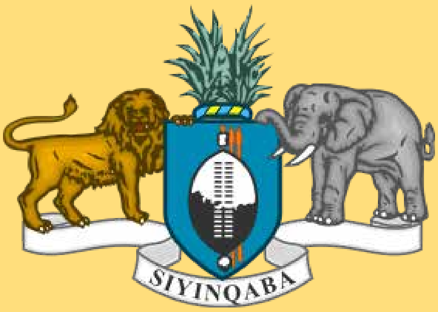

KINGDOM OF ESWATINI ENERGY MASTERPLAN 2034

Ministry of Natural Resources and Energy
The Kingdom of Eswatini

OCTOBER 2018

The Kingdom of Eswatini, previously known as the Kingdom of Swaziland, officially changed its name on 19 April 2018.

Disclaimer

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ABBREVIATIONS

AGOA	Africa Growth Opportunity Act
CHP	Combined heat and power
CO_2	Carbon dioxide
CSO	Central Statistics Office
CSP	Concentrated solar power
GDP	Gross domestic product
GIS	Geographic information system
GWh	Gigawatt-hour
INDC	Intended Nationally Determined Contribution
IPP	Independent power producer
IRENA	International Renewable Energy Agency
km	Kilometre
Kt	Kilotonne
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt-hour
LCOE	Levelised cost of electricity
LEAP	Long-range Energy Alternatives Planning System software
LED	Light-emitting diode
LPG	Liquefied petroleum gas
LUSIP	Lower Usuthu Smallholder Irrigation Project
m/s	Metres per second
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MNRE	Ministry of Natural Resources and Energy
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally Determined Contribution
NDS	National Development Strategy
NEP	National Energy Policy
O&M	Operation and maintenance
PJ	Petajoule
PPA	Power purchase agreement
PV	Photovoltaic
R	South African Rand
REEESAP	Renewable Energy and Energy Efficiency Strategy and Action Plan
REPN	SADC Regional Energy Planning Network
RERA	Regional Energy Regulators Association
RIDMP	Regional Infrastructure Development Master Plan
RISDP	Regional Indicative Strategic Development Plan
RSSC	Royal Swaziland Sugar Corporation
SACREEE	SADC Centre for Renewable Energy and Energy Efficiency
SACU	Southern African Customs Union

ABBREVIATIONS

SADC	Southern African Development Community
SAPP	Southern African Power Pool
SEC	Swaziland Electricity Company
SE4ALL	Sustainable Energy for All
SERA	Swaziland Energy Regulatory Authority
SPLAT-SW	SPLAT-Swaziland model
SWADE	Swaziland Water and Agricultural Development Enterprise
SZL	Swazi Lilangeni
TFEC	Total final energy consumption
TJ	Terajoule
TPES	Total primary energy supply
UNDP	United Nations Development Programme
USD	United States dollar
W/m^2	Watts per square metre

FOREWORD

Minister for Natural Resources and Energy

In the era of renewable energy, long-term energy planning is imperative for the transformation of the energy system of the Kingdom of Eswatini and its liberation to sustainable energy growth. For the country, energy planning is key for the achievement of universal electrification, to improve modern energy access and energy efficiency, and to foster technological breakthroughs, all by way of well-informed policy making.

The key challenge facing the country's energy system is a lack of security of supply. Consequently, electricity import tariffs will be exacerbated over the coming years, and a trend has been set for continually escalating tariffs for end-users. This has helped make the harnessing of indigenous energy resources to produce electricity become more competitive. For instance, falling technology costs have made renewable energy increasingly competitive, and the likes of domestic bagasse for co-generation from the sugar industry, solar PV, wind and hydropower could meet the country's electricity demand sustainably. Meanwhile, the harnessing of domestic resources should not undermine the electricity trade facilitated by existing interconnections with Mozambique and South Africa. Rather, the country should find an adequate balance between harnessing domestic resources and maintaining electricity trade with neighbouring countries.

This Energy Masterplan projects outcomes of the current and planned policies in the energy system to 2034 and shows comparative scenario results that assume deployment of diverse technologies and measures to meet the country's energy demand. The drivers of the policies suggested by the alternative scenarios bring a sustainable energy future within reach, which clearly supports the commitment to accelerate renewable energy deployment. The key driver of renewable energy is its economic feasibility, which the Energy Masterplan presents in the country's context. As renewable power generation costs fall rapidly, policy makers and investors need to confront the economic opportunities, as well as challenges, arising from a scale-up of renewable energy. This report shows that renewable energy costs are at the lower end of the fossil fuel cost range by 2034. In addition, several solar PV and wind power projects will provide some of the lowest-cost electricity from any source. Informed decision making about the role of renewables in future electricity systems will depend on continually updated reliable cost and performance data, as provided in this report from current assessment.

The Energy Masterplan assesses the cost of the energy system from the deployment of various energy technologies, showing renewables to be cost-competitive in a growing array of conditions. This is in accordance with the observed combination of expertise, purchasing power and access to international financial markets that drives down project costs and risks of renewables deployment globally. This Masterplan's modelling output will enable the country to structure policy advice and planning for the development of renewable energy projects in a robust manner.

The overall trend for the Eswatini energy system is clear: dependency on electricity imports will remain above 50 % in total electricity production to about 2019, then gradually decrease until 2034 to less than 10 %. By 2020 renewable power generation technologies can be expected to provide 40 % of all electricity generation, which increases to an average of 70 % across all the scenarios assessed in this Masterplan, by the end of the planning period (2034). As costs for renewables go head-to-head with or even out-compete fossil-based power solutions to provide new capacity without financial support, key opportunities exist to pursue cost-effective technology pathways.

It is therefore evident that renewable energy increasingly makes business sense for the country and for investors. For this reason, renewables will be the driving force of the Kingdom of Eswatini's energy transformation, while permitting affordable energy, enabling universal access to modern energy, increasing energy security and diversifying energy supply. Lastly, the Masterplan also recognises the opportunities that can be harnessed from the discovery of natural gas in neighbouring Mozambique.

All in all, I would like to express my utmost gratitude to all the stakeholders who contributed to this interactive exercise and provided valuable insights and directions in the energy sector at large. A special thanks to the International Renewable Energy Agency (IRENA) and its experts for their training support, guidance, expertise and financial assistance for the development of this Masterplan, that will help usher the country into the era that is about more than just resilience but also inclusiveness for all. The core national working team for this Energy Masterplan has gained good experience in long-term energy planning through working with this group of IRENA experts, and the resulting skills will benefit the country as a whole for the future.

Honourable Jabulile Mashwama (Senator)
Minister of Natural Resources and Energy

EXECUTIVE SUMMARY

The development of this Energy Masterplan has been long overdue in the Kingdom of Eswatini. The last comprehensive energy policy document was published in 2003, and since then the global and regional energy landscape surrounding the country have changed dramatically. In particular, the opportunities for developing indigenous resources are opening up rapidly as renewable energy costs become increasingly competitive, and pro-active planning is called for to better evaluate the needs and options in the future.

Against this background the Kingdom of Eswatini, in partnership with the International Renewable Energy Agency (IRENA), initiated a capacity-building programme on long-term strategic planning. The programme included a data preparation meeting, an online training and two 2-week national training courses provided to the national working team as well as frequent working team meetings and technical interactions with IRENA experts in the process of developing the Energy Masterplan. Long-term energy planning in the energy sector is essential for finding a balance between divergent legitimate expectations and views of the variety of stakeholders – including government, consumers and private sector – for development of the sector. This balance is attained through scenario planning using policy inputs that are modelled under specific constraints.

Consequently, the Energy Masterplan of the Kingdom of Eswatini seeks to provide national decision makers with the quantitative basis for planning future energy sector development through identifying and addressing the country's distinct barriers in the supply of energy. It is also nestled in analysis of the available energy resources and a need to maximise energy use for sustainable energy development. In addition, it seeks to help shape appropriate policy and regulatory choices through the determination of suitable energy sources and technologies that are relevant and consistent with national priorities.

The Energy Masterplan was developed to cover the use and supply of both electricity and primary fuels, which include biofuels, petroleum, coal, biomass and fuelwood. The scenario modelling is based on the planning horizon 2014–2034. The Masterplan provides suggestive guidance on the development and assessment of energy supply scenarios to meet domestic future energy demand, and outlines sector-specific development pathways through to 2034.

The planning tool used for development of the Masterplan is called SPLAT-Swaziland (SPLAT-SW; based on MESSAGE modelling software), and the review of energy demand scenarios is generated from the LEAP model. MESSAGE is a dynamic, bottom-up, multi-year energy system software applying linear and mixed-integer optimisation techniques; it allows for assessing the least-cost technically and economically feasible combinations of energy supply options to meet a specified demand under a set of conditions. On that basis it selects the least-cost optimal energy mix, taking into consideration the investment needs and other costs for new infrastructure, energy supply security, energy resource utilisation, rate of introduction of new technologies, and environmental and other constraints.

The Masterplan supports a growth in gross domestic product (GDP) of 1.8 % to 3 % between 2014 and 2020, and of 3 % from 2020 to 2034. Under the preferred future scenario (Limited import scenario 3 – see below), 676 MW of domestic capacity are required to meet the projected demand and to provide adequate reserves in 2034. The electricity demand increases from 1,270 gigawatt-hours (GWh) in 2014 to 2,648 GWh in 2034, liquid fuels from 10 petajoules (PJ) to 15 PJ and solid remain constant at around 24 PJ over the planning period. This assumes the implementation of demand-side management programmes, and a gradual reduction in energy intensity due to technology advancement.

Electricity demand forecasting established the basis for national generation, transmission and distribution expansion planning, and for assessing the impact of specific large energy-intensive projects on existing resources and infrastructure. An energy demand accounting model for Eswatini was created, as well as three energy demand pathways driven by different assumptions of economic growth, population growth and the electrification rate. The sectoral energy demand was formulated by taking into account the useful energy needs of energy consumers and their choice of technologies and appliances. The output level of each sub-sector was modelled separately and was combined with projections of its respective energy intensity and end-use shares to derive the expected consumption of each energy source by sub-sector.

Based on the projected demand, the modelled scenarios are built on policies such as those that will encourage participation in the generation of electricity through promoting the deployment of renewable energy technologies as well as the goals of Sustainable Energy for All. The model incorporates the latest information on energy technologies and costs, with some refinements to adequately characterise options available to Eswatini. The modelling approach has been expanded to cater to both the power and non-power sectors to take into account the demand for fuels other than electricity. A Base Case was created to depict the business-as-usual future, and serves as a point of reference for the alternative scenarios.

The accuracy of the Base Case is improved by regular reviews and updates as and when things change or when new information becomes available. In view of this, the long-term plan presented here is considered as indicative rather than definitive. The Masterplan aims to achieve a balance between affordability of energy in the competitive market and a move towards a sustainable energy supply.

The Base Case includes all other technology options such as coal power generation, natural gas, biomass and wind technologies, to name a few. The deployment of technologies is not forced in the model solution.

The nine alternative scenarios include two Forced Coal scenarios, which aim to provide insights into the impact of coal capacity in providing baseload power. These scenarios explore the possibility of reducing the country's reliance on imports by exploiting domestic coal endowments through constructing a new coal power plant. Coal is one of the resources that Eswatini has in abundance and has never exploited.

Three Domestic Resources scenarios assess the implications of becoming less import-dependent and maximising the use of domestically endowed energy resources. These scenarios (Limited Import 1, Limited Import 2 with forced hydro and Limited Import 3 without coal and with renewables) envision an increase in renewable energy deployment as a result of the coupling of rapid reductions in renewable energy costs and the country's renewable energy promotion policy with the reduction of reliance on imports. Two "No Import Enhancement" scenarios assume that no investment into expanding the import capacity is allowed; one of the scenarios assumes a higher local electricity demand, above the maximum electricity available to Eswatini from domestic sources and the current supply agreement with South Africa combined, and is contrasted with the case of no import enhancement but with the demand as in the Base Case. The Low Import Price scenario assesses conditions under no limit on imports of electricity and the assumption of a lower tariff for imports from South Africa. Finally, the Natural Gas scenario assesses the possible replacement of the coal options with natural gas imports, for demand-balancing power and as a way to reduce carbon emissions.

Throughout the planning horizon, electricity imports decline in all of the assessed scenarios, and new generation technologies that are increasingly economically feasible include solar PV, wind and biomass. The natural gas and coal technologies prove to not be economically feasible unless they are forced. The share of renewable energy shows an upwards trend in all of the scenarios except for the coal scenarios.

All 10 scenarios were assessed against key long-term goals, namely 1) the provision of sufficient energy supply; 2) the provision of access to clean energy technologies; 3) fostering industrialisation and 4) ensuring security of energy supply. Careful analysis of the modelling results indicates that the Limited Import 3 with renewables scenario possesses the most balanced combination of the desirable policy features. This analysis coincides with the feedback from the national stakeholder consultations held as part of the Masterplan development process, where the importance of the country's commitment to the Paris Agreement and to much stronger endorsement of renewable energy were highlighted.

The key recommendations of this Masterplan are the increased development of renewable energy options involving the private sector; the creation of a comprehensive distributed power generation plan; and the need to develop policies and regulations to facilitate private sector engagement in rural electrification. These recommendations need to be complemented by strengthening renewable energy targets, examining the constraints of existing grid infrastructure and exploring the best mechanisms to reduce costs and ease technical challenges.

Finally, throughout the process of developing this Masterplan, national energy planning capacity has been significantly enhanced, while areas of further enhancement were identified. To keep the Masterplan relevant, and to maintain and further strengthen the country's planning capability, it is recommended that processes for regular updates of this Masterplan are institutionalised and that the next round of updates start immediately, building on the learning from this exercise.

PART I:
ESWATINI ENERGY CONTEXT

1 INTRODUCTION

1.1 BACKGROUND

The Kingdom of Eswatini imports all of its petroleum product requirements and around 70 % of its power from South Africa and Mozambique, despite being well endowed with conventional and renewable energy resources, including coal, solar, hydro, wind and biomass residues from the sugar and forestry industries. These resources are potentially able to meet the entire national electricity demand if fully exploited, as well as potentially provide for the export of excess energy to Eswatini's neighbours. The high dependency on power imports contributes greatly to the country's account deficit and increases Eswatini's exposure to energy supply risks, in terms of both supply security and price shocks.

Almost 100 % of the electricity generated in Eswatini is from hydropower and sugarcane-based co-generation. Biomass (fuelwood and agricultural waste) is used mainly for household cooking and heating, as well as for co-generation in the sugar industry. Petroleum products are used mostly for transport, and paraffin and liquefied petroleum gas (LPG) are used for cooking and heating.

Energy development in Eswatini is guided by the National Energy Policy of 2003. Since then, the country's energy sector has been undergoing rapid transformation with the liberalisation of the electricity sector to encourage private sector investment. With the recent promising development of locally sourced renewable energy, Eswatini has an opportunity to reduce its excessive reliance on imports for energy products and to improve energy security.

The country previously did not have in place an energy master plan to help to identify least-cost energy supply options to meet future national energy demand. With a master plan in place it will be easier for Eswatini to follow a clear energy sector development plan to ensure that energy policies governing the country's sub-sectors are developed consistently, while bringing long-term policy stability that would help to reduce uncertainty for potential energy investors. The present Masterplan identifies the priorities, time frame and costs associated with the energy sector development goals. The time horizon of this Masterplan is 20 years, up to 2034.

To enhance energy security, affordability and environmental sustainability, Eswatini needs to develop domestic energy supply capacity and to diversify its national energy mix towards renewable supply options. Specifically, the long-term goal of energy sector development is a well-diversified energy mix that will:

- provide sufficient energy supply to support the country's developmental goals, as contained in the National Development Strategy (NDS);
- contribute to poverty alleviation and improvement of quality of life by providing access to clean energy technologies;
- foster industrialisation to bring about linkages with other sectors; and
- ensure security of energy supply to support economic growth and attract foreign direct investment.

1.2 OBJECTIVE AND SCOPE OF THE ENERGY MASTERPLAN

This document is a national Energy Masterplan that addresses Eswatini's distinct challenges and is designed to set the energy sector on firm footing for a sustainable future. The Masterplan aims to provide national decision makers with the quantitative base for planning future energy sector development.

The objectives of this Energy Masterplan are to:

- review the current national energy policy setting and energy balance;
- assess future national energy demand up to 2034;
- identify all of the energy sources needed to meet this demand, including untapped potential for domestic energy supply from renewable sources;
- provide quantitative paths for future energy sector development to 2034; and
- assess energy supply options in terms of their implications for financial requirements, energy security, energy access goals, carbon dioxide (CO_2) emissions and other related policy goals.

The national energy planning in this document covers the use and supply of both electricity and primary fuels, which include biofuels, petroleum, biomass and fuelwood. The scenario modelling is based on a 20-year planning horizon (2014 to 2034) that is consistent with the national development targets. The Masterplan provides suggestive guidance on the development and assessment of energy supply scenarios to meet domestic future energy demand, and outlines sector-specific development pathways through 2034. The methodologies used to develop energy scenarios are quantitative, traceable and consensus-based.

1.3 IMPLEMENTATION OF THE STUDY FOR THE MASTERPLAN DEVELOPMENT

This Masterplan has been developed with technical support from the International Renewable Energy Agency (IRENA), which provided training and data analysis support. Input from stakeholders was drawn from government agencies, the national utility, the national regulatory authority, civil society, academia and the private sector. A steering committee was formed to give policy direction to the national working team whose role was to collect and analyse data, model different energy scenarios and prepare the Masterplan report. The following stakeholders (listed in alphabetical order) were identified and consulted during development of the Masterplan.

- Biomass Group
- Central Statistical Office
- Coordinating Assembly on Governmental Organizations
- Department of Meteorology
- European Union
- Ministry of Economic Planning and Development
- Ministry of Finance
- Ministry of Natural Resources and Energy
- Oil Marketing Companies
- Renewable Association of Swaziland
- Royal Swaziland Sugar Association
- Swaziland Cane Growers Association
- Swaziland Economic Policy Analysis and Research Centre
- Swaziland Electricity Company
- Swaziland Energy Regulatory Authority
- Swaziland Sugar Association
- Swaziland Ubombo Sugar Limited
- The Climate Change Unit
- United Nations Development Programme
- University of Swaziland

The working team and steering committee members were drawn from this stakeholder list. As part of the process for developing this report, IRENA provided the national working team (consisting of 12 national practitioners – see full list of working team members in Annex A) with training on modelling tools and scenario development for energy planning, to equip these practitioners with the tools and means to manage and adapt national energy planning in line with developments and to serve as custodians of the country's sustainable energy future. The training aimed at addressing specific gaps and building the capacity of the national working team in the areas of long-term strategic energy planning, the development and implementation of the planning tool SPLAT-Swaziland (SPLAT-SW; based on MESSAGE modelling software) and the review of energy demand scenarios generated from the LEAP model.

2 PRESENT ENERGY POLICY SETTING

This Chapter reviews existing energy targets and other relevant development goals currently in place in Eswatini. The Energy Masterplan is built on these goals, and the comprehensive use of quantitative tools ensures the consistency of objectives in the future expansion of the energy sector.

2.1. NATIONAL ENERGY POLICY OF 2003

The Swaziland National Energy Policy (NEP) of 2003 was developed to address the challenges of transforming the energy sector and enhancing the overall development of the country. An aim of the NEP is "*ensuring that the development goals of the country are met through the sustainable supply and use of energy for the benefit of all citizens of the country*".

The vision of the NEP underlines the importance of the availability and accessibility of energy to cater to the development needs of the Eswatini nation. Energy should be affordable, and national energy resources should be harnessed with optimum efficiency while ensuring due attention to environmental concerns. The main objectives of the NEP are to:

- ensure access to energy for all
- enhance employment creation
- ensure security of energy supply
- stimulate economic growth and development
- ensure environmental and health sustainability.

The NEP was structured according to the demand sectors, supply sectors, rural electrification, cross-cutting issues and implementation.

2.2 ELECTRICITY LEGISLATION

Implementation of the NEP of 2003 has led to liberalisation of the energy market, aimed at improving services offered to consumers and encouraging private sector investment. The Ministry of Energy developed new legislation to govern the electricity sector in order to liberalise the electricity supply industry in Eswatini. The following pieces of legislation were promulgated as part of the unbundling process:

- Electricity Act of 2007
- Swaziland Electricity Company Act of 2007
- Swaziland Energy Regulatory Authority Act of 2007

The promulgation of the Electricity Act of 2007 and the Swaziland Electricity Company Act of 2007 transformed the Swaziland Electricity Board into the Swaziland Electricity Company (SEC). Further, the Swaziland Energy Regulatory Authority Act of 2007 created the Swaziland Energy Regulatory Authority (SERA) to regulate developments in the liberalised energy sector. The mandate of SERA is to administer the Electricity Act of 2007, and its primary and core responsibilities are to exercise control over the electricity supply industry and to regulate the generation, transmission, distribution, supply, use, import and export of electricity in Eswatini. SERA also is responsible for regulating electricity tariffs and the quality of supply and services.

To date, the SEC is still wholly owned by the Government of the Kingdom of Eswatini. It is semi vertically integrated since the SEC still enjoys monopoly ownership of the transmission and distribution of the energy supply chain, due mainly to the lack of technical and financial capacity to promote participation in these sectors. Municipal councils, particularly from the country's two cities, have expressed interest in participating in the distribution of electricity. Although transmission and most of the distribution networks are owned and operated by the SEC, prospective energy companies are allowed by law to use the existing infrastructure for electricity trade; however, such companies are expected to pay wheeling charges to the SEC.

The driving force behind the enactment of this electricity legislation was to ensure participation of the private sector in the generation, transmission and distribution of electricity. The generation component of the electricity supply industry in Eswatini is already fairly deregulated, as is apparent from the existence of two independent power producers (IPPs) and a range of private entities that are in the process of developing projects.

Recently, further work has been done to enhance IPP participation in the generation of electricity. The Government has completed a coherent and practical IPP Policy that will be vital in addressing many issues faced by potential IPPs, including in the renewable energy sector. The policy provides much-needed guidance to facilitate the growth and development of power generation projects in Eswatini. A key objective was to increase use of the country's extensive local energy resources including coal, biomass, solar, wind and geothermal.

2.3 SUSTAINABLE ENERGY FOR ALL GOALS

In response to the NEP's calls for ensuring access to energy for all and ensuring security of energy supply, Eswatini embraced the United Nations' Sustainable Energy for All (SE4ALL) initiative, that reflects the goals linked to long-term development of a well-diversified energy mix (see above). As a result, a country gap analysis exercise (SE4ALL Gap Analysis) was done, from which an Action Agenda and Investment Prospectus reports were developed in 2016. The SE4ALL targets are outlined in the following table adapted from the Swaziland Sustainable Energy for All Action Agenda, compiled by the Ministry of Natural Resources and Energy (MNRE) with the help of the United Nations Development Programme.

TABLE 2.1 SUSTAINABLE ENERGY FOR ALL GOALS

1. Ensuring universal access to modern energy services	• 5,000 households connected to grid electricity per annum to reach 18,500 additional households by 2018, reaching 75 % electricity access at household level • Build a 300 megawatt (MW) coal power plant to enhance security of supply by 2018 • 100 % access to electricity at the household level attained by 2022 • Effective policies and incentives for improved cook stoves established by end-2016 • Regulatory structures and mechanisms for LPG established by end-2016 • Penetration of improved cook stoves increased by 10 % per year from 2017 • Penetration of LPG for cooking increased by 10 % per year from 2017 • Geographic information system (GIS) database for rural energy access developed by 2017 • Rural energy master plan and implementation strategy to attain universal access to energy including LPG, improved cook stoves, solar home systems and biogas developed by 2018 • 100 % access to clean energy at the household level attained by 2030
2. Renewable energy	• Solar and wind maps developed by 2016 • 46 MW solar photovoltaic (PV) power plant (IPP) online by 2017 • 20 % of all public buildings to have solar water heating by 2018 • 134 MW of hydropower (SEC) by 2019 • 130 MW of co-generation from bagasse (IPP) by 2020 • 80 MW from wood waste from IPPs (with 40 MW online by 2019) • 10 % ethanol blending by 2016 • 50 % renewable electricity penetration in the electricity mix by 2030
3. Energy efficiency	• Attain 60 gigawatt-hours (GWh) of energy savings per year by 2018 • Attain 180 GWh of energy savings per year by 2025 • Energy efficiency policy and regulations developed by 2019 • 500,000 light-emitting diodes (LEDs) distributed to households by 2020 • Design and adopt an energy efficiency appliance labelling and standards programme

2.4 ESWATINI NATIONALLY DETERMINED CONTRIBUTION

In 2015 Eswatini submitted to the United Nations Framework Convention on Climate Change (UNFCCC) its Intended Nationally Determined Contribution (INDC) towards global greenhouse gas emission reductions. Of Eswatini's four mitigation actions outlined in the INDC, two are in the energy domain:

- Doubling the share of renewable energy in the primary energy mix, relative to 2010 levels[1], and
- Introducing an ethanol blend in petrol of at least 10 % (E10) by 2030.

Eswatini recognises that access to renewable forms of energy plays a significant role in improving the livelihoods of its people – in terms of both increasing social equity and improving economic growth. The doubling of the share of renewable energy in the primary energy mix would drastically reduce emissions from Eswatini's energy sector, which represented more than 20 % of the nation's greenhouse gas emission inventory in 2010.

The contribution covers on-grid and off-grid applications, where Eswatini will:

- Implement small-scale, decentralised renewable energy technologies to improve energy access in rural areas. This will also reduce unsustainable wood harvesting practices in the country.
- Increase the use of grid-connected renewable energy technologies fuelled by sources such as waste, solar, bagasse (from the sugar industry) and wood chips. This contribution has the further co-benefits of improving universal energy access and security of supply, which are particularly relevant in the context of the challenges experienced in the regional electricity system.

With regard to the second mitigation action in the energy domain, the ethanol to be blended is intended to be sourced from sugarcane molasses, a renewable source. This commitment will reduce emissions in the transport sector, which accounted for 9 % of the nation's greenhouse gas emission inventory in 2010. Transport-related emissions are anticipated to increase exponentially as more vehicles are purchased; currently the number of registered vehicles in Eswatini is growing at an average rate of 7 % per year.

Eswatini does not currently blend ethanol in petrol, although a successful pilot project was undertaken. The E10 blending commitment is likely to have a positive influence on the country's agricultural sector, particularly in the sugar industry as it has the potential to increase the production of sugarcane. By-products from this industry are bagasse and molasses, which can be used as feedstock for the production of ethanol.

2.5 REGIONAL ENERGY CONTEXT

Since the adoption of the SADC Energy Protocol in 1996, the Southern African Development Community (SADC) has enacted several strategic instruments for the energy sector, including the following:

- SADC Energy Cooperation Policy and Strategy (1996)
- SADC Energy Action Plan (1997)
- SADC Energy Activity Plan (2000)
- Regional Energy Access Strategy and Action Plan (2010). The plan defines the following objectives for improving energy access, which is a major goal of energy policy in all SADC Member States:

  - Harnessing regional energy resources to ensure, through national and regional action, that all people in the SADC region have access to adequate, reliable, least-cost, environmentally sustainable energy services.
  - Halving the proportion of people without electricity within 10 years for each end-use and halving this again in successive year periods until there is universal electricity access for all end-uses.

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[1] According to the Swaziland INDC, the share of renewable energy in the national energy mix in 2010 was 16 %, including both grid-connected renewable energy and sustainable/renewable biomass.

- SADC Framework for Sustainable Biofuels (2010). The objective is to provide a set of basic guidelines for the development of sustainable biofuel strategies. The regional guidelines can, in turn, be adapted to meet the requirements of SADC Member States, e. g., recognising different legislative regimes, national development priorities, land issues and specific conditions affecting biofuels crop production.
- Regional Infrastructure Development Master Plan (RIDMP) (2012). The RIDMP can serve as a key guide for the creation of efficient, cost-effective transboundary infrastructure connecting all SADC Member States in the energy, water, information and communications technology, and transport sectors. It will be implemented over a 15-year period that began in 2013.
- Revised Regional Indicative Strategic Development Plan (RISDP) (2015). This is a guiding document for the SADC regional integration and development programme over the period 2015 to 2020. The priorities are industrial development and market integration, infrastructure in support of regional integration, peace and security co-operation and special programmes with a regional dimension.
- Renewable Energy and Energy Efficiency Strategy and Action Plan (REEESAP) (2016). The REEESAP has been developed as a regional framework from which SADC Member States will develop their own renewable energy and energy efficiency strategies and Action Plans to accelerate efforts to promote renewable energy and energy efficiency in their State, hence contributing to energy security and energy access in the SADC region.

SADC's common goal is to achieve regional economic and social development in an environmentally sound manner by increasing access to modern energy services and improving energy security in SADC Member States. This goal is pursued through the newly established SADC Centre for Renewable Energy and Energy Efficiency (SACREEE), which is mandated to promote markets for renewable energy and energy efficiency technologies and services in the SADC region.

Eswatini also is represented, via the SEC, in the Southern African Power Pool (SAPP), where it benefits from regional coordination, energy planning and cross-border trading. The Government is obliged to implement policies and measures that will most favourably take advantage of market conditions and regulatory structures with regard to the SAPP. Connection to and participation in the SAPP affords Eswatini the opportunity to export and trade electricity generated locally into a competitive market with other interconnected SAPP members.

To improve regulation and governance in the power sector Eswatini joined the Regional Energy Regulators Association (RERA) with a view to benefiting from regional best practices, benchmarking information and shared experiences in addressing common power sector challenges.

2.6 CURRENT INSTITUTIONAL FRAMEWORK FOR ENERGY AND ELECTRICITY PLANNING

The Energy Department of the Ministry of Natural Resources and Energy is the custodian of policy and operational activities pertaining to the energy sector. Its mission is to effectively manage the national energy resources and to work towards affordable and sustainable energy provision for all people in the country, while ensuring the international competitiveness of the energy sector.

The Government leads the national energy planning process, with input from different energy sector stakeholders drawn from government agencies, the national utility, the national regulatory authority, civil society, academia, the private sector and IPPs. This serves to leverage the expertise and resources of other agencies and to promote diverse energy supplies, while integrating various energy sector priorities and goals and building consensus.

The Government develops national policies and programmes, while private energy companies have a key role in implementation and investment. Apart from the electricity sector, no quantitative long-term energy sector planning has been practiced. This Energy Masterplan is the first attempt to devise a comprehensive long-term framework for the entire energy sector. Integrated resource planning is becoming important to allow key stakeholders to participate in the identification and optimisation of the appropriate mix of energy resources to meet short- and long-term energy needs in a sustainable way.

2.6.1. ENERGY STATISTICS

Energy data are crucial for planning and monitoring the implementation of policies. The national Energy Department collects, analyses and disseminates energy statistics, in close collaboration with the Central Statistics Office (CSO). The CSO is instrumental in collecting data through the national census, the Eswatini household income and expenditure survey, and other means.

The Energy Department conducts annual surveys on energy statistics to collect primary data from major industries (*e.g.*, sugar-producing companies, timber industries, hotels). The Department also uses secondary data from various companies such as the SEC and oil companies, to cross-check the primary data.

The Department compiles annual energy balance tables using Excel-based software designed by the SADC Regional Energy Planning Network (REPN). However, technical support from SADC for operating the REPN software has long ceased, and Department staff have experienced technical difficulties.

The Department is further introducing GIS software for mapping energy infrastructure and renewable energy sources. For future projections of demand, trend analysis has been practiced. National energy statistics are disseminated internally as well as to external partners; however, the information is not widely published.

2.6.2 ELECTRICITY SECTOR

The national utility SEC, among its functions, is entrusted with the safe operation and control, expansion planning and maintenance of the electricity infrastructure, as well as energy trading. The electricity infrastructure expansion planning framework involves all relevant stakeholders, from the Government (in its function as policy maker) to customers and to IPPs and the utility.

The SEC plans for all expansion in the electricity sector. This includes grid expansion plans for the transmission and distribution networks, generation expansion plans and demand forecasting. Typical planning time horizons are 10 years.

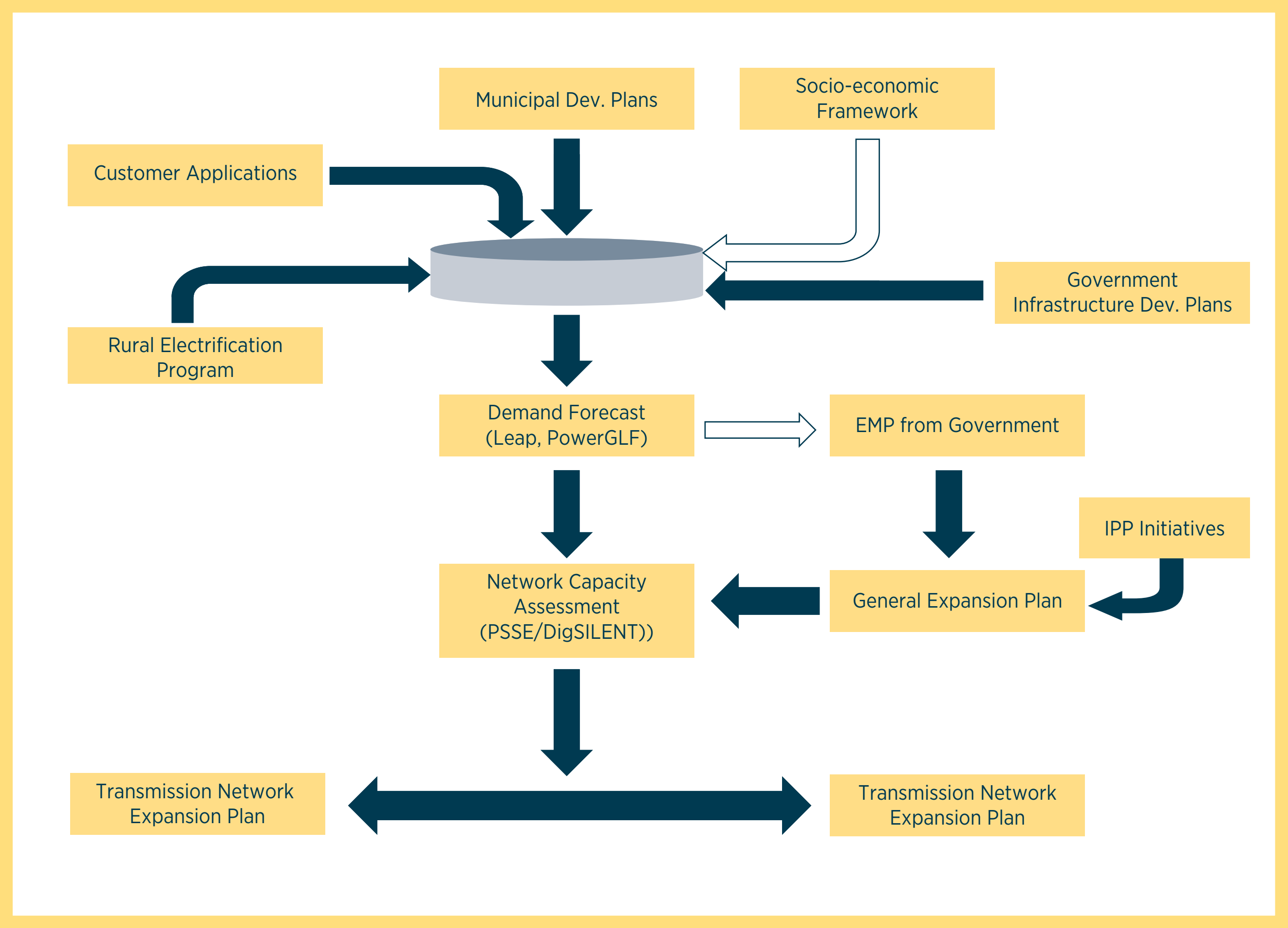
Demand forecasting is key in establishing the basis for national generation, transmission and distribution expansion planning as well as for assessing the impact of specific large energy-intensive projects on existing resources and infrastructure. The aim of demand forecasting is to determine the present and future electricity requirements of electricity end-users in order to reconcile these with the available resources and electricity infrastructure. Spatial consideration of electricity needs and requirements of various user sectors are considered, as determined by the characteristics and trends of each and highlighting where and when imbalances between electricity requirements and supply are most likely to occur. Broad socio-economic characteristics of study areas are assessed to enable the collection of data that provide a sketch of a holistic picture of the varying realities contained within the study areas as well to portray the impacts created by various factors.

Influential planning strategies at the town and village level are assessed, taking note of residential, commercial and industrial developments in order to develop electrical characteristics around proposed developments to predict future needs. Different methods based on the characteristics of customer sectors are applied to forecast the future demand, where demand and projected growth of the industrial sector differs dramatically from the residential sector, which is based on the growth of rural electrification. The types of forecast methods include spatial forecasts, point load forecasts and household forecasts.

Figure 2.1 demonstrates the planning process flow used by the utility. The components shown in broken lines are suggested to be included when the Energy Masterplan is completed.

The generation expansion plan will in future be driven from the output of this Energy Masterplan. The generation expansion plan programme is currently implemented by the utility and IPPs.

FIGURE 2.1 PLANNING PROCESS FLOW



3 ENERGY BALANCE:
RETROSPECTIVE AND GENERAL OVERVIEW

The development of this Energy Masterplan was initiated in 2016. The latest available year for energy sector statistics at that time was 2014, and Section 3.1 discusses the energy balance for that year. For time-series data, the statistics go back to 1994. Where available, data for more recent years beyond 2014 are presented in the time-series analysis in Section 3.2

3.1 ENERGY BALANCE FOR 2014

The Eswatini energy balance for 2014 is shown in Table 3.1. The table summarises the country's primary energy supply, transformation of primary energy, and final consumption. The structure of each of these items is discussed in the sub-sections below.

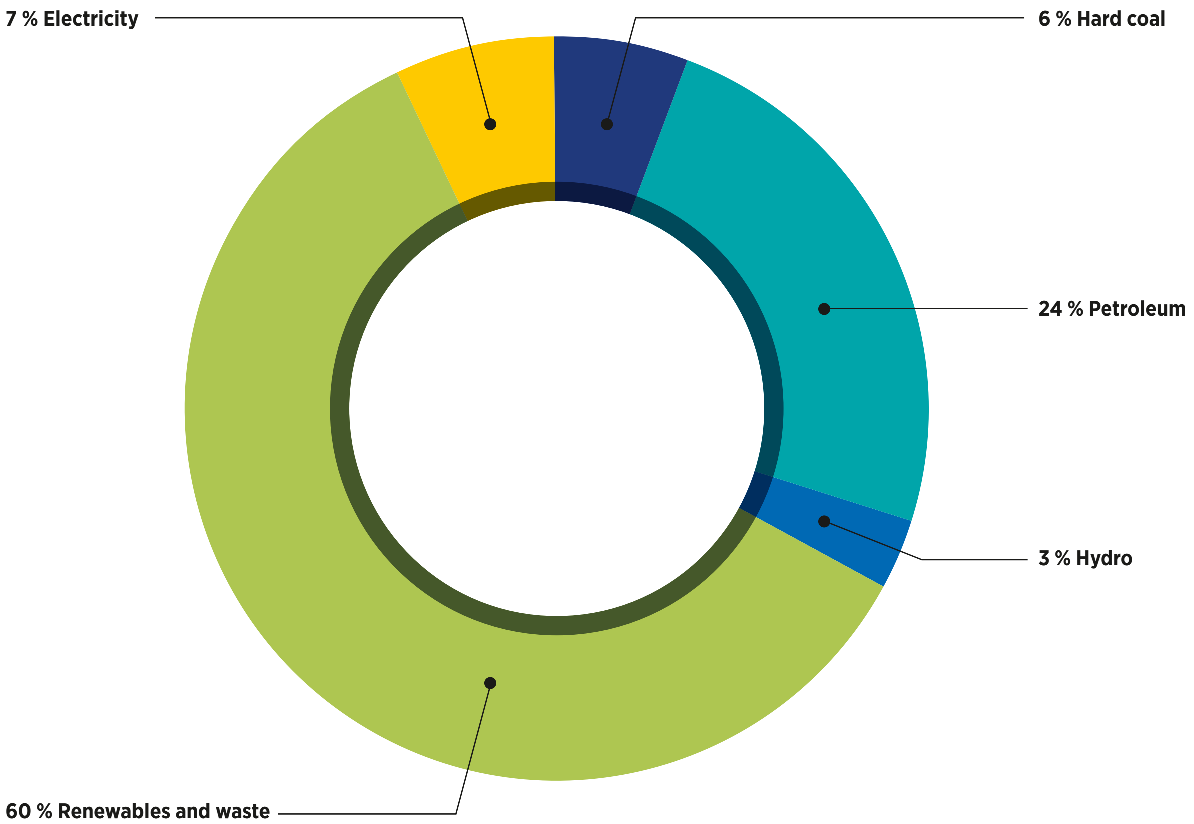
TABLE 3.1 ESWATINI ENERGY BALANCE FOR 2014

Eswatini Energy Balance 2014 (TJ)	Hard coal	Petroleum	Hydro	Renewables and waste	Electricity	Total
Indigenous production	5,554	–	1,157	25,796	–	32,507
From other sources	–	–	–	–	–	0
Import	2,449	10,412	–	151	3,097	16,109
Export	–5,554	–	–	–	–	–5,554
International marine bunkers	–	–	–	–	–	0
Stock changes	–	–	–	–	–	0
Total primary energy supply (TPES)	**2,449**	**10,412**	**1,157**	**25,947**	**3,097**	**43,062**
	–	–	–	–	–	0
Statistical differences	–	–1	–68	3	–	–66
	–	–	–	–	–	0
TRANSFORMATION	**–542**	**–**	**–1,089**	**–2,780**	**2,061**	**–2,350**
Losses	–	–	–	–	631	631
FINAL CONSUMPTION	**1,907**	**10,411**	**–**	**23,170**	**4,527**	**40,015**
Industry	1,264	88	–	11,194	1,771	14,317
Residential	–	356	–	11,976	1,218	13,550
Agriculture	–	394	–	–	1,168	1,562
Commerce and government services	643	234	–	–	370	1,247
Transport	–	9,339	–	–	–	9,339

3.1.1 TOTAL PRIMARY ENERGY SUPPLY

Sources of total primary energy supply (TPES) in Eswatini include hard coal, renewables and waste, hydropower, electricity and petroleum. The contribution of each energy source to the country's energy supply is shown in Figure 3.1 In 2014 renewables and waste contributed 60 % of the TPES; of the total supply of renewables and waste, 46 % is from domestic wood and 54 % from domestic bagasse. Hydropower contributed 3 % of TPES, and imported electricity contributed 7 % of TPES. Coal (imports) contributed 6 % of TPES, and petroleum (imports) contributed 24 %. Eswatini is reliant on imports for petroleum products that include petrol, diesel, paraffin, LPG and lubricants.

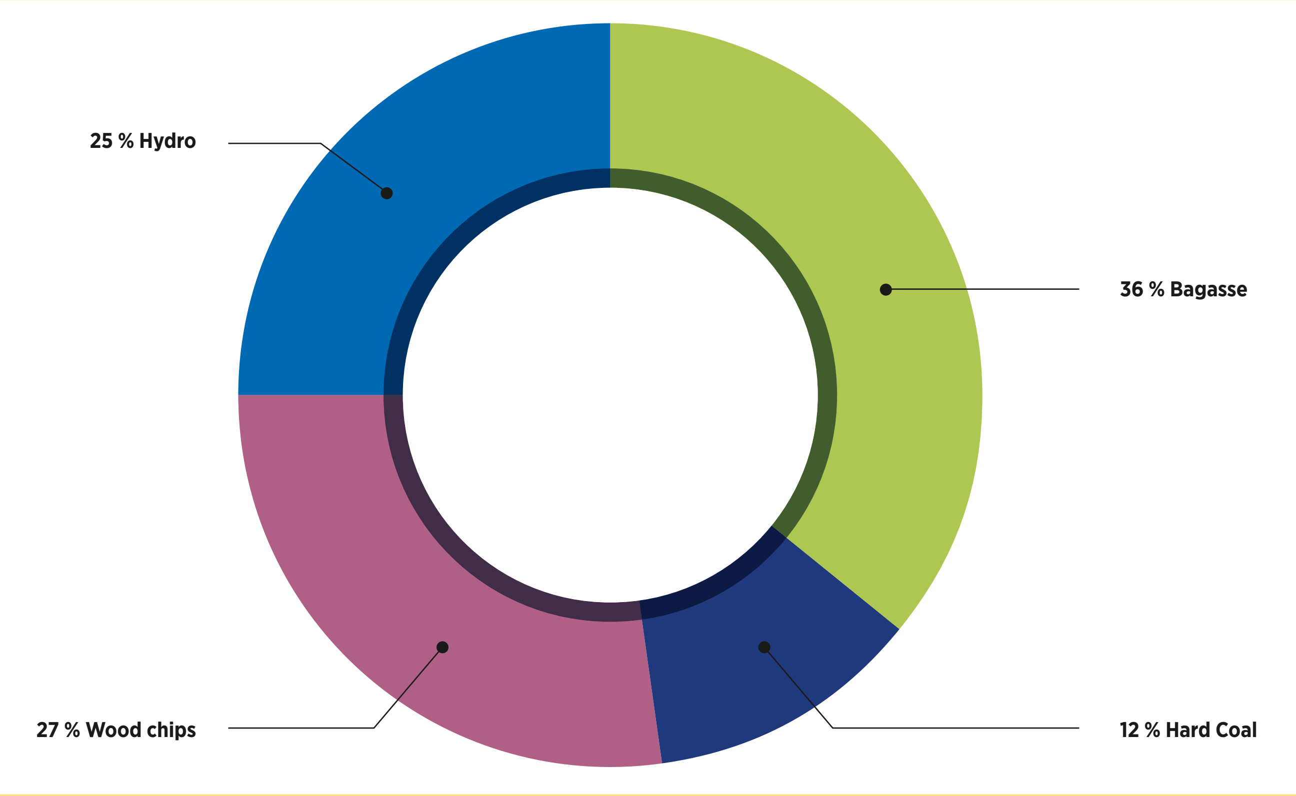
FIGURE 3.1 TOTAL PRIMARY ENERGY SUPPLY IN 2014



3.1.2 TRANSFORMATION OF PRIMARY ENERGY

Eswatini has a vibrant energy industry, which produces, transforms and supplies energy, mainly to provide heat and electricity. In 2014 an estimated 4,411 terajoules (TJ) of fuel was used to generate combined heat and power (CHP, via co-generation) from coal and from renewables and waste, particularly bagasse (36 %) and wood chips (27 %). Coal accounts for 12 % of total fuel use for power generation, and the remaining 25 % is from hydropower (Figure 3.2).

FIGURE 3.2 FUEL MIX FOR ELECTRICITY AND HEAT PRODUCTION IN 2014



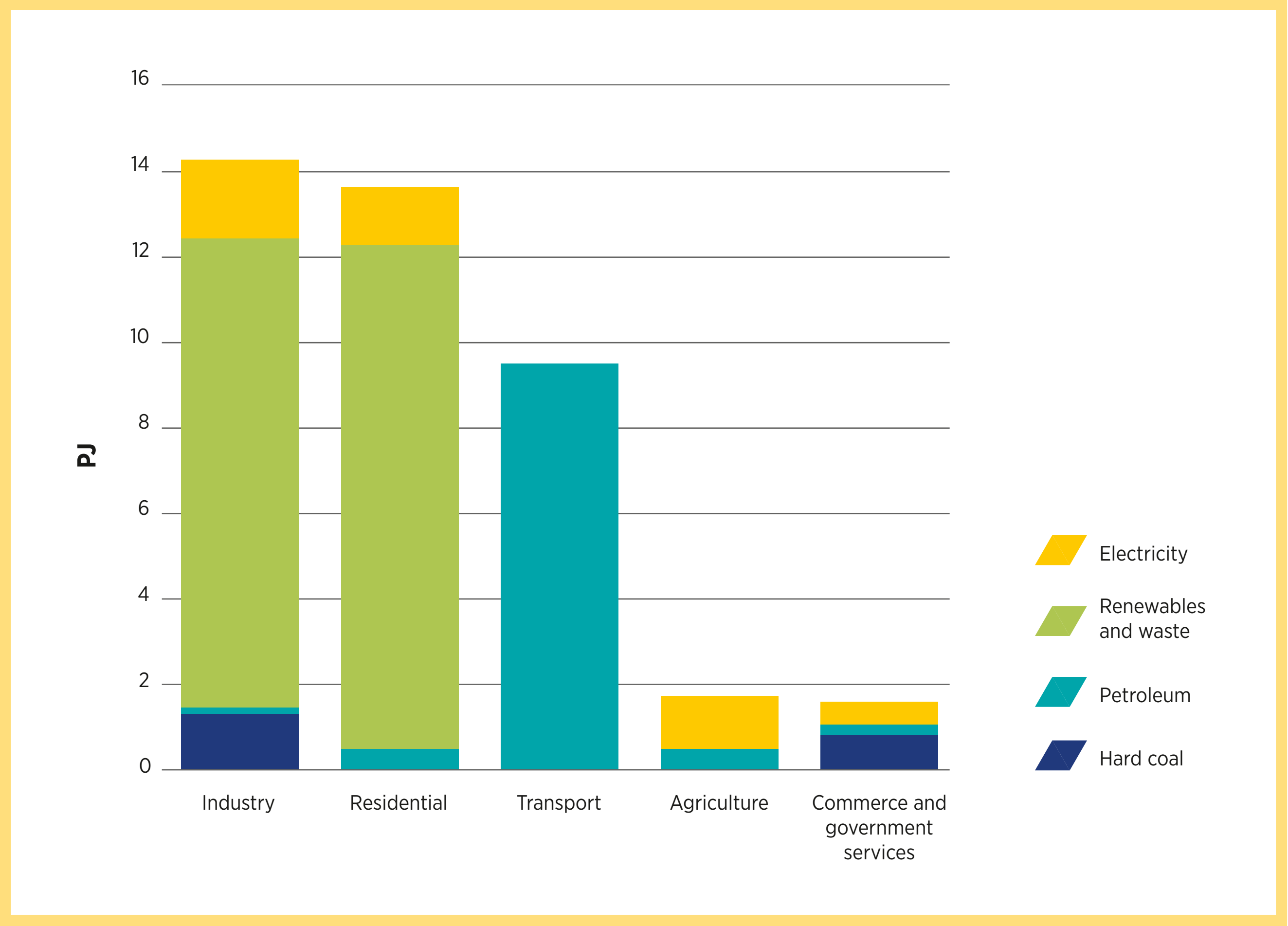
The total installed generation capacity in Eswatini in 2014 was around 180 MW, including 106 MW of biomass, 61.5 MW of hydropower, 9 MW of diesel and 2.2 MW of coal power plants. Due to the high operational costs, it is no longer financially or economically viable to run the diesel power plants. Approximately 304 GWh of electricity was generated in 2014 from the public utility's hydropower plants and biomass. Biomass plant generation is based on bagasse and wood chips that are used in combination as feedstock in the existing CHP plants. Sugar mills use waste produce (bagasse) and wood chips to run their mills during the season and generate steam to run the boilers and turbines (see Section 6.1 for further detail). Sugar mills are self-producers and export excess power to the grid.

Although Eswatini has proven domestic reserves of coal, the contribution of coal in the current energy mix remains small; in 2014, 15 GWh of electricity were generated from the 2.2 MW of distributed coal capacity.

3.1.3 TOTAL FINAL ENERGY CONSUMPTION

Total final energy consumption (TFEC) in the country is presented in the main sectors of *transport, industry, residential*, *agriculture,* and *commerce and government services*. The industry sector represents the sugar sector and other industrial sectors. Final energy use in 2014 by sector is shown in Figure 3.3 The transport sector used only oil products, mainly petrol and diesel. The sugar industry consumed electricity, and the residential sector used mainly wood, oil products in the form of paraffin and LPG, as well as electricity. The agriculture sector consumed electricity and oil products in the form of diesel. The commerce and government services sector comprises the hospitality industry and government departments. The use of coal and renewables and waste in this sector primarily represents inputs to cooking, as well as water and space heating in the health and hospitality industries.

FIGURE 3.3 FINAL ENERGY USE BY SECTOR IN 2014



For oil products, the majority (89 %) was consumed by end-users in the transport sector. The agriculture sector accounted for nearly 4 % of oil product consumption, and other end-uses were from the industry sector (1 %), commerce-related services (2 %) and households (4 %) (Table 3.2).

TABLE 3.2 OIL PRODUCT USE IN 2014

Sector	**Energy (TJ)**	**% of use**
Agriculture	394	3.8 %
Commerce and government services	234	2.2 %
Industry	88	0.8 %
Residential (households)	376	3.6 %
Transport	9,339	89.5 %
Total	**10,431**	**100 %**

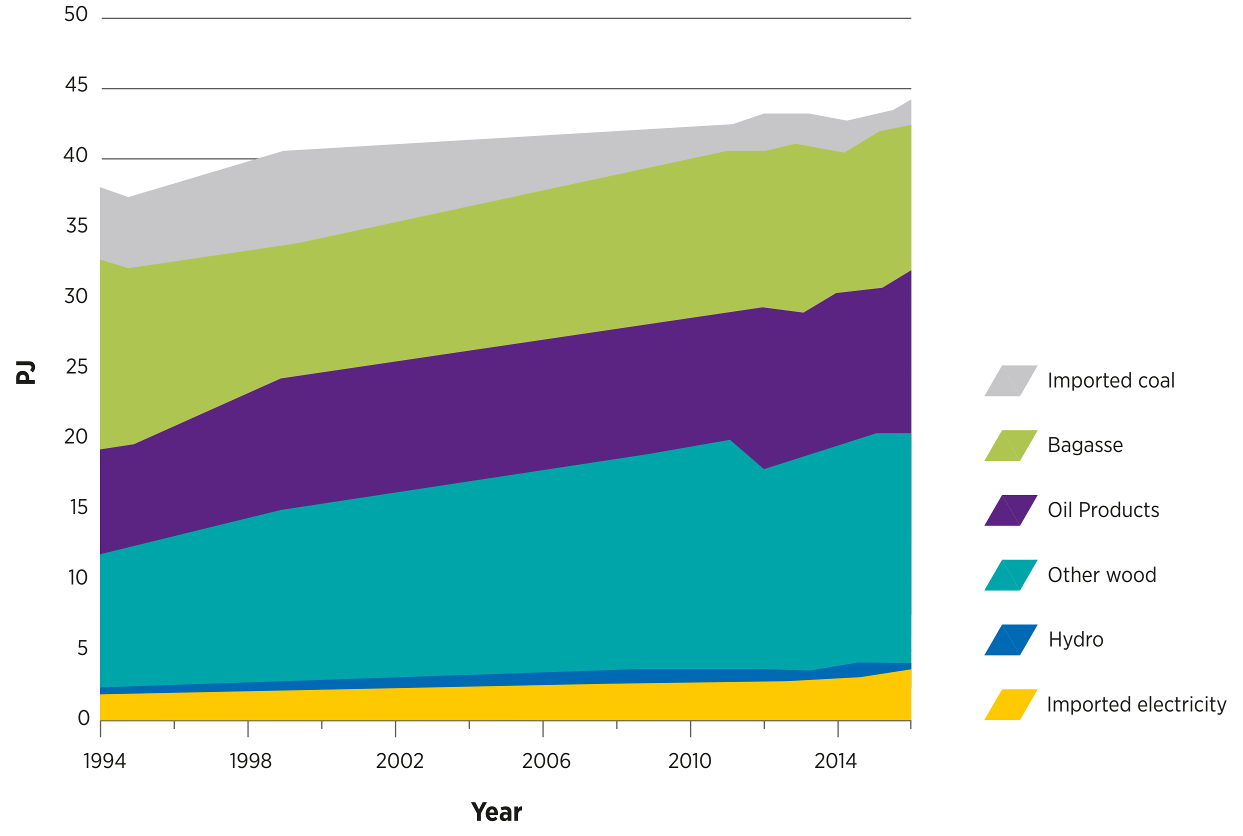
3.2 TRENDS IN ENERGY SUPPLY, TRANSFORMATION AND USE

Eswatini official energy statistics reach back to the year 1994. The following sub-sections discuss structural changes in the country's energy supply and demand between 1994 and recent years.

3.2.1 TOTAL PRIMARY ENERGY SUPPLY

As shown in Figure 3.4, the profile for Eswatini's TPES has not changed much between 1994–2016. However, apparent trends include the increased use of imported electricity and the decreased use of imported coal as a result of fuel switching from coal to electricity. The supply of wood increased over the years, as did the use of bagasse. The supply of electricity from hydropower increased slightly in 2011 due to a capacity increase of 20 MW.

FIGURE 3.4 TRENDS IN TOTAL PRIMARY ENERGY SUPPLY



3.2.2 TRANSFORMATION OF PRIMARY ENERGY

Trends in the transformation of input fuels for heat and electricity generation since 1994 are shown in Figure 3.5. Overall trends include the increased use of bagasse and decreased use of coal. Use of wood waste decreased in recent years. Use of hydropower similarly first increased and then declined in recent years; this reflects droughts that happened during that period. The fluctuation in the use of bagasse reflects a similar pattern, as it too is dependent on rainfall that affects sugarcane production.

FIGURE 3.5 TRENDS IN INPUT FUELS FOR HEAT AND ELECTRICITY GENERATION

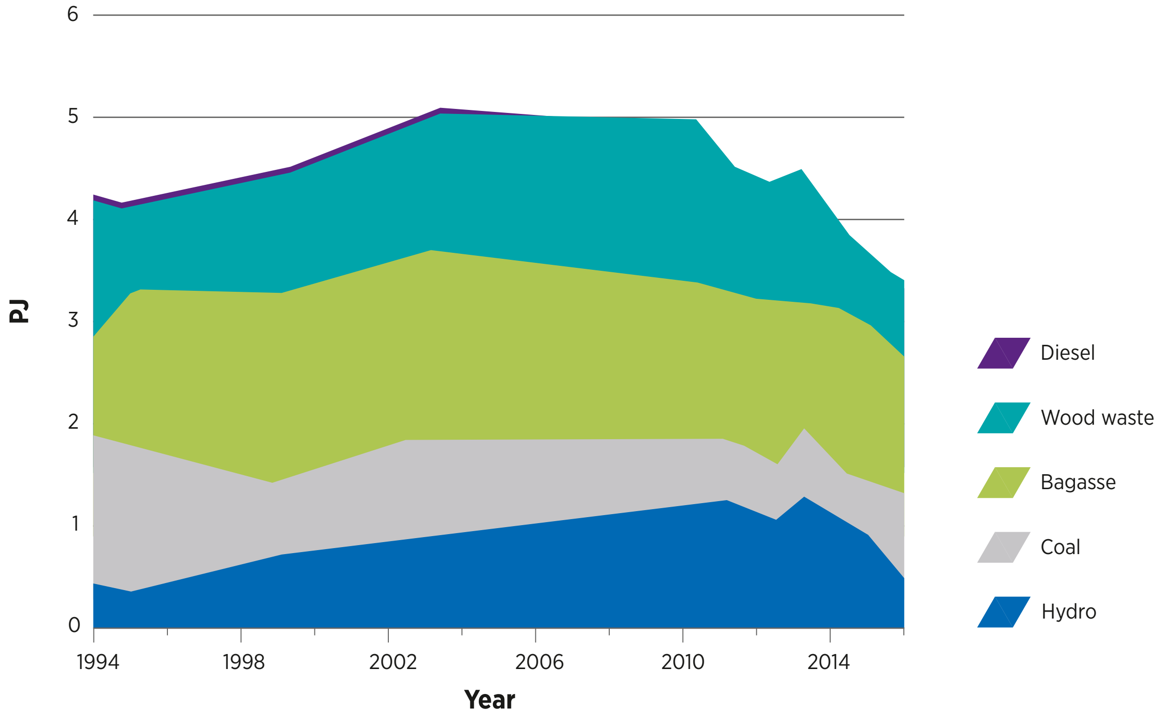
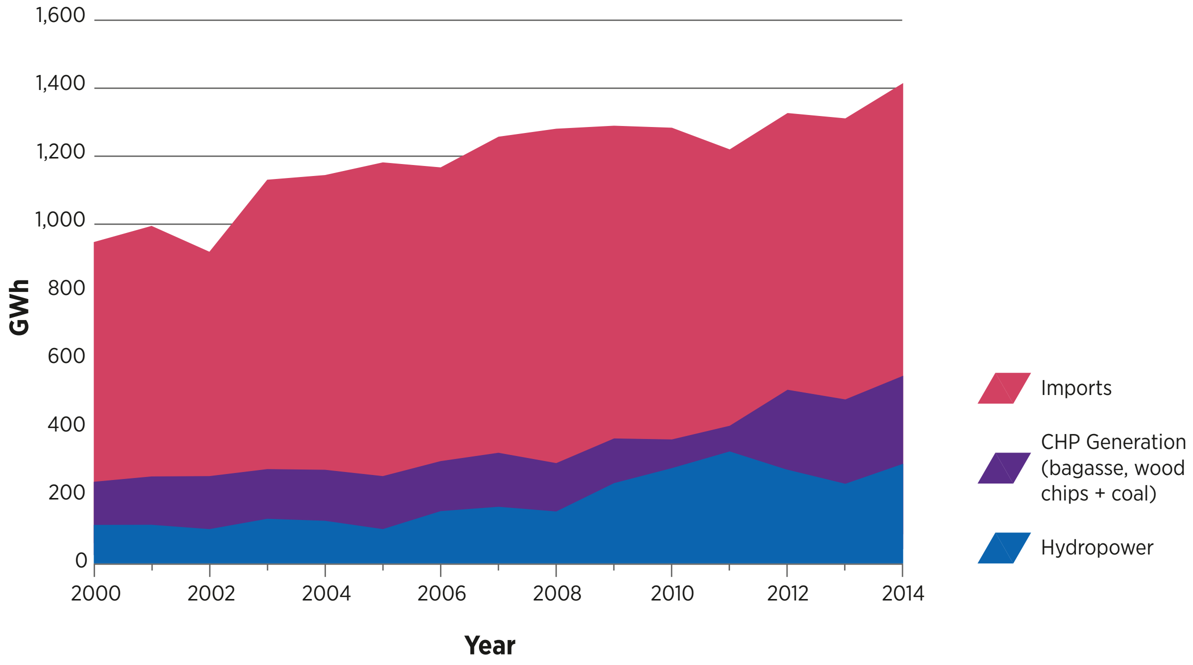


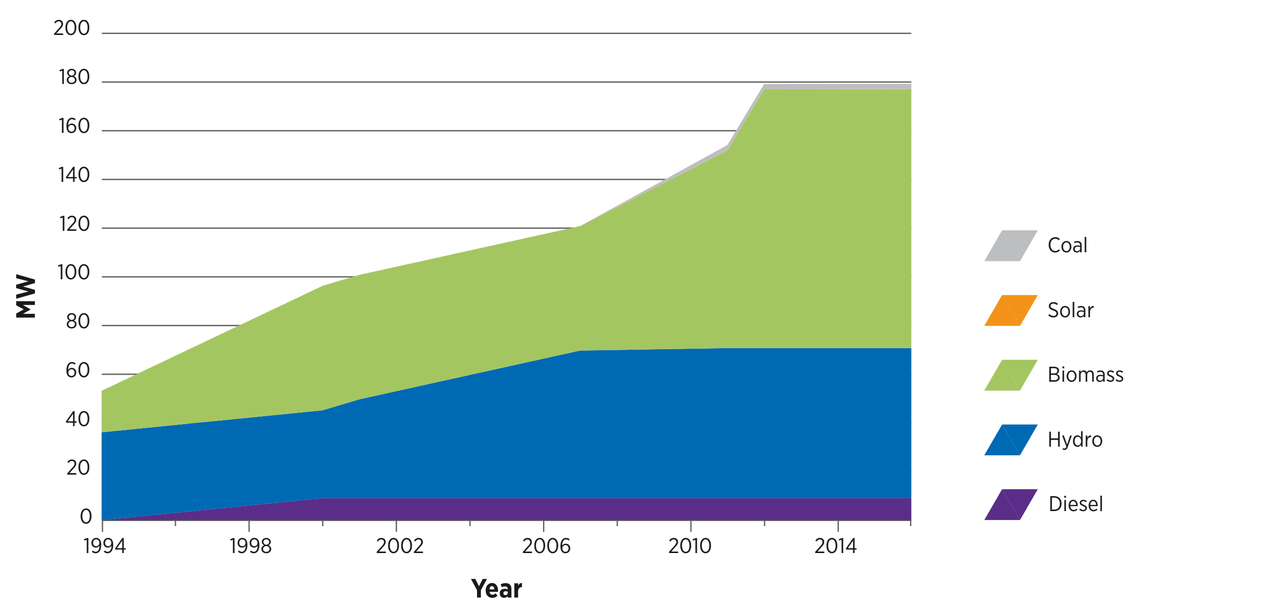
Figure 3.6 shows the trends in electricity output by source. Notably, the electricity supply has increased more than 50 % since 2000. The dominance of imported electricity continued over this period, and the supply from domestic CHP and hydropower generation has more than doubled in recent years. Corresponding to the fluctuation of the inputs, hydropower generation also fluctuates throughout this period, reaching a high of 1,200 GWh in 2011 as a result of the 20 MW of additional capacity.

FIGURE 3.6 TRENDS IN THE ELECTRICITY MIX



The country's installed generation capacity from 1994 to 2016 is shown in Figure 3.7. In 2012 new biomass capacity of about 39.5 MW from bagasse and wood chips was added. Hydropower capacity has been constant since 2011, with fluctuations in electricity output as depicted in Figure 3.6. Diesel capacity also has remained constant, with no production of electricity because the power plant is mothballed.

FIGURE 3.7 TRENDS IN INSTALLED CAPACITY



3.2.3 TOTAL FINAL ENERGY CONSUMPTION

Figure 3.8 shows the development of TFEC from 1994 to 2016. Over this period TFEC increased slightly, driven primarily by increased fuel use in the residential sector.

FIGURE 3.8 TRENDS IN FINAL ENERGY CONSUMPTION BY SECTOR

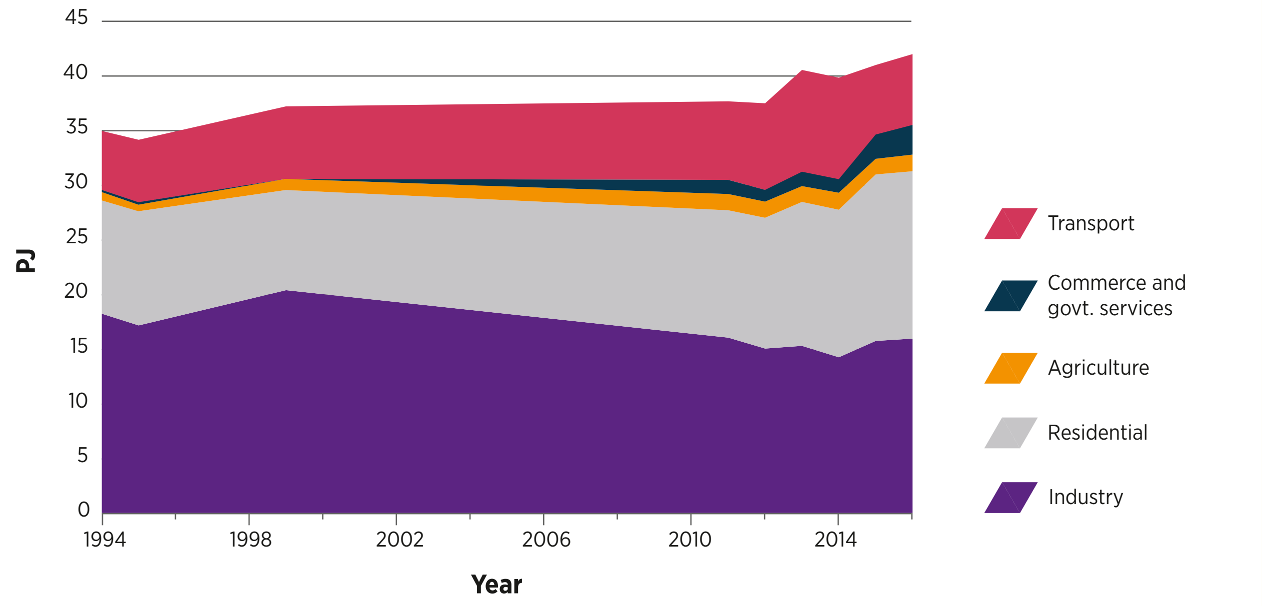
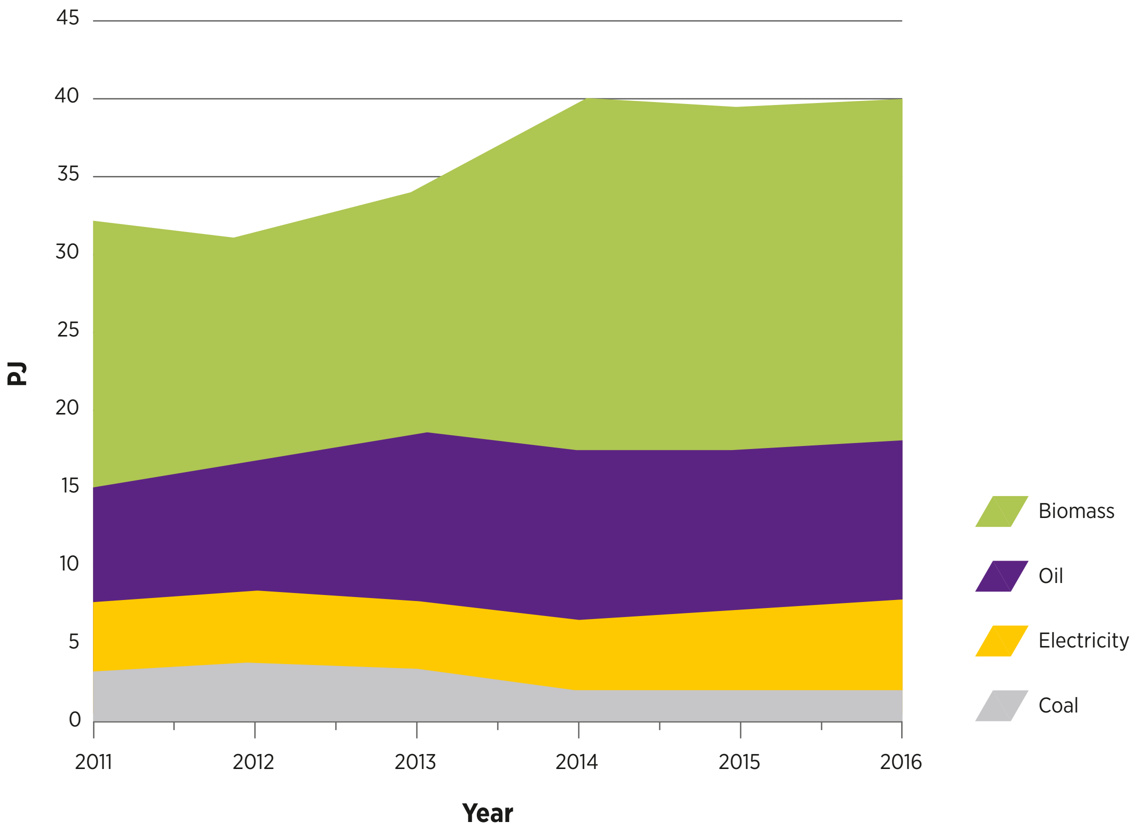


Figure 3.9 shows the development of TFEC between 2011 and 2016, by fuel. The use of biomass shows an upward trend, and the use of the remaining types of fuels remains relatively constant, except for a slight increase in oil use in the transport sector as a result of increased car ownership.

FIGURE 3.9 TRENDS IN FINAL ENERGY CONSUMPTION BY FUEL



PART II:

ENERGY DEMAND ASSESSMENT

4 ENERGY DEMAND ASSESSMENT 2015–2034: METHODOLOGY AND ASSUMPTIONS

4.1 BRIEF DESCRIPTION OF THE METHODOLOGY

Detailed energy demand assessment for the period between 2015 and 2034 was performed using the Long-range Energy Alternatives Planning System (LEAP) software. An energy demand accounting model for Eswatini was created, and three demand projections were formulated. The model used for the assessment was initially developed in 2015 by the Ministry of Tourism and Environmental Affairs with technical support from the Energy Research Centre of the University of Cape Town, as part of an exercise to identify CO_2 emission mitigation options for Eswatini's INDC. The model was further reviewed and updated for the purpose of assessing the overall energy needs used as a basis for this national Energy Masterplan. Note that the updated version greatly simplified the original assessment done in 2015, mainly in terms of the number of technology options assessed and the representation of end-use energy services.

The LEAP software[2] is a tool to generate a detailed accounting model to develop energy demand projections in a bottom-up manner, by taking into account energy consumers' useful energy needs and their choice of technologies and appliances. The tool can be used to describe individual policy measures that can then be combined into alternative scenarios. This approach allows policy makers to assess the impact on an individual policy as well as the interactions that occur when multiple policies and measures are combined.

The increase in energy demand is driven mainly by economic growth, population growth and the electrification rate. The model takes into account the energy intensity of short- and long-term efficiency improvements. End-user prices were mostly not taken into account, but historical data on the consumption of coal, oil products, electricity and biomass were used. The intensity of energy consumption per unit of each sub-sector's output and the share of each energy source are projected on an econometric basis. The output level of each sub-sector is modelled separately and is combined with projections of its energy intensity and end-use shares to derive the consumption of each energy source by sub-sector.

Population dynamics are also an important driver of energy trends and the assumptions. An increase in population increases the number of households. This factor is the key driver of energy demand in the residential sector.

The Eswatini energy demand model formulated with LEAP (hereafter referred to as the LEAP-Swaziland model) explicitly assesses the demand for the following sectors and energy services. Note that the numbers in brackets indicate the number of technology options modelled under each category.

- Industry sector sugar production [2: electricity and oil]
- Industry sector other [2: electricity and oil]
- Agricultural sector [2: electricity and oil]
- Mining [1: electricity]
- Commerce and government services [3: electricity, coal and LPG]
- Residential sector electrified cooking [4: electricity, LPG, wood and paraffin]
- Residential sector electrified water heating [5: geyser, solar water heating without back-up, solar water heating with back-up, other electricity and wood]
- Residential sector electrified refrigeration [1: electric refrigerator]
- Residential sector electrified air conditioning [1: air conditioning]
- Residential sector electrified lighting [1: electricity]
- Residential sector electrified television/ironing [1: electricity]
- Residential sector electrified other [1: electricity]
- Residential sector non-electrified [3: wood, LPG and paraffin]
- Transport sector [1: oil]

The industry is separated into two sub-sectors, the "sugar industry" and "other industry", allowing for a more detailed analysis of trends and drivers in the industrial sector by fuel.

The residential sector's energy consumption is split into electrified and non-electrified households, and the energy demand of electrified households is further divided into seven end-uses: cooking, water heating, refrigeration, air conditioning, lighting, television/ironing (appliances) and other. The energy consump-

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[2] For details on the LEAP software, see www.energycommunity.org/default.asp?action=introduction.

tion related to each end-use is computed as the product of an intensity variable. For each end-use, the intensity variable is projected econometrically and is linked to the impact of policies and measures to reduce energy intensity and promote energy efficiency. The fuel shares are also projected econometrically and are linked to a variable representing the impact of policies and measures to promote fuel switching. For example, in the case of fuelwood, fuel share is the function of variables taking into account the impact of policies such as rural electrification, clean cooking and cost-reflective tariffs.

The division of electrified/non-electrified households is made based on historical data from sample surveys, in order to better evaluate the differences in these households. As a result of the bottom-up analysis, estimated aggregate biomass use in the residential sector was revised downwards compared to the model from the Ministry of Tourism and Environmental Affairs, which did not assume energy efficiency improvements. Energy consumption for both electrified and non-electrified households was calculated for each fuel as a function of gross domestic product (GDP), the electrification rate and past consumption levels. Fuel demand is projected per household.

Economic activity is the main driver of electricity demand in all sectors. On average, electricity demand rises faster than income, hence electricity demand is income-inelastic. This difference reflects the penetration of various energy services (saturation effects) in the country, and it also reflects changes in the structure of economic activities. Electricity-intensive heavy industry has contributed more of the increase in GDP. The energy efficiency of electrical equipment and appliances is also generally lower, boosting electricity intensity.

4.2 KEY SCENARIO ASSUMPTIONS

Three demand scenarios were developed: the Reference, High Growth and Low Growth scenarios. They are differentiated by assumptions regarding the GDP growth rate and the electrification rate in the residential sector.

The overall energy demand development of the country is based on a GDP growth rate in the range of 1.8 % to 3 % between 2014 and 2020, and 3 % thereafter. This growth rate drives energy demand in the industrial and residential sectors, which is driven mainly by economic expansion. The growth in energy demand in Eswatini lags behind the global average of 4.9 %. The High Growth scenario assumes a 4 % increase in revenue from the mining sector.

With regard to electrification rates, in the High Growth scenario universal access is assumed to be achieved by 2022, in the Reference scenario by 2030, and in the Low Growth scenario by 2034. Population growth is assumed to overall decrease, from 1.2 % per year in 2014 to 0.8 % per year in 2034, according to official government projections. Key assumptions for the three scenarios are summarised in Table 4.1 and are discussed further in the sub-sections below.

TABLE 4.1 KEY SCENARIO ASSUMPTIONS

	Reference	High Growth	Low Growth
Annual GDP growth rate	1.8 % to 3 %: 2014 to 2020 3 %: 2020 to 2034	1.8 % to 3 %: 2014 to 2020 3 % to 3.5 %: 2020 to 2025 3.5 %: 2025 to 2034	0.9 % to 1.8 %: 2014 to 2020 1.8 %: 2020 to 2034
Electrification rate	100 % achieved in 2030	100 % achieved in 2022	100 % achieved in 2034
Annual population growth	Decrease from 1.2 % (2014) to 0.8 % (2034)		

4.2.1 CLIMATE

In general, the climatic conditions of Eswatini vary from tropical to near temperate. Winter in the country is generally dry and cold, with an average temperature of around 17 degrees Celsius (62.4 degrees Fahrenheit). During the winter time, most households require space heating.

The main source of energy used for this purpose is fuelwood; thus, larger quantities of fuelwood are consumed during the winter at the household level. Alternative sources of energy used are LPG, paraffin and electric heaters. In commercial buildings both air conditioners and heaters are used.

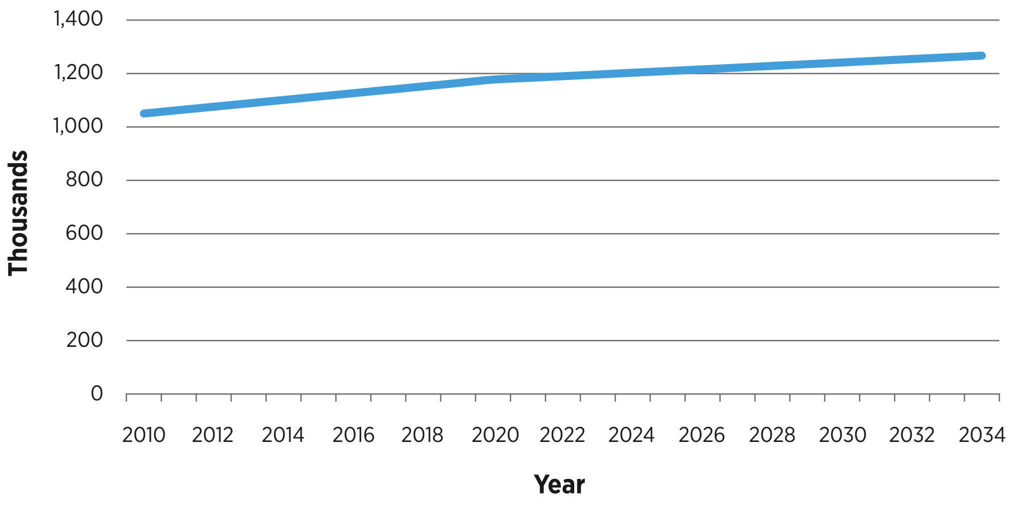
The SEC reports that during summer months the demand for electricity is attributed to an increase in the need for household and industrial cooling systems as well as irrigation systems for the sugar industry.

4.2.2 DEMOGRAPHY AND MAJOR DEMOGRAPHIC POLICY GOALS

Eswatini's population was estimated to be around 1.1 million people in 2014, with about 76 % living in rural areas and 24 % in urban areas. The distribution of the population among the four regions of the country is uneven, with Manzini accounting for the highest share at 32 %, Hhohho at 29 %, Shiselweni at 20 % and Lubombo at 19 %. The migration of people between regions is relatively low; however, it is very high between rural and urban areas as people search for job opportunities and for means of earning a living. Rapid growth in the urban population is attributed largely to rural-urban migration. Given that the migrants are usually young and able-bodied persons, this has the effect of impoverishing the rural areas from where they originate. More than half of the urban population is concentrated in the two cities of Mbabane and Manzini.

The country's official population projections (Figure 4.1) indicate that the population will increase at an annual rate of 1.2 % from 2014; this growth rate decreases to about 0.8 % annually by 2034. The decline in population growth is driven primarily by the declining fertility rate, which is expected to drop from 3.5 children per woman in 2014 to below 3.0 children per woman by 2030.

FIGURE 4.1 POPULATION PROJECTIONS, 2010 TO 2034

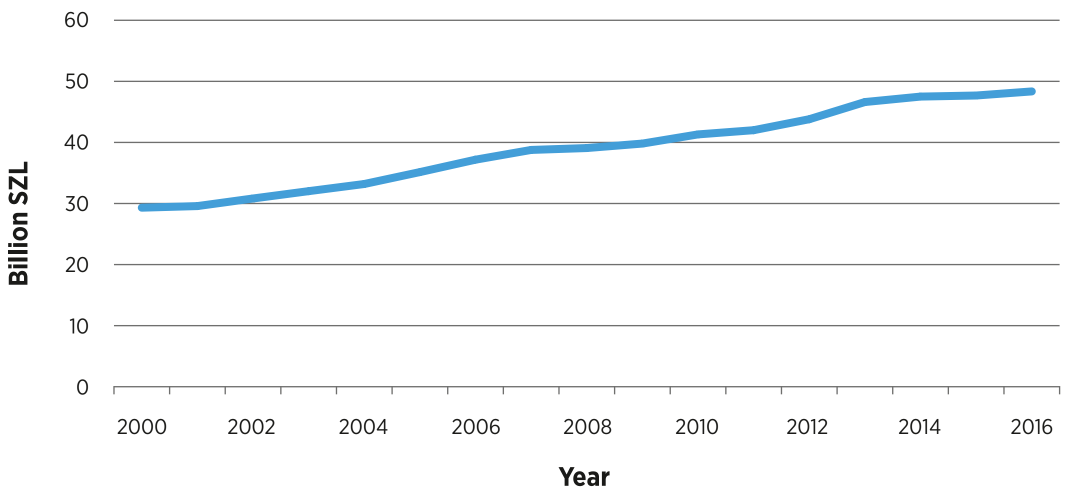


4.2.3 MACROECONOMIC SITUATION AND MAJOR ECONOMIC POLICY ISSUES

As shown in Figure 4.2 Eswatini's economy grew modestly in the period 2000–2016. From 2000 to 2007 the average GDP growth rate was 4.6 %. This growth then declined slightly, at an average of 2.5 %, to 2016. Significant development challenges continue, including high unemployment and poverty. In recent years, Eswatini's economy has geared towards an expansionary fiscal policy, while revenues from the Southern African Customs Union (SACU) have declined as a share of GDP since 2013/14. As a result, the fiscal balance turned into a deficit in 2014/15.

Eswatini's macroeconomic imbalances are also driven in part by the global economic decline and shocks. The country's loss of eligibility under the Africa Growth Opportunity Act (AGOA[3]) points to the importance of enhancing economic diversification and competitiveness. Stepped-up policy efforts in multiple areas are needed, including improving the business climate and export diversification.

FIGURE 4.2 TRENDS IN GDP BETWEEN 2000 AND 2016 (IN 2014 CONSTANT PRICES)



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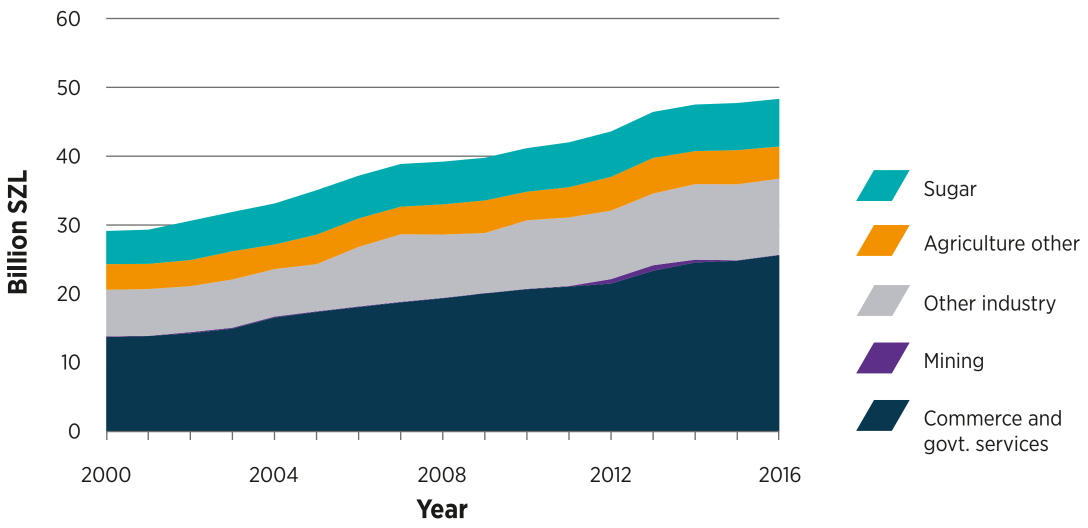
[3] The AGOA is a trade privilege scheme enacted by the United States to enhance access to the US market for qualifying sub-Saharan African countries. To qualify and remain eligible for the AGOA, each country must be working to improve its rule of law, human rights and respect for labour standards. The Act originally covered an eight-year period, from 2000 to 2008, but was later extended to 2015.

Figure 4.3 shows the sectoral composition of GDP and its development over the years. In 2016, the main contributor to GDP was commerce and government services at 53.1 %, followed by other industry at 25.2 %, the sugar industry at 14.3 %, agriculture at 7.3 % and mining at 0.1 %. Sugar is the key agricultural product, although its contribution is expected to fall drastically in the coming years due to the drought experienced in recent farming seasons. The effects of drought go beyond food insecurity and also adversely impact the production of energy. The contribution to GDP from the mining sector is negligible.

FIGURE 4.3 TRENDS IN GDP BY SECTOR BETWEEN 2000 AND 2016 (IN 2014 CONSTANT PRICES)

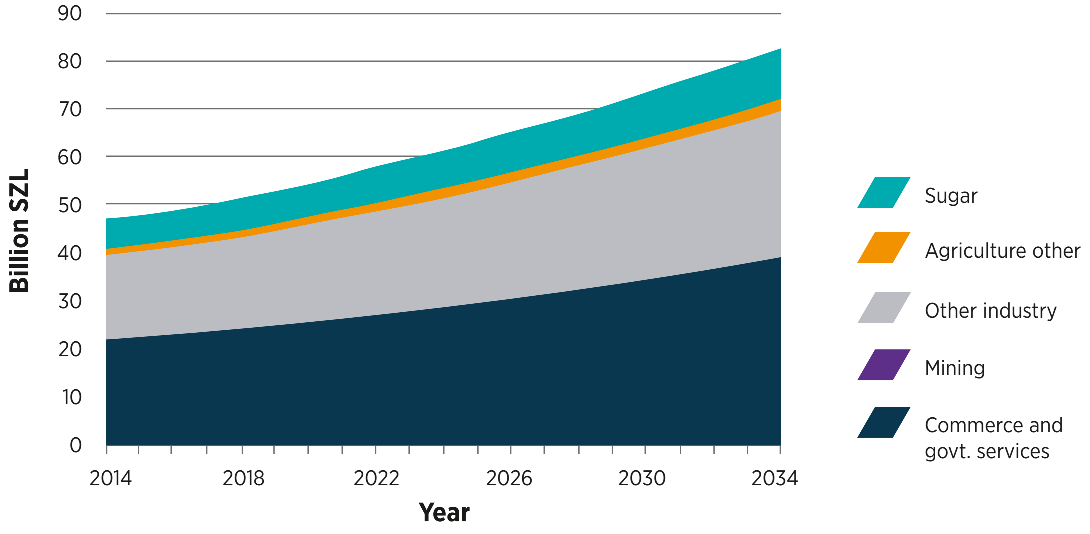


In the coming years, several key challenges lay ahead. They include:

- reduced GDP growth rate and forecasted deceleration in the coming years
- reduced demand for Eswatini's major exports
- lingering fiscal imbalances with unprecedented budget shortfalls and unhealthy accumulation of domestic arrears
- reduced external reserves (current account)
- increased dependence (over-reliance) on SACU revenues with high volatility.

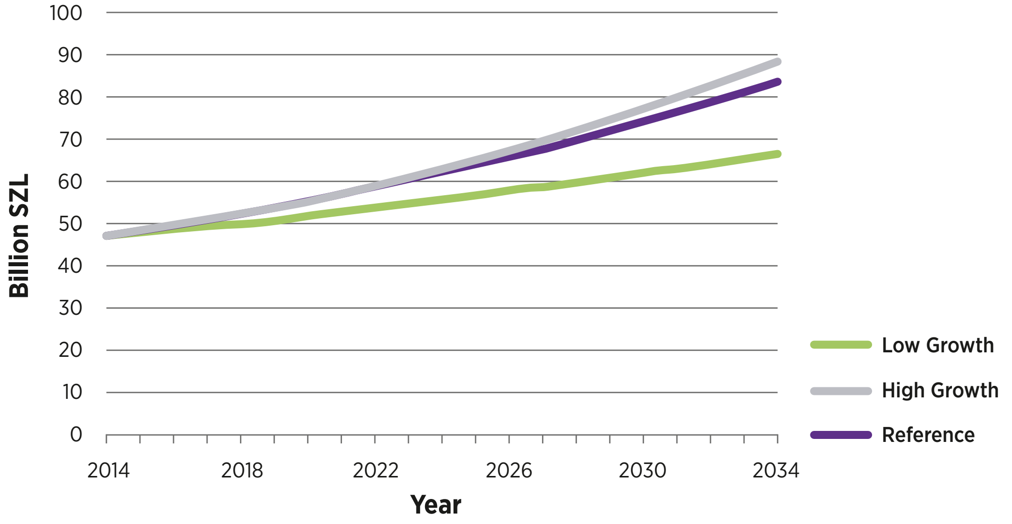
Despite the challenges ahead, the Government aims at GDP growth of 1.8 % per year for the coming years. Given the historical trends and policy priorities discussed above, the assumptions regarding the development of the country's economic structure are shown in Figure 4.4 for the Reference scenario. The commerce and government services sector is assumed to be the key driver of economic growth, with average annual growth of 1.8 % in 2014, rising to 3 % by 2020 and 3 % thereafter.

FIGURE 4.4 ASSUMPTIONS REGARDING THE COMPOSITION OF GDP



For the High Growth scenario, all of the sectors have the same GDP growth rate as in the Reference scenario, except that GDP growth increases to 3.5% from 2025 to 2034. In this scenario the mining sector is assumed to contribute SZL 4 billion (USD 286 million[4]) by 2034 (in the Reference case, GDP in the mining sector is zero), and growth in the entire demand sector is equal to economic growth, similar to the Low Growth scenario. The GDP assumptions for future years in the three scenarios are shown in Figure 4.5.

FIGURE 4.5 THREE GDP SCENARIOS FOR 2014 TO 2034



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[4] An Exchange Rate of 14 SZL = 1 USD was applied for this modelling analysis across the planning period 2014–2034.

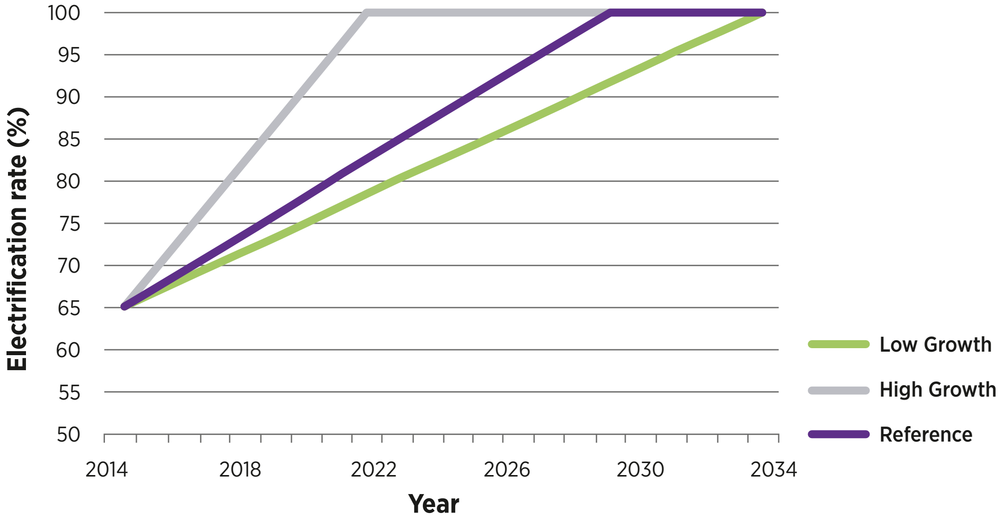
Electricity

In 2014 the national electricity access rate (*i. e.*, the share of households with electricity access) was 65 %, with the urban rate being 84 % and the rural household rate being 60 %. Rural electrification continues to be a priority issue in Eswatini. Robust implementation of the rural electrification programme in recent years has since increased household electricity access to 74 % in 2017.

The objective of the Government of Eswatini is to ensure that all citizens of the country have access to electricity by the year 2022. This ambitious target can only be realised with high investment support from the Government to extend the electricity grid to non-electrified areas. In recent years, the Government has collaborated with donor funding agencies to support implementation of the country's rural electrification programme.

For this particular exercise, modelling for the rural electrification targets has taken into account the slow injection of funds to support the rural electrification programme. Hence the target for universal access to electricity is projected to be reached later, in 2030 (and 2034 under the Low Growth scenario). To provide an outlook for electricity access until 2030, a model able to generate projection of electrification rates has been developed under the Reference scenario assumptions. The model was developed using the same economic and demographic assumptions, taking into account variables such as the rural electrification programme as well as the broad policy commitments and plans that have been announced around the world to tackle environmental and energy security concerns in the era of sustainable energy for all.

FIGURE 4.6 ELECTRIFICATION PROJECTIONS FOR 2014 TO 2034

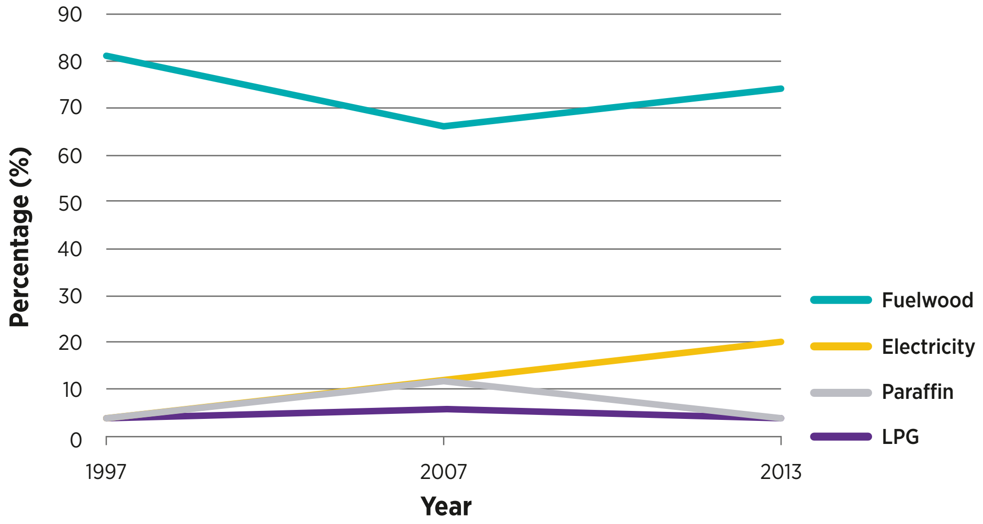


The results in Figure 4.6, however, assume that no additional policies to expand energy access, over and above those in place today, are enacted over the projection period. The model also assumes a 1.2 % increase in population. The model takes into account the required investment in limited funding for the rural electrification programme, estimated at SZL 120 million (USD 8.6 million) per year. The total number of households was estimated by dividing the total population by the estimated average household size (*i. e.*, persons per household). Currently the average household size is estimated to be 4.2 persons per household. Together with the electrification rate, the number of electrified households was computed.

Modern cooking fuels

In addition to electrical energy, modern energy resources include hydrocarbon fuels (*e.g.*, LPG, candles and coal). Despite a national electricity access rate of more than 60 %, the use of electricity for cooking in rural areas is not common. As shown in Figure 4.7, even though fuelwood has remained the major energy resource for cooking over the years, electricity use for cooking is increasing steadily and has remained higher than LPG and paraffin. Use of electricity in cooking is expected to continue to grow in the future.

FIGURE 4.7 SHARE OF HOUSEHOLD FUEL USED FOR COOKING



Source: Swaziland Households Energy Access Report, 2014

Fuelwood remains the main energy resource for cooking and space heating, particularly in rural areas. However, according to the 2016 Wood Efficient Cook Stoves survey conducted by the Renewable Energy Association of Swaziland on behalf of the Energy Department, fuelwood is generally used inefficiently in rural areas. Following a pilot project aimed at promoting the efficient use of fuelwood, the Government is planning to extend the use of wood-efficient cook stoves, which can aid in the worldwide fight against deforestation and climate change.

To assess the future demand for traditional biomass, assumptions were made regarding the share of households using biomass for cooking, and the efficiency of biomass cook stoves. In line with SE4ALL goals and other policies to promote alternative modern fuels for cooking, it was assumed that by 2030 the share of households using fuelwood would be 20 % (the same as in 2014), the share using LPG would be 20 % (up from 14 % in 2014), and the share using electric stoves would be 80 % (up from 69 % in 2014). The policy also promotes efficient cook stoves, and a 50 % efficiency improvement in wood cook stoves is assumed to 2034.

Residential water heating

Increased penetration of efficient water heating is expected in the residential sector, in line with various policy goals and technology developments on appliance energy efficiency standards. Current shares of water heating devices are estimated at 82 % for wood, 9 % for geysers, 5 % for solar water heaters with back-up, 0 % for solar water heaters without back-up and 4 % for other electric devices.

The most inefficient wood-based water heating is replaced by other more efficient options, reducing its share by 13 % by 2034. Reflecting its promotion under the SE4ALL initiative, the share of solar water heating is assumed to reach 50 % of households (25 % with back-up and 25 % without back-up).

4.2.4 ENERGY EFFICIENCY GOALS

The National Energy Policy of 2003 promotes improving energy efficiency in all sectors. According to the policy, energy efficiency and savings aim to reduce energy consumption at the end-user level as well as in the supply system. Energy efficiency is about reducing losses within a technical energy system by optimising energy use, whereas energy savings covers a broader conservation methodology, including behavioural and operational issues. Energy efficiency initiatives in Eswatini include awareness raising and information dissemination, promotion of energy management in all sectors, building standards, energy efficiency within government institutions, energy appliance labelling and demand-side management. Ongoing energy efficiency initiatives include:

- installation of solar water heaters in government buildings;
- awareness and information dissemination through live radio programmes, roadshows and outdoor advertising;
- implementation of time-of-use tariffs;
- energy audits of public institutions as well as corporate customers;
- roll-out of prepaid electricity metering;
- distribution of compact fluorescent lamps (CFLs) and LEDs to the public;
- installation of solar PV and LED lighting demonstration projects; and
- adoption of energy efficiency standards.

The SE4ALL initiative includes some specific efficiency improvement targets (see Section 2.3), which collectively aim to double the rates of improvements in energy efficiency by 2030. Across all of the scenarios in LEAP-Swaziland, the following efficiency improvements are taken into consideration:

- Coal use in the commerce and government services sector
- Wood cook stoves in the residential sector.

5 ENERGY DEMAND ASSESSMENT 2015–2034: RESULTS

5.1 OVERALL ENERGY DEMAND DEVELOPMENT: 2015–2034

5.1.1 ENERGY DEMAND DEVELOPMENT BY 2034 IN THE REFERENCE SCENARIO

The overall energy demand of the country is projected to increase from 39.4 petajoules (PJ) in 2014 to 48.5 PJ in 2034 (Figure 5.1). This projected increase is driven by the shift from inefficient traditional biomass use to more efficient modern fuels – in particular, electricity – in the residential sector. The demand for traditional biomass is projected to decrease by more than half, from 14.5 PJ in 2014 to 6.4 PJ in 2034. As a result of the electrification of non-electrified households, residential sector energy demand drastically decreases by 2030; once the residential sector switches to other energy sources, the demand starts to pick up again slightly between 2030 and 2034. The sugar industry, agriculture and other industry sectors are expected to see the largest increase in energy demand of all sectors, with 75 % expected growth respectively over the planning period. The energy demand in the transport and commerce and government services sectors is projected to grow by 48 % and 22 % respectively over the planning period.

FIGURE 5.1 FINAL ENERGY DEMAND BY SECTOR, 2014–2034

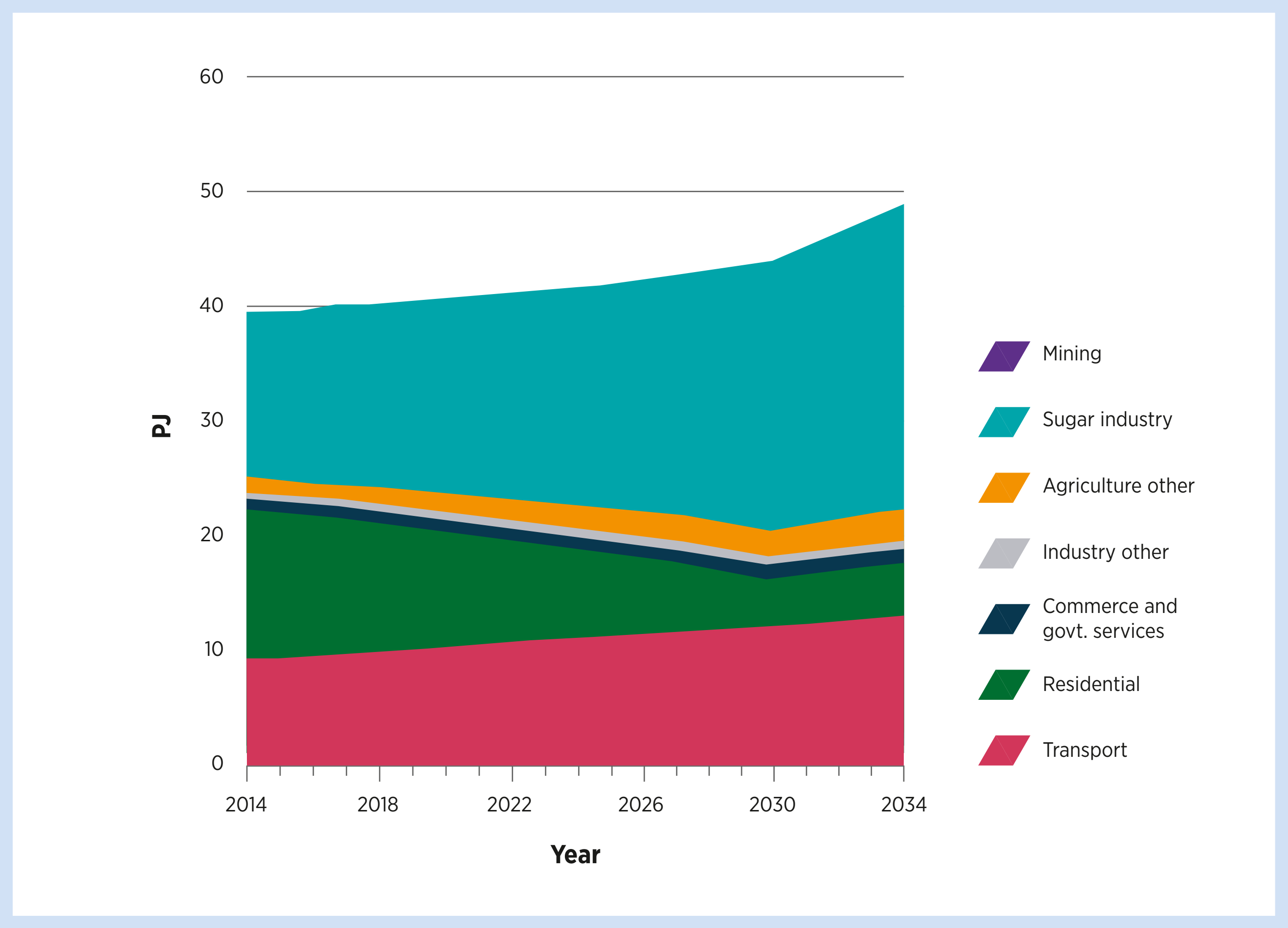


Figure 5.2 shows the same final energy demand projections, segregated by fuel type, between 2014 and 2034. Table 5.1 shows the final energy demand projected for 2034, presented by fuel type and by sector.

The demand for oil products experiences strong growth of around 50 % by 2034, with 95 % of this growth coming from the transport sector. Coal has a relatively constant share of total energy demand at around 5 % from 2014 to 2034, and remains concentrated in the sugar and commerce and government services sectors. Electricity demand more than doubles, from 1 270 GWh in 2014 to 2 648 GWh (9.5 PJ) in 2034.

Other industry (excluding sugar but including, *e. g.*, manufacturing, construction, food and tobacco) is currently the fourth largest end-user of electricity and its demand grows 80 % by 2034, when industry contributes around 15 % of electricity demand. This increase is due to economic growth that boosts energy demand, but is partly balanced off by more efficient energy use by industries over time, which constrains their growth in energy demand. Residential electricity demand increases from 1.2 PJ in 2014 to 3.7 PJ in 2034; it contributes the largest sector share of total electricity demand by 2034. The increase attributable to the gain in electricity access represents about 50 % of the total growth in electricity demand.

Note that in Figure 5.2, "Coal unspecified" refers to coal use in commerce and government services that does not include coal-fired power plants.

FIGURE 5.2 FINAL ENERGY DEMAND BY FUEL TYPE, 2014–2034

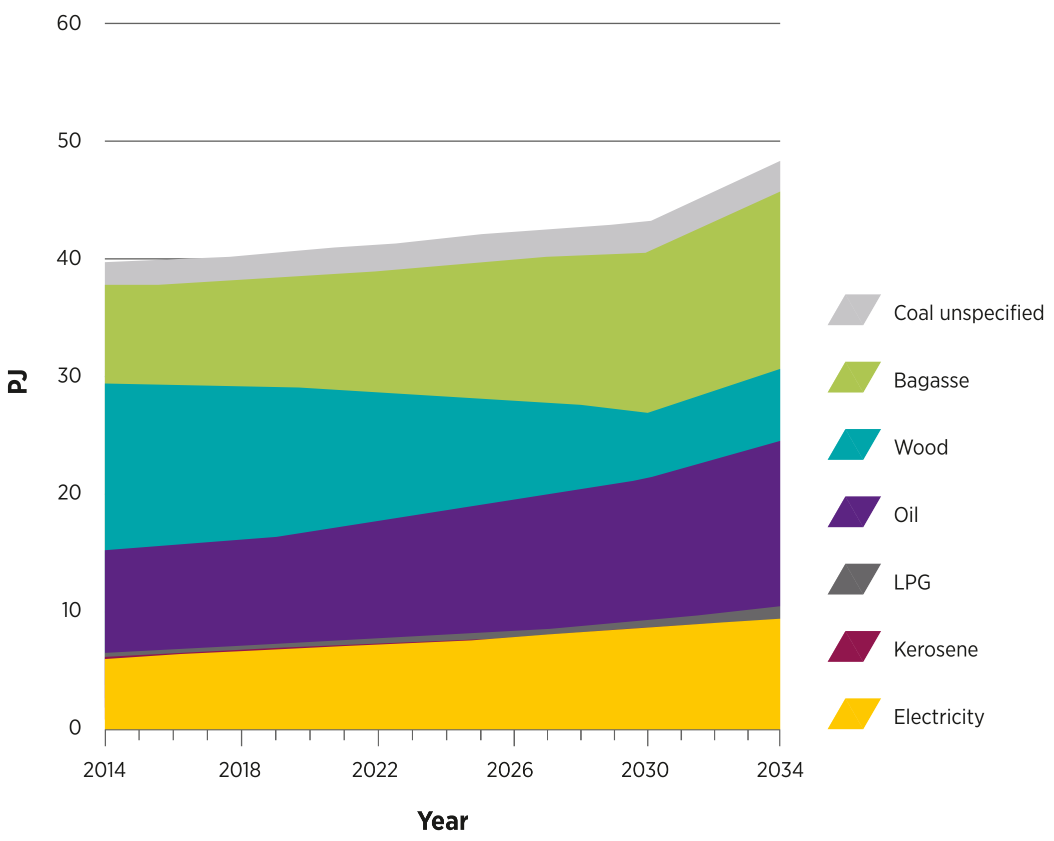


TABLE 5.1 FINAL ENERGY DEMAND BY SECTOR AND BY FUEL TYPE IN 2034 (IN PJ)

Sector	Electricity	LPG	Oil	Wood	Bagasse	Coal	Total
Sugar	2.3	–	0.1	4.7	14.8	2.1	24
Agriculture other	1.5	–	0.7	–	–	–	2.2
Industry other	1.4	–	0.1	–	–	–	1.5
Mining	–	–	–	–	–	–	–
Commerce and govt. services	0.6	0.4	–	–	–	0.5	1.5
Residential	3.7	0.6	–	1.7	–	–	6.0
Transport	–	–	13.3	–	–	–	13.3
Total	**9.5**	**1.0**	**14.2**	**6.4**	**14.8**	**2.6**	**48.5**

Note that an overview of detailed results of the demand assessment to 2034 is provided in Annex B.

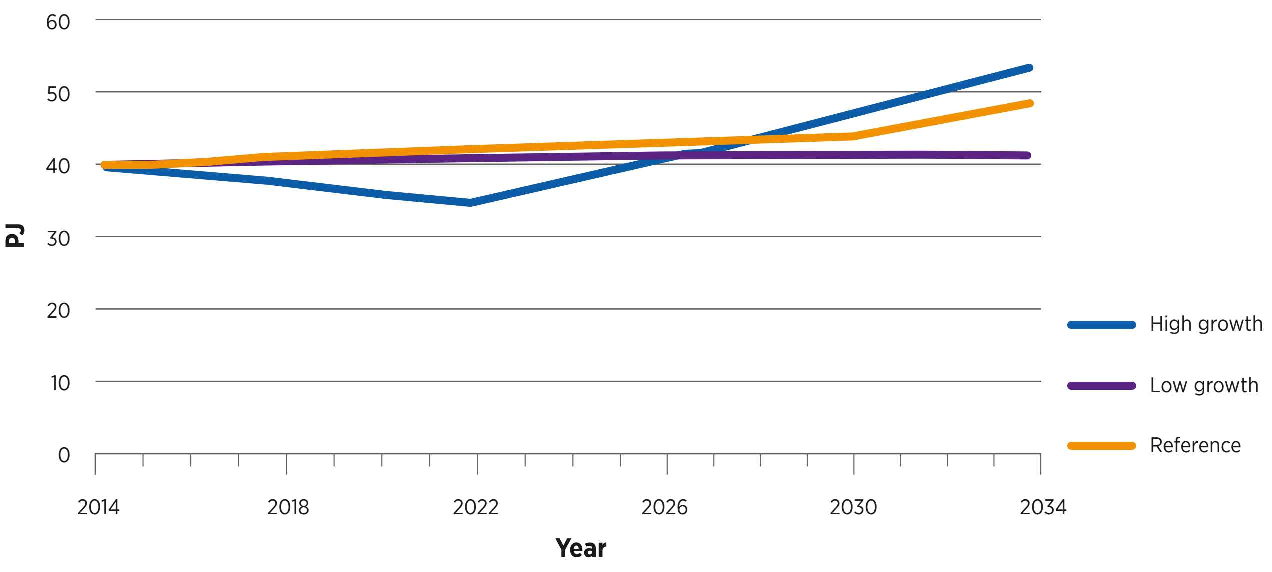
5.1.2 ENERGY DEMAND DEVELOPMENT BY 2034 IN ALTERNATIVE SCENARIOS

In all economic sectors, energy demand grows at the same rate as GDP. Figure 5.3 charts the energy demand growth forecasts for the Reference, High Growth and Low Growth scenarios. Using the GDP growth rate as one of the key drivers, energy demand projections were conducted for each energy demand sector.

The demand projections indicate a slight increase in total energy demand by 2034, as compared to 2014 levels. Under the High Growth scenario, there is a steep decline in energy consumption as a result of changes in the residential sector, driven largely by population growth coupled with increased modernisation. As living standards improve, people tend to consume more modern energy sources, which are more energy efficient; interventions in energy efficiency also tend to slow total energy demand.

Until 2028, the Reference scenario has the highest energy demand. Because it represents the most likely GDP growth for the country, the corresponding demand under this scenario was selected as the projected demand to be used as input to the modelling analysis of the energy supply strategy (Part III).

FIGURE 5.3 ENERGY DEMAND GROWTH UNDER THE THREE SCENARIOS

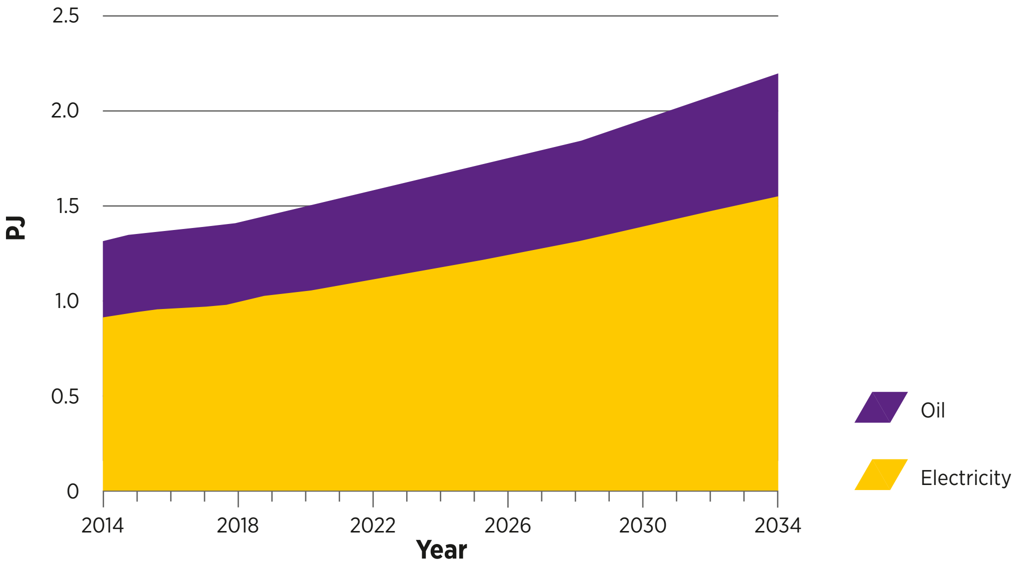


5.2 ENERGY DEMAND DEVELOPMENT IN KEY SECTORS

5.2.1 AGRICULTURE

The growth of the agriculture sector is highly dependent on favourable weather conditions, especially rainfall patterns as well as consumption patterns of agricultural products. Principal agricultural products in Eswatini include sugar, maize, cotton, forestry, citrus and livestock. GDP in the agriculture sector is assumed to be stimulated by economic growth over the next 20 years, as is consistent with trends in the last few years (Figure 5.4). Reflecting this, energy demand in the agriculture sector is assumed to increase nearly two-fold.

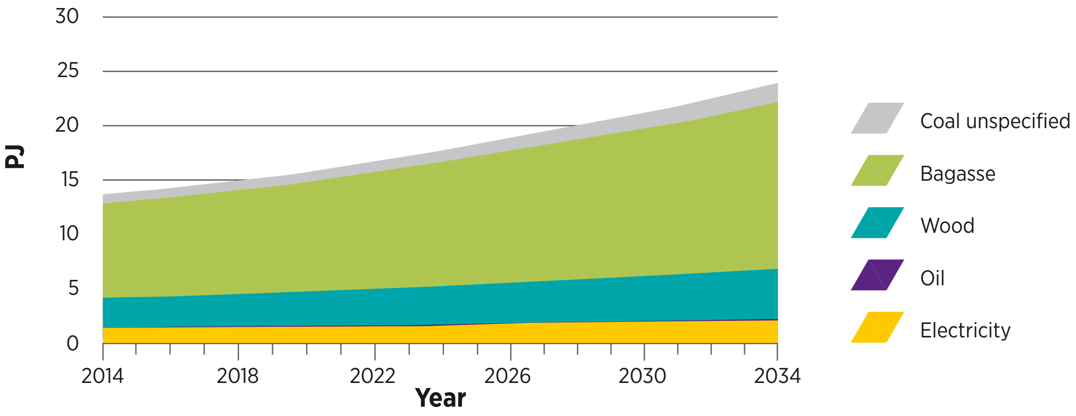
FIGURE 5.4 ENERGY DEMAND IN THE AGRICULTURE SECTOR



5.2.2 SUGAR INDUSTRY

Similar to the agriculture sector, GDP in the sugar industry is assumed to be stimulated by economic growth over the next 20 years, in line with past trends. Nevertheless, energy demand in the sugar industry is increasing by more than 2 % annually, which is replicated for the period 2014–2034.

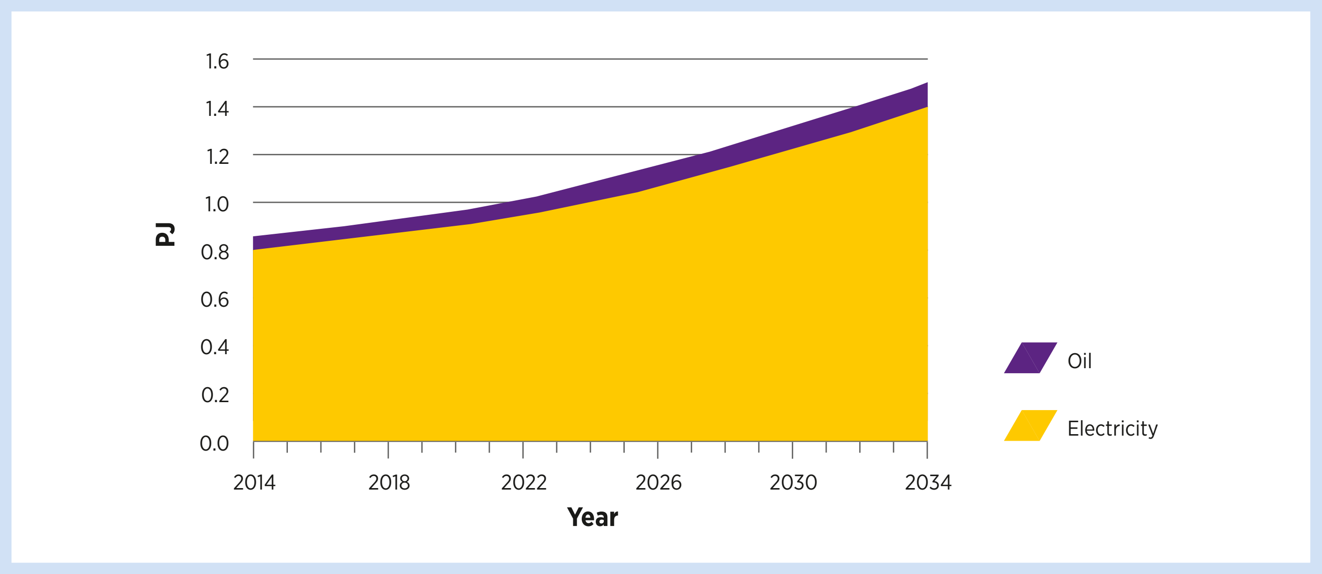
FIGURE 5.5 ENERGY DEMAND IN THE SUGAR INDUSTRY



5.2.3 OTHER INDUSTRY

Other industry refers to all industries except for the sugar industry, including construction, food and tobacco, manufacturing, textiles, etc. Reflecting the Government's policy on diversification of the economic structure, the other industry sector is expected to see modest growth in energy demand of about 3 % annually between 2014 and 2034. Electricity accounts for the vast majority of current energy use in this sector, and the future growth in energy demand is expected to be met primarily by electricity.

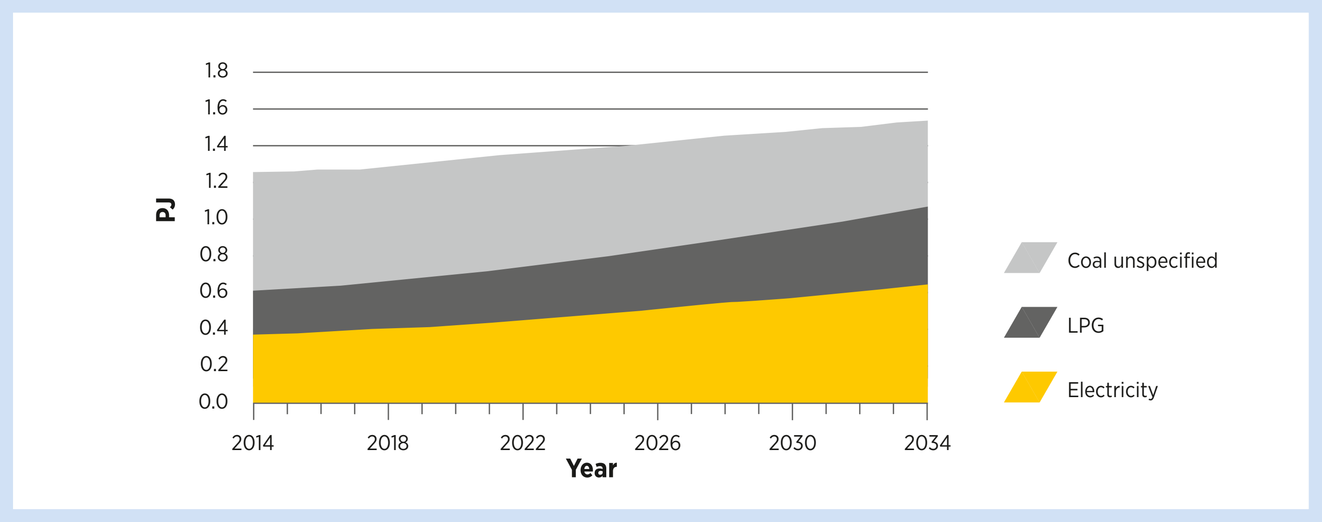
FIGURE 5.6 ENERGY DEMAND IN OTHER INDUSTRY



5.2.4 COMMERCE AND GOVERNMENT SERVICES

The commerce and government services sector is expected to be the biggest economic sector contributing to GDP by 2034. GDP in the sector is expected to grow by about 2.9 % annually in the Reference scenario. Energy demand is expected to grow at a slower pace, of around 1.0 %, due to efficiency improvements in coal use in this sector. While overall coal use in the sector declines over time, from 52 % of total sectoral energy demand in 2014 to 29 % by 2034, the demands for electricity and LPG increase in proportion to the GDP growth in this sector.

FIGURE 5.7 ENERGY DEMAND IN COMMERCE AND GOVERNMENT SERVICES



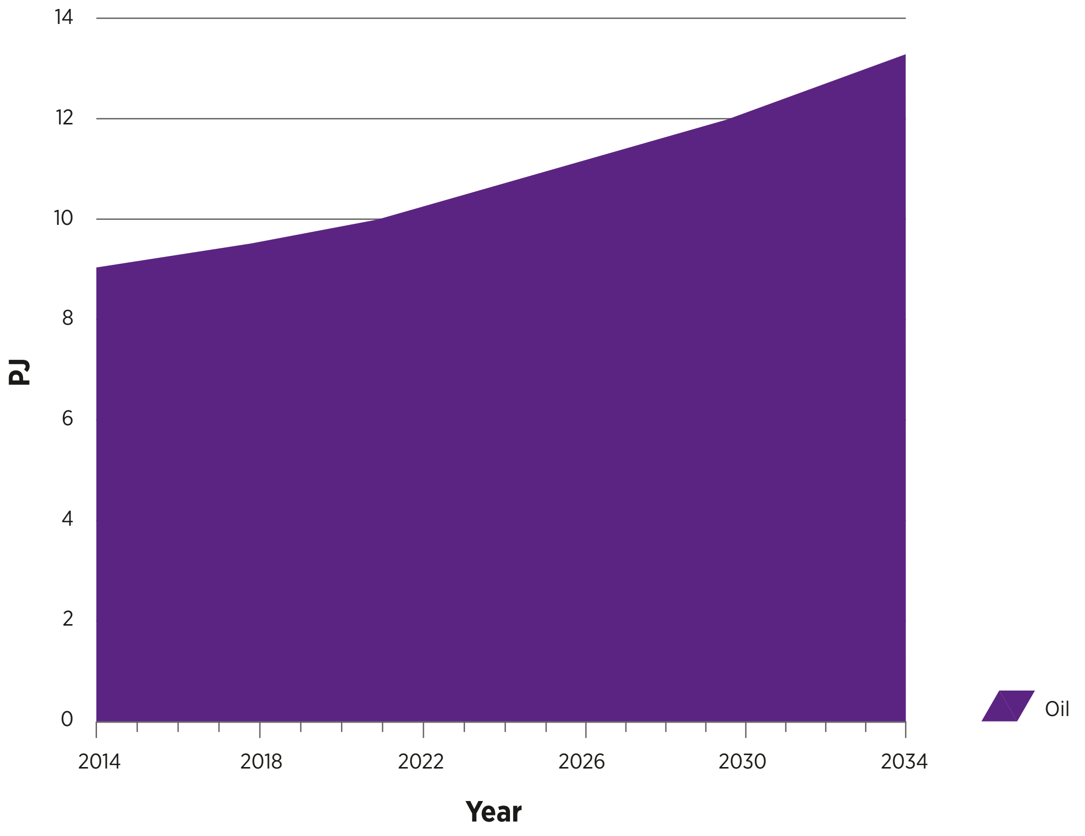
5.2.5 TRANSPORT

Only 10.5 % of the population of Eswatini owns a passenger light-duty vehicle, compared with 70 % in the United States, 50 % in Europe and 6 % in China, indicating huge growth potential. While the number of vehicle registrations is projected to double by 2034, this implies that only around 16 % of the population is expected to own a vehicle by 2034. As urban areas grow significantly in size, urban development policies play an important role in guiding users of transport services towards private or public forms of transport, and therefore influence future transport energy demand.

The transport sector remains almost entirely reliant on oil products, with policies in place to promote the use of alternative fuels, specifically biofuels. A constraint to increasing the fuel demand for road transport is the severe lack of paved roads. A second and more positive factor is vehicle fuel efficiency, which for new vehicles is expected to improve by more than 20 %, on average, to reach 7.2 litres per 100 kilometres by 2034. Eswatini relies heavily on imports of second-hand vehicles from Japan and Europe, both of which have in place comprehensive fuel economy standards. To a degree, these standards are progressively imported, helping to improve the average fuel efficiency of vehicles in Eswatini.

Diesel accounts for 60 % of the total demand for oil in the transport sector, and petrol accounts for 40 %. Energy demand in the sector is expected to increase by almost 50 % in the projected planning horizon.

FIGURE 5.8 ENERGY DEMAND IN THE TRANSPORT SECTOR



5.2.6 RESIDENTIAL

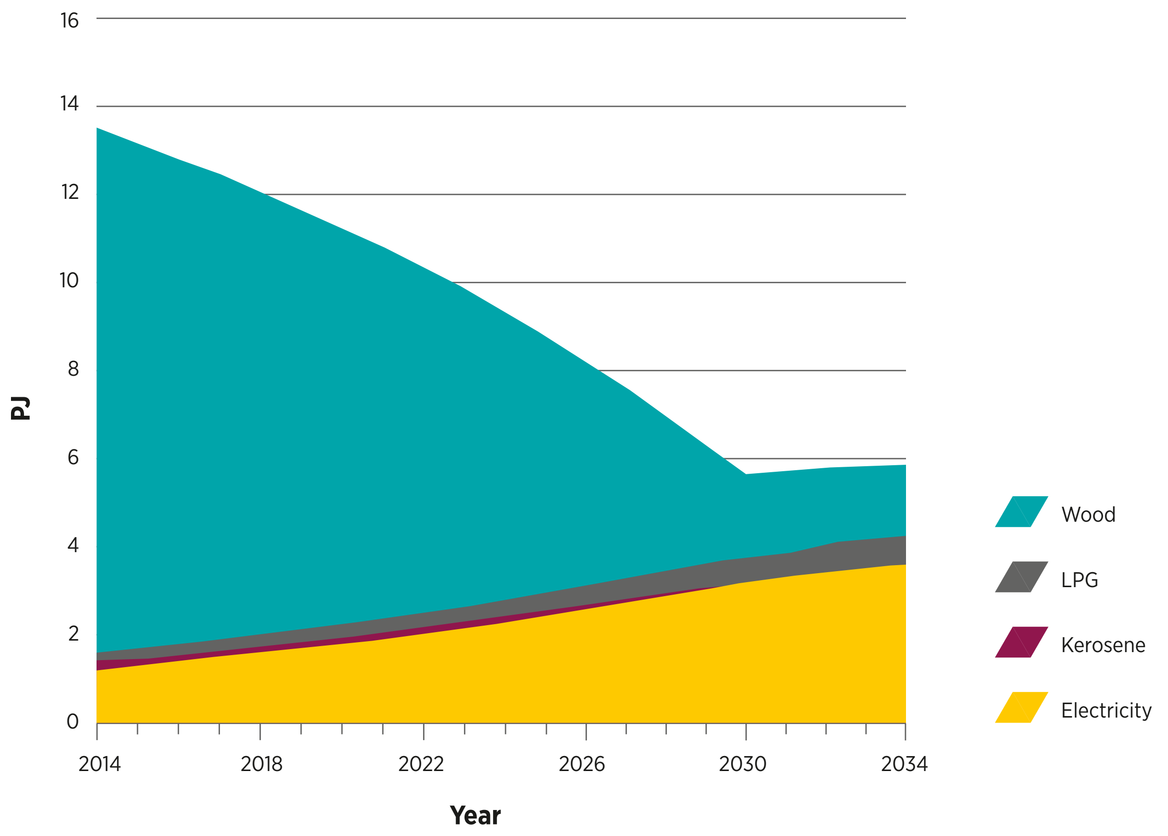
The choice of energy use in households is influenced by fluctuations in relative prices, but also by self-reliance in the physical availability of the alternatives to solid biomass. Where new sources of energy use in households are adopted, it does not mean that the use of older sources is discarded. Until distribution networks are sufficiently well established to ensure a reliable supply of alternative energy carriers at reasonably predictable prices, consumers prefer to retain the option to switch.

Fuelwood is adjusted to reflect relative scarcity in non-electrified and electrified households. In non-electrified households with extensive forestry, fuelwood has a smaller price increase where fuelwood remains untraded and has a zero price. Electrified households, on the other hand, see a more pronounced price increase. Average end-user electricity prices are generally assumed to adjust gradually over time to reflect the average cost of electricity supply, including domestic generation and the cost of electricity imports, network, retail and other costs. As a result, overall energy demand in the residential sector decreases by more than half due to higher efficiency in electric stoves.

The modelling of access to modern energy has undergone significant development to better reflect access to electricity and access to clean cooking facilities, and played a role in shaping energy demand in the residential sector. These are priority areas in SE4ALL's Agenda 2030. Urban areas dominate in the share of electricity supply, accounting for 70 % of total electricity consumption. Electricity access is improving in both urban and rural areas, but urban electrification rates continue to be higher, and urban households consume more electricity. Grid-based systems provide electricity to rural populations when those communities are in close proximity to transmission lines, and extending the grid to them is a viable option for rural areas to gain access to electricity.

The mix of technologies is distinct in the residential sector, with electricity and fuelwood being the dominant sources of energy supply. The use of wood in the sector decreases, mainly in cooking. This decline is driven by changes in both the fuels and cook stoves used: traditional use of solid biomass is gradually reduced on a per household basis as households switch to more efficient, less polluting cook stoves, such as improved biomass stoves, or to fuels such as LPG or electricity.

FIGURE 5.9 ENERGY DEMAND IN THE RESIDENTIAL SECTOR



Nationwide, 26 % of households do not have access to electricity (as of 2017). These households often utilise multiple sources of energy such as wood, LPG and paraffin for cooking, heating and lighting. Over the planning horizon of 2014 to 2034, the consumption of fuelwood declines gradually. The Government attempts to address energy deficits among non-electrified households through its successful household electrification programme. The rate of non-electrification starts at 35 % in 2014, declines to 0 % in 2030 and remains constant at 0 % until 2034. The absence of fuelwood use in 2034 is shown in Figure 5.10.

FIGURE 5.10 ENERGY USE IN NON-ELECTRIFIED HOUSEHOLDS

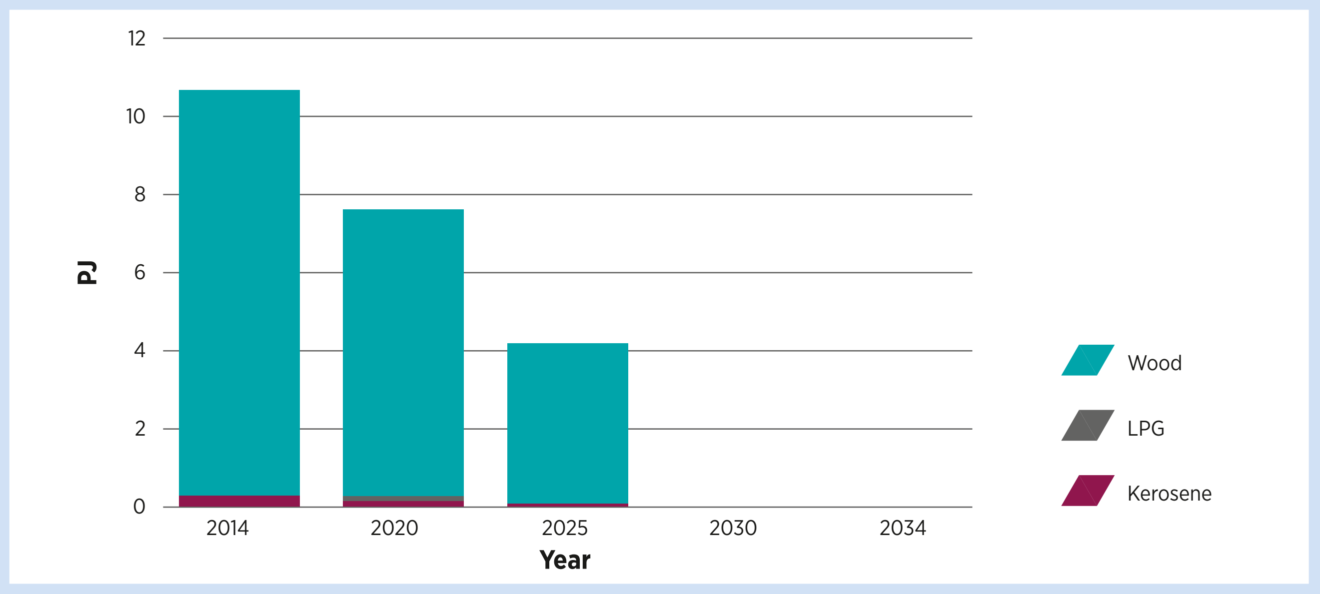


Figure 5.11 shows energy use in electrified households. These households require sufficient energy to conduct domestic chores such as cooking, heating, lighting, refrigeration, etc. The figure for 2034 represents 100 % of households, as it is assumed that a 100 % electrification rate is achieved by then. The increase reflects both the increased number of households as well as the increased consumption per household. In the absence of accessible or affordable modern energy services, many households turn to alternative sources of energy, including wood, LPG and kerosene. Fuelwood is the widely used alternative source due to its “free” availability from nature. While some of these sources provide practical alternatives for household energy requirements, they are costly.

The analysis of energy use in electrified households over time shows that the energy usage patterns of households are changing (Figure 5.12). These changes are driven primarily by electrification, particularly in non-electrified households. Electricity consumption in the residential sector increases more than three-fold, from 1.2 PJ in 2014 to 3.7 PJ in 2034.

Although progress in electrification has contributed greatly towards achieving improved access to safer, cleaner and more affordable energy services for households across the socio-economic spectrum, energy use continues to be characterised by the use of multiple sources of energy. LPG consumption develops in line with the overall trends for electricity demand in electrified households, rising from 0.2 PJ in 2014 to 0.6 PJ in 2034. Wood consumption increases slightly from 1.45 PJ in 2014 to 1.65 PJ in 2034, whereas kerosene consumption declines gradually until 2034, to zero.

The perception is that the transition from wood to modern fuels, particularly electricity, is associated with economic improvements and improvements in development. Low-income households tend to depend on wood for cooking and heating, while electricity is often limited to lighting, refrigeration, televisions, ironing and other appliances such as radios and mobile phone charging. As the years progress, the fuel used for cooking switches from biomass to electricity; electricity use for cooking increases 61 % from 2014 to 2034.

FIGURE 5.11 ENERGY END-USE IN ELECTRIFIED HOUSEHOLDS

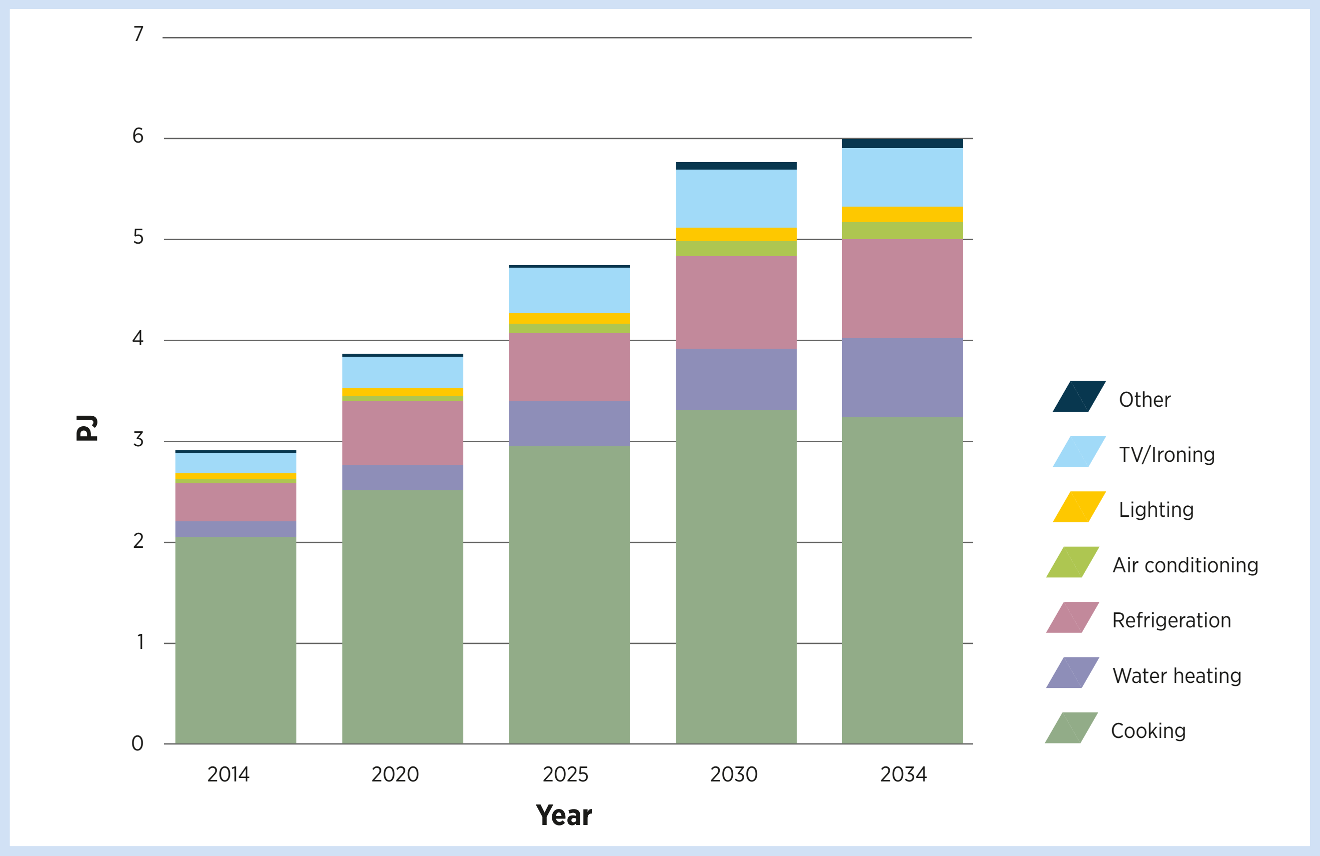
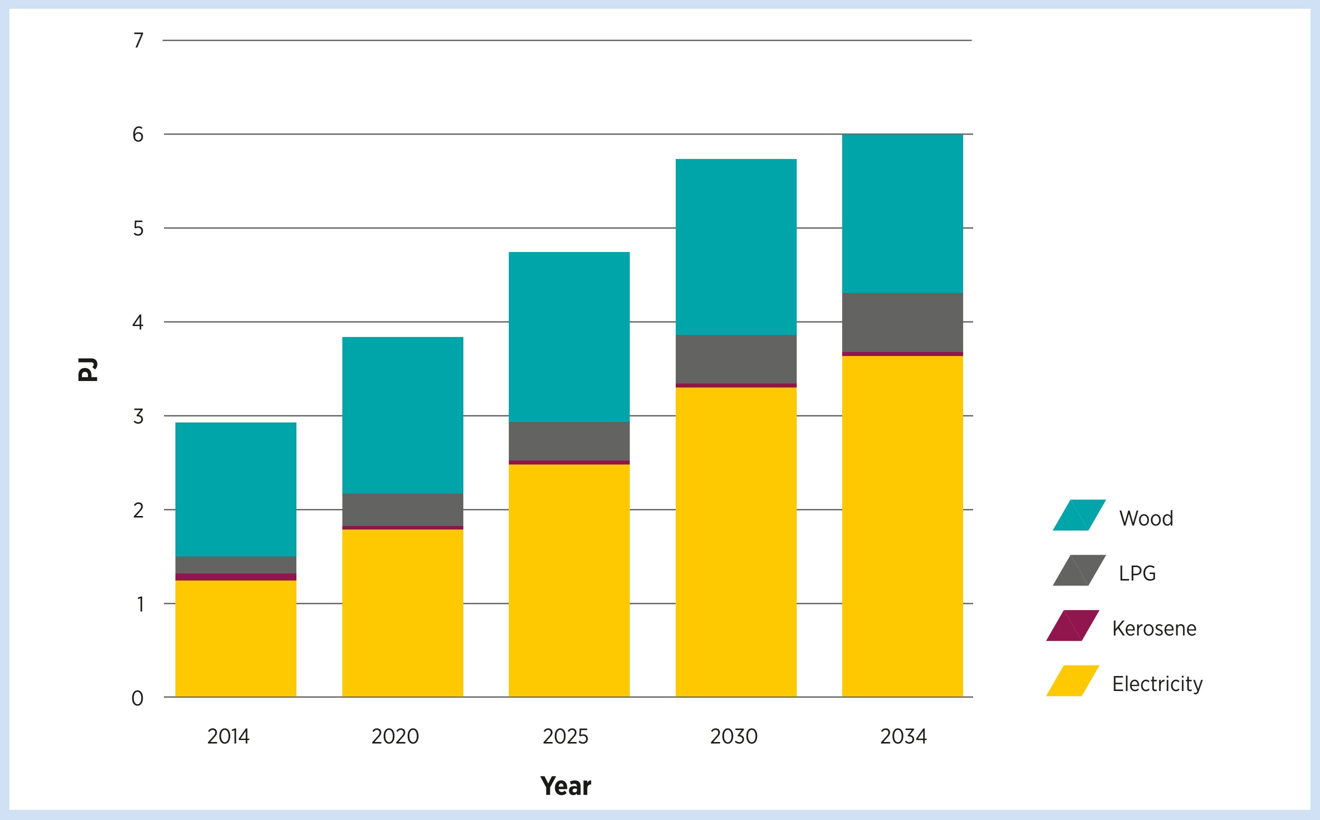


FIGURE 5.12 ENERGY USE IN ELECTRIFIED HOUSEHOLDS



PART III:

ENERGY SUPPLY ASSESSMENT

6 DOMESTIC ENERGY RESOURCES AND ENERGY TECHNOLOGY OPTIONS

6.1 SUGARCANE

Eswatini operates three sugar mills, Mhlume Mill, Simunye Mill and Ubombo Mill, all situated in the eastern part of the country. The first two mills are operated by the Royal Swaziland Sugar Corporation (RSSC), and the third is operated by Ubombo Sugar Limited. The three mills produce sugar from sugarcane grown in Eswatini. Sugar processing has two major by-products, bagasse and molasses. Bagasse is used with wood chips in boilers to produce process steam that is also used for power generation. Molasses is used for ethanol production.

Table 6.1 provides an overview of the area under cultivation, area harvested and sugarcane production in Eswatini between 2012/13 and 2016/17. Sugarcane production is increasingly becoming an area of investment by the private sector and community-based farmers. Despite the falling price of sugar, sugarcane production is anticipated to increase. Sugarcane is the main crop produced in Eswatini, with annual production of 5.8 million tonnes in 2015. Sugarcane production was anticipated to decrease to 4.6 million tonnes by the end of the 2016/2017 fiscal year as a result of El Niño-related drought in the country.

TABLE 6.1 OVERVIEW OF SUGARCANE AREA AND PRODUCTION, 2012/13 TO 2016/17

	2012/13	2013/14	2014/15	2015/16	2016/17*
Area under cultivation (ha)	57,263	58,979	59,586	59,924	61,798
Area harvested (ha)	53,666	55,478	56,438	57,685	58,520
Cane production (tonnes)	5,648,542	5,591,830	5,639,193	5,836,553	4,633,641

** Estimated figures*

Source: Swaziland Sugar Association

Sugarcane production is expected to increase in the near future, providing an opportunity to increase co-generation capacity. Co-generation also provides an opportunity for diversification in the sugar industry's revenue. Sugar companies have stated an interest in increasing their power generation capacity from 106 MW to 160 MW. Table 6.2 shows some of the planned capacity by selected independent power producers.

TABLE 6.2 PLANNED ENERGY GENERATION CAPACITIES BY THE SUGAR INDUSTRY

Independent power producer	New total capacity (MW)	Internal use (MW)	Grid supplied (MW)	Projected year of completion
Mhlume Sugar Mill	~50	22	~28	2024
Simunye Sugar Mill	~50	28	~22	2022
Ubombo Sugar Mill	25		15	2020

The RSSC has plans to increase its power generation capacity at the Mhlume and Simunye mills, which requires mill efficiency improvements and the installation of high-pressure boilers.

The Swaziland Water and Agricultural Development Enterprise (SWADE) has begun implementing the second phase of the Lower Usuthu Smallholder Irrigation Project (LUSIP), which involves the construction of three dams to form an off-river storage reservoir to impound 155 million cubic metres of water that will be diverted from the wet/rainy season flood flows into the Lower Usuthu River to irrigate a total area of 11,500 hectares of land, primarily sugarcane plantations. One hectare is estimated to yield about 100 tonnes of sugarcane. Therefore, upon completion of the project, sugar production has the potential to increase by an estimated 1,150,000 tonnes, providing an opportunity to also increase related power generation.

6.1.1 BAGASSE

Sugar millers use bagasse, a by-product of the sugar production process, as a fuel for boilers that produce process steam, which also can be used in power generation. From experience, an estimated 100 tonnes of sugarcane can produce 27 tonnes of bagasse. On average, local sugar millers have the capacity to produce 1,539,000 tonnes of bagasse annually. Table 6.3 shows bagasse production from 2012/13 to 2016/17.

TABLE 6.3 BAGASSE PRODUCTION, 2012/13 TO 2016/17

	2012/13	2013/14	2014/15	2015/16	2016/17*
Bagasse production (tonnes)	1,525,106	1,509,794	1,522,582	1,575,869	1,251,083

* *Estimated figures*

6.1.2 MOLASSES

Molasses is another useful by-product of sugar processing, and a total of 253,073 tonnes was produced in the 2015/2016 fiscal year (Table 6.4). Molasses is used mainly for ethanol production for the beverage and pharmaceutical industries, but it also is being considered for E10 biofuels production. RSSC and USA Distillers are the two major ethanol producers in Eswatini, making 134,000 litres per day and 120,000 litres per day, respectively. The combined total production capacity is approximately 60 million litres annually, which is currently used for non-energy purposes.

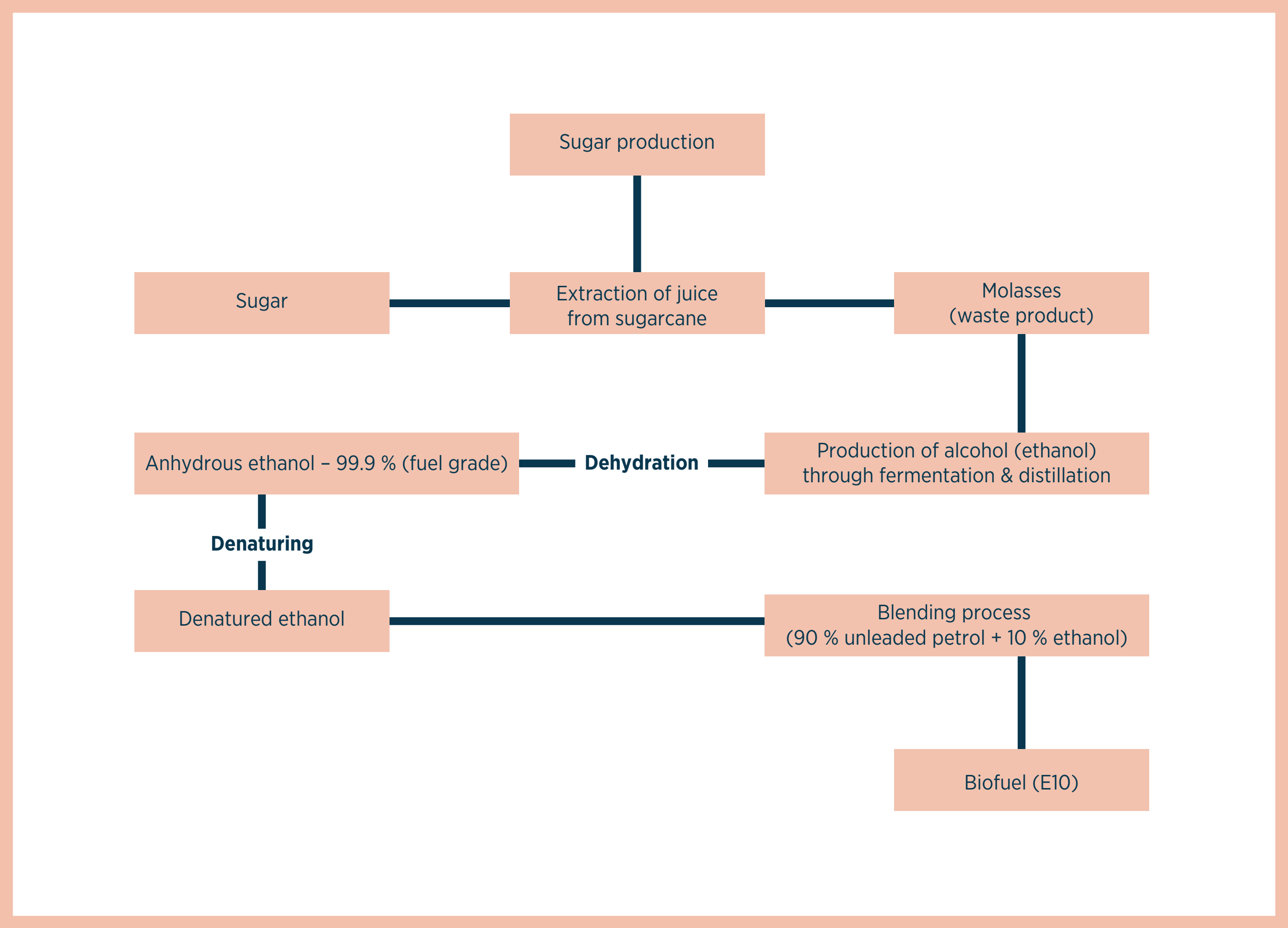
TABLE 6.4 MOLASSES PRODUCTION, 2012/13 TO 2016/17

Producer	2012/13	2013/14	2014/15	2015/16	2016/17*
Simunye Mill (tonnes)	72,700	76,338	76,179	84,180	61,616
Mhlume Mill (tonnes)	63,300	60,385	68,664	68,480	49,823
Ubombo Mill (tonnes)	111,267	101,041	117,641	100,413	92,383
Total industry (tonnes)	**247,267**	**237,764**	**262,484**	**253,073**	**203,822**

* *Estimated figures*

The flow chart in Figure 6.1 depicts the main steps in the production of ethanol from sugarcane molasses.

FIGURE 6.1 PROCESS OF ETHANOL PRODUCTION FROM SUGARCANE MOLASSES



The biofuels programme for Eswatini is preparing for the full roll-out of ethanol blending (E10). The objective is to introduce an alternative, locally produced and environmentally friendly fuel into the fuel mix and to enhance the country's energy security in terms of petroleum supply. The ethanol blending programme will support the Government's ambition to reduce carbon emissions, particularly in the transport sector, which currently contributes more than 70 % of the country's overall energy sector emissions.

6.2 WOODY BIOMASS

6.2.1 WOOD CHIPS

The use of wood chips in Eswatini is on the rise due to increased demand by sugar companies for use in co-generation. Currently the average annual demand for wood chips by the sugar industry is approximately 206,000 tonnes, and so far the timber industry is able to meet this demand. Key players in the timber and sugar industries have established an association that includes among its activities the exploration of power generation opportunities using available biomass resources. The timber industry has the potential to increase the fuel supply to meet new biomass power generation through the provision of wood chips and forestry waste.

Table 6.5 shows additional biomass power generation projects under consideration by the timber saw mills.

TABLE 6.5 POTENTIAL POWER GENERATION CAPACITIES IN THE TIMBER INDUSTRY

Independent power producer	Total capacity (MW)	Internal use (MW)	Grid supplied (MW)
Piggs Peak	15	10	5
Nhlangano	10	5	5
Bulembu	1	1	0
Usuthu Saw Mill	37	4	33

Montigny Investment, which operates the Usuthu Saw Mill (formerly Sappi Usuthu), has publicised its intention to develop a 33 MW power generation project. The company has attracted interested financiers for the project and is working through negotiations with the SEC to start developing the project.

6.2.2 FUELWOOD

Biomass accounts for over 60 % of Eswatini's total primary energy supply and comprises mainly traditional biomass and agro-industrial waste for co-generation. According to statistics from the Food and Agriculture Organisation of the United Nations, fuelwood production in Eswatini has increased 25 % in the last decade, reaching 1,093,333 cubic metres in 2012. Charcoal production increased 50 % over the same period, reaching 44,933 tonnes. The country's total forested area of 624,000 hectares represents 36 % of the land area; of the forested total, 464,000 hectares is indigenous forest and woodlands and the rest is commercial forest plantations.

According to the National Forestry Policy, over the years, the increase in population, coupled with the rising demand for fuelwood and poor management of indigenous forests, has placed a high burden on Eswatini's indigenous woodlands and forests. As a result biomass resources have been depleted in certain areas. The demand for fuelwood continues to increase, threatening the future availability of wood resources. The unsustainable gathering of fuelwood along with the clearing of woodlands for agricultural production and the construction of homesteads has resulted in deforestation and land degradation. The availability of fuelwood in the country averages 50 %, with most of the fuelwood obtained freely from non-commercial communal forests. Approximately 14 % of fuelwood is obtained from commercial supply, which is not regulated and is traded uncontrolled.

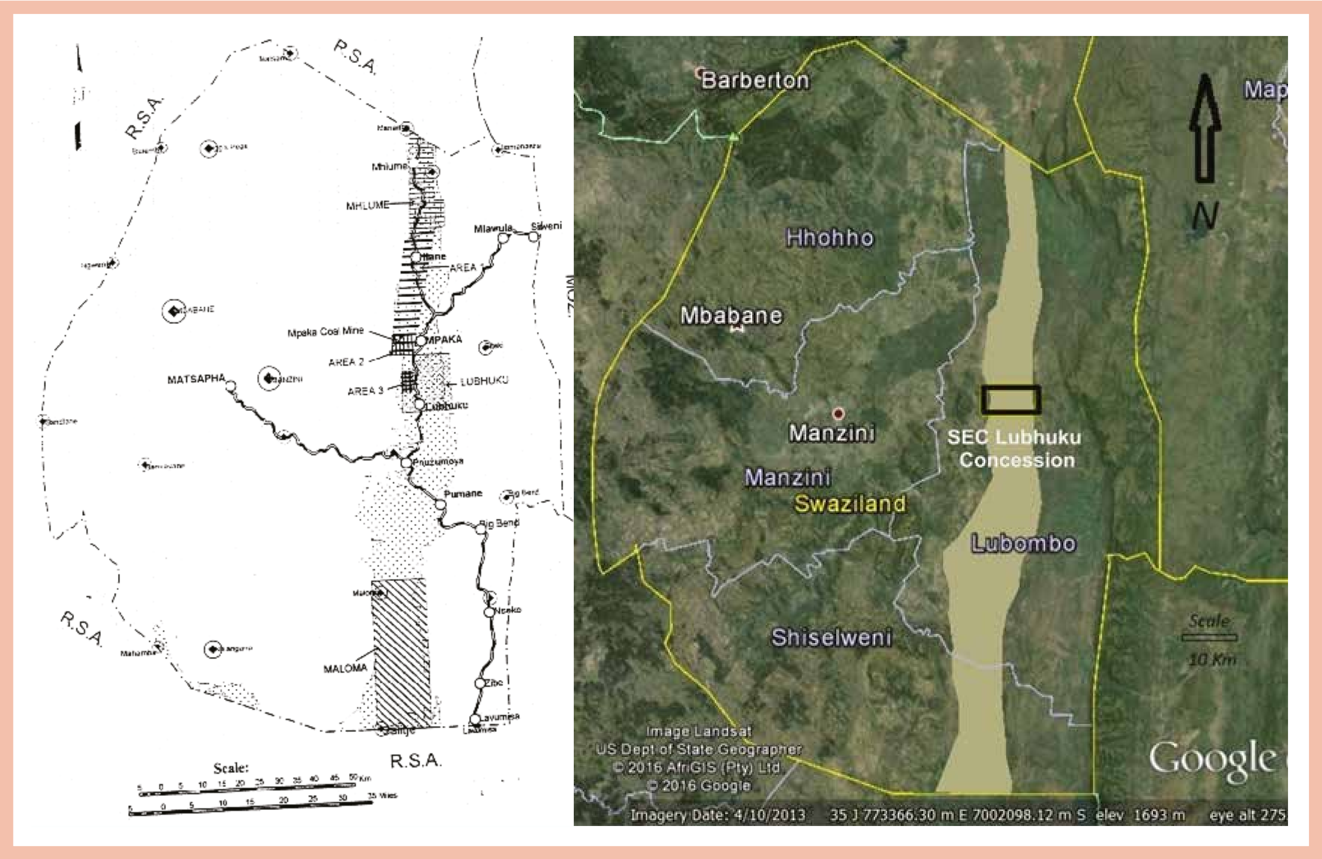
Eswatini has, however, controlled the exploitation of indigenous species of wood for fuelwood and other non-energy uses. Although desertification in the country is limited to soil erosion, biomass productivity and bush encroachment, Eswatini has a policy that safeguards against commercial use of fuelwood due to over-exploitation of the biomass resource. The magnitude of desertification in the country is not comparable with other sub-Saharan African countries, where large portions of the territory have been rendered unsuitable for human occupation.

Furthermore, Montigny has a Wattle Extension programme focused on combatting the unsustainable use of biomass and indigenous forest deforestation by promoting wattle management and land optimisation. The project aims to train landowners on how to control the spread of wattle by rehabilitating it into a commercial timber plantation while preserving some land for domestic use, easing the burden on indigenous forests.

6.3 COAL

Coal has been known to exist in Eswatini for a long time. Figure 6.2 depicts the concession map for the locality drawn in the late nineteenth century accurately showing the coal field of Eswatini.

FIGURE 6.2 LOCALITY MAP OF THE COAL FIELD OF ESWATINI



The coal field of Eswatini, in the eastern part of the country, forms a north-south continuous area with an average width of 15 kilometres. Located within the Lowveld, the coal field comprises Karoo sediments and occupies about one-sixth of the country's total area of 17,364 square kilometres. The mineable coal reserves, annual production and projected mine life for areas shown in Figure 6.2 are summarised in Table 6.6.

TABLE 6.6 MINEABLE COAL RESERVES, ANNUAL COAL PRODUCTION AND PROJECTED LIFE

Area	Mineable coal (million tonnes)	Estimated annual production (tonnes)	In-situ reserves (years)
Mhlume	18.4	665,000	27
Area 1	9.1	–	–
Area 2 Mpaka Mine	41.2	500,000	82
Area 3	20.6	500,000	41
Lubhhuku	18.9	510,000	37
Maloma	35.3	300,000	58
Total	**143.5**	**2,475,000**	–

The coal field of Eswatini consists of semi-anthracitic or lean coals and anthracite. Coals of the Upper Coal Zone are inferior-quality anthracite with a high ash content compared to some of the high-quality anthracite of the Lower Coal Zone. Maloma Colliery, Eswatini's sole active coal mine, is producing anthracite coal for export purposes with a production capacity of approximately 300 kilotonnes per year.

There is great potential for new developments in coal mining. The country is considering developing a coal-fired thermal power station that would result in the establishment of a new mine to generate feedstock for the power station. The production capacity of the mine is yet to be determined. Discussions are ongoing to resuscitate the defunct Mpaka Coal Mine for power generation as well as for export. The coal field of Eswatini is served by an adequate system of tarred roads designed to serve both the coal and sugar industries. Eswatini has direct automatic dialling telecommunication with all neighbouring states and the world at large.

Adequate electricity distribution networks already exist for any new coal mining development in the coal field. It will be necessary to develop adequate water storage facilities, as the coal field is liable to drought. The coal field is remote from the country's present administrative and industrial centres, making it necessary for new townships to be constructed for any new coal mines. Coal's relatively low cost remains an asset in regions concerned about the affordability of electricity. The coal currently consumed domestically is imported and includes bituminous coal. In 2014 a total of 208 kilotonnes of anthracite was exported, and 255 kilotonnes of bituminous coal was imported.

6.4 WIND

The Ministry of Natural Resources and Energy participated in the renewable zoning study under IRENA's Africa Clean Energy Corridor initiative (IRENA and LBNL, 2015)[5], which resulted in inventories of possible wind and solar project zones.

The zoning study inventory identified a total of 17 potential zones for wind power generation, which collectively amount to 4,300 MW of possible generation capacity. The total discounted generation potential of the 17 zones far exceeds the projected national power demand in 2030. Hence, applying the projected national power demand as the supply limit, and by means of the multi-criteria analysis tool developed for the zoning study (see below), the Eswatini working team selected for further analysis 5 priority zones from the 17 potential zones for wind power generation.

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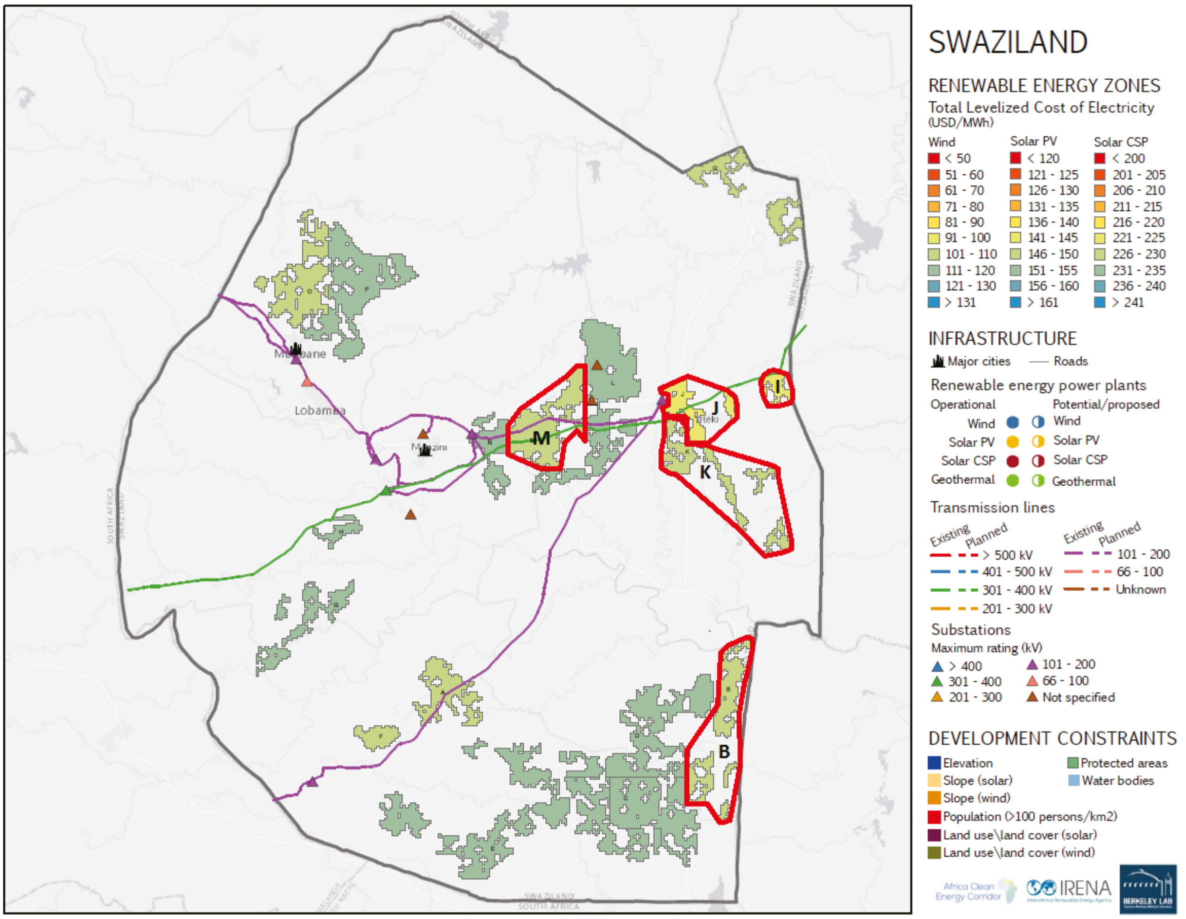
[5] IRENA and LBNL (2015). Renewable Energy Zones for the Africa Clean Energy Corridor — Multi-Criteria Analysis for Planning Renewable Energy. International Renewable Energy Agency and Lawrence Berkeley National Laboratory, Abu Dhabi, United Arab Emirates.

The multi-criteria analysis tool in the zoning study applies user-defined weighting factors to come up with a cumulative score for screening zones. The national working team decided to apply the following factors and respective weights for wind power zones: 70 % for the levelised cost of electricity (LCOE) of wind generation (including investment mark-up to account for the road and transmission infrastructure needs), 10 % for the capacity value (*i. e.*, production potential at times of high demand)[6], and 5 %, respectively, for distance to load centre, co-location potential with solar PV, population density and human footprint[7].

Figure 6.3 shows (in red) the five priority zones screened from this process – namely, zones J, I, B, K and M, in order of priority. The properties of these zones are summarised in Table 6.7. The five priority zones jointly correspond to about 880 MW of output, with a mean capacity factor of 28 % to 31 %. The LCOE of wind farms in these zones is expected to be in the range of USD 95 to USD 106 per megawatt-hour (MWh), including transmission and the associated road investment. Across the five zones, the cost mark-up is 3.4 % to 6.7 % for transmission and 0 % to 0.3 % for road infrastructure investments.

FIGURE 6.3 LOCATION OF THE FIVE PRIORITY ZONES FOR WIND POWER



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[6] "Capacity value" can be defined as "the contribution of a power plant to reliably meeting demand" and "the contribution that a plant makes toward the planning reserve margin" (Madaeni, S.H., Sioshansi, R., Denholm, P., (2012). *Comparison of Capacity Value Methods for Photovoltaics in the Western United States* (No. NREL/TP-6A2º874704). National Renewable Energy Laboratory (NREL), Golden, Colorado, US).

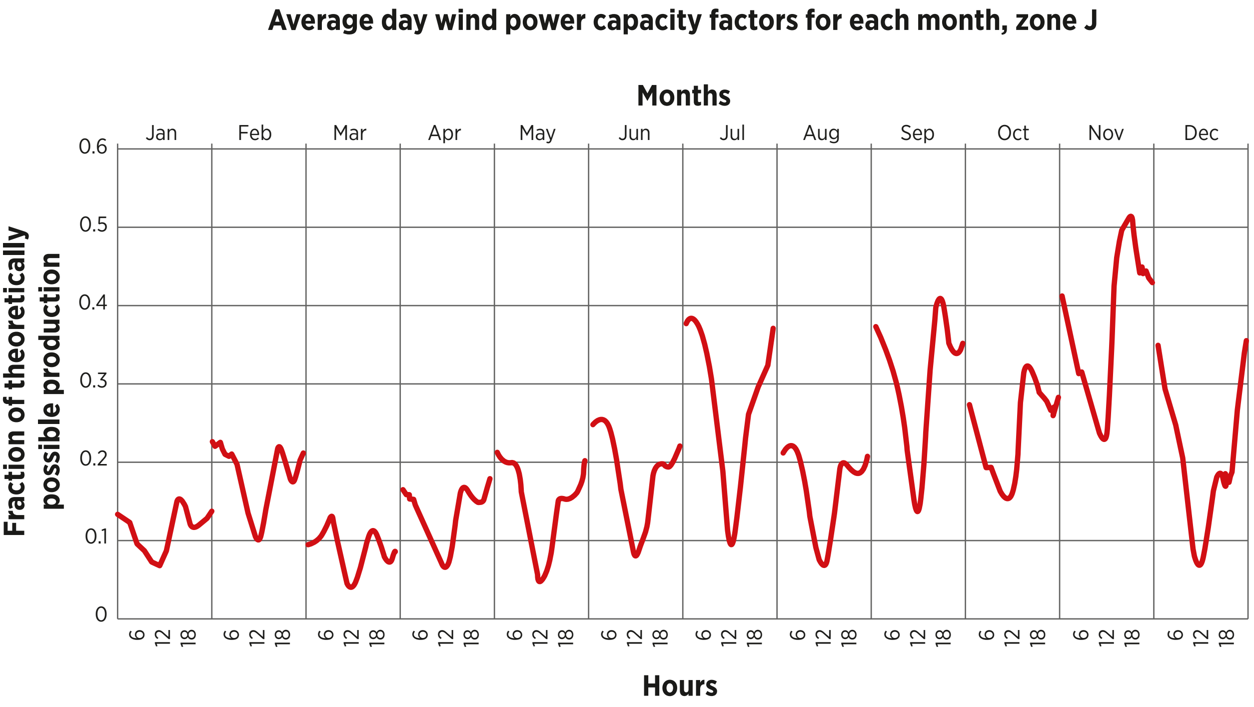
[7] The factor "human footprint" provides a proxy for the degree of human disturbance. More information on the zoning approach and the weighting factors is available at http://mapre.lbl.gov/.

TABLE 6.7 CHARACTERISTICS OF IDENTIFIED WIND ZONES

Zone name	Installed capacity (MW)	Annual electricity generation (MWh)	Distance to substation (km)	Distance to road (km)	Distance to load centre (km)	Average wind speed (m/s)	Mean capacity factor
B	226	584,000	81	0	77	4.7	0.29
I	44.4	116,000	25	0	67	4.9	0.30
J	121	327,000	6	0	50	4.6	0.31
K	206	514,000	21	1	55	4.6	0.28
M	283	687,000	8	1	22	4.4	0.28

While the capacity factors differ somewhat across zones, overall generation is assumed to follow a consistent pattern. Figure 6.4 shows the average day capacity factors for each respective month for wind power in zone J (*i. e.*, the best-ranking zone, as per the cumulative zone score). On average production is higher throughout the second half of the year. Across the whole year production is highest at night time, which somewhat complements solar PV that does not generate power during the night (see Section 6.5 below).

FIGURE 6.4 AVERAGE DAY WIND CAPACITY FACTORS FOR EACH MONTH, ZONE J (VALUES FROM 2015)[8]



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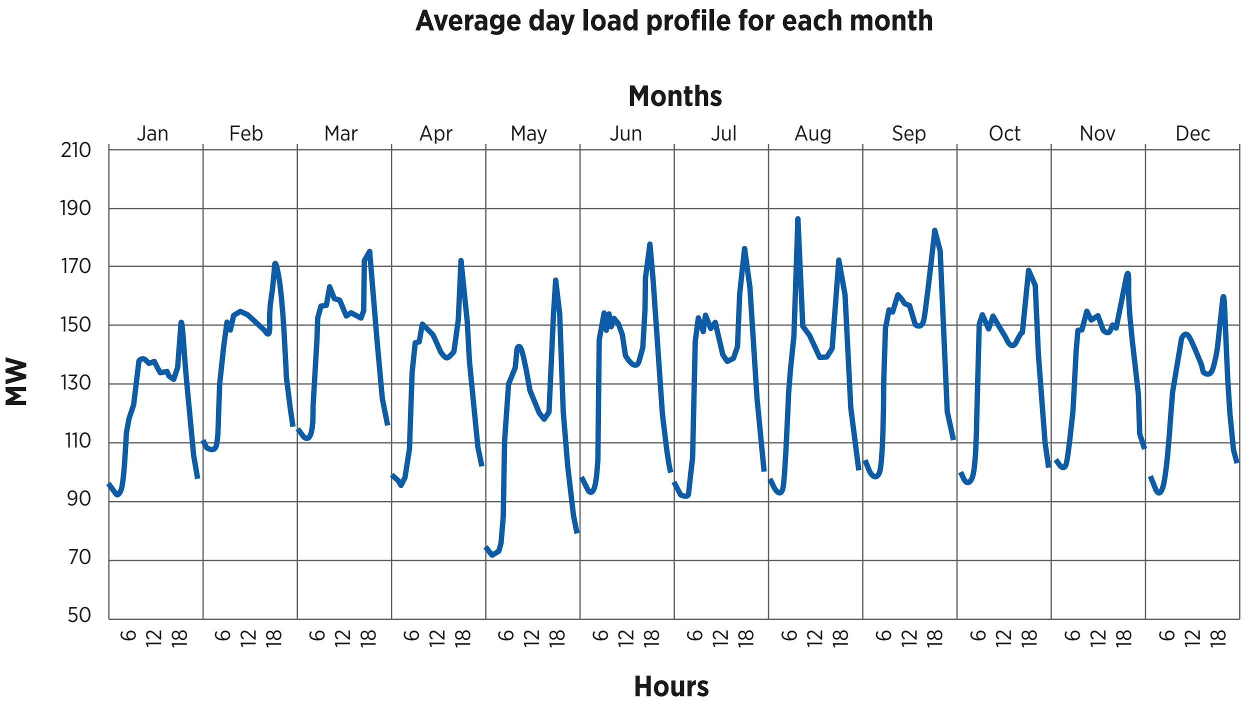
[8] Note that these average values are derived from hourly data for one year. It may reflect peculiarity of that year. The generating patterns that were assessed are likely to hold in the long term.

Figure 6.5 shows the load curves for Eswatini, of average days per respective month. Demand is lower during the southern hemisphere summer (especially in December and January), whereas the maximum is reached during winter time (August). All months have, on average, a peak in demand in the evening at around 6:00 p.m. This is a common pattern since, at that time, people generally arrive home and use most electricity for lighting and other appliances.

FIGURE 6.5 AVERAGE DAY LOAD PROFILES FOR EACH MONTH (VALUES FROM 2013)



6.5 SOLAR PV

Eswatini is well endowed with solar energy resources. According to the Swaziland Renewables Readiness Assessment report (IRENA, 2014), Eswatini has relatively abundant solar potential throughout the country with an estimated global horizontal irradiance of 4–6 kilowatt-hours (kWh) per square metre per day. The highest irradiation occurs during the summer months (December-March); the lowest irradiation occurs during the winter months (June-September) but is still adequate for both solar PV and solar water heating. No ground measurements have yet been carried out in Eswatini to validate satellite data.

For solar PV, the zoning study identified five zones for utility-scale solar PV farms. These zones are shown (in red) in Figure 6.6. The key characteristics of each zone are summarised in Table 6.8. The estimated capacity potential of these zones would total about 587 MW.

FIGURE 6.6 SOLAR PV ZONES IN ESWATINI

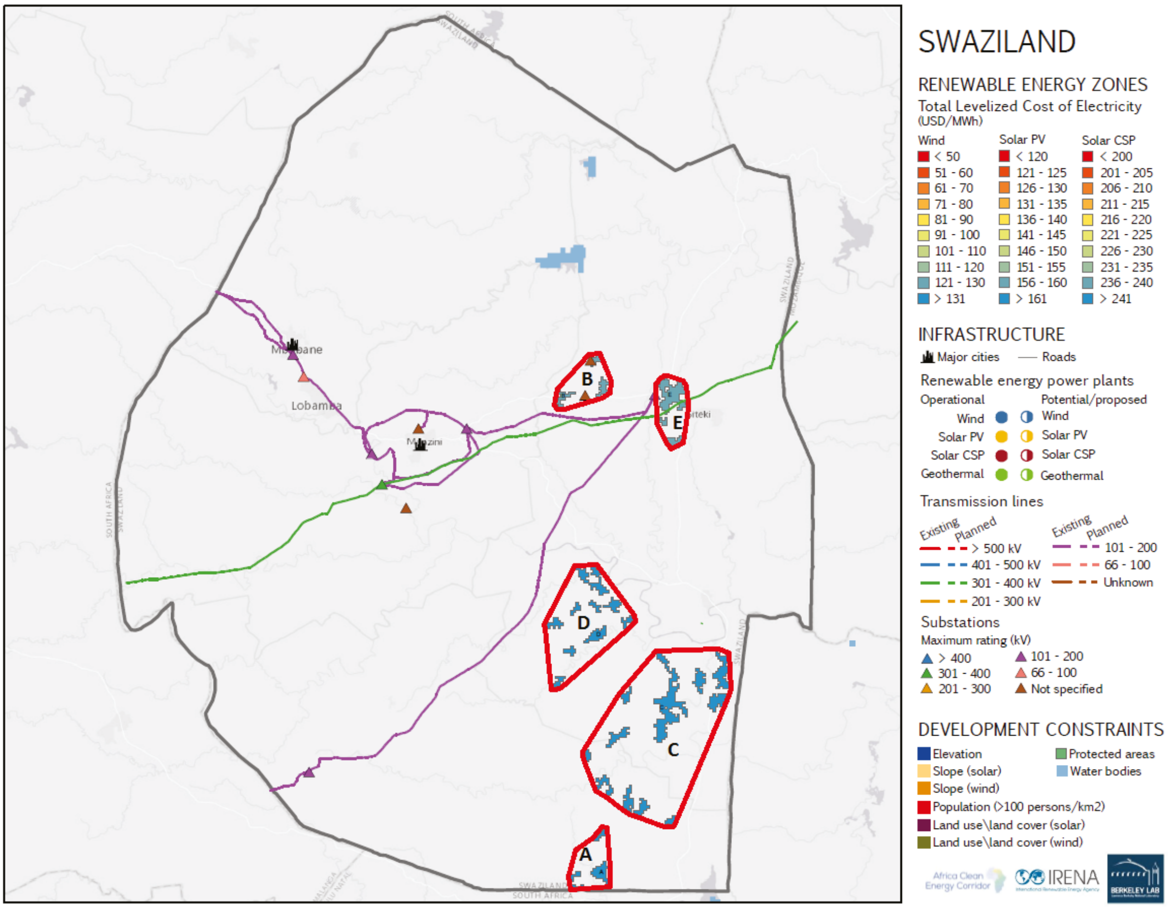


TABLE 6.8 CHARACTERISTICS OF IDENTIFIED SOLAR PV ZONES

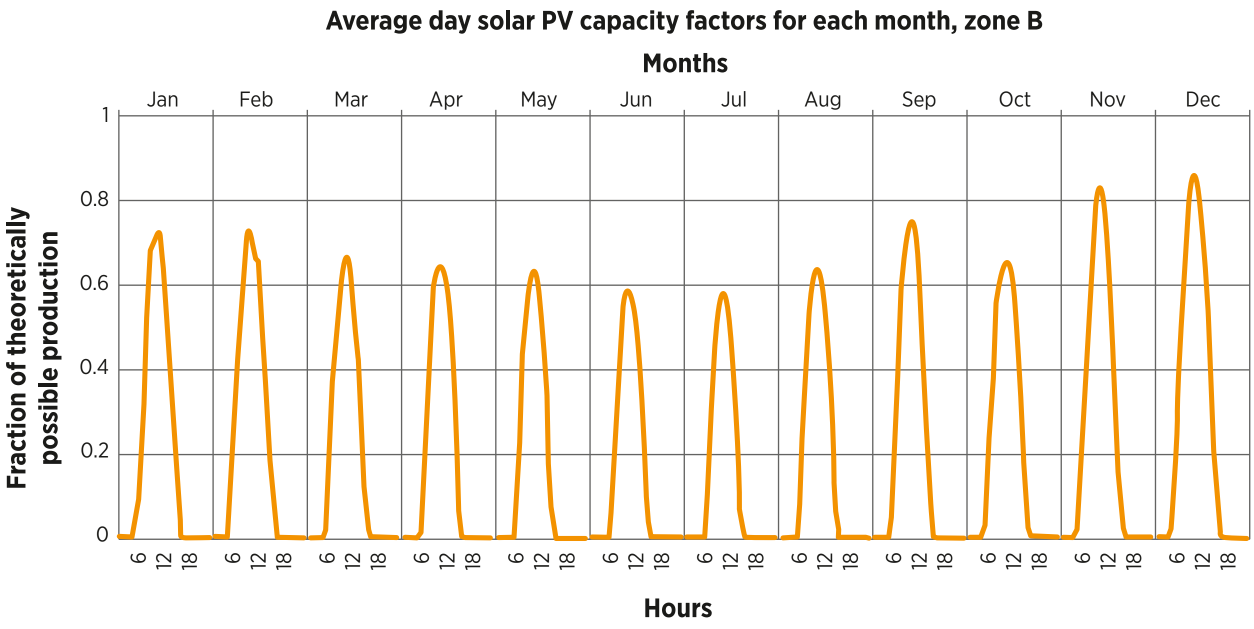
Zone name	Installed capacity (MW)	Annual electricity generation (MWh)	Distance to substation (km)	Distance to road (km)	Distance to load centre (km)	Mean resource quality (W/m²)	Mean capacity factor
A	45	78,600	75	2	89	216	0.199
B	39.8	70,400	2	2	33	219	0.202
C	288	503,000	75	4	71	216	0.199
D	127	222,000	51	6	46	217	0.2
E	87	153,000	3	0	48	218	0.201

The average LCOE for the zones ranges from USD 158 to USD 165 per MWh, including the transmission line and road infrastructure investment costs associated with each zone; transmission line and road infrastructure investments would add up to 4 % and 2.5 % of plant investment costs, respectively, depending on the distance to the nearest substations/to the road infrastructure.

Solar PV outputs change over the course of a day and across seasons, reflecting the changing levels of solar irradiation. Figure 6.7 shows the capacity factor (*i. e.*, the ratio of actual output to full-load output) for each hour of an average day for each respective month for zone B[9]. The capacity factors are higher during summer months (particularly November-January) than during winter months (June and July). The highest daily capacity factors are reached in the morning between 10:00 a.m. and 11:00 a.m.

Contrary to the solar PV capacity factor, demand is lower during the southern hemisphere summer and highest during winter time (Figure 6.5). A daily discrepancy of production peak and demand peak, as well as an annual discrepancy in production and demand variation, are noted.

FIGURE 6.7 AVERAGE DAY SOLAR PV CAPACITY FACTORS FOR EACH MONTH, ZONE B (VALUES FROM 2004)



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[9] Similar to the analysis for wind power zones, the national working team determined a weighting of factors to come up with a cumulative score for screening solar PV zones by means of the multi-criteria analysis tool: total LCOE (weight factor of 75 %), co-location potential with wind power (10 %), distance to load centre (5 %), population density (5 %) and human footprint (5 %). Zone B features the best cumulative score of the solar PV zones and is therefore considered as priority zone, and further analysed.

6.6 HYDROPOWER

Eswatini has good experience with small hydropower generation. Since 1970 numerous studies have been conducted to assess hydropower potential, which has led to an estimated theoretical potential of 440 MW and an estimated technical potential of 110 MW[10]. Currently Eswatini has an installed capacity of 61.5 MW, which is used for peaking. As part of its objective to expand the hydropower sector, the Ministry of Natural Resources and Energy (MNRE) built a database of potential sites that initially identified 35 micro and mini hydro schemes, ranging from 32 kW to 1.5 MW[11]. This was further reduced to 26 schemes, based on their potential for electricity generation. Four have been identified as viable schemes and are being promoted by MNRE: the Mbuluzi River (120 kW minimum), Lusushwana River (300 kW), Mpuluzi River (155 kW) and Great Usuthu River (490 kW).

In 2015 MNRE conducted a feasibility study for the Lubovane Dam that identified three potential sites; however, only one site, with a total capacity of 850 kW, was found to be financially viable.

The utility is developing the 13.5 MW Lower Maguduza Hydro project, which is an extension of the existing Maguduza Hydro Scheme. Preparations to commence construction are at an advanced stage. The country also conducted a prefeasibility study to ascertain the hydro potential that may exist along the Ngwempisi River. The study indicated potential of about 120 MW to 140 MW, but further analysis in the form of a feasibility study would need to be undertaken. MNRE received financial assistance from the African Development Bank to conduct a prefeasibility study for the 120 MW Ngwempisi Hydro Scheme. Upon commission of the 20 Maguga Hydro Project, it was indicated that a potential exists downstream of the existing power station and recommended that a feasibility study be conducted.

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[10] One example is the Swaziland Hydro Power Reconnaissance Study that was undertaken by the engineering consulting firms GIBB and Knight Piesold in 2007 and focused on the Ngwempisi Cascade.

[11] By classification, micro hydro ranges from 0 kW to 100 kW, mini hydro from 101 kW to 2 MW and small hydro from 2.1 MW to 10 MW.

7 ENERGY SUPPLY INFRASTRUCTURE

7.1 FOSSIL FUEL PRODUCTS

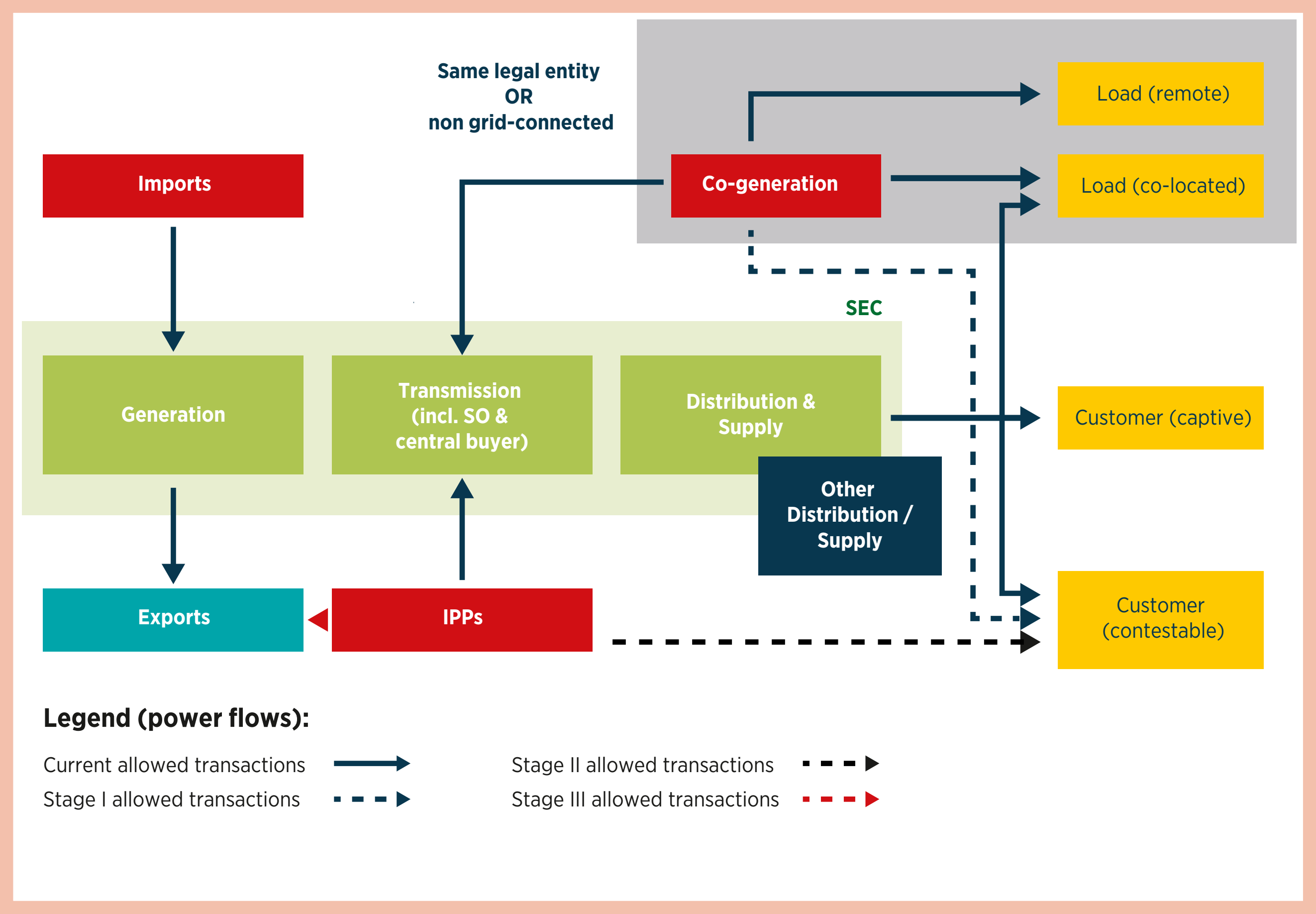
Eswatini imports all of its petroleum products, which are transported by road and rail from South Africa and Mozambique. The supply and distribution of these products is in the hands of private oil companies. Due to the strategic nature of petroleum products, the Ministry of Natural Resources and Energy regulates the prices and quality of the petroleum products. The oil companies own commercial depots for storage of the products. The petroleum products used in Eswatini include diesel and petrol for vehicle transport, paraffin and LPG for domestic applications, and heavy fuel oil for industry. Paraffin is also used in some industrial boilers. The Government intends to establish 90-day strategic stocks for petrol and diesel in order to improve the security of supply for these petroleum products.

In the petroleum sector, the Government is in the process of finalising the development of the Petroleum Bill to govern the sector. Eswatini has entered into a Memorandum of Understanding with Mozambique that covers the possible future supply of natural gas that could be used for electricity generation, cooking, space heating, lighting and transport.

7.2 ELECTRICITY SUPPLY SYSTEM

Eswatini's power market structure, the conceptual market structure/model proposed for the future, and the associated trading arrangements for the different market players are set out under the proposed stages as shown in Figure 7.1. This structure largely corresponds to that outlined in the recently published Swaziland Independent Power Producer Policy.

FIGURE 7.1 ESWATINI ELECTRICITY INDUSTRY MARKET STRUCTURE



Source: Swaziland Department of Energy, 2015

In the current stage, the SEC acts as a single buyer procuring all electricity imported from South Africa, Mozambique and the SAPP, as well as electricity generated by IPPs and excess power from CHP (co-generation). Sugar millers are the only entities that are currently undertaking co-generation and supplying loads within their estates (self-consumption), in particular irrigation and households for the RSSC. Ubombo Sugar Limited further sells excess power to the national utility (SEC). The sector is expected to consent to bilateral agreements in the near future where generators will be permitted to sell directly to certain large customers (contestable). Once the country has achieved security of electricity supply, IPPs will be allowed to export power to the SAPP.

TABLE 7.1 LIST OF POWER PLANTS IN ESWATINI

Company	Technology	Capacity (MW)
SEC	Hydropower plants	60.5
USL	Hydropower plant	1
USL	Biomass	40.5
SEC	Diesel	9
USA Distillers	Coal	2.2
Wundersight	Solar PV	0.1
RSSC	Biomass plant	65.5
Total		**178.8**

Efforts are being made to increase local generation through private sector participation in the form of IPPs. The utility also has signed Memorandums of Understanding and power purchase agreements (PPAs) with a number of potential IPPs for short-term power generation plans. Only one IPP-owned solar PV plant, a 100 kW plant, is operational at this stage. A 12 MW hydropower plant to be developed by an IPP is expected to be commissioned in June 2019. Short-term IPP plans that include plants at the inception stage include generation using solar PV of about 60 MW, biomass (bamboo and wood waste) of 35 MW and coal using coal finds from mine dumps of 30 MW.

7.2.1 GENERATION

The country's installed capacity by technology for the individual companies licensed to undertake generation is shown in Table 7.1. The SEC generates about 60.5 MW of peaking power through hydropower generation, from four hydropower stations: Ezulwini (20 MW), Edwaleni (15 MW), Maguduza (5.6 MW) and Maguga (19.8MW). The bulk of the power, including base-load supply, is imported from South Africa. The SEC also purchases power from IPPs. Currently only two IPPs sell power to the SEC: USL (up to 40.5 MW) and Wundersight (0.1 MW). All of the other IPPs generate for self-consumption. Table 7.2 shows SEC's existing generation plants, including rated capacity, commission year and current status.

TABLE 7.2 SEC POWER GENERATION STATIONS

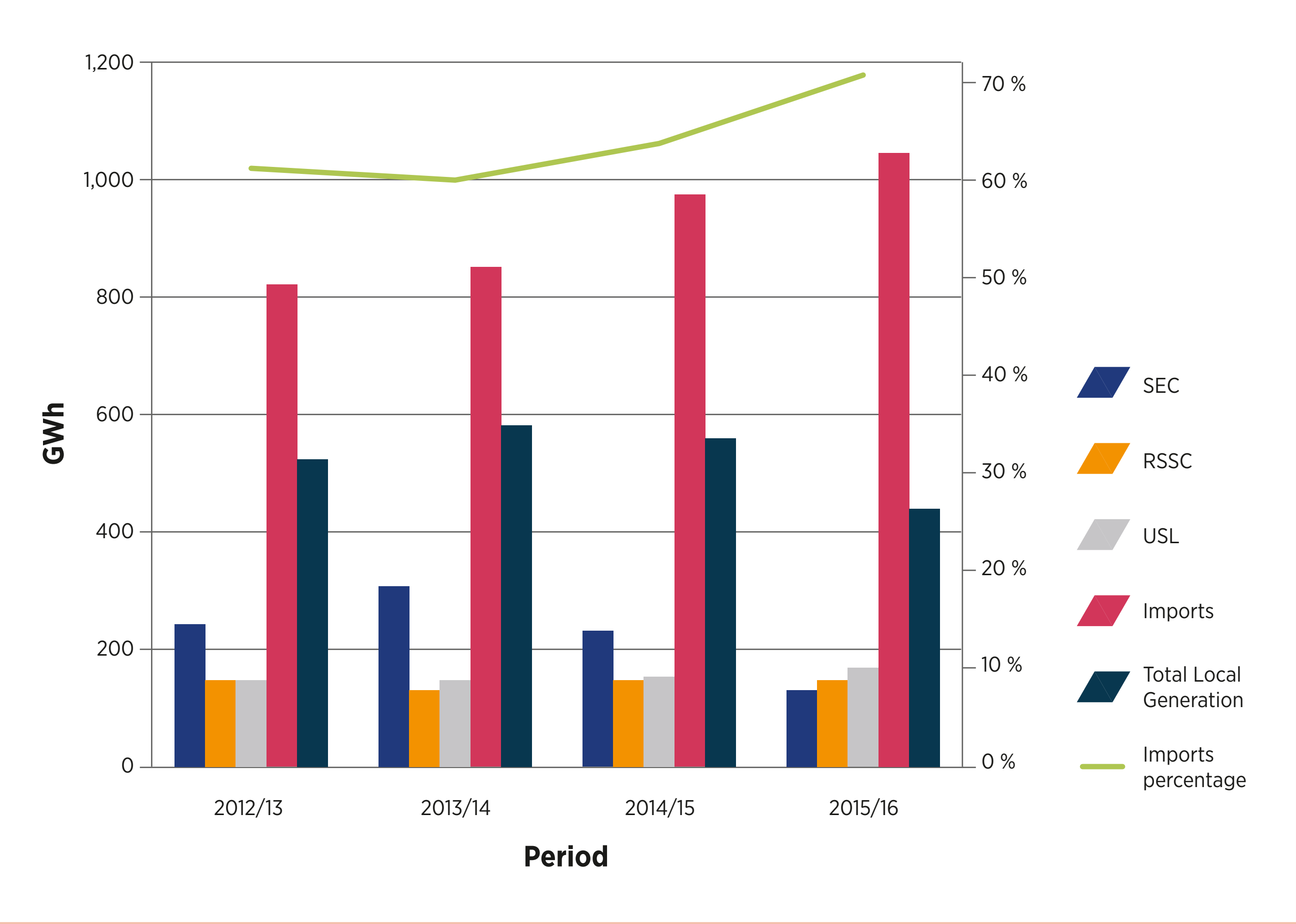
Name	Rated capacity (MW)	Year of commission	Status
Edwaleni Unit 1 Unit 2 Unit 3 Unit 4 Unit 5	15	1964 1964 1964 1965 1969	Operational
Ezulwini Unit 1 Unit 2	20	1985 1985	Operational
Maguduza	5.6	1969	Operational
Maguga Unit 1 Unit 2	19.8	2007 2010	Operational
Mbabane Hydro	0.5	1954	Mothballed
Edwaleni Diesel	9		

The development of a 300 MW coal-fired power station that would reduce the country's reliance on imports is still at the inception stage. Coal prospecting to ascertain the coal type and amount of reserves has been undertaken. A full feasibility study for the project is yet to be undertaken.

7.2.2 IMPORTS

As the industry matures and progresses according to the stages depicted in Figure 7.1 the utility (SEC) is expected to continue to play a central role in the importation of power, energy wheeling where bilateral agreements exist and the export of power to the SAPP. The SEC owns and operates the entire transmission network in the country, and the status quo is expected to remain even in the longer term due to the small size of the national economy. About 70 % of power is imported from Eskom (South Africa) and other SAPP countries, while the balance is met through local generation. Figure 7.2 indicates local production and the import trends from 2010 to 2014. The country's reliance on imports has increased steadily over the years due to rising national demand.

FIGURE 7.2 ESWATINI GENERATION AND IMPORT PROFILE

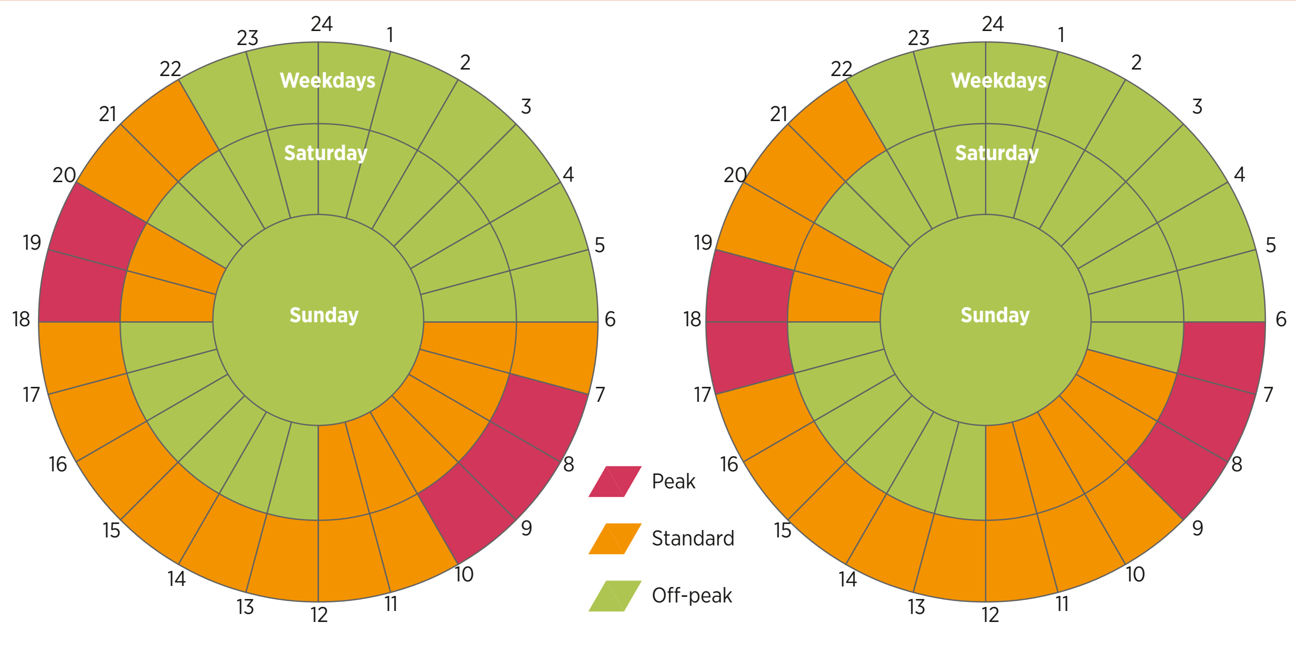


The SEC imports the bulk of its supply from Eskom according to the customer categories shown in Table 7.3. The utility pays for both energy and demand charges according to the terms and conditions outlined in the parties' PPA. The high-demand season occurs during the winter period from June to August, while the balance of the year falls under the low season. The time-of-use periods are generally the same during the two seasons except for the peak demand, which occurs an hour earlier during the high season. Figure 7.3 shows the time-of-use periods for the high and low seasons, respectively. The same seasons and time-of-use periods apply to customers in Eswatini.

TABLE 7.3 ESKOM MEGAFLEX CUSTOMER CATEGORIES

Megaflex tariff (no local authority)															
		Active energy charge [c/kWh]												Transmission network charge in South African Rand [R/kVA/m]	
Trans-mission Zone	Voltage	High Demand Season [June–Aug]						Low Demand Season [Sep–May]							
		Peak	VAT incl	**Stand-ard**	VAT incl	**Off Peak**	VAT incl	**Peak**	VAT incl	**Stand-ard**	VAT incl	**Off Peak**	VAT incl		VAT incl
≤300 km	< 500 V	**272.34**	310.47	**82.86**	94.46	**45.24**	51.57	**89.18**	101.67	**61.54**	70.16	**39.23**	44.72	R7.79	R8.88
	≥500 V & <66 kV	**268.06**	305.59	**81.21**	92.58	**44.10**	50.27	**87.44**	99.68	**60.19**	68.62	**38.18**	43.53	R7.12	R8.12
	≥66 kV & <132 kV	**259.58**	295.92	**78.63**	89.65	**42.71**	48.69	**84.69**	96.55	**58.28**	66.44	**36.98**	42.16	R6.94	R7.91
	≥132 kV	**244.85**	278.90	**74.11**	84.49	**40.25**	45.89	**79.82**	90.99	**54.92**	62.61	**34.85**	39.73	R8.76	R9.99

FIGURE 7.3 TIME-OF-USE TARIFFS FOR HIGH SEASON (LEFT) AND LOW SEASON (RIGHT)



7.2.3 TRANSMISSION AND DISTRIBUTION

A 400 kilovolt (kV) line is the major interconnector between South Africa, Eswatini and Mozambique and is used to facilitate power imports and exports among these countries. A 132 kV line also extends from Normandie in South Africa to the south of Eswatini and is used by Eswatini to import power from South Africa and to control the import maximum demand on the 400 kV line for the country. The power is then transmitted through 132 kV/66 kV substations where it is transformed from 132 kV to 66 kV. From these substations the power is further stepped down to the 11 kV distribution network. The SEC is currently not exporting power.

Transmission lines are maintained regularly. Most of the old wooden pole structures are gradually upgraded to steel structures. A total of fourteen 66 kV lines are on steel structures, and the other fifty 66 kV lines are still on wooden poles. Some of these lines are partially on steel structures and wooden poles.

TABLE 7.4 TRANSMISSION LINES

Capacity	Number of transmission lines	Distance (km)
400 kV	2	–
132 kV	9	296
66 kV	64	970

The maps in Figure 7.4 and Figure 7.5 depict the transmission system and electricity coverage, respectively, in Eswatini within a 1-kilometre radius.

FIGURE 7.4 TRANSMISSION SYSTEM MAP

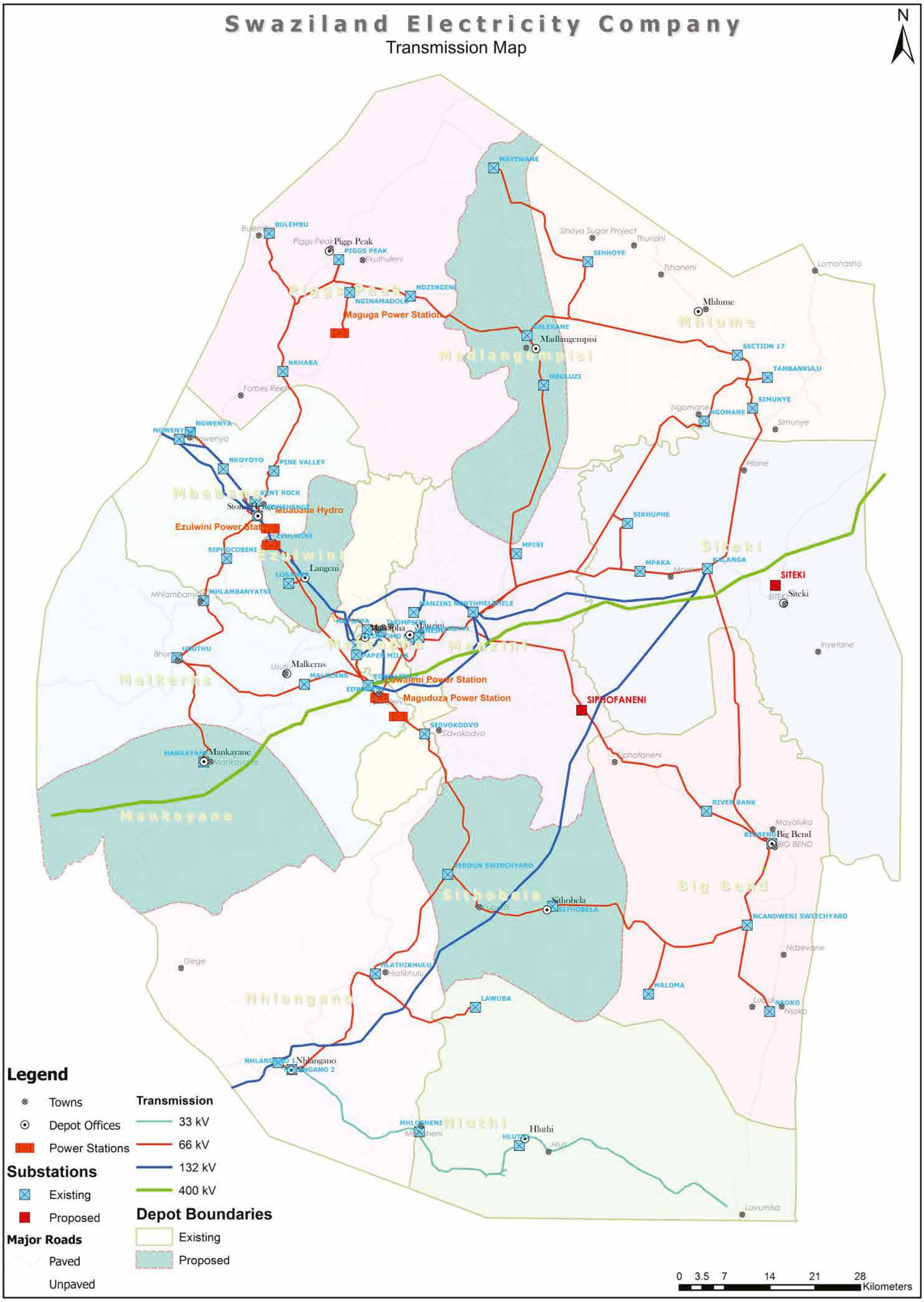
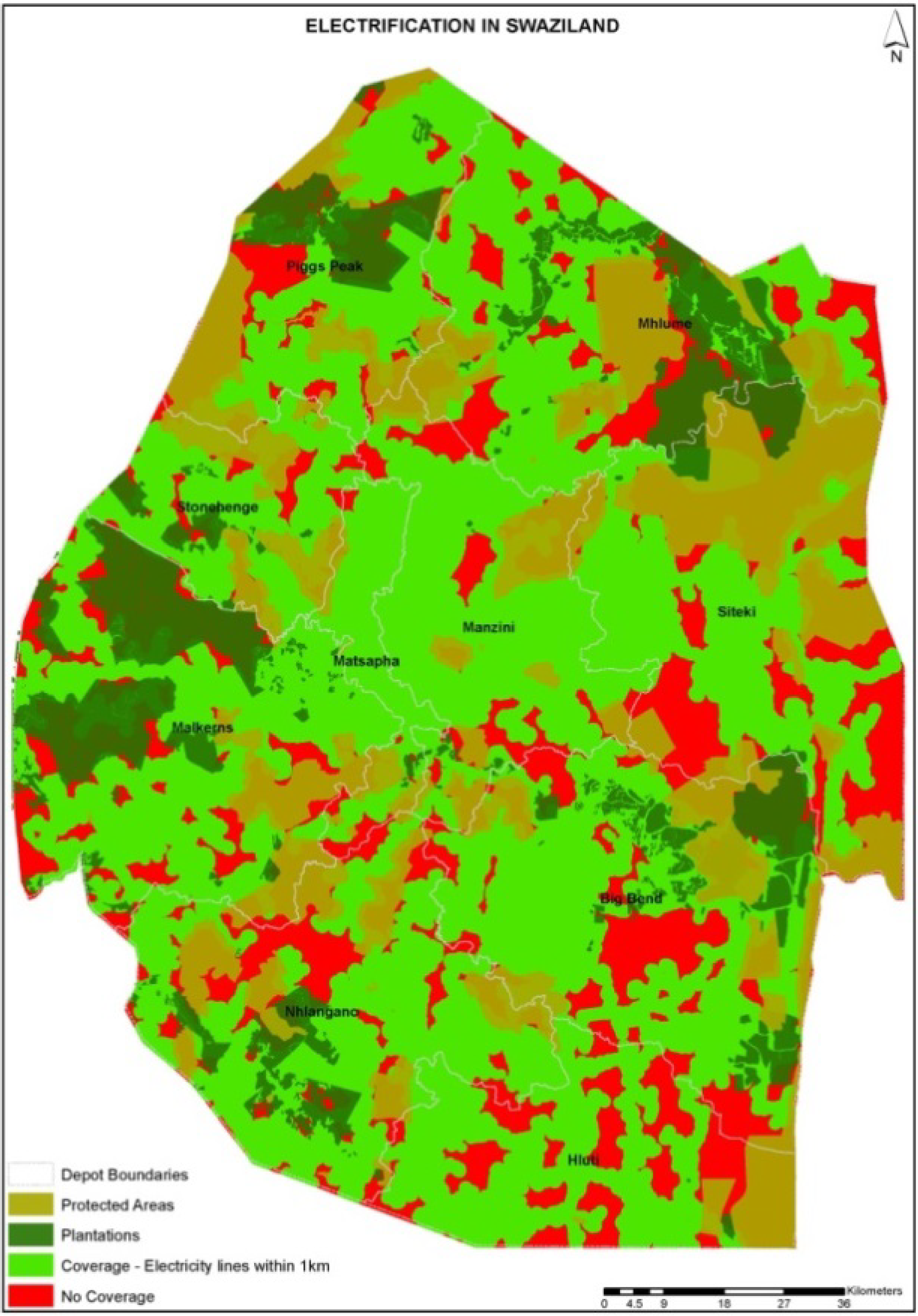


FIGURE 7.5 ELECTRICITY COVERAGE MAP



No major policies guide grid extension and rural electrification in Eswatini, except for national needs or the government targets stated in Chapter 4. The utility acts on instruction by the Government and based on available funding to meet the set targets. However, significant ground has been covered in extending the network countrywide, as shown in Figure 7.5. "Network coverage" represents transmission infrastructure that is within a 1 kilometre radius of the point of connection, while "actual access" depicts the actual connections. Network coverage in rural areas is estimated at 67 %, compared with actual access of 60 %. The low access rate compared to the availability of infrastructure signifies the need to accelerate rural electrification, including through the use of distributed systems in areas where grid extension is not expected in the foreseeable future due to high capital costs.

The RSSC also undertakes distribution in its estate, which accommodates mainly employees and third-party customers providing services to the estate.

7.3 BIOFUEL SUPPLY SYSTEM

The Government plans to introduce ethanol-blended fuel through a blending mandate for all unleaded petrol in the country. This is incorporated in the draft Petroleum Bill, and the relevant standards that have been developed will be turned into technical standards as part of the mandatory blending regulation.

The Government, in collaboration with the Royal Swaziland Sugar Association, conducted a pilot project on E10 blended biofuel. The pilot project ran for two years, from 2008 to 2010, and was considered a huge success. The RSSC anhydrous ethanol plant has a production capacity of 10,000 litres per day, and expansion of this capacity is being considered to meet the country's demand for petrol, which averages around 1.2 million litres per month. The RSSC has estimated that it would take about 12 months to expand the plant's existing capacity fourfold. Preparations to roll out the E10 blended biofuel are at an advanced stage while finalising the logistics for the E10 fuel blending programme. The Government intends to gradually introduce blending up to a 10 % ratio; according to the target set under the SE4ALL action plan, this was to be achieved by 2016.

Liquid biofuels do not need any special equipment for transport except that ethanol has a very high affinity for water, so tanks must be efficiently dried. Silica gel or any drying chemicals can be used in tankers transporting ethanol or ethanol-blended fuel by rail or road. However, pipelines are not suitable for ethanol transport because the fuel is highly corrosive, a property that is not favourable for the joints normally found in pipelines. Pipelines also are not suitable because they typically transport more than one product, which may contaminate the ethanol with water particles.

8 ENERGY SUPPLY PLANNING SCENARIOS FOR 2014–2034

8.1 BRIEF DESCRIPTION OF THE METHODOLOGY

The System Planning Test – Swaziland (SPLAT-SW) model is a planning tool developed by the Eswatini team, expanding on the SPLAT – Southern Africa (SPLAT-S) model originally developed by IRENA. The SPLAT-SW model was developed using the Model for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE) platform. MESSAGE is a dynamic bottom-up, multi-year energy system software that applies linear and mixed-integer optimisation techniques, used for medium- to long-term energy system planning. The software analyses the least-cost technically and economically feasible combinations of energy supply options to meet a specified demand under a set of conditions. On that basis it selects the least-cost optimal energy mix, taking into consideration the investment needs and other costs for new infrastructure, energy supply security, energy resource utilisation, rate of introduction of new technologies, and environmental and other constraints.

The SPLAT-SW model contains a set of demand projections and a catalogue of energy supply technology options characterised by economic and technical parameters as well as data on the prevailing investment stock and remaining life span. Within this set of assumptions, the model performs an assessment of different scenarios for a given energy demand. The model results include projections on, among others, investments, production, fuel use and trade, and CO_2 emissions.

The model incorporates the latest information on energy technologies and cost, with some refinements to adequately characterise options available to Eswatini. The modelling approach has been expanded to cater to both the power and non-power sectors to take into account the demand for fuels other than electricity.

As described in Chapter 4, the demand projections were made using a LEAP model, which, among other things, takes into account universal electricity access goals as well as the goal of providing the country with access to modern energy for cooking and eliminating sole reliance on the use of fuelwood. The SPLAT-SW model takes as inputs the demand projections from LEAP.

8.2 SCENARIO DEFINITION: KEY POLICY ISSUES TO BE ADDRESSED

This section provides information on the parameters and related assumptions that informed inputs into the SPLAT-SW model for the Base Case and alternative scenarios. The parameters are predetermined by known technical characteristics such as costs and efficiencies. The Base Case is the baseline for all of the alternative scenarios, meaning that the scenarios are created based on the Base Case, with alteration in specific parameters to define the relative policies that deviate from the Base Case. The scenarios are designed for the purpose of addressing different aspects of the existing energy policy objectives. They are:

- self-sufficiency in energy supply
- universal access to clean and affordable energy
- optimal use of domestic resources
- diversification of the energy supply mix to meet energy security concerns
- climate change goals, as captured in Eswatini's Nationally Determined Contribution (NDC).

Based on the base year (2014), one Base Case scenario and nine alternative scenarios were developed.

The Base Case provides the least-cost supply technology mix to meet the projected energy demand over the planning horizon, given some existing policies and macroeconomic trends.

The alternative scenarios considered different pathways that could be pursued to achieve the above-mentioned energy policy objectives. The alternative scenarios have been informed by the policy imperatives of high-impact policies within the energy sector that include, among others, a large coal power plant project, the SE4ALL targets and renewable energy targets in the National Development Plan. Key drivers of the alternative scenarios are to enhance energy security, to decarbonise the energy sector and to achieve self-sufficiency in energy supply using domestic resources.

8.2.1 THE BASE CASE

The Base Case is based on existing policy objectives and depicts the business-as-usual future. It therefore serves as a reference point/baseline for the alternative scenarios. Proposed and existing projects were taken into consideration; however, projects that have reached maturity in terms of bankability were included as committed in the model. These projects include the 13.5 MW Lower Maguduza Hydro Scheme and the 10 MW solar PV project at Lavumisa.

The Base Case includes all other technology options such as coal power generation, natural gas, biomass and wind technologies, to name a few. The deployment of these technologies is not forced in the model solution.

The biomass-based generation options were modelled as follows:

1) Technologies that use bagasse as a main fuel and coal and wood chips as supplementary fuels; they are used for self-consumption for the sugar industry and also for selling it to the main grid.

2) Technologies that use bagasse as a main fuel and wood chips as supplementary fuels; they are used for self-consumption for the sugar industry and also for selling it to the main grid.

3) Technologies that use wood chips as the only fuel for self-consumption in the industry, and for selling the reminder to the grid.

4) Technologies that use bagasse as a main fuel and wood chips as supplementary fuel; they are used for self-consumption for the sugar industry only.

8.2.2 FORCED COAL SCENARIOS

The Forced Coal scenarios use all technology assumptions from the Base Case, with additional alterations only on coal technology. The purpose of these scenarios is to provide insights into the impact of coal technology in providing baseload power. These scenarios explore the possibility of reducing Eswatini's reliance on imports by exploiting the country's coal endowments through constructing a new coal power plant. Coal is one of the resources that the country has in abundance but has never exploited. A feasibility study is ongoing to assess the technical and economical parameters of developing a coal mining operation for power generation. The plan for developing 300 MW coal-fired plants by 2018 was included in the SE4ALL Action Agenda.

Given that the domestic electricity-grade coal resource is virtually untapped, it is possible that the country would be in a position to negotiate long-term supply contracts for this coal, hence lowering fuel prices. Affordability is a key consideration in the coal scenarios. It was assumed that the coal-fired generation would be explored only with domestic coal and not with imported coal. Additional coal options would be undermined by a carbon tax regime, which would render local industries less competitive and put economic value, jobs and country growth at risk. However, a carbon tax was not taken into account in these scenarios.

The expected commissioning date of the power plant in the model, of 2025, has been set to coincide with the expiration of the existing bilateral electricity trade agreements with Eskom, while also allowing for sufficient lead time for project preparation and construction. Two Forced Coal scenarios are considered:

Forced Coal 1 (300 MW)

This scenario assumes that a 300 MW plant is built and commissioned in 2025. The objective of this scenario is to meet the country's peak demand capacity through the exploitation of local abundant coal, while meeting the country's emissions target. However, using local coal presents a great risk considering the high resource cost.

Forced Coal 2 (600 MW)

This scenario assumes that a 600 MW plant is built and commissioned in 2025. This scenario has similar assumptions to the Forced Coal 1 scenario (300 MW). However, this scenario looks into the possibility of meeting the growing demand and long-term cost reduction in developing a bigger coal-based power plant. Also, this scenario considers the potential benefits of using the domestic coal resource to generate electricity for exports to the regional market (SAPP) in order to generate income from exports.

8.2.3 DOMESTIC RESOURCES SCENARIOS

The domestic resources from hydro, wind, solar, biomass and coal are distributed across Eswatini and could provide affordable and secure supplies of energy and meet the country's electricity demand. The Domestic Resources scenarios assess the implications of becoming less import-dependent and maximising the domestically endowed energy resources. The scenarios envision an increase in renewable energy deployment as a result of the rapid reductions in renewable energy costs and the country's renewable energy promotion policy as well as reduced reliance on imports. The appetite for renewable energy in the market is growing rapidly. By developing renewables, the country envisages being able to meet its international climate and sustainability obligations and to access finance. It is against this background that renewable energy was considered when establishing the Energy Masterplan to ensure effective energy infrastructure planning and to achieve the targets of sustainable development goals.

According to the IRENA-LBNL Renewable Energy Zoning study[12] for Southern and Eastern African countries, done in the context of IRENA's Africa Clean Energy Corridor programme, the technical potential for wind and solar PV generation in Eswatini is approximately 880 MW, and the economically viable potential is 586 MW. Biomass (wood chips and wood waste) and sugarcane bagasse are the two main sources of biomass considered for power generation in the country. Domestic biomass has a technical potential of 100 MW. Hydropower is growing rapidly, with an installed capacity of 62 MW in 2014 and additional potential of 133.5 MW deemed economically feasible. In light of the existing potentials, these scenarios seek the implications of becoming less import-dependent and maximising the use of domestically endowed energy resources, primarily renewables.

Domestic Resources scenarios

Three scenarios were developed to determine the role of using domestic resources in meeting future energy requirements while increasing local capacity. Three policy choice options are identified.

- **Limited Import 1** seeks the implications of becoming less import-dependent and maximising domestically endowed energy resources (including all resources).
- **Limited Import 2 (with forced hydro)** seeks the implications of becoming less import-dependent and maximising domestically endowed energy resources, with an additional 120 MW of hydropower generation forced into the scenario.
- **Limited Import 3 (with renewables, without coal)** seeks the implications of becoming less import-dependent and maximising domestically endowed energy resources, with only renewable energy sources and without coal.

These scenarios serve the objective of increasing the share of renewable energy, as enshrined in the SE4ALL agenda, and ensuring that electricity consumed in the country is generated locally. Eswatini currently meets about 25 % of its electricity requirements from renewable energy resources. Several renewable energy resources were considered in the scenarios, based on the technology assumptions used in the Base Case, which assumes a ceiling on electricity imports of 35 % by 2020 and 25 % from 2025, with up to 35 MW from biomass power plants as of 2022 and up to 120 MW from hydropower plants as of 2025.

8.2.4 NO IMPORT ENHANCEMENT SCENARIOS

Two "No Import Enhancement" scenarios assume that no investment into expanding the import capacity is allowed. The "High Demand with no import enhancement" scenario assumes higher local electricity demand that exceeds the maximum electricity available to Eswatini from domestic sources and from the current supply agreement with South Africa combined. The current bilateral agreement with South Africa allows maximum energy imports of 185 MW a year. The objective of the scenario is to evaluate a situation in which the growth in local demand is so high that it can lead to insufficient supply from current electricity import options. As a reference, another scenario was developed with the same restriction on import enhancement, but with the demand as in the Base Case.

- **High Demand with no import enhancement**: with higher demand, but no investment into expanding the import capacity is allowed.
- **Base Case with no import enhancement**: with Base Case demand, but no investment into expanding the import capacity is allowed.

8.2.5 LOW IMPORT PRICE SCENARIO

There is a long-standing ambition to increase electricity trade across Africa through co-operative planning and improved transboundary transmission. However, trade within Southern Africa is currently constrained by limited supply. Eswatini is a net importer of electricity, which poses a risk for energy security. Electricity prices vary greatly, with much of the variability reflecting the relative ease of energy supply and the extent to which electricity prices are subject to government control. South Africa was recently affected by the shortage in supply, which led to high import prices for the country.

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[12] See: http://www.irena.org/publications/2015/Oct/Renewable-Energy-Zones-for-the-Africa-Clean-Energy-Corridor.

In the Low Import Price scenario, there is no limit on imports of electricity. The import of electricity is charged according to the Eskom tariff at the time of use. This scenario assumes a lower import tariff, with no general cost escalation and an annual import tariff increase of 3 %.

8.2.6 NATURAL GAS SCENARIO

This scenario assumes that a natural gas plant is built locally. It must consider the cost of importing the resource from neighbouring Mozambique. The scenario allows a comparison of natural gas imports with the coal options. Replacing coal-based generation with natural gas provides a way to reduce carbon emissions. This scenario also considers natural gas to be used for demand-balancing power to cushion the intermittency of renewable energy plants.

8.3 MODELLING OF THE ESWATINI ENERGY SYSTEM

The Eswatini energy system is modelled for analysing energy technology choices. In view of the close correlation between energy sector policy and technology choices, the model considers how the energy system can be used to inform policy.

The key assumptions that inform the modelling of the energy system include projected future energy demand, assumptions about the current and future energy technologies, energy prices and policy constraints. While demand is the key input into the model, other assumptions such as macroeconomic and demographic assumptions inform the projected demand. The demand projections for other various sectors are also significant. The main purpose of this modelling is to find the least-cost development path for the Eswatini energy system to the year 2034. Such a path is required to meet the predetermined demands for energy services within the given policy, environmental and economic constraints.

The modelling includes determination of the types of existing energy technologies and their properties. Possible future options based on the country's needs are assessed. This includes determining properties such as the efficiencies, capacity factors and operational life of all of the technologies. The domestic availability of natural resources such as coal, natural gas and biomass are considered as well as the costs of importing these resources. The model is then populated with the datasets, and the model runs for the Base Case and alternative scenarios executed and results analysed.

The primary energy supply includes extraction of coal and all forms of biomass (wood chips, bagasse, wood waste) and imports of natural gas and petroleum products. Renewable energy technical potentials of wind power and solar PV are also included. The technology options include a variety of electricity generation technologies for coal, wind, solar, hydro, biomass and natural gas resources. The cost of the whole energy system is determined by summing the costs related to the investments and activity of all of these technologies. The fuel prices are determined from the cost of using the technologies.

8.3.1 MODEL CONFIGURATION

The parameters defining the model are arranged according to the fuel and technology configurations and are grouped into technology, demands, costs, storage, activity and capacity. A number of characteristics define each parameter attributable to the energy system. The technology, fuel used (input and output of the technology), year and time slice are all dimensions considered within the energy system. Each parameter has a number of constraints defining it. The Base Case has information on parameters and assumptions that inform inputs into the model. The assumptions can be technical attributes such as costs and efficiencies, while others are determined on estimates such as potential for wind power.

In order to maintain an energy system approach, dummy technologies are defined for energy carriers in demand technologies for final demand sectors such as agriculture, commercial, industrial, etc. The function of these dummy technologies is to link the production of energy to final consumption within the model. There are no costs associated with these dummy technologies.

The technologies for electricity generation are means to convert energy carriers into usable electricity. They are defined by costs, primary sources, efficiency factors and emissions from transformation. These are split between existing and new generic technologies. Each technology is defined by certain technical parameters that determine the investment and operation costs and performance. Other parameters are less constraining, such as the maximum/minimum limits of the respective technology.

For the model's installed capacity, SEC power plants are dominated by hydropower plants, with one diesel power plant and bagasse/coal power plants operated by the sugar industry. The "committed"[13] power plants are all under development, with signed PPAs. The existing and committed plants are modelled as residual capacity, and variable costs collected are converted in USD per kilowatt (kW) per year. This also applies to fixed costs. Capital costs for new plants are also converted to USD per kW. Inputs for existing plants are based on performance characteristics. New plants for renewable energy have decreasing capital costs going into the future.

A constant electricity reserve margin of 10 %, including imports, is used in the model. Six time slices were used to calibrate the electricity demand profile. The sum of solar PV and wind power does not exceed 70 % of the system peak in order to limit the instantaneous penetration of variable renewable energy.

8.3.2 REFERENCE ENERGY SYSTEMS

The primary purpose of the energy system is to ensure that all demands for energy services are met. A reference energy system reflective of the country's energy flows and projected developments is defined in Figure 8.1 and Figure 8.2. The reference energy system presents the country's different energy forms, whether imported or available locally. The vertical lines represent energy commodities and the rectangles represent technologies, while the horizontal lines represent commodity flows among these.

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[13] "Committed" means that projects are under construction or are at an advanced stage of preparation in their development. This is in contrast to existing projects or "candidate" projects. The latter includes two categories: site-specific candidates and generic candidate projects, that may be built in future years.

FIGURE 8.1 REFERENCE ENERGY SYSTEM (POWER SECTOR PART)

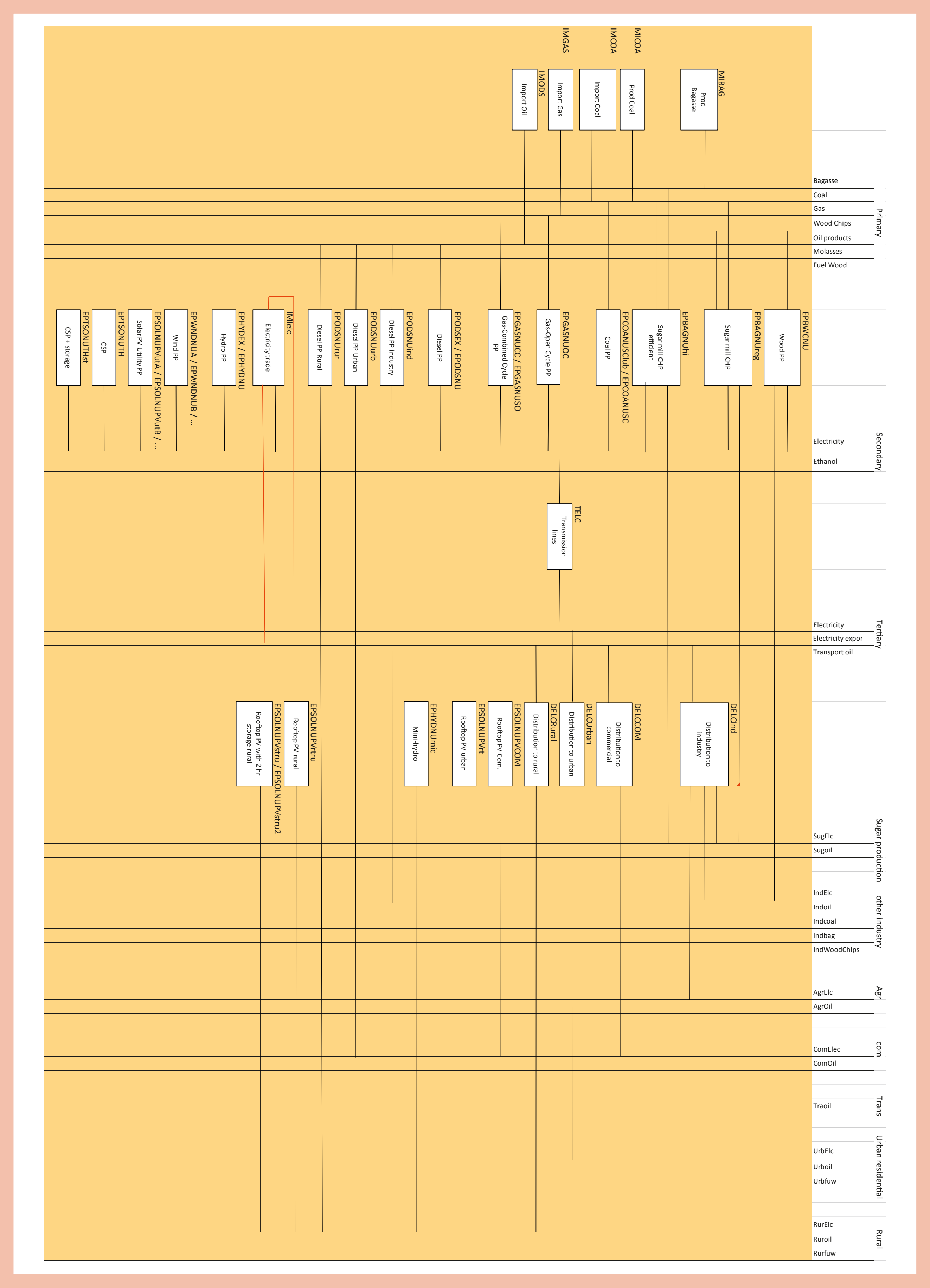


FIGURE 8.2 REFERENCE ENERGY SYSTEM (NON-POWER SECTOR PART)

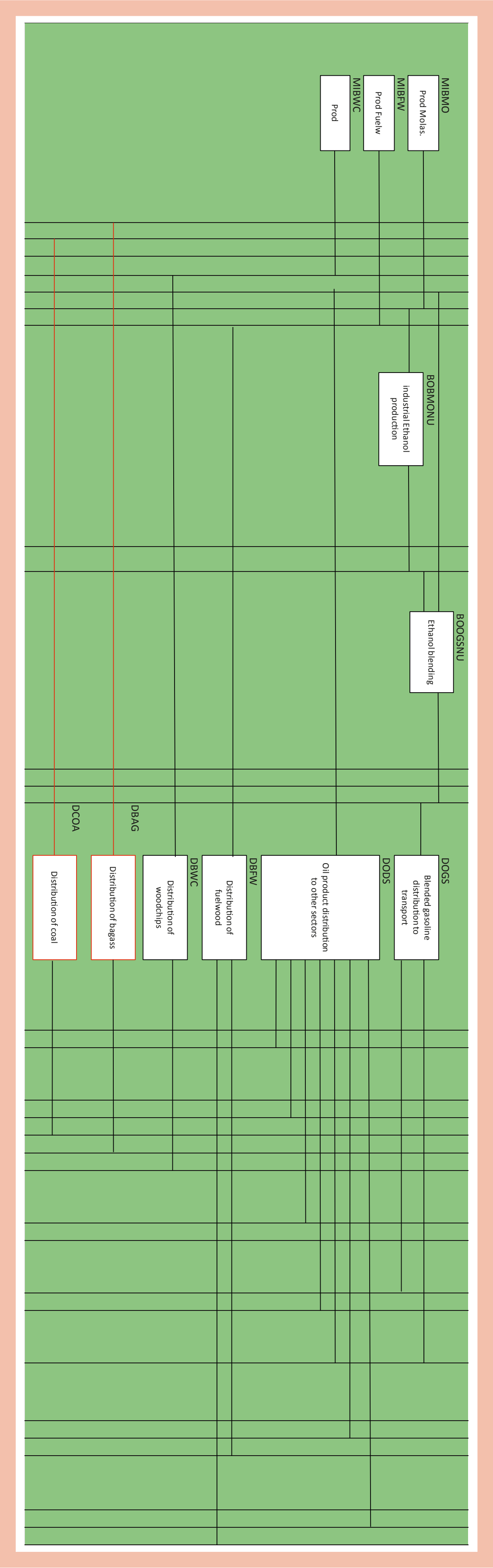


Figure 8.1 and Figure 8.2 illustrate significant components of the energy system. The process starts with primary forms of energy, which are converted into secondary forms of energy. Certain secondary energy carriers such as electricity and liquid fuel are imported directly into the energy system. The final processes in the energy value chain are performed by demand technologies that transform energy carriers into services.

Energy commodities represented in the SPLAT-SW model include:

- Primary energy: bagasse, coal, gas, wood chips, oil products, molasses, fuelwood
- Secondary energy: electricity, ethanol
- Tertiary energy: electricity, electricity export, oil products

Energy demand is divided into six categories, with the following fuel demands:

- Sugar production: electricity, oil
- Other industry: electricity, oil, coal, bagasse, wood chips
- Agriculture: electricity, oil
- Transport: oil
- Urban residential: electricity, oil, fuelwood
- Rural: electricity, oil, fuelwood

The cost of the whole energy system is measured by adding up all of the costs associated with the investments and activity of all technologies.

8.3.3 DEFINITIONS OF SEASONS AND DAILY LOAD REPRESENTATION

In the SPLAT-SW model, the daily load curves are defined for each season and for each day type (weekday and weekends). The load curves are defined with simplified blocks of hours. The same block definition and seasonal definitions are used to represent the output pattern of generations that are seasonal (all renewables) or that have the diurnal production patterns (solar and wind). Based on the analysis of the seasonal demand pattern, rainfall, solar and wind availabilities, and crop production, a total of five seasons was identified, each of 2–3 months, as presented in Table 8.1. Note that for the import tariff, season 3 corresponds to the “high-demand season”.

TABLE 8.1 SEASONS DEFINED IN THE SPLAT-SW MODEL

Season	Time of year (in months)	Description
1	1–3	High: hydro, solar, demand; Low: wind, crop
2	4–5	High: crop; Low: wind, hydro, solar, demand
3	6–8	High: wind, crop; Low: hydro, solar, demand
4	9–10	High: wind, solar; Low: hydro, crop, demand
5	11–12	High: hydro, wind, solar; Low: demand, crop

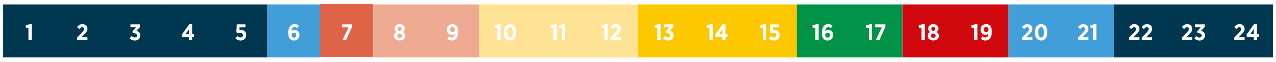
For the definition of the blocks within a day to represent the load profiles, the following observations were made:

- Solar daily output pattern: 16:00–5:00 (nearly zero); 6:00–8:00 (between zero and peak); 9:00–12:00 (peak production); 13:00–15:00 (between zero and peak)
- Wind daily output pattern: no clear pattern exists
- Demand: 6:00–7:00 morning peak; 8:00–10:00 weekend morning peak; 19:00–20:00 evening peak
- Tariff: weekdays 22:30–6:00 off-peak, 6:00–9:00 and 17:00–19:00 peak (low-demand period) and 7:00–10:00 and 18:00–20:00 peak (high-demand period).

Given these observations, the daily blocks were defined in the following manner. Note that the 24 hours of the day are divided into five to nine blocks, respectively, separated by the colour code.

The detailed load demand approximated for each season and each day type is presented in Figure 8.3.

Weekday (seasons 1–2, 4–5)



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Weekday (season 3)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Weekend (seasons 1 and 5 – summer)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

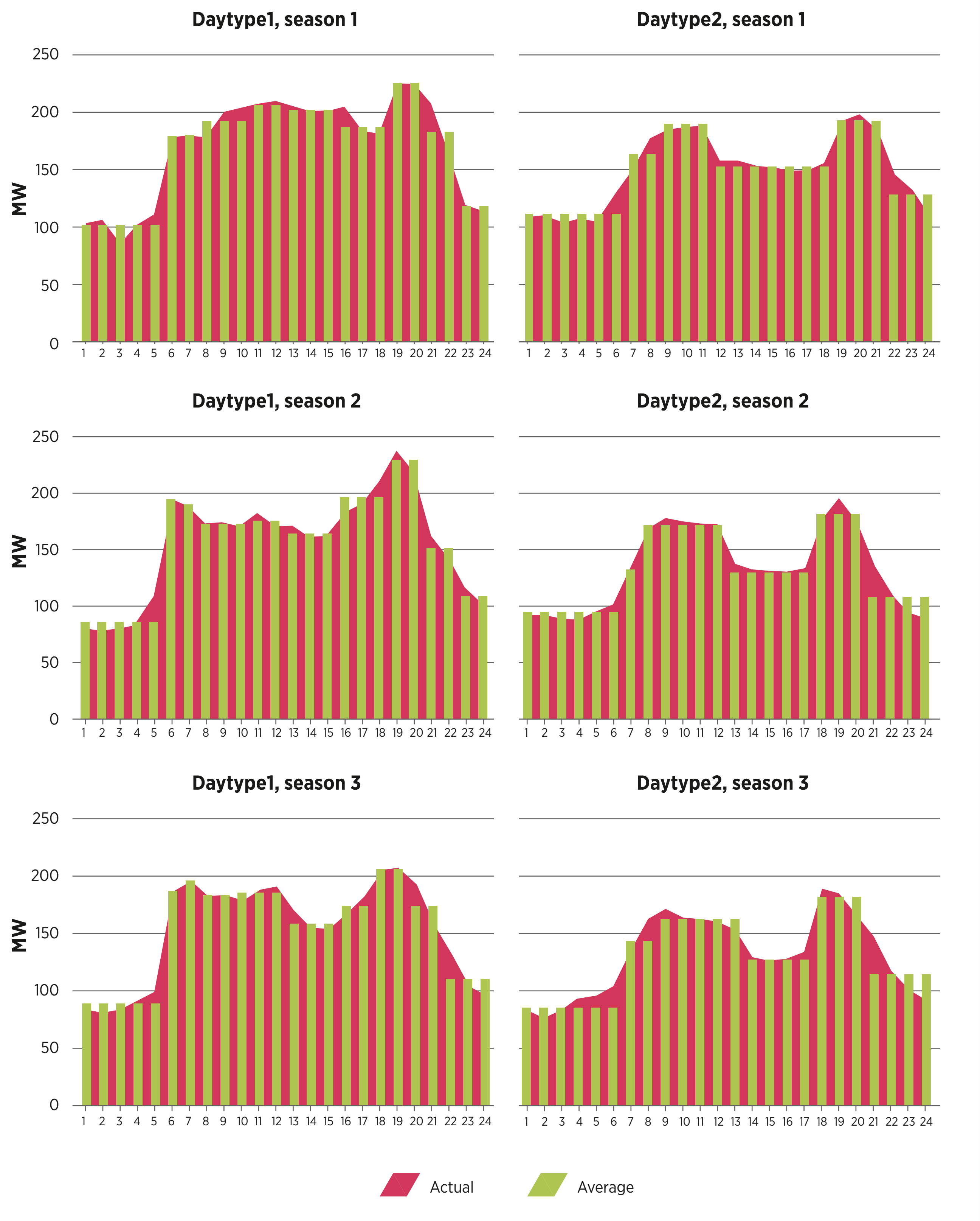
Weekend (season 3 – winter)

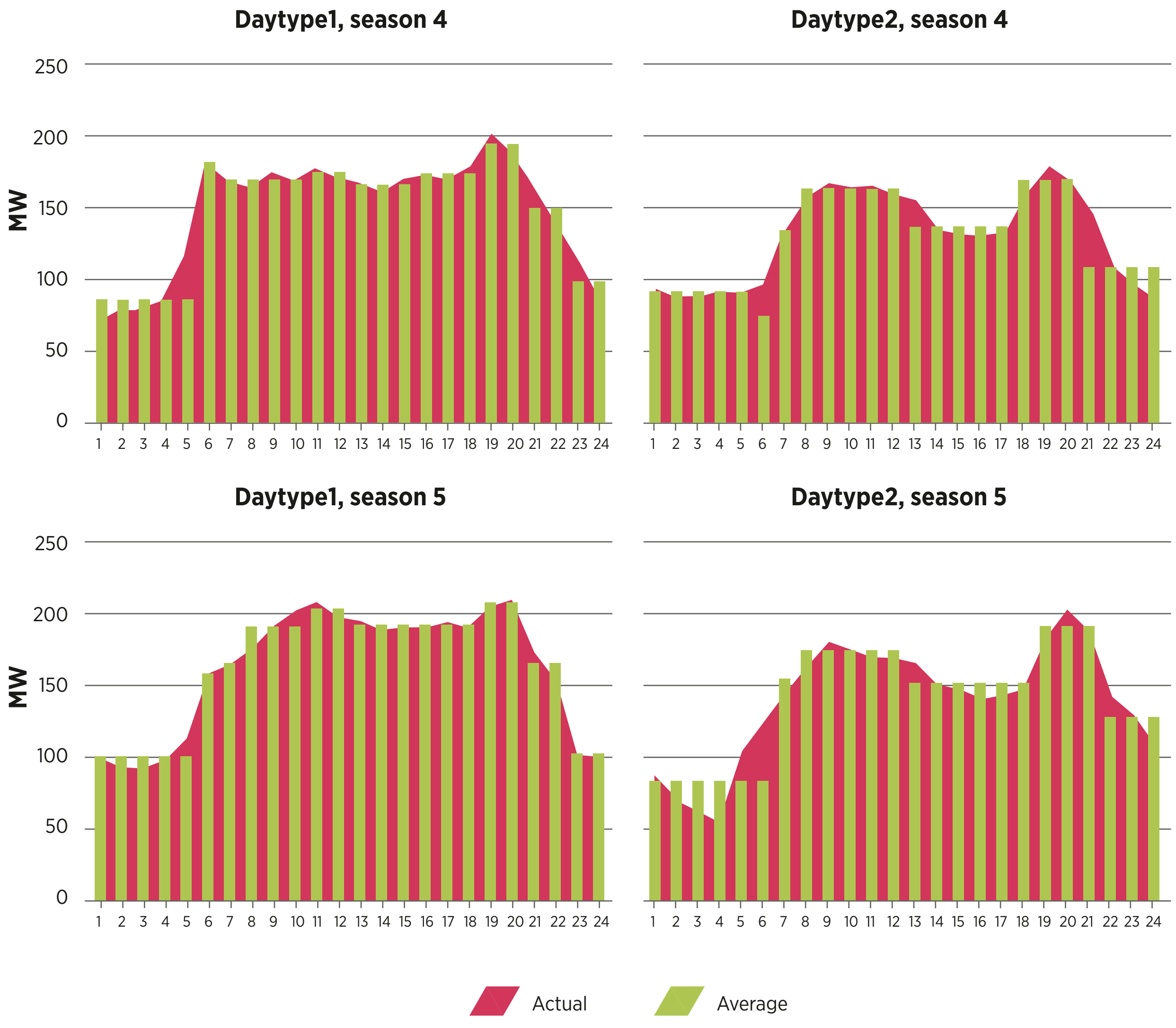
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Weekend (seasons 2 and 4)

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

FIGURE 8.3 LOAD PROFILE REPRESENTATIONS IN EACH SEASON AND IN EACH DAY TYPE




Daytype1, season 4
Daytype2, season 4
Daytype1, season 5
Daytype2, season 5
MW
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Actual
Average

8.3.4 KEY TECHNOLOGY PARAMETERS

Fuel price assumptions

Primary energy sources used in the models are coal (imported, domestic), LPG (imported), diesel (imported), petrol (imported), kerosene (imported), natural gas (imported), bagasse (domestic), wood chips (domestic), molasses (domestic) and fuelwood (domestic). The cost assumptions for some of these energy sources are summarised in Table 8.2. The fuel prices are assumed to stay constant in this analysis, except for imported gas.

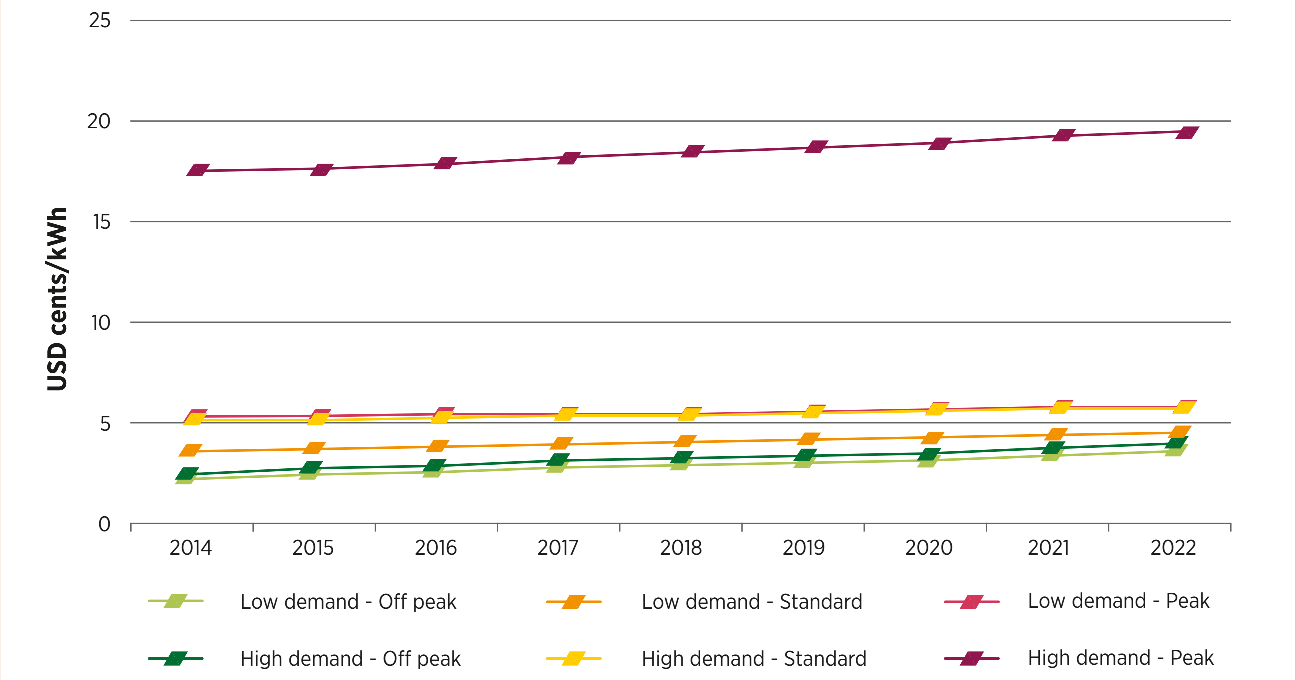
TABLE 8.2 FUEL PRICE ASSUMPTIONS

Parameter	Unit	Assumption for 2014	Assumption for 2034
Domestic coal	USD/GJ	2.7	2.7
Imported coal	USD/GJ	2.4	2.4
Imported natural gas	USD/GJ	18.9	25.6
Imported oil	USD/GJ	22.5	22.5
Domestic wood chips	USD/GJ	2.1	2.1
Domestic bagasse	USD/GJ	1.1	1.1
Fuelwood	USD/GJ	0.0	0.0
Molasses	USD/GJ	0.0	0.0

Import and export potential of fuels

There is no limitation on fuel imports, and fuel exports are not considered. Import of electricity is charged according to Eskom's time-of-use tariff (Figure 7.3). The electricity import price is assumed to increase by about 30 % to 80 % between 2014 and 2022 based on the Eskom projections (Figure 8.4).

FIGURE 8.4 ASSUMPTIONS ON ELECTRICITY IMPORT PRICE DEVELOPMENT



Ethanol production plans

The characteristics of current and future industrial ethanol production plants are given in Table 8.3.

TABLE 8.3 TECHNO-ECONOMIC PARAMETERS FOR INDUSTRIAL ETHANOL PLANTS

Current capacity (TJ/yr)	Start year	Main fuels	Efficiency	Overnight investment costs (USD/TJ/yr)	Fixed operation and maintenance costs (USD/TJ/yr)	Life (yr)
665	368.5 TJ/yr in 1998, and 368.5 TJ/yr in 2006	Electricity/bagasse/wood chips	88 %	35,535	355.45	20

Power generation

In the SPLAT-SW model, existing technologies and future technologies that constitute the reference energy system are modelled. Two types of future technologies are modelled, namely site-specific and generic technologies. Site-specific technologies may be characterised with project specific techno-economic parameters, while generic technologies are represented by generic techno-economic parameters.

The existing power plants that are currently in operation and modelled in the SPLAT-SW are summarised in Table 8.4. Assumptions on the site-specific planned power projects are given in Table 8.5.

TABLE 8.4 TECHNOLOGY ASSUMPTIONS FOR EXISTING POWER PLANTS

Description	Capacity (MW)	Start year	Capacity factor (%)	Main fuel
SEC existing diesel power plant	9		27	Diesel
USA Distillers coal power plant*	2.2	2011	28	Coal
SEC existing hydropower plants	40.5** 20	2001 2007	47	Hydro Hydro
USL existing hydropower plant*	1	2011	38	Hydro
USL existing biomass power plant	15.5 25	2000 2012	28	Bagasse
RSSC existing biomass power plant* (decentralised, for self-consumption only)	17 18.5 30	1989 2000 2011	27	Bagasse
Wundersight existing solar power plant	0.1	2016	–	Solar

** represents own consumption*

*** All plants refurbished between 1998 and 2001.*

TABLE 8.5 TECHNOLOGY ASSUMPTIONS FOR PLANNED POWER PROJECTS

Description	Capacity (MW)	Start year	Capacity factor	Main fuel	Overnight costs (USD/kW)
SEC Lower Maguduza power plant	13.5	2021	52	Hydro	4,500
Wundersight solar power plant	0.85	2018	–	Solar	3,000
Lavumisa	10	2019	–	Solar	1,400

The generic technology parameters used in this study are summarised in Table 8.6. Overnight investment cost assumptions as well as operation and maintenance (O&M) costs for the renewable energy technologies were assumed to decline in line with global trends.

TABLE 8.6 GENERIC TECHNOLOGY ASSUMPTIONS

Description	Start year (capacity online)	Capacity factor	Efficiency	Years	Overnight investment cost (USD/kW)	
					2014	2034
Diesel/Gasoline	–	90 %	35 %	25	650	650
Diesel/Gasoline 1 kW system (residential and commercial)	–	90 %	35 %	20	758.7	758.7
Diesel/Gasoline 1 kW system (rural)	–	90 %	16 %	10	728	728
Open-cycle gas turbine	2025	94 %	30 %	25	635	635
Combined-cycle gas turbine	2025	94 %	48 %	30	1,125	1,125
Coal	2025	90 %	33 %	35	2,812	2,812
Hydro	2026	95 %	100 %	50	4,500	4,500
Small hydro	2018	80 %	100 %	30	4,211	4,211
Biomass (wood chip)	2020	100 %	30 %	30	3,500	3,500
Bagasse (high efficiency)	2019	90 %	30 %	30	3,500	3,500
Bagasse (regular efficiency)	2022	90 %	28 %	30	3,200	3,200
Wind (zone J)	2018	33 %	100 %	25	2,458	1,200
Solar PV (zone C, utility)	2018	20 %	100 %	25	2,344	842
Rooftop PV (urban)	2017	18 %	100 %	20	2,414	1,023
Rooftop PV (rural)	2017	18 %	100 %	20	3,748	1,224
Rooftop PV (rural, two-hour battery)	2017	26 %	100 %	20	5,465	1,936
Concentrated solar power (CSP) without storage	–	18 %	100 %	25	3,000	1,556
CSP with storage	–	24 %	100 %	25	7,000	3,198

The utility-scale wind and solar plants are assumed to be built in the geographic zones identified in Chapter 6 (Table 6.5 and Table 6.6), with the maximum generation associated with each zone. Five zones each were identified for solar PV and wind, respectively. Note that the technology parameters for different zones are defined differently reflecting the local methodological conditions, and in Table 8.6, the numbers corresponding to the representative zones (zone J for wind and zone C for solar PV) are given.

Levelised cost of electricity

The levelised cost of electricity generation was calculated as below for the list of technologies analysed in the Masterplan. The LCOE for natural gas technologies increases due to the escalated gas import price. For solar and wind technologies, the reduction in investment costs and O&M costs leads to a strong reduction in the LCOE. The LCOE was calculated using the following formula:

$$\text{LCOE} = \{(\text{Overnight capital costs} \times \text{capital recovery factor} + \text{fixed O\&M cost}) / (8{,}760 \times \text{capacity factor})\} + (\text{fuel cost} \times \text{heat rate}) + \text{variable O\&M cost.}$$

TABLE 8.7 LEVELISED COST OF ELECTRICITY (USD/MWH), 2014 AND 2034

	2014	2034
Diesel/Gasoline generator	240	240
Diesel/Gasoline 1 kW system (residential and commercial)	243	243
Diesel/Gasoline 1 kW system (rural)	521	521
Open-cycle gas turbine	441	592
Combined-cycle gas turbine	254	334
Coal	57	57
Hydro	55	55
Small hydro	64	64
Biomass (wood chip)	63	63
Bagasse (high efficiency)	65	65
Bagasse (regular efficiency)	60	60
Wind (zone J)	122	59
Solar PV (zone C)	167	59
Rooftop PV (urban and commercial)	196	83
Rooftop PV (rural)	353	115
Rooftop PV (rural, two-hour battery)	336	119
CSP	243	141

Transmission and distribution of power

Transmission costs are taken into account. Distribution is assumed to incur costs specific to the demand categories. The distributed generation does not require that the power be delivered through the network.

TABLE 8.8 TECHNO-ECONOMIC PARAMETERS FOR TRANSMISSION AND DISTRIBUTION

	Transmission	Distribution		
		Industry/sugar/agriculture/ commercial	Urban	Rural
Efficiency loss	5 %	2 %	10 %	15 %
Investment cost	365 USD/kW	70 USD/kW	30 USD/kW	30 USD/kW

8.4 MODELLING OF ESWATINI ENERGY SYSTEM: KEY MODEL RESULTS

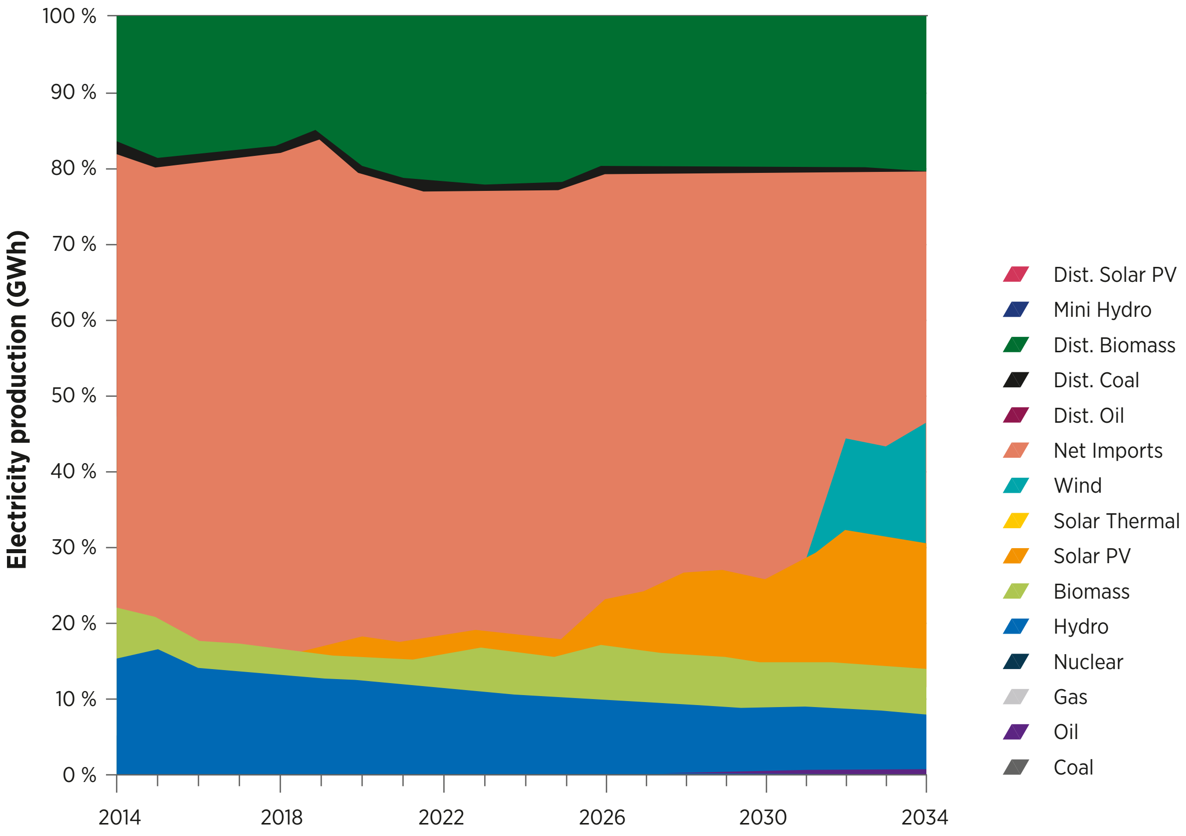
8.4.1 BASE CASE RESULTS: POWER SECTOR

The demand projections are a fundamental model input and a major driver of scenario results. As introduced, the Base Case outlines the least-cost path under business-as-usual policies. The objective is to ensure that future energy supply options meet the prospective energy demand. The abbreviation “dist.” used in the figures refers to distributed generation capacity (for own consumption), while the rest is centrally located (feeds to the national grid).

Power generation mix

The electricity supply mix for 2014–2034 under the Base Case scenario is shown in Figure 8.5. Electricity demand is projected to increase from 1,270 GWh to 2,648 GWh over the planning horizon. Currently electricity imports account for approximately 70 % of the country’s electric energy requirement. Following major investments in power generation from 2020, it is envisaged that the share of imports will fall to 65 % and further decline to 35 % by 2034. Two new sources of power generation, solar PV and wind, are projected to enter the generation mix, together accounting for one-third of total generation by 2034. There is also sizable biomass generation resulting in nearly four times the amount of centralised biomass compared to distributed biomass in 2034. The increase in distributed biomass is driven mainly by an anticipated increase in the use of biomass for power generation for own-use (not grid-connected).

FIGURE 8.5 BASE CASE: ELECTRICITY GENERATION



Generation capacity mix

Figure 8.6 shows the results of a capacity build-up programme under the Base Case. With the additional investment in centralised technologies of 585 MW and in decentralised technologies of 29 MW over the planning horizon, the total capacity (centralised and decentralised) by 2034 is expected to reach 742 MW, an over four-fold increase from the present installed capacity of 179 MW.

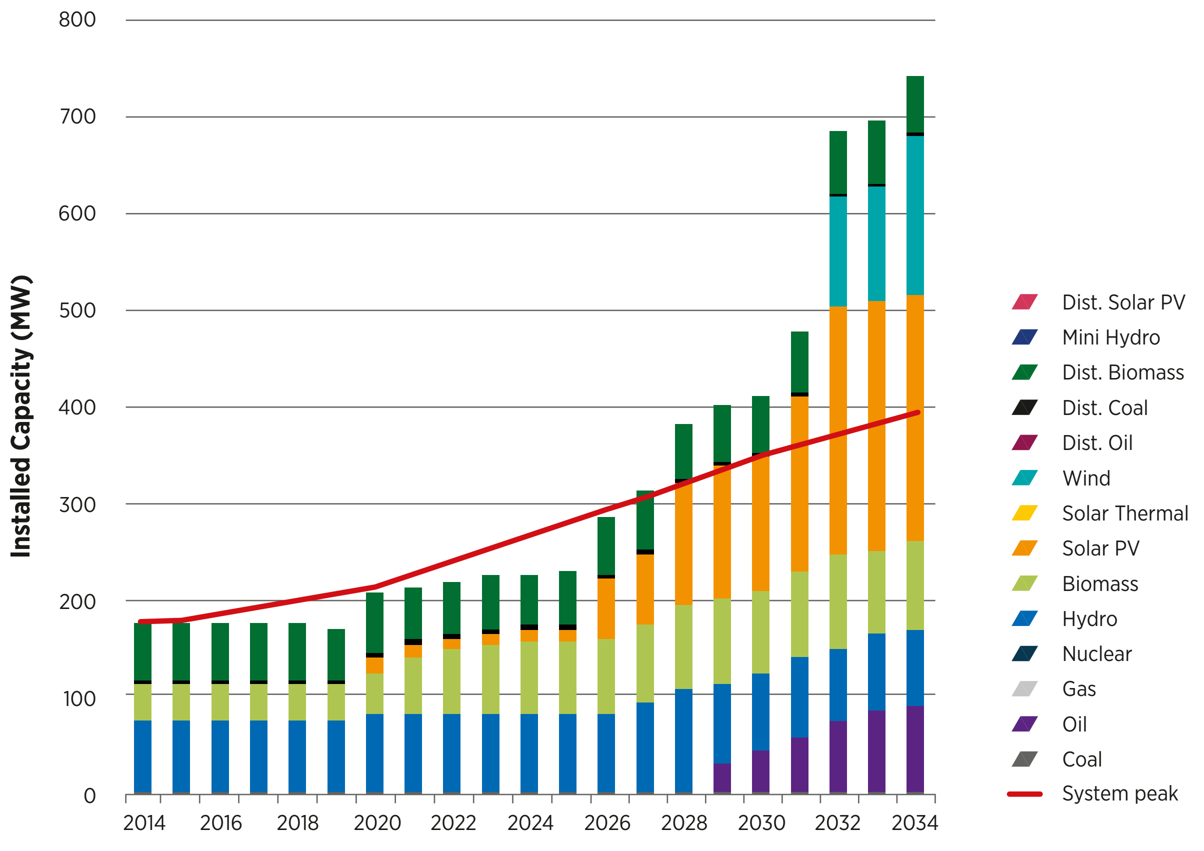
Under the Base Case assumptions, energy imports continue to dominate throughout the planning horizon. New grid-connected capacity is scheduled to be commissioned in 2020, namely 12 MW of biomass, 14 MW of hydropower and 10 MW of solar PV. Additional significant investments in solar PV and oil-based capacity commence later in the planning period, in around 2025; biomass capacity is further expanded continuously from 2020 to 2034. Significant new wind capacity is added in 2032 (121 MW) and 2034 (44 MW). A degree of reliance on imports is expected to continue because importing electricity is more economical than constructing new power plants under the Base Case, which assumes an annual increase of 5 % (in nominal terms) in the import price.

By 2034 the total centralised capacity of 681 MW is dominated by wind (165 MW) and solar PV (250 MW). The decentralised capacity of 61 MW is dominated by biomass (59 MW), with a small amount of coal (2 MW). This is mainly because biomass is the available resource in the country for co-generation; hence it is economically feasible for power generation. Wind and solar PV technologies are the most economical renewable energy sources due to the continuous cost decline in these technologies as they become increasingly competitive with conventional sources in the country around 2030. From an operator's perspective, studies will need to be undertaken to ensure that introduction of large centralised solar PV and wind plants does not compromise the integrity of the grid.

The total centralised capacity from oil amounts to 89 MW by 2034. This includes new capacity of 80 MW added between 2027 and 2034, which is triggered by the assumption that the price of imported electricity will rise later in the planning period (including already expensive peak power). However, other alternative measures including demand-side management interventions and/or imports can be utilised to reduce or eliminate the reliance on diesel generation for peaking purposes.

Eswatini is considering developing a coal-fired power plant to achieve self-sufficiency, even though coal is not a least-cost option. The price of domestic coal makes it non-competitive as compared to the price of imported electricity. However, whether domestic coal makes it into the capacity mix or not is highly sensitive to the assumptions made regarding the domestic coal price.

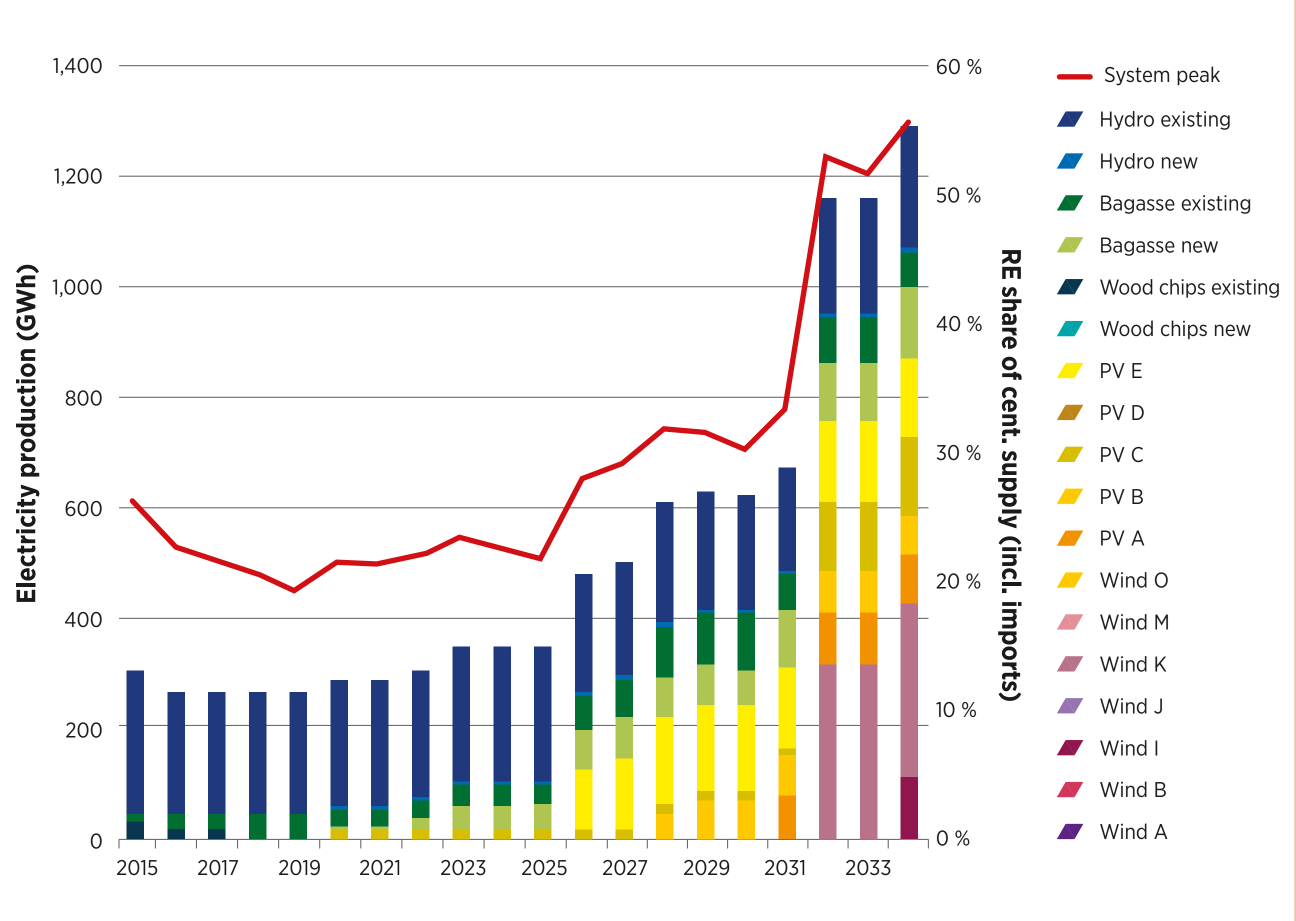
FIGURE 8.6 BASE CASE: ELECTRICITY GENERATION CAPACITY BY TYPE



Currently local power generation comprises mainly renewable energy sources (97 % of total domestic electricity production), and this remains at this high level throughout the planning period. However, when accounting for imports in the total power supply, the share of renewable electricity production in the total centralised power supply in 2014 falls to 27 %. With the projected decreasing share of imports, the share of renewables in centralised power generation is expected to increase to 55 % by 2034.

Figure 8.7 shows the breakdown of the installed renewable energy capacity for centralised generation, including specific zones for new solar PV and wind capacity to be deployed under the Base Case. For wind, seven potential zones are incorporated, and the deployment will happen mainly in zone J and a small amount in zone I. For solar PV, five zones are evaluated; zone E is deployed most, followed by zone C, zone A and zone B. Further details on the constitution and location of the zones is provided in Chapter 6. For biomass, all deployed capacity is bagasse-based generation that uses coal and wood chips as supplementary fuels. No deployment of wood chip-only generation is envisaged under the Base Case.

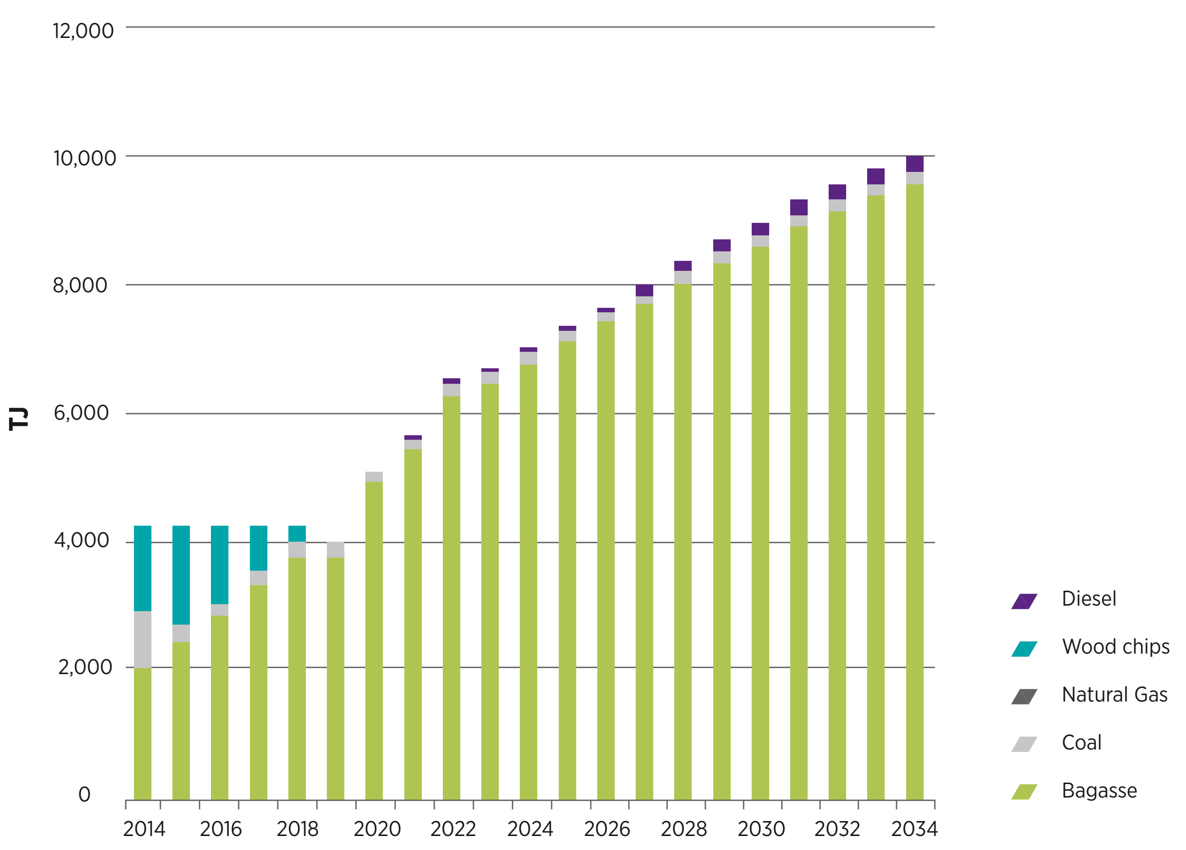
FIGURE 8.7 BASE CASE: CAPACITY EXPANSION OF RENEWABLE ENERGY



Fuel consumption for electricity generation

Bagasse and wood chips will remain the primary fuels for electricity generation. Most bagasse is replaced by wood chips after 2018. Diesel consumption is very limited and used only for peaking power. Bagasse and wood chips, and small amounts of coal, will be used for generation in the projected 101 MW of biomass power plants. Because of limited consumption of fossil fuels, the CO_2 emissions from power generation remain at a low level. In 2014 CO_2 emissions totalled 85 kilotonnes (Kt), due to relatively large use of coal as a secondary fuel in current biomass generation; emissions will fall to 39 Kt as the use of coal decreases over time.

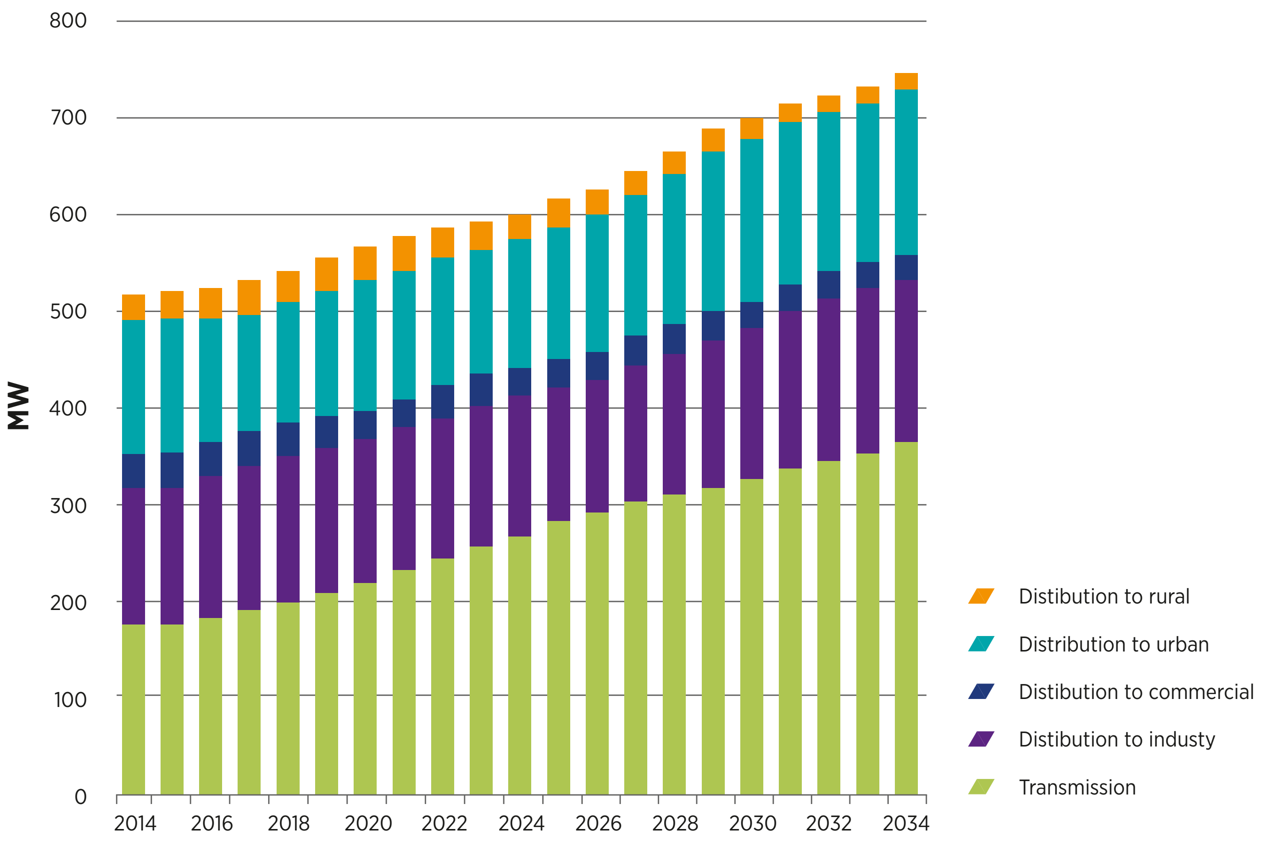
FIGURE 8.8 BASE CASE: FUEL CONSUMPTION OF ELECTRICITY PRODUCTION



Transmission and distribution needs

Figure 8.9 shows the investment needs for transmission and distribution. As the investment in centralised power plants starts to grow, the needs for investment in transmission grow accordingly. The transmission capacity, estimated at roughly 170 MW in 2014, has to more than double by 2034. Distribution to the commercial sector has to grow to around 32 MW by 2034, and distribution to the urban sector is expected to increase by about 70 %. Distribution to industry is expected to remain constant.

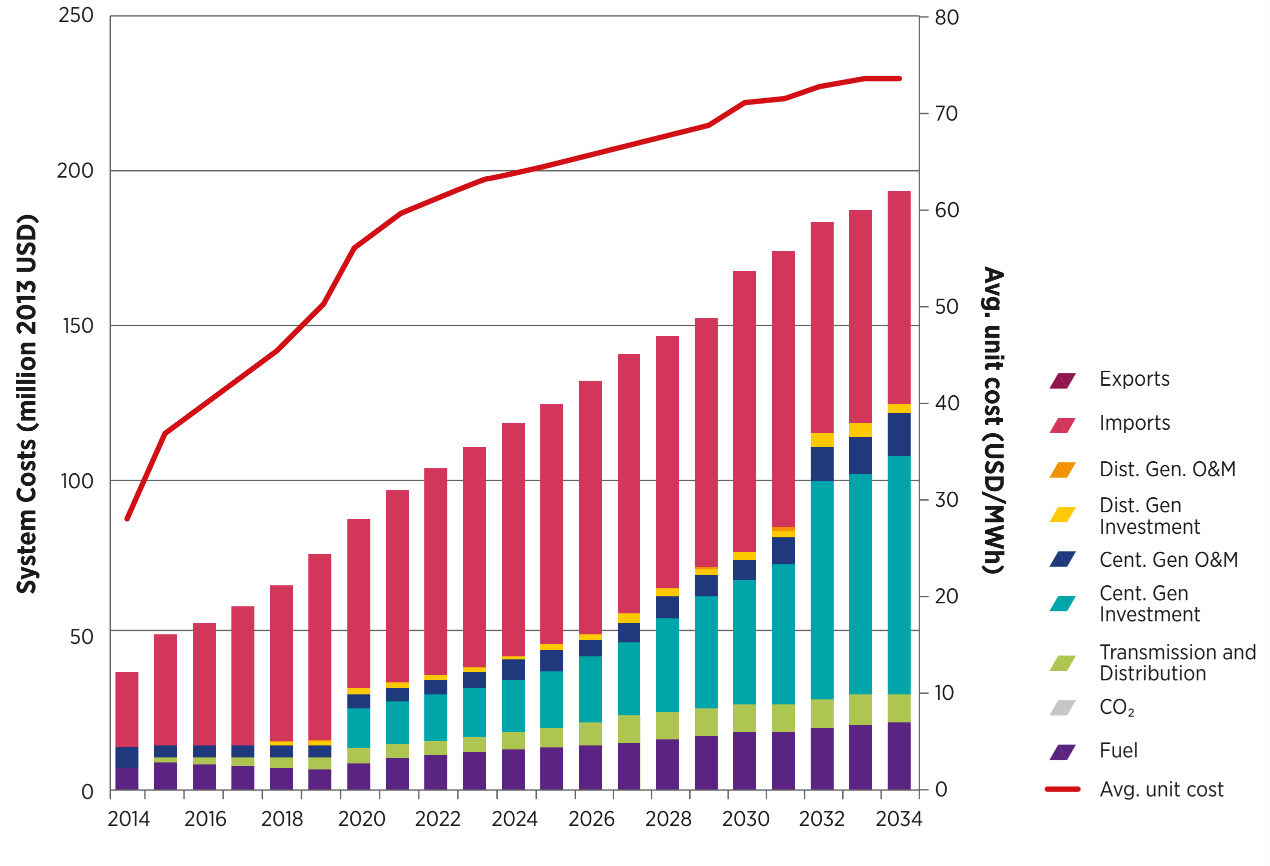
FIGURE 8.9 BASE CASE: TRANSMISSION AND DISTRIBUTION NEEDS



Total system costs

The development of the total system costs is shown in Figure 8.10. Investment costs are levelised over the life time of the plants. The need for new capacity development to achieve sufficient national electricity supply will result in a continuous increase in system costs over the years. Import costs account for the bulk of the overall system costs. This is mainly because imports are a cheaper alternative until solar PV and wind become competitive. From 2020 onwards, centralised generation investment costs will occupy a larger portion of the system costs. The fuel costs primarily for bagasse, wood chips and oil start to increase as these technologies come into the system. Overall average electricity supply costs (*i. e.*, total system costs divided by total electricity sold) increase from USD 28 per MWh in 2014 to USD 74 per MWh in 2034.

FIGURE 8.10 BASE CASE: SYSTEM COST SUMMARY



With regard to the financial implications of investment, the cumulative total investment needs over the planning horizon amount to around USD 888 million, of which 89 % is investments in centralised generation, 3 % investments in decentralised generation and 8 % investments in transmission and distribution.

8.4.2 ALTERNATIVE CASE RESULTS: POWER SECTOR

The alternative cases are policy options or “policy alternatives” for different pathways that could be pursued to achieve energy policy objectives (see Section 8.2 for existing energy policy objectives).

Forced Coal scenarios (300 MW and 600 MW)

The scenarios illustrate that large-scale coal-fired generation could be a part of the solution only when it is forced to be. Under the Forced Coal 1 scenario, a 300 MW coal capacity is committed in 2025; under the Forced Coal 2 scenario, 600 MW is committed in 2025.

The respective electricity supply mix under the two coal scenarios is shown in Figure 8.11. Under the Forced Coal 1 scenario, after 2025 the bulk of local electrical energy requirements are met through energy generated from the coal power plant, with some production from solar PV (after 2020), hydro, biomass and a small share of oil. Solar PV starts producing from 2020 at 17 GWh, which increases to 240 GWh in 2034. In the Forced Coal 1 scenario, Eswatini moves to being a net exporter from 2025 onwards. However, the introduction of the coal power plant limits the local exploitation of renewable energy resources.

FIGURE 8.11 FORCED COAL SCENARIOS: ELECTRICITY GENERATION

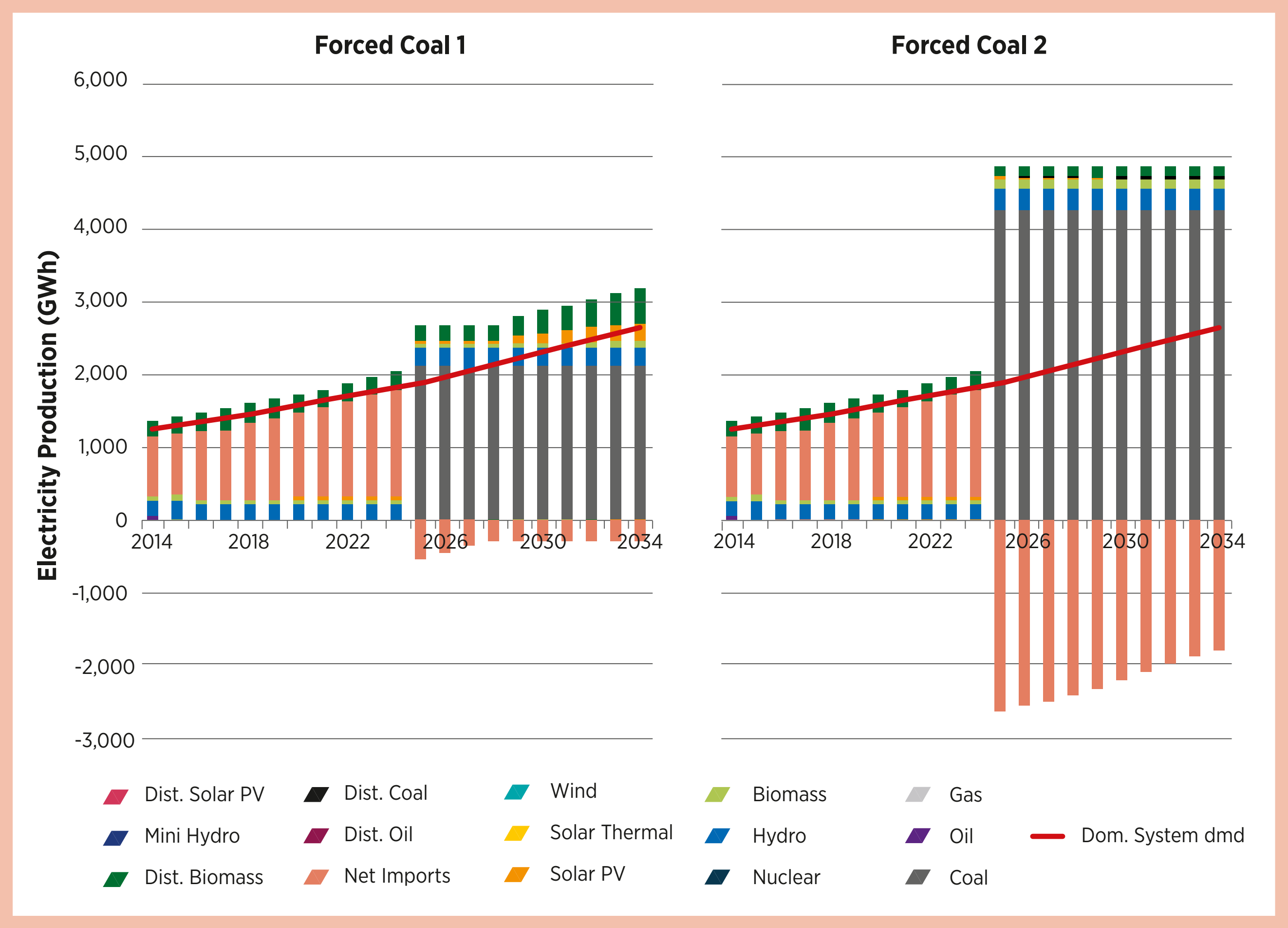
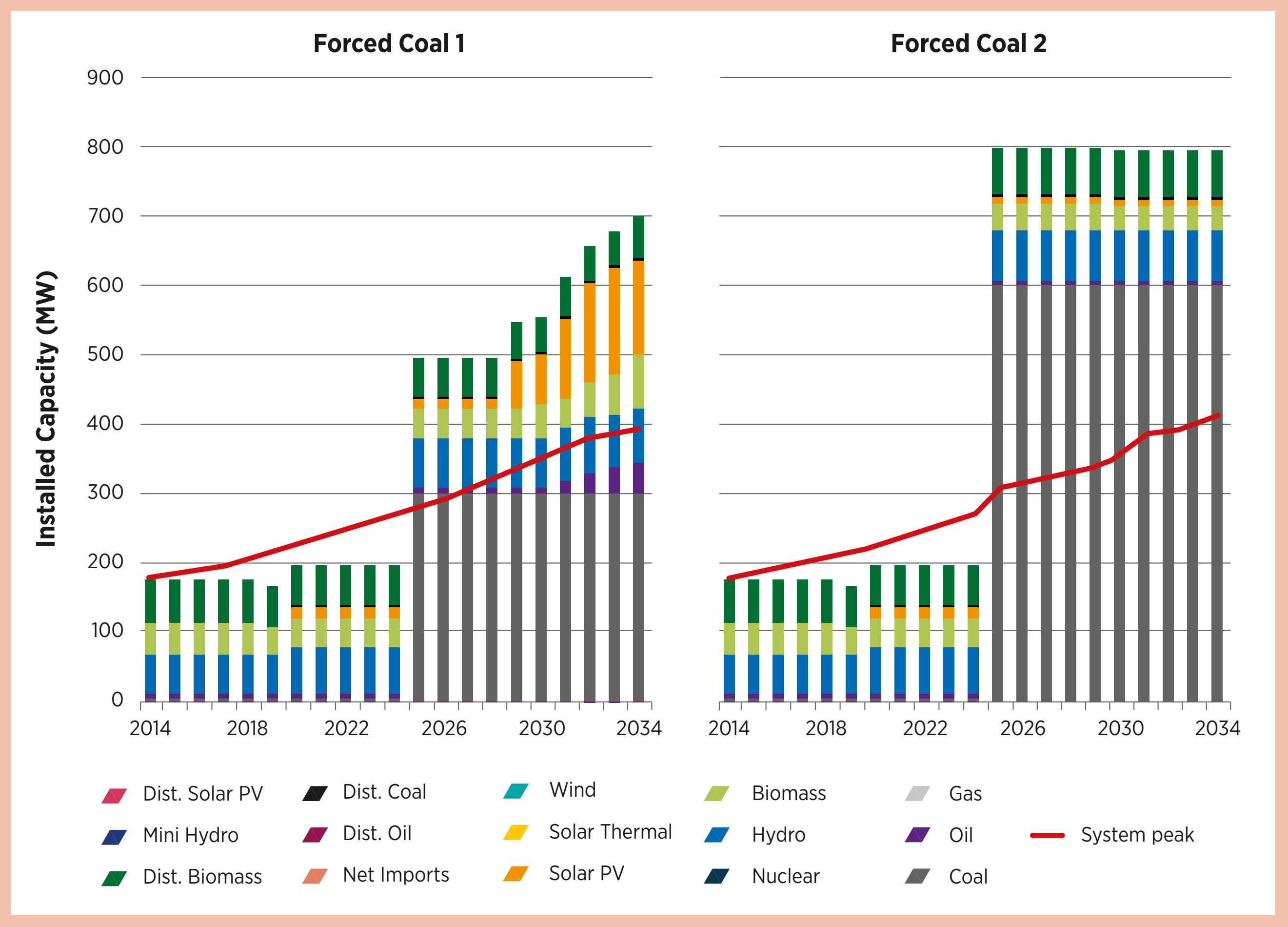


FIGURE 8.12 FORCED COAL SCENARIOS: CAPACITY MIX



As shown in Figure 8.12, both Forced Coal scenarios exhibit a similar pattern by eliminating wind power; however, the Forced Coal 2 scenario also greatly reduces solar PV. In this scenario, domestic production is increased significantly through coal capacity, which eliminates almost all other technology options and leads to higher exports. Besides coal, the energy mix is limited to the existing biomass and hydropower plants. This puts a severe limitation on the national objective of diversifying the electricity generation mix.

Apart from constraining diversification of the country's generation mix, both scenarios require significant amounts of capital investment. The overall investment requirements for the Forced Coal 1 scenario and the Forced Coal 2 scenario are USD 1,301 million and USD 1,879 million, respectively, whereas the Base Case investment amounted to USD 888 million. These high investment costs result in increased average unit costs. The average unit costs in 2034 for the Forced Coal 1 scenario is USD 73.6 per MWh, which is comparable to the Base Case. The average unit cost in 2034 for the Forced Coal 2 scenario is roughly USD 88 per MWh. Even though building the 600 MW coal power plant will make the country a net exporter, the revenues do not cover the cost of the higher capacity.

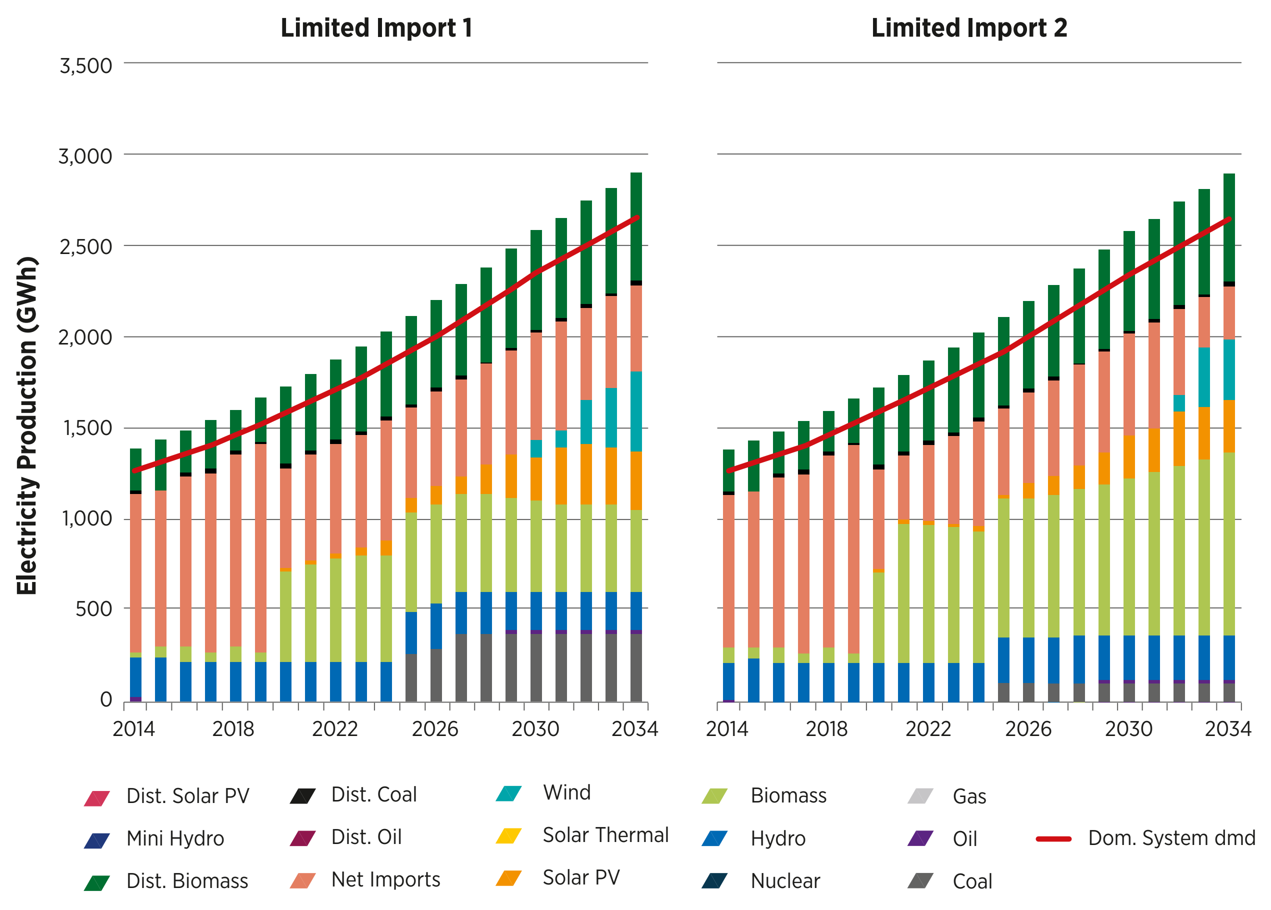
Domestic Resources scenarios (Limited Import 1, Limited Import 2 with forced hydro and Limited Import 3 without coal/with renewables only)

Improving self-sufficiency in power generation is one of the most important policy goals in Eswatini. Three scenarios were developed to explore the impacts of limiting imports from South Africa and making maximum use of domestically endowed resources, with a wide range of technology options. The first scenario (Limited Import 1) includes all of the generation options as optional (*i.e.*, not forced), while the second scenario (Limited Import 2) imposes deployment of 120 MW of hydropower plants in 2025. The third scenario (Limited Import 3) explores supply met only with renewable energy sources. Under all three scenarios, the share of imported electricity is reduced to meet up to 35 % of total domestic electricity demand by 2025, and 25 % by 2030.

In contrast to the Base Case, under the Limited Import 1 scenario coal generation enters into the solution, contributing about 14 % of total generation by 2034. This is a result of the commissioning of 36 MW of coal generation in 2025 and an additional 9 MW in 2026 and 8 MW in 2027 under Limited Import 1. Before the coal power plant is installed, biomass-based generation is increased significantly from 2020, adding 105 MW of capacity in the first half of the 2020s. Additional solar PV starts to get introduced in 2020, and by 2034 it contributes about 12 % of the country's electricity needs. Wind power starts producing from 2030 with 91 GWh and increases to over 440 GWh by 2034. By 2034 the generation mix has diversified with import needs reduced by 36 % over the planning horizon, from 858 GWh in 2014, to a peak of 1,129 GWh in 2019, to 513 GWh in 2034.

Under the second scenario, Limited Import 2, imports are limited and the deployment of 120 MW of hydropower is forced; this reduces coal to 15 MW in 2025, as the 120 MW of hydro added in 2025 together with other renewable options are sufficient to meet the self-sufficiency target. By 2034 the generation mix is well diversified with hydro, biomass, solar PV and wind generation, thus reducing imports by over 50 %, to 315 GWh, over the planning horizon (Figure 8.13).

FIGURE 8.13 LIMITED IMPORT 1 AND 2 SCENARIOS: ELECTRICITY GENERATION



Compared with the Base Case, where solar PV and wind account for as much as 60 % of the total installed capacity in 2034, the capacity mix under both Domestic Resources scenarios is more diverse, as shown in Figure 8.14. The share of solar PV and wind in the 2034 capacity mix is 46 % under the Limited Import 1 scenario and 44 % under the Limited Import 2 scenario with hydro. In 2034 installed capacity for wind is 165 MW under both Domestic Resources scenarios, as well as under the Base Case. Solar PV installation varies, from 182 MW by 2034 under the Limited Import 1 scenario to 167 MW by 2034 under the Limited Import 2 scenario with hydro. Under the Limited Import 1 scenario, a larger share of oil and coal installed capacity is deployed to meet the peak, whereas under the Limited Import 2 scenario with hydro, the peak demand is met sufficiently with hydropower, and thus no investment is needed in the oil installed capacity.

FIGURE 8.14 LIMITED IMPORT 1 AND 2 SCENARIOS: CAPACITY MIX

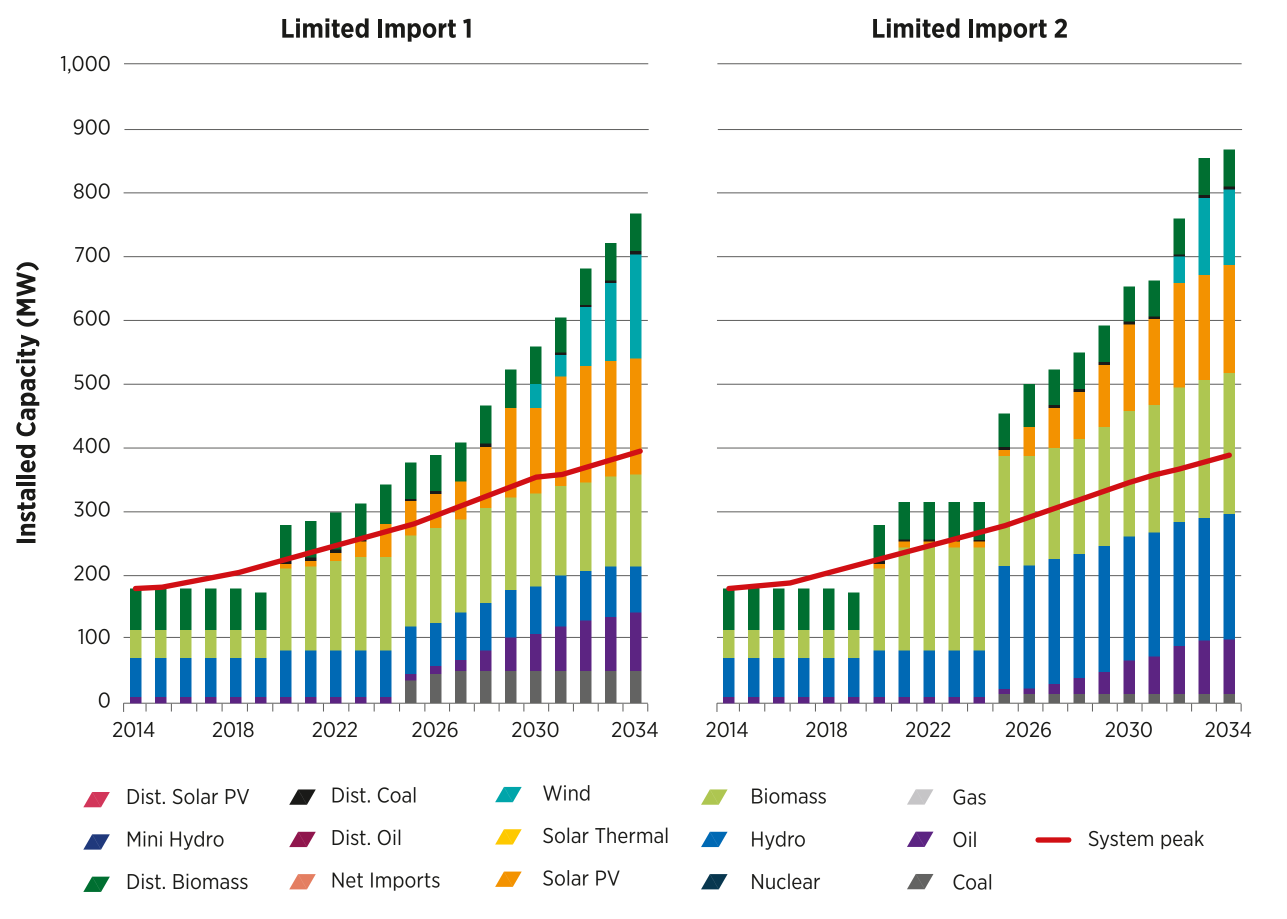
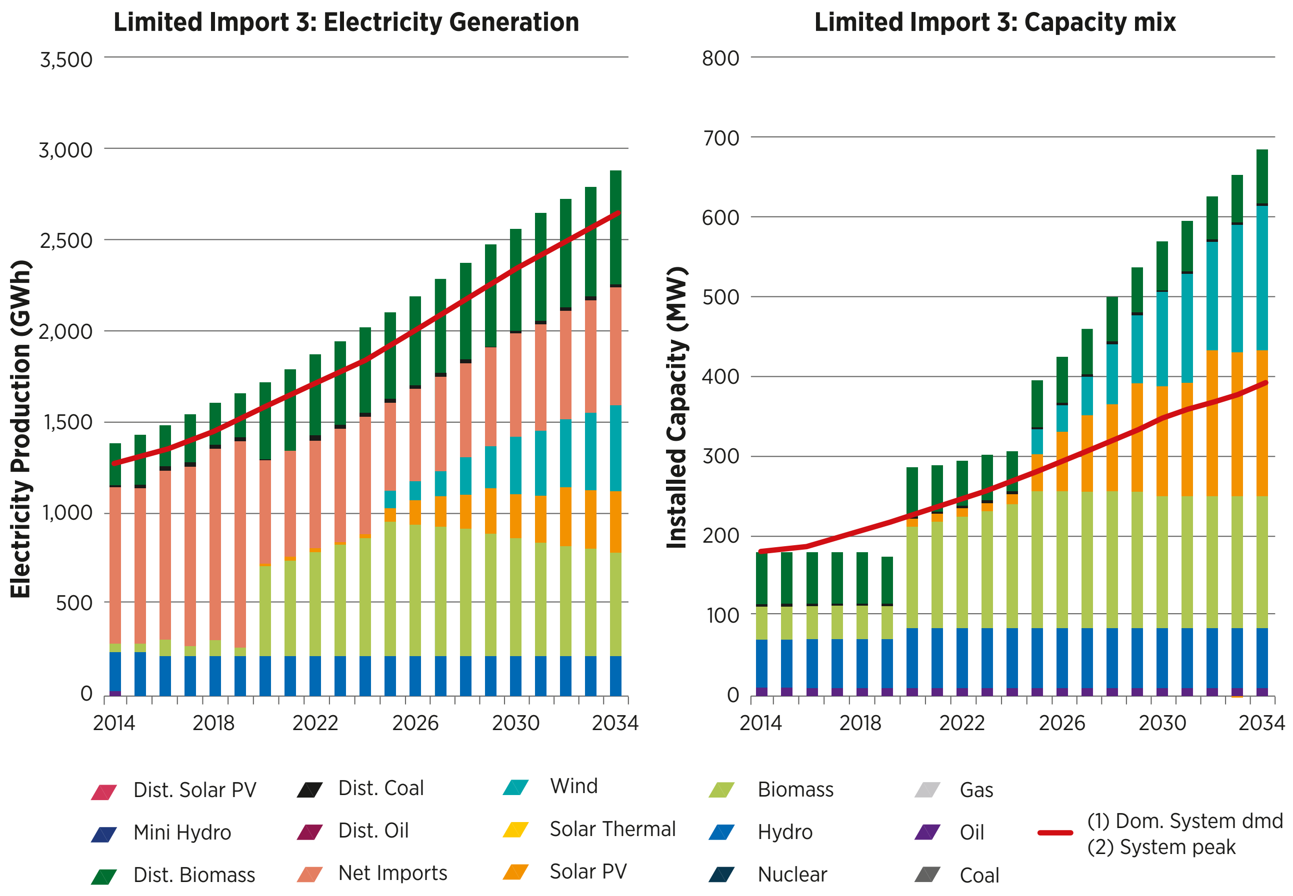


Figure 8.15 shows the results of the Limited Import 3 scenario, where only renewables are allowed to be introduced and the entry of coal- and oil-fired generation is limited. This scenario depicts a 100 % renewable path. In this scenario, in place of coal, wind is introduced in an earlier year (2025) compared with the Limited Import 1 scenario (wind introduced in 2030). Wind power and solar PV are introduced at about the same amount, reaching a capacity of around 180 MW each.

FIGURE 8.15 LIMITED IMPORT 3 SCENARIO: ELECTRICITY GENERATION AND CAPACITY MIX



The financial implication for the three Domestic Resources scenarios is that they require substantially higher investment compared with the Base Case. While the Base Case requires USD 888 million, the Limited Import 1 scenario and the Limited Import 2 scenario would require USD 1,113 million and 1,731 million of investment, respectively. The average supply costs in the Limited Import 1 scenario are similar to the Base Case, at around USD 74 per MWh by 2034. However, under the Limited Import 2 scenario, the average supply costs are higher, at around USD 90 per MWh by 2034. Under the Limited Import 3 scenario, the investment requirement is USD 1 027 million and average unit costs around 76.88 per MWh by 2034.

No Import Enhancement scenarios (High Demand with no import enhancement, Base Case with no import enhancement)

The “No Import Enhancement” scenarios assume that the import capacity is not expanded. Under the High Demand with no import enhancement scenario, electricity demand in the mining sector is expected to increase in the planning horizon, resulting in challenges in meeting the country’s electricity demand. This scenario depicts a pathway for how electricity demand can be met even as electricity imports are assumed to not exceed the 185 MW capacity limit outlined in the current bilateral agreement with South Africa. The Base Case scenario was run with a 185 MW capacity limit on imports, as a point for comparison. Figure 8.16 shows the resulting supply mix under both scenarios. As can be seen, the additional restriction on no import enhancement has little impact on the Base Case results.

Under the High Demand scenario, demand will reach 3,399 GWh by 2034, compared with 2,648 GWh under the Base Case. The increased demand will be met with coal-based generation of 160 GWh in 2025, rising to 785 GWh in 2034. Imports are stretched to the maximum degree. Coal-fired power plants come into play gradually from 2025 with 22 MW capacity, which increases to an overall capacity of 111 MW by 2034. Solar PV capacity increases by 289 MW, biomass capacity by 76 MW and hydro capacity by 14 MW.

FIGURE 8.16 NO IMPORT ENHANCEMENT SCENARIOS: ELECTRICITY GENERATION

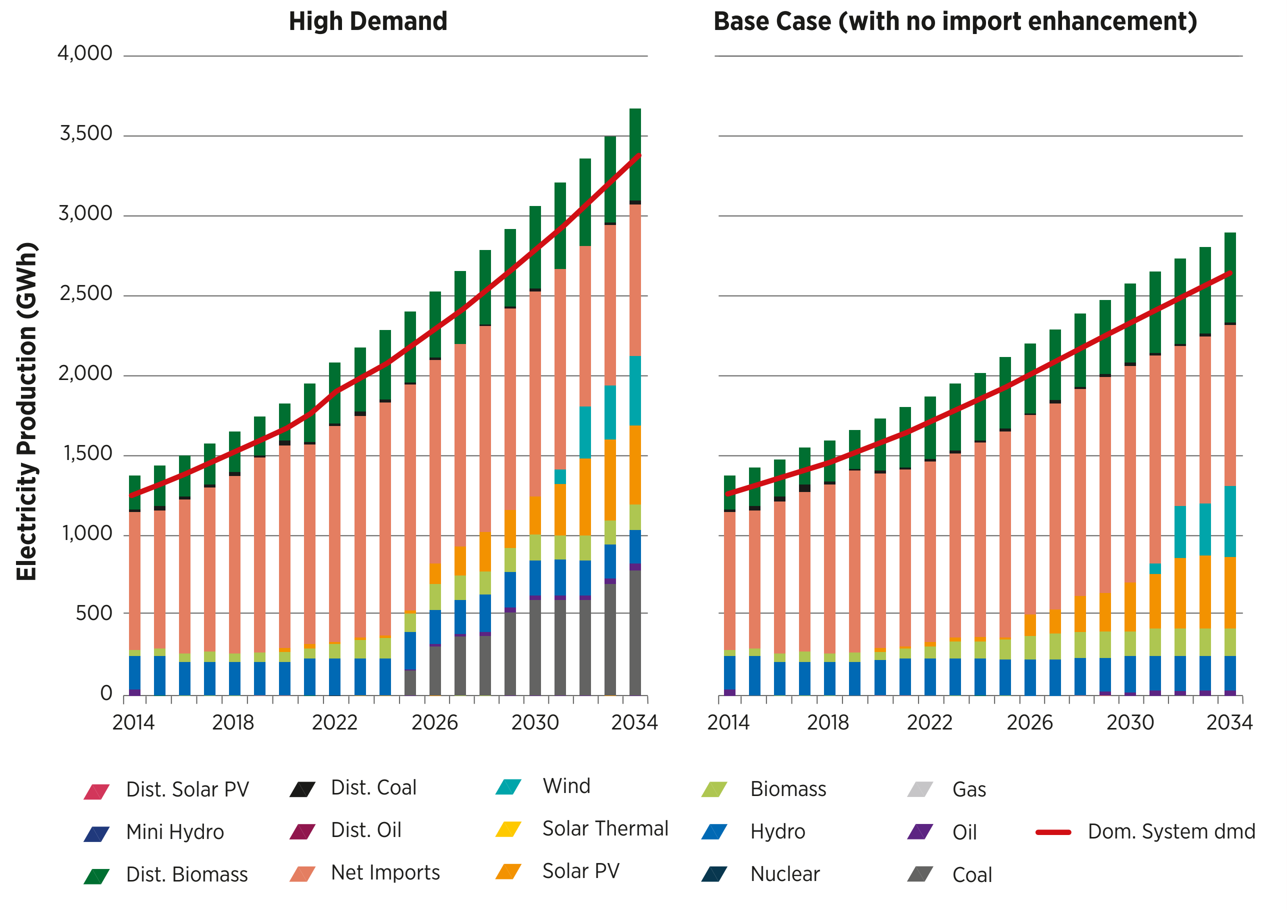
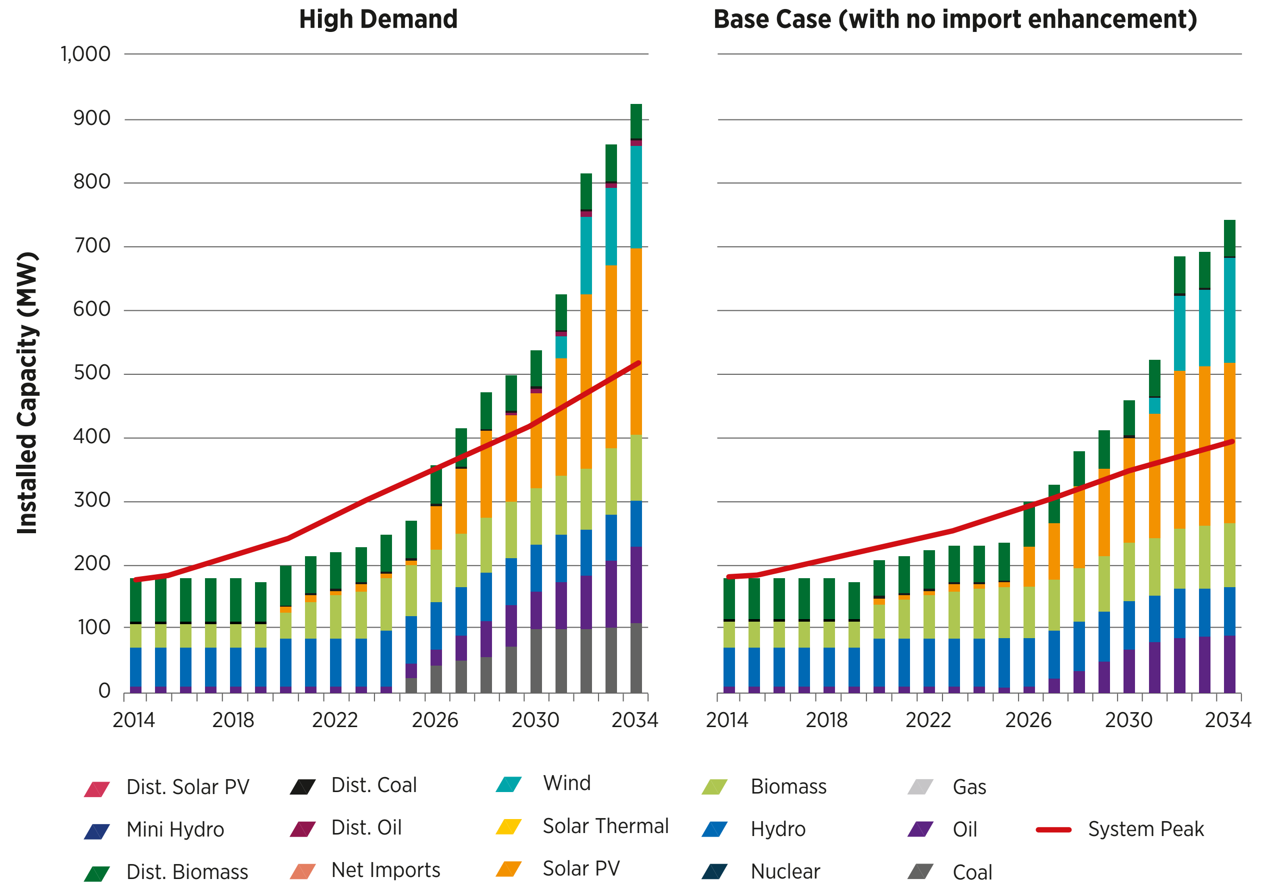


Figure 8.17 illustrates that in order to meet the high demand, 927 MW of installed capacity (centralised and decentralised) by 2034 is needed, compared with 742 MW under the Base Case. This would require additional investment in new capacity of 799 MW between 2014 and 2034, of which 71 % comes from renewable energy technologies. This includes 289 MW of solar PV, 165 MW of wind, 76 MW of biomass and 14 MW of hydro.

FIGURE 8.17 NO IMPORT ENHANCEMENT SCENARIOS: CAPACITY MIX



To achieve this scenario, a cumulative investment total of USD 1,310 million is required in the planning horizon, as compared to USD 888 million required in the Base Case.

Low Import Price scenario

Under this scenario, there is no limit on imports of electricity. The scenario assumes a low import tariff, with no general cost escalation and an annual import tariff increase of 3 %. As a result, the price of imported electricity is expected to be low over the planning horizon (USD 57.1 per MWh by 2034), and imports will dominate the supply of electricity (89 % of total demand by 2034, equivalent to around 2,361 GWh). The average generation cost per unit of electricity is around SZL 0.9 per kWh (USD 64 per MWh) by 2034. The scenario represents a pathway with relatively low electricity costs but a high degree of dependency on imports.

Figure 8.18 shows the resulting supply mix under the scenario. The domestic system demand is expected to be 2,648 GWh by 2034, similar to that under the Base Case. The mix of domestic generation in centralised generation in 2034 consists of hydro (222 GWh), biomass (52 GWh), solar PV (42 GWh) and a very minor share of oil. In addition, domestic supplies come from distributed biomass and distributed coal.

FIGURE 8.18 LOW IMPORT PRICE SCENARIO: ELECTRICITY GENERATION

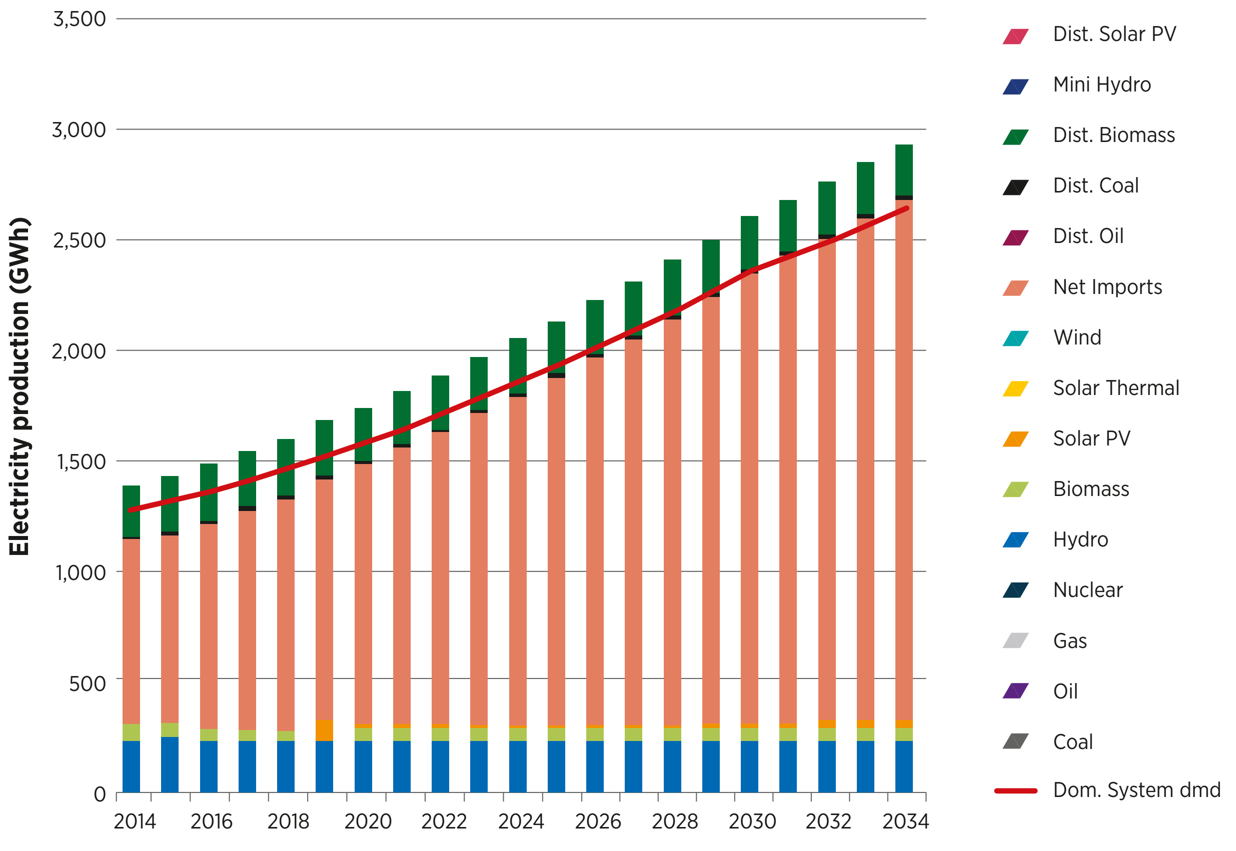
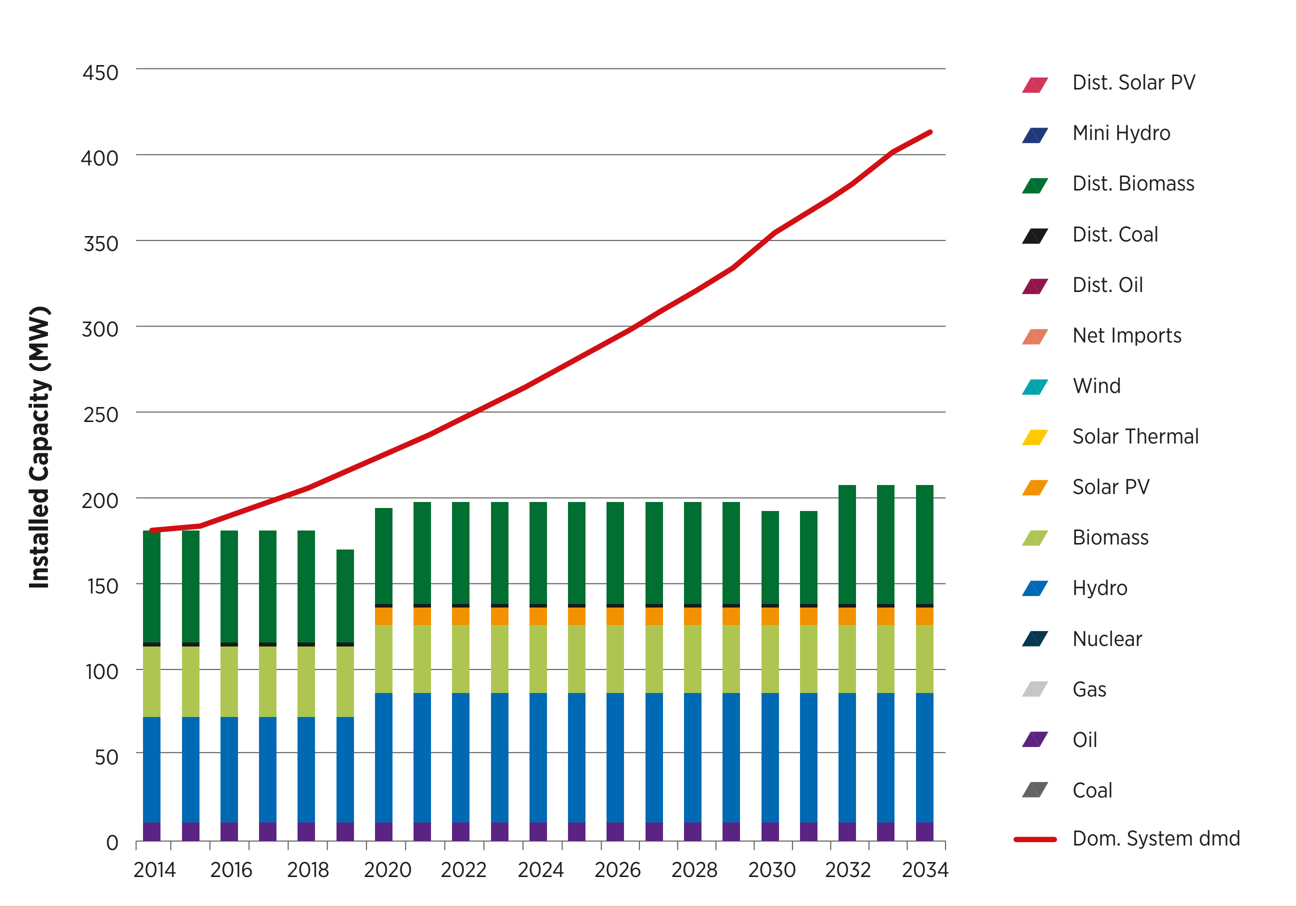


Figure 8.19 shows the capacity mix under the Low Import Price scenario. The only domestic capacity additions in the planning period are new capacities of 14 MW of hydro in 2020, 11 MW of biomass in 2030, 10 MW of solar PV in 2020 and 14 MW of solar PV in 2032, and overall new capacity in distributed biomass of 29 MW.

To achieve this scenario a cumulative investment total of USD 204 million is required in the planning horizon, as compared to the USD 888 million required in the Base Case. A large share (37 %) of the investment is required for enhancing domestic transmission and distribution.

FIGURE 8.19 LOW IMPORT PRICE SCENARIO: CAPACITY MIX

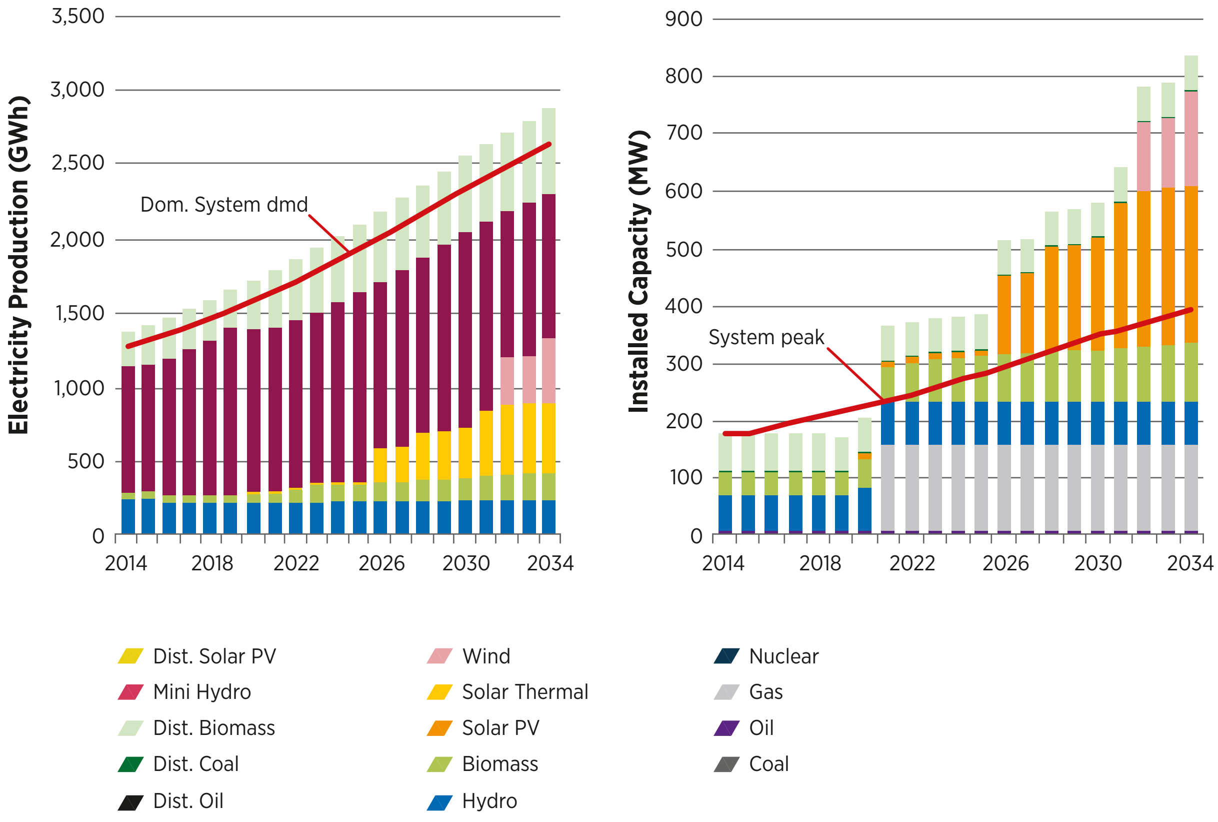


Natural Gas scenario

No natural gas options feature in the Base Case or in any of the alternative scenarios. In the Natural Gas scenario, these plants only feature where gas is explicitly enforced. As shown in Figure 8.20, 150 MW of gas power plants is forced to be installed in 2021, but the electricity supply mix shows that no electricity is generated from this capacity; hence this plant can be used as reserve capacity.

The generation mix under the Natural Gas scenario is almost identical to that under the Base Case, with the difference of using gas instead of oil as a peaking plant. The non-competitiveness of gas-based generation is due to the fact that natural gas combustion turbines are more expensive to operate than other types of power plants, in particular hydropower plants, and are also costlier than imports. Furthermore, the natural gas will be imported, and the infrastructure needs are capital intensive. In this scenario, generation from solar PV is expected to increase from 17 GWh in 2020 to 476 GWh in 2034, and wind is introduced in 2032, similar to under the Base Case.

FIGURE 8.20 NATURAL GAS SCENARIO: ELECTRICITY SUPPLY MIX AND CAPACITY MIX



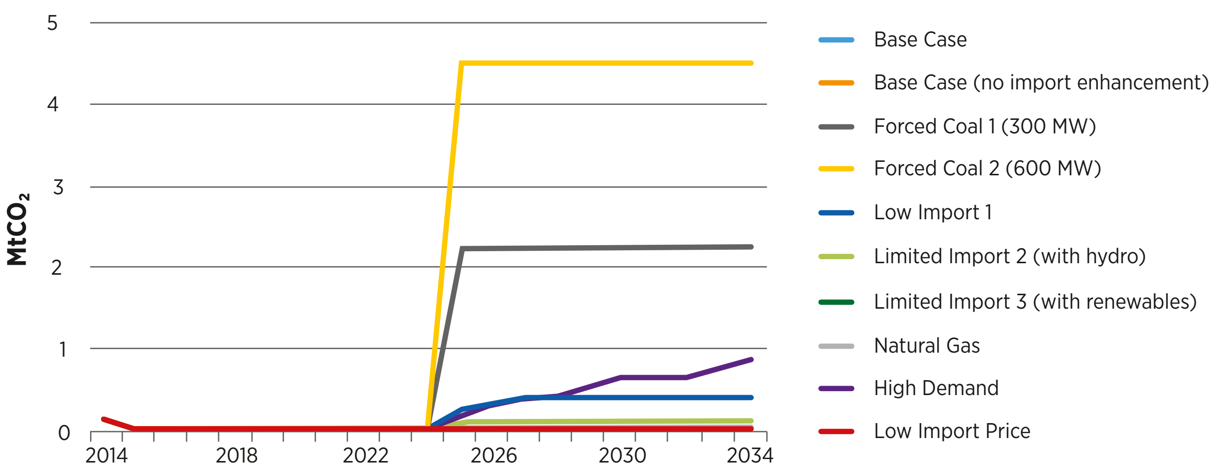
In terms of financial implications, the investment cost requirement under the Natural Gas scenario is about USD 960 million, which is more than the Base Case scenario. The average supply cost is slightly higher than in the Base Case due to additional investment in gas that is not fully made use of.

8.4.3 COMPARATIVE ASSESSMENT OF SCENARIOS: POWER SECTOR

Carbon dioxide emissions

Across the scenarios, the annual CO_2 emissions from the power sector remain negligible until 2024. The amount of CO_2 emissions from the power sector corresponds directly to the penetration of coal-fired power plants in each scenario. Under the Forced Coal 2 scenario, the emissions increase to 4.5 metric tonnes after 2024, and under the Forced Coal 1 scenario they remain at 2.2 metric tonnes; in the remainder of the scenarios emissions remain below 1 metric tonne. Figure 8.21 shows a comparison of CO_2 emissions for all scenarios from 2014 to 2034.

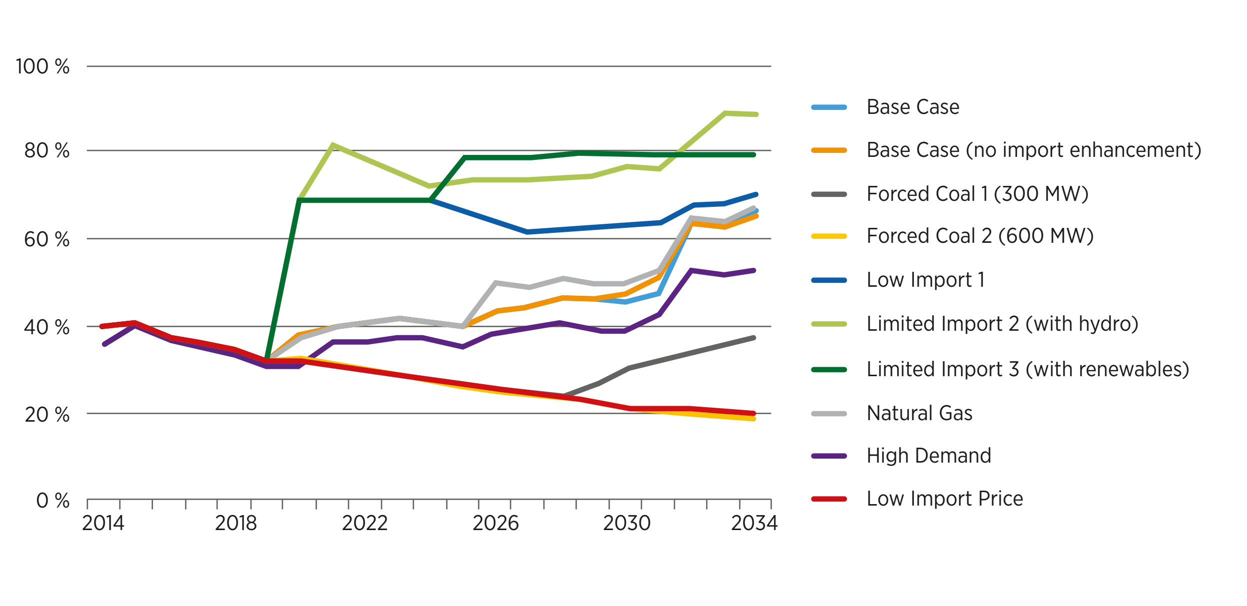
FIGURE 8.21 CUMULATIVE CARBON DIOXIDE LEVELS FROM 2014 TO 2034 FOR ALL SCENARIOS



Share of renewable energy in total demand

Figure 8.22 shows the share of renewable energy in total energy demand for all scenarios. In the Base Case the share grows from 44 % in 2014 to 66 % by 2034. In the Forced Coal 2 (19 %), Low Import Price (20 %) and Forced Coal 1 (37 %) scenarios the share of renewable energy is declining over the planning period. In all other scenarios, the share of renewable energy is increasing between 2014 and 2034, either moderately, as is in the case of the High Demand (53 %), Base Case with no import enhancement (66 %) and Natural Gas (67 %) scenarios, or more significantly, as in the Limited Import 1 (71 %) and Limited Import 2 (89 %) scenarios. The Limited Import 3 scenario depicts a pathway where 100 % of domestic electricity generation is met by renewables, although the overall share of renewables in total demand is limited to 80 % since 20 % of domestic demand is met by imports. The increased share of renewable energy can bring considerable economic benefits, mainly through reduced reliance on and spending for fossil-based fuels.

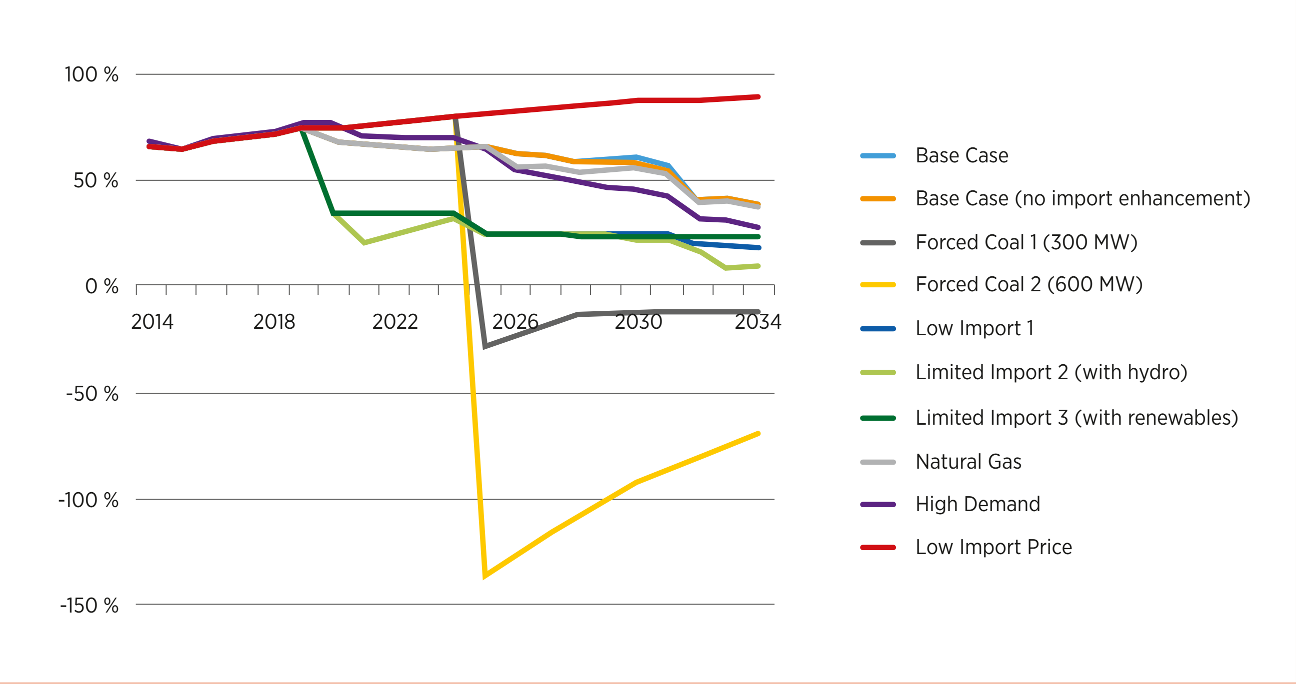
FIGURE 8.22 COMPARATIVE SHARE OF RENEWABLE ENERGY FOR ALL SCENARIOS



Import dependency

Electricity trade is crucial to harness the rich mix of energy resources in the country, while excessive reliance on imports hampers energy security. The scenarios were developed using different assumptions about trade. Across all scenarios, imports are crucial for the country until 2019, where they remain above 50 % of total electricity production. Apart from the Low Import Price scenario, which results in 90 % import dependency by 2034, the share of imports gradually decreases throughout the planning horizon, to below 50 % from 2019 onwards, while in the Forced Coal scenarios the excess electricity supply poses opportunities for exports from 2025 (Figure 8.23).

FIGURE 8.23 SHARE OF IMPORT ELECTRICITY IN TOTAL ELECTRICITY PRODUCTION FOR ALL SCENARIOS

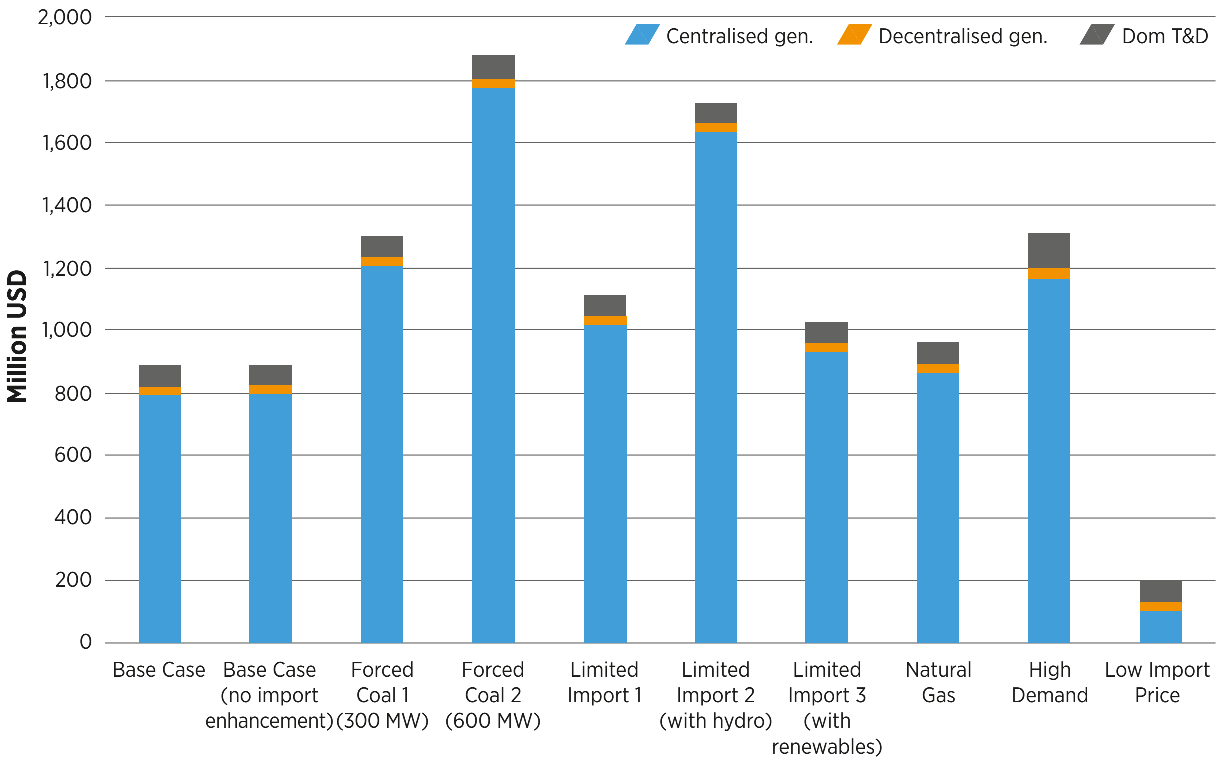


Investment requirements

Figure 8.24 shows the total cumulative investment costs between 2014 and 2034 in each scenario, and their breakdown into investments related to centralised systems, decentralised systems, and transmission and distribution. Total investment needs for the Forced Coal 2 (600 MW) scenario (USD 1,880 million) and the Limited Import 2 scenario (USD 1,713 million) are the highest among all scenarios at around, about twice the investment needs of the Base Case scenario (USD 888 million).

Investments under the Forced Coal 1 (300 MW) scenario (USD 1 301 million) and the High Demand with no import enhancement scenario (USD 1,310 million), as well as those under the Limited Import 1 scenario (USD 1,113 million), Limited Import 3 scenario (USD 1,027 million) and Natural Gas scenario (USD 960 million) constitute the middle ground. The Low Import Price scenario requires the least amount of investment at around USD 204 million, as it requires limited investment in building domestic generation infrastructure.

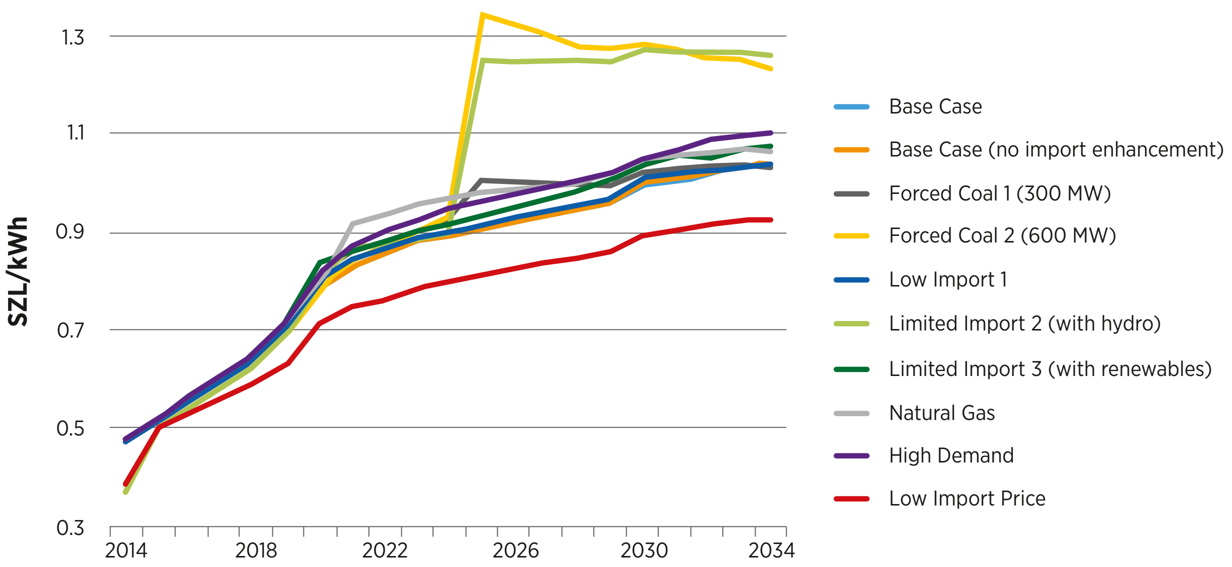
FIGURE 8.24 UNDISCOUNTED CUMULATIVE LUMP-SUM INVESTMENT COSTS BY TYPE OVER THE PERIOD 2014 TO 2034



Average generation costs

Figure 8.25 compares the average generation costs per kilowatt-hour across all scenarios. The unit cost increases gradually over the time horizon for all of the scenarios, with the exception of the Forced Coal 2 (600 MW) scenario and the Limited Import 2 with hydro scenario, where the costs increase drastically in 2025 and then decline slowly thereafter. The costs remain below SZL 1.00 per kWh (USD 71 per MWh) until around 2029.

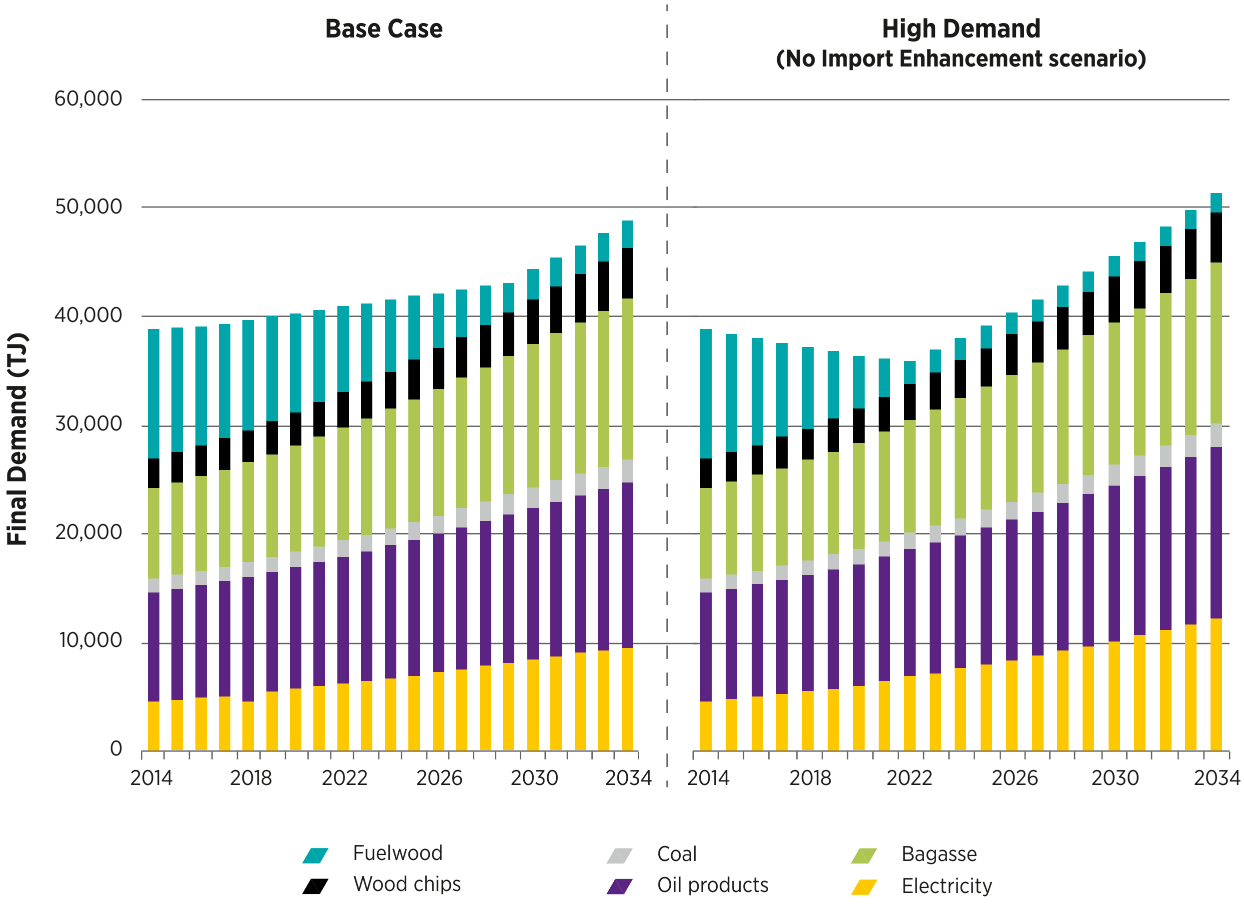
FIGURE 8.25 AVERAGE GENERATION COSTS FOR ALL SCENARIOS



8.4.4 PRIMARY ENERGY REQUIREMENT

Figure 8.26 shows the primary energy requirements for all scenarios. 9 out of the 10 scenarios assume the demand as under the Base Case, featuring a growth in primary energy requirement from 39.4 PJ in 2014 to 48.4 PJ in 2034. Growth is particularly strong in electricity requirement (more than doubles, from 4.6 PJ to 9.5 PJ). Demand for oil products (14.1 PJ by 2034) and coal (2.6 PJ by 2034) increase moderately. Demand for wood based supply reduces from 14.5 PJ in 2014 to 6.4 PJ in 2034, whereas bagasse requirement follows an opposite trend, growing from 8.4 PJ in 2014 to 14.8 PJ in 2034. The High Demand with no import enhancement scenario overall assumes a higher primary energy requirement. The primary energy requirement first reduces until 2022, due to the constraints of the scenario, but then gradually grows for the remainder of the planning period. The difference in requirement between the two cases stems from electricity requirement, which grows to 12.2 PJ in 2034 under the High Demand scenario.

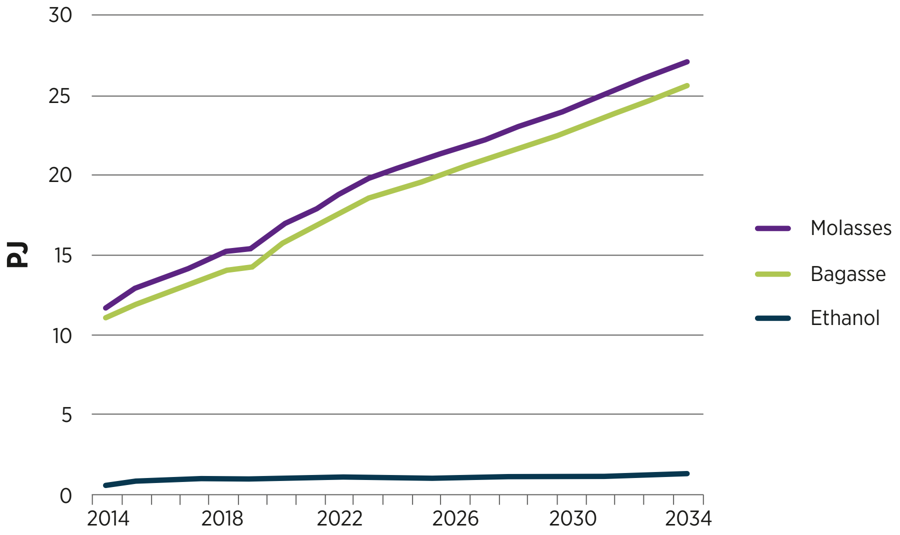
FIGURE 8.26 PRIMARY ENERGY REQUIREMENTS FOR ALL SCENARIOS



Implications for the sugarcane sector

Bagasse is the most viable biomass fuel for power generation, and is used together with wood chips for co-generation. To produce the additional 76 MW from biomass by 2034 in the Base Case there is a need to expand the domestic sugar sector as well as the timber industry for wood chip production. This would require additional ambition on top of the announcements by sugar companies to increase their power generation capacity from 106 MW to 160 MW during the planning horizon (see Section 6.1). Ethanol production would increase to meet the blending ratio of 10 % ethanol (E10) in unleaded petrol (see Section 7.3); the current production is not sufficient to achieve this blending ratio. Figure 8.27 shows the primary requirements of bagasse, molasses and ethanol throughout the planning horizon.

FIGURE 8.27 PRIMARY REQUIREMENTS FOR ETHANOL, MOLASSES AND BAGASSE PRODUCTION



9 VISION FOR 2034

The energy landscape in 2034 will be fundamentally different from that of today. Given the long lifespan of energy infrastructure, proper investment decisions made today can enhance the energy supply system for decades, and wrong decisions now can adversely affect the energy system for decades. For this reason, today's energy policy will decisively determine the future, by setting out clear pathways to improve the role of energy in the economic development of Eswatini. Long-term planning is crucial to support cost-effective development of energy infrastructure, including integrating larger shares of renewable energy into the generation mix.

This document provides a forward-looking plan to inform the direction of national energy policy. It provides a detailed evaluation of trends in the energy supply and demand of the country, drivers and resource prospects for various energy sources, costs and benefits related to the deployment of renewable energy technologies, and implications of pursuing different pathways for policy and investment decision making.

The analysis presented in this Masterplan was presented to stakeholders, and the concrete quantitative assessment of different pathway options outlined in the plan proved to be an effective basis for discussing the future of the national energy system. The process of developing this Masterplan highlighted the importance of defining an integrated and comprehensive long-term vision to guide effective policy making for a sustainable energy future.

9.1 KEY INSIGHTS FROM THE SCENARIO ANALYSIS

At the outset of this Masterplan, the key long-term goal of energy sector development was defined as achieving a well-diversified energy mix that will 1) provide sufficient energy supply; 2) provide access to clean energy technologies; 3) foster industrialisation; and 4) ensure security of energy supply. The following sections assess results from the scenarios analysed in this Masterplan in light of national policy goals.

Provision of sufficient energy supply

Part II of this report provides an assessment of the long-term energy needs to meet the growth ambition of the country as stipulated in the National Development Strategy. This includes an assessment of trends in demographic changes as well as in overall economic growth. According to the assessment the population of Eswatini is expected to increase slightly in the planning time horizon (2014–2034); economic growth increases modestly at an annual average rate of 1.8 %–3 % (2014 to 2020) to 3 % (2020 to 2034) under the business-as-usual trajectory. Under all scenarios, 100 % electrification is assumed to be achieved within the planning time horizon. Various goals under the SE4ALL initiative – such as the promotion of alternative modern fuels for cooking by replacement of wood; solar water heating; and energy efficiency improvements including increased use of efficient lighting – are also taken into account.

While the demand for wood-based supply is expected to be reduced significantly, demand for oil products and electricity are expected to grow under the Reference scenario for economic growth, from 9.4 TJ to 14.1 TJ for oil, and from 4.6 TJ to 9.5 TJ for electricity. Under the High Growth scenario (1.8 % to 3 % GDP growth per year until 2020, and over 3 % growth after 2020) the demand for oil is expected to reach 14.7 TJ and the demand for electricity is expected to reach 12.2 TJ, while under the Low Growth scenario (0.9 % to 1.8 % GDP growth until 2020 and 1.8 % growth thereafter until 2034), they reach 12.0 TJ and 8.2 TJ, respectively. In all three economic growth scenarios, demand for wood-based fuel is reduced from the current level of 11.9 TJ to 1.6 TJ.

To accommodate the modernisation of the energy supply though implementation of energy efficiency measures, a major shift in the use of energy-saving devices, such as solar water heaters and LED lighting, is required – supported by a clear government policy to such efforts. At the same time, the energy supply structure in Eswatini needs to expand; oil imports are expected to grow by 30 % to 60 % within the planning horizon (depending on the scenarios), while electricity production needs to grow by 90 % to 180 %.

With regard to power sector development, for adequate expansion of the system the total system cost of providing electricity is expected to increase about four- to five-fold, from the current level of around USD 40 million per year to the range of USD 175 million to USD 200 million by 2034. The increase in investments will be driven primarily by the need to develop domestic power generation infrastructure with the objective of gradually reducing dependency on imports. The development of generation infrastructure must be complemented by investments in transmission and distribution necessary to wheel energy to load centres and to support the transmission and distribution network, including to enable the system to integrate higher shares of renewable energy supplies.

Fostering industrialisation

The Government of the Kingdom of Eswatini acknowledges energy as one of the key drivers for economic development. Achievement of the country's macroeconomic development goals depends on clear, measurable and practical policy directions and actions for energy in the short, medium and long terms. The systematic uncertainty about the long-term supply or "just enough power" situations with high degree of uncertainty hampers the industrial investment appetite. This Masterplan is expected to be the primary point of reference in policy formulation, providing the foundation for clear policy goals.

Currently energy supply relies on imports from South Africa. Not only does the significant energy import undermine the trade balance, the price for peak import is higher than the domestic selling price, which puts some pressure on the future trajectory for the tariff in order to fully cover the cost of supply. In this Masterplan, various future paths that have higher levels of autonomy have been investigated. Under the Base Case scenario, import dependency is expected to be reduced from 66 % in 2014 to 38 % by 2034. Under the three Limited Import scenarios, import dependency is reduced to a range of 10 % to 24 % by 2034. This is achieved at the expense of higher generation costs, but the magnitude of the cost increase is relatively marginal at 1 %–5 %, except for the Limited Import 2 scenario where the additional investment in hydro leads to an increase of 22 % in average generation costs.

Furthermore, the Limited Import scenarios would require building domestic generation capacity, which would at the same time create jobs. In particular, the Limited Import 3 scenario with renewables would foster creating a new industry around solar and wind and further strengthen the existing biomass sector. Under this scenario over 180 MW of new capacity would be required for solar PV and wind each, and 140 MW of additional capacity would be required for bagasse-fuelled generation.

Another set of scenarios explored new industry development around coal resources. While new coal industry will also create jobs, the coal industry suffers from negative externalities – notably mining-related death and health impacts expected as a result of pollution from coal-based generation. In addition, global decarbonisation ambition makes it harder for the coal industry to be attractive. Many financiers are valuing the risk of coal investments becoming stranded assets. To be compatible with the Government's commitment to the Paris Agreement, industrialisation around clean energy appears to be more desirable than betting on new coal-based capacity.

Energy access

Eswatini's short-term goal is to accelerate the rural electrification programme that seeks to provide electricity/clean energy to rural households. Household electricity access stood at 74 % in 2017; Eswatini aims to achieve universal access to electricity by 2022, as part of the National Development Strategy and also supported by the country's Sustainable Energy for All goals. Substantial progress has been made over the past decade to improve household access to modern energy services in the country.

Yet, nearly 70 % of households still rely on inefficient fuelwood for cooking and heating; traditional biomass use creates social and environmental costs as a result of the negative impacts on air quality and health as well as having a high opportunity cost of time used for wood collection. Thus, besides expanding energy access, the country needs to also gradually replace the use of traditional biomass. Efforts are underway to increase access to efficient cook stoves and modern cooking fuels, in particular LPG.

According to the demand assessment discussed in Chapter 4, it is envisaged that the use of fuelwood will decrease by 90 % in the residential sector, while use of LPG will increase almost three-fold by 2034, relative to current levels. By 2030 the portion of the population relying on fuelwood for cooking and heating could fall from the current 70 % to 25 % if clean and sustainable cooking alternatives are incentivised through policy-based interventions such as rebate programmes to encourage households to use modern energy cook stoves.

With the envisaged reduction in the use of fuelwood, forest degradation is expected to slow, yielding important climate benefits. It is estimated that deforestation and forest degradation globally contribute about 15 % to 20 % of all greenhouse gas emissions. To reduce forest loss, Eswatini is poised to boost carbon sequestration in forests.

Furthermore, there is potential for the adoption and roll-out of decentralised/distributed generation based on household-level systems, mainly from solar PV. In addition, solar water heaters could potentially be deployed by 50 % of households, thereby replacing the most inefficient wood-based water heating devices. At a larger scale, off-grid stand-alone systems have a potential to be deployed to tap into locally available energy resources, such as bioenergy and solar PV, to electrify remote areas and meet the growing energy demand. These measures form an important part in achieving SDG 7, and particularly its sub-target of reaching universal access to affordable, reliable and modern energy services by 2030.

Energy security

Energy security has three key components: the affordability, reliability and environmental sustainability of energy supply, known as the *energy trilemma*. Addressing all three objectives simultaneously may in the near term require decision makers to strike a delicate balance between short-term (such as immediate economic growth gains) and long-term policy goals; the long-term objective is to design energy policy and markets in a way that aligns all three components. The main finding across scenarios is that renewable energy sources can play an increasingly important role in providing reliable, affordable and environmentally sound energy, while enhancing energy access including through decentralised solutions.

Reliability of supply

Total national electricity demand is expected to rise by 113 % between 2014 and 2034. Indigenous energy resources can provide a cost-effective and secure supply that underpins sustainable economic growth, and the balanced deployment of diversified resources is key to ensuring the secure supply of electricity. These resources encompass both fossil fuels and renewable energy options, such as hydro, solar, wind and bioenergy. Currently the production of electricity is based mainly on biomass and hydropower, and the share of domestic production in the total energy supply is below 35 %.

The 10 scenarios discussed in Chapter 8 explore different mixes of energy supply options. The shares of domestic production by 2034 range between 10 % and 100 % under the different scenarios. The 10 % domestic production corresponds to a Low Import Price scenario, whereas 100 % domestic production corresponds to the two Forced Coal scenarios in which the country expands domestic coal capacity and becomes a net exporter. All other scenarios suggest domestic production shares in the range of 62 % to 90 %, thus suggesting significant improvements towards reduced import dependency.

Notably, in some scenarios, renewable energy sources – including solar PV and wind – account for the largest share of production. The scenarios show the feasibility of a renewable pathway in the power sector without compromising other objectives, including supply adequacy. The supply adequacy is ensured by imposing a reserve margin of 10 % (firm capacity) and using a constraint that limits the share of the intermittent renewables (solar PV and wind) to a maximum of 70 % of generation at any point in time. It may be required that the country introduces state-of-the-art grid control technologies and operation rules to accommodate the high share of variable renewable energy.

Under the two Forced Coal scenarios, domestic energy production is dominated by coal-powered generation. These scenarios are not consistent with the government policy of diversifying the energy mix. All other scenarios show a balanced mix of different energy sources including hydro, solar, biomass and wind, and improve the diversification of energy sources compared to the 2014 power system structure; the exception is the Low Import Price scenario, where imports dominate the supply of electricity (89 % by 2034).

As for the transport fuel mix, the assessment shows that domestic production of ethanol from molasses can meet the 10 % blending requirement for petrol to be used in the transport sector. This has the potential to moderately contribute to further diversification of the energy mix.

Affordability

The average generation cost per unit of electricity is expected to increase in all of the 10 scenarios assessed. This is mainly driven by increases in the import price as well as the cost of new investment, as most of the current installations have already been 'paid off'. Two scenarios, namely the Forced Coal 2 (600 MW) scenario and the Limited Import 2 with hydro scenario, are at the high end of the generation costs – at around SZL 1.3 per kWh (USD 93 per MWh). All other scenarios are around SZL 1.05 per kWh (USD 75 per MWh); the exception is the sensitivity scenario that assumed lower import price (Low Import Price scenario), which is at the low end of the generation costs, at around SZL 0.9 per kWh (USD 64 per MWh). This indicates that higher investment costs compared to the Base Case in some scenarios (particularly, the Limited Import 1 scenario, the Limited Import 3 scenario and the Natural Gas scenario) are dampened by reduction of other energy system costs, such as fuel costs and import costs.

It is notable that the rapid cost declines for renewable energy technologies will reinforce the business case for scaling up the deployment of renewable energy options, mainly solar PV and wind. This can serve as an encouraging signal for IPPs and increase the appetite for investment in these technologies.

Environmental sustainability

The need to diversify the national energy mix with a view to achieving energy security has been emphasised in a number of national energy policies, also with regard to the environmental sustainability of energy supply. Currently the country relies mainly on hydropower, so there is no issue of pollution. The key environmental issues are presented by use of fuelwood, resulting in degradation of land and in health problems linked to indoor air pollution. If adequately deployed, renewables can mitigate negative impacts of energy use on the environment.

In the power sector, the key environmental concern is the emission of CO_2 from fossil fuel-based generation. The introduction of domestic coal power generation would greatly increase carbon emissions from the country's power sector. The Base Case scenario, No Important Enhancement with High Demand scenario, Limited Import 3 with renewables scenario, Natural Gas scenario and Low Import Price scenario all present a trajectory for the country to achieve clean energy policy goals, while other scenarios, particularly the two Forced Coal (300 MW, 600 MW) scenarios, would be inconsistent with these goals.

Energy end-use sectors, such as transport, industry, households and agriculture, play a key role in reducing emissions in line with the Paris Agreement and the greenhouse gas reduction targets set in Eswatini's NDC. Eswatini is exploring opportunities for scaling up renewable energy in end-use sectors beyond the power sector. For example, the domestic production of biofuels has significant growth potential to diversify the transport sector away from the dominance of imported oil products (*e.g.*, petroleum) and towards a more sustainable fuel mix. Eswatini already has a biofuel policy in place that includes blending mandates of biofuels in transport. This policy is particularly impactful in the country's major ethanol-producing sector, where a blending mandate for up to 10 % ethanol in petrol is currently under development.

Besides renewable energy deployment, the Natural Gas scenario envisions that natural gas partly displaces the consumption of carbon-intensive energy carriers, such as coal in power generation as well as liquid fuels in transport and the residential sector. With regard to the power sector, assessment of the Natural Gas scenario revealed that due to high fuel costs, there is no economic advantage to introducing gas-fired generation within the planning horizon. Since natural gas lacks competitiveness with other energy resources, the country has to formulate goals to take this opportunity and create favourable conditions that can lead the growth of natural gas use in the country.

Comparison of scenarios and implications

There are various pathways to achieve enhanced energy security and energy access through 2034, as illustrated in the scenario analysis. Each scenario emphasises different priorities and sets different constraints on the future energy system so as to test-run the use of specific energy carriers or measures.

The Base Case defines a business-as-usual baseline through 2034. It projects an increased share of renewable energy and a reduced import dependency. The country's first utility-scale solar PV power project is expected to come online in 2019, with a capacity of 10 MW. Additional hydropower capacity of 14 MW is expected in 2020. The new deployment of hydropower is limited to this capacity of currently committed projects, since hydropower is observed to be increasingly less competitive as compared to solar and wind technologies for power generation. Co-generation continues to be used to ensure reliable heat and electricity supply for the sugar industry; co-generation is expected to account for 11 MW of new installed capacity in 2020. In the Base Case, the share of renewables in the country's electricity mix is expected to reach 30 % by 2030, which is 20 percent short of the government target of 50 % for that year.

The alternative scenarios emphasise the use of particular energy carriers, including coal (under the Forced Coal 300 MW and 600 MW scenarios), natural gas (under the Natural Gas scenario) and hydro (under the Limited Import 2 with hydro scenario). All of these scenarios represent future options that are technically feasible.

Table 9.1 provides a summary overview of the results for key parameters, across the 10 scenarios developed for the power sector. Out of the 10 scenarios, the two No Import Enhancement scenarios and Low Import Price scenario are considered as sensitivity scenarios, meaning that they are not established to explore alternative policy paths but rather to explore sensitivities to assumptions on the external factors. That leaves seven scenarios for comparison of alternative policy paths.

As discussed above, those scenarios that meet the goal of reduced import dependency and further diversification of power generation sources are the Base Case scenario, the three Limited Import scenarios and the Natural Gas scenario. From an affordability point of view, the Forced Coal 2 (600 MW) scenario and the Limited Import 2 with hydro scenario are the least favourable. From the CO_2 emission perspective, the two Forced Coal scenarios and the Limited Import 1 scenario are the least favourable.

TABLE 9.1 SUMMARY COMPARISON TABLE FOR THE SCENARIOS

	Value for 2014	Value for 2034									
		Base Case	Base Case (no import enhancement)	Forced Coal 1 (300 MW)	Forced Coal 2 (600 MW)	Limited Import 1	Limited Import 2 with hydro	Limited Import 3 (with renewables)	Natural Gas	High Demand (no import enhancement)	Low Import Price
CO_2 emissions (kt)	85	39	39	2,258	4,489	425	136	19	29	871	19
Share of RE in total demand	40 %	66 %	66 %	37 %	19 %	71 %	89 %	79 %	67 %	53 %	20 %
Import dependency	66 %	38 %	38 %	−11 %	−70 %	18 %	10 %	24 %	37 %	28 %	89 %
Average generation costs (SZL/kWh)	0.38	1.03	1.04	1.03	1.23	1.04	1.26	1.08	1.07	1.10	0.92
Shannon's diversity index*	117 %	170 %	170 %	108 %	48 %	196 %	177 %	176 %	170 %	187 %	73 %

* Index = 0 indicates zero diversity. The higher the value is, the more diversified the production mix is.

Based on this assessment, among those scenarios that broadly meet the overall policy goals, the Limited Import 3 with renewables scenario seems to possess the most balanced combination of the desirable policy features. Detailed results of this scenario are given in Section 8.4.2.

9.2 RESULTS OF THE STAKEHOLDER CONSULTATIONS

The development of this Masterplan document featured an extensive process of stakeholder consultation and review. At country meetings with key national energy sector stakeholders, participants indicated a clear preference for embracing a renewable energy pathway and for gradually phasing out the use of fossil fuels and/or rejecting new fossil fuel capacity options such as those assessed under the two Forced Coal scenarios. Among several national stakeholder meetings, a meeting organised by the Ministry of Energy in November 2017 convened 40 stakeholders and was crucial in receiving feedback on the Base Case assumptions and on the draft set of scenarios. At this meeting, participants voiced their support for a strong national commitment to clean energy including in the context of the Paris Agreement and Eswatini's NDC, and urged the implementation of national climate policies as required under international commitments.

In this context, the coal options were opposed based on the adverse impacts of coal-fired power generation; rather, more ambitious renewable energy deployment was called for as the most appropriate means of power generation. Some participants supported the introduction of solar and wind earlier than the time frame applied in most scenarios (major uptake mid-2020). As was pointed out, with the reduction in cost for renewable energy technology options (both utility-scale and decentralised) power generation from renewables has become increasingly cost competitive with fossil fuels, even more so when factoring in external costs/benefits. Yet, there remains a need to address the intermittent behavior of the resource.

Cost-competitive renewable energy technologies are only part of the equation; determined government action is also required to unlock the energy sector's full potential. Stakeholders pointed out the need for clear policy support schemes for solar and wind deployment in order to address the existing constraints, and also stressed the social value that can be derived from inclusive development of renewable energy. The current policy gaps and the suggested way forward are outlined in the next section.

Addressing the energy security issue, stakeholders pointed out that biomass could provide sufficient feedstock for up to about 150 MW of baseload power from the timber and sugar industries. Natural gas and biogas also should be considered as viable options in the future energy mix.

9.3 WAY FORWARD: KEY POLICY GAPS

Under the business-as-usual pathway to 2034, Eswatini's dependency on fuel and electricity imports remains high, while domestic renewable energy resources remain under-utilised. Long-term oriented government action is required to unlock the full potential of Eswatini's energy sector.

The global policy landscape shows that new mechanisms such as auctions/competitive bidding schemes are increasingly supplementing traditional instruments such as feed-in tariff schemes to drive renewable energy growth in the power sector. A key challenge is the intermittency of certain renewable sources such as wind and solar. Some operational practices are known to support the integration of variable renewable energy, and introduction of these practices requires institutional adaptation of power system operation rules. A comprehensive grid code was developed, and it iterates the enabling conditions and clear market rules for integrating renewable energy into the grid, while setting appropriate standards for the quality of electricity supply and services. Complementary technology options and policy options are evolving to adapt to changing conditions relevant to solar PV, wind and hydropower, among others. These include smart grids and storage. Government action is needed to increase access to clean energy for lighting, cooking and heating, especially solar water heating.

Policy measures need to incentivise, or be complemented by, public and private investments in domestic power generation infrastructure, to gradually reduce dependency on imports. The rapid cost declines that have been witnessed for solar PV and wind technologies, and that are expected to continue, strengthen the business case for embracing renewable energy options and provide an encouraging signal for IPPs. For signing contracts with IPPs, however, careful evaluation of contract conditions (*e.g.*, take-or-pay contracts) needs to be performed, and a tool such as SPLAT-SW is useful for that purpose.

The zoning information (see Chapter 6 of this report) provides guidance on particularly suitable project sites in Eswatini. The development of a standardised PPA could increase the bankability of renewable energy power projects in the country and help to attract scalable investment and limit elaborate negotiations. Solar systems in particular present an opportunity for Eswatini to further increase electricity access and improve energy efficiency. An increased awareness of local financial institutions regarding their commercial viability, as well as adequate financial support (such as dedicated credit lines or guarantees), are needed to make improved use of this opportunity.

With regard to bioenergy, the sugar industry needs to be further encouraged to invest in energy-efficient equipment to boost bagasse-based electricity production. This could be done by extending existing tax credits and allowances to the sugar industry as well as through a generation-based incentive (*e.g.*, founded on the avoided costs of power generation (or import) to the utility). The ethanol blending mandate (E10) needs to be operationalised, together with guidelines for price-setting and control mechanisms.

Generation capacity investments need to be matched by investments in transmission and distribution infrastructure, including improvements to enable the grid network to integrate higher shares of renewable energy supplies. Demand-side investment is expected to make up almost a quarter of total energy sector investments to 2030, much of which will be focused on energy-efficient technologies. These measures have been further detailed in the National Energy Policy with a long-term perspective. The NEP has placed emphasis on implementing energy efficiency and conservation measures that can be applied to reduce energy consumption in all economic sectors, including through the development and enforcement of minimum energy performance standards for household and industrial equipment, through solar water heaters and through renewable energy mini-grid/off-grid technologies.

Based on the opportunity posed by the natural gas discoveries in Mozambique, there is a need to define areas of co-operation and the role that natural gas can play in improving energy security and encouraging economic development in Eswatini, including in the context of the overarching objectives of the SADC industrialization Strategy Framework. The use of natural gas could help reduce heavy reliance on fuelwood as well as promote industrial development for addressing electricity security issues.

9.4 ENHANCING NATIONAL ENERGY PLANNING CAPABILITY

This Masterplan document was drafted by a team of national energy experts set up to carry out the national SPLAT model development and scenario analysis, in close consultation with the steering committee and through consultation with a wider group of energy sector stakeholders.

Through the process, the working team collected the required data and developed a database, created and calibrated a country model, developed scenarios, and analysed them. A dozen national energy experts were engaged throughout the process and were equipped with the necessary skills for undertaking robust energy planning (see Annex A for a list of the working team members, and of trainers and key contributors). Although this process benefited greatly from the support from IRENA and its international experts, it was truly a country-driven process, and, as a result, ownership of this document is established fully by the Government. The Government acknowledges the importance of fully internalising the planning process and of further continuing the efforts to build and enhance the country-owned planning process.

This was the first such attempt for the government to develop an integral energy master plan driven by national experts, and the working team identified areas of possible enhancement to be implemented for the next update of the Masterplan.

1. Data collection

The national working team developed a database of the current energy system and a catalogue of future scenario assumptions. Although these are documented thoroughly in this document, more systematic management of the database would improve the transparency of the data. Publishing such a database, *e.g.*, through a government web-portal, would improve the accessibility of data and scrutiny of the data quality. Maintenance and consistency of the existing datasets as well as co-operation between key national stakeholders as well as with international organisations and experts will ensure the continued collection of meaningful data. Good energy policy is built on good data, and a sustained commitment to collecting adequate data is critical to meeting the country's future energy needs.

2. Institutional arrangement

The composition of the national working team reflected core technical expertise on Eswatini's energy sector that was complementary and well balanced. The working team comprised experts from the Ministry of Natural Resources and Energy, Swaziland Electricity Company, Swaziland Energy Regulatory Authority, the Central Statistical Office and the University of Swaziland. The team received training on energy statistics use in energy planning tools and on preparation of the Energy Masterplan. The training also focused on updating and maintaining the SPLAT-SW model as well as on expanding it to the entire energy system of the country (*i.e.*, beyond the power sector). The level of training received was adequate for the purpose, but continuous training and enhancement of expertise will be important. To ensure this, it is desirable that an energy planning team is institutionalised within the government, to lead and organise the master plan update process and further capacity enhancement for policy analysis.

3. Updating/reviewing the Masterplan

The process of developing this Masterplan took over two years, starting in March 2016. In the final phase of this development process, the national working team recognised that some assumptions made at the beginning of the process may require review or update. Once this Masterplan is adopted by the Cabinet, the government should immediately start the process of updating the document, building on lessons learned from the development process. The team recommends that the data management and model updates should be institutionalised and continuous in order to be able to deal with rapid changes in the energy sector and to support decision makers with up-to-date information. It is suggested that the Energy Masterplan be updated at a regular interval of, preferably, every two to three years, but not at an interval of longer than five years.

4. Key areas for further analysis

Given the importance of bagasse and molasses in the indicated energy mix, targeted consultation with the relevant industry stakeholders can be strengthened to further improve the quality of this analysis.

The demand assessment in this Masterplan focused on the impacts of different economic growth assumptions on energy needs, but was limited in regard to exploring the impacts of a fuller set of policy options. The potential of renewable energy deployment in the end-use sectors may require further analysis. In particular, the modelling of technology choices to assess pathways to achieve universal access to modern energy in the residential sector could be further strengthened by analysing effective policy choices under heterogeneous economic conditions. Policy analysis is needed related to the collection of fuelwood for cooking and heating and how the challenges related to the adoption of modern fuels can adversely affect households, especially in terms of affordability since fuelwood is a “free” energy source whereas modern energy sources can be costly.

For the power sector analysis, further assessment of dispatchability under critical conditions (*e.g.*, peak time) would be helpful to identify the required mitigation measures for operating the system with a high share of variable renewable energy. The analysis should focus on a 100 % renewable energy trajectory resulting from tapping the renewable resource potential in biomass, solar PV, wind and hydro that is established in the Masterplan. This analysis can guide expansion of the power sector using renewable energy technology options, systems integrity and infrastructure measures, as required to make the renewable energy path both technically and economically viable.

Further, analysis is required of the use of untapped resources such as biogas and natural gas in the residential and transport sectors, and for power generation in order to increase the use of clean energy. The analysis can identify different pathways crucial to most effectively directing investments in this area.

During the next phase of the master plan development, more attention could be given to the statistics on decentralised systems. Despite vast resource potential, the deployment potential of renewable-based decentralised systems including solar PV and solar water heaters was not thoroughly evaluated.

To tackle part of the further analysis required, the government will co-operate with the International Atomic Energy Agency (IAEA) for energy planning training and technical support, building on the analysis done for this Energy Masterplan. The IAEA has a long-standing track record in capacity building for energy planning in Africa, and can provide support in areas complementary to the support provided by IRENA. In particular, this collaboration will serve to improve the existing energy planning models and encourage applications of an optimisation framework to a reference energy system.

ANNEX

ANNEX A MEMBERS OF THE NATIONAL WORKING TEAM; TRAINERS AND KEY CONTRIBUTORS

MEMBERS OF THE NATIONAL WORKING TEAM

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ANNEX B DETAILED RESULTS OF THE DEMAND ASSESSMENT

TABLE A1 ENERGY USE BY FUEL AND BY SECTOR IN 2014 (PJ)

Fuels	Transport	Residential	Commerce and Govt. Services	Industry Other	Agriculture Other	Sugar	Total
Electricity	–	1.2	0.4	0.8	0.9	1.3	4.6
Kerosene	–	0.2	–	–	–	–	0.2
LPG	–	0.2	0.2	–	–	–	0.4
Oil	8.9	–	–	0.1	0.4	0.0	9.4
Bagasse	–	–	–	–	–	8.4	8.4
Wood	–	11.9	–	–	–	2.7	14.5
Coal Unspecified	–	–	0.6	–	–	1.2	1.9
Total	**8.9**	**13.5**	**1.2**	**0.8**	**1.3**	**13.7**	**39.4**

TABLE A2 DEMAND PROJECTION UNDER THE REFERENCE SCENARIO (PJ), 2014–2034

Fuels	2014	2020	2025	2030	2034
Electricity	4.6	5.7	7.0	8.5	9.5
Kerosene	0.2	0.1	0.1	0.0	0.0
LPG	0.4	0.6	0.7	0.9	1.0
Oil	9.4	10.5	11.7	13.0	14.1
Wood	14.5	12.1	9.5	6.0	6.4
Bagasse	8.4	9.8	11.3	13.1	14.8
Coal Unspecified	1.9	2.0	2.2	2.4	2.6
Total	**39.4**	**40.8**	**42.5**	**43.9**	**48.4**

TABLE A3 ENERGY USE BY FUEL AND BY SECTOR IN 2034 UNDER THE REFERENCE SCENARIO (PJ)

Fuels	Transport	Residential	Commerce and Govt. Services	Industry Other	Agriculture Other	Sugar	Total
Electricity	–	3.7	0.6	1.4	1.5	2.3	9.5
Kerosene	–	0.0	–	–	–	–	0.0
LPG	–	0.6	0.4	–	–	–	1.0
Oil	13.3	–	–	0.1	0.7	0.1	14.1
Wood	–	1.7	–	–	–	4.7	6.4
Bagasse	–	–	–	–	–	14.8	14.8
Coal Unspecified	–	–	0.5	–	–	2.1	2.6
Total	**13.3**	**6.0**	**1.5**	**1.5**	**2.2**	**24.0**	**48.4**

TABLE A4 DEMAND PROJECTION UNDER THE HIGH GROWTH SCENARIO (PJ), 2014–2034

Fuels	2014	2020	2025	2030	2034
Electricity	4.6	6.0	8.0	10.1	12.2
Kerosene	0.2	0.1	0.0	0.0	0.0
LPG	0.4	0.6	0.8	0.9	1.0
Oil	9.4	10.5	11.8	13.3	14.7
Wood	14.5	8.0	5.7	6.2	6.7
Bagasse	8.4	9.8	11.5	13.6	15.7
Coal Unspecified	1.9	2.0	2.2	2.5	2.7
Total	**39.4**	**37.0**	**39.9**	**46.7**	**53.0**

TABLE A5 ENERGY USE BY FUEL AND BY SECTOR IN 2034 UNDER THE HIGH GROWTH SCENARIO (PJ)

Fuels	Transport	Residential	Commerce and Govt. Services	Mining	Industry Other	Agriculture Other	Sugar	Total
Electricity	–	3.7	0.6	2.3	1.5	1.6	2.4	12.2
Kerosene	–	0.0	–	–	–	–	–	0.0
LPG	–	0.6	0.4	–	–	–	–	1.0
Oil	13.8	–	–	–	0.1	0.7	0.1	14.7
Wood	–	1.7	–	–	–	–	5.0	6.7
Bagasse	–	–	–	–	–	–	15.7	15.7
Coal Unspecified	–	–	0.5	–	–	–	2.3	2.7
Total	**13.8**	**6.0**	**1.5**	**2.3**	**1.6**	**2.3**	**25.4**	**53.0**

TABLE A6 DEMAND PROJECTION UNDER THE LOW GROWTH SCENARIO (PJ), 2014–2034

Fuels	**2014**	**2020**	**2025**	**2030**	**2034**
Electricity	4.6	5.4	6.3	7.3	8.2
Kerosene	0.2	0.2	0.1	0.1	0.0
LPG	0.4	0.5	0.7	0.8	0.9
Oil	9.4	10.0	10.7	11.4	12.0
Wood	14.5	12.9	11.1	8.6	6.1
Bagasse	8.4	14.9	10.0	11.0	11.8
Coal Unspecified	1.9	1.9	2.0	2.0	2.1
Total	**39.4**	**40.1**	**40.8**	**41.1**	**41.1**

TABLE A7 ENERGY USE BY FUEL AND BY SECTOR IN 2034 UNDER THE LOW GROWTH SCENARIO (PJ)

Fuels	**Transport**	**Residential**	**Commerce and Govt. Services**	**Industry Other**	**Agriculture Other**	**Sugar**	**Total**
Electricity	–	3.5	0.5	1.1	1.2	1.8	8.2
Kerosene	–	0.0	–	–	–	–	0.0
LPG	–	0.6	0.3	–	–	–	0.9
Oil	11.3	–	–	0.1	0.6	0.0	12.0
Wood	–	2.4	–	–	–	3.7	6.1
Bagasse	–	–	–	–	–	11.8	11.8
Coal Unspecified	–	–	0.4	–	–	1.7	2.1
Total	**11.3**	**6.5**	**1.2**	**1.2**	**1.8**	**19.1**	**41.1**

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