCO$_2$-e from CPS. This corresponds to a 24 per cent reduction from the BAU scenario, and a 16 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 summarized 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 reduced direct fuel combustion from the transport sector is significant. However, this is slightly compensated for the emissions associated with the increased electricity demand.

Table 7. **Estimated GHG emission reduction in 2030 (relative to CPS)**

<table>
<tr><th>Sector</th><th>Measure</th><th>Net GHG emission reduction ($ktCO_2$-e)</th></tr>
<tr><td rowspan="2">Residential</td><td>Improving clean cooking access rate to 100 per cent by 2030, via promotion of LPG stoves.</td><td>-20.0</td></tr>
<tr><td>Phasing out of non-LED lighting</td><td>7.2</td></tr>
<tr><td>Industry</td><td>Adoption of energy efficiency measures across all industrial categories.</td><td>87.7</td></tr>
<tr><td>Commercial</td><td>Enforcement of the Energy Conservation Promotion Act for existing designated buildings.</td><td>10.0</td></tr>
<tr><td rowspan="5">Transport</td><td>Reduces vehicle-km travel in passenger cars by 40 per cent compared to BAU baselines
- The provincial authority should consider increasing infrastructure for public transportation (e.g., LRT), in combination with promoting carpooling, bicycling, walking or even remote working to reduce the needed vehicle-km travel.</td><td rowspan="3">217.0</td></tr>
<tr><td>Increase the share of electric passenger cars to 20 per cent by 2030.</td></tr>
<tr><td>Increase the share of electric buses to 100 per cent by 2030.</td></tr>
<tr><td>Increase the share of electric motorcycles to 50 per cent by 2030.</td><td>38.8</td></tr>
<tr><td>Increase the share of electric freight trucks to 25 per cent by 2030.</td><td>26.3</td></tr>
<tr><td colspan="2">Total</td><td>367.2</td></tr>
</table>

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

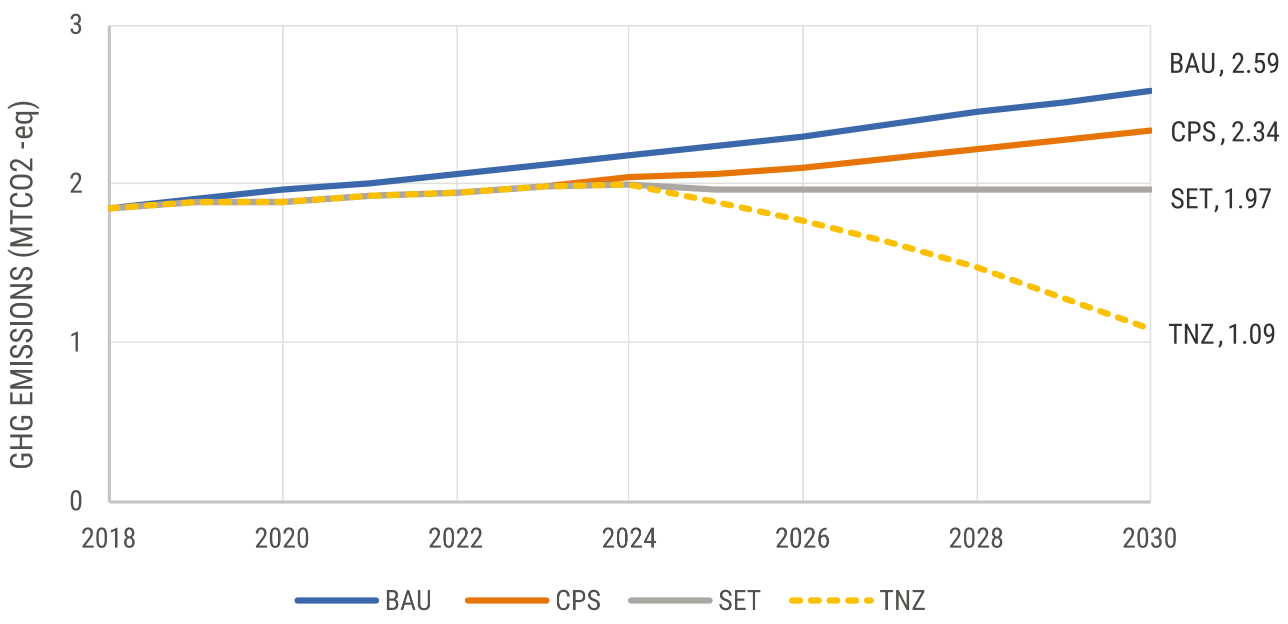
The SET scenario sets out various strategies in facilitating an economy-wide energy efficiency improvement in alignment with the national targets and commitment towards the Paris Agreement. Notwithstanding that, Udon Thani province may consider more ambitious pathways, moving towards a net zero society.

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 297 ktoe and emission reductions of 367 ktCO_2-e (15.6 per cent) relative to CPS. This also corresponds to a 24 per cent reduction in the BAU scenario, aligning with the national unconditional NDC commitment. Two ambitious scenarios have been modelled to further explore how Udon Thani may adopt more vigorous sustainable transport strategies and realise a steeper GHG emission reduction trajectory, moving towards a TNZ system in the near future.

The ambitious scenario, TNZ, aims to pave the way towards achieving net zero in the near future. The measures proposed include decarbonising the province's power supply and fuel/clean technology substitution.

The GHG emissions reduction that may be achieved with this ambitious scenario are as shown in figure 20. The two ambitious scenarios are further described in the following sections.

Figure 20. GHG emission trajectories, 2019-2030



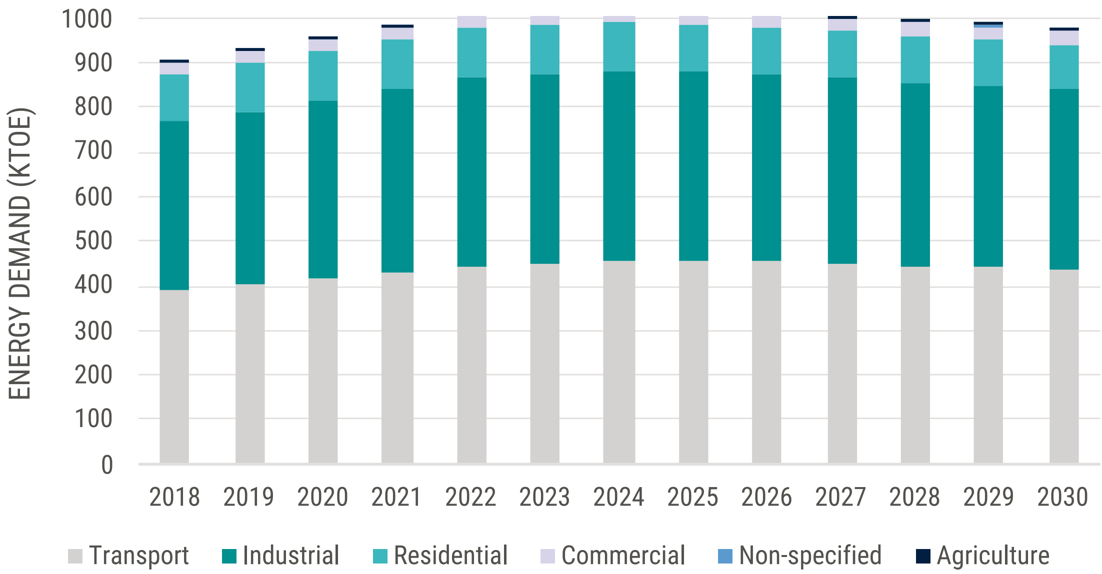
5.1. Towards a Net Zero scenario

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 by 2030 is challenging. However, Udon Thani may consider several ambitious measures to realise a more rapidly declining GHG emissions reduction trajectory, paving the way towards achieving net zero in the near future. The measures include, for example, decarbonizing the province's power supply and providing a fuel/clean technology substitution. The measures proposed (in addition to the ones already proposed for the SET scenario) are further explained in following sections.

5.1.1. Energy demand outlook

The total final energy consumption is expected to increase from 902 ktoe in 2018 to 975 ktoe in 2030, an increase of 3.6 ktoe compared with the SET scenario. The transport sector still has the largest share, at 45 per cent, followed by the industrial sector at 41.3 per cent, residential sector at 10.3 per cent and commercial sector at 3.1 per cent. Figure 21 shows the projected TFEC by sector under the TNZ scenario.

Figure 21. Energy demand by sector, TNZ scenario



5.1.2. 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 SET scenario) are summarized in table 8.

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

Sector	Measure	Energy demand reduction (ktoe)	GHG emission reduction ($ktCO_2$-e)
Power	Achieving a 100 per cent decarbonised power supply by 2030	-	804.5
Industrial	Fuel substitution in the industrial sector	0.35	40.5
Residential	Increase the adoption of electric cooking stoves to 50 per cent by 2030, while fulfilling the other 50 per cent by LPG stoves	-3.98	37.4
Total		**3.63**	**882.4**

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 made up around 34.5 per cent of Udon Thani's GHG emissions in 2018, decarbonising the electricity supply can be a cost-effective and efficient way in achieving a substantial GHG emissions reduction. Other measures are too important to Udon Thani'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.

5.1.3. Energy flows and balance, 2030

In the TNZ scenario, TPES is forecast to increase from 902 ktoe in 2018 to 975 ktoe in 2030. Figure 22 shows further the TPES breakdown by fuel type, while figure 23 shows the energy flows in 2030.

Figure 22. TPES breakdown by fuel type, TNZ in 2030

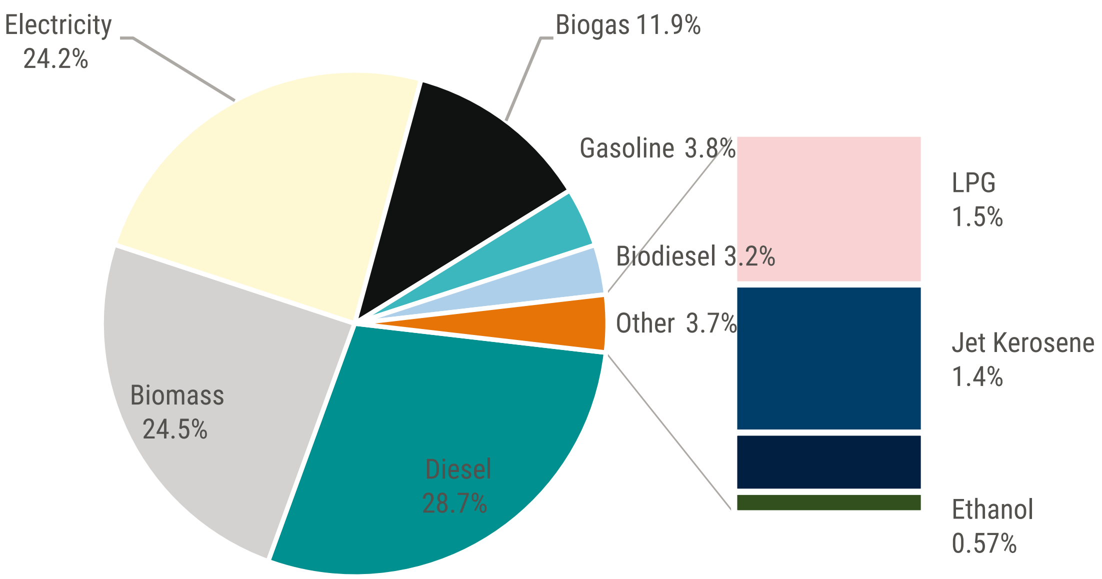
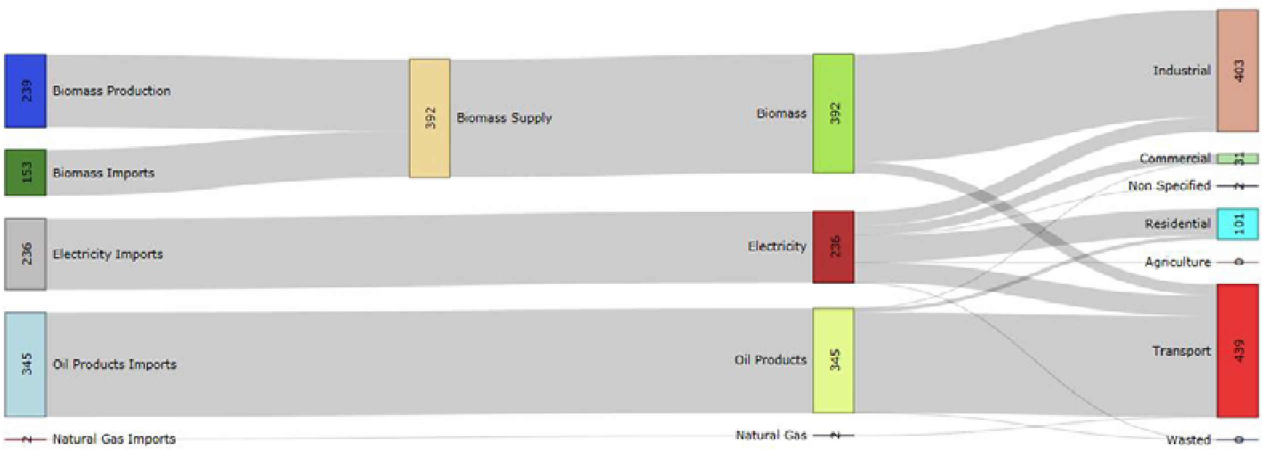


Figure 23. Sankey Diagram, TNZ in 2030 (unit: ktoe)



5.1.4. Pathways in decarbonizing Udon Thani's electricity supply

The electricity demand is projected to be 2,742 GWh in 2030. Udon Thani 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.

Challenges and opportunities to realise a 100 per cent renewable power

First, transformation towards 100 per cent renewable power requires a significant amount of investment cost. Second, the province currently does not have direct control of the central grid, only in the RE share or the grid emissions. Consequently, decarbonizing the province's energy supply needs collaboration to reach an agreement with the national Government and electricity generation authority. Third, the provincial government has to set the policies, including price and mechanism, and put these policies into practice.

Nevertheless, there are a few pathways/ opportunities that the province may 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 that reduce (1) the financial burden on the city for establishing the province's own utility-scale solar PV system, and (2) the 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 24 for LCOE comparisons).

(b) Establishing power purchase agreement (PPA). The province can enter into a special renewable energy power purchase agreement with interested RE suppliers. In turn, the supplier would supply Udon Thani with an agreed RE share of 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 a renewable energy auction.

(c) Lowering cost through renewable energy auctions. A more workable solution and the recent policy instrument is the RE auction. This approach is likely to substantially decrease the cost of electricity supply through a competitive pricing bidding and therefore, return a greater net benefit. For example, the 60 MW solar PV auction in Cambodia, has achieved US$0.0387 per kWh (ADB, 2019). Further details of renewable auctions can be found in box 4.

(d) Promotion of biomass power generation. The province of Udon Thani currently has 70 MW of biomass plant supply. The provincial biomass resource potential is quite substantial at around 1,523 ktoe per annum.[11] Additional capacity may be added as a way to increase the RE share of the province's electricity supply. As mentioned above, this may be done through a PPA and/or renewable energy auction, in collaboration with interested investors and facility operators. Moving forward, a feasibility study can be conducted to investigate the business case and potential technologies for such facilities. However, public perception should be one of the deciding factors.[12]

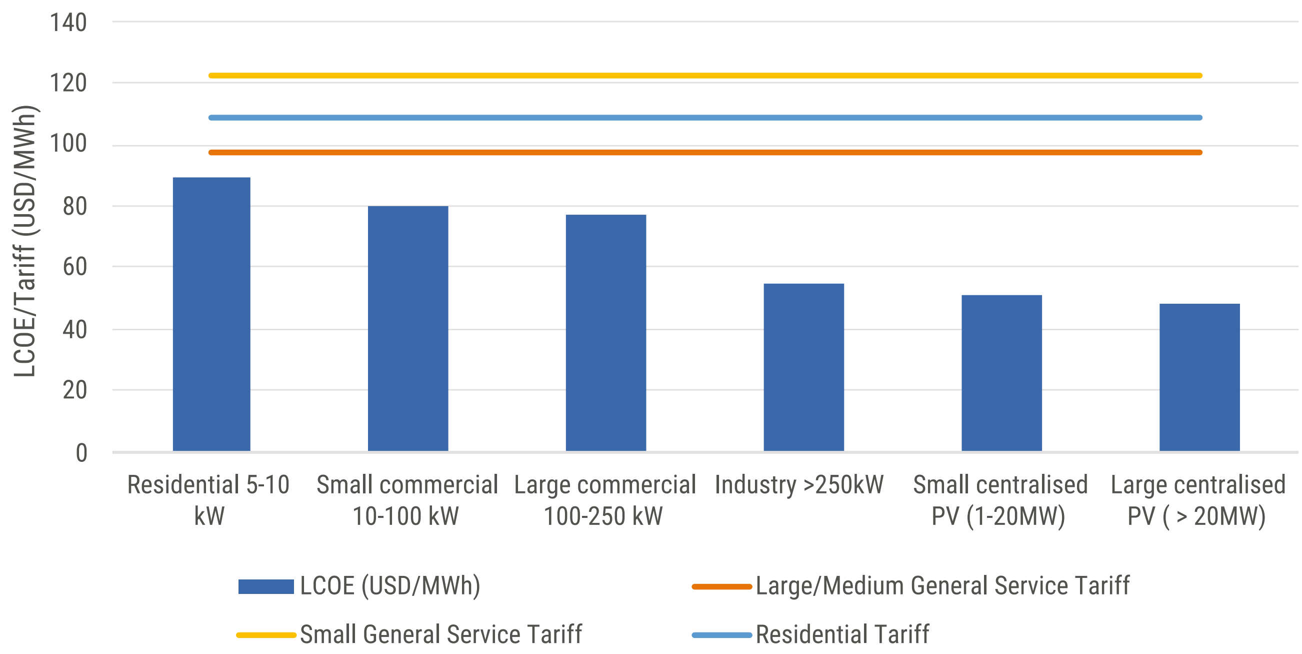
The above options are four different pathways that the province may pursue. A combination of one or more pathways, specifically with urban solar PV and renewable energy auctions, may be a good solution. Figure 24 shows that the LCOE of solar PV systems[13] is cheaper in comparison to the different tariff categories. The cost assumptions are included in the annex II.

11 The information was furnished by the provincial authority during the inception workshop.

12 As noted during the inception workshop, the province currently faces strong opposition against the construction of biomass plant.

13 Considers only CAPEX and fixed O&M and assumed discount rate of 5.37 per cent.

Figure 24. LCOE of solar PV systems at different scales compared with the average tariffs[14]



5.1.5. Cost benefit of decarbonizing Udon Thani's electricity supply

Table 9 shows further the financial savings and GHG reduction that can be achieved with different levels of provincially-arranged/generated renewable electricity targets.[15] For example, at a 100 per cent renewable electricity target, the GHG emission is reduced to only 1.09 $MTCO_2$-e. This remaining GHG emission is attributable to the remaining usage of LPG stoves for residential cooking, the use of fossil fuel in internal combustion engine (ICE) vehicles yet to be phased out as well as in other transport categories that are hard-to-abate in the near term (i.e., road freight, marine and aviation). Nonetheless, the TNZ scenario puts Udon Thani on the path towards realising net-zero in the coming decades as technologies continue to develop and mature.

The financial benefits to be gained through a decarbonised power supply will depend on the pathways the province undertakes. Table 9 compares emissions reduction and financial gains with different RE targets for the central grid by considering the price difference between an average tariff of US$ 0.107[16] and an auction price that has been reached in the ASEAN region of US$0.0387 per kWh. At a 100 per cent renewable electricity target, the annual saving will be around US$186 million in 2030.

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

15 Provincially-arranged/ generated renewable electricity target refers to the target share of electricity demand fulfilled through renewable electricity generated within the province or renewable electricity purchased through PPA or RE auction.

16 Note: The tariff quoted includes charges for transmission and distribution, and other service costs, hence the financial savings estimated might be an overestimation. A more precise estimation can be done if generation cost data are present.

Table 9. GHG emissions and financial savings at different levels of the RE target

	RE target				
	0%	25%	50%	75%	100%
Province's RE generation in 2030 (GWh)	0	685	1371	2056	2742
Emissions from Central Grid Electricity Supply (kTCO$_2$-e)	864	648	432	216	0
Total emissions in 2030 (kTCO$_2$-e)	1,954	1,738	1,522	1,306	1,090
Emission reduction relative to BAU in 2030	24.5%	32.9%	41.2%	49.5%	57.9%
Financial savings (million US dollars)	0	46	93	139	186

Notwithstanding, the RE price is likely to decrease further in the near future as the technology costs continue to decline. On the other hand, the grid generation cost may also decrease as RE penetration increases, lowering the central grid tariff. Table 10 shows sensitivity analysis of estimated financial savings at different uncertainty points. It can be observed that, in almost all cases, financial savings are positive. Considering the low solar PV generation costs compared with other conventional power plants, financial gains through a 100 per cent renewable-based electricity are guaranteed.

Table 10. Sensitivity analysis of financial savings at different levels of tariff and RE price

		Savings (million US dollars)				
		Change in RE price				
		50%	25%	0%	-25%	-50%
Change in national tariff	50%	279	306	332	359	385
	25%	206	232	259	286	312
	0%	133	159	186	213	239
	-25%	60	86	113	139	166
	-50%	-13	13	40	66	93

5.1.6. Moving towards Net Zero, 2050

Table 11 presents different measures that can be further considered to achieve net zero by 2050. NEXSTEP suggests the utilization of 100 per cent electric vehicles and electric cooking stoves by 2050 to achieve net zero.

Table 11. Measurements towards net zero 2050

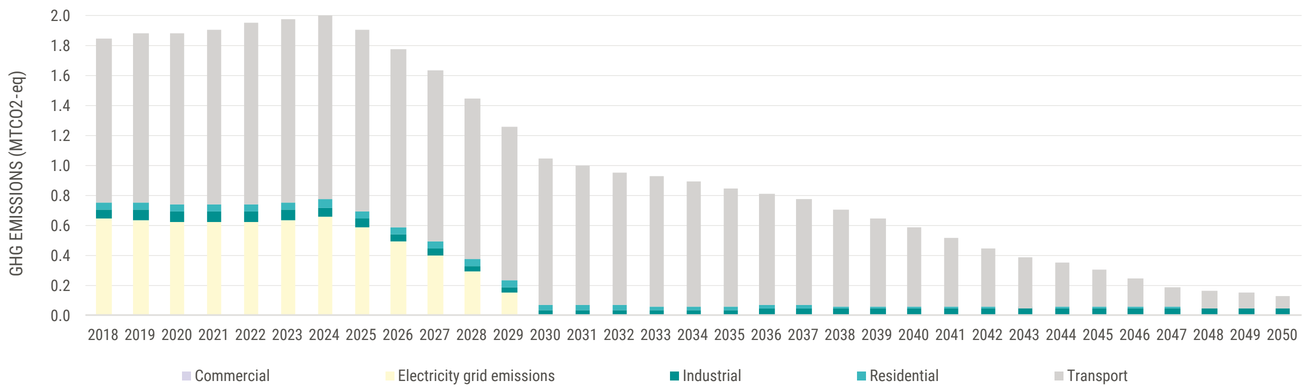
Sector	Measure
Residential cooking	100 per cent electric cooking by 2050
Passenger car	EV share in 2050: 100% (100% by 2042)
Motorcycle	EV share in 2050: 100% (100% by 2042)
Truck	EV share in 2050: 100% (100% by 2046)
Trailer	EV share in 2050: 100% (100% by 2050)

However, due to certain limitations to implementing measurements in the industrial and aviation sectors, small amounts of emission might still be produced in those two sectors. Therefore, a carbon sink, such as reforestation or forest management, or other carbon capture technologies, should be considered for absorbing the remaining carbon emissions.

Table 12. Remaining GHG emissions in 2050

Sector	Emissions	Description
Industry	54.4 $ktCO_2$-e	GHG emissions (non-CO2) from biomass usage, such as methane and nitrous oxide.
Aviation	79.8 $ktCO_2$-e	No measure has been considered for aviation.
Total	**134.2 $ktCO_2$-e**	

Figure 25. Udon Thani's energy sector emissions outlook, TNZ, 2018-2050



6. Policy recommendations for a sustainable energy transition

Chapter 4 demonstrates how sustainable energy transition can be accelerated to progress Udon Thani' province's development in line with the national targets and commitment towards Paris Agreement. Chapter 5 provides tangible low carbon transition pathways for Udon Thani, with the most ambitious pathway reaching a GHG emissions as low as 1.09 $MTCO_2$-e by 2030. This chapter presents several policy recommendations, which further elaborate on the proposed interventions.

6.1. Rapid adoption of electric vehicles to realise a low-carbon transport sector

The energy consumption of the transport sector is the highest – thus giving a substantial energy savings potential through transitioning to an electric vehicle mobility. Udon Thani's transport sector made up about 43.3 per cent of the total energy demand and contributed about 60 per cent of the province's GHG emissions in 2018. Hence, ambitious policy actions for the transport sector are critical for Udon Thani 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. The electric car sales passed 2 million globally in 2019, with a projected compound annual growth rate of 29 per cent through 2030 (Deloitte, 2020) . Various governmental policies have been introduced, which directly or indirectly promote the adoption of electric vehicles as a means to achieve environmental and climate objectives. Thailand similarly has a grand plan for e-mobility, targeting a 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 20 per cent electric share for passenger cars, 50 per cent for motorcycles, a 100 per cent electric vehicle share for buses and minibuses, and 25 per cent for freight trucks. Altogether, these are projected to reduce 128.4 ktoe of energy demand and 282.1 $ktCO_2$-e of GHG emissions reduction.

Promoting the use of public transport, specifically buses, can effectively reduce fuel consumption by the transport sector. It is also a means to reduce traffic congestion – a major problem in 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.

Two potential technical barriers to a widespread adoption of electric vehicles are increased demand for grid electricity and the lack of charging facilities. Close collaboration between Udon Thani province and power development agency should be fostered in order 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 as well as expanding public transport infrastructure.

The total length of highways with four or more lanes in Udon Thani province is approximately 207 km. It is assumed that fast-charging points (> 50kW) will be installed at 7 km intervals, with each costing around baht 1 million (US$ 30,000 equivalent). The total number of charging points required are an estimated 30 units. NEXSTEP estimates that establishing an extensive fast-charging (>50 kW) infrastructure in Udon Thani province may cost around US$ 900,000. An in-depth study should be conducted to come up with implementation strategies and a workable business model, with the possibility of public-private partnerships.

6.2. Transitioning to industrial best practices to realise substantial energy demand savings

As modelled in SET, the proposed energy efficiency interventions may allow an energy demand reduction of 146 ktoe – a 26 per cent reduction.

Without further region-specific information, the suggested energy savings potential for several industries is based on the potential savings provided by MOE (2011). These are approximately assessed by comparing Thailand's average specific energy consumption (SEC) in 2009 with the best SEC in other countries or within Thailand. Nonetheless, potential savings may vary from site-to-site, hence in-depth energy audits and baseline studies on a production site basis should be conducted to understand the energy efficiency and fuel switching potential in the industrial sector. Box 1 provides a list of energy improvement measures that are generally applicable in the different subsectors.

Industrial companies in Udon Thani should be encouraged to perform regular energy audits to assess their energy efficiency improvement potential as well as implementation of energy savings measures (i.e., the use of more efficient appliances). However, the high cost required to conduct energy audit and subsequently implementing energy efficiency measures are often the barrier to widespread adoption, particularly for small and medium-sized enterprises (SMEs). The provincial government may consider providing financial incentives and subsidies to encourage such practices. Needless to say, energy conservation awareness among industrial owners is imperative to ensuring a successful sustainable transition.

Box 1. Energy efficiency measures in the industrial sector

The areas of potential savings that are generally present in the different subsectors are, but not limited to:

- Improvement in motor loading;
- Replacement of old and rewound motors;
- Installation of more capacitor banks and increasing the efficiency of existing capacitor banks;
- Improvement in combustion efficiency of boilers;
- Regular cleaning and maintenance of boiler equipment (i.e., condenser pipes);
- Installation of more-efficient electric motors;
- Improvement of the steam distribution system, including leakage control and insulation;
- Electricity load management;
- Minimization of energy losses by partition of cooling areas, and installation and effective use of air curtains;
- Minimization of heat loss from boilers (or kilns for the cement sector);
- Condensation and waste heat recovery.

6.3. Pursuance of high renewable power share through cost-effective pathways

Renewable capacity has increased significantly across the globe amid climate change concerns. The decarbonization of the power sector is generally regarded as a low-hanging fruit, as the cost of renewable power technologies has decreased rapidly during the past decade. With electricity constituting about 15 per cent of the total fuel consumption and more than 35 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 subsection 5.1.4. 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, Udon Thani can work with the central Government to implement RE auctions at the city level. Box 2 explains in further detail the renewable energy auction.

Box 2. The 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 renewable-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. These 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 such 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 or a specific technology), auction frequency, and the upper and lower limits of project 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 put in place. There are two modes of penalty. In the monetary penalty, money will be deducted from a 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.

6.4. Moving towards net-zero carbon

Limiting temperature rise to 1.5°C requires a climate mitigation effort on an unprecedented scale and speed in order to reduce GHG emissions by about 45 per cent from 2010 levels by 2030, to reach net zero around 2050 (IPCC, 2018). Failing to act on the most pressing issue of this period may lead to a 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 agriculture sector could be significantly affected, whereby productivity decreases with the warming climate (World Bank and ADB, 2021).

The energy system of Udon Thani province is well-positioned for an accelerated decarbonization effort as the required net-zero technologies in decarbonizing its energy systems are readily available and matured, i.e., electric vehicles, electric cooking stoves and renewable power technologies. As detailed in section 5.1, decarbonizing its electricity supply is the key to deep decarbonization as it contributed around 35 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 at 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, and citizen's 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 keys to encouraging a widespread adoption of efficient technologies, such as electric vehicles. In addition, financial incentives can aid the transition, particularly in 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, have further expanded the NEXSTEP initiative to develop a Sustainable Energy Transition (SET) road map for Udon Thani province, as part of DEDE's "Energy for All" programme focusing on sustainable energy planning for cities.

The GDP of Udon Thani is projected to grow at 3.17 per cent per annum, while the population is expected to remain the same as it was in 2018. Under the current policy settings, the overall energy demand is projected to rise by an annual average rate of 2.9 per cent to 1,269 ktoe. Considering the increasing renewable energy generation share as per the Thailand Power Development Plan, 2018-2037, the GHG emissions are projected to be 2.34 $MTCO_2$-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 will strategically allow Udon Thani to align its energy sector performance with the national target 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 the largest energy-consuming sector and has a substantial energy savings potential. With an energy-saving potential ranging from 11 to 44 per cent across different subcategories, the energy demand reduction is projected to be 146 ktoe, if best practices are widely adopted. This corresponds to around a 26 per cent reduction from the BAU/CPS baseline. Energy conservation awareness should be further strengthened among industrial owners, while financial incentives may be provided to assist in overcoming the financial hurdles for SMEs.

Electric vehicle adoption is critical to achieving a 20 per cent GHG emissions reduction, aligning it with the national unconditional NDC commitment. The SET scenario explores a high level of electric vehicle penetration, which will realise an energy demand reduction and GHG emission reduction of 128.4 ktoe and 282.1 $ktCO_2$-e, respectively.

Climate change is one of the most pressing issues of this century, requiring hastened and widespread climate mitigation from all sectors. Udon Thani province may play its part by raising its decarbonization effort to realise a more rapidly declining GHG emissions trajectory, particularly through decarbonizing 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.

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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)	113.9 billion
GDP (2018, current US dollar)	3,525 million
PPP (2018, constant 2017 US dollar)[17]	8,737.4 million
GDP growth rate	3.17%

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

Parameter	Growth rate and size
Population (2018)	1,567,983
Population growth rate	0%
Number of households (2018)	528,347
Household size (constant throughout the analysis period)	3.0

(b) Demand analysis and growth projections, by sector

Residential:

- The residential sector is further divided into urban (37 per cent) and rural (63 per cent) households;
- The clean cooking access rate in 2018 is estimated to have been 62.8 per cent. The cooking distribution and assumed energy intensities are estimated in annex table 3.

17 The GDP in 2018 (in terms of local currency) is converted into PPP (current US dollar) with a conversion factor of 12.723 (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 (%)[18]	Energy intensity (GJ/household)
LPG stove	55.5	1.55
Electric stove	2.0	2.84
No cooking	5.1	-
Charcoal stove	37.4	6.58

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

Annex table 4. Residential appliance baseline assumptions for 2018

Category	Appliance	Ownership (%)	Electricity intensity (kWh/HH/year)
Lighting	Fluorescent	94.90	168.79
	Compact fluorescent	40.80	90.72
	LED E27	6.10	80.67
-	Air conditioner	15.10	1,648
-	Refrigerator	92.70	271.4
Television	LCD/LED/Plasma	38.5	67.7
	Common	61.5	150.8
-	Water heater	12.8	548
-	Electric stove	2.32	789
-	Electric fan	99.3	2,828
Washing machines	Top loading	97.1	28.8
	Front loading	2.9	177
-	Water pump	8.0	279
-	Iron	73.8	295.7

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

Transport:

- 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 are 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 2.5 billion vehicle-kilometres for road passenger transport and 1.9 billion vehicle-kilometres for road freight transport. The growth both in passenger transport and freight transport activities is assumed to have grown at the same rate as the GDP, i.e., 3.17 per cent per annum.

Annex table 5. Transport sector baseline assumptions for 2018

Passenger transport	Percentage share of vehicles by fuel type	Travelled mileage in 2018 (million km)	Fuel consumption	Percentage share of passenger-km
Passenger car	Gasoline – 32.8	4,028	12.5 km/l	63.21
	Diesel – 64.1		11.1 km/l	
	Hybrid – 0.43		20 km/l	
	LPG – 2.04		2.7 MJ/km	
	CNG – 0.63		2.7 MJ/km	
	Electric – 0.01		5 km/kWh	
Motorcycle	Gasoline – ~100	1,339	25.5 km/l	32.84
Bus and minibus	Gasoline – 0.5	5,037	5.15 km/l	3.95
	Diesel – 79.8.3		5.15 km/l	
	Natural gas – 19.7		7.3 MJ/km	
	LPG – 0.14		7.3 MJ/km	
Freight transport	No. of vehicles (%)	Travelled mileage in 2018 (million km)	Fuel consumption	Percentage share of tonne-km
Freight truck	Diesel – 98.99.1	1,709	9.29 km/l	91.01
	Natural gas – 0.93		9.29 km/l	
Trailer	Diesel – 100	167	3.00 km/l	8.92

Industry:

- The industrial sector is further differentiated into six 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 3.17 per cent, similar to the provincial GDP growth rate.

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

Passenger transport	Fuel consumption (ktoe)				
	Oil products	Biomass	Electricity	Biogas	Total
Cement and non-metallic quarry products	-	-	0.71	-	0.71
Textile and leather	-	-			
Iron and steel	-	-	0.44	-	0.44
Fertilizer, chemical, and rubber products	-		0.01	-	0.01
Food and beverages	2.27	135.1	40.1	111.24	288.7
Machinery and transportation tools	0.31	-	0.37	-	0.69
Wood and other products			0.72	-	0.72
Other industry	9.64	74.3	2.4	-	86.6
Total	**12.2**	**209.4**	**44.72**	**111.2**	**377.6**

Commercial:

- The commercial sector is differentiated into designated buildings and non-designated buildings.
- The total commercial floorspace of the designated buildings is estimated to have been 1.13 million m^2 in 2018. They can be further divided into six sub-categories. Projected growth is an annual rate of 3.17 per cent, a rate similar to the projected growth in provincial GDP.
- No floorspace data are available for non-designated buildings, but the fuel consumption in 2018 is measured at 15.55 ktoe. NEXPSTEP assumes a 3.17 per cent annual growth rate in fuel consumption, a rate similar to the projected growth in provincial GDP.
- The fuel intensities and consumption data in 2018 are 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)
Designated buildings	Private office	0.53	11.54	0.53
	Others	0.03	472.9	1.12
	Shopping mall	0.18	251	3.92
	Hotel	0.05	133.5	0.61
	Hospital	0.16	134	1.88
	University	0.17	38.9	0.56
Non-designated buildings	-	-	-	15.55

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 grow at an annual rate of 3.17 per cent, the same as the provincial GDP growth rate.

Annex table 8. Consumption in other sectors in 2018

Sector	Electricity consumption (toe)
Agriculture	0.18
Non-specified use	1.40

Annex II. Power technologies assumptions

Cost assumptions used for calculating the levelized cost of electricity (LCOE) of solar PV systems and biomass power plant:

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

	Installation cost[19]	
	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[20]	16.5 per cent for solar PV 66.5 per cent for biomass power plant
Fixed O&M (US$/MW)[21]	1.2 per cent of CAPEX for solar PV 6.5 per cent of CAPEX for biomass power plant
Lifetime	30 years
Biomass fuel cost[22]	12.5 US$/ton

19 Reference to the National Survey Report of PV Power Applications in Thailand 2018.

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

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

22 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

	BAU scenario	CPS scenario	SET scenario	Towards NetZero
Universal access to electricity	Already achieved			
Universal access to clean cooking	67.3% by 2030			100% by 2030
TFEC in 2030	1,271 ktoe	1,269 ktoe	971.5 ktoe	975 ktoe
Energy efficiency (in terms of TFEC)	8.63 ktoe/billion $baht_{2010}$	8.62 ktoe/billion $baht_{2010}$	6.61 ktoe/billion $baht_{2010}$	6.62 ktoe/billion $baht_{2010}$
Energy efficiency (SDG 7.3)	4.19 $MJ/US\$_{2017}$	4.18 $MJ/US\$_{2017}$	3.20 $MJ/US\$_{2017}$	3.21 $MJ/US\$_{2017}$
Renewable energy share in TFEC	42.6%	44.6%	44.6%	64.4%
GHG emissions	2.59 $MTCO_{2-e}$	2.34 $MTCO_{2-e}$ (9.7% from BAU)	1.97 $MTCO_{2-e}$ (24% from BAU)	1.09 $MTCO_{2-e}$ (58% from BAU)
RE share in electricity supply	17.8%	24.6%	24.6%	100%

Annex IV. Energy balance

Energy balance, 2018

	Electricity	Gasoline	Jet Kerosene	Diesel	LPG	Oil	Charcoal	Biogas	Ethanol	Biomass	CNG	Biodiesel	Total
Production	-	-	-	-	-	-	-	-	-	209.	-	-	209.
Imports	133.	52.	10.	291.	17.	12.	31.	111.	8.	-	6.	22.	693.
Exports	-	-	-	-	-	-	-	-	-	-	-	-	-
Total primary supply	133.	52.	10.	291.	17.	12.	31.	111.	8.	209.	6.	22.	902.
Total transformation	-	-	-	-	-	-	-	-	-	-	-	-	-
Residential	63.	-	-	-	15.	-	31.	-	-	-	-	-	108.
Industrial	45.	-	-	-	-	12.	-	111.	-	209.	-	-	377.
Commercial	24.	-	-	0.	0.	-	-	-	-	-	-	-	24.
Agriculture	0.	-	-	-	-	-	-	-	-	-	-	-	0.
Non-specified	1.	-	-	-	-	-	-	-	-	-	-	-	1.
Transport	-0.	52.	10.	291.	2.	-	-	-	8.	-	6.	22.	390.
Total demand	133.	52.	10.	291.	17.	12.	31.	111.	8.	209.	6.	22.	902.
Unmet requirements	-0.	-0.	-	0.	-	-	-	-	-0.	-	-	-	-

Energy balance, Sankey Diagram, 2018