ASEAN Centre for Energy
One Community for Sustainable Energy

IRENA
International Renewable Energy Agency

RENEWABLE ENERGY OUTLOOK FOR ASEAN

REmap 2030
A Renewable Energy Roadmap

A REMAP ANALYSIS

ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

About ACE

Established on 1 January 1999, the ASEAN Centre for Energy (ACE) is an intergovernmental organisation that independently represents the 10 ASEAN Member States' (AMS) interests in the energy sector. The Centre serves as a catalyst for the economic growth and integration of the ASEAN region by initiating and facilitating multilateral collaborations as well as joint and collective activities on energy. It is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an *ex-officio* member. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's headquarter is located in Jakarta.

The Renewable Energy Support Programme for ASEAN (ASEAN-RESP) is a joint project by ACE and GIZ, on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), and it enables regional exchange on renewable energy between ASEAN Member States. IRENA and ACE are grateful to ASEAN-RESP for its financial support for the two REmap ASEAN regional workshops.

Acknowledgements

This report was prepared by the International Renewable Energy Agency (IRENA) and the ASEAN Centre for Energy (ACE). It was prepared under the overall guidance of Dolf Gielen, IRENA Director for Innovation and Technology, and Ir. Dr. Sanjayan K.V. Velautham, Executive Director of ACE.

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Valuable review and feedback was provided by IRENA colleagues Rabia Ferroukhi, Laura Gutierrez and Jasper Rigter as well as ACE colleagues Badariah Yosiyana, Yudha Irmansyah Siregar, Nanda Febriani Moenandar and Dr. Atit Tippichai. Additional valuable review was provided by Kohji Iwakami (UN ESCAP), Rizky Fauzianto (GIZ), Putu Marsya Sabrina (GIZ), and Cecilia Tam (APERC). The authors would like to extend a special thanks to Maria-José Poddey (GIZ). The editor of this report was Ellen Thalman.

The report has benefited from input by numerous ASEAN Regional Energy Policy Sub-Sector Network (REPP-SSN) and Renewable Energy Sub-Sector Network (RE-SSN) Focal Points and Working Group experts, who provided information, reviewed country analysis, and participated in two working meeting and three webinars during the period March to October 2016. Their comments and suggestions were of great value and have shaped the final report.

AMS Working Group experts include: **Brunei Darussalam:** Dr. Andi Tabrani, Muhammad Rifdi; **Cambodia:** Kin Sothea, Ngin Yav, Munyphakdey Koet; **Indonesia:** Kartika Dewi Widiastut, Siti Suddatul Aisyah Novianty; **Lao People's Democratic Republic:** Litthanoulok Laspho, Phaysone Phouthonesy, Khonetavanh Douangchanh; **Malaysia:** Wong Tin Song, Law Yen Yang, Azah Ahmad, Nor Azaliza Damiri, Ahmad Syafiq Rosli; **Myanmar:** Hla Myo Aung, Swe Swe Than, Dr. Thi Thi Soe; **Singapore:** Poh Wei Chian, Erica Liu, Lindy Tan, Derek Wu; **Philippines:** Lilibeth Morales, Diana Christine Gabito, Jane Peralta, Cynthia Mañalac, Gaspar Escobar, Jr., Michael John Velasco; **Thailand:** Supit Padprem, Bubpha Kunathai, Sukanlaya Treewitthayanurak, Kulwaree Sajjawaporaporn, Lumyai Mungpanklang; **Vietnam:** Quach Quang Dong.

Special thanks to all the participating ASEAN Energy Ministers, Senior Officials and other Participants for their constructive feedback and discussions during the Ministers-CEO Dialogue on 23 September 2016 in Nay Pyi Taw, Myanmar, in the occasion of the 34th ASEAN Ministers on Energy Meeting (AMEM). In a Joint Ministerial Statement released at the event the Ministers commended ACE's productive collaboration with IRENA and GIZ towards the publication of the ASEAN Renewable Energy Outlook. The statement noted that the Ministers were encouraged by the findings of the Outlook and called for additional effort and robust framework from all AMS towards the timely achievement of the ASEAN renewable energy target.

IRENA is grateful to the German and Japanese governments, whose support of the REmap Programme make the publication of reports like this one a reality.

ISBN 978-92-95111-27-1 (print)
ISBN 978-92-95111-28-8 (PDF)

Report citation

IRENA & ACE (2016). *Renewable Energy Outlook for ASEAN: a REmap Analysis.* International Renewable Energy Agency (IRENA), Abu Dhabi and ASEAN Centre for Energy (ACE), Jakarta.

This report is available for download from **www.irena.org/publications,** the REmap **website www.irena.org/remap** and **www.aseanenergy.org/publications**

For further information or to provide feedback, please contact the IRENA REmap team at **remap@irena.org** and ACE team at **secretariat@aseanenergy.org**

DISCLAIMER

IRENA
International Renewable Energy Agency

The nations of Southeast Asia stand at a crossroads in terms of their collective energy future. Over the next decade, the region will experience rapid economic growth and a 50% rise in energy demand. With this growth comes challenges, as the region strives to supply energy affordably, sustainably and securely.

The Association of Southeast Asian Nations (ASEAN), recognising this challenge, has decided to chart a course towards a sustainable, secure and prosperous future based more heavily on renewable energy. Accordingly, the region has set out to make 23% of its primary energy renewable – more than double the current share.

This aspirational target, although ambitious to reach by 2025, is grounded in a firm awareness of the region's wealth of renewable energy resources. It also recognises a compelling business case, as tumbling technology costs for renewables make access to modern energy services increasingly feasible and affordable for all while bringing the region closer to a trajectory in line with the objectives of the Paris Agreement and the Sustainable Development Goals.

The International Renewable Energy Agency (IRENA) has worked intensively with the ASEAN Centre for Energy and ASEAN's ten member states to find ways to accelerate renewable energy deployment across the region. As this report indicates, renewable energy can bring lower overall costs, cleaner cities, and a more secure and robust energy supply.

But this future depends on action now – not only to scale up significantly the amount of renewable power, but also to switch to more renewable-based heating, cooking and transport. All ASEAN countries must act, at a national and regional level.

IRENA stands ready to support ASEAN Member States in charting out this exciting journey as they work together to build a secure, accessible, affordable and sustainable energy future.

Adnan Z. Amin

Director-General

International Renewable Energy Agency

ASEAN Centre for Energy
One Community for Sustainable Energy

At the beginning of this year, the ASEAN Centre for Energy (ACE) published the 4th ASEAN Energy Outlook (AEO4). Against the backdrop of various developments effecting the energy sectors, AEO4 presents two scenarios of the region's energy demand and supply to 2035: a Business as Usual Scenario which reflects the continuous trend of the energy sector's development from the past; and and Advancing Policy Scenario that incorporates progressive policy and action plans from each ASEAN Member States to achieve their official national targets for renewable energy and energy efficiency. The findings raised concerns in terms of energy security as the region will continue to depend on fossil fuels, with coal as the main energy source to meet the rapid growth of electricity demand. However, AEO4 also outlines the potentials to reduce energy intensity while highlighting the potentials to increase the contribution from renewable energy.

Seeing the importance to analyse these findings further ACE started a collaboration with the IRENA with the support of ASEAN Member States to identify the path for the region to achieve its aspirational target of 23% of RE in the energy mix by 2025. This regional target was set by the AMS at the 33rd ASEAN Ministers on Energy Meeting in 2015. This study not only indicates the status of renewables in Member States, but also available options for ASEAN to achieve its aspirational renewable energy target. Beyond that, it supports the main objectives of the ASEAN Plan of Action for Energy Cooperation 2016-2025 towards 'energy security, accessibility, affordability and sustainability for all'.

This publication is part of ACE's efforts to fulfil its function as a regional centre of excellence that builds a coherent, coordinated, focused and robust energy policy agenda and strategy for ASEAN. In its development process, it also received support from the Renewable Energy Support Programme for ASEAN, a project jointly implemented by ACE and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ). We are glad that the findings of this study have provided key discussion points during the Ministers-CEO Dialogue on the occasion of the 34th AMEM on 23 September 2016 in Nay Pyi Taw, Myanmar, and received positive feedback. We hope this publication will motivate all stakeholders in enhancing cooperation for renewables promotion and deployment in the region.

Ir. Dr. Sanjayan Velautham

Executive Director

ASEAN Centre for Energy

CONTENTS

LIST OF FIGURES

LIST OF TABLES

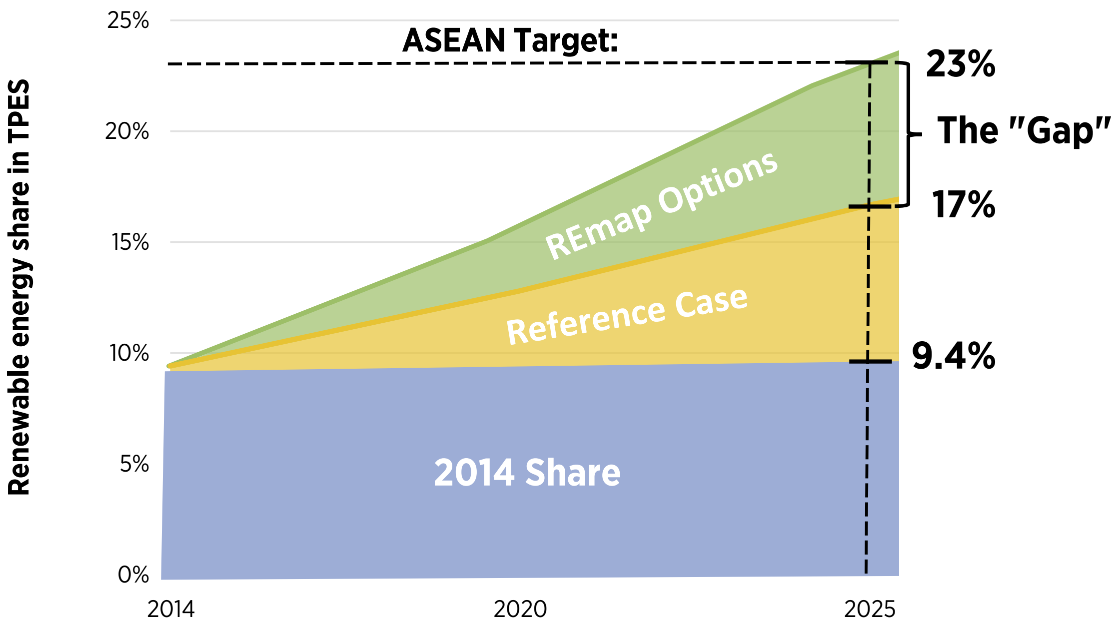
LIST OF BOXES

EXECUTIVE SUMMARY

A TARGET FOR A CLEAN, SUSTAINABLE AND PROSPEROUS FUTURE

The Association of Southeast Asian Nations (ASEAN) has set the aspirational target of securing 23% of its primary energy from modern, sustainable renewable sources by 2025. This objective implies a two-and-a-half-fold increase in the modern renewable energy share compared to 2014. At the same time, power generation will double by 2025, and overall energy demand will grow by almost 50%.

Figure ES1: Renewable energy share in the ASEAN region in total primary energy supply to 2025



The renewable energy share will need to increase two-and-a-half fold by 2025 with a six percentage-point gap between the Reference Case and 23% target

This target is well in line with the global thinking and ambition levels for renewables, but it will require a significant acceleration of renewable energy deployment over the coming decade. In 2014, the ASEAN region's renewables share in total primary energy supply (TPES) was 9.4%. By 2025 it is expected to increase to just under 17% if current policies and those under consideration are followed. Thus, the region must overcome a six percentage-point gap to reach its goal.

The challenge is how to implement this 23% renewable energy target. Doing so will require an understanding of what can individual countries contribute, what can different sectors contribute, and what are the costs and benefits of different technologies. This study explores the potential for deploying renewable energy technologies across the entire energy system of ASEAN Member States. It also quantifies costs and investments, environmental benefits, and identifies key challenges to ramping up renewables in the region.

GROWING ECONOMIES, POPULATION AND ENERGY DEMAND

The population of the ASEAN region will increase from around 615 million in 2014 to 715 million by 2025. The economy will grow more than 5% per year, resulting in a rapid rise in energy demand. The region will see 4% annual growth in energy demand until 2025, amounting to a rise of 50% over 2014 levels. Electricity demand will double between 2014 and 2025.

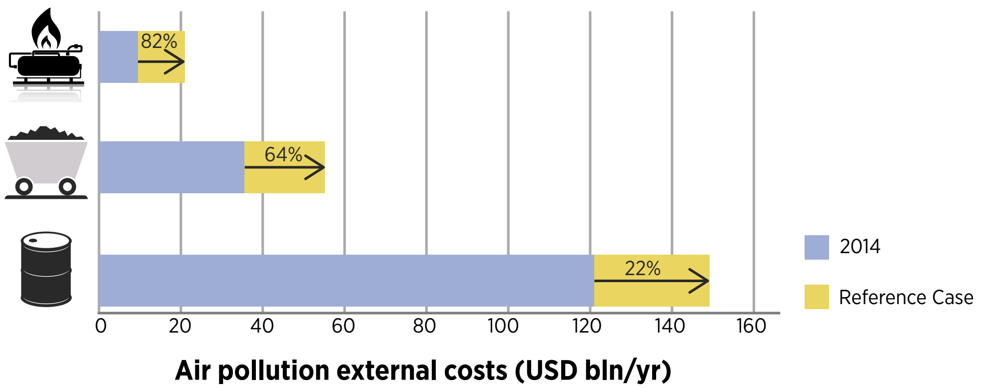
The region has insufficient indigenous fossil fuel resources to meet its growing energy demand, and the share of imported fossil fuel will increase, which has important energy security implications.

Energy demand for electricity production will rise at the fastest pace, but fuel demand in industry and transport will also increase rapidly. According to developments likely to occur based on current or planned policies or expected market developments (known in this report as the Reference Case), most demand will be met with fossil fuels, but it also foresees significant growth in hydropower, geothermal power, and some forms of modern bioenergy for heating and cooking.

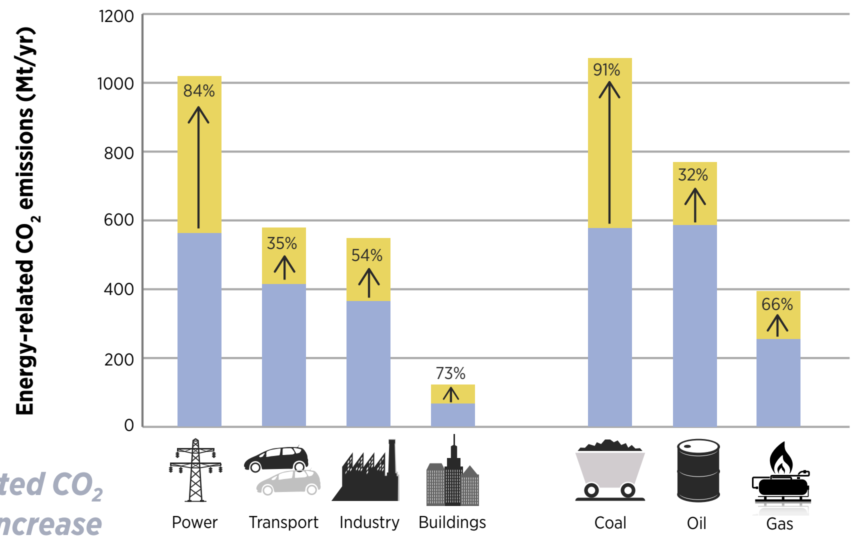
Rising fossil fuel demand will boost carbon dioxide (CO_2) emissions and exacerbate local air pollution. This has global implications. The share of global energy consumed in the region will increase from 5.7% today to 7.5% by 2025. In the Reference Case, energy-related CO_2 emissions will increase by 61% and total energy-related CO_2 emissions will amount to over 2.2 gigatonnes (Gt) annually in 2025.

External costs related to air pollution from the combustion of fossil fuels will increase by 35%, from USD 167 billion annually in 2014 to USD 225 billion in 2025. This would equal around 5% of the ASEAN region's gross domestic product (GDP) in 2025. Therefore, the region will see rising costs for energy supply, as well as rising costs from the negative effects of greater fossil fuel use in increasingly urban societies.

Figure ES2: Air pollution external costs (left figure) and energy-related CO_2 emissions (right figure) in the ASEAN region, 2014 and Reference Case in 2025



External costs associated with air pollution could reach USD 225 billion annually by 2025



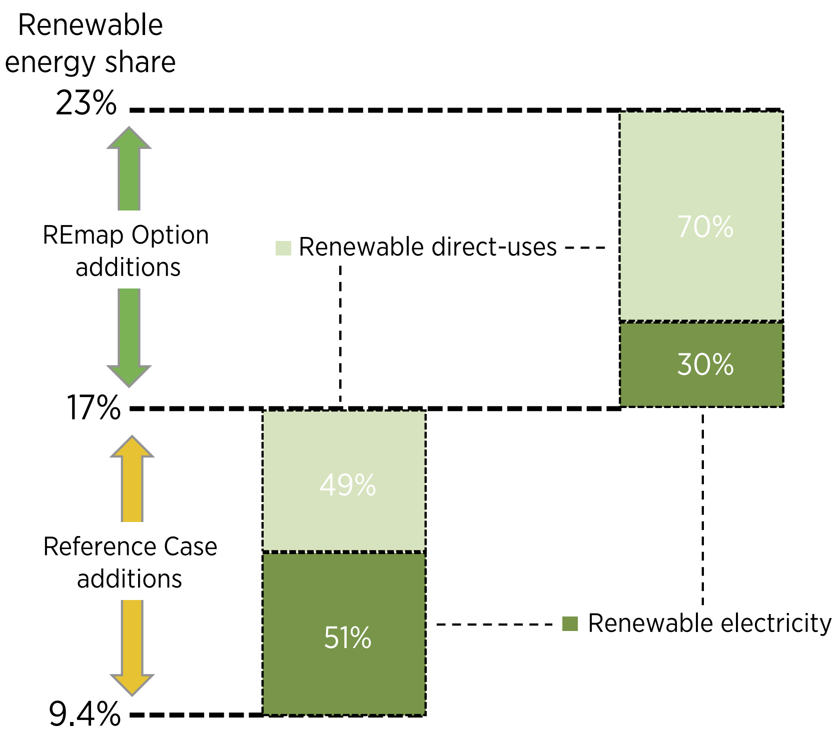
Energy-related CO_2 emissions will increase by over 60% by 2025

THE CASE FOR RENEWABLES

Renewable energy has emerged as the single largest source of new power capacity additions in recent years. The year 2016 has seen record low prices for utility-scale solar photovoltaics (PV) and onshore wind, as low as USD 0.03 per kilowatt-hour (kWh) for the lowest-cost project proposals. More and more countries are showing how significant shares of variable renewables can be integrated into existing grids, while maintaining or even improving power reliability and quality. This shifting energy landscape also comes at an important time for the climate, with the Paris Agreement entering into force. The shared objective to keep climate change below 2 degrees Celsius implies a global decarbonised energy system between 2050 and 2070. Renewable energy has a key role to play on the supply side to realise this objective.

ASEAN Member States can benefit from these global trends. This roadmap shows that by 2025 across most of the ASEAN region, renewable power technologies will be able to supply electricity at or below the cost of generation from non-renewable energy sources. Additionally, the region's ample renewable energy resources can provide opportunities for the cost-effective deployment of renewable technologies for heating and cooking, with large potential for solar thermal and modern bioenergy.

Figure ES3: Renewable energy additions in the Reference Case and REmap Options, by electricity and direct-use



Renewable electricity plays an important role in increasing the region's renewable share, but much of the additional potential identified in REmap comes from direct-uses of renewables for heating, cooking and transport

THE RENEWABLE TECHNOLOGY MIX

The REmap approach covers energy supply and demand – it looks at power, heating, transport and cooking, and at all renewable sources. Given the short time horizon and ambitious ASEAN target for 2025 – which is under a decade away – this broad, multi-sector scope is the best way to find a viable pathway.

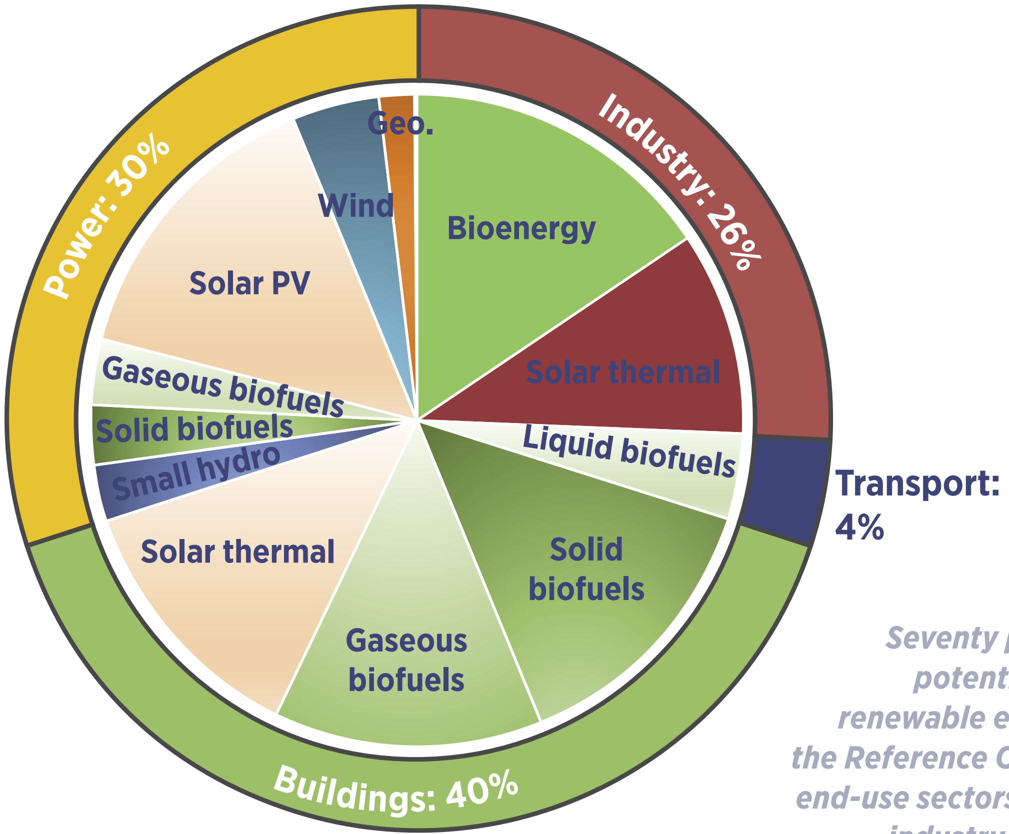
Around half of the modern renewables potential for 2025 is in the power sector. The other half is in end-use sectors, *i.e.* renewable fuels or direct-uses of renewables for heat, cooking, and transport. However, renewables deployment under government plans, knows as the Reference Case, and the additional potential identified in REmap differ significantly.

The Reference Case sees significant increases in hydropower, and more modest growth in geothermal power, liquid biofuels, and a reduction of around one-third in the traditional uses of bioenergy.

The REmap Options, which are the additional potential of renewables on top of the Reference Case, and which close the six percentage-point gap to reach the region's aspirational target, are made up of about one-third renewable power and about two-thirds renewables in heating, cooking and transport. Around 15% come from solar PV, with another 15% from wind, geothermal and bioenergy-based power. The remainder of the additions are made up of 25% from solar thermal, 35% from mainly biogas and modern bioenergy cookstoves in buildings (residential and commercial), as well as bioenergy used in industry and transport, and 10% from other renewable sources.

The distribution of renewable energy use varies significantly by country and sector, with renewable shares in countries ranging from 4% to 59% in REmap – a wide variation from the regional objective of 23%. The wide range can be attributed to a different resource endowment, different levels and growth rates of energy demand, and different starting points based on today's levels. Across the ASEAN region, the power sector has the highest share, followed by buildings, industry and transport. Additional potential for deploying renewables on top of the Reference Case exists in all sectors, but REmap shows that the largest increase can take place in buildings and industry by 2025.

Figure ES4: Breakdown of REmap Options by sector and renewable energy source



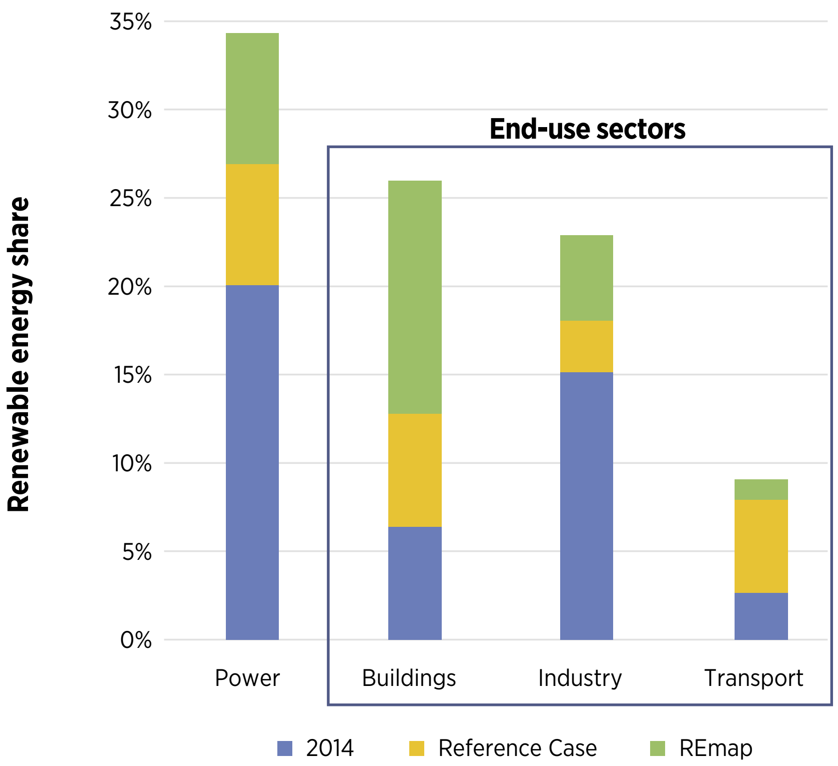
Seventy percent of the potential to increase renewable energy beyond the Reference Case lies in the end-use sectors of buildings, industry and transport

Note: Geo. stands for geothermal.

POWER

- The renewable energy share of total power generation will increase from 20% in 2014 to 27% in the Reference Case, and further to 34% in REmap by 2025. This would amount to 410 terawatt-hours (TWh) of renewable power growth from 2014 to 2025, 280 TWh of which occurs in the Reference Case and an additional 130 TWh in the REmap Options. Installed renewable capacity would increase from 51 gigawatts (GW) in 2014 to 184 GW by 2025, amounting to 43% of total power generation capacity in 2025.
- The findings indicate that additional renewable energy opportunities remain in power generation beyond what countries plan to deploy in their Reference Cases. More can be done especially with solar PV, both in distributed and in utility scale, which will increase from just 2 GW in 2014 to almost 60 GW in 2025 in REmap. Also bioenergy-based power and wind can grow faster than anticipated.
- The share of variable renewable power (VRE) across the ASEAN region will generally be low, but shares in individual countries and within individual power systems will vary. In some countries, the share of VRE in generation will exceed 10% if all REmap Options are implemented. Experience from other countries shows that such shares can be

Figure ES5: Renewable energy shares in the ASEAN region by sector to 2025



Note: End-use sectors include the consumption of electricity sourced from renewables. Shares presented in figure exclude traditional uses of bioenergy.

The highest renewable energy share will be in power, but high shares will also be seen in buildings and industry

accommodated with limited grid investments and operational adjustments.

TRANSPORT

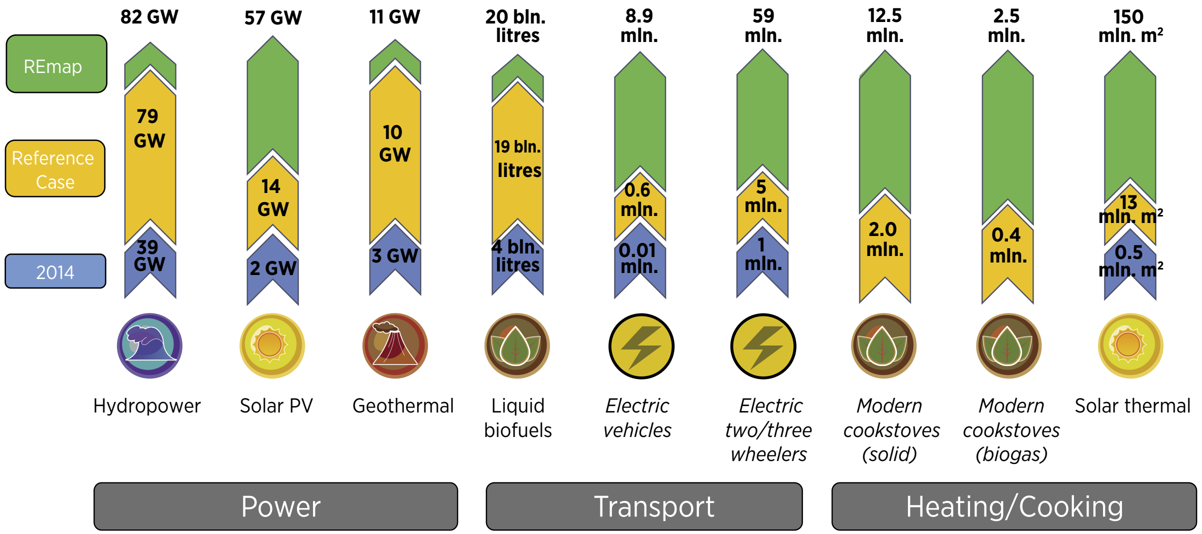
- The transport sector will see energy demand grow by 45% between 2014 and 2025. The sector has the lowest share of renewables of any sector, but some of the highest renewable growth potential. The share of renewable energy in the sector could triple from just 3% in 2014 to 9% in REmap.
- The technologies that would enable this growth include both biofuels and electric mobility. Most of the increase in the Reference Case will be from biofuels, with around 20 billion litres of total demand. The REmap Options show the significant additional potential of electric vehicles. There would be around 59 million electric two- and three-wheelers, and around 5.9 million electric four-wheel vehicles. Additionally, electrified public transport would grow rapidly within cities and for transit travel. The sector will become more electrified, with the share of transport energy coming from electricity rising from 0.2% in 2014 to 1.6% 2025. However the role of biofuels will still be evident.

BUILDINGS

- In buildings, the share of renewable energy from modern renewable energy sources, which excludes traditional uses of bioenergy, increases from 6% to 13% by 2025 in the Reference Case.

- In REmap, the renewable energy share is double that of the Reference Case, reaching 26%. Half of this increase is driven by greater use of modern bioenergy, such as in modern solid and biogas cookstoves, which replace

Figure ES6: Physical capacity growth of select renewable technologies in the Reference Case and REmap Options to 2025



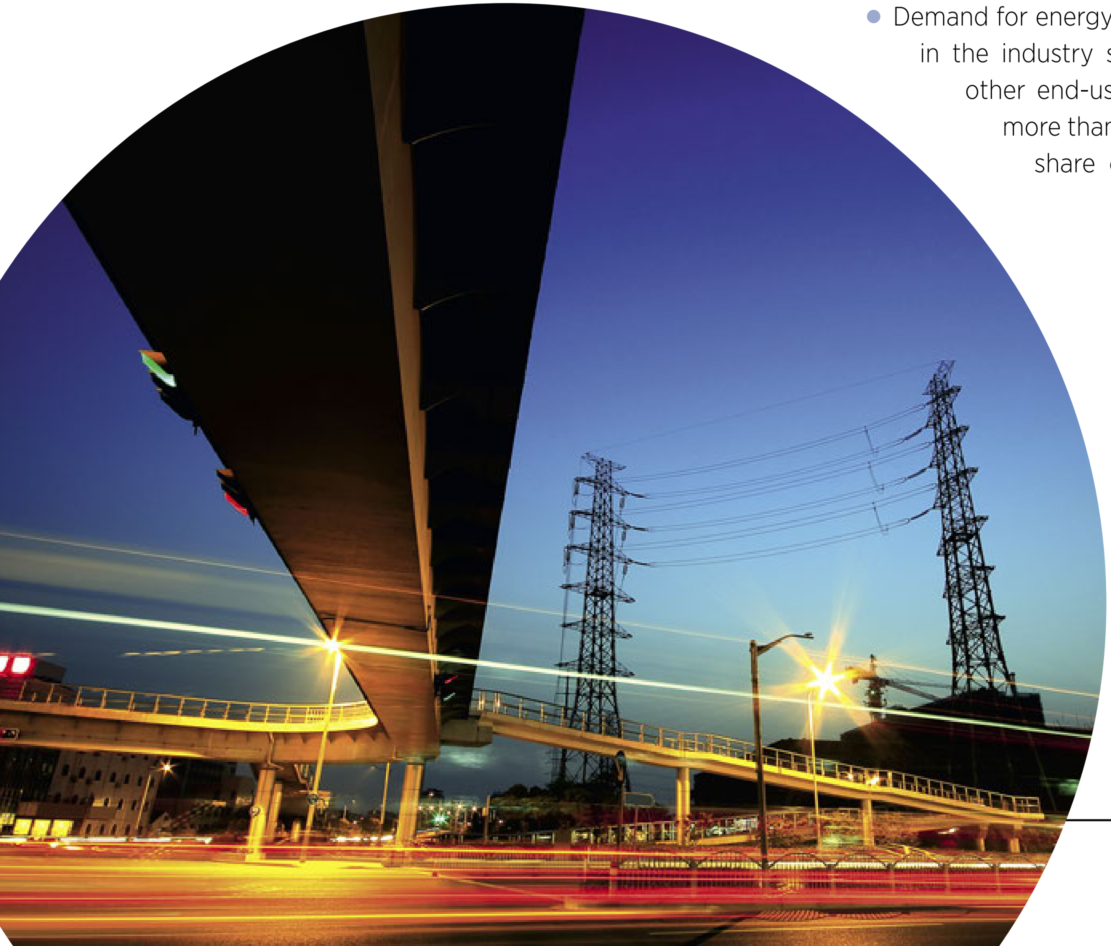
Note: The numbers in figure refer to the total end value in 2014, Reference Case 2025, or REmap 2025. They do not refer to additions taking place in each case.

Hydropower, geothermal and liquid biofuels see significant growth in the Reference Case; most other technologies see the majority of growth take place in the REmap Options

much of traditional use of bioenergy. By 2025 there could be 12.5 million modern cookstoves, 2.5 million biogas cooking installations, and 0.4 million biofuel cookers in operation. The other large source of renewable energy is solar thermal. Total collector area would expand by around 150 million square metres, bringing the region average to 0.2 square metres per capita.

INDUSTRY

- Demand for energy will grow by more in the industry sector than in any other end-use sector, rising by more than 60% by 2025. The share of renewables will only increase marginally, by 15%-18% in the Reference Case.
- REmap shows that additional potential lies in increased use of bioenergy to provide process heat generation and in co-generation of power and heat, as well as in solar thermal for lower-temperature industrial processes. The industry sector also provides opportunities for self-generation of power, *e.g.* from solar PV or bioenergy. The share of renewables in the sector could increase to as much as 23% in REmap.



It is important to note that there are multiple routes through which countries can increase renewables in their energy system. More emphasis could be given to one sector over another, for instance the rapid development of renewable power generation capacity and electrification of transport, cooking and heating. Or more emphasis could be put on deploying higher levels of modern, sustainable bioenergy. Also, regional energy trade for bioenergy fuels or electricity could be expanded and result in a shifting landscape of renewable energy deployment. Therefore, there is no single “true” distribution. The REmap insights can inform a discussion about an economically viable pathway, but variations on this pathway are possible.

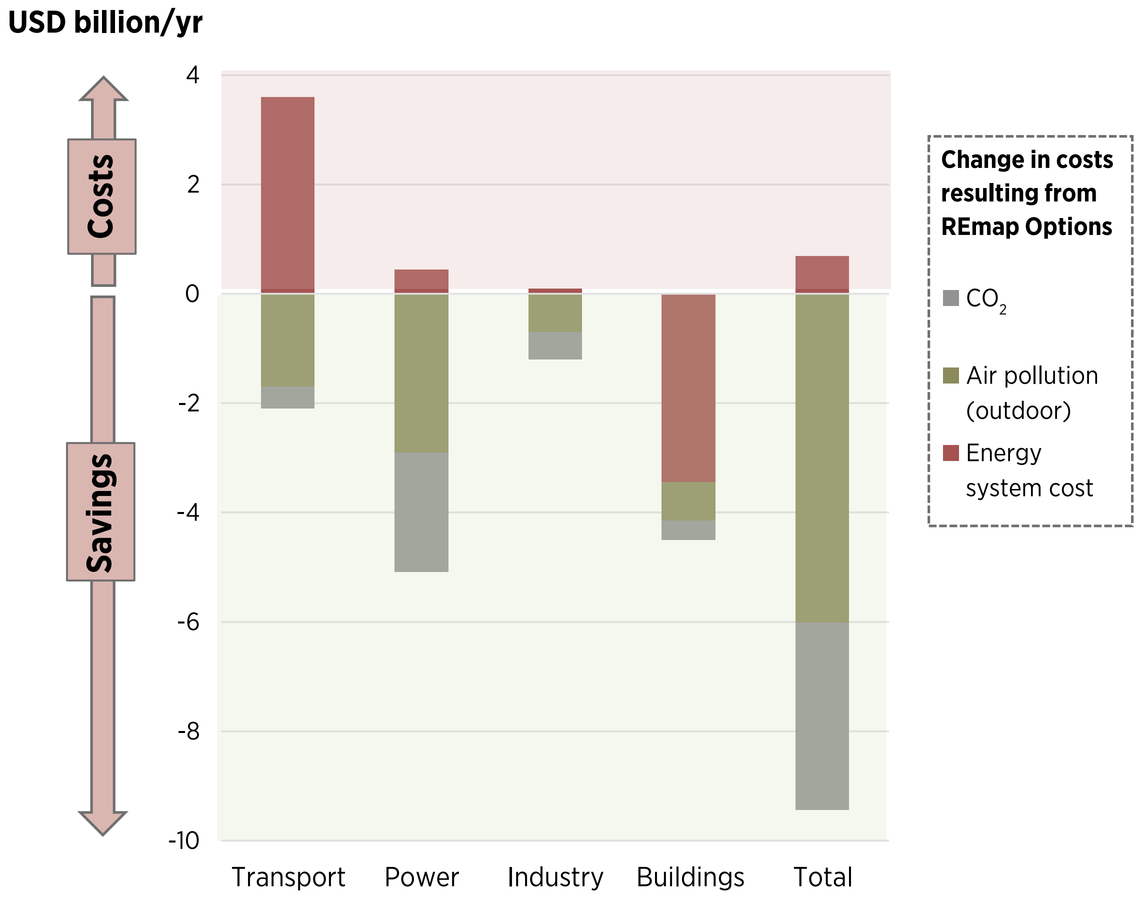
THE COSTS, BENEFITS AND INVESTMENTS NEEDED FOR RENEWABLE ENERGY

The portfolio of renewable options to increase the renewable energy share from the Reference Case level of 17% to ASEAN's 23% target would cost only USD 1.9 per megawatt-hour (MWh) of final renewable energy in 2025 (equal to around USD 0.7 billion in incremental energy system costs, or just 0.02% of annual GDP in 2025). Of all the REmap Options identified, around 60% are cost-effective, and around 40% result in additional costs.

However, benefits significantly exceed costs if reduced externalities are considered. Reduced externalities from lower levels of outdoor air pollution and CO_2 emissions result in savings at least 10 times higher than the incremental cost of the REmap Options. If indoor air pollution is included, savings increase significantly, to as much as 50 times more than costs. These savings are equal to between 0.2% and 1.0% of ASEAN's GDP in 2025, depending on whether indoor air pollution is considered (included in the higher level). These assessments are also only based on the low-end calculations for external cost reductions. If the high end is assumed, savings as a share of GDP could be over 2.0%. The power sector plays the key role in realising these reductions, as do the savings from air pollution and CO_2 emission reductions. The transport sector is also an important source of savings, resulting from lower levels of air pollution in cities.

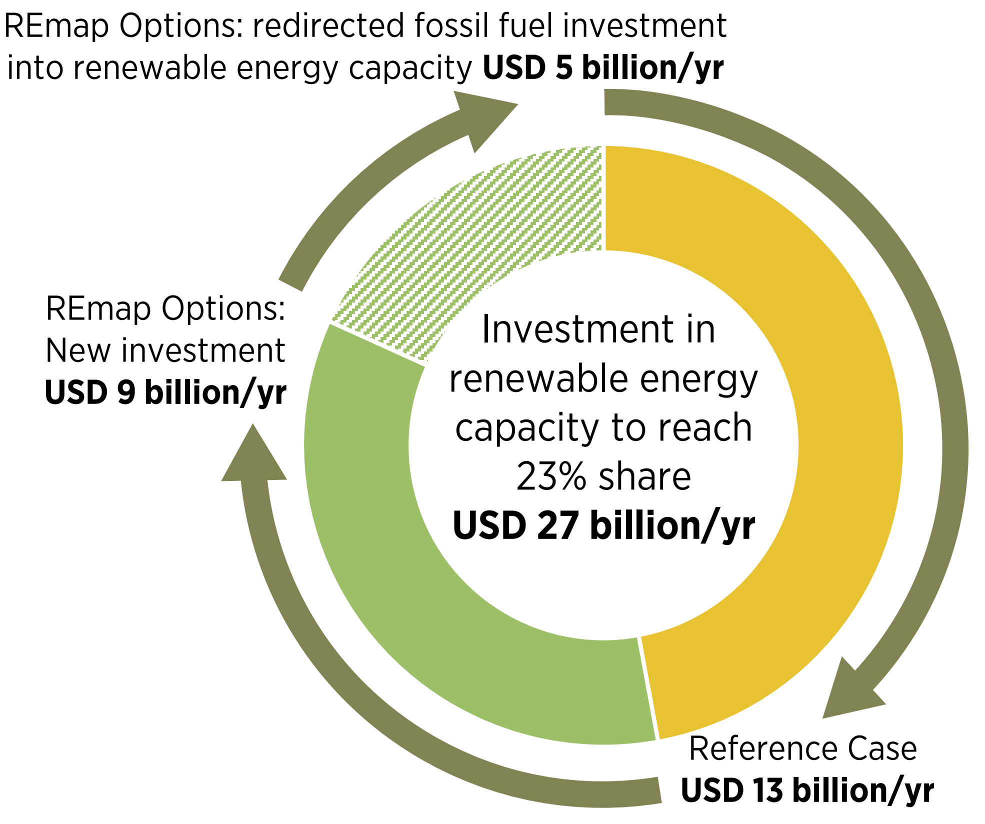
Reduced externalities resulting from higher deployment of renewables can amount to between 0.2-1.0% of GDP – at a minimum at least 10 times higher than costs

Figure ES7: Costs and savings of REmap Options in 2025



Note: Assumes low-end estimates for externalities for outdoor air pollution and CO_2, indoor air pollution excluded from figure.

Figure ES8: Annual investment needs in renewable energy capacity between 2014 and 2025 in the ASEAN region for Reference Case and REmap Options



The region will need to invest USD 290 billion in renewable energy capacity over the next decade

CO_2 emissions from energy will rise by 61% in the Reference Case. The REmap Options and closing the gap to ASEAN's renewable energy target will limit this rise to 47%. Additionally, the energy intensity of the region's economy will decline by around 30% by 2025 in REmap over 2005 levels, broadly in line with the region's targets for energy intensity improvement.

The ASEAN region will need to invest USD 27 billion annually, a total of USD 290 billion by 2025, in renewable energy capacity in order to meet the 23% renewable energy goal. Just under half of this will be investment that takes place in the Reference Case, and the remainder will come from the REmap Options. To close the gap, an additional USD 14 billion annually will be required on top of existing government plans. Of this, USD 5 billion annually can be redirected from investments in fossil fuels, but additional mobilisation of USD 9 billion annually will be needed.

The power sector will account for 75% of the average annual investment need of USD 27 billion. USD 7.5 billion per year will need to be invested in solar PV, and USD 6.3 billion in hydropower. The building and industry sectors will require around USD 7 billion annually in investment, focused largely on bioenergy and solar thermal.

ACTION AREAS FOR ENABLING ASEAN'S RENEWABLE ENERGY POTENTIAL

Accelerating the deployment of renewable energy technologies must take national circumstances into account. There is therefore no single set of solutions suited to the needs of the entire ASEAN region. Suggestions can, however, be grouped broadly into four areas:

1 **Action area 1:** increase power system flexibility in the ASEAN region while using renewables to provide modern energy access for all

2 **Action area 2:** expand efforts for renewable energy uptake for the power sector and for heating, cooking and transport sectors

3 **Action area 3:** create a sustainable, affordable and reliable regional bioenergy market

4 **Action area 4:** address the information challenge by increasing the availability of up-to-date renewable energy data and the sharing of best practice for renewable energy technologies

The full report *Renewable Energy Outlook for ASEAN* provides in-depth findings on technology and country-level deployment potential for renewables. It also sheds some insights into the main drivers, costs and benefits, and investments needs for renewable energy. Please visit *www.irena.org/remap* to download the report.

INTRODUCTION

In October 2015, the Association of Southeast Asian Nations (ASEAN) announced a region-wide aspirational target to achieve 23% renewable energy in total primary energy supply by 2025, a significant increase from just under 10% in 2014. The goal is part of ASEAN's Plan of Action for Energy Cooperation (APAEC) 2016-2025, adopted by its Member States at the 33rd ASEAN Ministers on Energy Meeting (AMEM) in September 2015 in Kuala Lumpur, Malaysia.

The International Renewable Energy Agency (IRENA) and the ASEAN Centre for Energy (ACE) agreed to conduct a study using IRENA's REmap analytical tools, to develop a Renewable Energy Outlook that would build on the 4th ASEAN Energy Outlook (AEO4, released in January 2016) (ACE, 2015). This study is in part supported by the Renewable Energy Support Programme for ASEAN (ASEAN-RESP), a joint project of ACE and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

ASEAN Member States must make an immediate and concerted effort if they are to realise the 23% aspirational target by 2025. The AEO4 study shows that, without additional efforts, the region will only reach a 15.4% renewable energy share. Thus, there is a significant gap to close if the region wants to achieve 23%. This study explores the potential for deploying renewable energy technologies across the entire energy system of ASEAN Member States in pursuit of the 23% renewables share. It also quantifies costs, associated benefits, and some key challenges to ramping up renewables in the region.

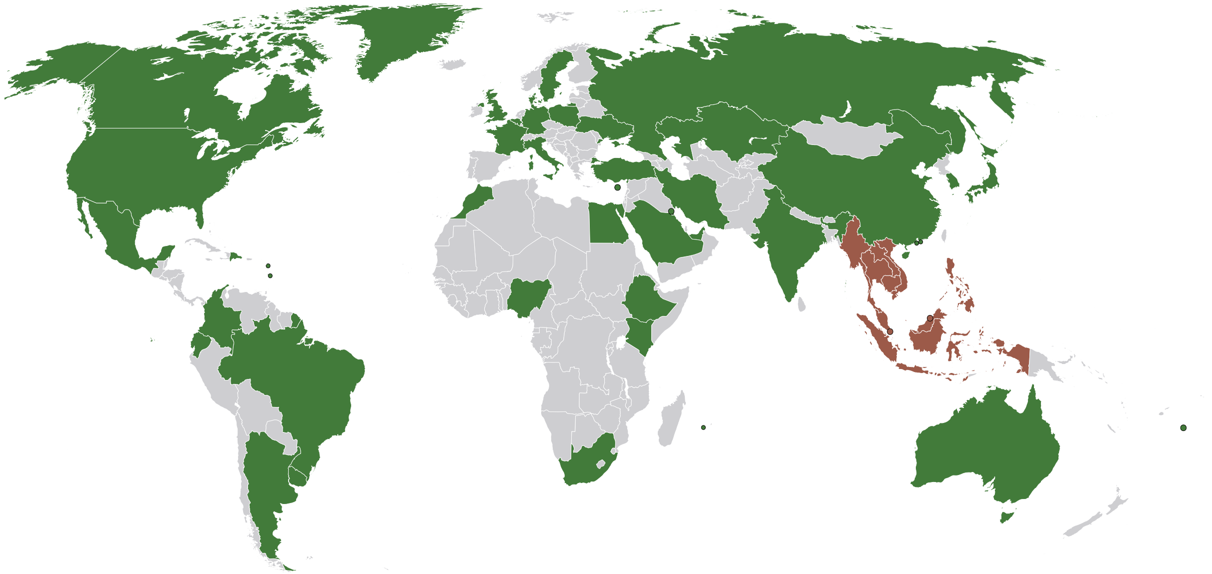
This report was previewed in September 2016 during the 34th ASEAN AMEM meeting held in Nay Pyi Taw, Myanmar. The ASEAN Member States in their Joint Ministerial Statement indicated their encouragement of the findings of the report and called for additional efforts and robust frameworks from all ASEAN Member States towards a timely achievement of the renewable energy target.

THE INTERNATIONAL RENEWABLE ENERGY AGENCY AND REMAP PROGRAMME

IRENA
International Renewable Energy Agency

The IRENA REmap programme shows how it is possible to significantly accelerate the global share of renewable energy by 2030. Such accelerated growth helps fulfil the United Nations (UN) Sustainable Development Goal 7 (SDG on energy), set in its 2030 Agenda for Sustainable Development, to ensure access to affordable, reliable,

Figure 1: Map of countries participating in IRENA's REmap programme and ASEAN regional report



Note: 40 countries participated as of early 2016 (green) including Indonesia and Malaysia, and the 8 remaining ASEAN Member States were added in mid-2016 as part of this study (all ASEAN Member States are marked in red).

sustainable, and modern energy for all. IRENA is also the hub for the renewable energy objective of the Sustainable Energy for All initiative (SEforALL), which aims to double the share of renewables globally by 2030.

REmap is a global study of renewable energy potential built from the bottom up. As of March 2016, it analyses 40 countries[6] that represent over 80% of global energy use, working closely with them to determine the potential of renewables (Figure 1). In addition to the power sector, the report looks at the end-use sectors of agriculture, buildings (residential, commercial, public, and services), industry and transport.

The study shows that when renewables are combined with accelerated improvements in energy efficiency, the world can set itself on a path towards a limited global temperature rise of two degrees Celsius or lower compared to the pre-industrial level. REmap also shows that higher levels of renewables would result in savings up to 15 times higher than costs.

REmap is developed in close cooperation and consultation with government-nominated experts (energy statisticians, energy modellers and energy policy experts). It is an analysis of the potential, costs and savings of renewable energy technology options. REmap provides a perspective on the options available at the sector level that represent the realistic potential of renewables beyond national energy targets and plans up to 2030.

6 These are Argentina, Australia, Belgium, Brazil, Canada, China, Colombia, Cyprus, Denmark, the Dominican Republic, Ecuador, Egypt, Ethiopia, France, Germany, India, Indonesia, Iran, Italy, Japan, Kazakhstan, Kenya, Kuwait, Malaysia, Mexico, Morocco, Nigeria, Poland, the Republic of Korea, the Russian Federation, Saudi Arabia, South Africa, Sweden, Tonga, Turkey, Ukraine, the United Arab Emirates, the United Kingdom, the United States, and Uruguay.

IRENA's approach in REmap follows two parallel tracks: (i) country-based analysis to identify actions on technology deployment, investment and policies in collaboration with REmap countries and regional associations, such as in the case of this study; and (ii) series of technology roadmaps to identify cross-country insights on the actions required to significantly increase the share of renewables in the global energy mix. For regions with rapidly growing energy demand, but which REmap does not yet fully cover with country analyses, REmap also develops regional outlooks, including for Africa (IRENA, 2015a), in addition to the present publication for Southeast Asia.

For more information about the REmap programme, to view a wide and expanding body of studies and reports, learn more about the methodology or assumptions, or view and download data, please visit *www.irena.org/remap.*

ASEAN CENTRE FOR ENERGY

ASEAN Centre for Energy
One Community for Sustainable Energy

Established on 1 January 1999, the ASEAN Centre for Energy (ACE) is an intergovernmental organisation that independently represents the 10 ASEAN Member States' (AMS) interests in the energy sector. The Centre serves as a catalyst for the economic growth and integration of the ASEAN region by initiating and facilitating multilateral collaborations as well as joint and collective activities on energy. It is guided by a Governing Council composed of Senior Officials on Energy from each AMS and a representative from the ASEAN Secretariat as an *ex-officio* member. Hosted by the Ministry of Energy and Mineral Resources of Indonesia, ACE's headquarter is located in Jakarta. For more information, please visit *www.aseanenergy.org*

APPROACH AND COUNTRY STAKEHOLDER ENGAGEMENT

REMAP PROGRAMME

REmap explores renewable energy options for decision makers for consideration in their energy planning and policy making. It uses information from countries' national plans, goals or outlooks to produce a baseline picture of a country's energy system to 2025 for this report, or 2030 and longer for others. This baseline is called the Reference Case.

In addition, it identifies pathways to harness the potential of renewable energy technologies beyond the Reference Case. These are the REmap Options. These options are customised for specific countries and sectors, and aim to close an important knowledge gap by giving policy makers a clearer understanding of the available opportunities for accelerating renewable energy deployment. The REmap Options consider resource availability, access to finance, local expertise and technical human resource needs, manufacturing capacity, policy environment, the age of existing capital stock and the costs of technologies by 2025.

The REmap programme does not set renewable energy targets. The political feasibility and challenges to implementing each option varies in different sectors and countries, depending on their particular circumstances and on the level of commercialisation technologies have reached. Targets are effective starting points, but policy makers need to know more: what is the renewable deployment potential, in which sectors and countries can this be found, and what barriers inhibit realisation of this potential?

REmap's methodology is different from other scenario studies and modelling exercises, as it is based on cooperation and consultation with countries to develop both the Reference Case and the REmap Options. The REmap spreadsheet tool allows the country experts to evaluate and create their own REmap analyses. Using this clear and dynamic accounting framework, they can evaluate and verify Reference Case developments and REmap Options. All results are displayed in a REmap-specific energy balance and an overview of these results on country level are provided in Annex A of this report.

There are multiple routes through which countries can increase renewables in their energy system. For instance, more emphasis

BOX 1: CASE AND TERMINOLOGY OVERVIEW

In this report, the two main energy pathways countries could pursue to 2025 and the gap between these are referred to as:

2014 "base year" – 2014 is the start year because it is the latest for which complete statistical data is available for all countries. ASEAN Member States completed a questionnaire to provide the data. This could mean that it may differ slightly from other sources due to differences in collection methodologies or technology grouping approaches, or if the data was subsequently revised.

The Reference Case – The most likely case based on planned policies and expected market developments for each country's energy sector. This Reference Case is based on energy demand forecasts submitted by ASEAN Member States for this report, or taken from the Advancing Policies Scenario (APS) of the 4th ASEAN Annual Energy Outlook (AEO4). It does not necessarily reflect business as usual, but includes some accelerated commitments relating to renewables and energy efficiency improvement that countries had already made as of early 2016. The Reference Case in this report results in a slightly higher renewable energy share than in the AEO4 APS scenario, because some countries updated their renewable outlooks and other related market conditions.

The REmap Options – The renewable energy technology options for closing the gap between Reference Case developments and the ASEAN aspirational target of a 23% renewable energy share in primary energy supply by 2025. The REmap Options are also often referred to as "the gap" in this report.

REmap – The case in which the REmap Options are assumed to be fully deployed, on top of developments in the Reference Case. The "REmap" case is thus in line with ASEAN's 23% goal.

can be given to increasing renewables in one sector over another, *i.e.* countries can focus on more rapid development of renewable electricity generation capacity and electrification of transport, cooking and heating. Alternatively, more emphasis can be put on deploying higher levels of modern, sustainable bioenergy. Regional energy trade can also be expanded and result in a shifting landscape of renewable energy deployment. Therefore, there is no single "true" distribution of renewables deployment. The REmap insights presented in this report are one possible pathway, developed in collaboration with experts from countries, and they can inform a discussion on meeting the region's renewable energy target. But just how to meet the joint objective is a political decision.

COUNTRY ENGAGEMENT

This study is a collaborative effort, built on IRENA's REmap analytical framework, and done in close collaboration with experts from ASEAN Member States and ACE. ASEAN's Member States include ten countries: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam.

Each country identified experts for a working group to help IRENA develop its REmap analyses over a six month period. The experts shared data, reviewed results and took part in three webinars and two workshops, one in Manila in March 2016 and one in Bangkok in June 2016 (see Annex B). During the workshops, findings were discussed and improved upon, and key drivers and needs for renewables were outlined. Two countries, Indonesia and Malaysia, had already been participating in REmap since 2014, and the remaining eight countries joined in early 2016. The final results of this report were presented during the 34th AMEM meeting in Myanmar in September 2016. Member States indicated their encouragement of the findings of the report and called for additional efforts and robust frameworks from all ASEAN Member States towards a timely achievement of the ASEAN renewable energy target.

This study is based largely on information, data and analysis ASEAN Member States provided during this period. These include government plans and studies, as well as other studies on how the region's energy use is expected to develop. Another important source of information is the AEO4, prepared by ACE and released in 2015 (ACE, 2015). The AEO4 focuses in detail on the energy sector and identifies renewable energy potential, but does not explore the detail a pathway to reaching the regions 23% renewable share target. Therefore, this roadmap serves as an important complement to the AEO4 from a renewable energy perspective. It also updates some data with the most recent information provided by the ASEAN Member States.

THE BASELINE TO 2025 – THE REFERENCE CASE

The starting point for a REmap analysis is the national energy plan or outlook of a country. Each country provides information on expected developments in the energy sector between today and 2025 or expected developments are taken from AEO4. The data provides a breakdown of demand among different energy carriers by sector, *i.e.* electricity generation, residential, commercial, services, transport and industry. In REmap, these sectors are then grouped into four main sectors: electricity generation (also called power sector), industry (including agriculture), transport and buildings (including residential, commercial, services, and public).

In the ASEAN region, the renewable energy share in primary energy supply was 9.4% in 2014 (excluding traditional uses of bioenergy[7]). According to the AEO4 business as usual case (which is a conservative

7 Traditional uses of bioenergy are generally not considered a modern renewable energy source for the purpose of this assessment and the ASEAN aspirational target.

outlook for renewable energy deployment), the share would remain at this level until 2025, estimated to rise to only around 10%. However, according to the outlooks and plans submitted for this report, many of which are in line with the Advancing Policy Scenario (APS) of the AEO4, the Reference Case[8] of this report shows the share could rise to 16.9% by 2025. This increase would result from the inclusion and successful implementation of stronger policies ASEAN Member States have defined in their official targets for increasing renewable energy and reducing energy intensity. It is also slightly higher than the 15.4% share envisioned in the APS. This difference is due in part to rapid developments in the renewable energy sector since the release of the AEO4. For instance, Indonesia, the Philippines and Thailand, all large energy consumers in the region, have set renewable energy targets that are reflected in this analysis. Despite these advances, there remains a gap of six percentage points to reach the 23% renewable energy share by 2025 as depicted in Figure 2.

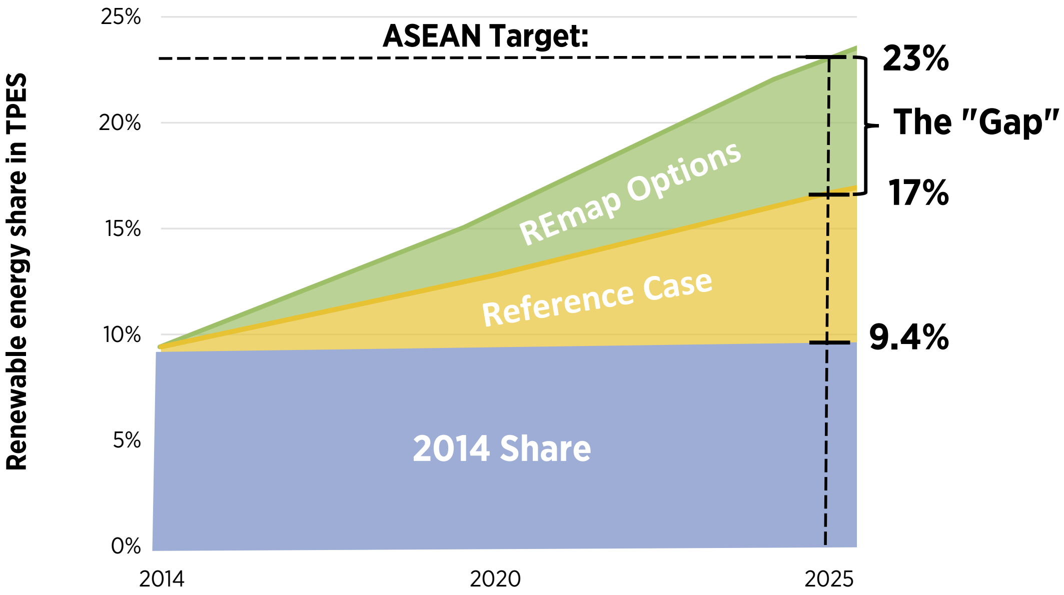
OBJECTIVE OF THIS STUDY: IDENTIFYING RENEWABLE ENERGY TECHNOLOGY OPTIONS TO CLOSE THE GAP

This study identifies renewable energy technology options to reach ASEAN's target of 23% renewables by 2025, above the Reference Case share of just below 17%. These REmap Options aim to close this six-percentage-point gap. They were identified in consultation with country experts, and using literature on accelerated renewable energy deployment scenarios, sectoral or technology-focused IRENA studies and other sources (see Annex C).

8 For the REmap Reference Case national projections were used for most countries. If a projection was not available, then the AEO4 APS scenario was used (see Annex C for an overview of sources).

Each REmap Option is characterised by its cost and benefits. The purpose of the cost-benefit analysis is to assess the cost-competitiveness of renewable energy technologies in several ways. The main method is to look at substitution costs, *i.e.* the attractiveness of renewable energy technologies compared to conventional variants. Benefits are estimated related to emissions of carbon dioxide (CO_2) from fossil fuels as well as indoor and outdoor air pollutants (see section 4 for more information). Investments required to deploy renewable energy capacity are estimated as a separate indicator. IRENA has developed its own methodology to assess these costs (IRENA, 2014a) and benefits (IRENA, 2016f) and more information about these indicators is available in Annex E.

Figure 2: Renewable energy share in ASEAN Member States to 2025 and 2030



BOX 2: OVERVIEW OF TERMINOLOGY: RE SHARE, TPES, TFEC, AND SECTORS GROUPING

This report uses terminology to describe energy demand, and assesses renewable energy shares as defined by the ASEAN target. Different countries use different accounting methods to estimate the renewable energy share in their total energy mix. For example, the UN's Sustainable Energy for All Initiative (SEforALL) uses Total Final Energy Consumption (TFEC). In comparison, other countries and regions, but most importantly ASEAN, use Total Primary Energy Supply (TPES).

Primary energy is, for instance, crude oil and coal before conversion into gasoline and electricity – the "final energy" – that reaches consumers. As useful as this distinction is in revealing system losses for energy sources with fuel (fossil, nuclear and biomass), it is problematic when comparing these sources to wind and solar – which have no fuel, and hence no losses between primary and final energy. When calculating consumption of finite resources, a focus on primary energy consumption makes sense: counting what is taken from nature's limited supply; but for solar and wind, resources are essentially boundless. For these sources, and geothermal and nuclear energy, there are different ways to estimate primary energy, which also results in differences in renewable energy share.

The report uses the following definitions for key indicators:

TPES: Total Primary Energy Supply – The sum of all energy used in a country, including production and imports, but excluding exports and storage changes. To estimate primary energy equivalents for non-fossil fuels or biofuels, the Physical Energy Content Method is used (see page 39 in this REmap report for more information: (IRENA, 2014c).

TFEC: Total Final Energy Consumption – TFEC is the energy delivered to consumers as electricity, heat or fuels that can be used directly as a source of energy. This consumption is usually sub-divided into transport; industry (including agriculture); and buildings (including residential, commercial and public buildings). It excludes non-energy uses of fuels.

Renewable share – Renewable shares are calculated in TPES, TFEC and the end-use sectors listed below. The renewable energy share used for this roadmap includes all renewable energy sources except "traditional" uses of bioenergy. This can be referred to as "modern" renewables. Traditional uses of bioenergy are used in the residential sector, which is often unsustainably harvested fuelwood or bioenergy feedstocks burned in inefficient stoves. This rule is applied unless a country differentiated between traditional and modern bioenergy use in the residential. For energy sources, such as nuclear, solar, wind, geothermal and hydro, the physical energy content method is used to calculate primary energy equivalents.

Definition of energy sectors in REmap: Energy demand is viewed in terms of end-users. This study groups them into three broad sectors: transport, buildings (where residential, commercial and public sectors are combined), and industry. Electricity is consumed in all three, but the power sector is considered separately in the analysis due to its supply characteristics. The energy use of agriculture is also included, but renewable options for the sector are not provided. Forestry and fishing are excluded from this study.

For more information about key terminology and units used in this report, please see Annex E.

ASEAN TO 2025

02

GROWING POPULATION AND PROSPERITY

- **By 2025, the population of the ASEAN region will increase from around 615 million in 2014 to 715 million, and the economy will grow by over 5% annually during the period. The result will be a 4% annual growth in energy demand, amounting to a rise of 50% over 2014.**
- **The region has set a goal of 23% of its energy in TPES to come from modern, sustainable renewable sources by 2025, up from 9.4% in 2014. The expected share by 2025 is just under 17% if current policies and targets are followed. Thus, the region must overcome a six-percentage-point gap to reach its goal.**

The ASEAN population was about 615 million in 2014 (and it is estimated that the population is around 625 million as of mid-2016), representing about 9% of the total global population. It is growing rapidly, and will expand to an estimated 715 million people over the next decade. While population growth rates from country to country are similar, economic activity is a different story.

If ASEAN were a single country, it would be the world's fifth largest economy, after the United States, China, Japan and Germany. The region is one of the fastest growing in the world (together with Africa and South Asia). Its GDP is projected to grow significantly, and by more than most other developing regions in the years to 2025. Countries' own projections show an annual growth rate of 5% across the region, with some differences. For example, some countries in the region will see growth averaging around 3% and others almost 7% per year to 2025 (Table 1).

Per capita energy consumption has been growing in tandem with GDP, but it remains substantially below the global average. Per capita electricity consumption, for instance, is about half the global average and the electrification rate is only 78.7% (AEO, 2015). With a growing population and greater economic prosperity, per capita energy demand is expected to increase rapidly, boosting overall energy demand as the population grows. Government plans of the ten ASEAN Member States anticipate significantly higher energy demand in the region by 2025, around 50% more than in 2014. In turn, ASEAN's share of global energy demand is expected to increase to around 7.5% by 2030 from around 5.7% today.

With higher income, more people living in cities, and more manufacturing and other energy-intensive industries, per capita energy demand will rise significantly. For example, Figure 3 shows how per capita electricity consumption rises with urbanisation. As a result, total power generation will need to double over the next 10 years.

Supplying this growing demand for energy affordably and sustainably will become a top priority. ASEAN's aim of a 23% renewable energy share by 2025 will enable the region to make better use of

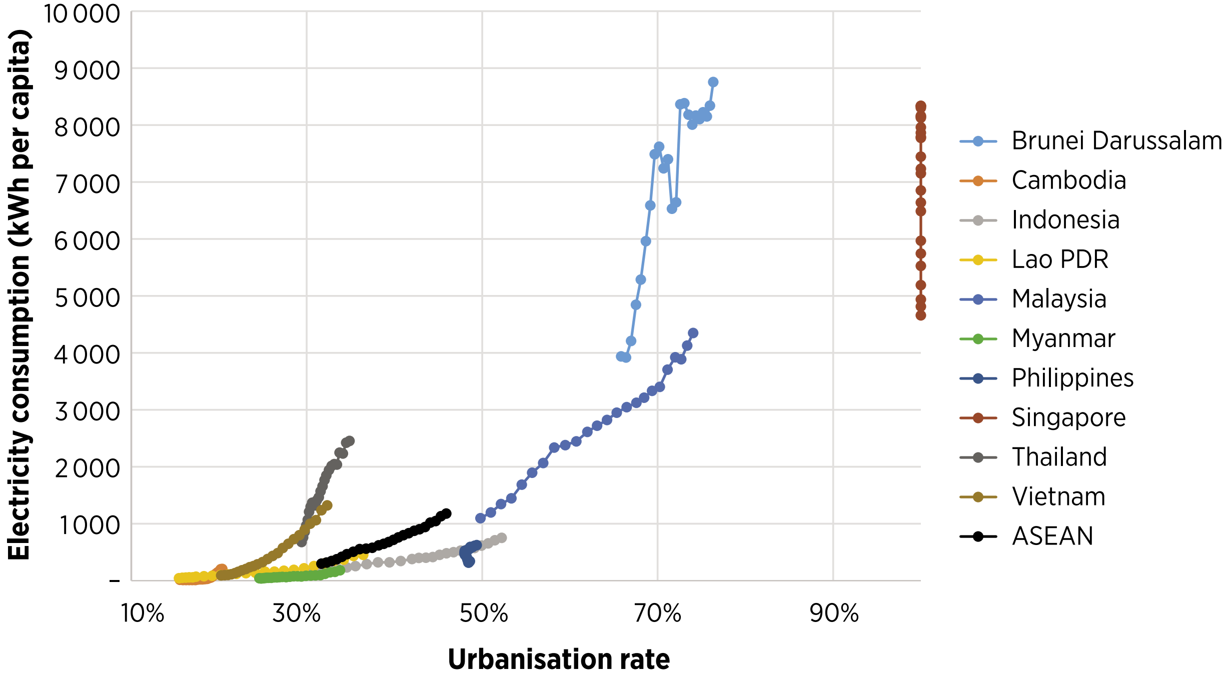
Table 1: Population and GDP growth in ASEAN Member States, 2014 and 2025

	Population				GDP			
	2014	2025	CAGR (2014-2025)	CAGR (1990-2013)	2014	2025	CAGR (2014-2025)	CAGR (1990-2013)
	(Mln.)	(Mln.)	(%)	(%)	(Bln. USD 2014)	(Bln. USD 2014)	(%)	(%)
Brunei Darussalam	0.4	0.5	1.6	2.1	14	26	5.9	1.2
Cambodia	15	21	2.7	2.3	15	25	4.7	7.8
Indonesia	250	276	0.9	1.5	868	1661	6.1	5.4
Lao PDR	6	7	1.5	2.1	8	14	4.7	7.4
Malaysia	31	34	0.9	2.2	313	428	2.9	4.7
Myanmar	53	64	1.7	1.0	60	100	4.7	9.5
Philippines	100	119	1.6	2.0	272	550	6.6	5.0
Singapore	5	6	1.3	2.5	297	398	2.7	5.4
Thailand	65	79	1.7	0.7	387	577	3.7	4.0
Vietnam	90	109	1.7	1.3	171	255	3.7	6.4
ASEAN	**615**	**715**	**1.4**	**1.5**	**2405**	**4034**	**4.8**	**5.2**

Note: CAGR – Compound Annual Growth Rate
Source: IRENA analysis based on country submissions for future years, historical based on ACE (2015) or ASEAN ACE (n.d.)

its indigenous – and significant – renewable resources and ensure a more sustainable supply of energy in each country. Achieving this goal requires a regional approach, and cannot be done by individual countries acting alone. It is therefore of paramount importance to understand what this target means for each country and to identify national contributions while also keeping in mind the regional efforts that are required. This study focuses on doing this with a main aim of identifying key technologies.

Figure 3: Relation between urbanisation rate and electricity consumption, 1990-2013



Note: First country data point is 1990 and the last is 2013

Source: ACE (2015)

RAPIDLY GROWING ENERGY DEMAND

- **The region will see 4% annual growth in energy demand until 2025, amounting to a rise of 50% over 2014 levels. The share of worldwide energy consumed in the region will increase from 5.7% today to 7.5% over the period.**
- **Energy demand for electricity production will rise at the fastest pace, but energy demand in industry and transport will also increase rapidly. According to the Reference Case, most demand will be met with fossil fuels, but it also foresees significant growth in hydropower, geothermal power, and some forms of modern bioenergy for heating and cooking.**

The challenge is how to supply the growing demand for energy while at the same time enhancing energy security. Indigenous fossil fuel resources are unevenly distributed across the region. But all countries have one thing in common: a large availability of many types of renewable energy resources. Increasing the use of these resources will help to meet the region's rising energy demand and reduce the growth in fossil fuel use. That will improve the security of supply and reduce associated hazards to human health, environment and the climate. Assessments at the country, sector and technology levels show how renewables can fulfil this role.

Table 2: Total primary energy supply by country, 2014 and Reference Case 2025

	Total primary energy supply			
	2014	Reference Case 2025	Share in 2025 of ASEAN energy demand	Compound Annual Growth Rate (2014-2025)
	(Mtoe/yr)	(Mtoe/yr)	(%)	(%/yr)
Brunei Darussalam	3.2	4.0	0.4	2
Cambodia	6.0	8.8	1	4
Indonesia	233.6	397.1	42	5
Lao PDR	3.1	14.1	1	15
Malaysia	86.4	96.8	10	1
Myanmar	17.0	20.9	2	2
Philippines	47.7	73.3	8	4
Singapore	36.4	38.9	4	1
Thailand	136.8	147.4	15	1
Vietnam	72.1	154.4	16	7
ASEAN	**642**	**956**		4

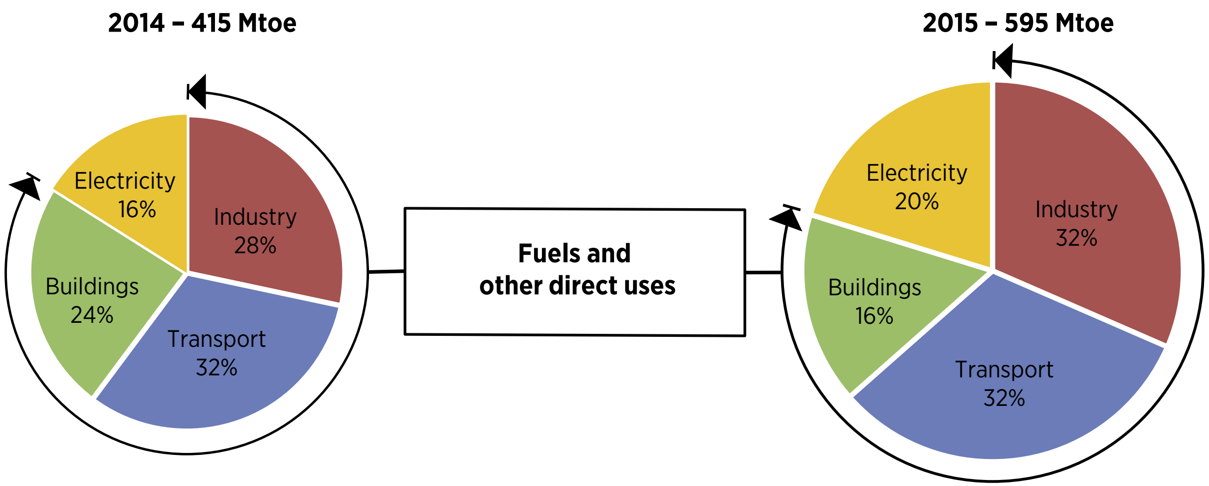
Note: The compound annual growth rate in Lao PDR is very large in part due to significant growth in electricity production from hydropower intended for export. In 2014, 73% of electricity in the country was exported.

TPES in the region was 642 million tonnes of oil equivalent (Mtoe) in 2014. According to the Reference Case, this will increase to 956 Mtoe by 2025, a rise of just under 50% (Table 2). Indonesia will continue to make up the largest share of the region's energy use, estimated at over 40% by 2025.

TFEC is expected to increase from 415 Mtoe in 2014 to 595 Mtoe by 2025, a rise of around 43% (Figure 4). This growth in final energy demand will be slightly lower than that in TPES. Growth in demand for energy will be driven largely by the electricity and industry sectors. The region is becoming more industrialised, raising demand for electricity and fuels for industrial processes. Electricity is in high demand across all sectors of the ASEAN economy. According to the Reference Case, low-efficiency, fossil fuel-based thermal power plants along with large hydropower dams will play the main role in meeting this growth in electricity demand in many countries.

Energy demand for producing electricity will increase 95% by 2025, and for industry by 63%. Demand for energy in transport will also grow, but its share in the total mix will remain the same and will be identical with that of industry in 2025. Figure 4 shows how fuel demand in the end-use sectors of industry, transport and buildings will account for 80% of TFEC. This means that using renewable energy to also help meet this increasing energy needs for these sectors, *i.e.* for heat, cooking, and in fuels for transport will very important.

Figure 4: Total final energy consumption by sector, 2014 and Reference Case 2025



At country level, the growth in energy demand and by sector varies (Figure 5). Countries with the lowest per capita income will see some of the largest growth over the period. Energy demand in Lao PDR will grow by an astounding 200% across most sectors, however much of the increase in the power sector is electricity intended for export. Other countries, such as Cambodia, Myanmar, Vietnam, demand will grow by 150-200%. Indonesia, the Philippines and Vietnam will all experience significant growth in energy demand in industry, buildings and transport. Some countries with higher per capita income and energy demand levels will see their energy demand grow as well, but by less than these high-growth countries.

Breaking growth down by sector shows how different renewable energy technologies and related infrastructure are required for each. The transport sector has traditionally required refined fuels, while the power sector has used expansive and expensive transmission and distribution networks. Industry requires various temperatures of heat, from as low as 150 degrees Celsius to as high as 1000 degrees Celsius or more. Solutions to meet these needs are equally complex.

In the Reference Case, growing energy demand is mostly met with fossil fuels. As Figure 6 shows, demand for coal will rise by 128 Mtoe to become the largest fuel source in 2025. Oil use will increase significantly, by 59 Mtoe, to become the second largest source, and natural gas will become the third largest, growing by 67 Mtoe. Compared to 2014, growth in the use of fossil fuels by 2025 will range from 31% for oil, with the majority still used in transport; 90% for coal, driven largely by

Figure 5: Increase in energy demand by 2025 over 2014 levels

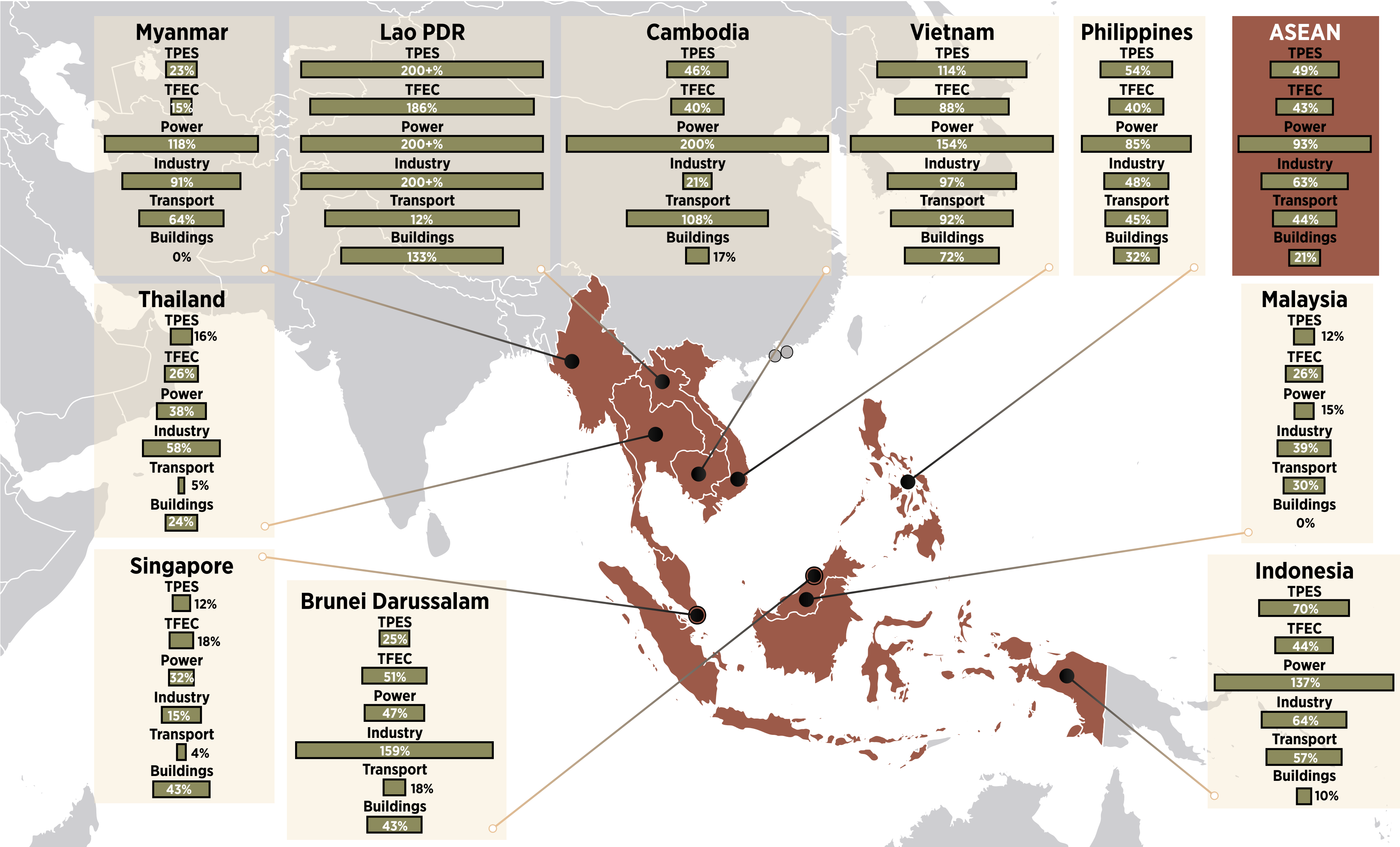
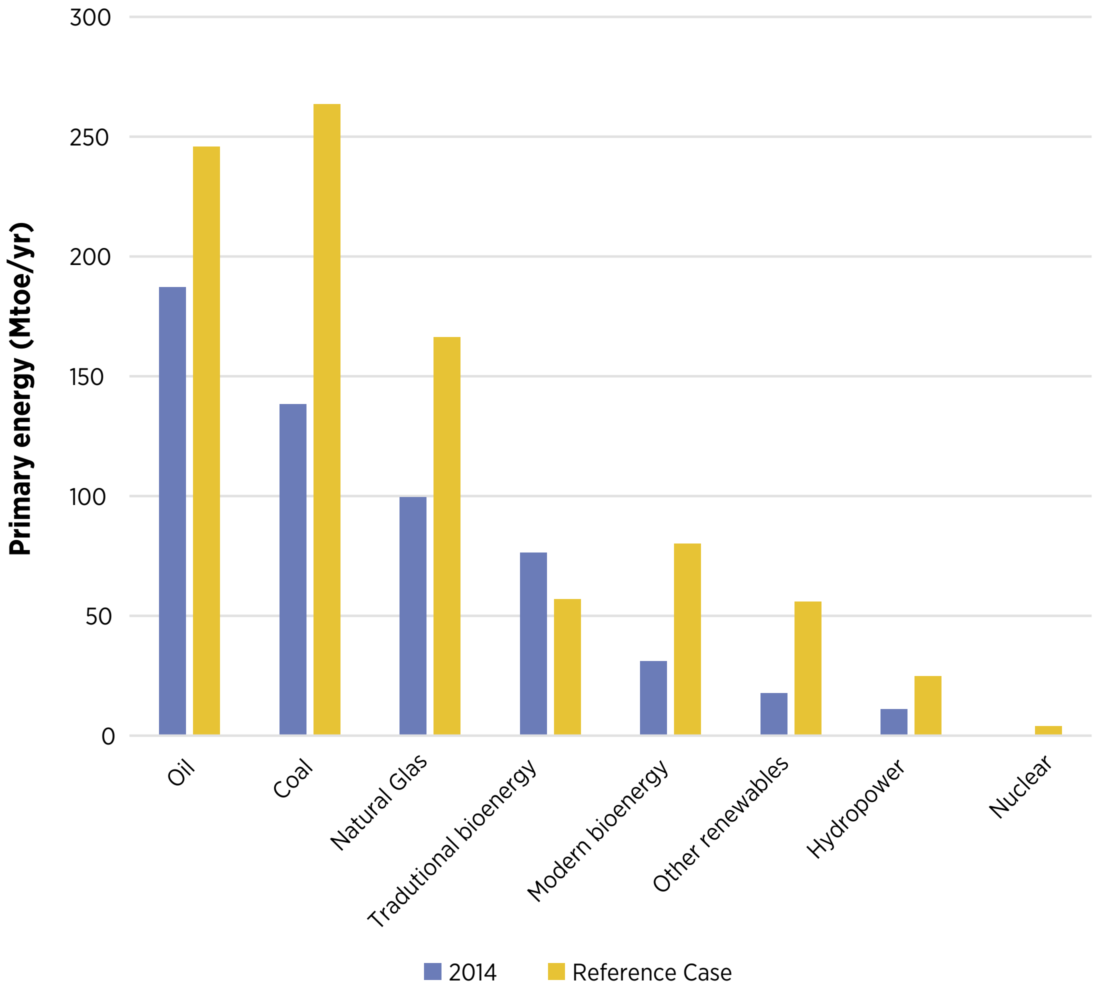


Figure 6: Primary energy demand by fuel or source, 2014 and Reference Case in 2025



power generation; and 65% for natural gas, which has mixed uses. With the exception of coal, the region has limited indigenous oil and natural gas supplies (Brunei Darussalam and Indonesia excluded) to meet this rising demand. An increasing share will have to be met with imports (ACE, 2015).

Among renewables, modern bioenergy will also grow in the Reference Case, increasing by around 50 Mtoe for both solid and liquid and gaseous forms. This is used largely for transport fuels or in cooking and heating applications. Modern bioenergy will overtake traditional bioenergy as the largest renewable energy source. Traditional uses of bioenergy will decline by around 25%, replaced largely by either liquefied petroleum gas (LPG) or modern biofuels, but will still remain substantial. Hydropower will increase by over 100%. As a group, solar thermal, solar PV, geothermal and wind will also grow by around 200% though in the Reference Case only make up a limited amount of primary energy.

Electricity demand will increase over the period significantly. Most of this increase is supplied by coal (42% of total generation), natural gas (23%) or large hydro (20%). The remaining 15% comes from a mix of renewable sources, including geothermal (5%), bioenergy (4%), wind (3%) solar PV (2%) and small hydro (1%).

How the sectors meet this rising demand for energy differs. While the transport sector will meet most of the increase with oil, industry will meet it with coal and natural gas. The building sector will meet greater demand largely with oil products or electricity. In fact, around 60% of the increase in demand for electricity will be in the building sector, with the remainder from industry.

ISSUES RELATED TO GROWING ENERGY DEMAND

- **The region has insufficient indigenous fossil fuel resources to meet its growing energy demand, and the share of imported fossil fuel will increase, which has important energy security implications. Rising fossil fuel demand will mean both air pollution levels and CO_2 emissions will grow significantly.**
- **In the Reference Case, CO_2 emissions from energy use will increase by 61% – one of the highest growth rates worldwide. Total energy-related CO_2 emissions will be around 2.2 gigatonnes (Gt) annually by 2025, or just above 5% of total global CO_2 emissions.**
- **External costs related to air pollution from the combustion of fossil fuels will increase by 35% from an average of USD 167 billion annually in 2014, to an average of USD 225 billion annually by 2025. This would equal around 5% of ASEAN's GDP in 2025.**

ENERGY SECURITY

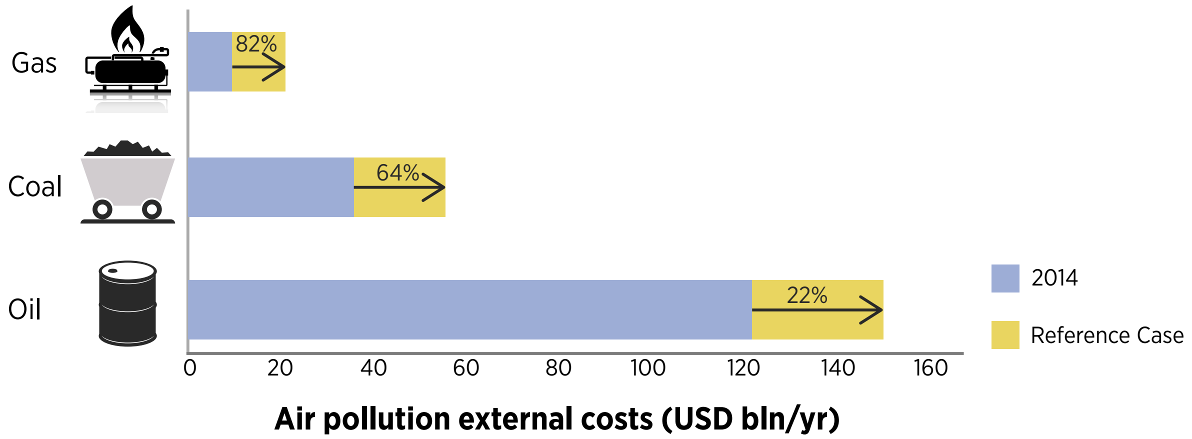
Fossil fuels will make up the largest share of the increase in ASEAN's energy demand by 2025. This means energy security will remain a major concern across the region, as mentioned in most countries' energy plans. All countries have emphasised the importance of diversifying their energy mix, ensuring the sustainability and diversity of imports, and findings ways to meet the rising demand with indigenous resources. Recent analysis shows the depletion of natural gas reserves between 2025 and 2035 in the APS scenario of the AEO4 (which is largely consistent with this study's Reference Case) (ACE, 2015). Accordingly, it is expected between 2020 and 2030 that the region will become a net gas importer. Even the large coal reserves in some countries will be reduced by around 60% (ACE, 2015). In this context, renewable energy is a way to increase the region's energy security through greater diversification of the energy mix and by reducing demand for fossil fuel imports.

AIR POLLUTION

Air pollution from energy production is a growing problem in Southeast Asia. The largest contributors to outdoor air pollution are generally the power and industry sectors, particularly when coal is used to make electricity, and the transport sector, especially in urban areas. High levels of indoor air pollution are also a concern in some countries, typically in rural areas, where people use traditional bioenergy. According to the International Energy Agency (IEA, 2016), 276 million people in the ASEAN region – more than a third of ASEAN's population – still rely on traditional bioenergy. Since air pollution affects most urban areas, and the ASEAN region is experiencing growing urbanisation with more and more megacities, the costs associated with health resulting from air pollution will rise considerably. It is estimated that exposure to outdoor air pollution in Southeast Asia resulted in 200 000 deaths and an associated cost of USD 280 billion in 2010 (OECD, 2014). In 2015, the number of premature deaths in Indonesia alone was estimated at 70 000 from outdoor pollution and 140 000 from indoor air pollution (IEA, 2016).

REmap has also done a separate assessment looking only into the associated external cost of air pollution, resulting in a similarly high

Figure 7: External costs associated with air pollution by energy carrier in ASEAN



number with an average[6] of USD 167 billion in 2014. In the Reference Case, external costs related to air pollution from the combustion of fossil fuels across the region will increase by 35% to an average of USD 225 billion annually by 2025 as shown in Figure 7.

REmap assesses the external costs of exposure to pollutants from fuel combustion, including health effects from outdoor exposure, those from indoor exposure due to traditional use of bioenergy, and effects on agricultural yields (IRENA, 2016f). The largest source of damages is oil use, with 80% of its associated damage coming from the transport sector. Although oil demand in the sector will increase by around 60% by 2025, the rise in related external costs will be lower, at 22%. This is due in part to improved tailpipe emission control and cleaner engines, and the fact that the vehicle stock will generally be more modern and efficient. However, oil will remain by far the largest contributor to ill health, and policy makers will need to find solutions to address this, particularly in large cities.

The external costs of burning coal in 2014 were split equally between electricity generation and industry, with associated external costs rising 64% by 2025. Natural gas will also grow strongly but it is a fairly clean fuel and has lower external costs relative to other fossil fuels.

Bioenergy presents a complex case. Air pollution and related costs from the combustion of modern bioenergy are expected to increase in the Reference Case, but associated external costs will be low. Associated costs for traditional uses of bioenergy will decrease by around 35%, as these are replaced with modern fuels, such as LPG, kerosene or modern bioenergy. Traditional forms of bioenergy are those that are unsustainable or combusted inefficiently in the residential sector and largely used in cooking. This causes high levels of indoor air pollution which have high associated damage to human health.

CO_2 EMISSIONS

CO_2 is the largest source of global greenhouse gas (GHG) emissions, and the energy sector is responsible for most of these emissions. But this is not the case in some ASEAN Member States, where forestry and agriculture are major sources of emissions. For instance, in Indonesia, land-use changes and deforestation make up the largest share of GHG emissions. This roadmap does not include these sources, and only energy-related CO_2 emissions are calculated.

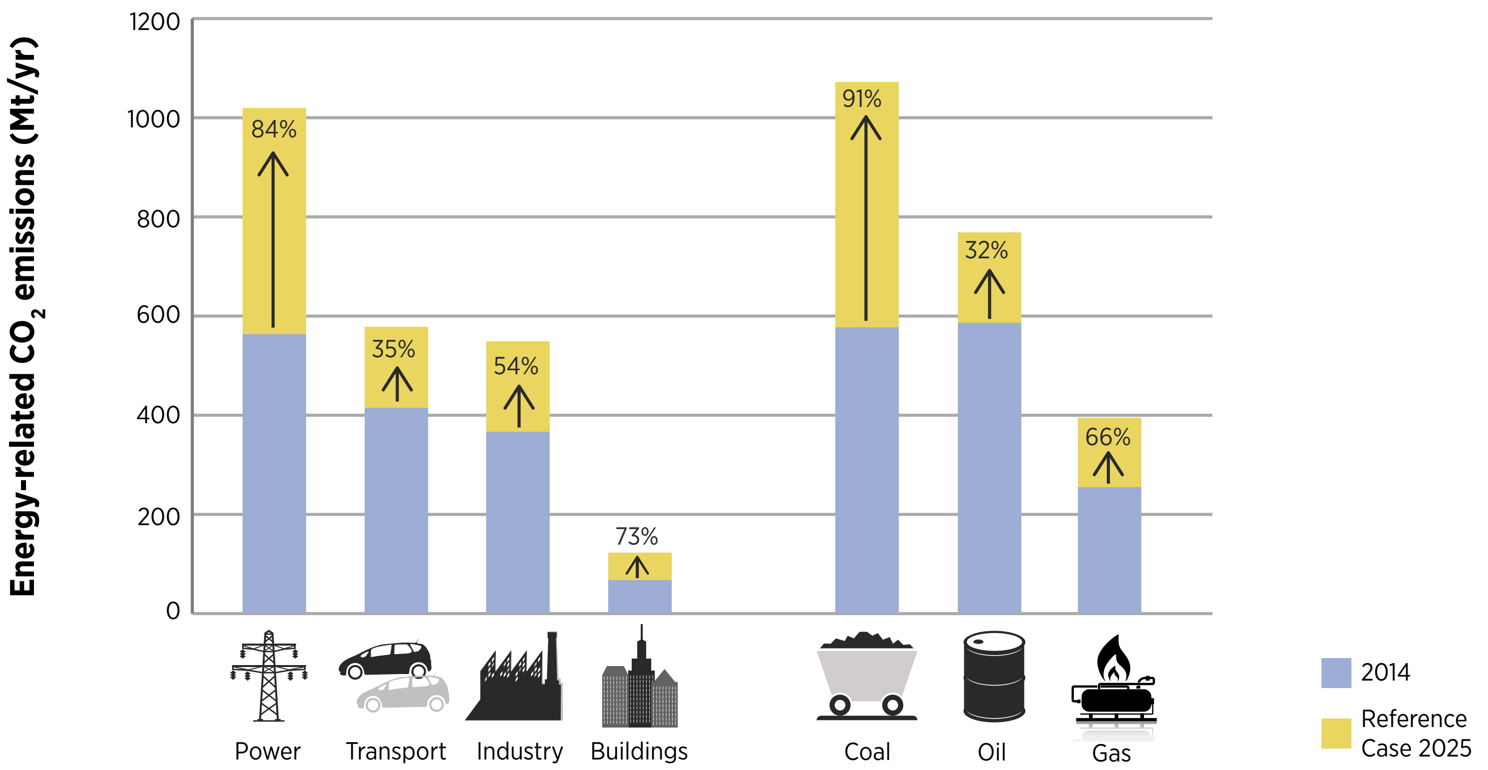
In the Reference Case, CO_2 emissions from energy will rise by 61% in the ASEAN region by 2025 – among the fastest growth worldwide. The primary driver will be coal-fired electricity production. CO_2 emissions

6 The REmap external cost assessment provides a low and high range; this number is presented as the average of the two.

used to generate power will increase 84% over the period to 1 Gt per year, much of this increase coming from coal. The industry and transport sectors will see a similar rise in emissions. Taken together, these two sectors' emissions will be as high as in the power sector.

Emissions from coal across different applications will increase by the most, at 91%, to over 1 Gt per year by 2025. Combustion of oil products will be the second largest source of CO_2 emissions, while natural gas will be the lowest, although natural gas consumption levels will be about the same as oil. Energy-related CO_2 emissions across the region will total approximately 2.2 Gt annually by 2025, or around 5% of expected global energy-related emissions in that year.

Figure 8: ASEAN's energy-related CO_2 emissions by sector and fuel, 2014 and Reference Case



DRIVERS FOR RENEWABLES

INCREASING COST-COMPETITIVENESS

- **This study shows that by 2025 in the ASEAN region the average cost of renewable power technologies will make it possible to supply electricity at or below the cost of generation from new, non-renewable energy sources.**
- **The region's ample renewable energy resources can provide opportunities for the cost-effective deployment of renewable energy technologies for heating and cooking, with large potential for solar thermal and modern bioenergy.**

Renewables are increasingly the least-cost option for electricity production, a trend that will accelerate over the coming decade (IRENA, 2015b, 2016d). Renewable energy is also competitive with some heating technologies. Figure 9 shows how various technologies compare in terms of levelised cost of electricity (LCOE) and heat (LCOH) for the year 2025 based on country and IRENA estimates.

By 2025 renewable power technologies in ASEAN will fall within the cost range of conventional generation or slightly below. Coal power generation will range from USD 60 to USD 100 per megawatt-hour (MWh) by 2025, based on assumptions for its price development (see Annex D). Hydropower (which grows significantly in the Reference Case and therefore is not assessed as having additional potential in REmap), geothermal and bioenergy (including waste) have low estimated LCOE, of between USD 40 and USD 60 per MWh. However, their deployment is limited to regions where resources are available, *e.g.* geothermal in Indonesia and the Philippines. The fastest deployment in capacity growth will occur in solar PV and wind, both of which have average costs of around USD 80 per MWh across the region, but could see costs as low as USD 40 per MWh for solar PV and USD 60 per MWh for wind.

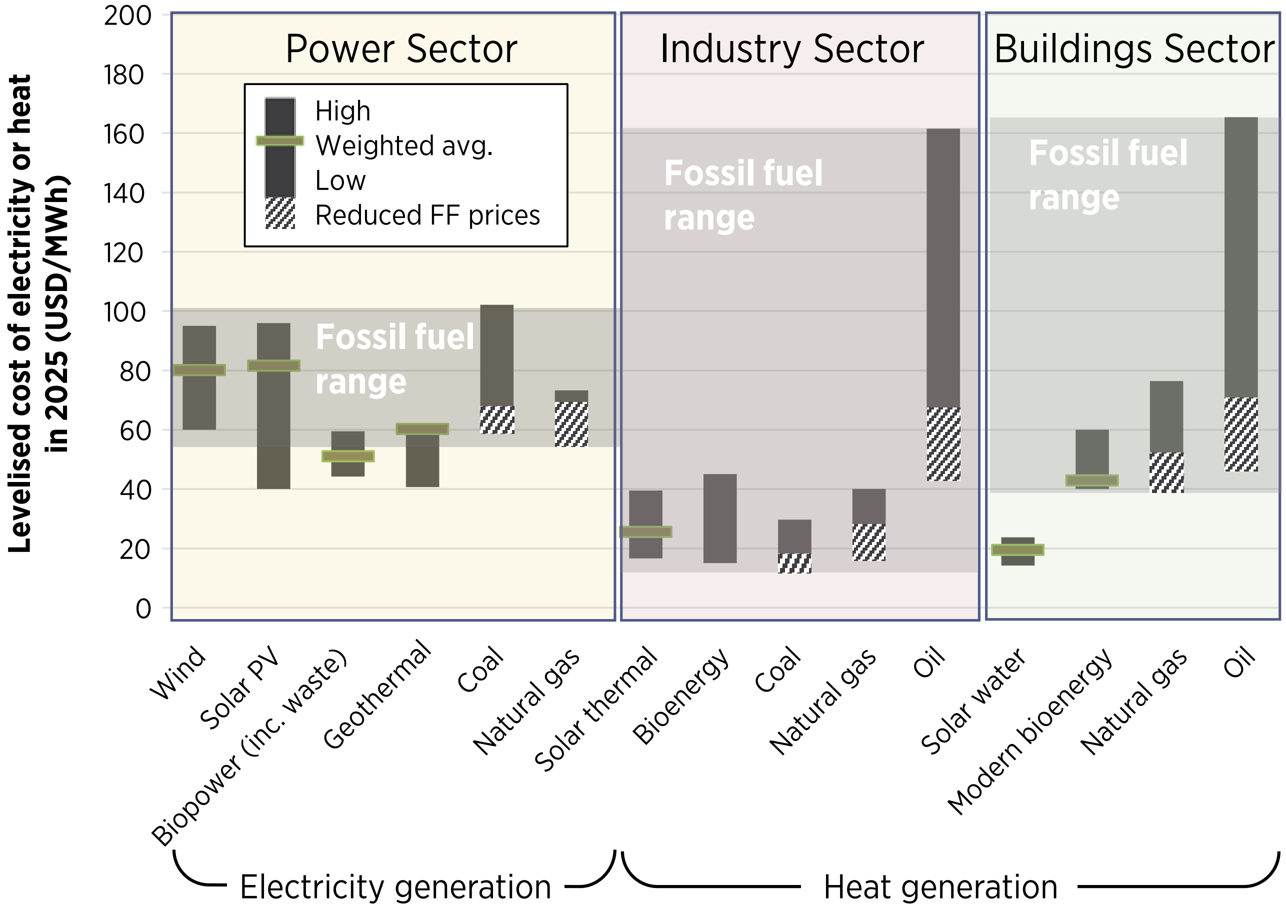
It is not just power technologies that compete well on a cost basis. Industry largely uses coal or natural gas to deliver process heat, typically costing between USD 18 and USD 40 per MWh. The most common renewable energy alternative to fossil fuels in industry is biomass and waste. Depending on availability, biomass residues can generate process heat cost-competitively at around USD 17-42 per MWh. Likewise, solar thermal heating technology for low-temperature applications (such as in food processing) can be cost-competitive in the regions and applications where they can be deployed.

There is also a strong case for renewables in buildings. Many countries in the region have, or plan to develop, infrastructure for natural gas or liquefied petroleum gas (LPG) for residential and commercial uses. Where those fuels are used to heat water, solar thermal is by far the most affordable technology. Heat can be produced at around USD 18-22 per MWh. Bioenergy-based feedstocks, when combusted efficiently, can provide heat for cooking at a cost below that of natural gas or LPG. This is especially true for residues but also for biogas digested from food or animal waste.

ABUNDANT RENEWABLE RESOURCE AVAILABILITY

The ASEAN region has abundant renewable energy resources. It also has some of the best untapped hydropower potential in the world, in countries such as Myanmar and Lao PDR. This is, however, already

Figure 9: Levelised cost of electricity or heat, by technology, ASEAN, in 2025



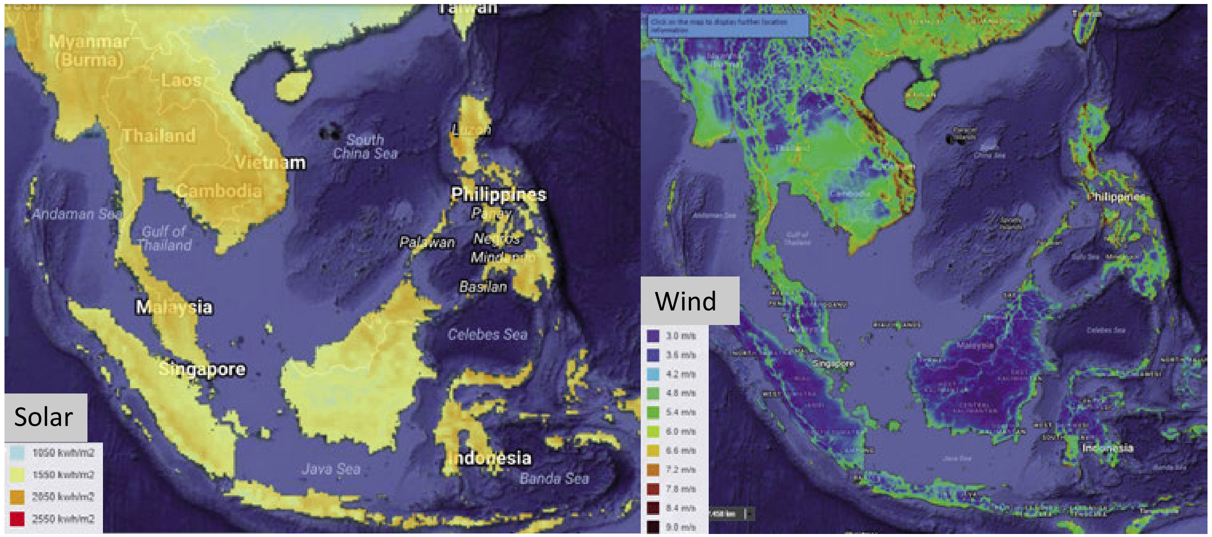
Source: IRENA analysis and forecasts based on IRENA (2015b, 2016a, 2016d)

Note: Reduced fossil fuel prices (hatched area below fossil fuel bars) assume lower average commodity prices for fossil fuels in 2025 for coal (-10%), natural gas (-20%) and oil (-30%) compared to the standard assumptions contained in Annex D.

reflected in their national energy plans. But there are also other renewable resources with significant potential. Solar irradiance – power from the sun – in the region is very strong, averaging over 1 500-2 000 kWh per square meter annually, which allows for capacity factors of 20% and above (Figure 10). Wind resources are more modest, but there are regions along the coasts and inland in Vietnam, Thailand, Indonesia and Myanmar where speeds average between six and seven metres per second, enabling capacity factors well into the high 30s or beyond.

Some countries, namely Indonesia and the Philippines, have significant geothermal potential – some of the best in the world. Finally, bioenergy supply potential is very large across the entire region, with supply estimates on the high end that are almost double expected demand by 2025 (see Chapter 3 Bioenergy for more information).

Figure 10: Solar and wind resource map from IRENA's Global Atlas, ASEAN region



Source: Solar map (left): © METEOTEST; based on www.meteonorm.com, extracted from IRENA Global Atlas www.irena.org/GlobalAtlas. Wind map (right): © VAISALA Global Wind Dataset 5km onshore wind speed at 80m height, extracted from IRENA Global Atlas www.irena.org/GlobalAtlas

SOCIO-ECONOMIC BENEFITS

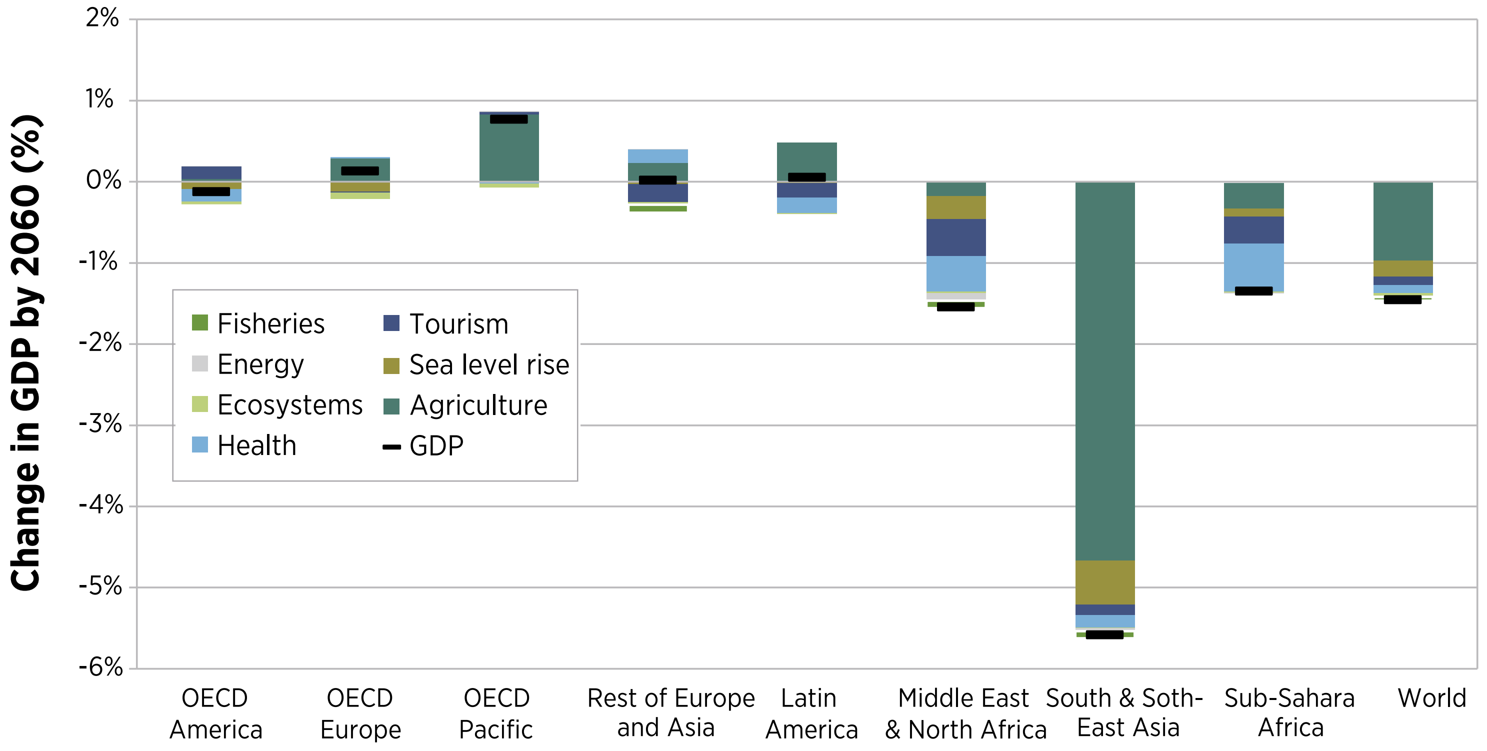
Many developing regions would benefit from pursuing green growth. ASEAN Member States are no exception. The region is highly vulnerable to climate change, posing a particular threat to farmers and coastal communities. People living in cities are also adversely affected, particularly by air pollution, with hundreds of thousands dying prematurely each year, costing well into the hundreds of billions of dollars (WHO, 2016).

For example, Figure 11 quantifies how climate change could impact different regions around the world by 2060. The striking finding is that Southeast Asia (which in the analysis includes India and other developing countries in the region) is by far the region most negatively impacted by a changing climate. According to the analysis, GDP could be more than 5% lower by 2060 if the region follows a high carbon baseline compared to a more sustainable, low carbon path (OECD, 2014). This large decline is because the region is still very dependent on the agricultural sector, where a predictable climate and stable weather conditions are essential for sustaining yields. In addition, the adverse effects of rising sea levels are also some of the largest anywhere in the world, due to the many coastal communities and islands in the region.

On a global scale, analysis from IRENA shows a positive correlation between higher levels of renewable energy and economic growth. In its report, *Renewable Energy Benefits: Measuring the Economics* (IRENA, 2016c), IRENA assessed the effect of two cases: a Reference Case

2030 and the REmap 2030 case (based on country results from the 2014 global edition of the REmap report (IRENA, 2014c)). In Indonesia (one of only two ASEAN Member States that were part of the REmap analysis in 2014), the study shows that GDP would be 0.2%-1.3% higher in the REmap case than in the Reference Case. Additionally, there would be between 0.3 million and 1.1 million more jobs.

Figure 11: Expected change in GDP due to climate change by 2060



Source: OECD (2014)

Note: „South and Southeast Asia" includes ASEAN Member States plus India and other developing Asian countries. In the Organisation for Economic Co-operation and Development (OECD) report the severity of climate change by 2060 is defined as a degree pathway of 4.5-6 °C.

RENEWABLE ENERGY PROSPECTS IN ASEAN

03

ROLE OF RENEWABLES TO 2025

The ASEAN region is growing across the board. By 2025 its population will increase 16%, while GDP will increase almost 70%. Primary energy demand will see similar growth, increasing almost 50% over the period. The region has a golden opportunity to leapfrog the polluting, resource-inefficient, dirty technologies of the past and develop a modern, clean and smart energy system of the future. There are three main routes ASEAN could follow:

i) A **business as usual** route, which takes into account no further policy commitments and a heavy reliance on fossil fuels (consistent with the BAU scenario in the AEO4). In this case the renewable energy share in 2025 remains at the 2014 level of around 10%.

ii) The **Reference Case** from this roadmap, based on planned policies and expected market developments for the energy sector. The Reference Case is based on plans submitted by ASEAN Member States, or taken from the APS scenario of the ASEAN AEO4. The Reference Case does not reflect business as usual, rather already some accelerated commitments of countries as of 2015, and as a result the share of renewable energy in primary energy increases to 17%.

iii) The **REmap** case, in which the REmap Options – the technologies necessary to close the gap between the Reference Case renewable energy share and the ASEAN aspirational target of a 23% share – are assumed to be fully deployed on top of developments in the Reference Case. The REmap case is in line with ASEAN's goal of a 23% renewables share by 2025.

This section will outline the REmap case, which is based on the accelerated renewable energy potential of the REmap Options. It will describe what is needed at the sector and technology levels to achieve higher renewable energy deployment.

DEVELOPMENTS FOR RENEWABLES IN THE REFERENCE AND REMAP CASES

- **The share of modern renewable energy in TPES was just under 10% in 2014. In the Reference Case, the share will increase to just under 17% by 2025. An additional six percentage points must be gained to reach the ASEAN goal of 23%.**
- **By 2025 in the Reference Case, renewable electricity will make up half the renewable energy consumed. In REmap, this will be reduced to 44% as direct-uses of renewable energy for heating, cooking and transport take on an important role in closing the gap to the ASEAN target.**

ASEAN Member States are expected to experience some of the fastest energy demand growth worldwide over the next 10 years, especially in electricity. By 2025 primary energy demand is expected to increase almost 50%. Under the Reference Case this increase in energy demand is driven largely by expanding demand for electricity (for use in the buildings and industry sectors) and for fuels in industry. The largest increases in supply to meet this rapidly growing demand come from coal and natural gas. However, renewables also grow, with higher levels of modern bioenergy and significantly more renewable power (based largely on large hydropower). The result is that the renewable energy share (excluding traditional uses of bioenergy) in primary energy will increase from 9.4% in 2014 to 16.9% in the Reference Case in 2025 (Figure 12).

REmap takes these developments in the Reference Case and explores the potential to increase renewable energy use even further across all energy sectors in each country. An analysis for each country was carried out, using data and information provided by the country combined with the REmap analytical framework. Countries were engaged throughout the process, and contributed to the development of the REmap Options.

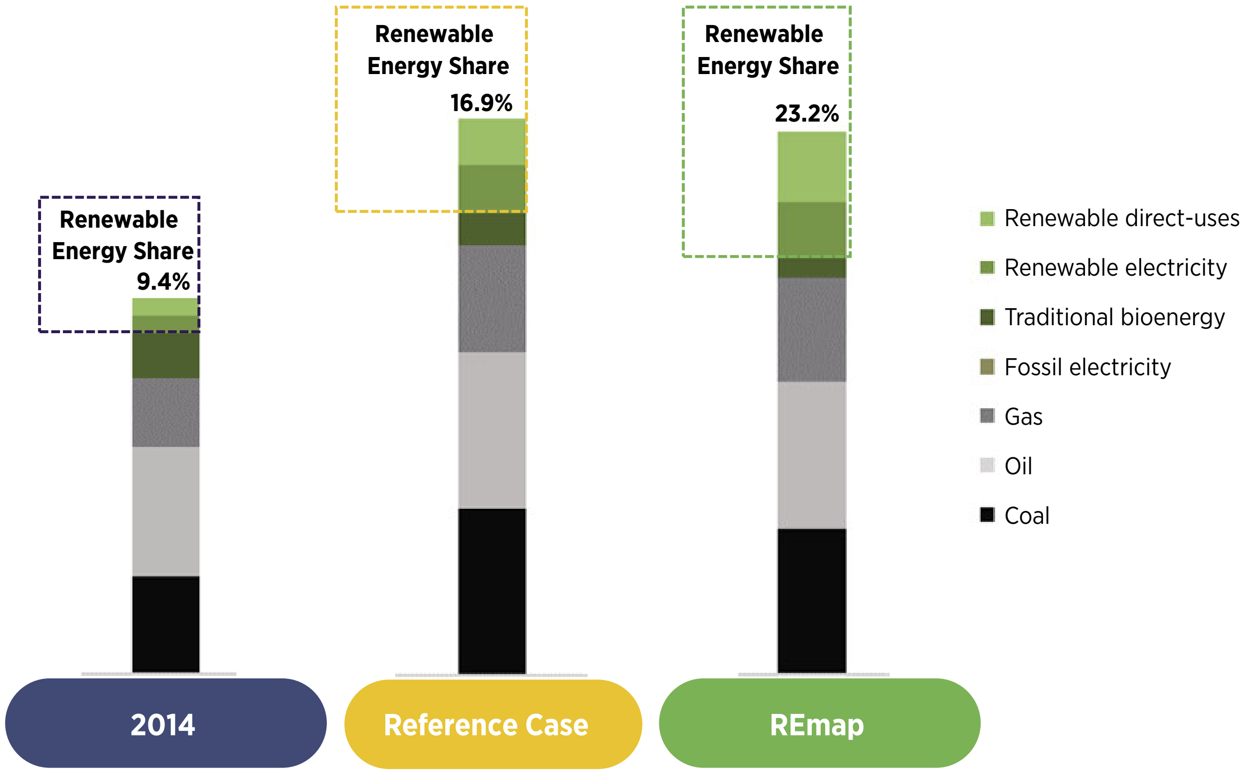
Table 3 is an overview of the key indicators and energy supply for the Reference Case and REmap. The REmap Options are technologies identified for further renewables deployment beyond the Reference Case. Countries not only have to meet their own goals in the Reference Case, many of which already include higher levels of renewables, but they have to do even more, as detailed by the REmap Options. If they can do both, then the region can achieve its aspirational target of 23% renewable energy.

Table 3: REmap ASEAN roadmap table

		ASEAN	Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**195**	**387**	**422**
		Renewable capacity	*GW*	51	124	180
		Hydropower (excl. pumped hydro)	*GW*	39	79	82
		Wind	*GW*	1	6	12
		Biofuels (solid, liquid, gaseous)	*GW*	6	13	18
		Solar PV	*GW*	2	13	55
		CSP	*GW*	0	0	0
		Geothermal	*GW*	3	10	11
		Marine, other	*GW*	0	3	3
		Non-renewable capacity	*GW*	144	263	242
		Total electricity generation	*TWh*	**856**	**1 656**	**1 674**
		Renewable generation	*TWh*	173	459	580
		Hydropower	*TWh*	129	289	303
		Wind	*TWh*	1	24	40
		Biofuels (solid, liquid, gaseous)	*TWh*	22	54	81
		Solar PV	*TWh*	2	19	81
		CSP	*TWh*	0	0	0
		Geothermal	*TWh*	20	59	67
		Marine, other	*TWh*	0	9	9
		Non-renewable generation	*TWh*	683	1202	1094

		ASEAN	Unit	2014	Reference Case 2025	REmap 2025
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**217**	**284**	**267**
		Direct uses of renewable energy	*Mtoe*	94	89	85
		Solar thermal – Buildings	*Mtoe*	0	0	4
		Solar thermal – Industry	*Mtoe*	0	0	3
		Geothermal (Buildings and Industry)	*Mtoe*	0	0	0
		Bioenergy (traditional) – Buildings	*Mtoe*	76	57	33
		Bioenergy (modern) – Buildings	*Mtoe*	1	2	11
		Bioenergy – Industry	*Mtoe*	16	29	34
		Non-renewable – Buildings	*Mtoe*	22	38	31
		Non-renewable – Industry	*Mtoe*	102	158	151
		Non-renewable – BF/CO	*Mtoe*	0	0	0
	Transport	**Total fuel consumption**	*Mtoe*	**133**	**190**	**184**
		Liquid biofuels	*Mtoe*	4	15	16
		Biomethane	*Mtoe*	0	0	0
		Non-renewable fuels	*Mtoe*	129	176	168
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**416**	**595**	**573**
Total primary energy supply			***Mtoe***	**634**	**952**	**929**
RE shares	RE share in electricity generation			20%	27%	35%
	RE share in buildings – final energy use, direct uses (modern)			1%	3%	19%
	RE share in industry – final energy use, direct uses			14%	16%	20%
	RE share in transport fuels			3%	8%	9%
	Share of modern RE in TFEC			**8%**	**13%**	**19%**
	Share of modern RE in TPES			**9.4%**	**16.9%**	**23.2%**
Financial indicators	System costs (USD bln/yr in 2025)			*N/A*	*N/A*	0.7
	RE investment needs (USD bln/yr annually (2015-2025))			*N/A*	13	27
	Investment support for renewables (USD bln/yr in 2025)			*N/A*	*N/A*	5
	Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)			*N/A*	*N/A*	13
	Reduced externalities – CO_2 (USD 50/tonne CO_2) (USD bln/yr in 2025)			*N/A*	*N/A*	11
	CO_2 emissions from energy (Mt/yr)			1 359	2 194	1 996

Figure 12: TPES growth and renewable energy share



BOX 3: CLOSING THE GAP BY COUNTRY AND A DIFFERENTIATED APPROACH

The ASEAN Member States vary significantly in population, economy and energy demand. Thus, a differentiated approach to expanding renewables is necessary. The modern renewable energy share in TPES in ASEAN was 9.4% in 2014. Under the Reference Case it will increase to approximately 17% by 2025 – still below the aspirational target of 23%. An additional six percentage points is needed to close this gap (the REmap Options).

The contributions ASEAN countries have put forth to close this gap vary. Some put more emphasis on expanding renewables than others. This can be due to a variety of factors, such as large overall energy demand or demand growth, the availability of local renewable resources, or the level of ambition and growth in renewables already in the Reference Case (leaving less potential for the REmap Options).

Table 4 shows how each country contributes to increasing the renewable energy share from the Reference Case level of 16.9% to 23.2% in REmap in 2025. The contributions vary significantly but are roughly proportional to the size of each country's energy system. Based on their relative contributions, it is clear that in order to meet the target, countries near the top, such as Indonesia, Vietnam, Malaysia, and Thailand, must take action. These four countries will account for 80% of the increase in share.

This method of assessing relative contribution by country is based on the REmap Options, which explore the potential to increase renewables across all countries and sectors. The REmap approach is a mixed approach – it looks at power, heating, transport and cooking, and at all renewable sources. There is less than a decade to meet the target, so a mixed approach is likely the fastest way to increase the renewable share. It also reduces the risk of changes to markets or policies that could put individual sectors or resources at a disadvantage.

However, there are multiple routes through which countries can increase renewables in their energy system. More emphasis could be given to one sector over another, for instance the rapid development of renewable power generation capacity and electrification of transport, cooking and heating. Or more emphasis could be put on deploying higher levels of modern, sustainable bioenergy. Also regional energy trade, for bioenergy fuels or electricity, could also be expanded and result in a shifting landscape of renewable energy deployment. Therefore, there is no single "true" distribution. The REmap insights can inform a discussion but just how to meet the joint objective is a political decision.

Table 4: Country contribution towards increasing ASEAN's renewable energy share to 23%

		Modern renewable energy share in TPES
2014		**9.4%**
Reference Case 2025		**16.9%**
	Indonesia	+1.7%
	Vietnam	+1.3%
	Malaysia	+1.0%
	Thailand	+1.0%
	Philippines	+0.4%
	Myanmar	+0.4%
	Lao PDR	+0.2%
	Singapore	+0.1%
	Cambodia	+0.1%
	Brunei Darussalam	+0.02%
REmap 2025		**23.2%**

RENEWABLE ENERGY SHARES BY SECTOR

- **The REmap approach covers energy supply and demand – it looks at power, heating, transport and cooking, and at all renewable sources. Given the short time horizon and ambitious ASEAN target for 2025 – which is under a decade away – this broad, multi-sector scope is the best way to find a viable pathway to achieving the region's renewable goals.**
- **The distribution of renewable energy use varies significantly by country and sector. Generally, the power sector has the highest share, followed by buildings, industry and transport. Additional potential for renewable deployment exists in all sectors.**

Countries in ASEAN are spread across a wide and rich geographical landscape. The region has some of the most diverse and abundant renewable sources anywhere on earth. In some regions, fossil fuels are also available. The result is a radical mix of renewable energy use across countries and sectors, and vast differences in how the share of renewable energy could develop in the Reference Case and with the REmap Options.

In most countries, the largest share of renewable energy is in the power sector. Most have plans to increase renewables in their Reference Cases. Many have ample hydropower and shares exceeding 60% in their Reference Cases, such as Lao PDR, Cambodia and Myanmar.

The REmap Options show that all countries, including those with high shares to begin with, have the potential to increase renewable power further. If all the REmap Options were implemented, the share of renewable energy in electricity generation would reach between 11% (Brunei Darussalam) and 90% (Lao PDR). Across the ASEAN region, the overall share would reach 35% by 2025, representing an increase of eight percentage points from the Reference Case.

If all REmap Options were implemented, buildings would have the second-highest renewable energy share. Traditional uses of bioenergy are excluded as a renewable source, otherwise the share would be even higher. REmap Options for the sector are plentiful, ranging from solar thermal to modern uses of bioenergy (both solid biofuels and biogas) to substitute its traditional uses for cooking and heating. Additionally, over half of all electricity is consumed in the building sector, and as the share of renewable power increases, so does the share of the renewable energy in the overall sector demand. In REmap, most countries see large increases in their renewable energy share in buildings, with total shares in 2025 ranging from 10% to 45% (Lao PDR is the outlier with 88%).

The industry sector ranks third after buildings in REmap, dropping from second place in the Reference Case. A number of ASEAN Member States have significant potential to increase the share of renewables in industry – by between 5% and 23%. The key technology option is bioenergy and electricity produced with renewable energy.

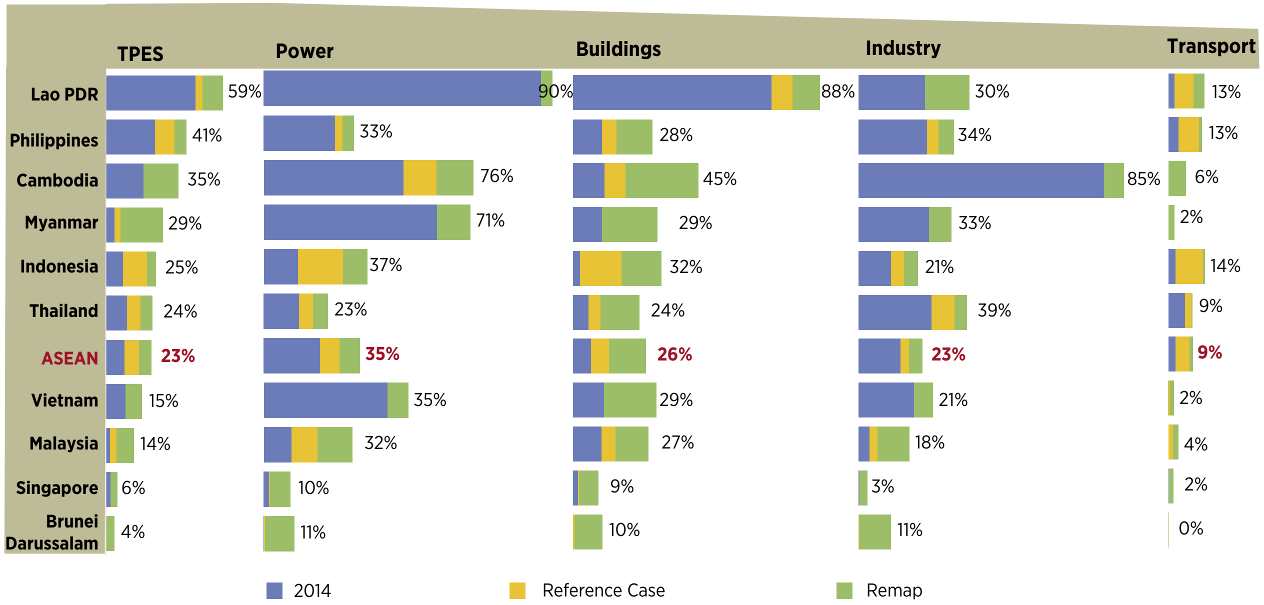
Transport remains a laggard, with the lowest share of renewable energy in both cases. The sector does grow significantly in the Reference Case from 3% to 8%, driven entirely by greater use of liquid biofuels. The Indonesian government, for example, has plans to increase its share significantly. The REmap Options assume small quantities of additional liquid biofuels, but significantly more electric mobility. However, because of the efficiency of electric drives, and the fact that only the renewable portion of electricity is calculated in the share, the effect of this electric mobility on the renewable share is limited. Nonetheless the sector does triple the share by 2025 over 2014 levels.

THE RENEWABLE TECHNOLOGY MIX

- **The technology mix changes significantly by 2025. The Reference Case sees slight increases in the relative share of hydropower and geothermal power in primary energy, and a halving of the share of traditional uses of bioenergy. REmap results in growth in the contribution of modern bioenergy, solar and wind.**
- **The REmap Options, which are the additional potential of renewables on top of the Reference Case and which close the six percentage-point gap to reach the regions aspirational target, are made up of about one-third renewable power and about two-thirds renewables in heating, cooking and transport.**
- **In the power sector, the largest increase in renewable power is solar PV. There are also additions of wind, small hydropower, geothermal and bioenergy.**
- **In end-uses, where most of the additional renewable potential on top of the Reference Case is identified, there is strong growth in modern bioenergy (in part substituting traditional uses of bioenergy), solar thermal energy, and increased electrification.**

The technology mix in ASEAN will change significantly by 2025. As energy demand rises by almost 50%, the relative share of coal and natural gas increases, as does the share of renewables, largely through

Figure 13: Renewable energy share in ASEAN Member States by sector, 2025

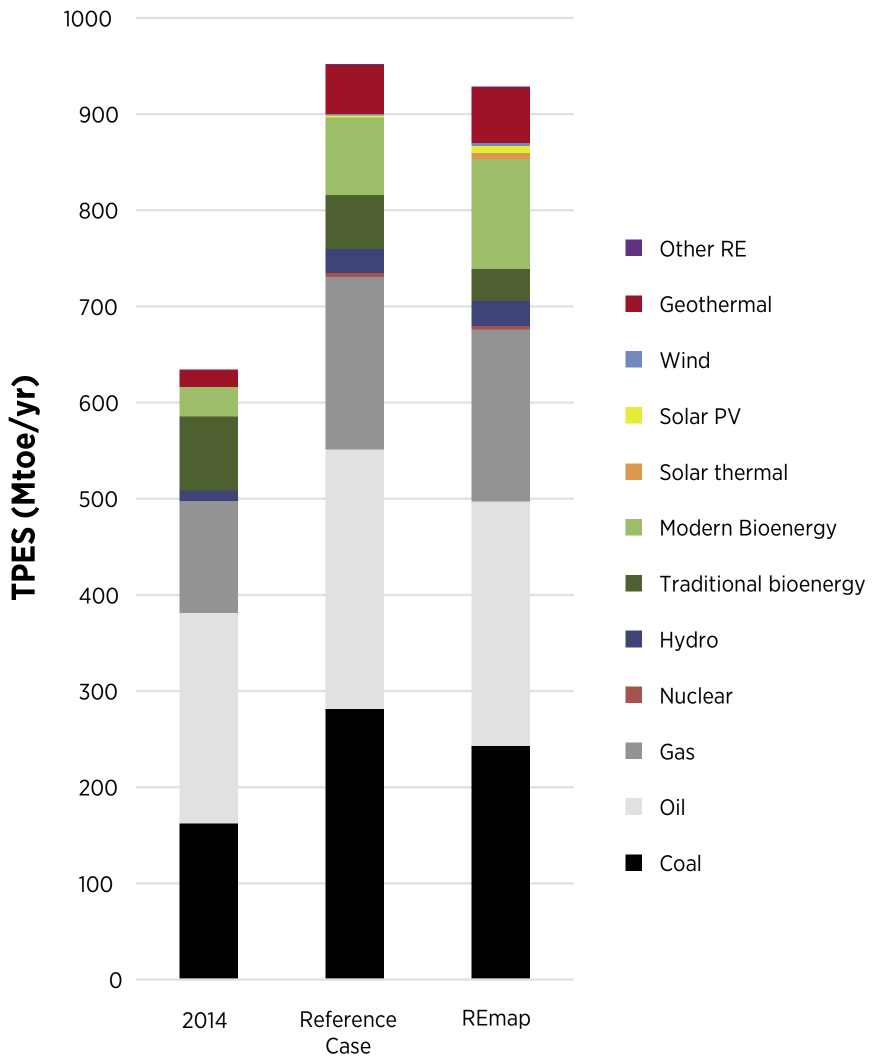


Note: End-use sectors of buildings, industry and transport include renewable electricity in the share.

more renewable power and transport biofuels in the Reference Case (see Figure 12). The REmap Options focus mostly on modern bioenergy, solar PV, solar thermal and wind. These also have the added benefit of decreasing overall demand for energy by almost 3%, due to the efficiency of some renewable technologies.

Viewing these findings in terms of primary energy masks changes that occur when energy is ultimately consumed, in the end-use sectors of buildings, industry and transport. Therefore, it is useful to look at the breakdown in final energy terms.

Figure 14: TPES by fuel in 2014, and 2025 for the Reference Case and REmap



In 2014, almost 70% of all final renewable energy consumption was traditional uses of bioenergy. Modern biofuel use in buildings (a charcoal, biogas or efficiently combusted solid bioenergy) contributed only around 1%. Biofuel use in industry for process heat generation via decentralised boilers made up the second-largest share of final renewables use (15%). Only 3% of renewable energy use came from liquid biofuel use in transport. Renewable electricity made up the remaining 12%, mainly from hydropower.

In the Reference Case, total final renewable energy consumption increases from 110 Mtoe to 136 Mtoe. The share of traditional uses of bioenergy declines as countries replace it with modern fuels. The relative share of bioenergy in industry increases. Biofuel use in transport also grows, largely the result of policy action in Indonesia, but also in Thailand and the Philippines. The amount of hydropower and its share increase significantly, while solar PV and wind also make up small shares, at around 1% each. The amount of modern renewable energy increases from 34 Mtoe to 79 Mtoe, a much higher increase than overall renewable energy when traditional uses of bioenergy are included (see Figure 15).

The REmap Options more aggressively replace traditional uses of bioenergy, increase the types of uses of direct heat from solar thermal sources, and increase renewable power. In ASEAN, less than 40% of all REmap Options are renewable power technologies, the bulk are technologies related to heating or cooking in industry, buildings, or fuels used in transport. For heat and other direct uses in the building and industry sectors, two main trends occur: significant growth in solar thermal heat, both in low-temperature process heating applications in industry, and growth in solar hot water in the commercial and residential sectors. Also, a little under half of the traditional uses of

Figure 15: Renewable energy consumption in TFEC in 2014, and in 2025 for the Reference Case and REmap

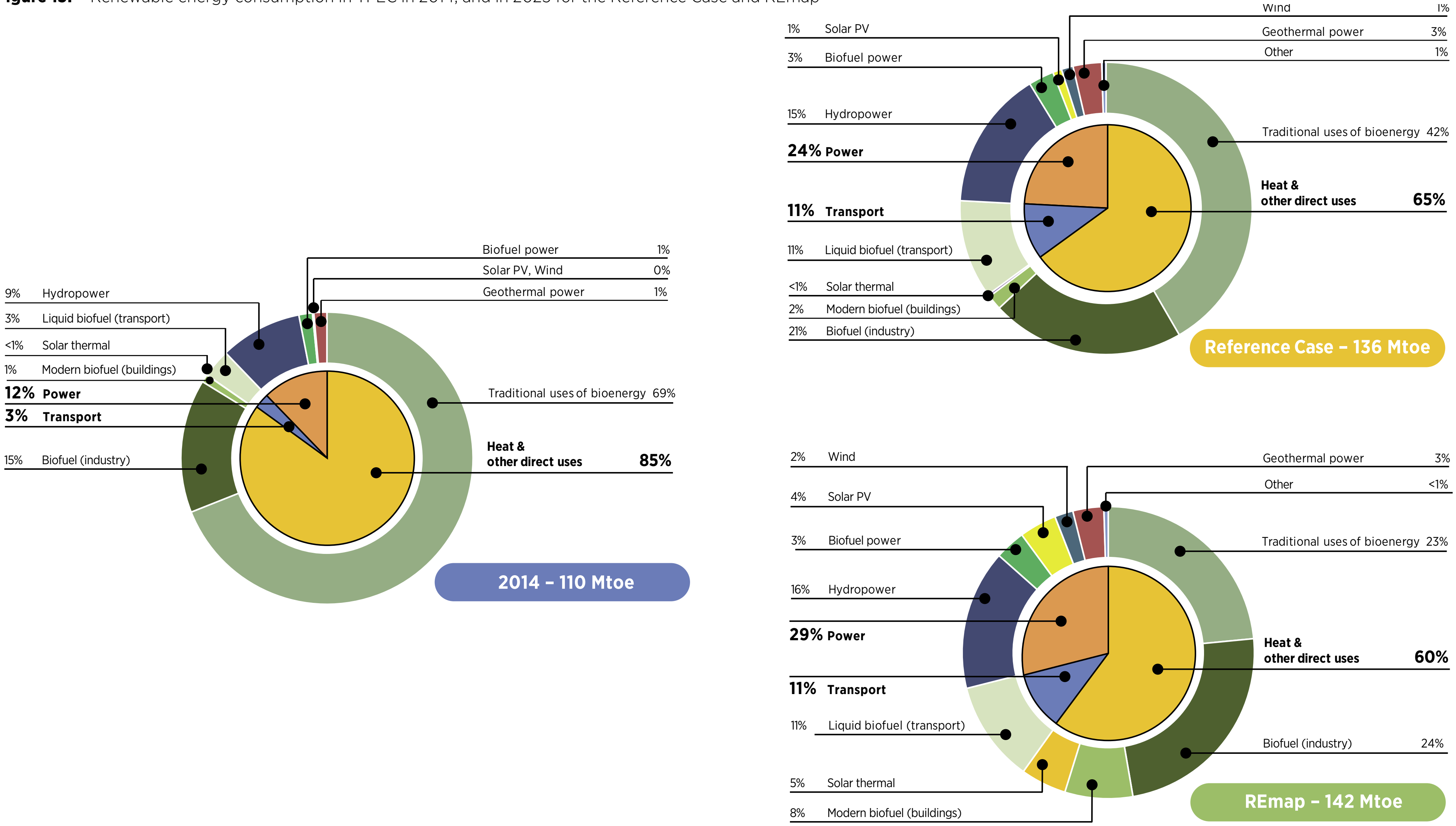
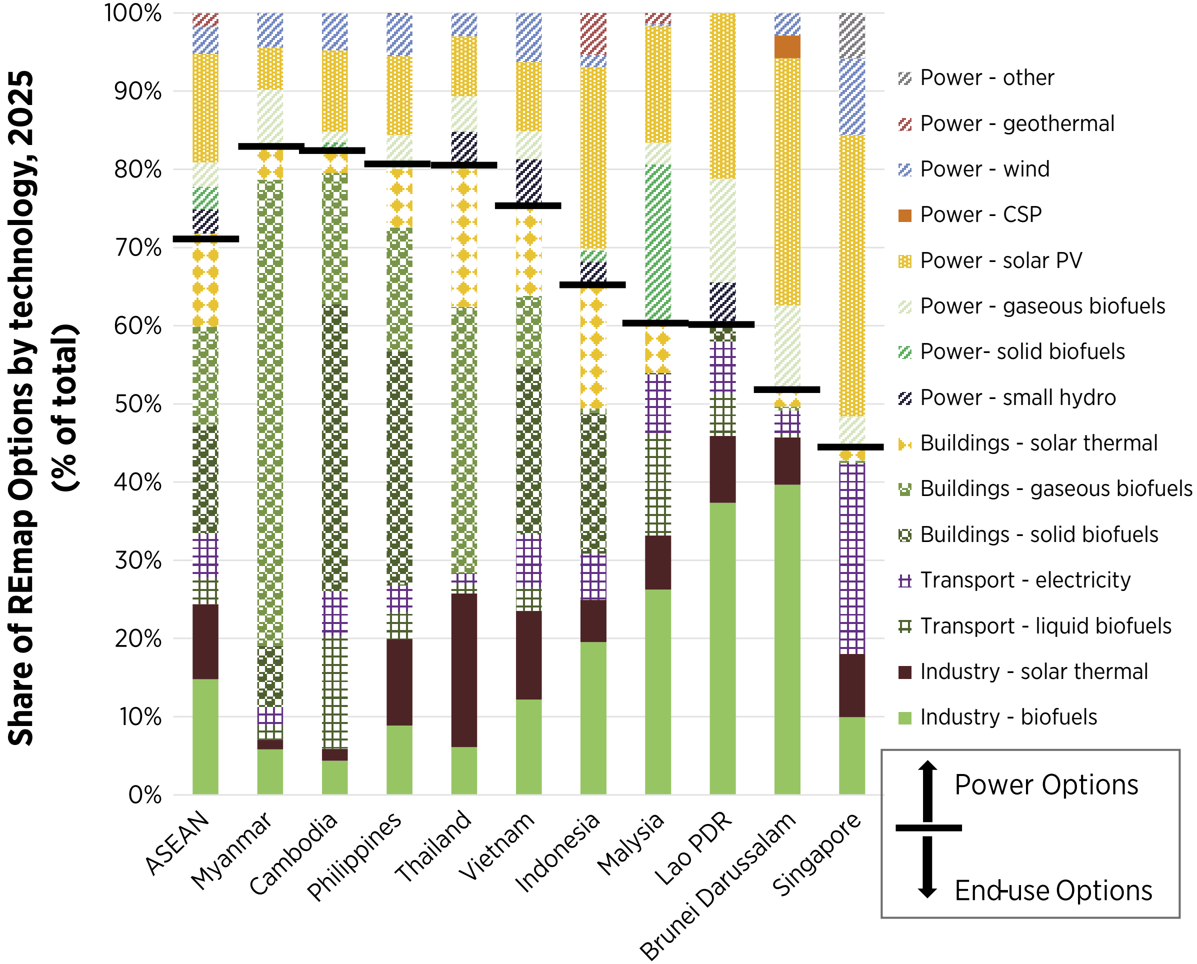


Figure 16: Breakdown of REmap Options by technology and by country



bioenergy are replaced with modern forms of bioenergy, so that the share of modern biofuels in industry rises from just 2% to 8%.

The largest increase in renewable power is solar PV, which sees four times more additions than the next highest – wind. There are also additions of small hydropower, geothermal and biofuel power.

With all the REmap Options, total final modern renewable energy use in ASEAN will triple to 109 Mtoe per year by 2025 compared to 2014. These options are sufficient to close the gap to ASEAN's renewable energy target in 2025. The next section will highlight some key trends and country findings of the REmap Options.

ACCELERATING RENEWABLES – THE REMAP OPTIONS

OVERVIEW

The previous section highlighted the key sectors and big-picture technology trends across the ASEAN region in view of the region's 23% renewables target. However, reaching this share and realising a more sustainable, diverse and affordable energy supply requires an understanding of what must be done at the country level. This section examines key trends and differences between countries in terms of their renewable energy potential.

Figure 16 details the sector breakdown of the REmap Options by country to show the importance of exploring renewable potential in all sectors and energy applications. The renewable energy potential varies significantly between countries. In only two countries will half or more of the REmap Options occur in the power sector – Singapore

Table 5: REmap Options importance by technology and sector

	Brunei Darussalam	Cambodia	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam
Industry Sector										
Bioenergy	+++	+	+++	+++	+++	++	+++	++	++	++
Solar thermal	++	+	++	++	+	+	+++	+	+++	++
Transport Sector										
Liquid biofuels	+	++		+	++	+	++		+	+
Electric mobility	++	+	++	+	++	+	++	++	+	++
Building Sector										
Solid bioenergy		+++	+++	+	+	++	+++			+++
Biogas	+	++	+			+++	+++	+	+++	++
Solar thermal	+	+	+++		++	++	++	+	+++	++
Power Sector										
Small hydro			+	+						
Solid bioenergy		+	+		+++					
Biogas	++	+	+	++	+	++	++	+	++	+
Solar PV	+++	++	+++	+++	+++	++	+++	+++	++	++
Wind	+	+	+		+	++	++	+++	++	++
Geothermal				++	+		+			

Note: The colour and + indicator is meant to provide a qualitative perspective on the relative importance of the technology in the REmap Options. One + (light orange) indicates a low contribution, ++ (blue) indicates a moderate contribution, and +++ (green) indicates a high contribution.

and Brunei Darussalam. These countries have limited land, and per capita income and electricity demand have already risen. In other countries, additional renewable energy potential comes largely from technology options in end-use sectors. In the power sector, solar PV by far dominates the additions, followed by wind. Some countries do have a small amount of additional bioenergy, geothermal or small hydropower.

Countries with large renewable energy potential in industry are also those experiencing rapid industrialisation. Growing demand for energy generally entails investments in greenfield capacity that allows for easier and more affordable integration of renewables. Some countries, such as Myanmar, Cambodia, the Philippines, Thailand and Vietnam all have significant potential from both ample bioenergy and solar resources.

In transport, electric mobility is shown as a separate category. This is a key enabling technology for the sector, even though it is not a source of renewable energy on its own. REmap assumes that renewable power can supply the additional demand from more electric mobility, making an important contribution to the sector's total renewable energy share.

Table 5 also shows the relative importance of different sectors and technologies among the REmap Options. The power sector has the most diverse set of technology options, and all countries have either medium (++) or high (+++) deployment of solar PV. All countries also have low (+) or medium deployment of wind and biogas (including waste, sewage, or landfill gas). The industry sector, which details only heating applications, shows high potential for bioenergy, and generally medium potential for solar thermal process heating technologies.

The building sector has a mix of technologies with varying levels of deployment. In countries where traditional uses of bioenergy are used, the potential to substitute it with modern solid or biogas technologies is large. Generally, there is potential across the region for solar thermal systems for hot water. In transport the potential is lowest, but all countries have low-to-medium potential for electric mobility, and low-to-little potential for liquid biofuels.

To better understand this broad technology deployment at the sector and country level, the following sections will break down the key technology potential in more detail.

POWER

- **Gross electricity generation will double in the ASEAN region by 2025. The largest increase in renewable electricity in the Reference Case will be from hydropower. The REmap Options show that significant additional potential will come from solar PV, making up half of the additional renewable power generation potential.**
- **The share of renewable power generation will increase from 20% in 2014, to 27% in the Reference Case, and further to 35% in REmap.**

In the coming years, demand for electricity will almost double in the region. Today the share of electricity in total final energy demand is 15%. This will likely grow to 20% by 2025 as its use increases in the residential sector (for instance for appliances and cooling) and in services, and as electric mobility, transport, and industrial activity grow. As the use of electricity grows as does the share of electricity that is supplied with renewables.

REmap suggests that 35% of ASEAN's power generation can be sourced with renewable power by 2025, up from 20% in 2014, and compared to a 27% share in the Reference Case. Figure 17 shows how the power generation mix changes over the period, during which gross electricity generation doubles.

Development in the renewable energy mix according to the Reference Case is dominated by hydropower, continuing the existing trend. Today, hydropower has the largest installed capacity, totalling 39 GW. This is expected to double to approximately 79 GW by 2025, accounting for more than half of the renewable capacity additions between now and 2025. Geothermal, biofuels-based power and solar PV follow hydropower, but all in comparatively moderate amounts. In total, renewable energy-based power-generation capacity will likely increase from 52 GW in 2014 to 125 GW by 2025 according to the Reference Case, accounting for a third of the total installed capacity of 389 GW in 2025.

Capacity additions differ remarkably in the REmap Options (see Figure 18). Solar PV represents half of all additions in renewable power capacity, with a total installed capacity of 57 GW by 2025. This compares with 14 GW in the Reference Case, implying all country plans underestimate solar PV's promising potential in the region. Hydropower additions are much lower in comparison to the Reference Case, only 3 GW, taking the total to 82 GW. Onshore wind and biofuels-based power, from both solid and gaseous biofuels, also play a large role, representing 20% of the total. REmap suggests total onshore wind capacity of 13 GW and biofuels-based power capacity of 15 GW by 2025. In total, renewables-based power generation capacity will reach 184 GW according to REmap.

Each addition in renewables-based power generation capacity in REmap compared to the Reference Case results in the substitution of a fossil fuel-based capacity. This analysis mainly assumes the substitution of coal-based power generation capacity. The REmap Options would cut 21 GW of coal-based power generation capacity by 2025 to an installed 118 GW from 139 GW in the Reference Case. Total capacity for gas, oil and nuclear remains nearly the same in the two cases at 13 GW, 110 GW and 2 GW, respectively. Coal is the most emission-intensive type of fossil fuel and its substitution reduces both air pollutants and CO_2 emissions.

The way ASEAN Member States contribute to these developments differs substantially. Figure 20 shows the overview of annual installation

Figure 17: Breakdown of power generation in ASEAN, 2014 and 2025 for the Reference Case and REmap

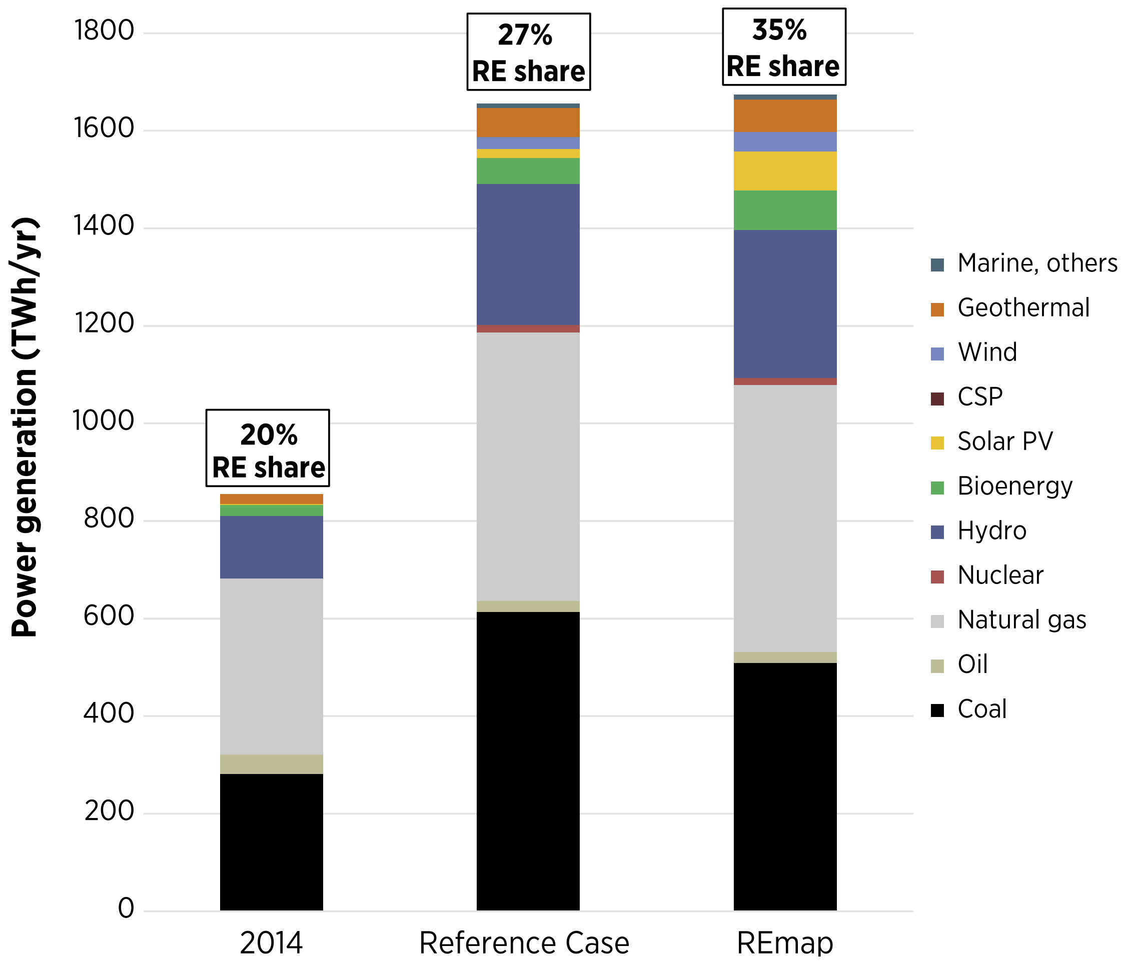


Figure 18: Power capacity in ASEAN region, 2014, Reference Case and REmap

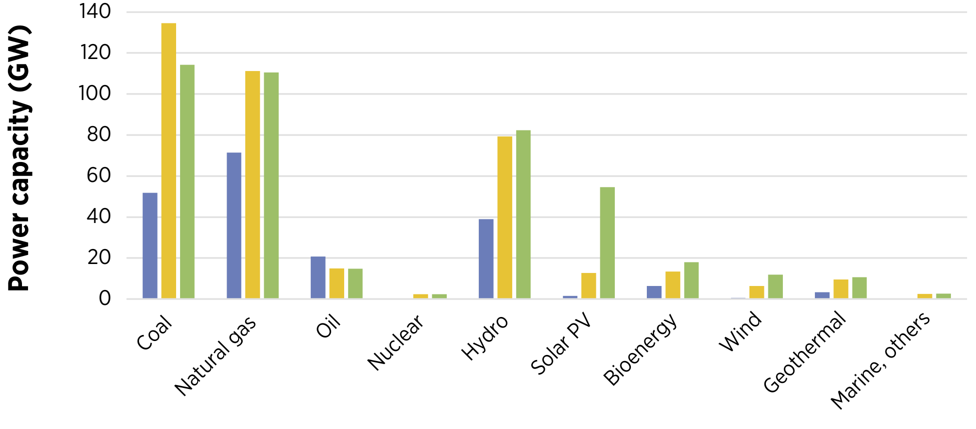
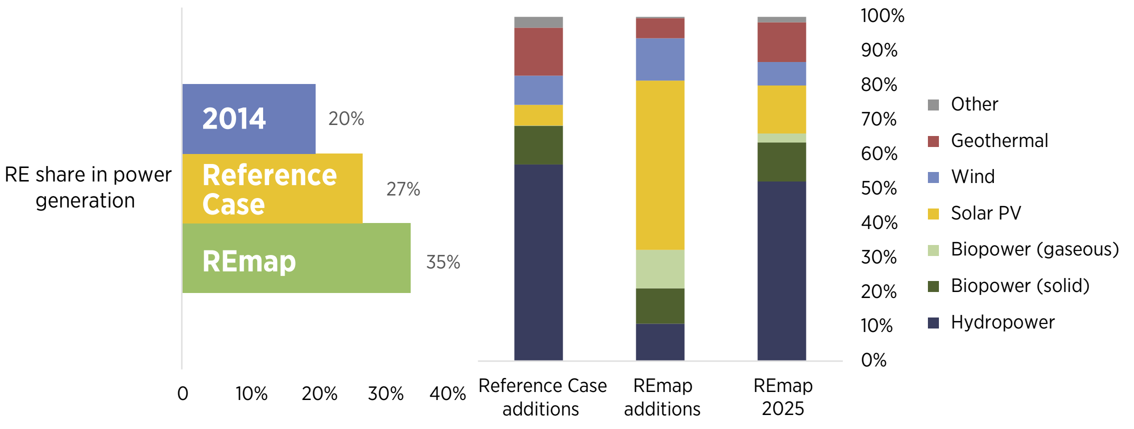


Figure 19: Power sector renewable energy share, renewable energy additions and total, 2014-2025



rates for various renewable power technologies by country. Indonesia and Lao PDR foresee a significant increase in hydropower capacity. Lao PDR's Reference Case triples annual installations from 2015 to 2025 compared to the period 2006-2015. Indonesia will add even more hydropower capacity, an increase of more than 8 times over the previous period. In all other countries, annual installations are projected to continue at rates similar to what was achieved in the past decade, except Vietnam which will see its installation rate decline. There are also efforts to step up annual capacity additions in bioenergy. According to the Reference Case, Indonesia, which already has a large share of bioenergy, is projected to quadruple its capacity additions from its approximately 75 MW per year to 300 MW per year in the next decade. The Philippines needs to triple its installation rates. Vietnam also have bioenergy installations, but its Reference Cases project an increase of approximately 25 MW per year. The largest increase in REmap is estimated for Malaysia and to some extent for Indonesia, mainly driven by the increased use of bioenergy for heating in industry, coupled with power cogeneration and biogas-based power-alone systems.

Solar PV requires the most effort to ramp up capacity installations as it has generally the largest gap between rates occurring in the Reference Case and the potential deployment identified in REmap. In the past decade, annual installations have averaged about 15-20 MW per year in the Philippines and Malaysia. The largest rate of installation is in Thailand with about 175 MW per year. According to the Reference Case, Thailand needs to double this trend, while Malaysia needs to increase its efforts by a factor of six and triple this further if it is to realise its REmap potential. Indonesia faces the biggest challenge. Today, annual installation rates are just around 1 MW per year. The Reference Case foresees an ambitious rate of 500 MW per year between 2015 and 2025. REmap's potential is significantly higher at 2 500 MW per year, due in part to the significant potential of island and off-grid solar PV systems.

Realising the large potential of other renewable energy technologies, such as onshore wind and geothermal, requires similarly ambitious increases in annual installation rates according to Indonesia's Reference Case, as well as in REmap.

THE NEED FOR FLEXIBILITY IN ASEAN'S POWER SYSTEM

- **The share of variable renewable power (VRE) across ASEAN will generally be low, but shares in individual countries and within individual power systems will vary. In some countries, the share of VRE in generation will exceed 10% if all REmap Options are implemented.**

Hydropower will provide most of the growth in the renewable energy share of power. However, solar PV, and to some extent onshore wind, will also play a role. Solar PV and wind are variable renewable energy (VRE) sources. Their output is correlated to the availability of the resource at any given time, as opposed to demand for power. Consequently, wind and solar generators cannot follow power demand as thermal or hydropower can. A high share of variable renewable power in a power system can pose challenges to the stability of the grid. Thus, it requires the power system to be flexible.

In ASEAN, the VRE share will reach 8.2% of generation by 2025 with deployment of all REmap Options, up from only 3.4% in the Reference Case. But it is important to look at VRE shares on a country basis, to

Figure 20: Annual installation rate for various renewable power technologies per year, by country, to 2025

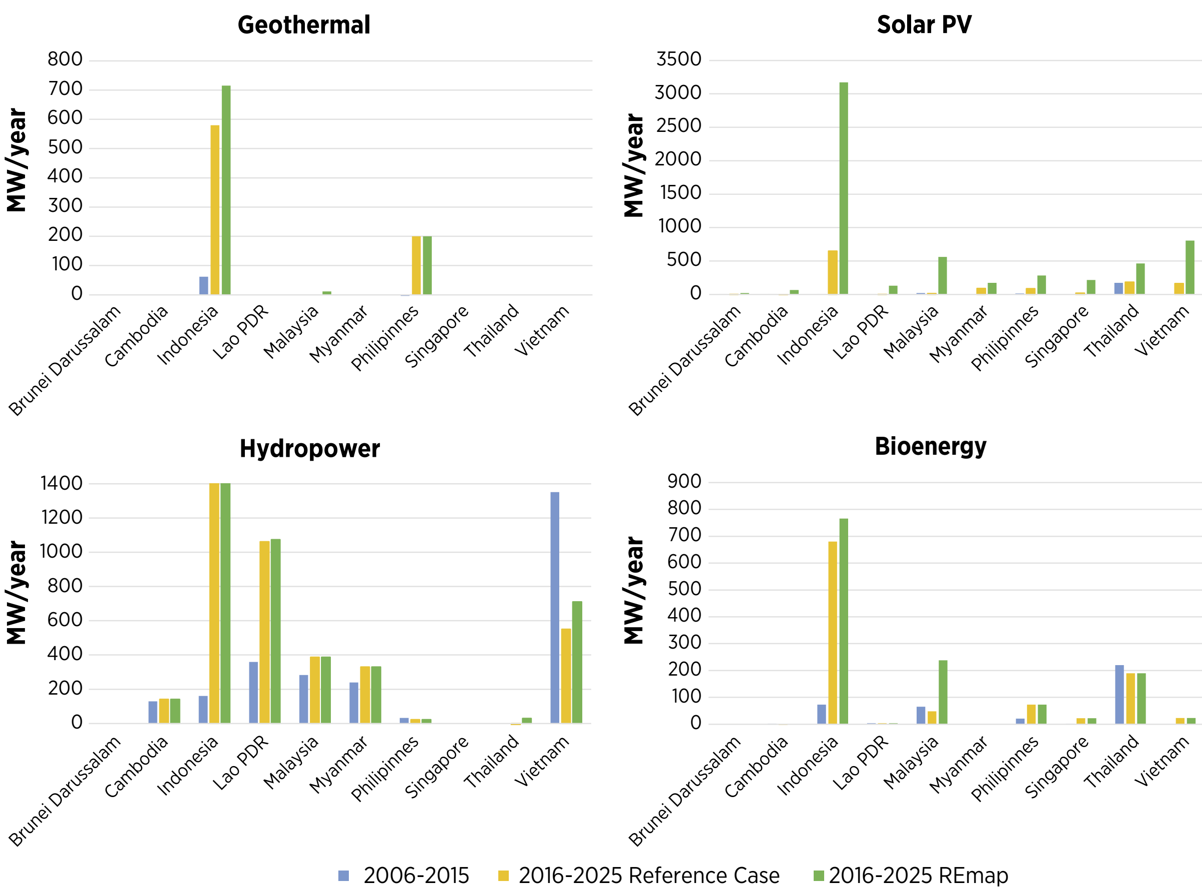
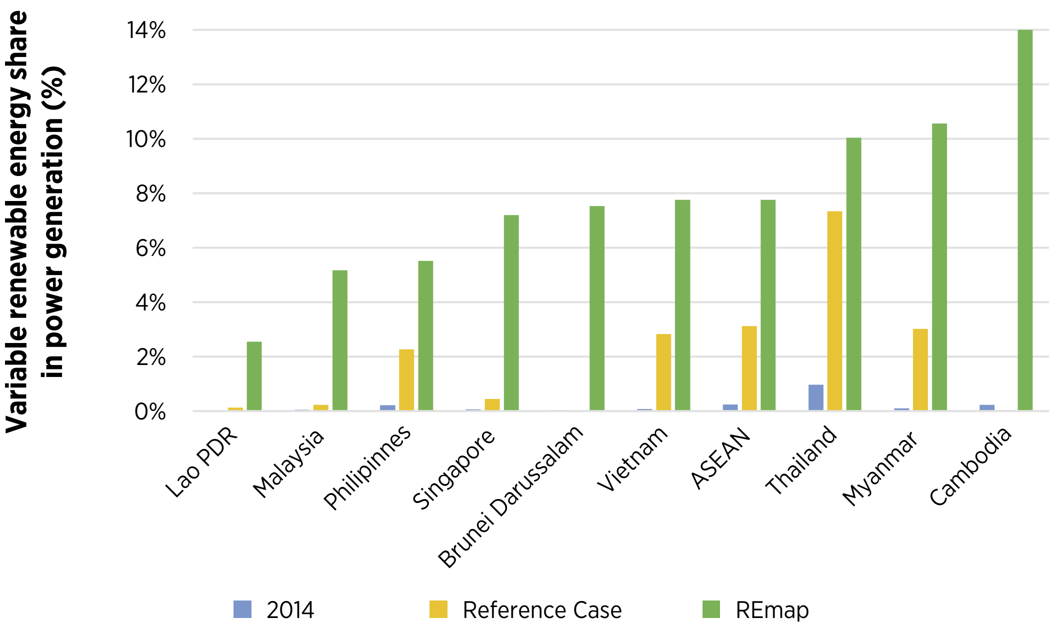


Figure 21: Variable renewable energy shares of ASEAN Member States in power generation, 2014-2025



see which countries will have to deal with greater volumes of VRE. Experience in countries like Spain, Ireland, Italy or Germany, has shown that it is feasible to accommodate VRE shares of up 15%, but every grid is different. These countries generally have strong national grids, interconnection capacity with neighbouring countries with a large dispatchable capacity, and they plan in advance for transition.

The Reference Case shows low VRE shares generally across ASEAN Member States, with Thailand the only exception. In REmap, the picture is different. Individual countries, such as Thailand, Myanmar, Cambodia and Singapore would have even higher shares of VRE than the ASEAN average, reaching 10% or more by 2025.

One way to overcome the challenge of integrating VRE into the grid is through a better integration of the region's ten power markets. One approach is the ASEAN Power Grid (APG). Regional power grid expansion to date amounts to 3.5 GW of interconnector capacity operating across 11 connectors, between six pairs of countries as of the end of 2014. Another 13 projects with a total capacity of 7 GW are under development to be completed latest by 2020, but still delayed compared to initial plans. Another 20 GW of interconnector capacity is envisaged after 2020 (Andrews-Speed, 2016). If all were to be built, interconnector capacity would total over 30 GW. ASEAN's newly adopted plan for energy cooperation, APAEC, prioritises the integration of power markets and connectivity. The main challenge is differences in how power markets are coordinated among Member States. With better and more consistent regulatory frameworks within countries and across the power interconnectors, standards for trade and grid codes for planning, design, operation and maintenance of power markets could help to overcome these challenges.

In addition to expanding interconnector capacity within ASEAN and with neighbours such as China, flexibility can be created within each country's power mix. Nearly all countries have large capacity for hydropower, for example. But the expected rapid growth in demand for electricity will not only be met with renewable energy, but also with new coal and gas capacity. If this expansion can be achieved using flexible generation technologies, it can create another source of flexibility for the power system.

Outside its own structure, the power system can gain flexibility through links with other energy sectors, especially transport. REmap suggests a significant uptake of electric forms of transport in most

Table 6: Flexibility mechanisms in the ASEAN power system, in 2025

Technology	(GW)
New fossil fuel-based power generation capacity that can be built with better flexibility	25-35
Pumped hydro capacity	3.5-4
Electricity storage capacity from electric mobility, active vehicles and second life batteries	60-100
Interconnector capacity	20-30

ASEAN Member States, such as two-, three-, and four-wheel electric vehicles. These vehicles store electricity. For some, charging can be synchronised during the peak hours of solar and wind generation. However, bi-directional charging must be possible in the vehicle and charging station, which will not be possible in all cases. The stored power can then be released when the electricity is needed. Together with the pumped hydro storage capacity of 3.5-4 GW, energy storage capacity offered by electric vehicles would include 45-80 GW of active stock available on the grid, and 15-20 GW of second life batteries (Table 6).

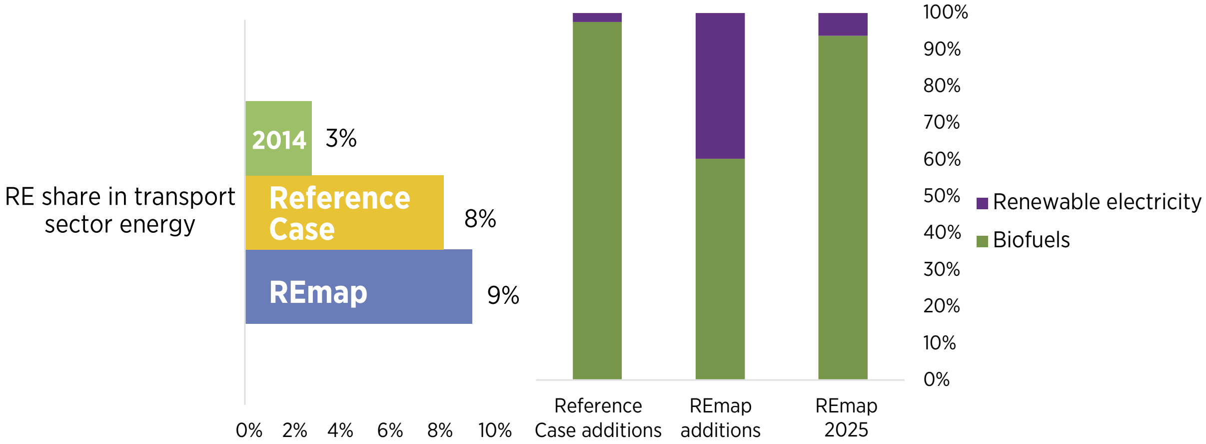
TRANSPORT

- **The transport sector will see energy demand grow by 45% between 2014 and 2025. The sector has the lowest share of renewables of any sector, but some of the highest renewable growth potential. The share of renewable energy in the sector could triple from just 3% in 2014 to 9% in REmap.**
- **The technologies that would enable this growth include both biofuels and electric mobility. Most of the increase in the Reference Case will be from biofuels, but the REmap Options show the significant additional potential of electric scooters and cars, and increased electrified public transport within cities and across regions.**

Southeast Asia has a low share of passenger car ownership. Today there are 43 cars per 1000 inhabitants. In Japan, the rate is 10 times higher. The only two ASEAN Member States with high ownership rates are Malaysia and Singapore, at 325 and 117 per 1000 people, respectively. Car ownership rates will rise as the economy grows. By 2025 it could increase to 60 out of 1000 across the region, meaning the number of passenger four-wheelers on the road would rise to 43 million from 26 million today. In addition, many people drive two- and three-wheelers in cities and between population centres. Population growth and more passenger cars mean future energy use in the sector will be 45% higher than today.

In 2014, only 3% of this was covered by renewables. This share is projected to increase to 8% in the Reference Case. Nearly all renewable energy additions are related to liquid biofuels. Malaysia and Indonesia are well-known producers of biofuels in ASEAN, supplying biodiesel to domestic and global markets. However, biofuel exports are expected to decline as they are redirected towards domestic use. Their production and consumption would account for three-quarters of ASEAN's total 20 billion litres by 2025. The remainder of the additions are largely in Thailand and the Philippines. The 20 billion litres of liquid biofuels is made up of six billion litres of conventional ethanol and 13 billion litres of biodiesel. The main feedstocks for conventional ethanol will be palm oil

Figure 22: Transport sector renewable energy share, renewable additions and total, 2014-2025



and sugar cane. Advanced ethanol production will amount to 1 billion litres, around 5% of the total ethanol demand.

The renewable energy share in transport sees only minor growth of one percentage-point in REmap, from 8% to 9%. This is because there are already significant additions of liquid biofuels in the Reference Case, so little additional potential is assumed. However, there is significant potential in advanced biofuels. An upcoming IRENA report shows that in Southeast Asia, using just one advanced production pathway – lignocellulosic conversion – the potential for advanced biofuel on land freed by reduced food waste could supply 40%-100% of transport fuel use today (the range depends on regional plans for reducing food waste, which would free up land for biofuel production) (IRENA, forthcoming). This is just one example of a possible liquid biofuel production pathway that would enable higher production without negatively affecting or degrading land. However, the REmap Options have not assumed significant additions of liquid biofuels due to cost and time constraints. Nevertheless, additional potential could be assumed after 2025.

REmap sees the main increase in renewable energy in transport from electrification. It expects the total number of electric two- to three-wheelers to reach 59 million (up from just 5 million in the Reference Case) by 2025. Four-wheel battery-electric vehicles will amount to 5.9 million, and there will be three million plug-in hybrids for a total of 8.9 million electric four-wheel vehicles (EVs) by 2025 (up from around 0.6 million EVs in the Reference Case). EVs would make up about 20% of the passenger automobile stock on the roads. Despite this significant increase in electric vehicle ownership in ASEAN Member States, electricity would only represent 2% of energy demand in its transport sector. This is explained by the significant efficiency gains from electric vehicles compared to internal combustion engines, which are 3-4 times more efficient than internal combustion engines. Nonetheless, increasing power consumption in the sector would also boost its share of renewables. This is because renewables supply 35% of the region's electricity production, significantly higher than the transport sector average.

BUILDINGS

- **In the building sector, the modern renewable energy share increases from 6% to 13% by 2025 in the Reference Case, due largely to greater electricity consumption sourced with renewables.**
- **In REmap, the share is double that of the Reference Case, reaching 26%. Half of this increase is driven by more use of modern energy, such as efficient cookstoves and biogas or electric cooking, which replaces much of the traditional use. The other half is split equally between solar water heaters and use of renewable power.**

The building sector includes the residential, commercial and public subsectors. It accounts for a quarter of ASEAN's total energy demand. When only the total demand for fuels is considered (excluding electricity demand), the sector's renewable energy share is 78%. Including electricity demand lowers the share to 62%, but it is still significant. The decrease is explained by the fact that a smaller fraction of the total electricity consumed originates from renewable energy sources. These shares also include traditional uses of bioenergy. If these traditional uses were excluded, as they are in the accounting for the regional ASEAN target, then the shares would be significantly lower, at just 6% when considering only renewable fuels and direct uses, and 8% when also considering renewable electricity.

Traditional use of bioenergy was the main form of energy use in buildings in 2014. Traditional bioenergy is typically combusted in inefficient stoves to generate heat for cooking or for heating water. It is often unsustainably harvested from forests to produce firewood in rural areas to serve basic energy needs. Depending on the size of the population, the use of traditional bioenergy can contribute to deforestation. There is limited knowledge about the volume and the actual extent of firewood use in country statistics. The International Energy Agency (IEA) definition suggests that all solid biofuel use in the residential sector can be regarded as traditional uses of biofenergy.

For the Reference Case, countries indicated whether they used modern bioenergy, otherwise all bioenergy used in the sector was assumed to be traditional. Based on this definition, modern renewable energy in buildings made up only 6% out of the 62% in 2014. As populations grow, households' demand for energy will also increase in the years up to 2025. Continuing to rely on traditional uses of bioenergy will threaten sustainability, with the pressure on land, water and forest resources intensifying even further. Therefore, more efficient use and

Figure 23: Building sector modern renewable energy share, renewable additions and total, 2014-2025

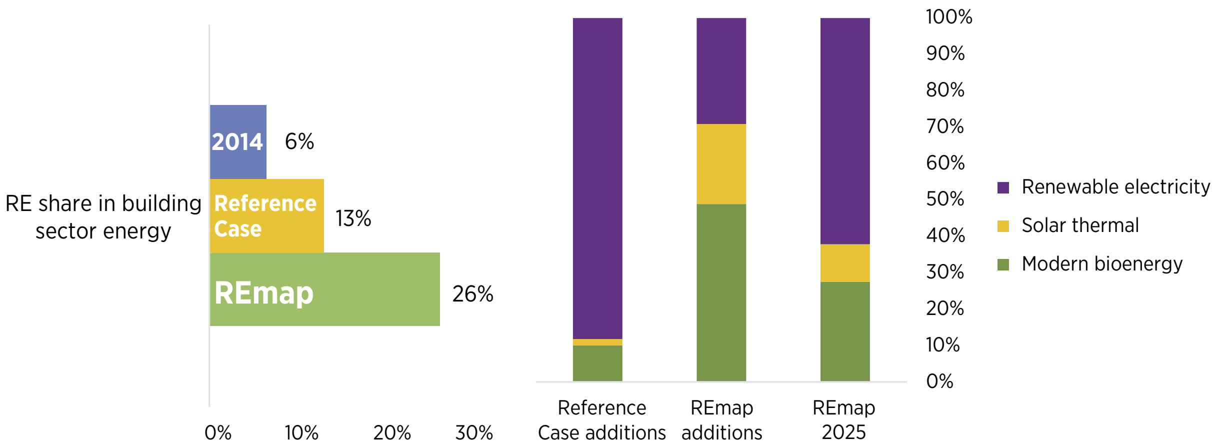
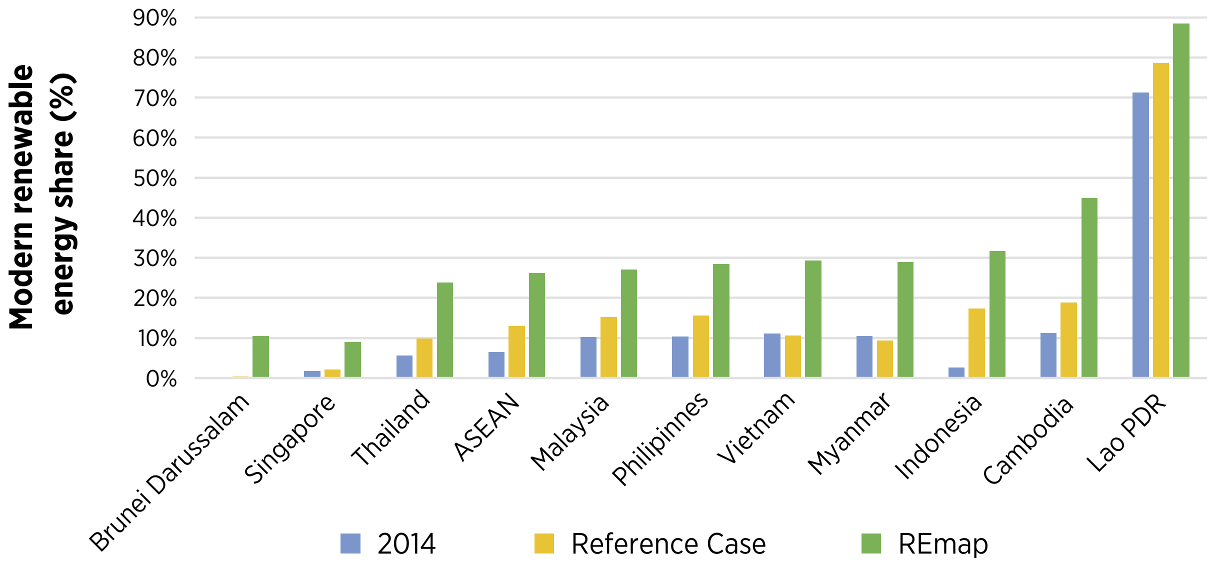


Figure 24: Development of the modern renewable energy share in buildings of the ASEAN Member States, 2014-2015



sustainable sourcing of biofuels is a key part of the transition towards a sustainable bioenergy supply. But as the sector grows, there is also a trend to using more LPG. The Reference Case shows this growing by 140% over the period. Therefore, solutions for meeting both the challenge of traditional bioenergy and supplying growing fossil fuel demand will need to take centre stage.

According to the Reference Case, the share of modern renewable energy in buildings will more than double from 6% to 13% between 2014 and 2025. Although in absolute terms, total demand for traditional biofuels will decrease from 180 megatonnes (Mt) to 130 Mt per year, people will continue to rely mainly on this fuel type to meet their basic energy needs. Renewable electricity is the main technology used to raise the modern renewable energy share in the Reference Case (see Figure 23). The share of electricity in building sector energy demand will increase to 41% by 2025 from 29% in 2014. About a quarter of this total demand is sourced with renewable energy, making it the biggest contributor to raising the share of modern renewable energy in this sector, according to the Reference Case. The remainder is split into modern biofuels (half solid biofuels and half biogas), and some solar water heater capacity (mainly in Thailand as foreseen in its national energy plan).

In REmap, the modern renewable energy share doubles to 26% from 13% in the Reference Case. The REmap additions are quite different than those in the Reference Case. In many rural areas modern biofuels play a major role due to their ability to substitute much of the traditional uses of bioenergy. For instance, in the Reference Case only an estimated 3 million modern cookstoves will be deployed across the entire region. In REmap, however, this number increases to a total of 12.5 million modern cookstoves, 2.5 million biogas installations, and 0.4 million cooking units running on biofuels. The result is that the traditional use of bioenergy would be cut in half (the remainder would be phased out by 2030). Electric cooking provides another alternative, in particular induction stoves, which are highly efficient.

The remaining increase in the renewable energy share comes from solar water heaters and additional renewable electricity (mostly the result of the increasing share of renewable power). Solar water heater capacity grows from just three GW in the Reference Case to 45 GW in REmap, with additions across all ASEAN Member States. This would result in around nine million units in operation. Assuming the region has around 140 million households, approximately 6% would be served by a solar hot water system. Biogas plays a key role in providing energy

BOX 4: ELECTRIFYING THE RURAL POPULATION IN ASEAN

Some countries in the ASEAN region have achieved full electrification, such as Brunei Darussalam, Malaysia, Singapore and Thailand, or near full in the case of Vietnam (estimated at 99%). Some countries have high levels of access today and are expected to reach full electrification by 2025 according their Reference Cases. This is the case for Indonesia, Lao PDR and the Philippines (Table 7).

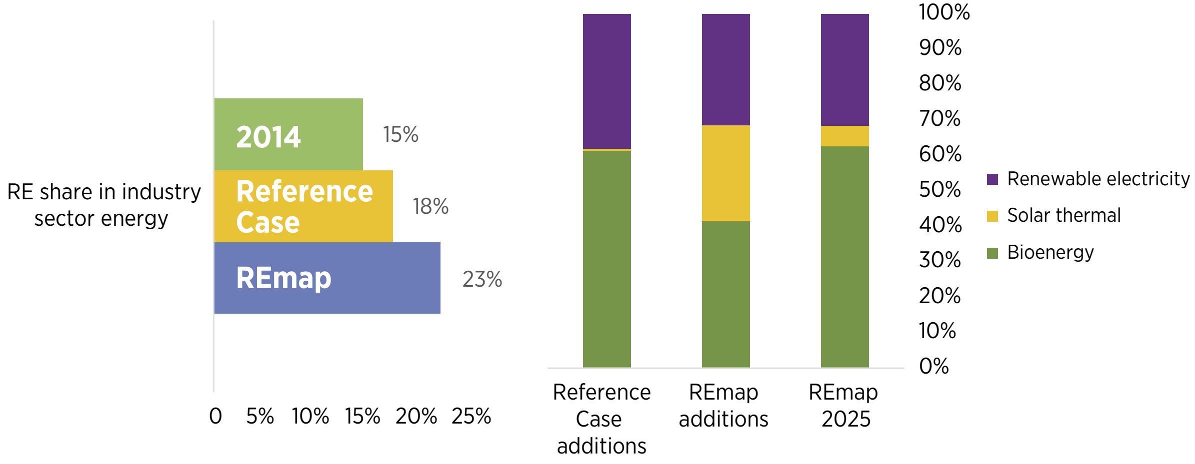
Two countries, however, are still devising electrification schemes to enable full access for their populations. Cambodia aims to achieve 100% electrification of its villages by 2020, including battery lighting. An estimated 32% of Myanmar's population had access to electricity as of 2014, the year it developed a national plan to fully electrify by 2030 (Castalia, 2014).

Table 7: Electrification rates in select ASEAN Member States

	2014/2015	2025
ASEAN	**78%**	**100%**
Vietnam	**99%**	**100%**
Indonesia	**88%**	**100%**
Lao PDR	**88%**	**90% by 2020**
Philippines	**90%; 100% (village)**	**100%**
Myanmar	**32%**	**100% by 2030**
Cambodia	**30%**	**100% (village) by 2020**

Note: Remaining ASEAN Member States have full electrification.
Most rates in the table refer to household electrification rates.

Figure 25: Industry sector renewable energy share, renewable additions and total, 2014-2025



for cooking and water heating, with total consumption of 9 billion m^3 by 2025.

The modern renewable energy share of various ASEAN Member States would double or quadruple according to REmap, depending on the starting point and the potential offered by biofuels and renewable electricity. Lao PDR, which already had a modern renewable energy share of 70% in 2014 would reach about a 90% modern renewable energy share by 2025.

INDUSTRY

- **Demand for energy will grow by more in the industry sector than in any other end-use sector, rising by more than 60% by 2025. The share of renewables will only increase marginally, from 15% in 2014 to 18% in the Reference Case.**
- **REmap shows that additional potential lies in increased use of bioenergy to provide process heat generation and in co-generation of power and heat, as well as in solar thermal for lower-temperature industrial processes. The industry sector also provides opportunities for self-generation of power, *e.g.* from solar PV or bioenergy. The share of renewables in the sector could increase to as much as 23% in REmap.**

The industry sector accounted for more than a third of ASEAN's total final energy demand in 2014. This share is projected to increase to almost 40% by 2025, driven by a 63% increase in energy in the sector, by far the highest of all sectors. This growth is explained by a number of factors. Demand for bulk materials produced in energy-intensive sectors, such as cement, iron, steel or chemicals, will increase as the region's economy and population grow. These materials are required for the construction of buildings and infrastructure. Energy for the production of food and other consumer goods will also grow. The region is expected to increasingly become a material production hub for neighbouring countries, as more production capacity shifts to growing economies like Indonesia and Vietnam.

In 2014, the sector's renewable energy share was approximately 15%. Solid biofuels made up 11% and renewables-based electricity made up 4%. Biofuels are a readily available source of renewable energy as they are by-products of various agricultural and production processes linked with the industry sector. Their use is projected to make up the majority of the renewable energy additions in the Reference Case by 2025 as the share of renewables will increase to 18%. In REmap, there is also large potential for solar water heaters of 23 GW for industrial process heat generation, making up about a quarter of the additional potential. This would supply about 1.7% of the region's total final process heat demand, up from no use today. The remaining increase comes from renewable electricity as the overall share of renewable power in the grid increases.

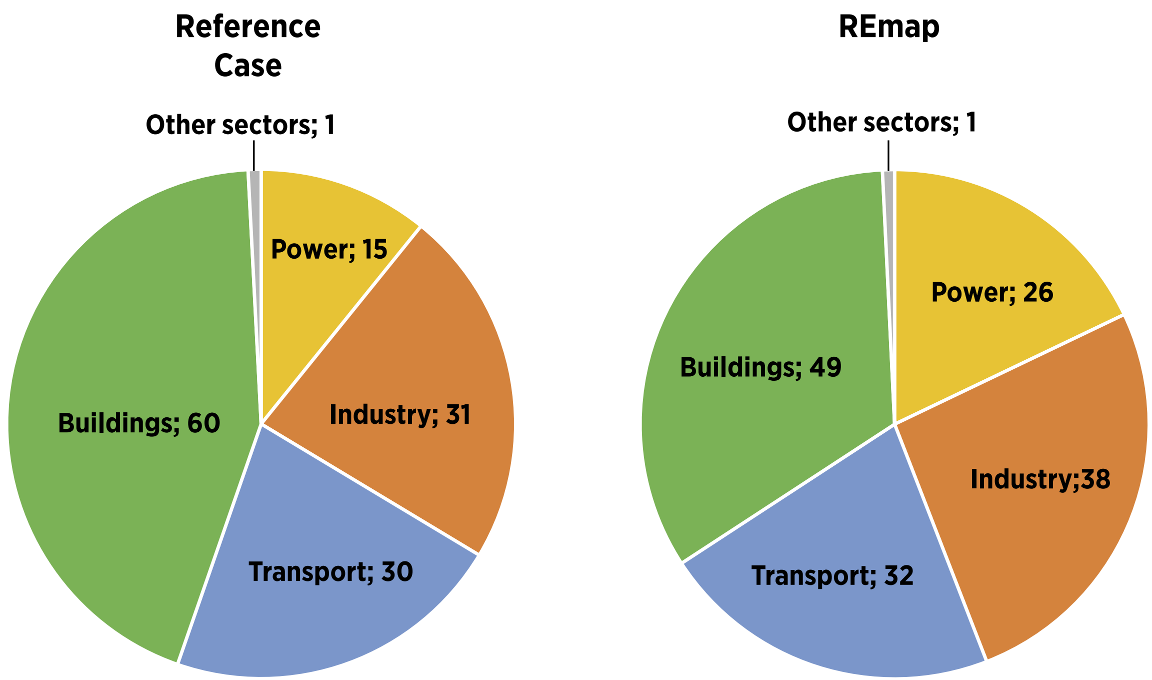
BIOENERGY

- **Bioenergy is a unique resource that can to be used for power and heat production or as a transport fuel. Its potential in the ASEAN region is large, however important sustainability concerns exist. Scaling up sustainable, modern forms of bioenergy will be crucial both to address the energy access challenge, and to increase renewable energy use in both industry and transport.**

Bioenergy is particularly important in ASEAN as it could represent 15% of ASEAN's total primary energy supply by 2025. In REmap, around 60% of this total would be considered modern forms of bioenergy, with the remainder traditional uses of bioenergy. But bioenergy has a wide range of applications, including electricity generation, industrial process heat, space heating and cooking in buildings, and liquid biofuels for transport.

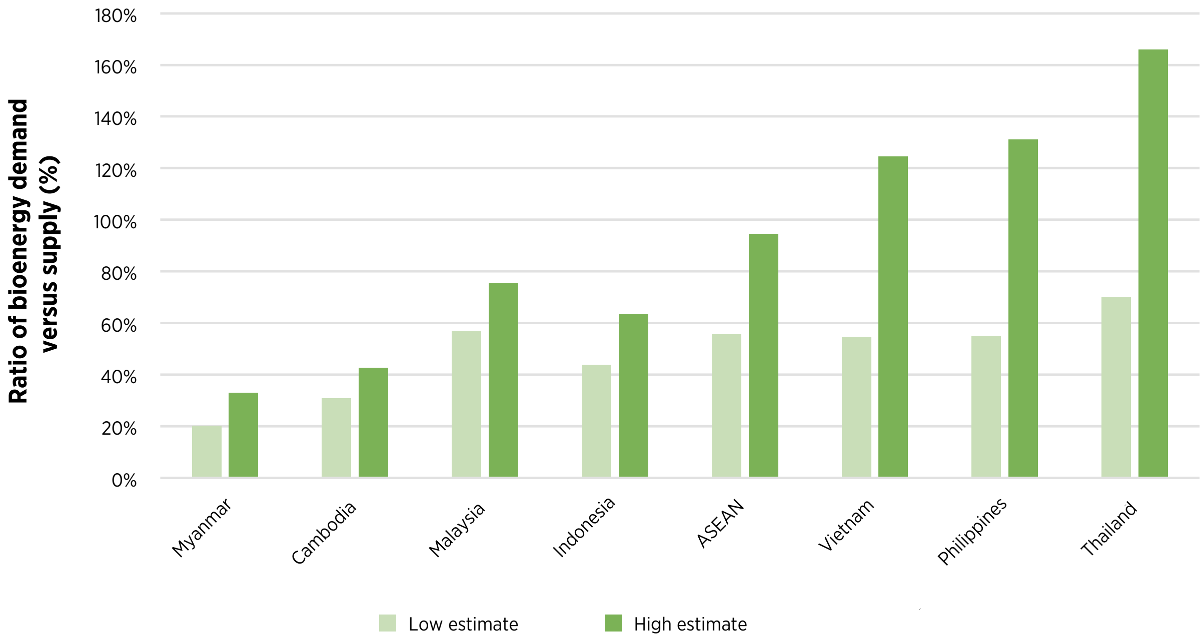
Total demand for primary biomass would reach 146 Mtoe per year in REmap by 2025 (see Figure 26). This compares with a total supply potential of 155-265 Mtoe per year in 2025, according to an assessment

Figure 26: Total demand for primary biomass in ASEAN, 2025



Note: units in Mtoe

Figure 27: Demand vs supply ratio of biomass in select ASEAN Member States, 2025



Note: Brunei Darussalam, Lao PDR and Singapore have been excluded from the graph, either because of limited data or no demand or supply.

by IRENA (IRENA, 2014b). This assessment considers bioenergy from farm and forest residues, industrial and municipal waste, and traditional bioenergy crops. However it does not include additional energy crops on land that could be made available by raising food crop yields, reducing waste and losses in the food chain, or restoring degraded land to production – all of which would increase supply.

According to Figure 27, there would be sufficient biomass feedstocks in all ASEAN Member States to meet demand, when compared to the high-end of the supply potential in IRENA's supply assessments (IRENA, 2014b). A few countries might reach the limits of their supply potential if only the low end of the base supply assessment is considered. This potential can be sustainably raised through a number of strategies and guidelines. These would increase the efficient use of land and make more land available without adverse environmental, social and economic effects on local communities and their ecosystems. These strategies include the systematic collection of agricultural residues, planting of grasses and trees on land freed up by more intensive cultivation of croplands, and reduced waste and losses in the food chain. This should be coupled with sustainable forest management and efficient biofuel conversion technologies.

Accelerating yield growth by promoting research and development and expanding the use of modern agricultural practices should make it possible to grow the same amount of food on less land. Intensified agricultural extension services in rural communities could help close the gap between projected and potential yields, which remains substantial for many crops. Farmland needed for food production could also be reduced by curtailing waste and losses in the food chain (considering losses in production, post-harvesting handling and storage, processing and packaging, retail market distribution, and consumption), which, according to the Food and Agriculture Organization of the United Nations (FAO), amount to 32% of food produced in South and Southeast Asia (FAO, 2011).

The supply potential identified in IRENA's bioenergy working paper (IRENA, 2014b) does not consider several practices that could increase sustainable bioenergy supply. Based on a forthcoming analysis, the low end of supply estimates will be increased, thereby decreasing the utilisation share for supply potential (see IRENA, forthcoming).

BOX 5: A VIEW TO 2030 FOR RENEWABLE ENERGY

REmap assesses renewable energy developments to 2030. This timeframe is consistent with the one set forth for the UN Secretary General's SEforALL initiative, and the achievement of the Sustainable Development Goals. IRENA is the hub for the SEforALL renewable energy objective. Its REmap programme aims to operationalise that objective, through country engagement, the REmap Global Reports released every two years (IRENA, 2014c, 2016a), and REmap's contribution to the biannual Global Tracking Framework (SEforALL, 2013, 2016). In addition to a 2025 analysis for ASEAN, IRENA also conducted an analysis to 2030. While this report focuses on 2025, to address ASEAN's own target for that year, it is valuable to look ahead to 2030 as well.

Renewable energy potential and growth is expected to continue accelerating after 2025, due to increasing local technical capabilities and expertise on renewable energy technologies. The improving economics of many of these technologies will also boost renewables.

Across the ASEAN region energy demand will increase 80% by 2030 over 2014 levels. CO_2 emissions from energy will grow by 83% in REmap, but by significantly less than the 110% in the Reference Case by 2030. That slowdown is due to rapidly increasing renewable energy shares over the 2025-2030 period. The share of renewable energy in TPES will increase to 29%, and the share of renewable power generation will also increase by a similar amount to almost 40%. The end-use sectors will also see strong growth, with the buildings sector seeing the largest, as all remaining forms of traditional uses of bioenergy are phased out.

On a country level, the renewable energy share in TPES also increases significantly (Table 9). Countries that completely phase out traditional uses of bioenergy, such as Cambodia, Indonesia and Myanmar, see their shares rise the most. In six countries, renewable energy will provide more than one-third of primary energy demand. Overall, the ASEAN region will reach a nearly 30% renewable energy share in TPES, essentially a tripling of the modern renewable energy share over 2014 levels.

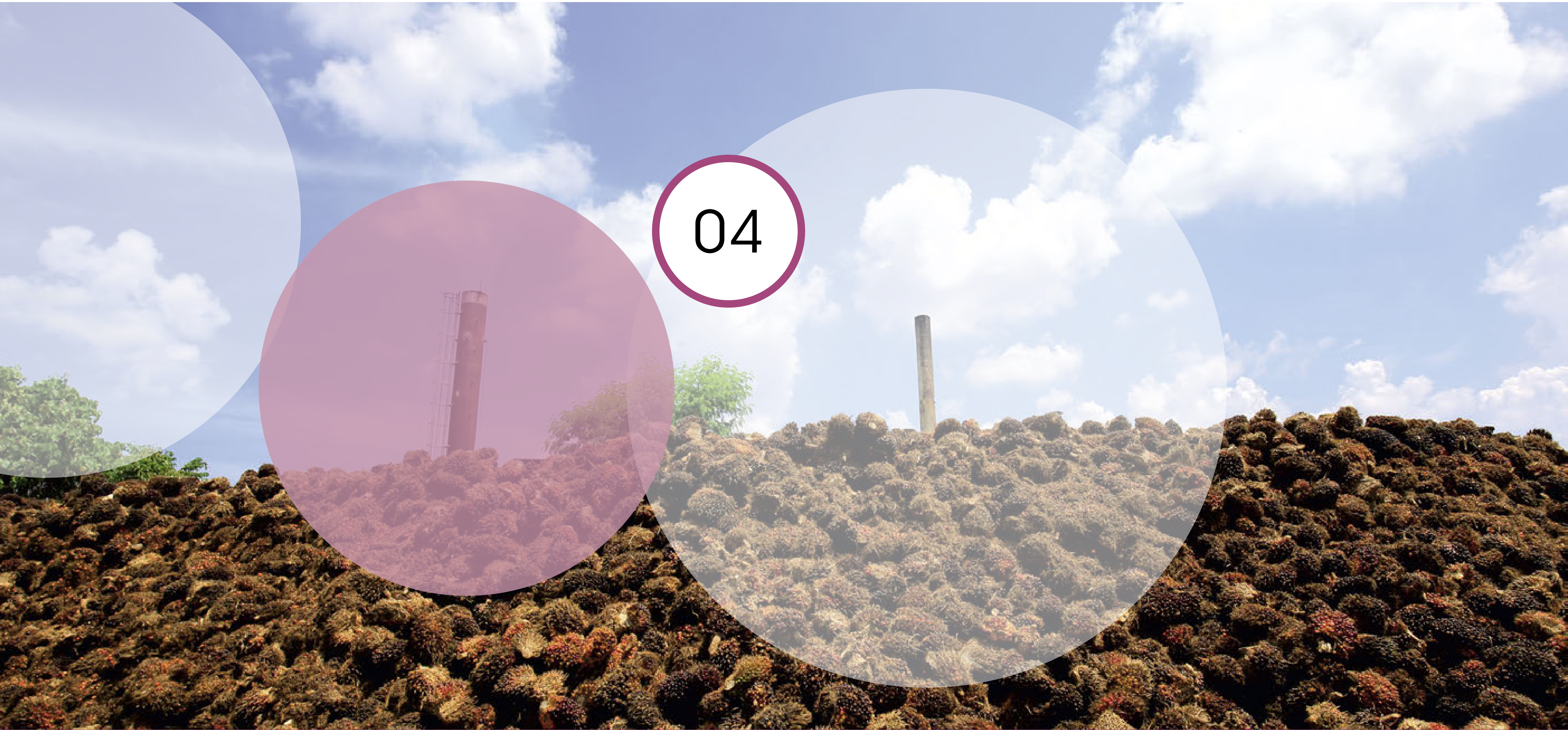
Table 8: Key indicators and shares in ASEAN, 2025 and 2030

ASEAN		
Growth over 2014	**REmap 2025**	**REmap 2030**
TPES	+45%	+80%
CO_2	+47%	+83%
Renewable energy shares		
TPES	23%	29%
Power generation	35%	39%
Buildings	26%	39%
Transport	9%	12%
Industry	23%	26%

Table 9: Renewable energy shares in TPES in ASEAN Member States, 2025 and 2030

	REmap 2025	**REmap 2030**
Renewable energy share in TPES		
ASEAN	23%	29%
Brunei Darussalam	4%	7%
Cambodia	35%	44%
Indonesia	36%	31%
Lao PDR	59%	61%
Malaysia	14%	22%
Myanmar	29%	46%
Philippines	41%	47%
Singapore	3%	4%
Thailand	24%	33%
Vietnam	15%	17%

COSTS, BENEFITS AND INVESTMENT NEEDS OF RENEWABLES



The previous sections provided an overview of the potential of accelerated renewable energy uptake and discussed the technologies needed across all energy sectors. This section outlines the associated costs and benefits of higher renewables deployment, and discusses the level of investment that would be required.

REmap assesses costs and benefits using an internally developed tool, and provides a perspective based on a variety of indicators[6]. These include:

- A substitution approach, detailing if there is an incremental cost or saving from a renewable energy technology compared to a substituted conventional technology. This view looks only at the associated cost of energy service, *i.e.* the relative cost of providing the same amount of energy from a renewable technology versus a conventional one. It does not assess savings from reduced external costs.
- An external cost assessment approach that values reductions in air pollution and CO_2.
- An assessment of the level of investment needed to deploy all the renewable energy capacity outlined in the Reference Case and the REmap options.

6 For an overview of the key indicators and methodology, please see Annex E, for more information about the costing methodology used by REmap please see (IRENA, 2014a)

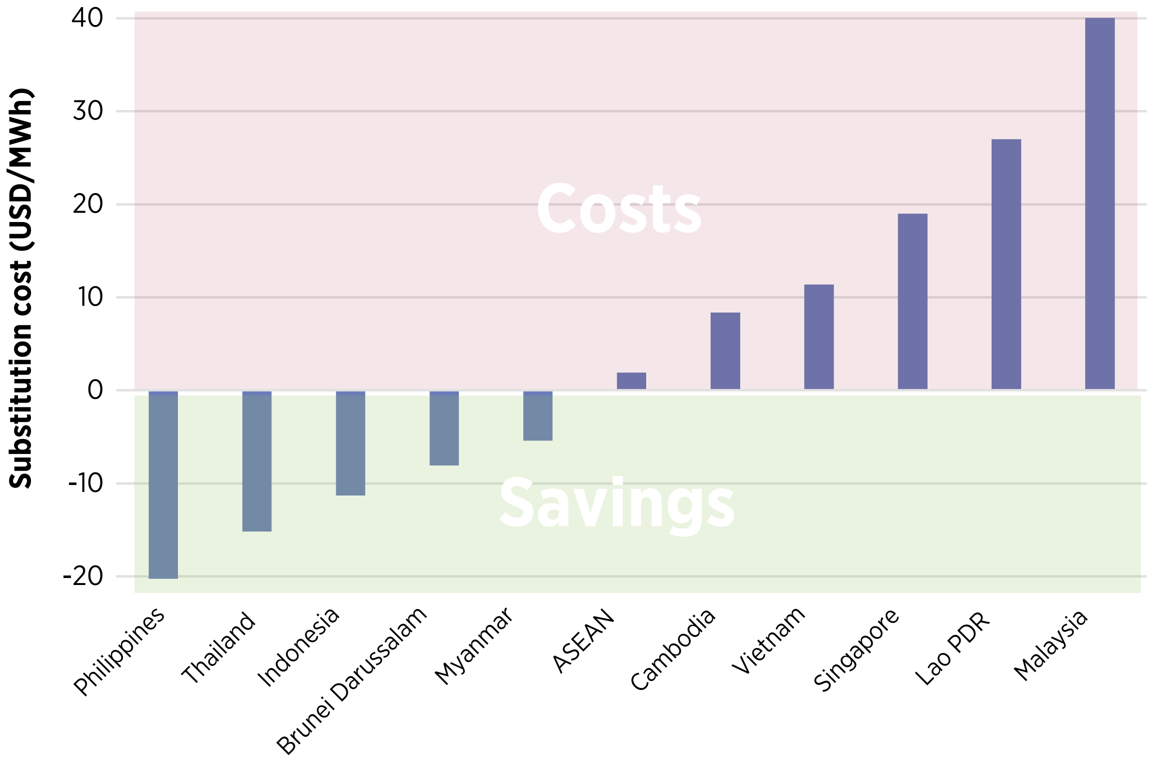
SUBSTITUTION COSTS

- **The portfolio of renewable options needed to increase the renewable energy share from the Reference Case level of just under 17% to ASEAN's 23% target would result in an incremental cost of only USD 1.9 per MWh of final renewable energy. This is the annualised cost of all REmap Options relative to the costs of the non-renewable energy technologies they substitute.**
- **This marginal additional cost comes with multiple benefits. One of them is the reduction of ASEAN's fossil fuel energy bill that could lower expenditure on fuels by USD 40 billion by 2025.**

The substitution cost compares the relative attractiveness of renewable energy technologies to conventional variants. These conventional variants are technologies that exist in the Reference Case and are replaced by renewable technologies in the REmap assessment (REmap Options). Substitution cost therefore measures the relative cost or savings of this substitution. It can be shown at the individual technology level (through the use of technology cost supply curves), or at the sector or country level. This section presents the costs of the REmap Options by country, and overall in ASEAN by both technology and sector.

A variety of factors can affect the substitution cost. These include the capital cost of technologies, their performance characteristics, the assumed discount rate (weighted average cost of capital) and fuel costs. The cost is also driven by the type of conventional technology substituted, *i.e.* if low-cost coal is substituted by oil, the substitution cost of replacing coal will likely be higher. Also another important driver is whether many cheaper renewables have already been deployed in the Reference Case, leaving costlier choices for the REmap Options. Finally, some sectors are generally more cost-competitive than others.

Figure 28: REmap Options substitution cost by country from the government perspective



If one country has significant potential in a costlier sector, its overall substitution cost will increase.

The technologies identified in the REmap Options to help ASEAN achieve its 23% goal are generally very cost-competitive. The substitution cost for all options across all countries is only USD 1.9 per MWh of final renewable energy (Figure 28). However, this cost differs by country for various reasons.

On the low end are countries like the Philippines, which has abundant geothermal and solar resources and limited domestic fossil fuel supply. Thailand is similar, with its heavier emphasis on bioenergy (in particular biogas). Indonesia has high solar and geothermal resources, but also ample coal supply, and therefore a lower substitution cost. In Brunei Darussalam, oil is generally substituted (which has a higher fuel cost than coal or natural gas), resulting in substitution savings.

Countries with positive substitution costs also have a variety of drivers. Some, like Cambodia, Vietnam and Lao PDR, have large amounts of traditional uses of bioenergy as a share of the REmap Options. These are costlier to replace with modern bioenergy, but their replacement offers significant external benefits as further detailed below. These countries also tend to have very high shares of renewable power already in their Reference Cases, which means greater emphasis on technologies in the end-use sectors that are more expensive than renewable power. The two countries with the highest substitution costs are Malaysia, which has an ample supply of fossil fuels and significant transport sector options (generally more expensive than renewables for power or heat), and Singapore, which has very limited national resources and a significant focus on transport and industry. It is important to note that for all these countries there are technologies that result in cost savings and have negative substitution costs. Importantly, the substitution cost indicator does not include reduced externalities, which are significant in most cases. More information on the individual competitiveness of technologies at the country level can be found in Annex A and the individual country cost-supply curves.

Table 10 also provides another important result of the REmap options. It shows the changes in fuel expenditures when more renewable energy is deployed. The REmap Options replace mostly fossil fuels, which could reduce the annual fuel bill across the region by USD 40

Table 10: Change in fuel cost expenditures by 2025 due to REmap Options

	(USD bln/yr)
Fossil fuels, all	-40
Liquid biofuels, all	13

billion by 2025. Some expenditure is redirected to renewable fuels, which can only be bioenergy-based fuels. Spending on these would increase by USD 13 billion annually by 2025. The remainder is savings from renewable sources that have no fuel, such as solar, geothermal, and wind.

BENEFITS RELATING TO AIR POLLUTION AND CO_2

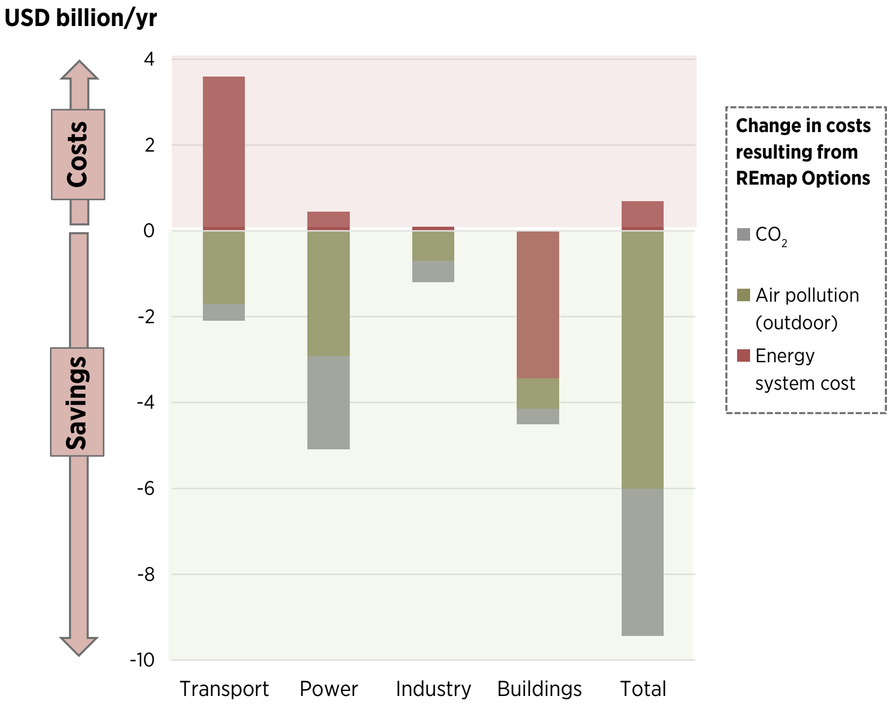
- **Reduced externalities from lower levels of outdoor air pollution and CO_2 emissions result in savings at least 10 times higher than the incremental cost of the REmap Options. If costs from indoor air pollution are included, savings increase significantly.**
- **The power sector plays the key role in realising these reductions, as with the savings from air pollution and CO_2 emission reductions. The transport sector is also an important source of savings from lower levels of air pollution in cities.**

The substitution costs presented in the previous section exclude savings related to reduced externalities that result when fossil fuels and traditional uses of bioenergy are substituted. Figure 29 shows these savings across the region as a whole compared to substitution costs. It shows how the technologies grouped by sector will affect the annual system cost in 2025 (resulting in either incremental costs or savings) and the amount of reduced externalities from those renewable technologies.

A few general drivers can shed light on sector-level competitiveness. The effect of the REmap Options on the entire energy system cost is marginal, at an incremental cost of USD 0.7 billion per year by 2025 (or as shown in the previous section just USD 1.9 per MWh). This varies at the sector level. The power sector results in a marginal cost of USD 0.4 billion per year because many renewable power technologies are highly competitive. The same is the case for industry, which generally fares well on costs due to the availability of bioenergy residues and biogas, and solar thermal for limited uses. The transport sector has the highest costs, due to the significant amount of electric mobility required, including electric vehicles and forms of modal shift, both of which result in additional costs to the energy system. The additional costs from the transport sector are offset by the building sector, which deploys highly competitive technologies such as solar thermal and biogas. Next to transport, the building sector is most likely to offset costs from LPG or other oil products.

These system costs do not take into account reduced externalities, as can also be seen in Figure 29. These reduced externalities are the result of lower levels of outdoor air pollution and CO_2, which improves human health and the local environment. Air pollution is a cause of ill health, particularly in cities, and also hurts crops. REmap assesses both outdoor and indoor air pollution. CO_2 is assessed using a social

Figure 29: Energy system costs and reduced externalities relating to REmap Options, by sector



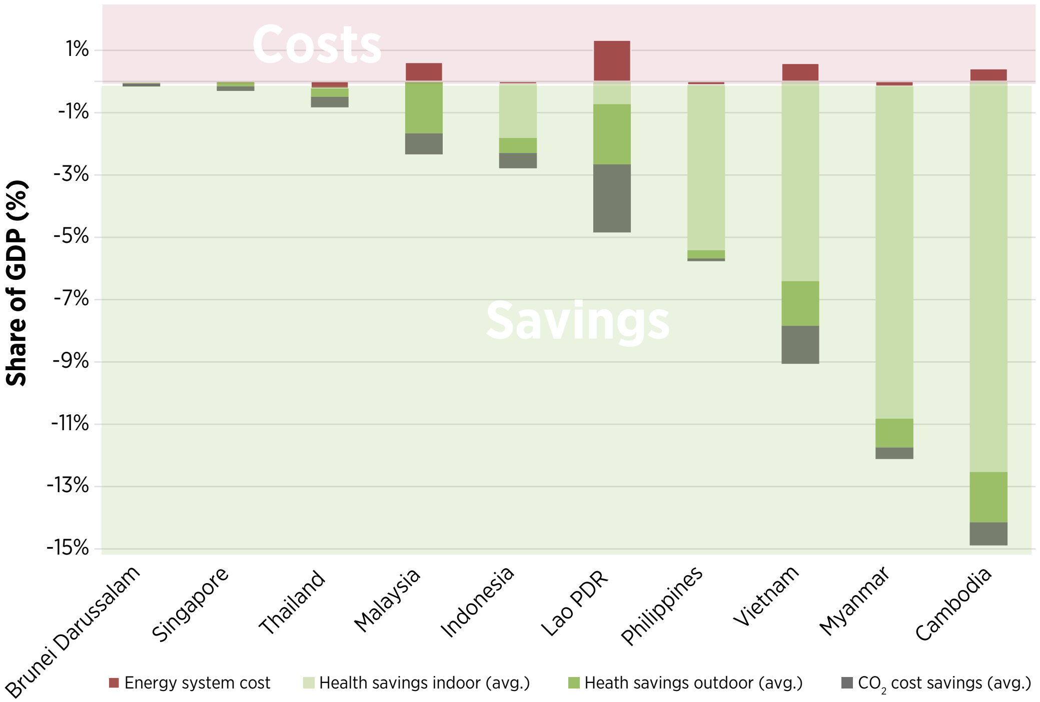
Note: Assumes low-end estimates for externalities for outdoor air pollution and CO_2, indoor air pollution excluded from figure

cost of carbon ranging from USD 17 to USD 80 per tonne of CO_2. The figure provides important conclusions about the how much the various sectors reduce external costs. The power sector contributes equally to the reduction in costs associated with air pollution and CO_2. This is because the fossil fuel technologies (coal) being substituted have a high CO_2 intensity. The same can be stated in the case of industry. The transport sector has a larger share of external cost reductions, mainly from air pollution, because most substituted technologies are internal combustion engine vehicles operating in cities, where pollution damages are high.

In all sectors lower externalities significantly outweigh system costs. For outdoor air pollution alone, savings from reduced externalities are higher than costs. This is also the case if only looking at CO_2-related externalities. Combining both outdoor air pollution and CO_2 results in savings for all renewable technologies that at least 10 times higher than the incremental cost of the REmap Options. But this isn't the full picture. Very large additional savings come from reduced externalities from indoor air pollution (caused by the combustion of fuels, mostly traditional bioenergy, for cooking or water heating). If these were included, then the REmap Options would result in average savings as high as 50 times costs. Therefore, savings are equal to between 0.2% and 1.0% of ASEAN's GDP in 2025. These assessments are also only based on the low-end calculations for external cost reductions. If the high end is assumed, savings as a share of GDP could be over 2.0%.

The effect on individual countries is similarly striking (Figure 30). The figure shows the substitution cost by country, annualised and then compared to share of GDP. Whereas Figure 28 shows the costs per unit, and Figure 29 shows total costs, this figure shows how these totals compare to country GDP in 2025. The cost effect of the REmap Options to the energy system ranges from a savings of 0.05%-0.22% of GDP, to incremental costs of 0.01%-1.3% of GDP. But savings from reduced externalities relating to air pollution and CO_2 far outweigh these costs in all countries. This is the case for outdoor air pollution alone, and also if only CO_2 is considered. Considering indoor air pollution reveals even more significant savings, such as for Indonesia, Lao PDR, the Philippines, Vietnam, Myanmar and Cambodia – countries with traditional uses of bioenergy. However you measure it, the reduced externalities outweigh costs.

Figure 30: Cost and savings of REmap Options, share of GDP in 2025

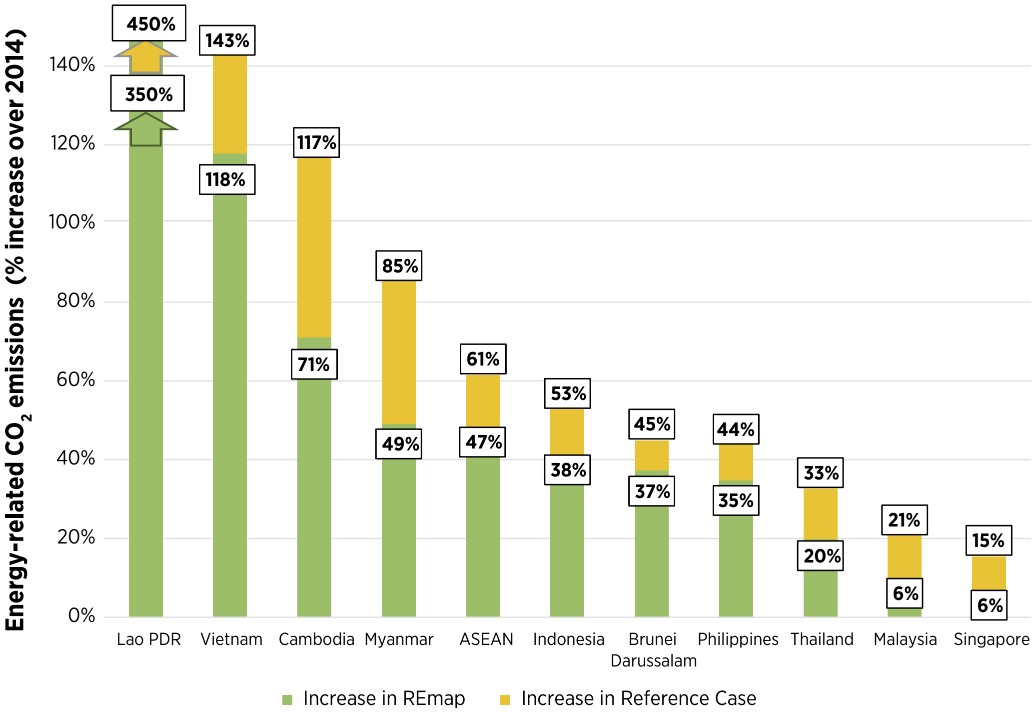


Note: Assumes average estimates for externalities

CHANGES IN CO_2 EMISSIONS

- **CO_2 emissions from energy will rise by 61% in the Reference Case. The REmap Options and closing the gap to ASEAN's renewable energy target will limit this rise to 47%.**
- **The energy intensity of the region's economy will decline by around 30% by 2025 over 2005 levels, broadly in line with the region's targets for energy intensity improvement.**

Figure 31: CO_2 emissions from energy, increases in Reference Case and REmap in 2025



Note: The figure has been scaled for presentation purposes. Lao PDR emission growth is 450% in the Reference Case, and 350% in REmap.

Due to the significant growth in energy demand across the region, all ASEAN Member States see CO_2 emissions growing, especially as energy growth is driven by both the power generation sector and industry. CO_2 emissions will increase by 61% by 2025 in the Reference Case, but the REmap Options would restrain this rise at 47% (Figure 31). Countries that are also expected to see the largest per capita growth in energy demand, such as Lao PDR, Vietnam, Cambodia and Myanmar, all see

BOX 6: ENERGY EFFICIENCY AND ENERGY INTENSITY IMPROVEMENT

The ASEAN region is expected to reduce the overall energy intensity of their economies. Energy intensity measures of the amount of energy required to produce a given unit of economic activity, for instance the tonnes of oil equivalent (toe) per million USD (in purchasing power parity). The ASEAN Plan of Action for Energy Cooperation (APAEC) targets a reduction of energy intensity in ASEAN of 20% in 2020 and 30% in 2025, based on the 2005 level.

The 2005 level of energy intensity was 133 toe per million constant 2005 USD. The Reference Case already makes advances toward this, and by 2025 it will be reduced to 92 toe per million USD – a reduction of 30% over 2005 and broadly consistent with the APAEC goal. The REmap Options focus on increasing the renewable energy share, and are not explicitly energy efficiency options, but there are some synergies between renewable deployment and increased energy efficiency (see (IRENA and C2E2, 2015). The result is that in REmap in 2025, energy intensity would fall further to 91 toe per million USD. By 2030 in the Reference Case, the intensity would fall even further, to 86 toe per million USD, a 35% reduction over 2005 levels, and in REmap to 83 toe per million USD, a 38% reduction over 2005 levels.

Therefore, some improvement in energy efficiency can be achieved through higher deployment of renewables, but the major advances will need to be made through traditional approaches to reducing energy demand.

emissions double or more in the Reference Case, but from a low starting point. The more developed countries, such as Malaysia, Singapore, Thailand, and Brunei Darussalam, see lower emissions growth of 15%-45% but start from higher levels. The REmap Options would cut CO_2 over the Reference Case by as much as 40% for Cambodia, Myanmar, Singapore and Thailand, and on the lower end, by 17-20% in some countries. Across the ASEAN region the average reduction is 23%.

INVESTMENT NEEDS TO CLOSE THE GAP

- **The ASEAN region will need to invest an average of 1% of its GDP annually (USD 27 billion), a total of USD 290 billion by 2025, in renewable energy capacity in order to meet the 23% renewable energy goal. Just under half of this will be investment that takes place in the Reference Case, and the remainder will come from the REmap Options.**
- **The power sector will consume 75% of the investment volume needed to boost capacity. USD 7.5 billion per year must be invested in solar PV, and USD 6.3 billion in hydropower. The building and industry sectors will require around USD 7 billion annually in investment, focused largely on bioenergy and solar thermal.**

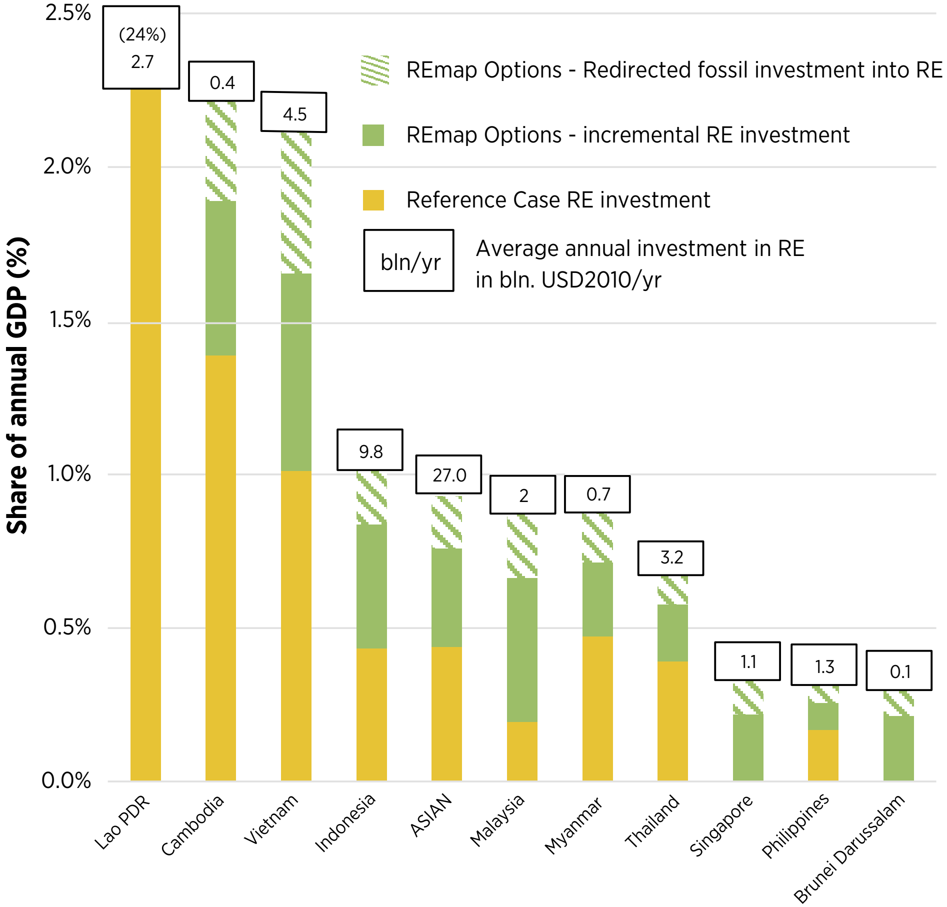
Significant investments are required in the energy system across the ASEAN region due to the rapidly increasing demand for energy. Investments are required across the entire energy system, in electricity generation, transmission, capacity for heating, cooling and cooking, and the transport sector.

To reach ASEAN's 23% renewables goal by 2025 will require an estimated total investment over the period of USD 290 billion in renewable energy capacity. This would be an estimated annual investment in of approximately USD 27 billion per year between now and 2025. To put this in perspective, this is around 10% of the total investment in renewable energy that took place globally in 2015.

The USD 27 billion would be broken down into investments in renewable energy capacity of USD 13 billion per year on average in the Reference Case, with the REmap Options requiring an additional USD 14 billion annually. However, not all of the investment resulting from the REmap Options is additional. The REmap Options redirect investments of around USD 5 billion annually from fossil fuel technologies into renewables. Therefore, the additional investment required on top of the Reference Case would be around USD 9 billion annually. This higher investment need relates to the higher capital cost of many renewable technologies. However, all except bioenergy-based technologies require no fuel costs.

Indonesia, Vietnam and Thailand would account for two-thirds of the total ASEAN investment needs in renewable energy capacity between 2014 and 2025. Comparing investment to GDP shows how big they are relative to a country or region's economy. The average annual total investment needs for renewable energy capacity between 2014 and 2025 will be around 1% of ASEAN's total GDP. Around 45% of this is investment that would be made in the Reference Case. The additions from the REmap Options make up the remaining share, but 35% is new investment and 20% is investment that would be required for fossil fuels but instead is redirected to renewable energy. The share of investment relative to GDP differs per country, from as high as 2.5% for

Figure 32: Annual renewable energy investment needs to 2025



Note: Lao PDR's includes significant investment in large hydropower in the Reference Case with the intent for much of the electricity for export. The share of annual GDP is based on the period average from 2014-2025.

Lao PDR (with low GDP per capita today) to as low as 0.3% for Brunei Darussalam, which benefits from its existing hydrocarbon industry. It should be noted that the investment figures listed above focus on the supply side and do not include investment in complementary infrastructure.

Table 11 shows the investment needs by technology and sector for the ASEAN region as a whole. About 25% of investment in renewable capacity (USD 7 billion per year) is in the heating sector (industry and buildings). Around USD 1.7 billion is investment redirected from fossil fuel heating capacity. In the industry sector, bioenergy-based heating technologies dominate, with almost USD 5 billion per year. But around USD 1 billion per year will still need to be invested in solar thermal technologies. In the building sector the majority of investment goes to solar thermal hot water, and only a small amount to modern bioenergy.

The power sector sees 75% of investment flows into capacity. Investments are split into those for solar PV (USD 7.5 billion per year), hydropower (USD 6.3 billion per year, but most occurring already in the Reference Case) and biofuel power (USD 5.3 billion per year). Wind is also important, but much less than other technologies, with total investment needs of USD 2.5 billion per year. Investment in natural gas and nuclear-based generation capacity remains almost the same in REmap, but investment in coal-based generation declines significantly, from USD 2.5 billion per year to zero.

Assessing capital investment in capacity for the power, industry and buildings sectors is straightforward, but for the transport sector this is more complex. The investment figures discussed so far do not include transport sector-related investment. Rather than capacity investments, the sector requires investment in roads or other related infrastructure, for example for EVs or regional mass transit (the assessment of which is outside the bounds of this analysis). REmap does assess investments in liquid fuel production capacity, however. The region sees strong growth in transport fuel production investment in the Reference Case, both for petrol and diesel (USD 31 billion per year), and for liquid biofuels (USD 17 billion per year). The REmap Options reduce investments in petrol and diesel by around USD 5 billion per year, and see a slight uptick in investment in liquid biofuels of around USD 1 billion. But the major driver for reducing investment in petrol and diesel is the significant uptake in electric vehicles. Investment is required in related charging infrastructure, although these have not been quantified (for a discussion on infrastructure investment needs for EVs please see the IRENA working paper "A Renewable Route to Sustainable Transport" (IRENA, 2016e).

Table 11: Technology investment in ASEAN, average between 2014 and 2025

Annual investment in capacity (USD bln/yr)		
Industry	**Reference Case**	**REmap**
Coal boilers	1.2	0.9
NG boiler	0.3	0.3
Biofuel boilers	2.0	4.8
Solar thermal	0.02	0.8
Buildings		
Oil products	0.5	0.5
Modern biofuels	–	0.1
Solar thermal	0.03	1.3
Power		
Coal power plant	2.5	–
NG power plant	3.3	3.2
Nuclear	0.4	0.4
Hydropower	5.8	6.3
Geothermal power	0.1	0.4
Solar PV	1.0	7.5
CSP	–	–
Wind	1.3	2.5
Biofuel power	0.5	5.3
Annual investment in transport fuel production capacity (USD bln/yr)		
Conventional biofuels	16.5	17.5
Advanced biofuels	–	0.1

ACTION AREAS FOR ENABLING ASEAN'S RENEWABLES POTENTIAL

The ASEAN region will experience some of the world's largest growth in energy demand over the next ten years. ASEAN Member States have identified the expansion of renewables as essential to meeting this growing energy demand, in addition to overcoming the related challenges of rising fossil fuel use. Increasing renewable energy will not only improve energy security and help the region meet this demand, but it will be far cheaper than not doing so, as it will significantly reduce air pollution and CO2 emissions. However, countries need to act to make this happen, and it is vital that they cooperate on many levels.

ASEAN has been a successful model for regional cooperation, driving social and economic development over the past half a century. With the establishment of the ASEAN Economic Community (AEC) in 2015, regional ties will be strengthened on all levels of activity in all sectors, particularly the energy sector. Undoubtedly, energy connectivity, sustainability and market integration will be given top priority, with the aim of yielding multiple positive effects from the ASEAN-wide integrated energy system.

Accelerating the deployment of renewable energy technologies is complex, as circumstances in each country differ. There is therefore no single set of solutions suited to the needs of the entire ASEAN region. In view of this regional diversity, four action areas that stem from the REmap analysis are presented below. While they are relevant to the regional energy landscape of ASEAN, they also have implications for specific countries.

Action area 1: increase power system flexibility in the ASEAN region while using renewables to provide modern energy access for all

Transmission and distribution grids across the region must be expanded and strengthened. Fast-growing demand for electricity and higher shares of renewable power, some of it variable, underline the need to ensure grid development and enhancement in order to make power system infrastructure robust and flexible. Also, increasing interconnection capacity between countries and power systems is one of the key measures to improve grid access and system reliability and to accommodate higher shares of variable renewable energy.

It will also be important for ASEAN to develop flexibility measures within individual countries, including flexible thermal capacity, energy storage, demand response and the coupling of power and end-use sectors, such as enabling high use of electricity for transport, heating and cooking.

In places where electrification through conventional methods is difficult, there is a lack of knowledge, awareness, technical expertise and business models for alternatives, particularly renewable-based, decentralised or mini-grid energy systems that are capable of delivering the most cost-effective energy solutions in remote or island areas. ASEAN Member States can also consider renewable-based off-grid electrification to supply electricity more affordably and more quickly than the traditional means of diesel generation or grid-connection.

Action area 2: expand efforts for renewable energy uptake in power but also importantly in the heating, cooking and transport sectors

As shown in the REmap analysis, technologies in the end-use sectors (needed for heating, cooking and transport) make up two-thirds of the capacity needed to meet ASEAN's renewable energy goal. Developing renewables in these sectors will provide a win-win solution by providing modern, clean and affordable energy services. To unlock potential, ASEAN renewable energy technology deployment in the end-uses will need to be complemented with efforts to create awareness among users in these sectors.

Action area 3: create a sustainable, affordable and reliable regional bioenergy market

Bioenergy will continue to play a key role in the region, and ASEAN needs to expand and improve its existing bioenergy market. Demand will need to be facilitated through the development of gradually increasing targets across sectors, subject to country specifics, in order to maximise the sustainable use of bioenergy resources. On the supply side, agricultural resource potential is abundant, but current practices in various parts of the region have shown that sustainability is at stake. Yield improvements and the use of degraded lands alone might not be enough, but deserve more attention. The use of sustainable residues and waste feedstocks should be maximised, but challenges related to the seasonality of supply should be considered in planning. Innovative approaches and technologies on both the supply side and demand side should be included, while the environmental, social, and economic sustainability should be ensured.

Action area 4: address the information challenge by increasing the availability of up-to-date renewable energy data and the sharing of best practice for renewable energy technologies

The knowledge and expertise on renewable energy development differ greatly from country to country. Accurate and up-to-date statistical data and information is important to understand the rapid changes and growth in energy in the ASEAN region. The sharing of this information regionally and monitoring the process is also necessary to understand progress towards the region's renewable energy target.

Additionally, the sharing of best practices for renewable energy deployment and technology will be crucial for the region to maximise its potential in the most cost-efficient manner. Today each ASEAN Member State has an expertise in the deployment of a number of renewable energy technologies. Other countries can benefit from this knowledge to accelerate their own deployment. Member States should share more of this information among its countries, but also with those from outside ASEAN borders.

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LIST OF ABBREVIATIONS

ACE	ASEAN Centre for Energy
AEC	ASEAN Economic Community
AEO4	4th ASEAN Energy Outlook
AMEM	ASEAN Ministers on Energy Meeting
AMS	ASEAN Member States
APAEC	Plan of Action for Energy Cooperation
APS	Advancing Policies Scenario
ASEAN	Association of Southeast Asian Nations
ASEAN-RESP	Renewable Energy Support Programme for ASEAN
EVs	electric four-wheel vehicles
GDP	gross domestic product
GHG	greenhouse gas
Gt	gigatonnes
GW	gigawatts
IRENA	International Renewable Energy Agency
kWh	kilowatt-hour
LCOE	levelised cost of electricity
LCOH	levelised cost of heat
LPG	liquefied petroleum gas
Mtoe	million tonnes of oil equivalent
MWh	megawatt-hour
PV	photovoltaics
RE	renewable energy
SEforALL	Sustainable Energy for All initiative
TFEC	Total Final Energy Consumption
toe	tonnes of oil equivalent
TPES	Total Primary Energy Supply
TWh	terawatt-hours
UN	United Nations
yr	year

ANNEX A:

COUNTRY OVERVIEW TABLES

A

ASEAN

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	GW	**195**	**387**	**422**
		Renewable capacity	GW	50.9	123.9	180.2
		Hydropower (excl. pumped hydro)	GW	39.0	79.3	82.3
		Wind	GW	0.5	6.3	12.0
		Biofuels (solid, liquid, gaseous)	GW	6.4	13.4	18.0
		Solar PV	GW	1.6	12.8	54.7
		CSP	GW	0.0	0.0	0.0
		Geothermal	GW	3.4	9.6	10.6
		Marine, other	GW	0.0	2.5	2.6
		Non-renewable capacity	GW	144.0	263.1	242.2
		Total electricity generation	TWh	**856**	**1 656**	**1 674**
		Renewable generation	TWh	173.3	453.8	580.3
		Hydropower	TWh	128.8	288.9	302.7
		Wind	TWh	0.6	24.3	39.8
		Biofuels (solid, liquid, gaseous)	TWh	22.0	53.8	80.8
		Solar PV	TWh	1.6	18.6	80.7
		CSP	TWh	0.0	0.0	0.0
		Geothermal	TWh	20.3	59.4	66.8
		Marine, other	TWh	0.0	8.9	9.4
		Non-renewable generation	TWh	682.5	1201.9	1093.7
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	Mtoe	**217**	**284**	**267**
		Direct uses of renewable energy	Mtoe	93.6	88.6	85.3
		Solar thermal – Buildings	Mtoe	0.0	0.2	4.0
		Solar thermal – Industry	Mtoe	0.0	0.1	3.2
		Geothermal (Buildings and Industry)	Mtoe	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	Mtoe	76.3	56.8	33.4
		Bioenergy (modern) – Buildings	Mtoe	1.0	2.2	10.7
		Bioenergy – Industry	Mtoe	16.4	29.2	33.9
		Non-renewable – Buildings	Mtoe	21.5	37.5	31.2
		Non-renewable – Industry	Mtoe	101.6	158.3	150.7
		Non-renewable – BF/CO	Mtoe	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	Mtoe	**133**	**190**	**184**
		Liquid biofuels	Mtoe	3.5	14.9	15.9
		Biomethane	Mtoe	0.0	0.0	0.0
		Non-renewable fuels	Mtoe	129.1	175.5	168.3
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**416**	**595**	**573**
Total primary energy supply			***Mtoe***	**634**	**952**	**929**
RE shares		RE share in electricity generation		20%	27%	35%
		RE share in Buildings – final energy use, direct uses (modern)		1%	3%	19%
		RE share in Industry – final energy use, direct uses		14%	16%	20%
		RE share in Transport fuels		3%	8%	9%
		Share of modern RE in TFEC		**8%**	**13%**	**19%**
		Share of modern RE in TPES		**9.4%**	**16.9%**	**23.2%**
Financial indicators		System costs (USD bln/yr in 2025)		N/A	N/A	0.7
		RE investment needs (USD bln/yr annually (2015-2025))		N/A	13	27
		Investment support for renewables (USD bln/yr in 2025)		N/A	N/A	5.3
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		N/A	N/A	13.0
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		N/A	N/A	11.3
		CO_2 emissions from energy (Mt/yr)		1 359	2 194	1 996

BRUNEI DARUSSALAM

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**0.9**	**1.1**	**1.3**
		Renewable capacity	*GW*	0.0	0.0	0.3
		Hydropower (excl. pumped hydro)	*GW*	0.0	0.0	0.0
		Wind	*GW*	0.0	0.0	0.0
		Biofuels (solid, liquid, gaseous)	*GW*	0.0	0.0	0.0
		Solar PV	*GW*	0.0	0.0	0.2
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	0.9	1.1	1.0
		Total electricity generation	*TWh*	**4.1**	**5.9**	**6.0**
		Renewable generation	*TWh*	0.0	0.0	0.7
		Hydropower	*TWh*	0.0	0.0	0.0
		Wind	*TWh*	0.0	0.0	0.0
		Biofuels (solid, liquid, gaseous)	*TWh*	0.0	0.0	0.2
		Solar PV	*TWh*	0.0	0.0	0.4
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	4.1	5.9	5.3
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**0.1**	**0.4**	**0.4**
		Direct uses of renewable energy	*Mtoe*	0.0	0.0	0.0
		Solar thermal – Buildings	*Mtoe*	0.0	0.0	0.0
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.0
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	0.0	0.0	0.0
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.0	0.0
		Bioenergy – Industry	*Mtoe*	0.0	0.0	0.0
		Non-renewable – Buildings	*Mtoe*	0.0	0.0	0.0
		Non-renewable – Industry	*Mtoe*	0.1	0.3	0.3
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**0.5**	**0.5**	**0.5**
		Liquid biofuels	*Mtoe*	0.0	0.0	0.0
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	0.5	0.5	0.5
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**0.9**	**1.4**	**1.4**
Total primary energy supply			***Mtoe***	**3.2**	**4.0**	**4.1**
RE shares		RE share in electricity generation		0.0%	0.4%	10.9%
		RE share in Buildings – final energy use, direct uses (modern)		0.0%	0.0%	5.9%
		RE share in Industry – final energy use, direct uses		0.0%	0.0%	11.6%
		RE share in Transport fuels		0.0%	0.0%	0.1%
		Share of modern RE in TFEC		**0.0%**	**0.2%**	**6.9%**
		Share of modern RE in TPES		**0.0%**	**0.2%**	**4.5%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	-0.01
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	0	0.06
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.02
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	0.01
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	0.02
		CO_2 emissions from energy (Mt/yr)		5	7	6.5

CAMBODIA

Section	Sub-sector	Indicator	Unit	2014	Reference Case 025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**1.7**	**3.5**	**4.2**
		Renewable capacity	*GW*	1.1	2.6	3.5
		Hydropower (excl. pumped hydro)	*GW*	1.1	2.6	2.6
		Wind	*GW*	0.0	0.0	0.2
		Biofuels (solid, liquid, gaseous)	*GW*	0.0	0.0	0.1
		Solar PV	*GW*	0.0	0.0	0.7
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	0.5	0.9	0.7
		Total electricity generation	*TWh*	**3.8**	**11.5**	**12.0**
		Renewable generation	*TWh*	1.9	7.1	9.1
		Hydropower	*TWh*	1.9	7.1	7.1
		Wind	*TWh*	0.0	0.0	0.5
		Biofuels (solid, liquid, gaseous)	*TWh*	0.0	0.0	0.2
		Solar PV	*TWh*	0.0	0.0	1.2
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	1.9	4.3	2.9
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**3.8**	**3.9**	**2.9**
		Direct uses of renewable energy	*Mtoe*	3.6	3.5	2.6
		Solar thermal – Buildings	*Mtoe*	0.0	0.0	0.0
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.0
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	2.7	2.6	1.2
		Bioenergy (modern) – Buildings	*Mtoe*	0.2	0.2	0.7
		Bioenergy – Industry	*Mtoe*	0.7	0.7	0.7
		Non-renewable – Buildings	*Mtoe*	0.1	0.2	0.2
		Non-renewable – Industry	*Mtoe*	0.1	0.2	0.1
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**1.2**	**2.4**	**2.3**
		Liquid biofuels	*Mtoe*	0.0	0.0	0.1
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	1.2	2.4	2.2
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**5.4**	**7.6**	**6.2**
Total primary energy supply			***Mtoe***	**6.0**	**8.8**	**7.5**
RE shares		RE share in electricity generation		50%	62%	76%
		RE share in Buildings – final energy use, direct uses (modern)		8%	8%	34%
		RE share in Industry – final energy use, direct uses		91%	81%	87%
		RE share in Transport fuels		0%	0%	5%
		Share of modern RE in TFEC		**21%**	**20%**	**37%**
		Share of modern RE in TPES		**19%**	**18%**	**35%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	0.1
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	0.3	0.4
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.2
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	0.3
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	0.2
		CO_2 emissions from energy (Mt/yr)		6	13	11

INDONESIA

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**57.6**	**130.5**	**149.5**
		Renewable capacity	*GW*	8.4	45.2	74.6
		Hydropower (excl. pumped hydro)	*GW*	5.3	21.0	21.8
		Wind	*GW*	0.0	1.8	2.9
		Biofuels (solid, liquid, gaseous)	*GW*	1.7	8.6	9.5
		Solar PV	*GW*	0.0	6.5	31.7
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	1.4	7.2	8.6
		Marine, other	*GW*	0.0	0.1	0.1
		Non-renewable capacity	*GW*	49.2	85.3	74.9
		Total electricity generation	*TWh*	**240.3**	**772.3**	**781.4**
		Renewable generation	*TWh*	29.9	221.0	292.4
		Hydropower	*TWh*	15.2	111.0	117.5
		Wind	*TWh*	0.0	5.1	8.2
		Biofuels (solid, liquid, gaseous)	*TWh*	4.6	41.5	45.8
		Solar PV	*TWh*	0.0	12.4	60.4
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	10.0	50.7	60.3
		Marine, other	*TWh*	0.0	0.3	0.3
		Non-renewable generation	*TWh*	210.4	551.3	489.0
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**105.2**	**91.4**	**90.7**
		Direct uses of renewable energy	*Mtoe*	45.3	12.4	15.8
		Solar thermal – Buildings	*Mtoe*	0.0	0.0	0.0
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.0
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	38.7	0.0	0.0
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.9	2.4
		Bioenergy – Industry	*Mtoe*	6.6	11.5	13.4
		Non-renewable – Buildings	*Mtoe*	9.0	13.7	11.9
		Non-renewable – Industry	*Mtoe*	50.9	65.3	63.0
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**48.8**	**75.9**	**72.7**
		Liquid biofuels	*Mtoe*	1.4	9.6	9.6
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	47.5	66.3	63.1
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**174.8**	**227.1**	**224.2**
Total primary energy supply			***Mtoe***	**233.6**	**387.6**	**352.4**
RE shares		RE share in electricity generation		12%	33%	37%
		RE share in Buildings – final energy use, direct uses (modern)		0%	3%	17%
		RE share in Industry – final energy use, direct uses		12%	14%	17%
		RE share in Transport fuels		3%	13%	13%
		Share of modern RE in TFEC		**6%**	**17%**	**21%**
		Share of modern RE in TPES		**9%**	**23%**	**26%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	-1.0
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	4	10
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.9
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	3.1
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	5.0
		CO_2 emissions from energy (Mt/yr)		584	893	806

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LAO PDR

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**3.1**	**18.1**	**19.2**
		Renewable capacity	*GW*	3.1	14.7	16.3
		Hydropower (excl. pumped hydro)	*GW*	3.1	14.5	14.7
		Wind	*GW*	0.0	0.0	0.0
		Biofuels (solid, liquid, gaseous)	*GW*	0.0	0.1	0.3
		Solar PV	*GW*	0.0	0.0	1.3
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	0.0	3.4	2.9
		Total electricity generation	*TWh*	**15.2**	**84.2**	**84.7**
		Renewable generation	*TWh*	15.2	72.5	76.4
		Hydropower	*TWh*	15.1	72.1	72.6
		Wind	*TWh*	0.0	0.1	0.1
		Biofuels (solid, liquid, gaseous)	*TWh*	0.1	0.3	1.6
		Solar PV	*TWh*	0.0	0.0	2.1
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	0.0	11.6	8.3
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**0.5**	**2.0**	**2.0**
		Direct uses of renewable energy	*Mtoe*	0.1	0.3	0.5
		Solar thermal – Buildings	*Mtoe*	0.0	0.1	0.1
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.1
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	0.1	0.1	0.0
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.1	0.1
		Bioenergy – Industry	*Mtoe*	0.0	0.0	0.3
		Non-renewable – Buildings	*Mtoe*	0.0	0.0	0.0
		Non-renewable – Industry	*Mtoe*	0.4	1.7	1.4
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**0.9**	**2.4**	**2.2**
		Liquid biofuels	*Mtoe*	0.0	0.2	0.3
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	0.9	2.1	1.9
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**1.8**	**5.3**	**4.9**
Total primary energy supply			***Mtoe***	**3.1**	**14.1**	**14.1**
RE shares		RE share in electricity generation		100%	86%	90%
		RE share in Buildings – final energy use, direct uses (modern)		37%	70%	86%
		RE share in Industry – final energy use, direct uses		0%	0%	18%
		RE share in Transport fuels		2%	10%	12%
		Share of modern RE in TFEC		**17%**	**18%**	**28%**
		Share of modern RE in TPES		**46%**	**49%**	**59%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	0.1
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	2	3
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.3
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	0.2
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	0.3
		CO_2 emissions from energy (Mt/yr)		5	25	21

MALAYSIA

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	GW	**30.8**	**47.3**	**52.1**
		Renewable capacity	GW	6.3	10.6	18.3
		Hydropower (excl. pumped hydro)	GW	4.8	8.5	8.5
		Wind	GW	0.0	0.0	0.1
		Biofuels (solid, liquid, gaseous)	GW	1.3	1.7	3.8
		Solar PV	GW	0.2	0.3	5.8
		CSP	GW	0.0	0.0	0.0
		Geothermal	GW	0.0	0.0	0.1
		Marine, other	GW	0.0	0.0	0.0
		Non-renewable capacity	GW	24.5	36.7	33.8
		Total electricity generation	TWh	**143.8**	**164.7**	**168.1**
		Renewable generation	TWh	14.5	31.9	53.6
		Hydropower	TWh	13.5	25.1	25.1
		Wind	TWh	0.0	0.0	0.2
		Biofuels (solid, liquid, gaseous)	TWh	0.9	6.4	19.0
		Solar PV	TWh	0.1	0.4	8.5
		CSP	TWh	0.0	0.0	0.0
		Geothermal	TWh	0.0	0.0	0.8
		Marine, other	TWh	0.0	0.0	0.0
		Non-renewable generation	TWh	129.3	132.7	114.5
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	Mtoe	**11.3**	**14.6**	**14.6**
		Direct uses of renewable energy	Mtoe	1.7	0.8	2.3
		Solar thermal – Buildings	Mtoe	0.0	0.0	0.2
		Solar thermal – Industry	Mtoe	0.0	0.0	0.3
		Geothermal (Buildings and Industry)	Mtoe	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	Mtoe	1.4	0.6	0.6
		Bioenergy (modern) – Buildings	Mtoe	0.3	0.2	0.2
		Bioenergy – Industry	Mtoe	0.0	0.0	1.0
		Non-renewable – Buildings	Mtoe	1.5	1.9	1.6
		Non-renewable – Industry	Mtoe	8.1	11.9	10.7
		Non-renewable – BF/CO	Mtoe	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	Mtoe	**24.3**	**31.7**	**31.1**
		Liquid biofuels	Mtoe	0.0	0.6	1.1
		Biomethane	Mtoe	0.0	0.0	0.0
		Non-renewable fuels	Mtoe	24.3	31.1	30.0
Total final energy consumption (electricity, DH, direct uses)			**Mtoe**	**47.7**	**60.2**	**59.9**
Total primary energy supply			**Mtoe**	**86.4**	**96.8**	**97.8**
RE shares		RE share in electricity generation		10%	19%	32%
		RE share in Buildings – final energy use, direct uses (modern)		10%	6%	15%
		RE share in Industry – final energy use, direct uses		0%	0%	11%
		RE share in Transport fuels		0%	2%	4%
		Share of modern RE in TFEC		**3%**	**5%**	**12%**
		Share of modern RE in TPES		**2%**	**5%**	**14%**
Financial indicators		System costs (USD bln/yr in 2025)		N/A	N/A	1.8
		RE investment needs (USD bln/yr annually (2015-2025))		N/A	0.6	2.9
		Investment support for renewables (USD bln/yr in 2025)		N/A	N/A	2.2
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		N/A	N/A	3.4
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		N/A	N/A	1.6
		CO_2 emissions from energy (Mt/yr)		196	236	208

MYANMAR

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**4.8**	**16.8**	**17.8**
		Renewable capacity	*GW*	3.2	7.1	8.7
		Hydropower (excl. pumped hydro)	*GW*	3.2	6.2	6.2
		Wind	*GW*	0.0	0.0	0.5
		Biofuels (solid, liquid, gaseous)	*GW*	0.0	0.0	0.3
		Solar PV	*GW*	0.0	0.9	1.7
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	1.6	9.7	9.1
		Total electricity generation	*TWh*	**14.2**	**30.9**	**31.3**
		Renewable generation	*TWh*	8.8	18.2	22.2
		Hydropower	*TWh*	8.8	17.2	17.2
		Wind	*TWh*	0.0	0.0	1.1
		Biofuels (solid, liquid, gaseous)	*TWh*	0.0	0.0	1.7
		Solar PV	*TWh*	0.0	0.9	2.2
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	5.3	12.7	9.1
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**12.6**	**13.3**	**9.6**
		Direct uses of renewable energy	*Mtoe*	10.1	9.1	5.8
		Solar thermal – Buildings	*Mtoe*	0.0	0.0	0.1
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.0
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	10.1	9.1	4.4
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.0	1.2
		Bioenergy – Industry	*Mtoe*	0.0	0.0	0.1
		Non-renewable – Buildings	*Mtoe*	1.2	1.8	1.6
		Non-renewable – Industry	*Mtoe*	1.3	2.4	2.3
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**1.7**	**2.8**	**2.7**
		Liquid biofuels	*Mtoe*	0.0	0.0	0.0
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	1.7	2.8	2.7
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**17.6**	**20.2**	**16.2**
Total primary energy supply			***Mtoe***	**17.0**	**20.9**	**18.1**
RE shares		RE share in electricity generation		62%	59%	71%
		RE share in Buildings – final energy use, direct uses (modern)		0%	0%	17%
		RE share in Industry – final energy use, direct uses		0%	0%	5%
		RE share in Transport fuels		0%	0%	1%
		Share of modern RE in TFEC		**11%**	**11%**	**25%**
		Share of modern RE in TPES		**4%**	**7%**	**29%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	-0.1
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	0.4	0.7
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.1
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	0.7
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	0.3
		CO_2 emissions from energy (Mt/yr)		16	29	23

PHILIPPINES

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	GW	**17.9**	**30.7**	**32.8**
		Renewable capacity	GW	5.9	10.0	12.9
		Hydropower (excl. pumped hydro)	GW	3.5	3.8	3.8
		Wind	GW	0.3	0.4	1.1
		Biofuels (solid, liquid, gaseous)	GW	0.1	0.9	1.1
		Solar PV	GW	0.0	1.0	3.0
		CSP	GW	0.0	0.0	0.0
		Geothermal	GW	1.9	3.9	3.9
		Marine, other	GW	0.0	0.0	0.0
		Non-renewable capacity	GW	12.0	20.7	19.9
		Total electricity generation	TWh	**77.3**	**142.6**	**143.4**
		Renewable generation	TWh	19.8	40.6	46.7
		Hydropower	TWh	9.1	14.8	14.8
		Wind	TWh	0.2	0.6	2.2
		Biofuels (solid, liquid, gaseous)	TWh	0.2	2.5	3.8
		Solar PV	TWh	0.0	2.6	5.7
		CSP	TWh	0.0	0.0	0.0
		Geothermal	TWh	10.3	20.1	20.1
		Marine, other	TWh	0.0	0.0	0.0
		Non-renewable generation	TWh	57.5	101.9	96.8
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	Mtoe	**13.4**	**17.0**	**14.7**
		Direct uses of renewable energy	Mtoe	7.4	8.6	6.9
		Solar thermal – Buildings	Mtoe	0.0	0.0	0.2
		Solar thermal – Industry	Mtoe	0.0	0.0	0.2
		Geothermal (Buildings and Industry)	Mtoe	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	Mtoe	5.9	5.8	2.6
		Bioenergy (modern) – Buildings	Mtoe	0.4	0.6	1.6
		Bioenergy – Industry	Mtoe	1.1	2.1	2.3
		Non-renewable – Buildings	Mtoe	2.5	3.2	2.9
		Non-renewable – Industry	Mtoe	3.5	5.3	4.8
		Non-renewable – BF/CO	Mtoe	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	Mtoe	**9.1**	**12.7**	**12.4**
		Liquid biofuels	Mtoe	0.3	1.3	1.4
		Biomethane	Mtoe	0.0	0.0	0.0
		Non-renewable fuels	Mtoe	8.8	11.3	11.0
Total final energy consumption (electricity, DH, direct uses)			**Mtoe**	**28.0**	**39.3**	**36.7**
Total primary energy supply			**Mtoe**	**47.7**	**73.3**	**71.1**
RE shares		RE share in electricity generation		26%	28%	33%
		RE share in Buildings – final energy use, direct uses (modern)		4%	6%	24%
		RE share in Industry – final energy use, direct uses		24%	29%	35%
		RE share in Transport fuels		4%	11%	11%
		Share of modern RE in TFEC		**12%**	**17%**	**24%**
		Share of modern RE in TPES		**25%**	**35%**	**41%**
Financial indicators		System costs (USD bln/yr in 2025)		N/A	N/A	-0.5
		RE investment needs (USD bln/yr annually (2015-2025))		N/A	0.7	1.3
		Investment support for renewables (USD bln/yr in 2025)		N/A	N/A	0.2
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		N/A	N/A	1.1
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		N/A	N/A	0.5
		CO_2 emissions from energy (Mt/yr)		89	128	120

SINGAPORE

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**12.90**	**16.47**	**18.07**
		Renewable capacity	*GW*	0.29	0.56	2.95
		Hydropower (excl. pumped hydro)	*GW*	0.00	0.00	0.00
		Wind (offshore)	*GW*	0.00	0.00	0.27
		Biofuels (solid, liquid, gaseous)	*GW*	0.26	0.35	0.42
		Solar PV	*GW*	0.03	0.21	2.15
		CSP	*GW*	0.00	0.00	0.00
		Geothermal	*GW*	0.00	0.00	0.00
		Marine, other	*GW*	0.00	0.00	0.11
		Non-renewable capacity	*GW*	12.61	15.90	15.12
		Total electricity generation	*TWh*	**48.27**	**64.81**	**64.81**
		Renewable generation	*TWh*	0.92	1.47	6.18
		Hydropower	*TWh*	0.00	0.00	0.00
		Wind	*TWh*	0.00	0.00	0.83
		Biofuels (solid, liquid, gaseous)	*TWh*	0.88	1.18	1.51
		Solar PV	*TWh*	0.04	0.29	3.34
		CSP	*TWh*	0.00	0.00	0.00
		Geothermal	*TWh*	0.00	0.00	0.00
		Marine, other	*TWh*	0.00	0.00	0.50
		Non-renewable generation	*TWh*	47.35	63.34	58.63
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**8.33**	**9.04**	**9.10**
		Direct uses of renewable energy	*Mtoe*	0.00	0.00	0.12
		Solar thermal – Buildings	*Mtoe*	0.00	0.00	0.01
		Solar thermal – Industry	*Mtoe*	0.00	0.00	0.05
		Geothermal (Buildings and Industry)	*Mtoe*	0.00	0.00	0.00
		Bioenergy (traditional) – Buildings	*Mtoe*	0.00	0.00	0.00
		Bioenergy (modern) – Buildings	*Mtoe*	0.00	0.00	0.00
		Bioenergy – Industry	*Mtoe*	0.00	0.00	0.06
		Non-renewable – Buildings	*Mtoe*	0.25	0.32	0.31
		Non-renewable – Industry	*Mtoe*	8.08	8.72	8.67
		Non-renewable – BF/CO	*Mtoe*	0.00	0.00	0.00
	Trans-port	**Total fuel consumption**	*Mtoe*	**2.22**	**2.23**	**1.78**
		Liquid biofuels	*Mtoe*	0.00	0.00	0.00
		Biomethane	*Mtoe*	0.00	0.00	0.00
		Non-renewable fuels	*Mtoe*	2.22	2.23	1.78
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**14.53**	**17.04**	**16.79**
Total primary energy supply (excluding bunkers)			***Mtoe***	**28.05**	**35.21**	**34.48**
RE shares		RE share in electricity generation		2%	2%	10%
		RE share in Buildings – final energy use, direct uses (modern)		0%	0%	4%
		RE share in Industry – final energy use, direct uses		0%	0%	1%
		RE share in Transport fuels		0%	0%	0%
		Share of modern RE in TFEC		**1%**	**1%**	**4%**
		Share of modern RE in TPES		**1%**	**1%**	**3%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	0.1
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	0.01	1.1
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.1
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	0.4
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	0.3
		CO_2 emissions from energy (Mt/yr)		51	59	55

THAILAND

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**35.6**	**45.9**	**48.8**
		Renewable capacity	*GW*	7.3	12.6	17.5
		Hydropower (excl. pumped hydro)	*GW*	3.0	3.1	3.8
		Wind	*GW*	0.2	0.9	1.8
		Biofuels (solid, liquid, gaseous)	*GW*	2.8	5.1	5.7
		Solar PV	*GW*	1.3	3.4	6.2
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	28.3	33.3	31.3
		Total electricity generation	*TWh*	**174.5**	**240.0**	**240.9**
		Renewable generation	*TWh*	22.1	42.7	55.8
		Hydropower	*TWh*	5.2	3.3	6.5
		Wind	*TWh*	0.3	13.0	15.1
		Biofuels (solid, liquid, gaseous)	*TWh*	15.2	21.8	25.1
		Solar PV	*TWh*	1.4	4.6	9.0
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	152.4	197.3	185.1
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**30.0**	**44.1**	**43.9**
		Direct uses of renewable energy	*Mtoe*	14.1	16.1	20.1
		Solar thermal – Buildings	*Mtoe*	0.0	0.2	1.1
		Solar thermal – Industry	*Mtoe*	0.0	0.1	1.1
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	8.3	3.6	3.6
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.1	1.8
		Bioenergy – Industry	*Mtoe*	5.8	12.1	12.4
		Non-renewable – Buildings	*Mtoe*	2.6	8.1	5.4
		Non-renewable – Industry	*Mtoe*	13.3	19.9	18.4
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**28.6**	**30.0**	**29.8**
		Liquid biofuels	*Mtoe*	1.8	2.6	2.6
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	26.8	27.4	27.1
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**75.8**	**95.8**	**94.3**
Total primary energy supply			***Mtoe***	**136.8**	**147.4**	**147.2**
RE shares		RE share in electricity generation		13%	18%	23%
		RE share in Buildings – final energy use, direct uses (modern)		0%	2%	24%
		RE share in Industry – final energy use, direct uses		30%	38%	42%
		RE share in Transport fuels		6%	9%	9%
		Share of modern RE in TFEC		**12%**	**19%**	**25%**
		Share of modern RE in TPES		**11%**	**18%**	**24%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	-0.9
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	1.9	3.2
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	0.2
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	1.1
		Reduced externalities – CO_2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	1.7
		CO_2 emissions from energy (Mt/yr)		230	306	276

VIETNAM

			Unit	2014	Reference Case 2025	REmap 2025
Energy production and capacity	Power sector	**Total installed power generation capacity**	*GW*	**29.5**	**69.8**	**77.2**
		Renewable capacity	*GW*	15.2	27.6	38.5
		Hydropower (excl. pumped hydro)	*GW*	15.1	22.1	23.7
		Wind	*GW*	0.05	3.5	5.7
		Biofuels (solid, liquid, gaseous)	*GW*	0.1	0.4	1.0
		Solar PV	*GW*	0.0	1.6	8.1
		CSP	*GW*	0.0	0.0	0.0
		Geothermal	*GW*	0.0	0.0	0.0
		Marine, other	*GW*	0.0	0.0	0.0
		Non-renewable capacity	*GW*	14.3	42.2	38.7
		Total electricity generation	*TWh*	**134.4**	**341.4**	**348.0**
		Renewable generation	*TWh*	60.0	93.3	121.3
		Hydropower	*TWh*	59.9	82.4	89.0
		Wind	*TWh*	0.1	7.4	14.6
		Biofuels (solid, liquid, gaseous)	*TWh*	0.1	1.2	5.3
		Solar PV	*TWh*	0.0	2.3	12.4
		CSP	*TWh*	0.0	0.0	0.0
		Geothermal	*TWh*	0.0	0.0	0.0
		Marine, other	*TWh*	0.0	0.0	0.0
		Non-renewable generation	*TWh*	74.4	248.2	226.7
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	*Mtoe*	**31.4**	**49.9**	**44.9**
		Direct uses of renewable energy	*Mtoe*	11.3	13.5	11.9
		Solar thermal – Buildings	*Mtoe*	0.0	0.0	1.0
		Solar thermal – Industry	*Mtoe*	0.0	0.0	0.9
		Geothermal (Buildings and Industry)	*Mtoe*	0.0	0.0	0.0
		Bioenergy (traditional) – Buildings	*Mtoe*	9.2	11.0	4.0
		Bioenergy (modern) – Buildings	*Mtoe*	0.0	0.0	2.5
		Bioenergy – Industry	*Mtoe*	2.1	2.5	3.5
		Non-renewable – Buildings	*Mtoe*	4.3	8.0	6.6
		Non-renewable – Industry	*Mtoe*	15.7	28.4	26.4
		Non-renewable – BF/CO	*Mtoe*	0.0	0.0	0.0
	Trans-port	**Total fuel consumption**	*Mtoe*	**15.3**	**29.3**	**27.3**
		Liquid biofuels	*Mtoe*	0.0	0.1	0.4
		Biomethane	*Mtoe*	0.0	0.0	0.0
		Non-renewable fuels	*Mtoe*	15.3	29.2	26.9
Total final energy consumption (electricity, DH, direct uses)			***Mtoe***	**56.8**	**106.6**	**100.1**
Total primary energy supply			***Mtoe***	**72.1**	**154.4**	**147.1**
RE shares		RE share in electricity generation		45%	27%	35%
		RE share in Buildings – final energy use, direct uses (modern)		0%	0%	25%
		RE share in Industry – final energy use, direct uses		12%	8%	14%
		RE share in Transport fuels		0%	0%	1%
		Share of modern RE in TFEC		**12%**	**9%**	**18%**
		Share of modern RE in TPES		**10%**	**7%**	**15%**
Financial indicators		System costs (USD bln/yr in 2025)		*N/A*	*N/A*	1.0
		RE investment needs (USD bln/yr annually (2015-2025))		*N/A*	2.2	4.5
		Investment support for renewables (USD bln/yr in 2025)		*N/A*	*N/A*	1.1
		Reduced externalities – outdoor air pollution (avg.) (USD bln/yr in 2025)		*N/A*	*N/A*	2.6
		Reduced externalities – CO2 (USD 50/tonne CO2) (USD bln/yr in 2025)		*N/A*	*N/A*	2.6
		CO2 emissions from energy (Mt/yr)		177	430	386

ANNEX B: WORKSHOP PROCEEDINGS

IRENA and ACE, with financial support from GIZ, conducted two in-depth technical workshops with ASEAN Member States. The detailed workshop proceedings are available for viewing at the following links:

1st workshop, 14 March 2016, Manila, Philippines: *http://www.irena.org/remap/Renewable_Energy_Outlook_for_ASEAN.aspx*

2nd workshop, 22-24 June 2016, Bangkok, Thailand: *http://www.irena.org/remap/ASEAN.aspx*

C

ANNEX C: DATA SOURCES FOR COUNTRIES

	2014	2030 Reference Case		REmap
	Baseyear	Power sector	End-use sectors	REmap Options
Brunei Darussalam	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		IRENA and country assessment; workshops (see Annex B) and webinars; assessments including ACE (2015); IRENA (2014b, 2014d, 2016a, 2016d), OECD (2014)
Cambodia	Country supplied via REmap questionnaire, and (IEA, 2015)	APS from ACE (2015)		
Indonesia	Country statistics	MEMR (2016)	Dewan Energi Nasional, (2014)	
Lao PDR	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		
Malaysia	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		
Myanmar	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		
Philippines	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		
Singapore	ACE (2015), with country statistics; and (IEA, 2015)	APS from ACE (2015)		
Thailand	Country supplied via REmap questionnaire	Country supplied via REmap questionnaire		
Vietnam	Country supplied via REmap questionnaire, and ACE (2015)	APS from ACE (2015)		

ANNEX D: ASEAN COMMODITY PRICE AND TECHNOLOGY COST ASSUMPTIONS

Commodity prices	Unit	Business Perspective				Government Perspective			
		2014		2025		2014		2025	
		Low	High	Low	High	Low	High	Low	High
Steam coal	USD/GJ	2.0	4.3	2.6	4.3	2.0	4.8	3.2	6.0
Electricity household	USD/kWh	0.05	0.23	0.05	0.24	0.05	0.23	0.05	0.24
Electricity industry	USD/kWh	0.06	0.17	0.07	0.18	0.06	0.18	0.07	0.18
Natural gas household	USD/GJ	7.0	13.2	10.9	21.1	7.0	11.0	10.9	17.6
Natural gas industry	USD/GJ	4.6	11.6	6.3	18.5	5.1	9.6	6.9	18.5
Petroleum products for heating / electricity	USD/GJ	15.0	37.3	17.5	39.1	12.8	33.6	15.0	37.3
Gasoline for transport	USD/GJ	12.2	49.4	15.6	51.8	16.1	27.1	18.9	34.2
Diesel for transport	USD/GJ	6.3	34.1	8.0	35.8	16.0	24.4	18.7	28.6
Conventional liquid biofuels for transport	USD/GJ	24.8	39.5	21.7	36.1	21.7	36.1	20.1	33.1
Advanced liquid biofuels for transport	USD/GJ	43.5	82.7	29.8	56.9	32.2	38.2	25.6	34.8
Biomethane	USD/GJ	22.8	44.4	22.8	44.4	20.0	25.0	20.0	30.5
Primary bioenergy	USD/GJ	10.8	18.7	10.0	22.4	10.8	18.7	10.0	22.4
Bioenergy residues	USD/GJ	2.5	4.7	2.1	4.9	2.5	4.7	2.1	4.9
Waste	USD/GJ	1.1	1.2	1.1	1.2	1.1	1.2	1.1	1.2
Discount rate	%/year	5.0	15.0	5.0	15.0	8.0	10.0	8.0	10.0

*Business Perspective: commodity prices reflect business prices, so **including** taxes and subsidies.*
*Government Perspective: commodity prices reflect government prices, so **excluding** taxes and subsidies.*
For more information see Annex E

Renewable Energy Technologies Cost and Performance	Capacity Factor	Lifetime	Overnight capital cost	O&M costs	Conversion efficiency
INDUSTRY SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Solar thermal	12-20	25	300	5	100
Geothermal, direct-use	~55	42	1500	38	100
Biomass boilers	70-85	25	580	15	88
Biogas heat	70-80	25	200	5	85
BUILDINGS SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Water heating: Biomass	20-30	15	600	15	80
Water heating: Solar (thermosiphon)	10-20	20	150	4	100
Cooking biogas (from anaerobic digesters)	10-15	25	40	1	48
Cooking biomass (solid)	10-15	20	15	0.4	30
TRANSPORT SECTOR	(%)	(years)	(USD / vehicle)	(USD / vehicle / yr)	(MJ/passenger or freight-km)
First generation bioethanol (passenger road vehicles)	N/A	12	28000	2800	1.64
Second generation bioethanol (passenger road vehicles)	N/A	12	28000	2800	1.64
Biodiesel (passenger road vehicles)	N/A	12	30000	3000	1.54
Biodiesel (freight/public road vehicles)	N/A	20	100000-120000	6000-8000	0.52-1.15
Biomethane (freight/public road vehicles)	N/A	20	150000	15000	1.35
Plug-in hybrid (passenger road vehicles)	N/A	12	30000	3000	0.98
Battery electric (passenger road vehicles)	N/A	12	32000	2880	0.69
Battery electric (light freight/public road vehicles)	N/A	15	100000-135000	5000-7000	0.16-1.1
Battery electric (two- and three wheeler)	N/A	8	4000	400	0.07
POWER SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Hydro (small)	40-60	40	2500	50	100
Wind onshore	20-36	30	1500	60	100
Wind offshore	30-35	30	2870	158	100
Solar PV	15-21	30	1000-1400	10-20	100
Solar CSP (part-time storage)	30	35	4000	120	33
Biomass	70	25	2750	69	38
Landfill gas	70	25	1800	45	32
Geothermal	60-80	50	2500	100	10
Tide, wave, ocean	50	25	3500	35	100

Conventional Energy Technologies	Capacity Factor	Lifetime	Overnight capital cost	O&M costs	Conversion efficiency
INDUSTRY SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Coal (steam boiler)	70-85	25	300	7.5	90
Petroleum products (steam boiler)	85	25	200	5.0	85
Natural gas (steam boiler)	85	25	100	2.5	95
BUILDINGS SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Water heating: petroleum products (boiler)	10-20	15	175	6.1	85
Water heating: coal (boiler)	10-20	15	162	5.7	90
Water heating: natural gas (boiler)	10-20	15	150	5.3	95
Water heating: traditional biomass	20-30	15	100	2.5	50
Water heating: electricity	20-30	10	150	3.8	85
Cooking LPG/kerosene	10-15	20	10	0.3	50
Cooking traditional biomass	10-20	3	10	0.3	10
TRANSPORT SECTOR	(%)	(years)	(USD / vehicle)	(USD / vehicle / yr)	(MJ/passenger or freight-km)
Petroleum products (passenger road vehicles)	N/A	12	28000	2800	1.6
Petroleum products (freight road vehicles)	N/A	15	120000	12000	1.16
Petroleum products (public road vehicles)	N/A	20	1000000	10000	0.52
Petroleum products (two- and three-wheelers)	N/A	8	4000	400	1.75
POWER SECTOR	(%)	(years)	(USD/kW)	(USD/kW/yr)	(%)
Coal	70-80	60	1300	52	30
Natural gas	50-60	30	1000	40	55
Oil	20-30	50	1200	18	40
Nuclear (non-OECD)	80-85	60	5500	138	33
Diesel (Gen-set)	40	20	1500	38	42

The technology and performance assumptions presented in this table represent regional values for the year 2025. For individual ASEAN country analyses, technology cost and performance was localised. Generally this involved updating the capacity factor, overnight capital and O&M costs, and conversion efficiency based on country information and projections.

ANNEX E: REMAP METHODOLOGY, METRICS AND TERMINOLOGY DESCRIPTIONS

METRICS FOR ASSESSING OPTIONS

In order to assess the costs of REmap Options, ***substitution costs*** are calculated. This report also discusses the costs and savings from renewable energy deployment and the consideration of related externalities from climate change and air pollution. Four main indicators have been developed, namely ***substitution costs, system costs***, ***total investment needs*** and ***needs for renewable energy investment support***.

SUBSTITUTION COST

Each renewable and non-renewable technology has its own individual cost relative to the non-renewable energy it substitutes. This is explained in detail in the methodology of REmap (IRENA, 2014a) and is represented in the equation:

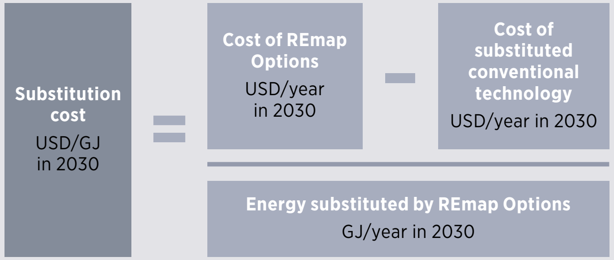
For each REmap Option, the analysis considers the costs to substitute a non-renewable energy technology to deliver the same amount of heat,

Cost of Technology/ REmap Options USD/year in 2030 = **Equivalent annual capital expenditure** USD/year in 2030 + **Operating expenditure** USD/year in 2030 + **Fuel cost** USD/year in 2030

electricity or energy service. The cost of each REmap Option is represented by its **substitution cost**[6 7] :

6 Substitution cost is the difference between the annualised cost of the REmap Option and the annualised cost of the substituted non-renewable technology, used to produce the same amount of energy. This is divided by the total renewable energy use substituted by the Remap Option.

7 1 GJ = 0.0238 tonnes of oil equivalent (toe) = 0.238 gigacalories = 278 kilowatt-hours (kWh).



This indicator provides a comparable metric for all renewable energy technologies identified in each sector. Substitution costs are the key indicators for assessing the economic viability of REmap Options. They depend on the type of conventional technology substituted, energy prices and the characteristics of the REmap Option. The cost can be positive (additional) or negative (savings). This is because many renewable energy technologies are, or by 2025 could be, cost-effective compared to conventional technologies.

SYSTEM COSTS

Based on the substitution cost inference can be made as to the effect on **system costs**. This indicator is the sum of the differences between the total capital and operating expenditures of all energy technologies based on their deployment in REmap and the Reference Case in 2025.

INVESTMENT NEEDS

Investment needs for renewable energy capacity can also be assessed. The total **investment needs** of technologies in REmap are higher than in the Reference Case due to the increased share of renewables which, on average, have higher investment needs than the non-renewable energy technology equivalent. The capital investment cost (in USD/kW of installed capacity) in each year is multiplied with the deployment in that year to arrive at total annual investment costs. The capital investment costs of each year are then summed over the period 2015-2025. Net incremental investment needs are the sum of the differences between the total investment costs for all technologies, renewable and non-renewable energy, in power generation and stationary applications in REmap and the Reference Case in the period 2015-2025 for each year. This total was then turned into an annual average for the period.

Average investment needs (USD/year 2016–2030) = [**Renewable capacity installed** (Total GW 2016–2030) X **Average capital expenditure** (USD/GW 2016–2030)] / **15** (Number of years 2016–2030)

RENEWABLE INVESTMENT SUPPORT

Renewable investment support needs can also be approximated based on the REmap tool. Total requirements for renewable investment support in all sectors are estimated as the difference in the delivered energy service cost (*e.g.*, in USD/kWh or USD/GJ based on a government perspective) for the renewable option against the dominant incumbent in 2030. This difference is multiplied by the deployment for that option in that year to arrive at an investment support total for that technology. The differences for all REmap Options are summed to provide an annual investment

Investment support for RE (USD/year in 2030) = **Substitution cost: government perspective** (Technologies with positive substitution cost; USD/GJ in 2030) X **REmap Options** (Technologies with positive substitution cost; GJ/year in 2030) support requirement for renewables. It is important to note that where the renewable option has a lower delivered energy service cost than the incumbent option, which begins to occur increasingly by 2025, it is not subtracted from the total.

GOVERNMENT AND BUSINESS PERSPECTIVES

Based on the substitution cost and the potential of each REmap Option, costs can be assessed from two perspectives: ***government*** and ***business***:

- ***Government perspective*:** cost estimates exclude energy taxes and subsidies, and in the latest global REmap study (IRENA, 2016a), a standard 10% (for non-OECD) or 7.5% (for OECD) discount rate was used. This approach allows for a comparison across countries and for a country cost-benefit analysis; it shows the cost of the transition as governments would calculate it.
- ***Business perspective:*** it considers national prices (including, for example, energy taxes, subsidies and the cost of capital) in order to generate a localised cost curve. This approach shows the cost of the transition as businesses or investors would calculate it. In the case of ASEAN Member States the range is between 5% and 15% depending on the country.

In this report only the government perspective is presented. By estimating the costs from two perspectives, the analysis shows the effects of accounting for energy taxes and subsidies whereas all other parameters are kept the same. The assessment of all additional costs related to complementary infrastructure are excluded from this report (*e.g.*, grid reinforcements, fuel stations, etc.).

EXTERNALITY ANALYSIS

The externality reductions that would be obtained with the implementation of REmap Options that are considered include health effects arising from outdoor exposure, health effects arising from indoor exposure in the case of traditional use of bioenergy, and effects on agricultural yields. Additionally, the external costs associated with social economic impacts of carbon dioxide (CO2) are estimated (IRENA, 2016f).

Further documentation and a detailed description of the REmap methodology can be found at www.irena.org/remap. Further details on metrics for assessing Options can be consulted in Appendix of the global report 2016 edition (IRENA, 2016b).

CASE AND TERMINOLOGY OVERVIEW

This report uses terminology to describe the two main energy pathways that countries could pursue to 2025, and the gap between the two. In this report these are referred to as:

The Reference Case – The case based on planned policies and expected market developments for the energy sector. In this study the Reference Case is based on plans submitted by ASEAN Member States, or taken from the APS scenario of the ASEAN AEO4. The Reference Case does not necessarily reflect business as usual, rather already some accelerated commitments of countries as of 2015.

The REmap Options – the technologies necessary to close the gap between the developments in the Reference Case renewable energy share and the ASEAN regional target of achieving 23% renewable energy share in primary energy supply by 2025. The REmap Options are also often referred to as “the gap” in this report.

REmap – The case in which the REmap Options are assumed to be fully deployed in addition to developments occuring in the Reference Case. The REmap case is in line with the 23% renewable share goal set by ASEAN

UNITS

Finally, energy supply and demand numbers in this report are generally provided in kiloton oil equivalent (ktoe), megaton oil equivalent (Mtoe), megawatt-hour (MWh), gigajoule (GJ), petajoule (PJ) or exajoule (EJ). In ASEAN, commonly used units are tonnes of oil equivalent (toe). Below the relevant conversion factors to convert between units:

- 1 GJ = 0.0238 tonnes of oil equivalent (toe)
- 1 GJ = 277.78 kilowatt-hour (kWh)
- 1 PJ = 0.0238 million tonnes of oil equivalent (Mtoe)
- 1 PJ = 277.78 gigawatt-hour (GWh)
- 1 EJ = 23.88 million tonnes of oil equivalent (Mtoe)
- 1 EJ = 277.78 terawatt-hour (TWh)

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