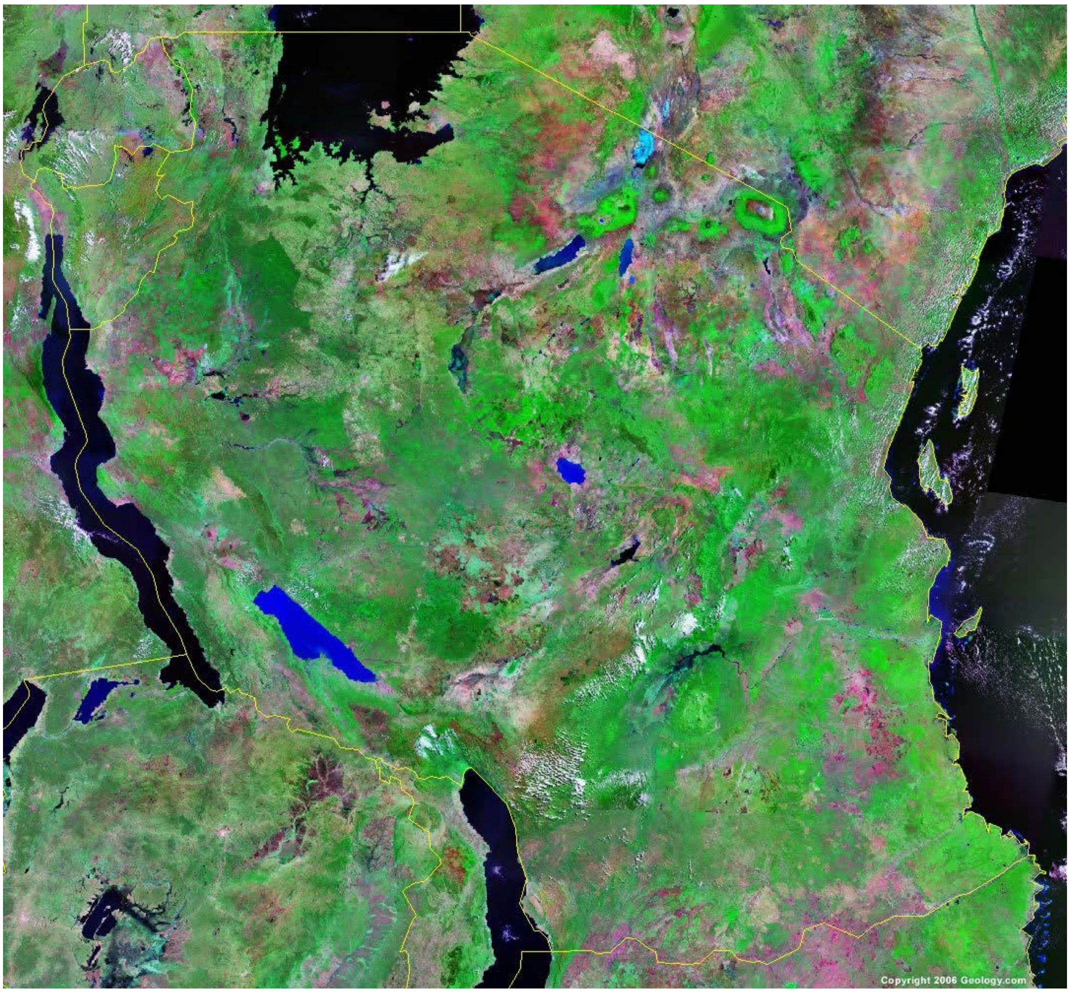

100% RENEWABLE ENERGY FOR TANZANIA

Access to renewable energy for all within one generation

Prepared for: Bread for the World

UTS Institute for Sustainable Futures

2017

ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) was established by the University of Technology Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.
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The energy scenario software for the long-term projections and economic parameters has been developed by the German Aerospace Centre (DLR), Institute for Technical Thermodynamics, Pfaffenwaldring 38-40, 70569 Stuttgart/Germany and applied to over 100 energy scenario simulations for global, regional and national energy analysis.

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All conclusions and any errors that remain are the authors own.

DISCLAIMER

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1 INTRODUCTION AND SCOPE OF WORK

In 2016, CAN-Tanzania (CAN-TZ), the World Future Council (WFC) and Bread for the World (BftW) embarked on an 18-month project in Tanzania to develop a coherent strategy to implement 100 per cent Renewable Energy (RE) as part of the country's Sustainable Low Carbon Development (LCD) Initiatives and Poverty Reduction Goals. This project builds on the previous experience of the project partners in facilitating the deployment of LCD and RE in Tanzania.

Through an inclusive and interactive approach engaging local stakeholders and key decision makers in the energy transformation and poverty reduction process, this project intends to:

- inspire stakeholders and build hands-on knowledge of how 100 per cent RE adds value to local economic development and community sustainability
- strengthen synergies, networks and platforms for multi-stakeholder dialogue and follow-up at the national level among government, parliamentary committees, policy-makers, civil society, trade unions, churches and media on LCD, poverty reduction and 100 per cent RE
- identify necessary legislation and policy reforms.

The proposed assignment aims to support the project by informing a policy framework on 100 per cent RE with the following aims:

1. **providing universal access to renewable energy**
2. **fully decarbonising Tanzania's economy, and**
3. **boosting socio-economic development and reducing inequalities.**

To put Tanzania on such a pathway, Bread for the World, the World Future Council and Climate Action Network (CAN) Tanzania aims to analyse:

1. the technical RE potential of the country
2. the country's future energy demand given universal energy access
3. optimal RE expansion trajectories to achieve 100 per cent RE by 2030, 2040 and 2050.

Using the estimated costs and investment needed to realise different trajectories, and in a further step not within the scope of this study, CAN-TZ, World Future Council and Bread for the World will develop policy recommendations in a workshop based on the results of this analysis.

The Institute of Sustainable Futures (ISF) at the University of Technology Sydney has produced an economic and technical scenario model for transition towards a renewable energy system. The model describes Tanzania's future energy system, including an assessment of technology pathways and cost implications of three future energy scenarios. The model used by ISF was created by the German Aerospace Agency in cooperation with Greenpeace International, and has previously been used to inform the German Government's 'Energiewende' and climate mitigation scenarios for the Intergovernmental Panel on Climate Change (IPCC).

The key results of the modelling are presented in Section 2, followed by methodology in Section 3, assumptions in Section 4 and detailed results and cost analysis in Section 5.

2 KEY RESULTS

Tanzania is one of the world's poorest economies in terms of per capita income, averaging US$864.90 per year – equivalent to less than 9 per cent of the global average. Though its per capita income is slightly ahead of the average per capita income of low income countries (US$615.60), it remains significantly below lower middle-income countries (US$1988.20) and even further from middle income countries (US$4736.70). Nonetheless, Tanzania has achieved high growth rates based on its vast natural resource wealth and tourism; GDP growth in 2009-15 was 6 to 7 per cent per annum, making it one of the 20 fastest growing economies in the world.

Tanzania needs to build and expand its power generation system to be almost entirely new in order to increase the energy access rate to 100 per cent. Building new power plants – no matter the technology – will require new infrastructure, such as power grids, spatial planning, a stable policy framework and access to finance.

With decreased prices for solar photovoltaic and onshore wind in recent years, renewables have become an economic alternative to building new gas power plants. As a result, renewables achieved a global market share of over 50 per cent of all new build power plants since 2014. Tanzania is blessed with vast solar and wind resources, and renewables generation costs are generally lower with increased solar radiation and wind speeds. However constantly shifting policy frameworks often lead to high investment risks, and therefore higher project development and installation costs, for solar and wind projects relative to countries with more stable policy.

Long-term and energy access scenarios

The Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS) calculated three long-term scenarios using a special energy model developed by the German Aerospace Center (DLR). Based on those results, an hourly simulation of the entire electricity market for Tanzania has been conducted, and the [R]E24/7 model used for the hourly calculation has been developed by UTS/ISF. The scenario was calculated as follows

- The **REFERENCE scenario (REF)** reflects a continuation of current policies and is based on the Tanzanian Government forecasts in *Tanzania Power System Masterplan 2016*.
- The **RENEWABLES scenario (RE)** is designed to meet Tanzania's energy-related targets to achieve 100 per cent renewable energy for electricity, buildings and industry as soon as possible. The renewable energy trajectories for the initial years are taken from the joint publication of Bread for the World, World Future Council and Climate Action Network Tanzania entitled *Policy Roadmap for 100% Renewable Energy and Poverty Eradication in Tanzania*, published in May 2017 (WFC (2017))[1].
- The **ADVANCED RENEWABLES scenario (ADV RE)** takes a more ambitious approach to transforming Tanzania's entire energy system towards 100 per cent renewable energy supply. The consumption pathways remain almost the same as in the RENEWABLES scenario, however under this scenario a much faster introduction of new technologies leads to a complete decarbonisation of energy for stationary energy (electricity), heating (including process heat for industry) and transportation. The latter requires a strong role for storage technologies such as batteries, synthetic fuels and hydrogen.
- The **ENERGY ACCESS SCENARIO (EAS)** simulated the results of the RENEWABLES scenario (RE) and calculates hourly supply and demand curves along with storage demand requirements.

All scenarios presented in this analysis include assumptions on policy stability, the role of future energy utilities, centralised fossil fuel-based power generation, population and GDP, firm capacity and future costs.

- **Policy stability:** This research assumes that Tanzania will establish a secure and stable framework for the deployment of renewable power generation. In essence, financing a gas power plant or a wind farm is quite similar. In both cases a power purchase agreement, which ensures a relatively stable price for a specific quantity of electricity, is required to finance the project.
- **Strengthened energy efficiency policies:** Existing policy settings, namely energy efficiency standards for electrical applications, buildings and vehicles, will need to be strengthened in order to maximise cost-efficient use of renewable energy and achieve a high energy productivity by 2030.

[1] WFC (2017) Bread for the World, World Future Council and Climate Action Network Tanzania *"Policy Roadmap for 100% Renewable Energy and Poverty Eradication in Tanzania"*, May 2017

- **Role of future energy utilities:** With 'grid parity' of rooftop solar PV under most current retail tariffs, this modelling assumes that the energy utilities of the future take up the challenge of increased local generation and develop new business models that focus on energy services, rather than only selling kilowatt-hours.
- **Population and GDP:** The three scenarios are based on the same population and GDP assumptions. Projections of population growth are taken from the *World Population Review* while the GDP projection assumes long-term average growth of around 2 per cent per year over the scenario period.

Key results of the long-term energy pathway for Tanzania
100 per cent renewable energy for all Tanzanian's is technically and economically possible, and a realistic pathway for Tanzania to align with the Paris Agreement and Sustainable Development Goals.

- **Final energy demand:** Combining the projections on population development, GDP growth and energy intensity results in future development pathways for Tanzania's final energy demand. Under the REFERENCE scenario, total final energy demand increases by 40 per cent from the current 1000 PJ/a to 1400 PJ/a in 2050. Under both RE scenarios, due to economic growth, increasing living standards and electrification of the transport sector, overall electricity demand is expected to increase despite efficiency gains in all sectors.
- **Electricity demand:** This will rise from around 5 TWh/a to 110 TWh/a by 2050 in the basic RE scenario. For the heating sector, it is assumed that renewable heating technologies for residential and commercial buildings – mainly geothermal heat pumps and solar collectors – will significantly influence building and construction standards.
- **Electricity generation, capacity and breakdown by technology**: The renewable energy market grows dynamically, and renewable electricity's share in the required electricity supply is increasing. By 2020 wind and solar photovoltaic will overtake hydro, currently the largest contributor to the growing renewable market. After 2020, growth shares from solar thermal, bio- and geothermal energy will complete the variety of new technologies, and by 2050, 100 per cent of the electricity produced in Tanzania will come from renewable energy sources under the basic RENEWABLES scenario. 'New' renewables – mainly wind, PV, ocean and geothermal energy – will contribute 75 per cent to total electricity generation. By 2020, the share of renewable electricity production will already be 53 per cent, and 75 per cent by 2030; the installed capacity of renewables will reach about 20 GW in 2030 and 60 GW by 2050. New gas power plants will operate within around 20 years, while the financial write-off time is calculated with 10 years, therefore avoiding stranded investments.
- **Energy supply for heating:** In 2015, renewables meet around 90 per cent of Tanzania's energy demand, primarily through traditional use of biomass for cooking. Dedicated support instruments are required to ensure a dynamic development, in particular for renewable technologies for cooking, buildings and renewable process heat production for increased industrial process heat requirements. In the basic RENEWABLES scenario, renewables already provide 90 per cent of Tanzania's total heat demand in 2030 and 100 per cent in 2050. Energy efficiency measures help to reduce the currently growing energy demand for wood fuel for cooking stoves and shifts 100 per cent to modern sustainable biomass, solar and geothermal heating, as well as electric cooking and heating, by 2050.
- **Transport:** Due to population increase, GDP growth and higher living standards, energy demand arising from the transport sector is expected to increase in all scenarios by around 601 per cent to 590 PJ/a in 2050. Additional modal shifts and technology switches lead to energy savings in the ADVANCED scenario of 4 per cent (20 PJ/a) in 2050 compared to the REFERENCE scenario. Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will deliver large efficiency gains. By 2030, electricity will provide 4 per cent of the transport sector's total energy demand in the RENEWABLES scenario, while in 2050 the share will be 40 per cent (and 75 per cent in the ADVANCED scenario). These changes are achieved by introducing incentives for people to keep public transport as the preferred transport mode and to significantly increase its convenience. Individual transport should rely to a large extend on smaller and more efficient vehicle concepts. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the large and expanding metropolitan areas.
- **Primary energy consumption:** Under the basic RENEWABLES scenario, primary energy demand will increase by 82 per cent from today's 1100 PJ/a to around 2000 PJ/a. Compared to the REFERENCE scenario, overall primary energy demand will be reduced by 2 per cent in 2050 under the RE scenario (REF: around 2000 PJ/a in 2050), while the ADVANCED scenario results in additional conversion losses in a primary energy consumption of around 2200 PJ/a in 2050. The overall renewable primary energy share of the basic RENEWABLES case will be 72 per cent in 2030 and 82 per cent in 2050, with the remaining 18 per cent comprised of fossil fuels used in the transport sector. In the ADVANCED scenario, all fossil fuels are phased out by 2050 and 100 per cent renewable energy is achieved across all sectors.
- **CO_2 emissions trajectories:** Whilst Tanzania`s CO_2 emissions will increase by a factor of 7, from 12 million tonnes to over 90 million tonnes, between 2015 and 2050 under the REFERENCE scenario, the

RENEWABLES scenario will result in a moderate increase to 24.5 million tonnes with a population increase from 53 to 137 million people in the same period. As such, annual per capita emissions will remain at 0.2 tonnes. In spite of increasing power demand, CO_2 emissions will decrease in the electricity sector. In the long run, efficiency gains and the increased use of renewable electricity in vehicles will also dramatically reduce emissions in the transport sector. With a 98 per cent share of CO_2, the transport sector will be the largest source of emissions in 2050 in the basic RE scenario. By 2050, Tanzania´s CO_2 emissions will increase by 15 million tonnes on 2015 levels in the RENEWABLES scenario while energy consumption is fully decarbonised in the ADVANCED case.

- **Future costs of electricity generation:** The introduction of renewable technologies under both RENEWABLES scenarios may increase the cost of electricity generation in the future compared to the REFERENCE scenario for a short period – around 2025 or 2030, depending on the assumed coal and gas price. However, this difference in the full cost of generation will be less than 1.7 cents/kWh in the basic RE scenario and about 1.4 cents/kWh in the ADVANCED scenario. Electricity generation costs will fall under the REFERENCE case by around 2030 under the RENEWABLES scenarios. By 2050, the cost will be 4.5 cents/kWh, respectively, below those in the REFERENCE case. Thus, the RENEWABLES energy pathways are the low cost option compared to the REFERENCE case when taking into account the entire lifetime of the power plants.
- **Future investments in the power sector:** Under the RENEWABLES case the additional investment is estimated at $3.2 billion compared to the REFENCE case, with fuel cost savings adding up to $5.3 billion. Thus, the additional investment required would more than refinance via fuel cost savings. With high uncertainties both for future investment costs for power generation equipment and for fossil fuel prices, it seems certain that the overall cost balance is economically beneficial for the RENEWABLES scenario.

Under the ADVANCED RENEWABLES scenario, the additional investment cost is estimated to be around $7.6 billion compared to REFERENCE case, with the fuel cost saving adding up to $2.4 billion without the transport sector and $8.1 billion including transport fuel cost savings. Just as in the RENEWABLES case, the ADVANCED case leads to fuel cost savings that will more than refinance the investment in renewable power generation.

Table 1: Overview of key results of the long-term energy pathway for Tanzania

Tanzania ENERGY ACCESS SCENARIO – detailed assessment of the RENEWABLES scenario
Tanzania has sufficient renewable energy resources to keep storage shares well below 20 per cent while securing supply of 100 per cent renewable energy. The ENERGY ACCESS SCENARIO (EAS) aims to provide universal access to energy – particularly electricity – for all by 2050, while increasing the electrification and comfort standard to the level of industrialised countries.

The growing economy requires a reliable power supply for small and medium businesses (SME's), industry and the transport sector. It is assumed that households will use modern and energy-efficient applications according to the highest efficiency standards in order to slow down the power demand growth, and to allow the parallel expansion of energy infrastructure and the construction of renewable power plants. The electrification will be organised from the 'bottom up' in a new and innovative approach developed by UTS/ISF:

- **3-Step—Solar-Swarm Grid (3SG) expansion** – from pico-grid via micro grid to transmission grids. Currently over 70,000 households in Tanzania get access to electricity via start-up companies such as Mobisol and/or bboxx. Those companies supply small solar systems in varying sizes from 80 to 200 Wp to match the various energy needs of differing households. Solar home systems SHS) provide enough electricity to power bright efficient LED lights, radios, mobile phones, TVs, DC fridges and a variety of other household and consumer appliances. However, this development is not currently coordinated with the national grid expansion plans of the Tanzanian government. The project aims to develop a technical and economic concept along with a real test case, to interconnect SHS to a micro grid in a first step and – in a second step – a number of micro grids to distribution power grid, equal to those in industrialised countries. As the third and final step, distribution grids will be interconnected to a transmission grid.

  The industry will continue to expand on-site power generation (auto-produce) for their own supply – wherever possible with cogeneration plants – and as dispatch power plants for balancing high shares of grid-connected utility scale solar PV and wind. The fuel will move from natural gas to biogas and/or hydrogen and synfuels after 2030.

Households: Closing the gap to industrialised countries
The EAS assumes a gradual transition towards a full electrified household. Nine different household types have been developed to calculate the rising power demand, beginning with very basic needs such as light and mobile phone charging towards a household-standard of industrialised countries. In order to phase out unsustainable biomass for cooking, a direct leap from cook stoves directly to electrical cooking is assumed. The third phase of a rural household includes an electric oven, fridge, washing machine, air-conditioner and entertainment technologies and aims to provide the same level of comfort as households in urban areas in industrialised countries. An adjusted level of comfort for households in the city and in rural areas aims to prevent residents – especially young people – from leaving their homeland and moving to big cities. Rapidly expanding cities proved problematic as infrastructure for transport and energy supply and the requirement for residential apartment buildings cannot match the demand, often leading to social tensions.

Security of supply and storage requirements
The [R]E 24/7model calculates demand and supply by cluster and four different voltage levels. The long-distance transmission grid (TA) serves as an interconnector across the country, while the regional transmission grid (TZ) connects to the medium (DA) and finally to the low (DZ) voltage level.

Storage technologies – particularly decentralised batteries and pumped hydro – are used to avoid curtailment of solar photovoltaic and wind power and to guarantee security of supply. Batteries are assumed to be installed as decentralised application on the lowest voltage level, while pumped hydro power is likely to be connected to the medium or high voltage level.

The storage requirements are still relatively minor in 2030, and short-term storage demand to even out day and night variations of solar photovoltaic systems are required most. In 2050, batteries continue to shoulder more than half of the entire storage demand, mainly in connection with solar photovoltaic systems. The uneven results of charge and discharge from pumped hydro indicate a regional and seasonal storage requirement.

Both technologies play an important role: batteries for short term storage requirements, for example to balance demand and supply over a few hours or days; and hydro power for seasonal storage, for example wind power to bridge several weeks or months. Pumped hydro can also balance demand and supply across regions as they are connected to the transmission grid. The overall supply share from storage technologies under the assumed regional demand and supply situation is for 2030 and 2050. The overall share of storage technologies to ensure security of supply and to avoid un-economic curtailment for solar photovoltaics and wind power is still very minor in 2030, with an average of 6 per cent across Tanzania.

Variable power generation in some regions exceed demand, while in other regions generation cannot supply regional demand. The analysis does not include an optimisation process for regional generation, but places variable generation where demand, solar- and/or wind resources are highest. Regional difference indicates power transport demand (= transmission network expansion).

Conclusion [R]E 24/7 modelling

The hourly modelling of the long-term scenario shows that the chosen mix is suitable to guarantee security of supply and that storage technologies in the order of 15 to 20 per cent of total generation are sufficient. A regional distribution via an interconnected power grid can reduce storage demand and curtail variable renewable power generation. However, the development of storage costs will have a huge influence on whether or not all variable power generation will be stored, or whether the share of dispatchable renewable power generation will be increased at the expense of variable power generation and storage.

3 GLOBAL ENERGY CONTEXT

Global energy markets are changing rapidly. Renewable energy technologies now constitute more than half of the new power plants built worldwide each year[2]. In 2014, growth rates for coal use stalled globally for the first time, including in China, and this trend continued throughout 2015 and 2016[3]. Oil and coal prices are now at record lows, halting the development of most new coal and oil mining projects.

While electric vehicles still have a negligible share of the global car transport market, this is likely to change as most international car manufacturers prepare for a massive shift toward electric vehicle technologies. It is very possible that the market for electric vehicles could follow the same exponential development pathways as the solar photovoltaic (PV) market, when rapid growth in solar technology between 2010 and 2015 delivered increasing market shares and significantly reduced investment costs. Today, solar photovoltaic at the household level is now cheaper than retail electricity prices (tariffs) in most industrialised countries, making it cost-effective for many households to produce their own power.

In addition, wind power has become the least expensive technology globally for new power plants, spurring a huge global market for wind that saw an additional capacity of 54,000 megawatts added during 2016 – equivalent to installing one new turbine every 20 minutes.

With renewable energy technologies now faster and more economical to build than fossil fuel-based power generation facilities, and subsequent reduction in dependency on imported fuels, these global developments support Tanzania's goal of providing access to energy for all.

3.1 ACCESS TO ENERGY – 7TH SUSTAINABLE DEVELOPMENT GOAL

The growth of megacities and the slow process of providing access to energy services are closely related, and in many cases two sides of the same coin. Young people leave the rural areas for large cities due to the lack of professional opportunities, while access to energy is fundamental to sustain economic activities and alleviate poverty. For well over 1 billion people around the world, obtaining access to the energy required to meet very basic needs remains a daily struggle. In rural areas of many developing countries, as well as some urban slums and peri-urban areas, connection to central electric grids is economically prohibitive and may take decades to materialise, if at all (REN21-GSR 2016). Recent progress has been too slow to meet changing needs.

In 2013, the United Nations Development Programme (UNDP) launched the *Sustainable Energy for All* initiative to aid in accelerating the rate of increased energy access for the least developed countries. The first step in the process was to develop a central database in order to make previously dispersed information available to decision makers. The UNDP – in cooperation with a number of other energy advocacy organisations such as the IEA and REN21 – published the *Global Tracking Framework*[4] report, providing a statistical overview of the progress of energy access between 1990 and 2010. Information from these reports combined with new data from the *REN21 Global Status* report provides a clear picture of progress in this area.

[2] REN21 (2016) *Renewables 2016 Global Status Report*, Paris, REN21 Secretariat. Available at: www.ren21.net/status-of-renewables/global-status-report/

[3] Li Junfeng, Director General at the National Climate Change Strategy Research and International Cooperation Centre: *The Guardian Interview*, 20th January 2016. Available at: www.theguardian.com/environment/2016/jan/19/chinas-coal-burning-in-significant-decline-figures-show

[4] UNDP 2013: The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa, May 2013 http://www.undp.org/content/undp/en/home/librarypage/environment-energy/sustainable_energy/SEFA-resources/global-tracking-framework.html

3.2 ENERGY ACCESS PLANNING FOR DEVELOPING COUNTRIES

Between 1990 and 2010, an additional 1.7 billion people worldwide gained the benefits of electrification, while 1.6 billion people secured access to generally less polluting non-solid fuels. Furthermore, the successful implementation of energy efficiency measures led to a significant reduction in energy intensity. As a result, economic growth and the growth of energy demand began to disconnect. This was a significant that avoided 2,300 exajoules of new energy supply over the past 20 years; in other words, without these measures the global energy demand would have been 25 per cent higher during that period. In addition, renewable energy supplied a cumulative global total of more than 1,000 exajoules between 1990 and 2010, comparable to the combined total energy consumption of China and France over the same period (UNDP 2013).

Unfortunately, the rapid demographic and economic growth over the last 20 years has to some extent diluted the impact of these advances. Between 1990 and 2010:

- the proportion of the world’s population with access to electricity and non-solid fuels grew 1.2 per cent and 1.1 per cent respectively each year
- renewable energy supply grew by around 2 per cent per annum
- energy demand grew by 1.5 per cent per annum.

As a result, the global renewable energy share increased from 16.6 per cent in 1990 to 18 per cent in 2010 (UNDP 2013) – an average of only 0.07 per cent per year. The majority of successful electrification in the past took place in urban areas, close to cities where the electrification rate was twice as high as in remote areas. Even with this significant expansion, however, electrification only just kept pace with rapid urbanisation in the same period so that the overall urban electrification rate remained relatively stable, growing from 94 to 95 per cent across the period (UNDP 2013). Improvements to cooking devices are an important factor in increasing public health, particularly in developing nations. Globally, almost two million deaths each year from pneumonia, chronic lung disease and lung cancer are associated with exposure to indoor air pollution resulting from cooking with biomass and coal; 99 per cent of these deaths occur in developing countries. Almost half the global population (45 per cent) still rely on solid fuels for household use with dramatic impacts on health, particularly for children and women. Some 44 per cent of these deaths occur in children; of the adult deaths, 60 per cent occur in women in developing countries (UNDP 2013).

Status quo: Access to energy services

Currently, approximately 1.5 billion people in developing countries lack access to electricity and around 3 billion people rely on solid fuels for cooking. More than every second person without access to electricity lives in Sub-Saharan Africa. The entire African continent has a total installed capacity of approximately 150 gigawatts – equal to one-seventh of Europe’s power plant capacity – and consumes about the same amount of electricity as Germany, while Africa’s population is 12 times larger.

In East Asia and the Pacific, less than 200 million people lack electricity access, but almost 1.1 billion people rely on solid fuels for cooking (UNDP 2013). Figure 1 and Figure 2 provide an overview of the key statistics.

Figure 1: World electricity access in developing countries, 2014 (REN21-GSR 2017)

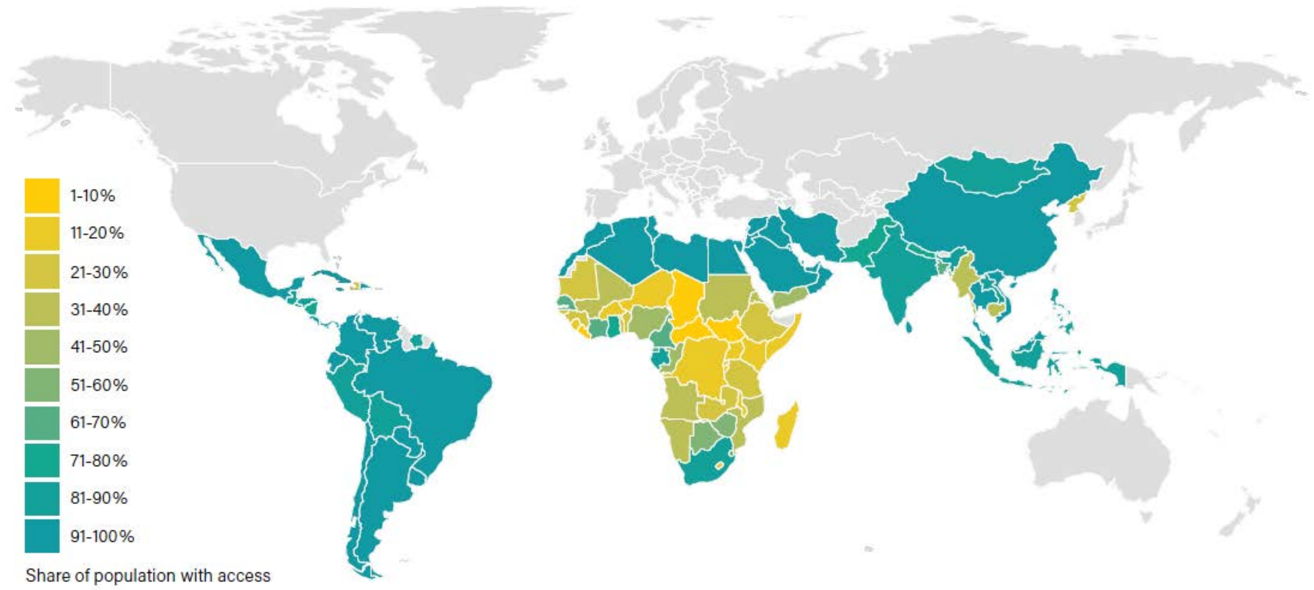
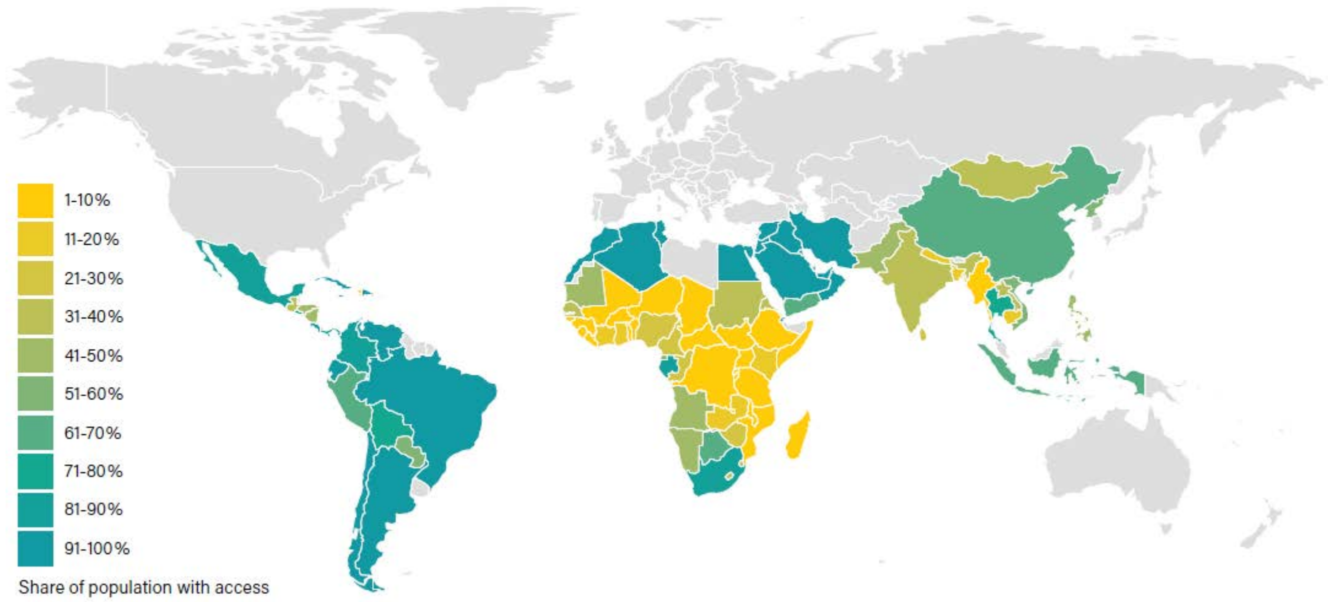


Figure 2: Access to clean cooking facilities in developing countries, 2014 (REN21-GSR 2017)



Status quo: Distributed renewable energy technologies for energy access

Distributed renewable energy (DRE) systems need to provide electricity for lighting, communication and small businesses, as well as energy for residential heating and process heat for applications such as in the agricultural sector and cooking. DRE systems can serve as a complement to centralised energy generation systems, or as a substitute (REN21-GSR 2016). These technologies and systems must operate reliably and with low maintenance requirements over many years, with multiple proven benefits including:

- improved health through the displacement of indoor air pollution
- reduced greenhouse gas emissions
- enabling of small business activities
- increased security, for example, via street lighting at night
- enhanced communications and facilitation of greater quality and availability of education through access to affordable lighting.

Table 2: Examples of Distributed Renewable Energy Use for Productive Energy Services (REN21-GSR2016)

ENERGY SERVICE	INCOME-GENERATING VALUE	RENEWABLE ENERGY TECHNOLOGIES
Irrigation	Better crop yields, higher-value crops, greater reliability of irrigation systems, enabling of crop growth during periods when market prices are higher	Wind, solar PV, biomass, micro-hydro
Illumination	Reading, extension of operating hours	Wind, solar PV, biomass, micro-hydro, geothermal
Grinding, milling, husking	Creation of value-added products from raw agricultural commodities	Wind, solar PV, biomass, micro-hydro
Drying, smoking (preserving with process heat)	Creation of value-added products, preservation of products that enables sale in higher-value markets	Biomass, solar heat, geothermal
Expelling	Production of refined oil from seeds	Biomass, solar heat
Transport	Reaching new markets	Biomass (biodiesel)
TV, radio, computer, Internet, telephone	Support of entertainment businesses, education, access to market news, co-ordination with suppliers and distributors	Wind, solar PV, biomass, micro-hydro, geothermal
Battery charging	Wide range of services for end-users (e.g., phone charging business)	Wind, solar PV, biomass, micro-hydro, geothermal
Refrigeration	Selling cooled products, increasing the durability of products	Wind, solar PV, biomass, micro-hydro

There are three main categories of energy access technology designs. The choice depends on a variety of different factors, one of them being the geographical situation. Furthermore, system designs also serve different business concepts and each of these models has advantages and drawbacks. Standalone, isolated devices and systems for power generation at the household level as well as for heating, cooking and production use mini or micro grid systems to supply whole communities with grid-based electrification, where the grid is extended beyond urban and peri-urban areas (REN21-GSR 2016).

Energy access market development: Power

According to the most recently available data, an estimated 26 million households (or 100 million people) worldwide are served through DRE systems (REN21-GSR 2016).

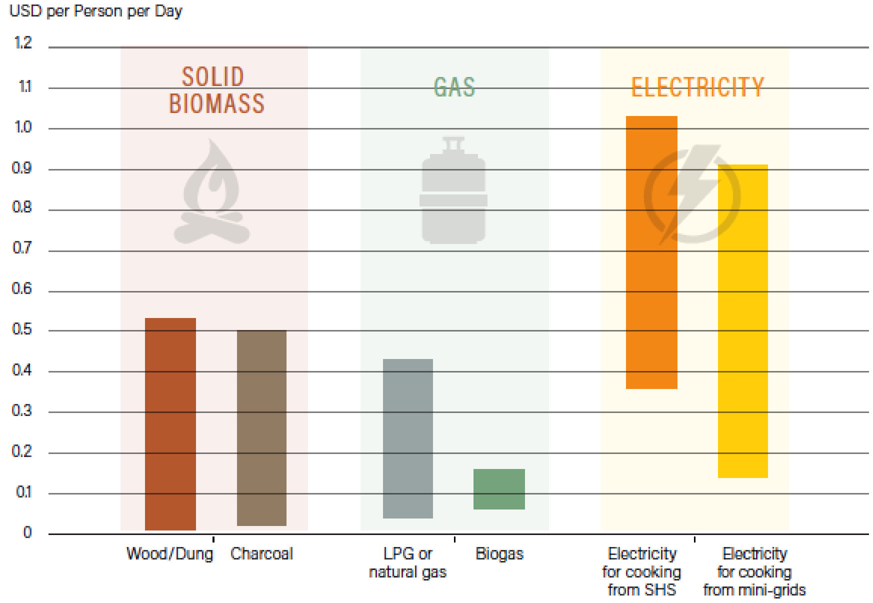
- 20 million households with solar home systems.
- 5 million households with renewables-based mini grids (mainly micro-hydro).
- 0.8 million households supplied by small-scale wind turbines.

Markets for DRE systems continue to grow rapidly, with some countries already experiencing comparatively high market penetration.

Cooking with firewood, gas or electricity

A variety of technologies can provide cooking services in different capacities, with corresponding variances in performance and cost. Wood, charcoal and dung are still widely used around the world as fuels for cooking; dung is a major cooking fuel for about 185 million people. A number of substitutes already exist, including improved and cost-efficient biomass cook stoves, biogas cook stoves and electric hot plates powered by SHS or mini grids. While electric cooking has reduced the consumption of firewood and/or charcoal by between 10 per cent and 40 per cent, biogas stoves – which are more widely used – offer a reduction in consumption levels of between 66 and 80 per cent (REN21-GSR 2017). Electric cooking costs are expected to decrease in line with reducing electricity generation costs for decentralised renewables, in particular solar photovoltaic.

Figure 3: Costs of various cooking technologies (REN21 GSR 2017)



3.3 THE ROLE OF SCENARIOS IN ENERGY POLICIES

Increasing the access to energy in developing countries requires thorough planning based on comprehensive information on all aspects of the energy sector. Scenarios are necessary to describe possible future development paths, giving decision-makers a broad overview of the implications of various options. A scenario is by no means a prognosis of what will happen, but an "if-then" analysis that provides decision-makers with an indication of how they can shape the future energy system.

Three scenarios have been developed to show possible pathways for Tanzania's future energy supply system:

- REFERENCE scenario based on Tanzanian government forecasts and reflecting a continuation of the status quo.
- RENEWABLES scenario focused on renewable energy in the stationary power sector while the transport and industry sectors remain dependent on fossil fuels.
- ADVANCED RENEWABLES scenario for a fully decarbonised power sector by 2030 and a fully renewable energy supply system – including for the transport and industry sectors – by 2050.

Changes to energy markets require long term decision-making because of the potential for changes in infrastructure to be required and are not dependent on short term market developments. Without long-term planning for infrastructure the power market cannot function optimally. Grid modifications and the rollout of smart metering infrastructure, for example, requires several years to implement. These technologies form the basis for the energy market and enable energy trading.

This report specifically looks at possibilities to increase energy access for all citizens from the current 10 per cent to 100 per cent within just over a decade. The Institute for Sustainable Futures has developed the methodology to simulate a bottom-up electrification from mini grids towards an interconnected national power grid on the basis of three energy models. The methodology is documented in Chapter 4.

4 METHODOLOGY AND ASSUMPTIONS

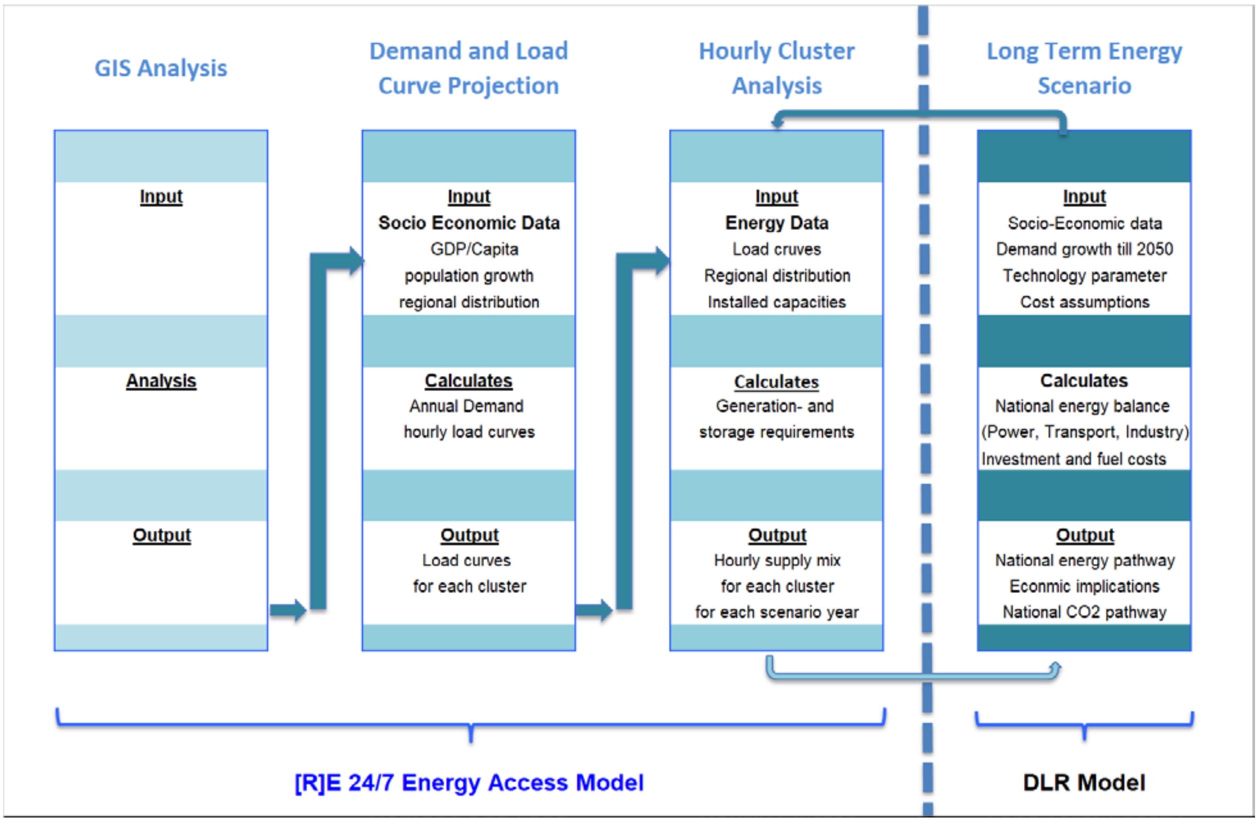
The *[R]E24/7 energy access* pathway methodology was developed by the Institute for Sustainable Futures (ISF) at the University of Technology Sydney (UTS) and based on the long-term energy scenario model of the Institute for Thermodynamics of German Aero Space Centre (DLR), energy models developed for various UTS/ISF surveys and the [R]E24/7[9] model. The following section explains the methodology and provides an overview of the required input parameter, basic functions and calculated outputs.

4.1 MODELLING OVERVIEW

The entire modelling uses four modules:

- GIS analysis:
  - for a regional analysis in regard to population, renewable energy resource and infrastructure
  - to define the cluster break down.
- Demand and load curve projection:
  - for detailed demand development analysis
  - to develop hourly load profiles for full years (8760 hours).
- Hourly cluster analysis for one year:
  - for detailed supply analysis
  - to develop detailed regional energy access and/or energy development plans.
- Long-term energy scenario:
  - for a long term energy development pathway
  - to develop detailed national energy plans including cost- and carbon emissions analysis.

Figure 4: Overview – Modelling concept



4.2 [R]E 24/7 - GIS MAPPING TOOL

The primary purpose of geographic information system (GIS) mapping is to ascertain the renewable energy resources (primarily solar and wind) available in Tanzania. It also contributes to a regional analysis of geographic and demographic parameters as well as available infrastructure that could be leveraged in developing the scenarios.

For this project, the mapping has been undertaken with the computer software '*QGIS*'. *QGIS* is a cross-platform, free and open-source desktop GIS application that supports viewing, editing and analysis of geospatial data. It analyses and edits spatial information in addition to composing and exporting graphical maps, and has been used to allocate solar and wind resources as well as for demand projection for each calculated region. Population density, access to electricity via the central power grid or mini grids and the distribution of wealth, or the economic development projections, are key parameters for the region-specific analysis of Tanzania's future energy situation.

Open source data and maps from various sources are used to visualise the country and its regions and districts. The regions and districts are divided as per the energy cluster concept based on transmission levels (described in detail, further in this section). Further demographic data related to population and poverty, as well as infrastructure for centralised transmission networks, power plants and decentralised mini grids, Mobisol[5] installations, etc., are also plotted on the map.

Table 3: [R]E 24/7 - GIS-mapping – data sources

Data	Source
Regions	National Bureau of Statistics, Tanzania
Land use/land cover	RCMRD GeoPortal
Mini grids	World Bank
Mobisol installations	Mobisol
Population	AfriPop/WorldPop project
Poverty	Afripop dataset
Power plants	Enipedia
Rainfall	World Conservation Monitoring Center (WCMC)
Rivers	Africover, FAO GeoNetwork
Solar irradiance	ESMAP, World Bank
Terrain/topography	Google Satellite / Earth
Transmission lines and network	World Map, Center for Geographic Analysis, Harvard University.
Water bodies	National Bureau of Statistics, Tanzania
Wind speed	IRENA/ESMAP, World Bank

[5] The Berlin-based company Mobisol combines solar energy with a payment plan via mobile phone, which is also used as a customer service and remote monitoring technology. The company offers low-income customers in developing nations quality solar home systems that come in varying sizes, from 80 to 200 Wp to match the various energy needs of differing households. These solar home systems provide electricity to power efficient LED lights, radios, mobile phones, TVs, DC fridges and a variety of further household and consumer appliances. The systems are powerful enough to run small businesses, enabling entrepreneurial customers to create incremental income. In June 2017, Mobisol installed over 85,000 solar home systems in households and businesses in East Africa.

Wind speed data in metres per second at different levels was obtained from ESMAP under the World Bank. For this analysis, wind speed at a height of 50 meters was used to determine the electricity generation potential. Wind speeds are categorised and mapped within the range of 6 to 12 metres per second to gain an understanding of the potential of generation across the country, with speeds under 6 metres per second ignored in order to plot optimal sites. Land cover types were constrained to bare soil, annual cropland, perennial cropland, grassland and ocean, and offshore water bodies (ocean) within 50-60 kilometres of the coast were included in the analysis. As such, it accounts for both onshore and offshore generation potential.

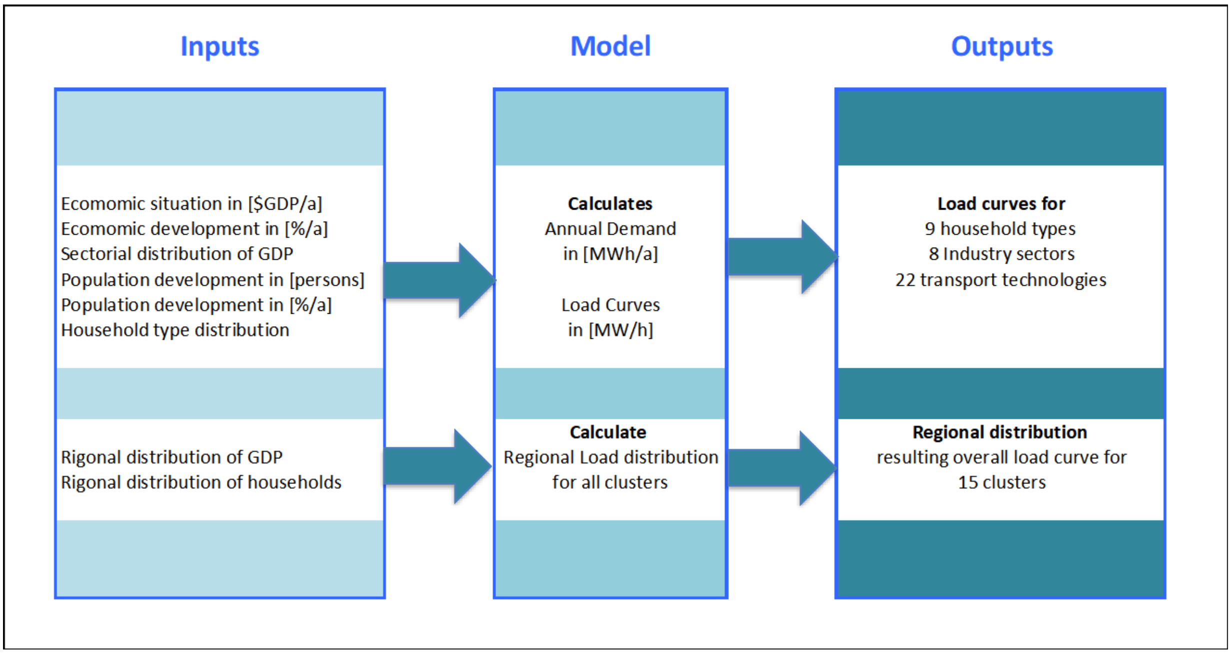
Similarly, solar irradiance data was sourced from ESMAP, World Bank. The average yearly DNI (Direct Normal Insolation/Irradiation) values range from 1 to 5 MWh/m^2 per year, and data categorised by DNI was mapped to estimate the potential of PVs in Tanzania. In order to avoid conflict with competing uses of land, only land cover types of bare soil, perennial cropland and open bushland were included in the analysis.

The area of land available for potential solar and wind power generation was calculated at a national and cluster level using the ellipsoidal area tool in the *QGIS* processing toolbox. Intersects were created between the transmission level layers and the solar/wind utility vector layers to break down the total land area available cluster wise. A correction was put in place for sites that intersected the cluster boundaries and were part of two transmission levels. This input feeds into the calculations for the Energy Access Model as described below.

4.3 [R]E 24/7 – ENERGY ACCESS MODEL

Energy demand projection and load curve calculation are an important factor, especially for energy supply concepts with high shares of variable renewable power generation, in calculating supply security and required dispatch and storage capacities. The detailed bottom-up projection of increased access to energy on the basis of used applications, demand patterns and household types allows a detailed demand forecast. Infrastructure needs such as power grids in combination with storage facilities require an in-depth knowledge of local loads and generation capacities.

Figure 5: Overview – energy demand and load curve calculation module



4.3.1 ENERGY DEMAND PROJECTION AND LOAD CURVE CALCULATION

The [R]E24/7 Energy Access model calculates future power demand development and the resulting possible load curves. Actual load curves – particularly in developing countries with low access to energy rates – do not yet exist and must be calculated based on a set of assumptions. The model generates load curves and resulting annual power demands for three different consumer groups/sectors:

- households
- industry and business, and
- transport.

While each sector has its specific consumer groups and applications, the same set of parameters are used to calculate load curves:

- electrical applications in use
- demand pattern (24hours)
- efficiency progress (base year 2015) for 2020 until 2050, in 5 year steps.

Load curve calculation for households

The model differentiates 9 household groups with various degrees of electrification and equipment:

- Rural – phase 1: Minimal electrification stage
- Rural – phase 2: White goods are introduced and increase the overall demand
- Rural – phase 3: Full equipped western standard household with electrical cooking and air conditioning and vehicle(s).
- Urban single: one person household with minimal equipment
- Urban shared Flat: 3-5 persons share one apartment in the centre of larger cities. Full equipped western household, but without vehicles.
- Urban – Family 1: 2 adults 2-3 children – middle income
- Urban – Family 2: 2 adults more than 3 children and/or higher income
- Suburbia 1: average family, middle income, full equipment high transport demand due to extensive commuting
- Suburbia 2: High income household, fully equipped, extreme high transport demand due to high end vehicles and extensive commuting.

The following electrical equipment and applications can be selected from a drop-down menu:

- Lighting: 4 different light bulb types
- Cooking: 10 different cooking stoves (2+4-burner, electricity, gas, firewood)
- Entertainment: 3 different computer, TV and radio types
- White goods: 2 different efficiency each for washing machines, dryer, fridge, freezer
- Climatisation: 2 different efficiency levels each for fan, air-conditioning
- Water heating: a selection of direct electric, heat pump and solar

Load curve calculation for business and industry

The industrial sector is clustered in 8 groups based on widely used statistical categories:

- Agriculture
- Manufacturer
- Mining
- Iron and steel
- Cement industry
- Construction industry
- Chemical industry
- Service and trade

For each sector are between 2 and 6 different efficiency levels available. The data is taken from international statistical publications [IEA (2016)[6], IRENA (2016)[7], DLR (2012)[8]].

[6] IEA (2016), World Energy Balances, 2016

[7] Report citation IRENA (2016), REmap: Roadmap for a Renewable Energy Future, 2016 Edition. International Renewable Energy Agency (IRENA), Abu Dhabi, www.irena.org/remap

[8] DLR et. al. (2012) Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global Schlussbericht BMU - FKZ 03MAP146 (DLR), (IWES), (IFNE), 29 March 2012

Load curve calculation for transport

The transport sector is divided into individual, public and freight, with the following technologies:

Individual transport

- two-wheeled: bicycle, e-bike, scooter, e-scooter
- combustion engines: small, medium and large (SUV) car
- electric vehicles: small, medium, large fuel cell

Public Transport

- light rail (electric)
- rail (electric)
- rail (diesel)
- mini-bus (diesel)
- mini-bus (electric)
- large bus (diesel)
- large bus electric/fuel cell

Freight transport

- battery electric transport (medium size)
- fuel cell/electric transport (large)
- diesel transport (medium)
- diesel transport (large)

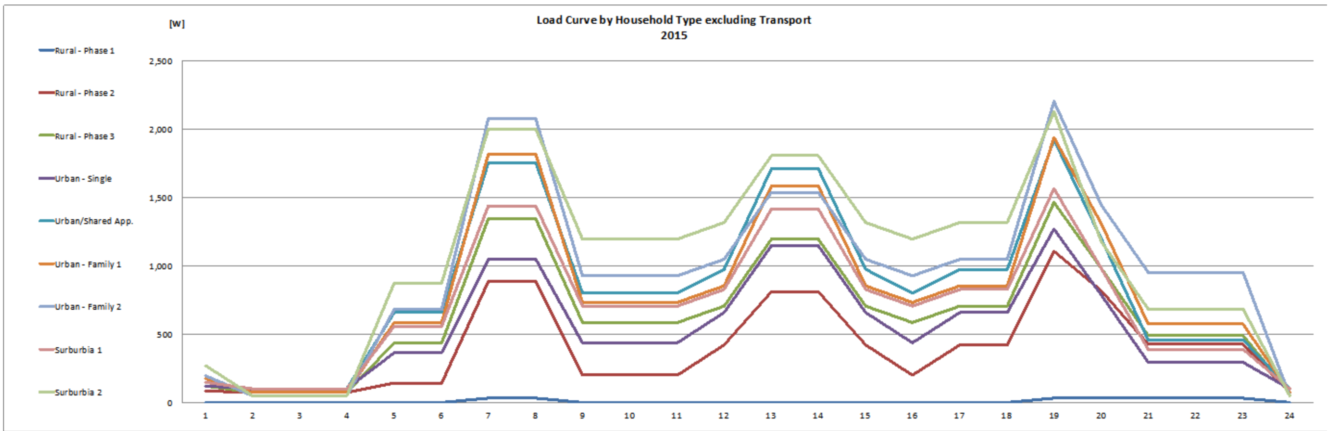
The various vehicles can be assigned to the analysed sectors of households, industry and trade.

Load curve generation via demand pattern

The energy intensities for various industry sectors; small- and medium businesses and transport technologies are derived from the long-term model (see 4.4) and further broken down by hour. Heavy industry sectors are assumed to require baseload, while public- and individual transport are expected to need baseload with demand reduction from midnight until 5am. The development of household profiles are based on interviews with local households in Tanzania about typical demand patterns. with the specific times for meals and their preparation, average equipment features , etc., used for the calculation of possible load curves.

In order to verify assumed demand patterns and calculated load curves, UTS/ISF analysed measured load curves from solar power provider *MobiSol*[5]. Figure 6 shows calculated household demand curves as a result of the above-described methodology.

Figure 6: Calculated household demand curves excluding electricity demand for transport



4.3.2 ENERGY CLUSTER CONCEPT

The basic model has been developed by Teske (2015) under the name RE24/7[9] as a grid analysis tool that uses the commercial MESAP/PlaNet software also used for the long term analysis.

Three-dimensional topographical concept

The topographical concept of the model is key for the methodology, and one cluster represents one specific voltage level in a specific region. The objective of the [R]E 24/7 model is to simulate electricity flows for a variety of different regions and/or countries, and thus uses a modular system of clusters. The individual combinations and the number of those basic model clusters depend on the geographical and technical conditions of the grid. The constant developments in electricity grid technologies over the past decades lead to very different technology combinations, depending on where and when the relevant grid was built. As a result, electricity grids around the world use a combination of different voltage levels for long distance transmission and distribution. Four different grid categories have been developed specifically for the [R]E 24/7 model in order to reflect this, (Table 4).

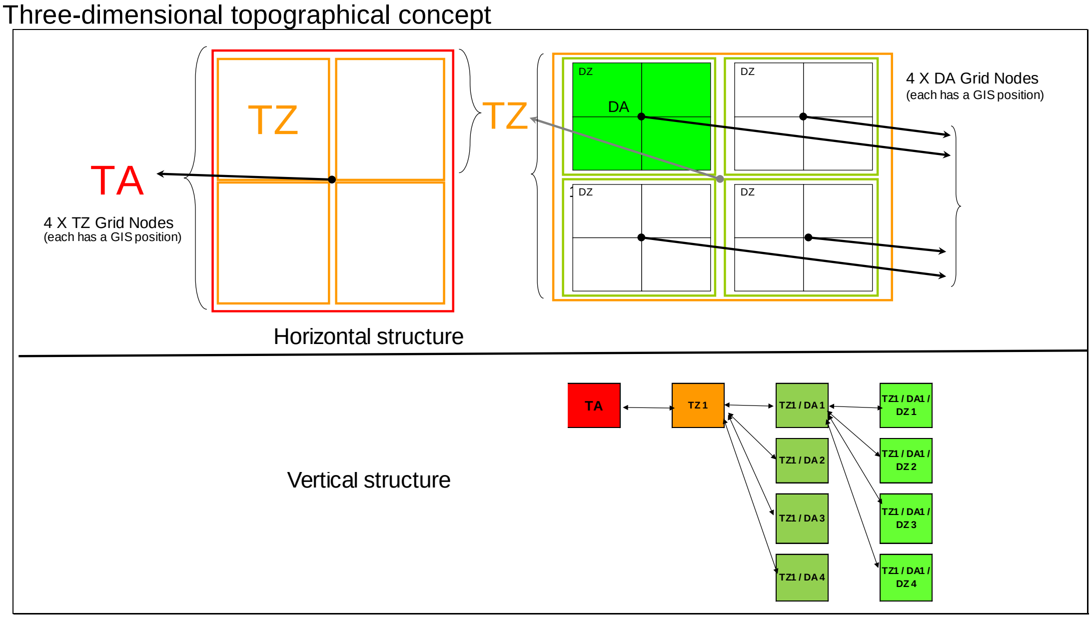
Table 4: Grid categories for the [R]E 24/7 model

Grid category	Voltage Level	Abbreviation	Name in the literature
Transmission area:	≥ 300 kV	TA	Highest voltage
Transmission zone:	≥ 100 kV	TZ	High voltage
Distribution area:	≥ 10 kV	DA	Medium voltage
Distribution zone:	≤ 10 kV	DZ	Low voltage

While high voltage lines transmit electricity over several hundred kilometres, low voltage lines in distribution zones transport electricity across short distances only. The cluster size for each voltage level is therefore different. Transmission Areas (TA) of several hundred kilometres can cover areas of 400 square kilometres or more, and [R]E 24/7 therefore defines this area as the average TA cluster size. For lower voltage levels, the model needs to be simplified and the number of clusters reduced.

The number of clusters for each grid level has been reduced for this analysis in order to keep calculation times for each simulation short and to limit the required amount of input data. If necessary, more than four clusters – for example, for the DZ level – can be implemented in the model. Each cluster represents a grid node so as to identify specific geographical areas for each cluster and to assign the actual grid topology in this region.

Figure 7: Three-dimensional topographical concept



[9] RE24/7 is based on a thesis by ISF Research Director Dr. Sven Teske (2015), 'Bridging the Gap between Energy-and Grid Models: developing an integrated infrastructural planning model for 100% renewable energy systems in order to optimize the interaction of flexible power generation, smart grids and storage technologies', University Flensburg, Germany.

4.3.3 LOAD DISTRIBUTION BY ENERGY CLUSTER

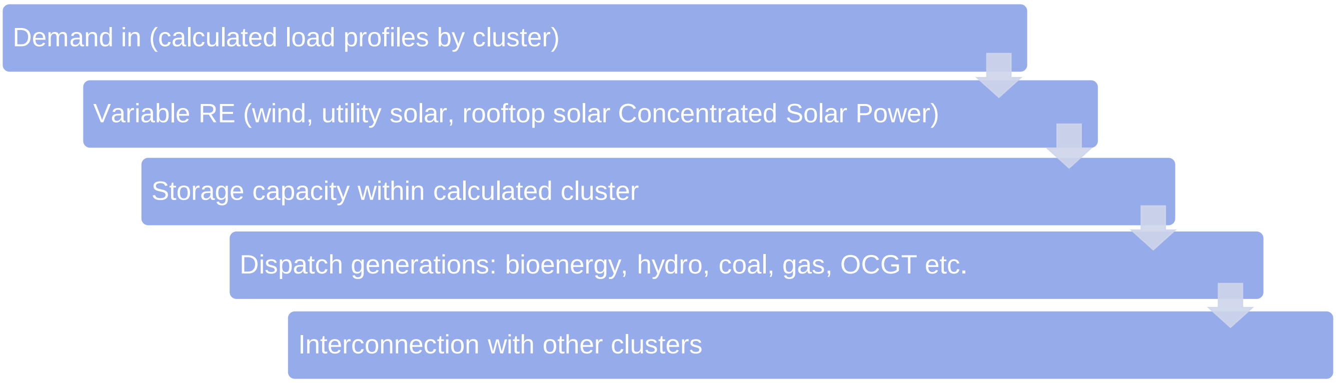
For the Tanzania analysis, the overall number of clusters has been reduced in order to decrease calculation time and data volume. The load distribution for each cluster is connected to the projected GDP and population values for the specific regions. In the first step, the percentages of population distribution and GDP by cluster are defined on the basis of the GIS analysis; in the second step, the resulting population and GDP values are multiplied with normalised load curves calculated as defined in 3.3.1. Each cluster number has an hourly load curve over one entire year (8760 hours).

4.3.4 THE [R]E24/7 DISPATCH MODULE

Though the dispatch module for the [R]E24/7 energy access model has been developed specifically for this study, integral parts have been taken from the model developed for analysis of generation and storage needs for a micro grid on Kangaroo Island (Dunstan, Fattal, James, & Teske, 2016) and Australian Storage Requirements (ACOLA)[10]. The key objective of the modelling is to calculate the theoretical generation and storage requirements for energy adequacy for each cluster and for the whole survey region.

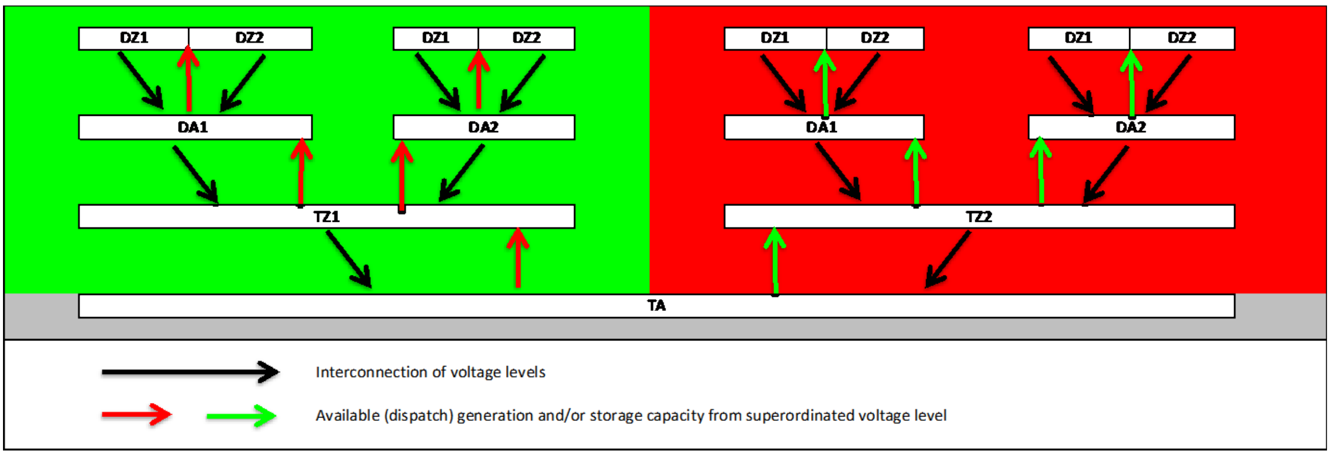
Figure 8 provides an overview of the dispatch calculation process. The dispatch order can be changed in regard to the order of renewables and the dispatch power plant, as well as the order of the generation categories: variable, dispatch generation and storage. Key inputs include the generation capacities by type, demand projections and load curves for each cluster, interconnection with other clusters and meteorological data to calculate solar and wind power generation in hourly resolutions. Installed capacities are derived from the long term projections described in 4.4, while the resulting annual generation in megawatt hours is calculated on the basis of meteorological data (in case of solar and wind) or dispatch requirements.

Figure 8: Dispatch order within one cluster



While the MESAP/PlaNet based RE24/7 model[9] simulates power flows across multiple voltage levels including the high voltage transmission level, the present model iteration does not include constraints in power flows between clusters. The interconnections of clusters are limited to directly connected and/or neighbouring regions in regard to voltage levels. The overall power flow has been simplified as follows:

Figure 9: Interconnection of clusters

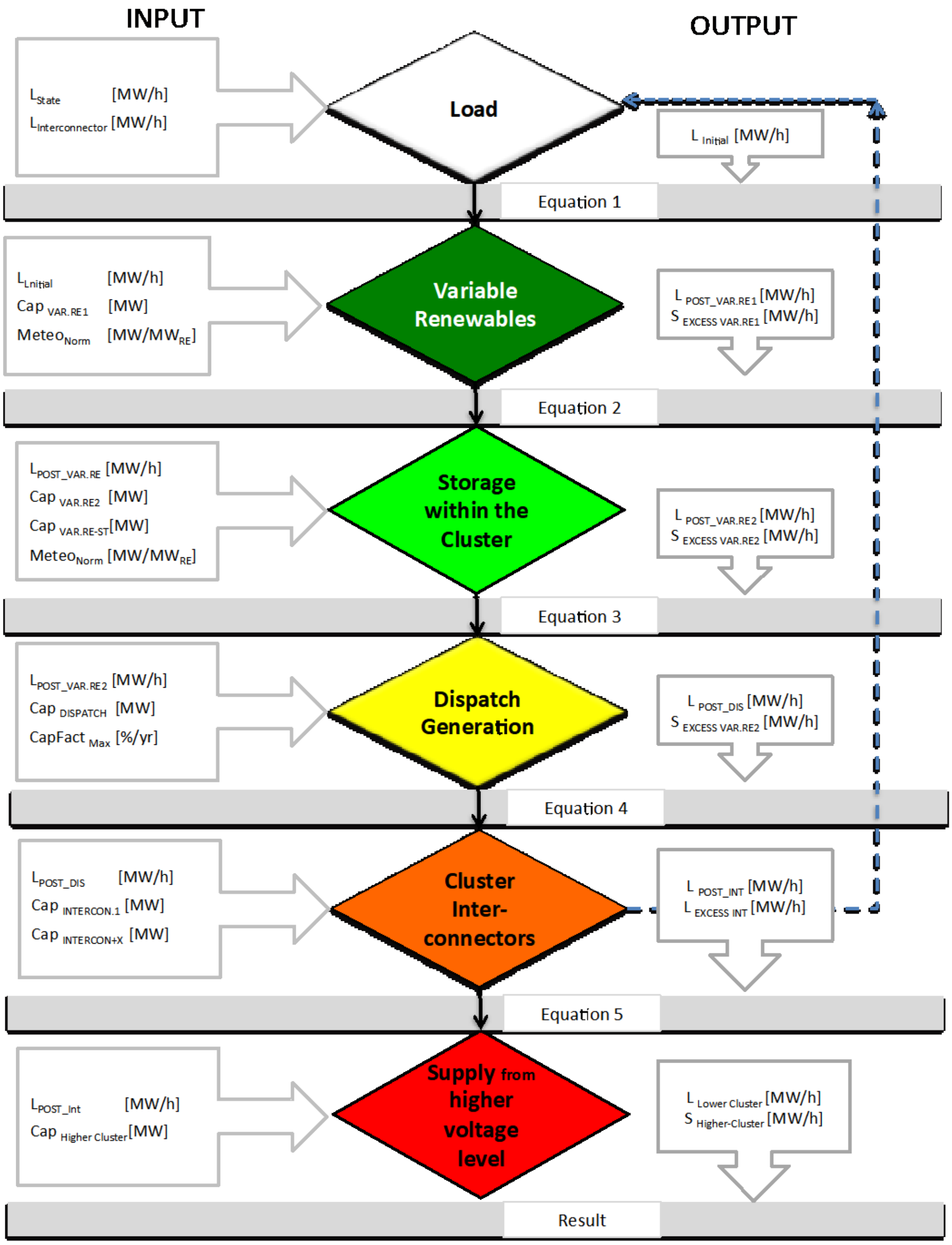


[10] Rutovitz, J., James, G., Teske S., Mpofu, S., Usher, J, Morris, T., and Alexander, D. 2017. Storage Requirements for Reliable Electricity in Australia. Report prepared by the Institute for Sustainable Futures for the Australian Council of Learned Academies (ACOLA)

Overview: input and output – [R]E 24/7 energy dispatch model

Figure 10 provides an overview of the input and output parameter and dispatch order. While the model allows a change in the dispatch order, the 100 per cent renewable energy analysis always follows the same dispatch logic. The model identifies excess renewable production, defined as potential wind and solar photovoltaic generation greater than the actual hourly demand in MW during a specific hour. In order to avoid curtailment, the surplus renewable electricity must be stored in some form of electric storage technology or exported to a different cluster. Within the model, excess renewable production accumulates through the dispatch order. If storage is present, it will charge the storage within the limits of the input capacity. If no storage is included, this potential excess renewable production is reported as 'potential curtailment' (pre-storage). It has been assumed that a certain amount of behind-the-meter consumer batteries will be installed, independent of system requirements.

Figure 10: Overview: input, output and dispatch order



4.4 LONG-TERM SCENARIO MODELLING

The long-term modelling approach used in this research is the development of target-orientated scenarios. In this approach, a target is set and technical scenarios are developed to meet this target and then compared to a reference case. The scenarios are based on detailed input data sets that take into account defined targets, renewable and fossil fuel energy potential and specific parameters for power, heat and fuel generation in the energy systems. The data sets are then fed into a model developed by DLR that uses MESAP/PlaNet software, an accounting framework for the calculation of the complete energy system balance to 2050. The simulation model PlaNet that includes MESAP, an energy and environmental planning package (MESAP, 2008) created to assist long-term strategic planning at a national, regional or local level. PlaNet consists of two independent modules:

1. a flow calculation module, balancing energy supply and demand annually, and
2. a cost calculation module for the calculation of the corresponding generation and fuel costs.

The PlaNet flow calculation uses a set of linear equations that can be solved sequentially. Please note that this is not a dispatch model, such as the [R]E 24/7 energy access model used to calculated a further regional and hourly power, or a technical grid simulation (including frequency stability) such as DIgSILENT's PowerFactory, which is out of the scope of this analysis. The MESAP/PlaNet model is a bottom-up integrated energy balance model. Different modelling approaches each have their benefits and drawbacks; this model is particularly good at helping policy makers and analysts understand the relationships between different energy demand types in an economy – across all sectors and over a longer time period, usually 30 to 40 years.

Historically, heating, electricity and mobility have been quite separate in terms of their energy sources, requiring different infrastructure and therefore planning – electricity for stationary power, petrol and diesel for mobility and onsite heat for buildings and industrial processes. Things are changing, however, with increasing electricity projected for use in heating and mobility, such as via electric vehicles. As such, it is important to take an integrated approach across heat, mobility and electricity/stationary power when developing future energy system scenarios, as this model does.

In a simulation model, the user specifies the drivers of energy consumption, including forecast population growth, GDP and energy intensities.

Specific energy intensities are assumed for:

- electricity consumption per person
- the industrial heat demand to GDP ratio
- demand for energy services, such as useful heat
- different transport modes.

For both heat and electricity production, the model distinguishes between different technologies characterised by their primary energy source, efficiency and costs. Examples include biomass or gas burners, heat pumps, solar thermal and geothermal technologies, and several power generation technologies such as PV, wind, biomass, gas, coal, nuclear, combined heat and power.

For each technology, the market share with respect to total heat or electricity production is specified according to a range of assumptions including targets, potential costs and societal, structural and economic barriers.

The main outputs of the model are:

- final and primary energy demand, broken down by fuel, technology and sectors of the economy as defined by the International Energy Agency (IEA) – industry, power generation, transport and other (buildings, forestry and fisheries)[11]
- results broken down by the three main types of energy demand – electricity, heating and mobility (transport); specifically, the required energy, technology deployment and financial investment for each of these energy demand types
- total energy budget, being the total cost of energy for the whole energy system
- energy-related greenhouse gas emissions over the projection period.

[11] Note these industry sectors correspond to IEA energy statistics input into the model.

5 SCENARIO ASSUMPTIONS

5.1 TANZANIA COUNTRY OVERVIEW

This chapter is based on *Policy Roadmap for 100 per cent Renewable Energy and Poverty Eradication in Tanzania*, a joint publication of Bread for the World, the World Future Council and CAN-International published in May 2017. The parameters in **Table 5** through to **Table 11** of this section are used as inputs for both scenario models.

5.1.1 POLITICAL CONTEXT

Tanzania is a single state under a presidential parliamentary democratic system. The parliament of Tanzania is based in Dodoma, while the government sits in Dar-es-Salaam. The current parliament is the 11th of Tanzania, with 369 members. Political power since independence has remained highly centralised around the presidency, with extensive power and responsible for direct appointment of key members of the executive and judiciary[12].

Tanzania is currently embarked on its second *Five Year Development Plan 2016/17-2020/21* (FYDP II)[13] "to bring about fundamental improvements in the lives of Tanzanians", as expressed by the President of Tanzania. With the theme 'Nurturing Industrialisation for Economic and Human Development', the focus as described by plan has three pillars: industrialisation, human development and implementation effectiveness.

As the Government of Tanzania states, the Five-Year Development Plan has also been designed with the goal of "embarking on broader social and economic transformation" to realise the development aspirations articulated in the *Tanzania Development Vision 2025*[14]. Published by Tanzania Planning Commission in 1999, *Vision 2025* is still the main strategy document in outlining the general development for the country, with the goal of setting "the new driving forces capable to graduate the country from a least developed country to a middle-income country with a high level of human development by 2025".

As part of the efforts devised within *Vision 2025*, Tanzania established the Big Results Now (BRN)[15] initiative in 2012, aiming to speed up project completion in six priority areas – one of which is the energy sector. The prospects of the other five priority areas – agriculture, water, education, transport and mobilisation of resources – lean largely on improving the bottlenecks in the energy system to ensure accessible, affordable and sustainable energy for all. Energy BRN proposes several steps to improve electricity access, strengthen the financial capacity of the public utility Tanzania Electric Supply Company (TANESCO), and develop mini- and off-grid renewable opportunities[16].

As the Tanzanian Ministry of Energy and Minerals outlines in the *National Energy Plan 2015*, the development of the country and their citizens is limited without the opportunity for all citizens to participate in "the mainstream energy economy"**[17]**.

[12] Anyimadu, A. (2016) "Politics and Development in Tanzania: Shifting the Status Quo" https://www.chathamhouse.org/sites/files/chathamhouse/ publications/research/2016-03-18-politics-development-tanzania- anyimadu_1.pdf
[13] For further information, please see: Tanzania Ministry of Finance and Planning (2016) "Five Year Development Plan 2016/17-2020/21 (FYDP II)" http://www.mof.go.tz/mofdocs/msemaji/Five%202016_17_2020_21.pdf
[14] Government of Tanzania: http://www.mof.go.tz/mofdocs/overarch/Vision2025.pdf
[15] For further information, see: Tanzania Prime Minister's Office "Big Results Now (BRN) http://www.pmoralg.go.tz/quick-menu/brn
16 USAID (2015) "Investment Brief for the Electricity Sector in Tanzania" https://www.usaid.gov/sites/default/files/documents/1860/Tanzania%20_ IG_2015_05_03.pdf
[17] Government of Tanzania, Ministry of Energy and Minerals (2015): https://mem.go.tz/wp-content/uploads/2015/02/NATIONAL-ENERGY- POLICY-2015-Feb-2015.pdf

5.1.1.1 POWER SYSTEM MASTER PLAN – 2016 UPDATE

The Ministry of Energy and Minerals of the United Republic of Tanzania published a comprehensive master plan for the country's power system. It stated that:

> *The 2016 Power System Master Plan (PSMP) reflects and accommodates recent development in the economy, including development in the gas sub sector as well as government policy guidelines. The policy guidelines include, among others the desire by the government to accelerate economic growth through the Vision 2025, MKUKUTA and the Five-Year Development Plan–II (2016/17-2020/21, FYDP-II). The government also aims to expedite economic growth by means of the revival and renovation of industries.*
>
> *Among the outcomes associated with the attainment of these objectives, FYDP 2016/17-2020/21 will raise annual real GDP growth to 10 percent by 2021 (from 7.0 percent in 2015), per capita income to US$ 1,500 (from US$ 1,043in 2014) and reduction of the poverty rate to 16.7 percent from 28.2 percent recorded in 2011/12. The Plan also envisages raising FDI flows from US$ 2.14 billion in 2014 to over US$ 9.0 billion by 2021; increase electricity generation from 1,501MW in 2015 to 4,915MW by 2020 and improving electricity connections to 60 percent of the population, up from 36 percent in 2015. On average, manufacturing sector will grow by over 10 percent per annum with its share in total exports increasing from 24 percent in 2014/15 to 30 percent in 2020. The government vision is to become a middle-income country by 2025 with electricity consumption of 490kWh/capita.*
>
> *The fundamental objective is also to attain stable power supply in order to achieve Economic Growth, Energy Security and Environmental Protection. The government of Tanzania set the maximum target to reduce poverty by achieving high economic growth, which could be achieved through a stable and efficient power system.*
>
> *The overall objective of the Plan is to re-assess short-term (2016 - 2020), mid-term (2021 - 2025) and long term (2026 - 2040), generation and transmission plans requirements and the need for connecting presently off-grid regions, options for power exchanges with neighbouring countries, and increased supply of reliable power. While the short-term plan requires immediate decision and actions, the mid - long term plans require coordinated planning and project development studies to ensure that future electricity supply utilizes the least cost projects in consistent with sound planning criteria in order to address national interests. This report has been prepared drawing inference on specific data items or detailed procedures in the previous PSMP 2008 and the subsequent* 2009 and 2012 Update studies.

This master plan provided the basis for the reference case described in chapter 6.1.

5.1.2 POPULATION DEVELOPMENT

Tanzania is East Africa's largest country, with a population of 53,470,420 inhabitants – 45 per cent of whom are under the age of 15. Ranking 27th in the world in terms of its population[18], Tanzania has an average annual population growth rate (1960-2015) of 3.1 per cent and is expected to reach 82.6 million people by 2030[19]. It has a population density of 60 per km^2 [20] and is widely dispersed, with around 70 per cent of the population living in rural areas. In those rural areas there exists significant variation in population distribution; for instance, in the arid regions population density is as low as 1 person per square kilometre, while in the water-rich mainland highland that figure is closer to 53 people per square kilometre[21]. Projections for population and economic growth are important factors in energy scenario-building because they affect the size and composition of energy demand, both directly and through their impact on economic growth and development. World Bank projections detail expected population development (see Table 5).

5.1.3 ECONOMIC CONTEXT

Tanzania is one of the world's poorest economies in terms of per capita income, averaging US$864.90 per year – equivalent to less than 9 per cent of the global average. Though its per capita income is slightly ahead the average per capita income of low income countries (US$615.60), it remains significantly below lower middle-income countries (US$1988.20) and even further from middle income countries (US$4736.70)[22]. Nonetheless, Tanzania has achieved high growth rates based on its vast natural resource wealth and tourism; GDP growth in 2009-15 was 6 to 7 per cent per annum[23], making it one of the 20 fastest growing economies in the world. Over the same period, Tanzania's inflation has been reduced to 5.4 per cent as at March 2016 from the 2011 average of 12.6 per cent. The trade deficit also shrank in the last 5 years, falling from US$5 billion in 2010 to US$3 billion in 2015[24].

Table 5: Tanzania's population and GDP projections

Economic + population development	Parameter	Unit	2015	2020	2025	2030	2035	2040	2045	2050
	GDP (direct input + linked)	[$/a]	46,400,000,000	93,326,973,500	187,713,878,937	316,056,673,674	422,585,748,426	499,405,181,975	578,947,480,035	671,158,803,986
	GDP/Person (calculated)	[$/capita]	868	1,502	2,614	3,826	4,469	4,640	4,759	4,917
	Population (calculated)	[persons]	53,470,420	62,137,471	71,817,765	82,603,769	94,557,831	107,632,136	121,657,019	136,505,977
Annual growth assumptions			**2015**	**2015-2020**	**2020-2025**	**2025-2030**	**2030-2035**	**2035-2040**	**2040-2045**	**2045-2050**
	Economic growth	[%/a]	7.0%	15.0	15.0	10.0	5.0	3.0	3.0	3.0
	Population growth	[%/a]	3.1%	3.1	2.9	2.8	2.7	2.6	2.5	2.3

The economy relies largely on the agricultural sector, which accounts for more than one-quarter of GDP, provides 85 per cent of exports and employs approximately 80 per cent of the work force[25]. Tourism is another key sector; with an average value of US$2 billion a year, in the past three years the tourism sector has delivered Tanzania the largest influx in foreign currency[26]. Construction, wholesale and retail trade, public administration and manufacturing contribute respectively to 12, 10, 7 and 6 per cent of Tanzania's GDP[27].

The 2016/17 budget aims to improve basic infrastructure for the provision of water, power and transportation for industrial development, as well as raising production of agricultural produce used as industrial raw materials[28]. Specifically, the government has budgeted US$2.45 billion (TZS 5.47 trillion)[29] – equivalent to 25.4 per cent of the total budget – for infrastructure projects.

About 5 per cent of the total budget, or US$0.5 billion (TZS 1.13 trillion), will be directed towards the power sector to ensure availability of a reliable power supply for industrial and domestic uses. Among the projects earmarked for implementation are rural electrification and completion of projects such as KinyerezI I and KinyerezI II gas fired electricity generation plants[30].

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[19] World Bank (2016) "Tanzania: Data" http://data.worldbank.org/country/tanzania
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[23] US Central Intelligence Agency (2016) "Economy Overview: Tanzania" https://www.cia.gov/library/publications/the-world-factbook/fields/ print_2116.html
[24] Tanzania Invest (2016) "World Bank projects 7.1% GDP growth rate for Tanzania" http://tanzaniainvest.com/economy/world-bank-wb-tanzania-gdp- growth-2017-2018
[25] US Central Intelligence Agency (2016) "Economy Overview: Tanzania" https://www.cia.gov/library/publications/the-world-factbook/fields/ print_2116.html
[26] Deloitte (2016) "Tanzania Economic Outlook 2016" https://www2.deloitte.com/content/dam/Deloitte/tz/Documents/tax/ Economic%20Outlook%202016%20TZ.pdf
[27] US Central Intelligence Agency (2016) "Economy Overview: Tanzania" https://www.cia.gov/library/publications/the-world-factbook/fields/ print_2116.html
[28] Tralac (2016) "Tanzania Budget Speech 2016/17: "Industrial Growth for Job Creation" https://www.tralac.org/news/article/9859-tanzania-budget- speech-2016-17-industrial-growth-for-job-creation.html
[29] Exchange rate 31.May 2017 – used throughout the report US$1 = Tanzanian Shilling (TZS) 2237
[30] Deloitte (2016) "Tanzania Economic Outlook 2016"
https://www2.deloitte.com/content/dam/Deloitte/tz/Documents/tax/ Economic%20Outlook%202016%20TZ.pdf

5.1.4 SOCIAL CONTEXT

Tanzania is one of the fifty Least Developed Countries (LDCs). While the economic growth experienced by the country has alleviated Tanzania's poverty rates, falling to around 28 per cent in 2012 from 34 per cent in 2007, this growth has not delivered a commensurate reduction in poverty. Today, approximately 12 million Tanzanians still live below the national poverty line – almost unchanged from 2007 due to high population growth – and a significant proportion of the population also risks falling back into poverty in the event of socio-economic shocks[31].

Across the country, urban households are better off than their rural counterparts due to a high gap in assets ownership, employment and educational attainment. Approximately 90 per cent of Tanzania's poor people live in rural areas[32]. The urban-rural differentials in returns to employment of households have widened over time, driven mainly by an increase in returns to wage employment in the public and private sectors and, to a lesser extent, to non-farm businesses in the urban areas[33].

The current *Five-Year Development Plan*'s focus on the education sector rests on improving the quality of education at each level. Likewise, it aims at re-orienting human capital development towards key productive sectors such as agriculture, manufacturing, energy, ICT, transport and tourism[34].

5.1.4.1 Development perspectives

The prospects of Tanzania's socio-economic development lean largely on improving bottlenecks in the energy system. This would improve the management of energy infrastructure, the delivery of health and education services, and an environment conducive to business development and productivity – most notably in key areas such as agriculture.

This is even more critical if we consider:

- population growth prospects – expected to reach 87.2 million by 2030
- increase in energy demand – growing at the rate of 9 t0 10 per cent each year
- newcomers to the employment market – with approximately 800,000 youth entering the labour force every year, nurturing energy infrastructure to allow for productive jobs for them is critically important for the socio-economic development of the country[35].

At present, Tanzania is undertaking a nationwide local government reform program with the goal of reducing the proportion of Tanzanians living in poverty, and of improving quality, accessibility and equity in public service delivery, particularly to the poor. Supporting this commitment are the *Tanzania Development Vision 2025*, the *5 Year Development Plan* and the recent Marrakesh Vision pledge to implement 100 per cent renewable energy as soon as possible.

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[32] IFAD (2014) "Investing in rural people in the Republic of Tanzania" https://www.ifad.org/documents/10180/feb514f1-a0d2-4111-8d98- 50be8ddd0184
[33] World Bank (2015) "Tanzania Mainland Poverty Assessment" http://www.worldbank.org/content/dam/Worldbank/document/Africa/ Tanzania/Report/tanzania-poverty-assessment-05.2015.pdf
[34] UNESCO (2015) "United Republic of Tanzania – Mainland: Education for all 2015 National Review" http://unesdoc.unesco.org/images/0023/002314/231484e.pdf
[35] World Bank (2016) "Tanzania: Overview" http://www.worldbank.org/en/country/tanzania/overview

5.1.5 ENERGY CONTEXT

Tanzania has begun to establish and expand its own national energy market. While still at an early stage, the sector is experiencing rapid growth and is at the heart of the nation's development program.

5.1.5.1 Energy security

Tanzania is largely dependent on imported fossil fuels for its electricity. During the 2014–2015 financial year, the country imported a total of 4.6 billion litres of petroleum products[36]. Tanzania also imports around 16MW of power from Kenya, Uganda and Zambia[37].

This represents a heavy burden on the country's socio-economic development and energy plans. Increasing dependence on fossil fuels is resulting in fuel price shocks and inflation, and is hindering government efforts to expand energy access due to the scarcity of financial resources.

Preliminary studies indicate that carrying out the government's plan to increase the rural electrification ratio to 26 per cent and the urban electrification ratio to 75 per cent will require an investments of approximately US$3.5 billion[38].

In addition, the nearly 1 million tonnes of charcoal consumed annually produces 20 to 50 million tonnes a year in CO^2 emissions and requires an estimated 30 million cubic metres of wood, with annual average loss in forest cover of 100,000 to 125,000 hectares[39]. This energy supply and end use structure reflects Tanzania's low level of development and contributes to the intensification and perpetuation of poverty.

5.1.5.2 Energy (access) policy

The Government of Tanzania is currently implementing a national energy policy – the National Rural Electrification Program (2013–2022) – with the goal of increasing the overall electricity access for country's the population from 36 per cent in 2014 to 50 per cent by 2025, and to at least 75 per cent by 2033.

The National Rural Electrification Program, led by the Ministry of Energy and Minerals and the Rural Electrification Agency, includes both on-grid and off-grid solutions and has four priorities: (i) the connection of new customers to the grid in already electrified settlements; (ii) new connections to the grid; (iii) electrification through off-grid investments; and (iv) the development of distributed technologies, in particular off-grid solar and other renewable technologies[40].

With regard to access to the national grid, only 10 per cent of households in Tanzania are connected and only 1 per cent are able to use electricity for cooking. This situation is compounded by the low level of electrification, where only 7 per cent of rural people and 40 per cent of urban people have access to electricity[41], seriously constraining the population's potential for growth and levels of earning.

Beyond this, the poor spend about 35 per cent of their household income on energy while those who are better off spend only 14 per cent. in addition, even those connected to the grid tend to opt for burning cheaper biomass in an attempt to avoid paying high electricity prices.

5.1.5.3 Energy demand – status quo

In the view of the ENERGY ACCESS SCENARIO, the national energy balance is dominated by biomass-based fuels: about 88 per cent of total energy consumption is biomass in the form of firewood and charcoal for cooking, with rural areas accounting for about 85 per cent of the total primary national energy consumption (1.102 TOE per capita)[42]. Petroleum products comprise 9.2 per cent of total final consumption, while electricity accounts for just 1.8 per cent. Indeed, Tanzania's per capita electricity consumption is very low – less than 108 kWh per year in 2016, compared to Sub-Saharan Africa's average consumption of 550 kWh per year, and the 2,500 kWh per annum global average consumption[43].

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[36] Tanzania Invest (2016) "Tanzania Electricity Profile" http://www.tanzaniainvest.com/energy
[37] Energy Charter Secretariat (2015) "Tanzanian energy sector under the universal principles of the energy charter" http://www.energycharter.org/fileadmin/DocumentsMedia/ CONEXO/20150827-Tanzania_Pre-Assessment_Report.pdf
[38] African Development Bank Group (2015) "Tanzania: Country Profile" http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf
[39] African Development Bank Group (2015) "Tanzania: Country Profile" http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf
[40] Enerdata (2016) "World Bank lends US$200m for electrification project in Tanzania" http://www.enerdata.net/enerdatauk/press-and-publication/energy-news-001/world-bank-loans-us200m-electrification-project-tanzania_37546. html
[41] UNDP (2016) "Tanzania" http://www.undp.org/content/undp/en/home/ ourwork/environmentandenergy/strategic_themes/climate_change/carbon_finance/CDM/tanzania.html
[42] Energy Charter Secretariat (2015) "Tanzanian energy sector under the universal principles of the energy charter" http://www.energycharter.org/fileadmin/DocumentsMedia/ CONEXO/20150827-Tanzania_Pre-Assessment_Report.pdf
[43] Tanzania Invest (2016) "Tanzania Electricity Profile" http://www.tanzaniainvest.com/energy

As at August 2014, the electricity demand growth rate was about 10 to 15 per cent per annum and the peak demand was around 905.05 MW. Tanzania's public utility, TANESCO, anticipates a sustained increase in electricity demand in the coming years as a result of productive investments, population increase and further expansion of electricity access.

5.1.5.4 Energy demand – future projections

Government plan until 2040

The *Tanzania Power System Masterplan 2016* forecasted power demand for the industry and the private sectors and developed three scenarios: high, low and base demand. For the reference case calculated for the long-term scenarios, the base case has been chosen. Due to methodological differences in demand and supply calculation as well as in energy productivity assumption, the results of this analysis may be reached in +/- 5 years compared to results of Tanzania's power system masterplan.

Table 6: Power generation demand forecasts under the *Tanzania Power System Masterplan 2016*

Unit GWh

Year	High	Base	Low
2015	6,310	6,310	6,310
2016	7,870	7,820	7,640
2017	9,070	8,970	8,650
2018	10,460	10,270	9,780
2019	12,040	11,740	11,060
2020	13,840	13,440	12,470
2025	24,640	22,430	19,450
2030	45,270	36,000	29,250
2035	82,830	57,340	43,660
2040	145,470	87,890	63,090
2040/2015	13.4 %	11.1 %	9.6 %

Table 7: Peak power demand forecasts under the *Tanzania Power System Masterplan 2016*

Unit MW

Year	High	Base	Low
2015	974	974	974
2016	1,280	1,270	1,250
2017	1,480	1,460	1,410
2018	1,700	1,680	1,600
2019	1,960	1,920	1,800
2020	2,260	2,190	2,030
2025	4,020	3,660	3,170
2030	7,380	5,870	4,770
2035	13,510	9,350	7,120
2040	23,720	14,330	10,290
2040/2015	13.6 %	11.4 %	9.9 %

5.1.5.5 Energy supply - status quo

Electricity generation, transmission and distribution is provided by a central grid, owned by the state public utility TANESCO (responsible for 98 per cent of electricity supply), and by isolated mini grids in remote areas[44]. Currently Tanzania's generation capacity is 135,769 MW, composed of 56,679 MW (42 per cent) hydro, 607 MW (45 per cent) natural gas and 17,340 MW (13 per cent) liquid fuel. Only 59 per cent of total capacity is supplied by TANESCO; Independent Power Producers (IPP) and Emergency Power Producers (EPP) provide 26 per cent and 13 per cent respectively, which they sell wholesale to TANESCO. In addition, Small Power Producers (SPP) – independent producers with a capacity inferior to 10 MW and who may sell electricity wholesale to TANESCO or to retail consumers – account for 2 per cent of total capacity. Finally, private diesel-based captive generation is estimated at 300 MW nationally, with costs exceeding US$0.35 per kWh[45].

For around two decades now, hydro systems have supplied approximately 80 per cent of electricity needs in the country[46]. The contribution of hydro to the total supply has fallen dramatically in recent years as a result of extensive drought in Tanzania, which has forced TANESCO to use extensive load shedding, thermal power plants for base load, and hire emergency power installations – all at a considerable financial cost[47].

5.1.5.6 Energy supply – future projections

The government has embarked on a long-term strategy to: (i) expand production capabilities from 4175 GWh in 2010 to 47,723 GWh in 2035; (ii) strengthen transmission capabilities, including through the construction of new high voltage 400 kV transmission lines throughout the country[48]; and (iii) increase installed peak capacity seven-fold by 2035, from about 1000 MW in 2013 to around 4700 MW by 2025 and 7400 MW by 2035[49].

Furthermore, the government's plan under the Big Result Now (BRN) initiative, to be implemented by 2020, is to generate 1500 MW from gas, 160 MW from oil, 100 MW from wind, 60MW from solar, 11 MW from small hydropower and 200 MW from coal, as well as 650 MW from estimated geothermal potential[50].

The Power System Masterplan sets up six different generation scenarios (see Table 8). The REFERENCE case in the analysis is according to Scenario-6, with approximately 40 per cent gas, 30 per cent coal and 30 per cent renewables, but with a lower share of hydro power and a higher share of new renewables due to reduced solar and wind power costs.

Table 8: Power development scenarios under the *Tanzania Power System Masterplan 2016*

Scenarios	Generation Mix			
	Gas	Coal	Hydro	Renewable etc.
Scenario-1	50%	25%	20%	5%
Scenario-2	40%	35%	20%	5%
Scenario-3	35%	40%	20%	5%
Scenario-4	25%	50%	20%	5%
Scenario-5	50%	35%	10%	5%
Scenario-6	40%	30%	20%	10%

[44] African Development Bank Group (2015) "Tanzania: Country Profile" http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf
[45] Tanzania Invest (2016) "Tanzania Electricity Profile" http://www.tanzaniainvest.com/energy
[46] Tanzania Ministry of Energy and Minerals (2016) "The Draft National Energy Policy 2015" https://mem.go.tz/wp-content/uploads/2015/02/NATIONAL- ENERGY-POLICY-2015-Feb-2015.pdf
[47] African Development Bank Group (2015) "Tanzania: Country Profile" http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf
[48] Tanzania Ministry of Energy and Minerals (2016) "The Draft National Energy Policy 2015" https://mem.go.tz/wp-content/uploads/2015/02/NATIONAL- ENERGY-POLICY-2015-Feb-2015.pdf
[49] African Development Bank Group (2015) "Tanzania: Country Profile" http://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Renewable_Energy_in_Africa_-_Tanzania.pdf
[50] Energy Charter Secretariat (2015) "Tanzanian energy sector under the universal principles of the energy charter" http://www.energycharter.org/fileadmin/DocumentsMedia/ CONEXO/20150827-Tanzania_Pre-Assessment_Report.pdf

5.1.6 ENERGY ACCESS SCENARIO

The ENERGY ACCESS SCENARIO (EAS) aims to increase access to energy – especially electricity – for all by 2050 while increasing the electrification and comfort standard to the level of industrialised countries. The growing economy requires a reliable power supply for small and medium businesses (SME's), industry and the transport sector. It is assumed that households will use modern and energy-efficient applications according to the highest efficiency standards in order to slow down the power demand growth, and to allow the parallel expansion of energy infrastructure and the construction of renewable power plants. The electrification will be organised from the 'bottom up' in a new and innovative approach developed by UTS/ISF: **3-Step–Solar-Swarm Grid (3SG) expansion** – from pico grid via micro grid to transmission grids.

Currently more than 70,000 households in Tanzania get (limited) access to electricity via start-up companies such as Mobisol and/ bboxx. Those companies supply small solar systems in varying sizes from 80 to 200 Wp to match the various energy needs of differing households. Solar home systems (SHS) provide enough electricity to power bright efficient LED lights, radios, mobile phones, TVs, DC fridges and a variety of further household and consumer appliances. However, this development is not currently coordinated with the national grid expansion plans of the Tanzanian government. The project aims to develop a technical and economic concept along with a real test case, to interconnect SHS to a micro grid in a first step and, in a second step, a number of micro grids to a distribution power grid, equal to those in industrialised countries. As a third and final step, distribution grids will be interconnected to a transmission grid.

The industry will continue to expand on-site power generation (auto-produce) for their own supply – wherever possible with cogeneration plants – and as dispatch power plants for balancing high shares of grid-connected utility-scale solar PV and wind. Fuel will move from natural gas to biogas and/or hydrogen and synfuels after 2030.

5.1.6.1 Energy access – household demand

The electric applications for each of the nine household types will gradually increase from those with very basic needs, such as light and mobile phone charging, to a household standard matching that of industrialised countries. Table 9 shows the electrical equipment assumed for each household type. In order to phase out unsustainable biomass for cooking, a direct leap from cook stoves to electrical cooking is assumed. The third phase of a rural household includes an electric oven, fridge, a washing machine, air-conditioner and entertainment technologies and aims to provides the same level of comfort as households in urban areas in industrialised countries. An adjusted level of comfort for households in the city and in rural areas aims to prevent residents – especially young people – from leaving their homeland and moving into big cities.
Rapidly expanding cities proved problematic as infrastructure for transport and energy supply and the requirements of residential apartment buildings cannot match the demand, often leading social tensions.

Table 9: Equipment per household type – assumptions for all scenarios

	Rural - Phase 1	Rural - Phase 2	Rural - Phase 3	Urban - Single	Urban/Shared App.	Urban - Family 1	Urban - Family 2	Suburbia 1	Suburbia 2
Persons per household	12	10	8	2	4	8	8	4	4
Equipment									
Lightbulbs	1	3	5	10	14	10	15	15	20
TV/Radio	0	1	2	1	2	2	3	1	3
Computer	0	1	2	1	2	2	3	1	3
Cooking	0	1	1	1	1	1	1	1	1
Washing Maschine	0	1	1	1	1	1	1	1	1
Dryer	0	1	1	1	1	1	1	1	1
Fridge	0	1	1	1	1	1	1	1	1
Freezer	0	1	1	1	1	1	1	1	1
Other applicances	0	1	1	1	1	1	1	1	1
Fan	0	1	2	1	2	2	3	1	3
AIRCON	0	0	1	1	2	2	2	2	3
Water heating (technology	0	1	1	1	1	1	1	1	1

According to the most recent survey, published by the Ministry of Energy and Mineral (MEM) and the National Bureau of Statistics in December 2016, 67.3 per cent of Tanzania's households have access to electricity. The percentage varies significantly between urban households (97.3 per cent) and rural households (49.3 per cent)[51].

However, the majority of households had an annual per capita demand of under 100kWh per year. The analysis presented in this report assumes a higher degree of electrical applications leading to higher annual power demands per household.

The development of the country-wide share of various household types is presented in Table 10. The electrification starts with basic household types such as rural phase 1, urban family 1 and suburbia 1 and moves to better equipped households. Thus, the share of fully-equipped households grows constantly while the basic households increase in the first years and decrease towards the end of the modelling period. By 2050, the majority of households have a medium to high comfort equipment degree.

The authors of this report have deliberately chosen a higher standard for Tanzania's households in order to close the gap between households in industrialised countries and developing countries and achieve greater equity.

Table 10: Household types – development of shares countrywide

Household Types - Development of shares - average countrywide		2015	2020	2025	2030	2035	2040	2045	2050
Annual electricity consumption below 100 kWh/a		**90.0%**	**85.0%**	**50.0%**	**30.0%**	**25.0%**	**10.0%**	**5.0%**	**0.0%**
1	Rural - Phase 1	3.0%	4.0%	10.0%	10.0%	5.0%	3.0%	2.0%	1.0%
2	Rural - Phase 2	2.0%	2.0%	10.0%	25.0%	30.0%	35.0%	35.0%	30.0%
3	Rural - Phase 3	1.0%	2.0%	10.0%	10.0%	15.0%	25.0%	30.0%	40.0%
4	Urban - Single	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	Urban/Shared App.	1.0%	2.0%	2.0%	3.0%	3.0%	3.0%	3.0%	3.0%
6	Urban - Family 1	1.0%	2.0%	5.0%	6.0%	6.0%	7.0%	7.0%	7.0%
7	Urban - Family 2	0.5%	1.0%	5.0%	6.0%	6.0%	7.0%	7.0%	9.0%
8	Surburbia 1	1.0%	1.0%	5.0%	6.0%	6.0%	6.0%	6.0%	6.0%
9	Surburbia 2	0.5%	1.0%	3.0%	4.0%	4.0%	4.0%	4.0%	4.0%

5.1.6.2 Energy access –industry and business demand

Analysis of Tanzania's economic development is based on the 2015 GDP breakdown, and assumes that the overall structure of the economy does not change and that all sectors grow at equal rates to GDP (see Table 5). Agriculture and services and trade remain the backbone of Tanzania's economy, followed by construction, chemical and other industries such as mining.

Table 11: Development of GPD shares by industry sector

Industry and Business	GDP shares [%]	2015	2020	2030	2040	2050
Industry		71%	71%	71%	71%	71%
1	Manufaction / Industry	6.0%	6.0%	6.0%	6.0%	6.0%
2	Mining	4.0%	4.0%	4.0%	4.0%	4.0%
3	Iron + Steel	6.0%	6.0%	6.0%	6.0%	6.0%
4	Cement	6.0%	6.0%	6.0%	6.0%	6.0%
5	Construction	12.0%	12.0%	12.0%	12.0%	12.0%
6	Chemical Industry	8.0%	8.0%	8.0%	8.0%	8.0%
7	Agriculture	29.0%	29.0%	29.0%	29.0%	29.0%
Service and Trade		29.0%	29.0%	29.0%	29.0%	29.0%
8	Food/Trade	17.0%	17.0%	17.0%	17.0%	17.0%
9	Tourism	5.0%	5.0%	5.0%	5.0%	5.0%
10	Office	7.0%	7.0%	7.0%	7.0%	7.0%

[51] Energy Access Situation Report, 2016, Tanzania Mainland, The United Republic of Tanzania, February 2017, http://www.nbs.go.tz/nbs/takwimu/rea/Energy_Access_Situation_Report_2016.pdfhttp://www.nbs.go.tz/nbs/takwimu/rea/Energy_Access_Situation_Report_2016.pdf

5.1.6.3 Energy Access – Demand Transport

The development of transport demand for electric vehicles is shown in Table 12 . Public transport will gradually move from diesel trains and buses to electric drives, especially in urban areas. The electrification of individual transport is assumed to start after 2025 due to the high cost of plug-in hybrid or fully electric cars, and the need for infrastructure such as charging stations and strong distribution grids. Tanzania will benefit from the development and experience of industrialised countries and will transition to electric mobility once all technical and economic challenges are addresses. The electrification of the individual transport sector will start with e-bikes.

Table 12: Development of transport demand by demand sector

Transport - Freight	2015	2020	2030	2040	2050
Freight [ton km/person]	4,000	4,500	5,500	6,500	7,500
Freight [ton km]	213,881,680,000	279,618,621,130	454,320,727,102	699,608,881,413	1,023,794,825,502
Service + Agriculture	29%	29%	29%	29%	29%
Industry	71%	71%	71%	71%	71%

TRANSPORT	2015	2020	2030	2040	2050
e-Mobility - Individual Transport					
Rural - Phase 1	0.0%	0.0%	0.0%	0.0%	0.0%
Rural - Phase 2	0.0%	0.0%	10.0%	30.0%	100.0%
Rural - Phase 3	0.0%	0.0%	10.0%	30.0%	100.0%
Urban - Single	0.0%	0.0%	10.0%	30.0%	100.0%
Urban/Shared App.	0.0%	0.0%	10.0%	30.0%	100.0%
Urban - Family 1	0.0%	0.0%	10.0%	30.0%	100.0%
Urban - Family 2	0.0%	0.0%	10.0%	30.0%	100.0%
Surburbia 1	0.0%	0.0%	10.0%	30.0%	100.0%
Surburbia 2	0.0%	0.0%	10.0%	30.0%	100.0%
e-Mobility - Public Transport					
Rural Transport	0.0%	0.0%	0.0%	0.0%	0.0%
Urban Transport	0.0%	0.0%	10.0%	30.0%	100.0%
Long Distance	0.0%	0.0%	10.0%	30.0%	100.0%
e-Mobility - FRIGHT Transport					
Service + Agriculture	0.0%	10.0%	20.0%	30.0%	100.0%
Industry	0.0%	10.0%	20.0%	30.0%	100.0%

5.1.7 FUEL PRICE PROJECTIONS

Global oil prices have fluctuated dramatically in recent years, and this has been considered in the price projections for this modelling. In the IEA's *World Energy Outlook 2014*, oil price projections by 2040 range from $100 per barrel in the '450-ppm scenario' up to $155 per barrel in the 'Current Policies scenario' (in 2013 USD). At the time of this analysis in mid-2017, the oil price was around US$50 per barrel, with a historic low of only US$30 per barrel in January 2016. Gas prices have also fluctuated significantly and international coal prices fell dramatically to reach a low of US$50 per tonne in early 2016.

To account for these fluctuations, the IEA's 2014 projections have been adjusted to the fuel prices of January 2016, which were less than half the price originally projected for that year. The oil price assumption for all futures is taken from the IEA *World Energy Outlook 2014* '450-ppm scenario'.

Given the very high uncertainties of fossil fuel price projections, this research has taken into account the following cost projections for the power generation sector (coal and gas):

- the IEA WEO High Coal and Gas Price Scenario (WEO 2014)
- a continuing low coal price (as at January 2016), with the price staying at this current low price through to 2050
- a low coal price (as at January 2016), with the price recovering (escalating) in line with the IEA's trajectory
- a low gas price (as at January 2016), with the price recovering (escalating) in line with the IEA's trajectory
- the average coal price of the past five years and prices increasing according to the IEA's trajectory.

Table 13: Development projections for fossil fuel and biomass prices in US$/GJ

in US$/GJ		2015	2020	2025	2030	2035	2040	2045	2050
	IEA WEO High Price	4.7	5.1	5.9	6.3	6.6	7.0	7.3	7.6
	Historic low price	1.6	1.7	2.0	2.1	2.2	2.4	2.4	2.5
	Average price	2.3	2.5	3.0	3.2	3.3	3.6	3.6	3.8
	Continuing low price	2.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	IEA WEO High Price	16.2	19.1	20.6	22.1	23.6	25.1	27.4	29.7
	Historic low price	5.4	6.4	6.9	7.3	7.9	8.4	9.2	9.9
	High price	7.7	9.1	9.8	10.5	11.2	11.9	13.0	14.1
	Current and continuing low price	7.7	9.1	9.1	9.1	9.1	9.1	9.1	9.1
Crude oil	IEA WEO	18.3	21.5	23.1	24.8	24.8	24.8	24.8	24.8
	DLR	3.6	3.9	4.1	4.3	4.6	4.7	5.1	5.3
	Biomass and waste	1.7	1.8	2.0	2.1	2.1	2.3	2.4	2.5

Source: IEA WEO 2014, DLR/GPI - Energy [R]evolution 2015

The results presented in 6.1 utilise the fossil fuel and biomass price projections of the IEA WEO HIGH Price scenario.

5.1.8 COST PROJECTIONS FOR INVESTMENT, OPERATION AND MAINTENANCE COSTS

Assumptions for the specific investment and operation costs of coal, gas, brown coal and oil power plants have been made according to the World Energy Outlook (WEO) *2014 Special Report on Investments*[52]. Because these resources are at an advanced stage in terms of both technology and market development, the potential for cost reduction is limited. Various renewable energy technologies have different costs, levels of technical maturity and development potential. While hydropower has been widely used for decades, other technologies – such as the gasification of biomass or ocean energy – have yet to reach market maturity; other renewable technologies being employed today are at a relatively early stage in market development, while others have already developed mature markets. It is expected, however, that those large cost reductions can come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades. By their very nature, some renewable sources, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. However, although in many cases renewable energy technologies are 'distributed' – their output being generated and delivered locally to the consumer – they also have large-scale applications like offshore wind parks, photovoltaic power plants or concentrating solar power stations.

To identify long term cost developments, learning curves have been applied to the model calculations to reflect how the cost of a particular technology changes in relation to cumulative production volumes. For many technologies, the learning factor (or progress ratio) sits between 0.75 for less mature systems to and 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10 per cent every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years, whilst that for wind energy varies from 0.75 in the UK to 0.94 in the German market.

ISF's research partner, the German Aerospace Centre (DLR) Institute for Technical Thermodynamics, Technology and System-Analysis, developed cost projections for renewable energy technologies. Assumptions on future costs for renewable electricity technologies were derived from a review of learning curve studies of Lena Neij[53], the analysis of technology foresight and road mapping studies, including the European Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[54], the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

In 2014 and 2015, DLR updated and revised those cost projections for the Greenpeace International Energy [R]evolution research[55]. Due to significant cost decreases between 2014 and 2016, recent market developments have been taken into account leading to a further reduction in assumed costs , particularly for photovoltaics and solar thermal power plants (including heat storage). However, to increase consistency in the modelling, cost assumptions from WEO 2014 are adopted for biomass power plants, hydro, wind power and ocean energy.

These cost assumptions – especially for the base years – have been adapted to current Australian costs on the basis of the Australian Power Generation Technology Report[56]. Future cost projections have been compared with several other projections including the International Renewable Energy Agency (IRENA) Renewable Power Generation Costs in 2014[57].

It should be noted that all the publications referred to above are within the same cost estimation range. These cost assumptions – investment, operation and maintenance costs – are detailed in Appendix A. It should also be noted that the solar PV costs listed in Appendix A assume an average between rooftop and utility-scale solar PV.

Numerous cost projections, particularly for renewable power generation technologies – have been published in recent years. In August 2017, a comprehensive survey – the *2017 Annual Technology Baseline* (ATB) – was published by the US-based National Renewable Energy Laboratory (NREL)[58]. All publications show that renewable power generation continues to reduce costs, though costs vary significantly by region. In this research, a conservative cost reduction rate has been chosen due to the relatively small size of Tanzania's current renewable energy market. Even with high growth rates, the market is likely to remain small in

[52] IEA 2014: *Power Generation in the New Policies and 450 Scenarios - Assumed investment costs, operation and maintenance costs and efficiencies in the IEA World Energy Investment Outlook 2014*, data file download: http://www.worldenergyoutlook.org/investment/
[53] Neij, L, 'Cost development of future technologies for power generation - a study based on experience curves and complementary bottom-up assessments', *Energy Policy* 36 (2008), 2200-2211
[54] www.needs-project.org
[55] This research has been undertaken for more than 10 years and resulted in more than 100 country analyses
[56] CO2CRC Limited, 2015, *Australian Power Generation Technology Report*:, Australia, www.co2crc.com.au
[57] IRENA, *Renewable Power Generation Costs in 2014*, January 2014, Abu Dhabi, www.IRENA.org
[58] National Renewable Energy Laboratory (NREL), Annual Technology Baseline (ATB) August 2017, https://www.nrel.gov/news/press/2017/nrel-updates-baseline-cost-and-performance-data-for-electricity-generation-technologies.html

comparison to global standards, therefore the cost reductions assumed in this analysis are conservative and may be larger, further increasing the economic benefits of the RENEWABLES cases.

5.1.9 ASSUMPTIONS FOR HYDROGEN AND SYNFUEL PRODUCTION

In the ADVANCED RENEWABLES scenarios, hydrogen and sustainable synthetic fuels (synfuels) are introduced as a substitute for natural gas and make up a significant share of transport fuels after 2030. Hydrogen is assumed to be produced via electrolysis, resulting in an additional electricity demand supplied by extra renewable power production capacity, predominantly from wind, PV and CSP.[59] Renewable hydrogen and synthetic fuels are essential for a variety of sectors.

- For the industry sector, hydrogen serves as an additional renewable fuel option for high-temperature applications, supplementing biomass in industrial processes, whenever direct use of renewable electricity is not applicable.
- The transport sector also increasingly relies on hydrogen as a renewable fuel, where battery-supported electric vehicles reach their limitations and where limited biomass potential restricts the extension of biofuel use. However, future hydrogen applications may not be sufficient to replace all fossil fuel demand, especially in aviation, heavy duty vehicles and navigation. The ADVANCED RENEWABLES study introduces synthetic hydrocarbons from renewable hydrogen, electricity and biogenic/atmospheric CO_2. These synfuels are introduced after 2030 and provide for the remaining fossil fuel demand that cannot be met by biofuels due to limited potential**.**

5.1.10 RENEWABLE ENERGY POTENTIAL

Information on renewable energy potential is taken from the African-EU Renewable Energy Initiative (website)[60], a survey from the World Future Council, Bread for the World and Climate Action Network, WFC (2017)[1], along with additional research by UTS/ISF. Tanzania has a high and mostly untapped potential for renewable energy sources, and the only resource significantly in use at a large scale is hydropower. Additionally, small hydropower has excellent potential and is particularly feasible in rural areas. Biomass resources are mostly exploited in traditional but unsustainable ways, though there exists great potential in the large amounts of organic waste generated by the agricultural sector. Solar energy is abundant, with initial efforts being undertaken to exploit this resource through both off-grid and grid-connected solutions. Wind resources have been assessed with promising results, and plans are underway for future developments. The World Bank is mapping renewable energy resources within their ESMAP Programme (RECP 2017)[61].

Wind energy

Based on the available information, Tanzania has plentiful wind resources, with much of it located around the Great Lakes, the plains and the highland plateau regions of the Rift Valley. Wind resource assessments indicate that areas such as Kititimo (Singida) and Makambako (Njombe) have adequate wind speed for grid-scale electricity generation. Small-scale off-grid wind turbines along the coastline and in the islands also hold great potential in Tanzania, where areas of wind power potential cover more than 10 per cent of the country. This are is equivalent in size to Malawi and has greater potential than the US state of California, as underlined in a recent World Bank report[62].

Initial assessments have shown Tanzania to have promising wind resources, with Kititimo (9.9 m/s average wind speed at 30m) and Makambako (8.9 m/s) identified as having adequate wind speeds for grid-scale electricity generation. The Ministry, in collaboration with TANESCO, is conducting wind resource assessments on eight further sites throughout the country, and additionally the REA supports wind measurements on Mafia Island. To date, four private companies have expressed interest in investing in wind energy, considering construction of farms in the 50 to 100 MW range (RECP).

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[59] Note this is also good for balancing the energy system – on very windy and sunny days, where generation exceeds supply, the excess generation can be used to create synfuels.
[60] https://www.africa-eu-renewables.org/market-information/tanzania/tanzania-renewable-energy-potential/
[61] (RECP 2017) Texts with those references are taken from the RECP website. RECP = The Africa-EU Renewable Energy Cooperation Programme is a multi-donor programme that supports the development of markets for renewable energy in Africa; it was launched by more than 35 African and European Ministers and Commissioners under the Africa-EU Energy Partnership (AEEP).
[62] World Bank (2015) “Tanzania: Solar and Wind Potential Could Help Meet Future Power Generation Goals” http://www.worldbank.org/en/news/feature/2015/06/09/tanzania-solar- and-wind-potential-could-help-meet-future-power-generation-goals

Solar energy

Tanzania enjoys average annual solar radiation levels of between 4 and 7 kWh/m^2 per day. As grid electricity reaches roughly only 1 per cent of the nation's rural population, the use of solar electricity is an attractive option given Tanzania's abundant sunlight.

Solar photovoltaic

Since 2014, it is estimated that more than 500 kWp of PV has been installed across Tanzania for various applications, with 30 to 40 per cent of the total installed capacity consisting of Solar Home Systems (SHSs) – though its application in solar cooking, pasteurising and advanced solar crop drying is not widely practiced. Taken as a whole, solar photovoltaic and thermal technologies are still under development, as indicated by John F Kitonga, senior engineer at the Ministry of Energy and Minerals of the United Republic of Tanzania in *Tanzanian energy sector under the universal principles of the Energy Charter*[63].

To date, only about 6 MWp of PV solar has been installed. In a country with such a potential for solar power capacity, solar photovoltaic can play a key role in the provision of affordable, sustainable and locally generated electricity for lighting, heating and ventilation systems, as well as drying – most notably in areas where connection to the main grid is not economically viable.

The government, through the REA and various donors, has supported a number of solar PV expansion programs. One grid-connected PV plant has been commissioned to date, with the 1 MW plant producing around 1800 MWh/year. The potential for grid-connected solar PV is estimated at 800 MW (RECP 2017).

In the short-term, the *Power System Master Plan (PSPM) 2007-2031* envisages the construction of 120 MW of PV capacity by 2018. Several private companies have expressed interest in developing 50–100 MW solar plants (RECP 2017).

Concentrated solar power (CSP)

Tanzania has promising levels of solar energy, which would allow the installation of concentrated solar power plants (CSP) ranging between 2,800 and 3,500 hours of sunshine per year and a global horizontal radiation of 4–7 kWh per m^2 per day. Solar radiation is particularly high in the central region of the country (RECP 2017). There are no CSP project developments known by the time of the research (May/June 2017).

Table 14 shows the required areas for three types of renewable energy technologies.

Technology		Unit	2020	2030	2040	2050	Percentage of landmass of Tanzania (for 2050)
	Total installed capacity	GW	1.25	8.41	27.50	44.84	
	Specific nominal capacity	kW/m^2	0.15	0.16	0.17	0.17	
	Area	km^2	1	8	28	45	
	Total installed capacity	GW	1.20	12.40	26.68	50.92	
	Average capacity	MW	3.00	3.50	5.00	7.00	
	Number of plants	#	400	3,543	5,335	7,275	
	Specific nominal capacity	MW/km^2	4	5	5	7	
	Area	km^2	300	2,480	5,335	7,275	
	Total installed capacity	GW	0.00	4.00	11.08	20.92	
	Average capacity	MW	6.00	7.50	8.50	9.00	
	Number of plants	#	0	533	1,303	2,325	
	Specific nominal capacity	MW/km^2	7	8	9	10	
	Area	km^2	0	485	1,185	2,113	

[63] Energy Charter Secretariat (2015) "Tanzanian energy sector under the universal principles of the energy charter" http://www.energycharter.org/fileadmin/DocumentsMedia/ CONEXO/20150827-Tanzania_Pre-Assessment_Report.pdf

Geothermal energy

Tanzania has geothermal potential in most parts of the East African Rift Valley System, with some of the prominent sites being Songwe (Mbeya), LuhoI (Rufiji), Lake NatronI (Manyara) and KisakI (Morogoro). In addition, some coastal areas also show surface manifestations of geothermal resources. Estimates of Tanzania's geothermal potential indicate that the country could generate about 650 MW of electricity, however this potential has not yet been used and has only been explored to a limited extent[64].

Bio energy

The country has considerable biomass resources from forest and agricultural residues. There are about 15 million tonnes per annum of crop residues, animal droppings from 14 million cattle and 11 million goats and sheep, 200,000 tonnes of volatile solid sisal waste and 1.1 million tonnes per year of forest residues – with an estimated potential of 500 MW[65]. In addition to this, the more than 17,000 hectares of sugarcane plantations offer an estimated co-generation potential of more than 315 GWh per year, which is equal to 11 per cent of the current national electricity generation[66] (BfdW).

While there is currently only one grid-connected biogas plant (18 MW) in place, several agro-industrial companies have constructed captive power systems based on biomass to generate electricity for their operations. The potential for modern biomass uses is high, considering that the available raw material is abundant and includes 1.5 million tonnes per year (MT/a) of sugar bagasse, along with sisal (0.2 MT/a), coffee husk (0.1 MT/a), rice husk (0.2 MT/a), municipal solid waste (4.7 MT/a) and forest residue (1.1 MT/a) (RECP 2017).

In summary, there are 7.8 million tonnes of biomass available for energy generation in Tanzania.

Hydropower

Hydropower has traditionally been the main source of electricity in Tanzania, however intermittent river flows have decreased its reliability. Another key challenge facing hydropower is the regional mismatch between hydro sites and major demand centres, with a strengthened transmission system required for further development. Tanzania does intend to further develop its large-hydro capacity with estimated potential calculated as high as 4,000 MW; the *Power System Master Plan* (PSMP) includes 16 projects with a combined capacity of 3,000 MW to be finalised by 2031 if developed large hydropower still exceeds 30 per cent of generation capacity after 2025 (RECP 2017).

Of the presented installed grid connected capacity, two small-scale hydro power plants are owned by TANESCO (Nyumba ya Mungu 8MW, Uwemba 4MW), and a further two by private developers (Mwenga 4MW, Yovi 1MW). Beyond these existing developments, Tanzania has significant small hydropower potential (installed capacity <10 MW) estimated at 315 MW. Further site level assessments undertaken by TANESCO and financed by the Ministry of Energy and Minerals (MEM) have identified 131 specific small hydro sites across the country, while complimentary economic analysis has concluded that a number of sites are commercially viable for generating electricity for the national or mini grids (RECP 2017).

[64] Mnjokava, T. (2012) "Geothermal Development in Tanzania – a Country Update" https://www.geothermal-energy.org/pdf/IGAstandard/ ARGeo/2012/Mnjokava.pdf
[65] UNDP (2016) "Tanzania" http://www.undp.org/content/undp/en/home/ ourwork/environmentandenergy/strategic_themes/climate_change/carbon_ finance/CDM/tanzania.html
[66] Energy Charter Secretariat (2015) "Tanzanian energy sector under the universal principles of the energy charter" http://www.energycharter.org/fileadmin/DocumentsMedia/ CONEXO/20150827-Tanzania_Pre-Assessment_Report.pdf

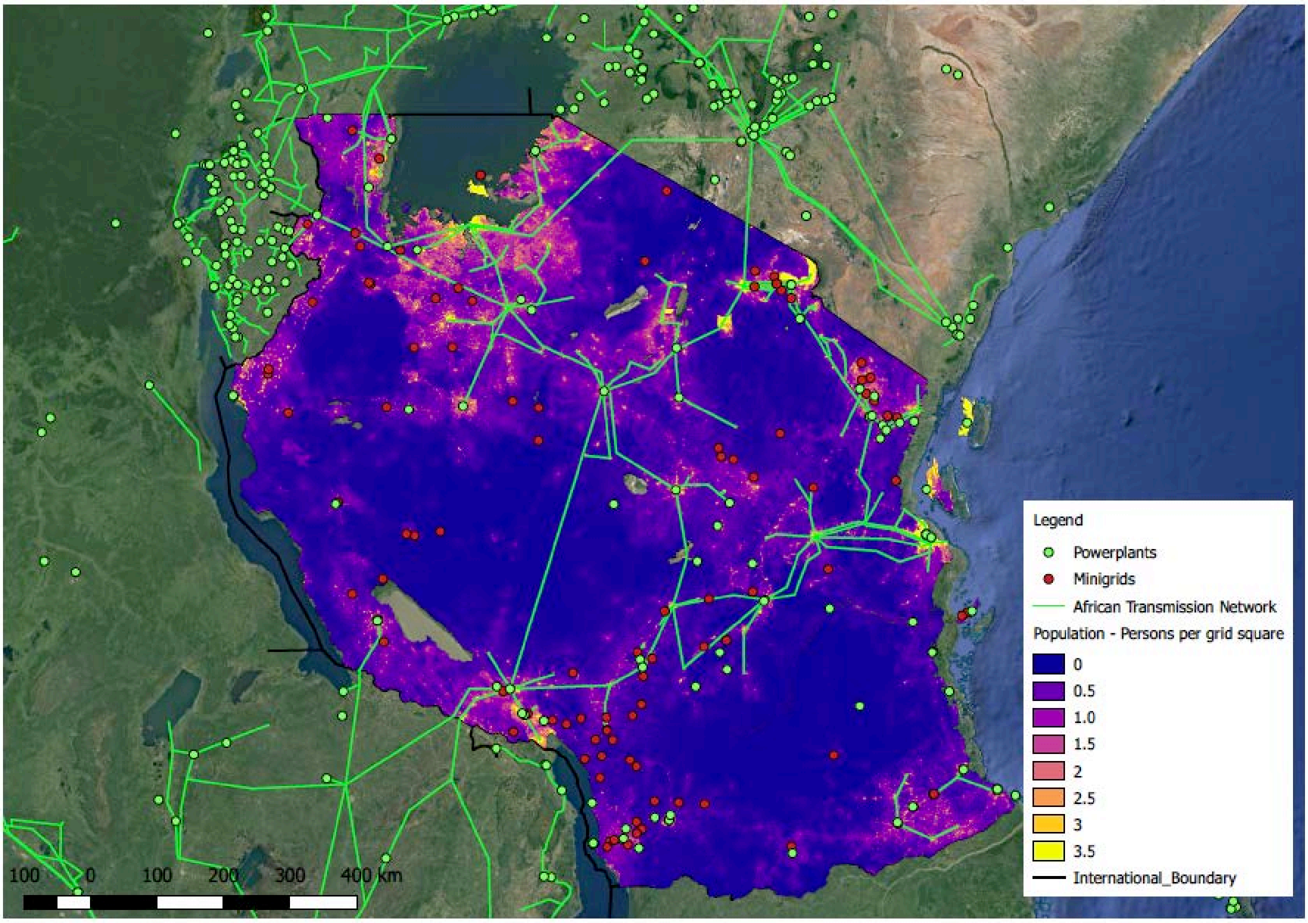
5.2 TANZANIA – ASSUMPTIONS BY REGION

The regional distribution of demand and supply is based on interviews with experts in Tanzania and the results of mapping analysis with QGIS (see 4.2) as input data for the [R]E 24/7 energy access analysis. This section provides an overview of the key mapping results.

Distribution of population, power grid and poverty

The distribution of Tanzania's populations in relation to the existing power grid is shown in Figure 11. The majority of the population lives around the Lake District and the city of Mwanza in the north, between Arusha near the Kilimanjaro National Park and Tanga on the east coast, Dar-es-Salam and the city of Mbeya and on the south close to the border of Sambia and Malawi. The power grid connects those main population centers while mini grids are distributed across Tanzania.

Figure 11: Distribution of population in relation to existing power grid and mini grids



Source: ISF mapping, August 2017

Figure 12 shows the distribution of poverty in relation to the existing power grid and mini grids. The map shows that poverty is at the highest levels where there is no energy infrastructure. It also shows the location of power plants, and shows several power plants not connected to the main power grid that supply mining or other industrial processes directly. Those power plants are listed under auto producers in the results table (see ANNEX).

Figure 12: Distribution of poverty in relation to existing power grid and mini grids

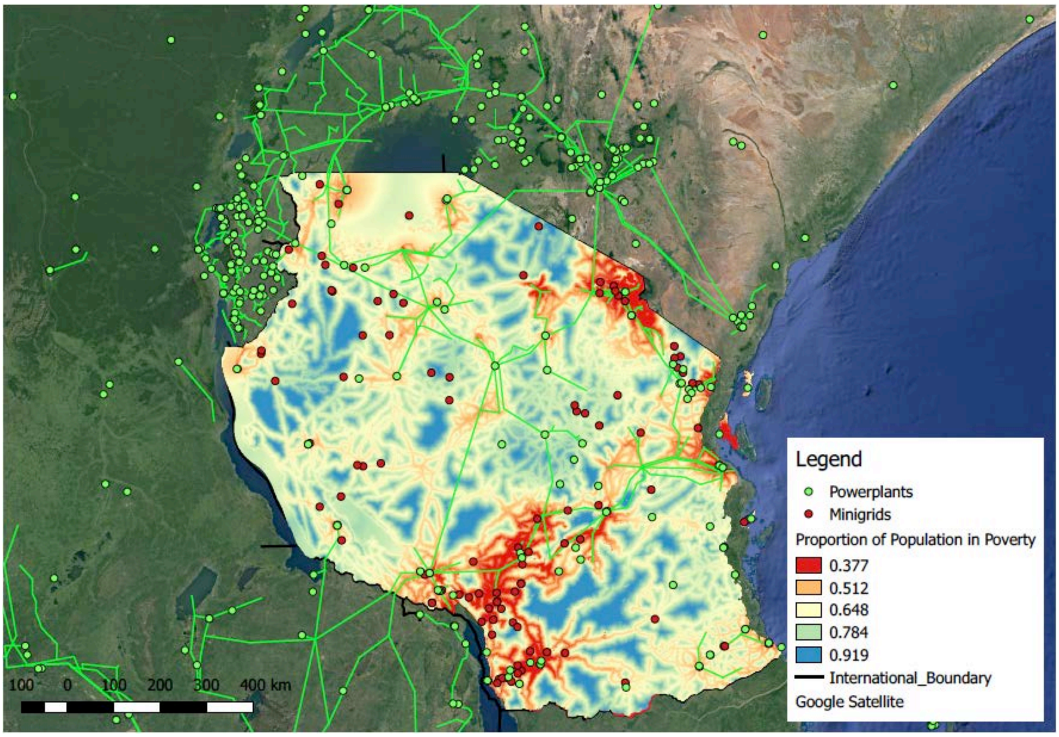
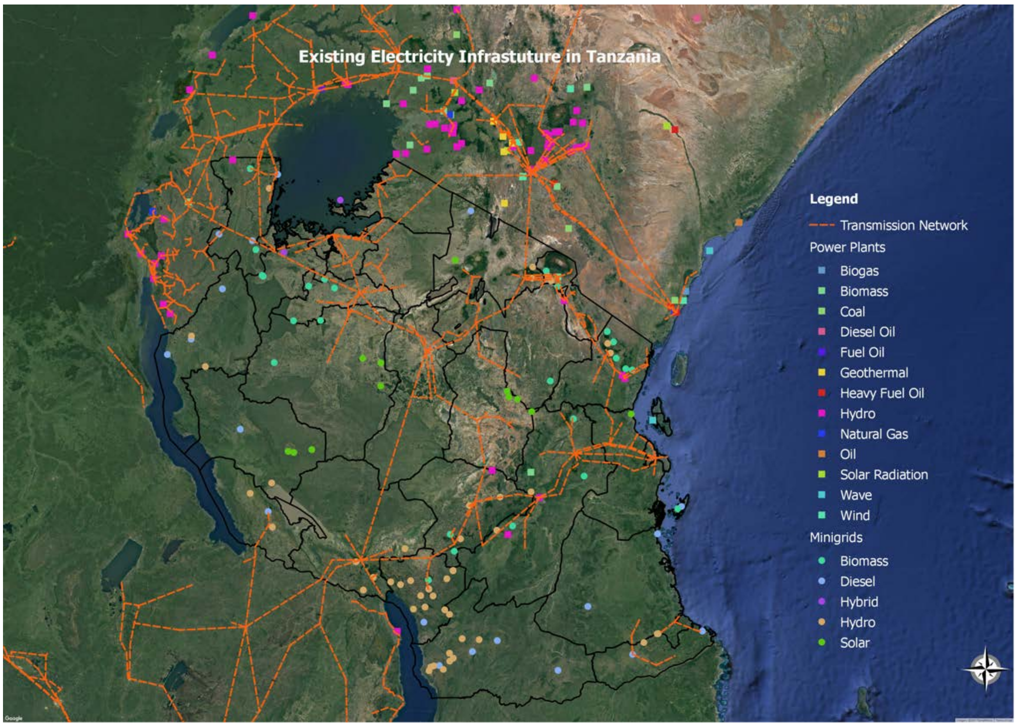


Figure 13 shows the different types of grids and power stations in the country. In addition to the main grid, there are mini grids distributing power generated from biomass, diesel, hydro and solar, represented by the circles. Similarly, larger power plants that feed into the grid are represented as squares. The different colors highlight the fuel source, ranging from fossil fuel-based coal and oil plants to alternative fuel-based solar, biomass and wind power plants.

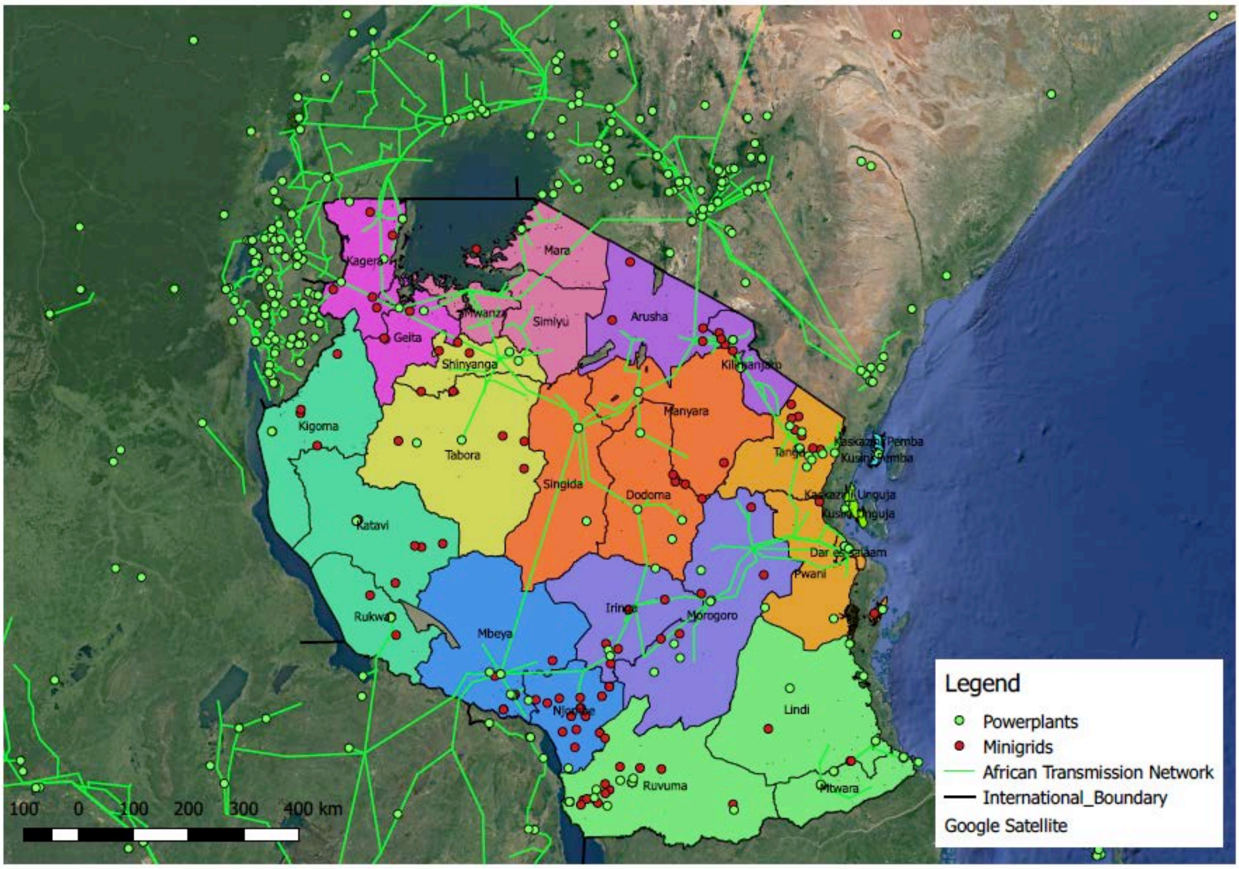
Figure 13: Existing electricity infrastructure by type



For regional modelling, the following 10 regions have been allocated (see Figure 14):

1. Lake Zone: Shinyanga, Geita, Mara, Simiyu, Mwanza and Kagera
2. Northern Highlands Zone: Manyara, Arusha, Kilimanjaro
3. Southern Coast Zone: Mtwara and Lindi
4. Western Zone: Tabora, Katavi and Kigoma
5. Southern Highlands Zone: Iringa, Njombe, Songwe, Rukwa and Mbeya
6. Northern Coastal Zone: Tanga, Morogoro and Pwani
7. Southern Zone: Ruvuma
8. Central/Capital: Dodoma and Singida
9. Dar-es-Salam
10. Zanzibar Island

Figure 14: Regional breakdown for this project



Source: ISF mapping, August 2017

Regional breakdown of economic activity

Based on information from experts in Tanzania, economic activities have been assigned for each of the modelling clusters. These economic activities influence the demand projection in each region.

		DZ1	Households	Lake Zone: Mining, fishing, agriculture, high population Shinyanga, Geita, Mara, Simiyu, Mwanza and Kagera
		DZ2	Households	Northern Highlands Zone: Mining, agriculture, tourism Manyara, Arusha, Kilimanjaro
		DZ1	Households	Southern Coast Zone: Agriculture, fishing, mining Mtwara and Lindi
		DZ2	Households	Western Zone: Fishing, agriculture, mining Tabora, Katavi and Kigoma
		DZ1	Households	Southern Highlands Zone: Agriculture, fishing, mining, tourism, livestock Iringa, Njombe, Songwe, Rukwa, and Mbeya
		DZ2	Households	Northern Coastal Zone: Fishing, tourism, agriculture Tanga, Morogoro and Pwani
		DZ1	Households	Southern Zone: Coal, gas, mining, agriculture Ruvuma
		DZ2	Households	Central/Capital: Livestock, agriculture Dodoma and Singida

5.3 OVERVIEW – LONG TERM SCENARIO

Tanzania needs to build up and expand its power generation system to be almost entirely new in order to increase the energy access rate to 100 per cent. Building new power plants – no matter what the technology – will require new infrastructure, such as power grids, spatial planning, a stable policy framework and access to finance.

With decreased prices for solar photovoltaic and onshore wind in recent years, renewables have become an economic alternative to building new gas power plants. As a result, renewables achieved a global market share of over 50 per cent of all new build power plants since 2014. Tanzania is blessed with vast solar and wind resources, and renewables generation costs are generally lower with increased solar radiation and wind speeds. However, constantly shifting policy frameworks often lead to high investment risks and therefore higher project development and installation costs for solar and wind projects relative to countries with more stable policy.

The scenario-building process for all scenarios includes assumptions on policy stability, the role of future energy utilities, centralised fossil fuel based power generation, population and GDP, firm capacity and future costs.

- **Policy stability:** This research assumes that Tanzania will establish a secure and stable framework for the deployment of renewable power generation. In essence, financing a gas power plant or a wind farm is quite similar. In both cases a power purchase agreement, which ensures a relatively stable price for a specific quantity of electricity, is required to finance the project. Daily spot market prices for electricity and/or renewable energy or carbon are not sufficient for long-term investment decisions for power plants with technical lifetimes of 20 years or longer.
- **Strengthened energy efficiency policies:** Existing policy settings, namely energy efficiency standards for electrical applications, buildings and vehicles, will need to be strengthened in order maximise cost-efficient use of renewable energy and achieve a high energy productivity by 2030.
- **Role of future energy utilities:** With 'grid parity' of rooftop solar PV under most current retail tariffs, this modelling assumes that the energy utilities of the future take up the challenge of increased local generation and develop new business models that focus on energy services, rather than just on selling kilowatt-hours.
- **Population and GDP:** The three scenarios are based on the same population and GDP assumptions. Projections of population growth are taken from the *World Population Review* [18] while the GDP projection assumes long-term average growth of around 2 per cent per year over the scenario period, as documented in Section 4.1.3.
- **Firm capacity:** The scale of each technology deployed and the combinations of technologies in each of the three scenarios target a firm capacity. Firm capacity is the "proportion of the maximum possible power that can reliably contribute towards meeting peak power demand when needed."[67] Firm capacity is important to ensure a reliable and secure energy system. Note that fluctuating or variable renewables still have a firm capacity rating, and the combination of technology options increases the firm capacity of the portfolio of options (see also 'security of energy supply' point in the RE scenarios).
- **Cost assumptions:** The same cost assumptions are utilised across all three scenarios. As technology costs decline with deployment scale rather than time, the renewable energy cost reduction potential in both RENEWABLES cases may even be larger than in the REFERENCE case due to larger market sizes. The reverse is true for the fuel cost assumptions as all three scenarios are based on low fossil fuel price projections; while both RENEWABLES scenarios have a significant drop in demand, the REFERENCE case assumes increased demand that may lead to higher fuel costs. As such, the costs should be considered conservative. The cost assumptions are documented in section 4.1.4.

[67] http://igrid.net.au/resources/downloads/project4/D-CODE_User_Manual.pdf

5.3.1 THE REFERENCE SCENARIO

The REFERENCE scenario (REF) reflects a continuation of current policies and is based on Tanzanian Government forecasts in the *Tanzania Power System Masterplan 2016* (5.1.5.4). Energy statistics are taken from the International Energy Agency's *World Energy Balances of OECD Countries 2016*[68] as well as other sources documented in Sections 5.1.5.3 to 5.1.4.1.

5.3.2 ASSUMPTIONS FOR BOTH RENEWABLES SCENARIOS

Both the RENEWABLES (RE) and ADVANCED RENEWABLES (ADV RE) scenarios are built on a framework of targets and assumptions that strongly influence the development of individual technological and structural pathways for each sector. The main assumptions considered for this scenario-building process are detailed below.

- **Emissions reductions:** the main measures to meet CO_2 emission reductions in the RE and ADV scenarios include strong improvements in energy efficiency resulting in doubling energy productivity over the next 10 to 15 years, and the dynamic expansion of renewable energy across all sectors.
- **Renewables industry growth**: dynamic growth in new capacities for renewable heat and power generation is assumed based on current knowledge about potential, costs and recent trends in renewable energy deployment (see energy potentials discussed in Section 4. and 5). Communities will play a significant role in the expansion of renewables, particularly in regard to project development, inclusion of local population and operation of regional and/or community owned renewable power projects.
- **Fossil fuel phase-out:** the operational lifetime for gas power plants is conservatively estimated to be 40 years. In both scenarios, coal power plants are phased out early on, followed by gas power plants**.**
- **Future power supply:** the capacity of large hydropower remains flat in Tanzania over the entire scenario period, while the quantities of bioenergy grow within the nation's potential for sustainable biomass (see below). Wind power and solar power – both photovoltaic and concentrating solar power (CSP) – are expected to be the main pillars of future power supply, complemented by smaller contributions from bioenergy, geothermal (hydrothermal and Enhanced Geothermal Systems [EGS]), and the future expansion of small and medium-sized ocean energy. Note that solar PV figures combine both rooftop and greenfield development.
- **Security of energy supply:** the scenarios limit the share of fluctuating or variable power generation and maintain a sufficient share of controllable, secured capacity. Power generation from biomass and CSP, as well as a share of gas-fired back-up capacities and storage, are considered important for the security of supply in a future energy system, related to the output of firm capacity discussed above.
- **Sustainable biomass levels:** the sustainable level of biomass use for Tanzania is assumed to be limited to 1000 PJ. Low-tech biomass use, such as in inefficient household wood-burners, are largely replaced in the RENEWABLES scenarios by state-of-the-art technologies, primarily highly efficient cogeneration plants.
- **CSP technology:** CSP implementation after 2030 was assumed to include thermal energy storage to provide energy for 12 hours per day of full-load turbine operation. This requires additional collector fields which are only used to produce steam for storage purposes, and additional costs are assumed for CSP storage.
- **Electrification of transport**: efficiency savings in the transport sector are a result of fleet penetration with new highly efficient vehicles such as electric vehicles, but also assumed changes in mobility patterns and the implementation of efficiency measures for combustion engines. The scenarios assume limited use of biofuels for transportation given the limited supply of sustainable biofuels.
- **Hydrogen and synfuels:** hydrogen and synfuels generated by electrolysis using renewable electricity are introduced as a third renewable fuel in the transportation sector, complementary to biofuels, the direct use of renewable electricity and battery storage. Hydrogen generation can have high-energy losses; however, the limited potential of biofuels and mostly likely also battery storage for electric mobility mean it is necessary to have a third renewable option in the transport sector. Alternatively, this renewable hydrogen could be converted into synthetic methane and liquid fuels depending on economic benefits (storage costs versus additional losses) as well as technology and market development in the transport sector (combustion engines versus fuel cells).

[68] International Energy Agency, 2017, *World Energy Balances of OECD Countries.* Available at: https://www.iea.org/statistics/relateddatabases/energybalancesofoecdcountries/

5.3.3 THE RENEWABLES SCENARIO

The RENEWABLES scenario (RE) is designed to meet Tanzania's energy-related targets to achieve 100 per cent renewable energy as soon as possible, as outlined in section 5.1. The energy efficiency projections for each sector are calculated as documented in section 4.3. The renewable energy trajectories for the initial years are taken from the joint publication of the World Future Council, Bread for the World and Climate Action Network[1] *Policy Roadmap for 100% Renewable Energy and Poverty Eradication in Tanzania*, published in May 2017. Renewable energy markets in developing countries are projected to grow at a rate equal to the renewable energy markets of OECD countries, with consistent and reliable energy policies over the past decade and into the next decade. In addition, pathways for the deployment of renewable energy and efficiency measures reflect the technology trends of recent years and market estimations of the solar photovoltaic, wind industry and other innovative technologies.

This scenario includes significant efforts to fully exploit the extensive potential for energy efficiency available through current best-practice technology. At the same time, various proven renewable energy sources are integrated – to a large extent for electricity generation, and also to a lesser extent for the production of synthetic fuels and hydrogen for heating (domestic, commercial and industrial) and transport.

5.3.4 THE ADVANCED RENEWABLES SCENARIO

The ADVANCED RENEWABLES scenario (ADV RE) takes a more ambitious approach to transforming Tanzania's entire energy system towards 100 per cent renewable energy supply. The consumption pathways remain almost the same as in the RENEWABLES scenario, however under this scenario a much faster introduction of new technologies leads to a complete decarbonisation of energy for stationary energy (electricity), heating (including process heat for industry) and transportation. The latter requires a strong role for storage technologies such as batteries, synthetic fuels and hydrogen.
The resulting final energy demand for transportation is lower compared to the RENEWABLES scenario based on the assumptions that:

- Future vehicles and particularly electric vehicles will be more efficient and
- There will be greater improvement in the public transport system

The ADVANCED RENEWABLES scenario increases the share of electric and fuel cell vehicles. This scenario also relies on greater production of synthetic fuels from renewable electricity for use in the transport and industry sectors. Renewable hydrogen is converted into synthetic hydrocarbons that replace the remaining fossil fuels, particularly in heavy-duty vehicles and air transportation – albeit with low overall efficiency of the synfuels system. Note that since renewable synfuels require (gas) pipeline infrastructure, this technology is not widely applied for Tanzania's energy access plan due to relatively high costs in the early development stages. It is assumed that synfuels and hydrogen will not enter Tanzania's energy system before 2040; to compensate for the high energy losses associated with the production of synthetic fuels, it requires more fundamental infrastructure changes that seems too costly for a developing country as this stage. In the heating sector, mainly heat for industry, electricity and hydrogen play a larger role in replacing remaining fossil fuels. In the power sector, natural gas is also replaced by hydrogen. Therefore, electricity generation increases significantly in this scenario, assuming power from renewable energy sources to be the main 'primary energy' of the future.
The ADVANCED RENEWABLES scenario also models a shift in the heat sector towards increased direct use of electricity because of the enormous and diverse potential for renewable power and the limited availability of renewable fuels for high-temperature process heat in industry. Increased implementation of district heating infrastructure (interconnection of buildings in Central Business Districts) and geothermal heat pumps for office buildings and shopping centres in larger cities is assumed, leading to a growth in electricity demand that partly offsets the efficiency savings in these sectors. A rapid expansion of solar and geothermal heating systems is also assumed.

The increasing shares of variable renewable power generation, principally by wind farms and photovoltaics, will require the implementation of smart grids and a fast interconnection of micro and mini grids with regional distribution networks, storage and other load balancing capacities. Other infrastructure requirements include the increasing role of on-site renewable process heat generation for industries and mining and the generation and distribution of synthetic fuels. The ADVANCED RENEWABLES scenario therefore assumes that such infrastructure projects will be implemented in all parts of Tanzania without serious societal, financial or political barriers. Scenarios by no means claim to predict the future; they provide a useful tool to describe and compare potential development pathways from the broad range of possible 'futures'. The ADVANCED RENEWABLES scenario was designed to indicate the efforts and actions required to achieve the ambitious objective of a 100 per cent renewable energy system and to illustrate the options available to change our energy supply system into one that is truly sustainable. They may serve as a reliable basis for further analyses of possible concepts and actions needed to implement pathways for an energy transition.

6 RESULTS

The following results are from both the long-term scenario model as well as the [R]E 24/7 model described in chapter 3. The models are not directly connected, and as such the results for power generation can vary by +/- 5 per cent as a result of differing modelling methodologies. The [R]E 24/7 model calculates hourly generation profiles with a chosen dispatch order, which influences capacity factors, whereas the long term model calculates annual accounting totals with assumed capacity factors. As a result, dispatch power plants may be calculated with higher capacity factors.

6.1 LONG TERM SCENARIO

In this section we outline the key results across a range of areas, both in terms of the impacts and the costs of the different scenarios. Firstly, we consider stationary energy, focusing on electricity generation, capacity and breakdown by technology. We then examine energy supply for heating with a focus on industrial heat supply, followed by a consideration of the impacts and costs of the different scenarios on transport and the development of CO_2 emissions. The section ends with an examination of the final costs, outlining the required energy budget.

To understand the results, it is first necessary to clarify the metrics used. Two of the main metrics used in the energy industry to analyse energy are primary energy consumption and final energy demand. Final energy demand "is a measure of the energy that is delivered to energy end users in the economy to undertake activities as diverse as manufacturing, movement of people and goods, essential services and other day-to-day energy requirements of living."[69] Primary energy consumption is defined as the "direct energy use at the source, or supply to users without transformation, of crude energy; that is, energy that has not been subjected to any conversion or transformation process."[70]

Primary energy statistics often make the renewables share appear lower than other forms of energy. For example, IEA's 2010 statistics listed the global primary energy share for nuclear energy as 6 per cent and hydropower at 2 per cent, however both technologies produced the same amount of power generation in terawatt hours. This is due to the fact that nuclear power is a thermal process with an average efficiency of around 30 per cent – thus the input of uranium (the primary energy resource) is therefore three times higher than the final energy (3:1), while hydropower, which does not involve a thermal process is calculated as final energy, is equal to primary energy (1:1).

6.1.1 TANZANIA FINAL ENERGY DEMAND

Combining the projections for population development, GDP growth and energy intensity leads to future development pathways for Tanzania's final energy demand. These are shown in Figure 15 for the REFERENCE and RENEWABLES scenarios. Under the REFERENCE scenario, total final energy demand increases by 40 per cent from the current 1000 PJ/a to 1400 PJ/a in 2050. Both RENEWABLES scenarios increase demand at close to the same rate as the REFERENCE case as it is assumed that energy-efficient electrical appliances compliant with international efficiency standards will be imported and used in Tanzania. Furthermore, the phase-out of traditionally inefficient use of biomass for cooking and the introduction of modern, efficient bioenergy applications maintains overall final energy increase at levels significantly lower than the economic and population growth rates.

The ADVANCED scenario results in some additional reductions as a result of a higher share of electric vehicles. This reduction can be particularly achieved through the introduction of highly efficient electronic devices using the best available technology in all demand sectors. The transformation to a carbon-free energy system in the ADVANCED scenario will further increase the electricity demand in 2050 up to 100 TWh/a. Electricity will become the major renewable 'primary' energy – not only for direct use for various purposes but also for the generation of synthetic fuels as a substitute for fossil fuels. Around 30 TWh are used in 2050 for electric vehicles and rail transport in the ADVANCED scenario and around 10 TWh for hydrogen generation for the transport sector (excluding bunkers).

Under both RENEWABLES scenarios, overall electricity demand is expected to increase despite efficiency gains in all sectors as a result of economic growth, increasing living standards and electrification of the transport sector (see Figure 17). Total electricity demand will rise from about 5 TWh/a to 110 TWh/a by 2050 in the basic RENEWABLES scenario. In the heating sector, assumed renewable heating technologies for residential and commercial buildings – mainly geothermal heat pumps and solar collectors – will significantly influence building

[69] http://www.seai.ie/Energy-Data-Portal/Frequently-Asked-Questions/Energy_Use_FAQ/
[70] https://stats.oecd.org/glossary/detail.asp?ID=2112

and construction standards. As a result of energy-related renovation of the existing stock of residential buildings, the introduction of low energy standards and ‘passive acclimatisation’ for new buildings, and highly efficient air conditioning systems, enjoyment of the same comfort and energy services will be accompanied by much lower future energy demand.

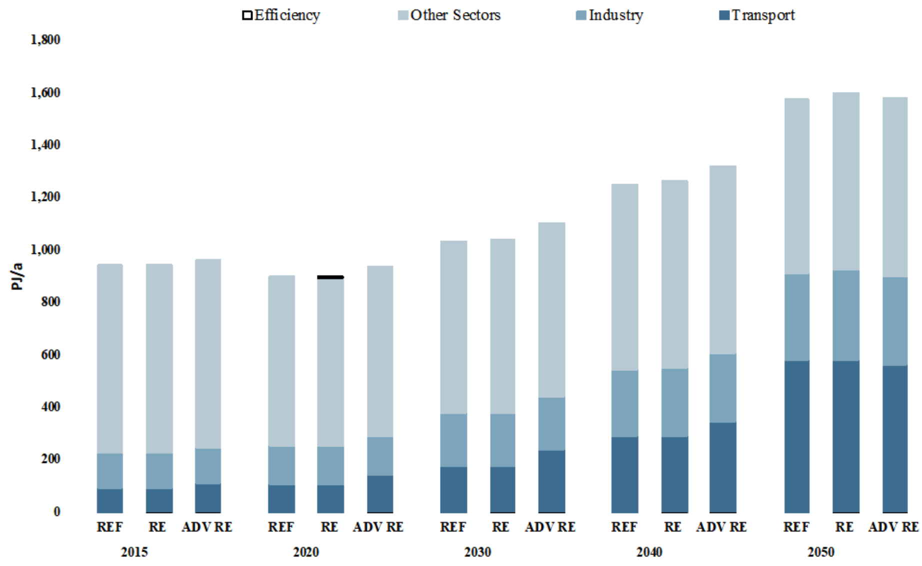


Figure 15: Projection of total final energy demand by sector

(excluding non-energy use and heat from CHP auto producers)

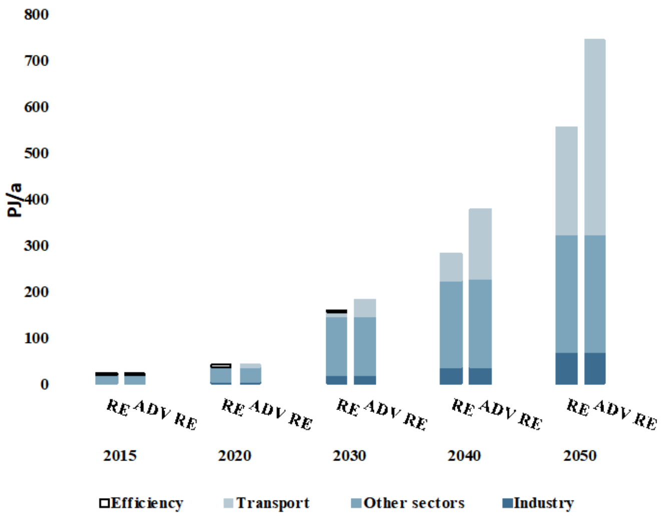


Figure 16: Development of electricity demand by sector in both RENEWABLES scenarios

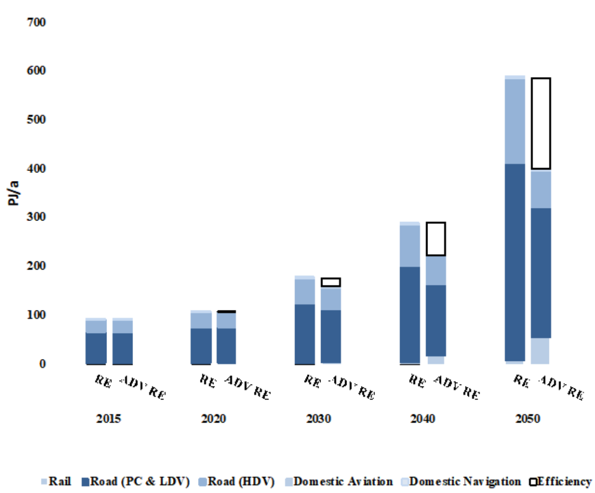


Figure 17: Development of the final energy demand for transport by sector in the RENEWABLES scenarios

6.1.2 ELECTRICITY GENERATION

6.1.2.1 Electricity generation, capacity and breakdown by technology

The renewable energy market grows dynamically and has an increasing share in the required electricity supply. This trend will more than compensate for the phasing out of fossil power production in the RENEWABLES scenarios, continuously reducing the number of coal and gas-fired power plants as well. By 2050, 100 per cent of the electricity produced in Tanzania will come from renewable energy sources in the basic RENEWABLES scenario. 'New' renewables – mainly wind, PV, ocean and geothermal energy – will contribute 75 per cent to the total electricity generation. By 2020, the share of renewable electricity production will already be 53 per cent, and 75 per cent by 2030; the installed capacity of renewables will reach about 20 GW in 2030 and 60 GW by 2050.

Table 14 shows the comparative evolution of the different renewable technologies in Tanzania over time. Hydro will remain the main renewable power source until 2020, when it will be overtaken by wind and PV – currently, the largest contributor to the growing renewables market. After 2020, the continuing growth of wind and PV will be complemented by electricity from solar thermal, geothermal and ocean energy. The RENEWABLES scenarios will already lead to a high share of variable power generation (PV, wind and ocean) of 48 to 60 per cent by 2030 and 56 to 69 per cent by 2050. Therefore, smart grids, demand side management (DSM), energy storage capacities and other options need to be expanded in order to increase the flexibility of the power system for grid integration, load balancing and secure supply of electricity via storage technologies.

Figure 18: Breakdown of electricity generation by technology

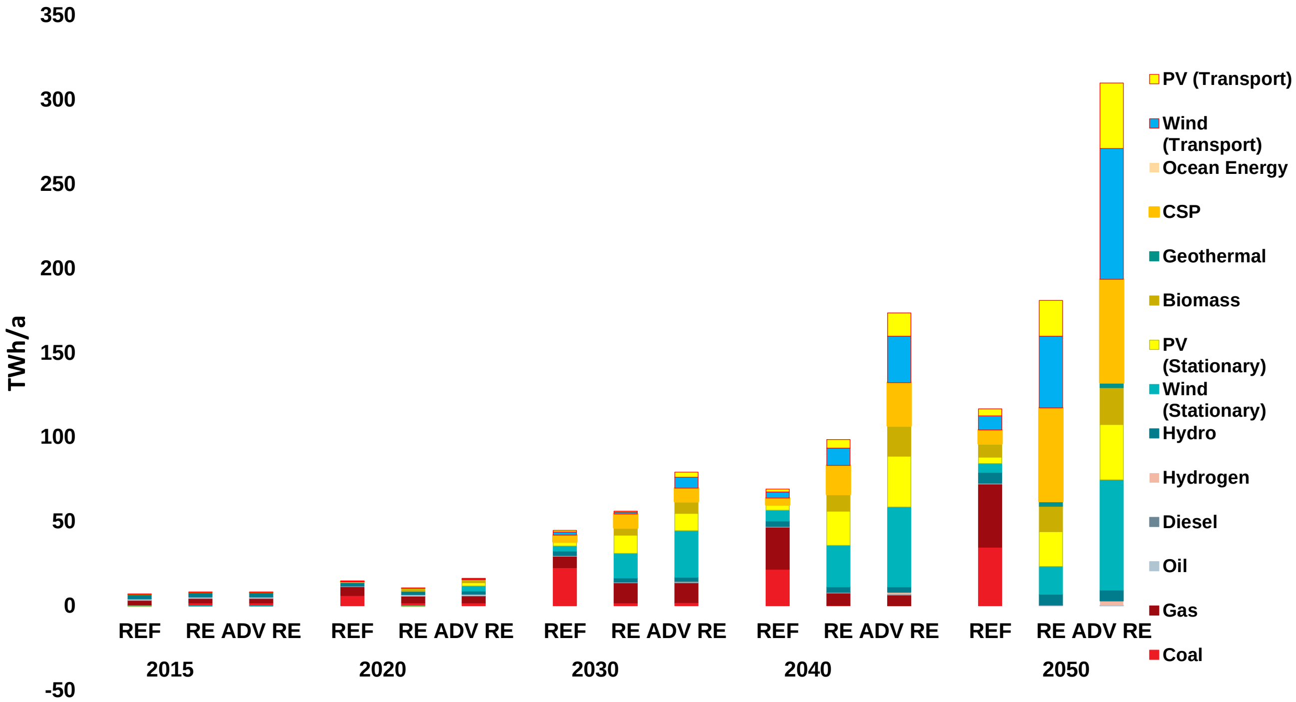


Table 15: Projection of renewable electricity generation capacity

In GW		2015	2020	2030	2040	2050
	REF	0.863	0.611	0.833	1.055	2.111
	RE	0.863	0.611	0.833	1.055	2.111
	ADV	0.863	0.611	0.833	1.055	2.111
	REF	0.006	0.030	0.040	0.060	0.090
	RE	0.006	0.475	1.125	2.500	3.750
	ADV	0.006	0.475	1.311	3.134	3.881
	REF	0.000	0.299	1.982	3.926	5.348
	RE	0.000	0.800	4.800	10.800	16.000
	ADV	0.000	1.200	12.400	26.677	50.923
	REF	0.000	0.000	0.000	0.000	0.000
	RE	0.000	0.000	0.000	0.000	0.667
	ADV	0.000	0.000	0.000	0.000	0.600
	REF	0.011	0.200	2.000	3.000	5.000
	RE	0.011	1.250	7.156	15.878	26.206
	ADV	0.011	1.250	8.406	27.500	44.844
	REF	0.000	0.000	1.000	1.000	2.000
	RE	0.000	0.000	2.000	4.250	13.875
	ADV	0.000	0.000	3.200	10.220	30.625
	REF	0.000	0.000	0.000	0.000	0.000
	RE	0.000	0.000	0.000	0.000	0.000
	ADV	0.000	0.000	0.000	0.000	0.000
	REF	0.880	1.140	5.855	9.042	14.549
	RE	0.880	3.137	15.915	34.484	62.609
	ADV	0.880	3.537	26.151	68.587	132.984

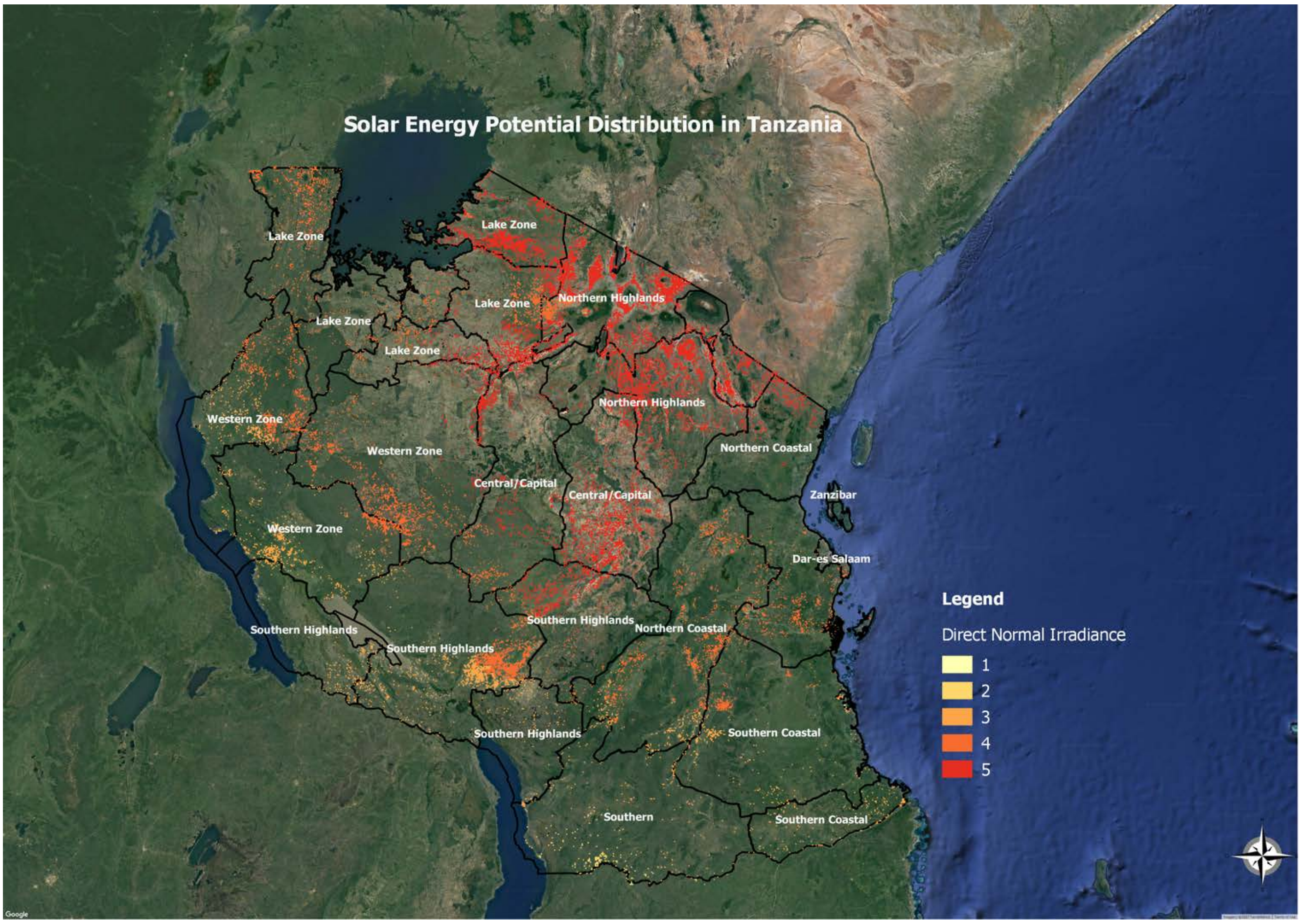
Figure 19: Average annual capacity change by technology in the ADVANCED RENEWABLES case

6.1.2.2 Regional distribution of solar and wind resources

Tanzania has almost 72,850 square kilometres of available land where 1821 gigawatts of solar power can potentially be harvested through utility scale solar farms. In order to avoid conflicts with National Parks and other competing uses of land, only bare soil, perennial cropland and open bushland land cover types were included in the analysis. Both utility scale solar photovoltaic and concentrated solar power (CSP) are included in the analysis, and CSP would be built in regions with the highest direct normal irradiance, accounting for approximately 15 to 20 per cent of this area. In Table 15 it is assumed that 80 per cent of the suitable area will be used for utility-scale solar photovoltaic and 20 per cent for concentrated solar power.

Less than 5 per cent of these need to be harvested to meet the current and future energy needs of the country, thus offering a diversity of options for interested investors to set up renewable energy plants.
Figure 20 shows the distribution of potential sites that are ideal for setting up utility scale solar plants.

Figure 20 : Solar energy generation potential in Tanzania

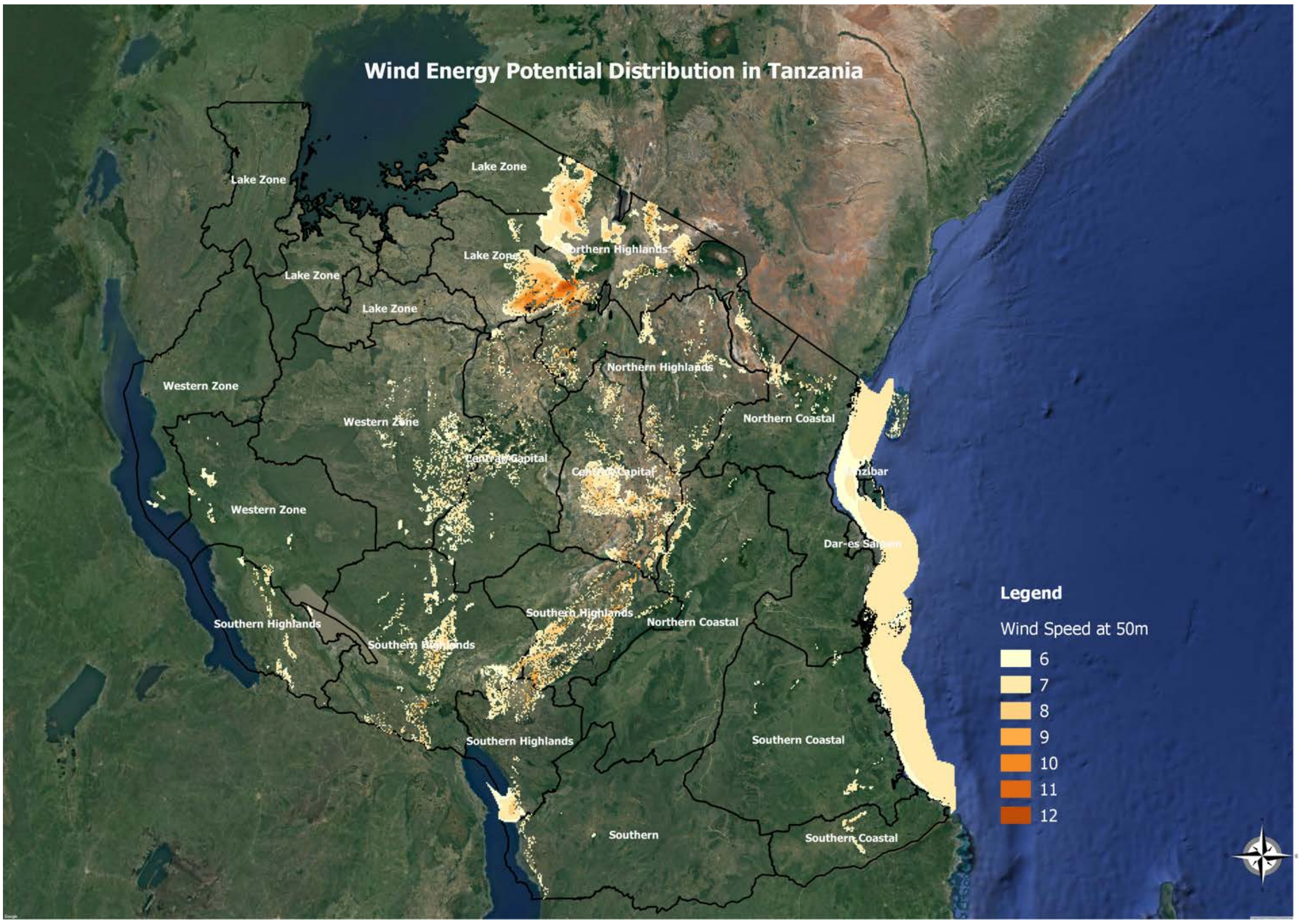


Source: ISF mapping, August 2017

The distribution of potential sites for optimal wind power generation is shown in Figure 21. The map highlights the significant amount of land available for renewable energy generation.

Potential exists to install at least 447 gigawatts of wind power (on- and offshore) from sites spread over 89,400 square kilometres across Tanzania. This analysis takes into account only wind speeds of 6 metres per second and above in order to plot optimal sites. Site selection is restricted to include only the following land cover types: bare soil, annual cropland, perennial cropland, grassland and ocean. Offshore water bodies (ocean) within 50 to 60 kilometres of the coast were included in the analysis. This leads to an estimated offshore wind potential of 150 gigawatts and an onshore wind potential of around 300 gigawatts.
Only a small percentage of this needs to be tapped to meet the current and projected demands of the country.

Figure 21 : Wind energy generation potential in Tanzania



Source: ISF mapping, August 2017

Table 16: Renewable energy potential – results from QGIS mapping

Resource	Maximum installable generation capacity [GW]	Maximum recoverable electricity [TWh/year]	ADVANCED RENEWABLES 2050: installed capacity [GW]	ADVANCED RENEWABLES 2050: generation [TWh/year]
Wind – onshore	300	750	30	75
Wind – offshore	150	480	21	68
Solar Photovoltaics	1,450	2,320	45	72
Concentrated Solar Power (CSP)	365	700	31	61
Total	**2,265**	**4,250**	**127**	**276**

SOURCE: ISF mapping, August 2017, values are rounded

6.1.3 ENERGY SUPPLY FOR HEATING

Renewables currently meet around 92 per cent of Tanzania's energy demand, primarily through the traditional use of biomass for cooking. Dedicated support instruments are required to ensure dynamic development, particularly with regard to renewable technologies for cooking, buildings and renewable process heat production to meet increasing industrial process heat requirements. In the basic RENEWABLES scenario, renewables already provide 90 per cent of Tanzania's total heat demand in 2030 and 100 per cent in 2050.

- Energy efficiency measures help to reduce the currently growing energy demand for wood fuel for cooking stoves and shifts 100 per cent to modern sustainable biomass, solar- and geothermal heating, as well as electric cooking and heating, by 2050.
- In the industry sector, solar collectors, geothermal energy including heat pumps and electricity and hydrogen from renewable sources are increasingly substituting for fossil fuel-fired systems.
- A shift from coal and oil to natural gas in the remaining conventional applications leads to a further reduction in CO_2 emissions.

Table 16 shows the development of different renewable technologies for heating in Tanzania over time. Biomass remains the main contributor, along with increasing investment in highly efficient modern biomass technology. After 2030, a massive growth in solar collectors, and a growing share of geothermal and environmental heat along with heat from renewable hydrogen, can further reduce dependence on fossil fuels. The ADVANCED scenario results in a complete substitution of the remaining gas consumption by hydrogen generated from renewable electricity.

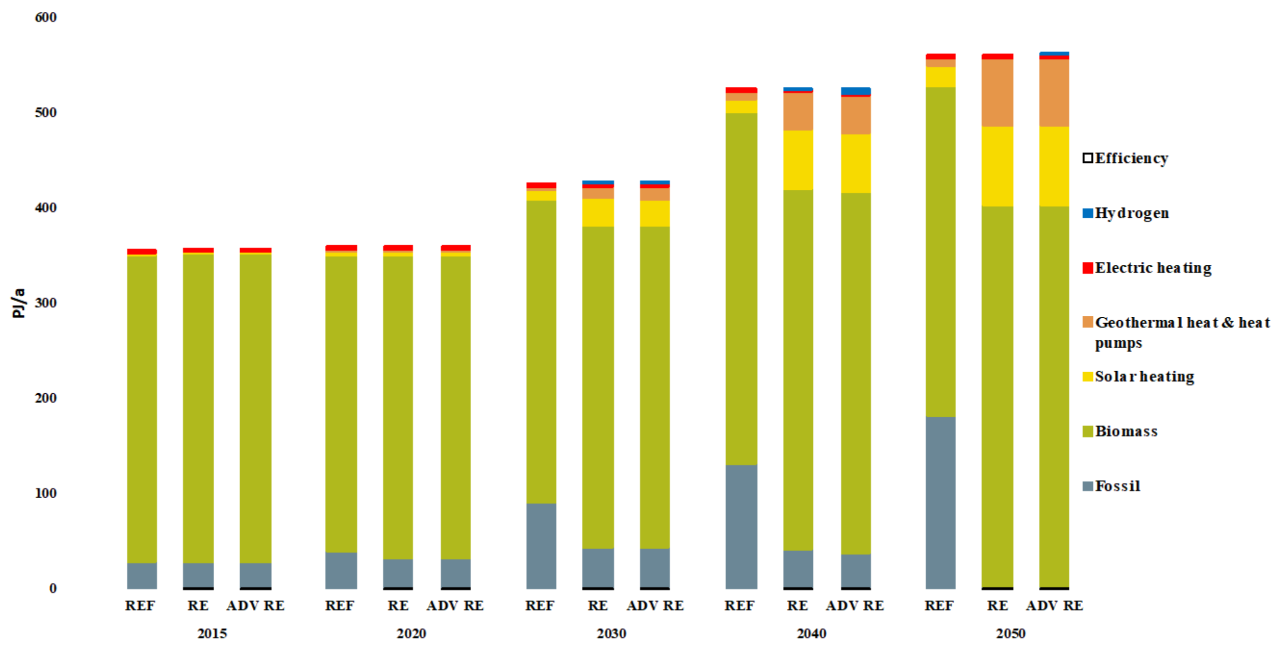


Figure 22: Projection of heat supply by energy carrier (REF, RE, ADV RE)

Table 17: Projection of renewable heat supply

in PJ/a		2015	2020	2030	2040	2050
	REF	325	310	318	369	347
	RE	325	318	338	379	402
	ADV RE	325	318	338	379	402
	REF	2	5	10	14	21
	RE	2	5	29	63	83
	ADV RE	2	5	29	63	83
	REF	1	1	4	8	8
	RE	1	1	13	39	71
	ADV RE	1	1	13	39	71
	REF	0	0	0	0	0
	RE	0	0	0	1	0
	ADV RE	0	0	1	4	0
	REF	325	317	333	390	376
	RE	328	325	380	482	556
	ADV RE	328	325	380	485	556

Table 18: Installed capacities for renewable heat generation

in GW		2020	2030	2040	2050
	REF	110	89	86	65
	RE	110	96	95	84
	ADV RE	110	96	95	84
	REF	0	0	0	0
	RE	0	0	0	1
	ADV RE	0	0	0	1
	REF	2	3	4	6
	RE	2	9	20	26
	ADV RE	2	9	20	26
	REF	0	1	1	1
	RE	0	2	5	9
	ADV RE	0	2	5	9
	REF	111	93	91	73
	RE	112	106	120	119
	ADV RE	112	106	120	119

6.1.4 TRANSPORT

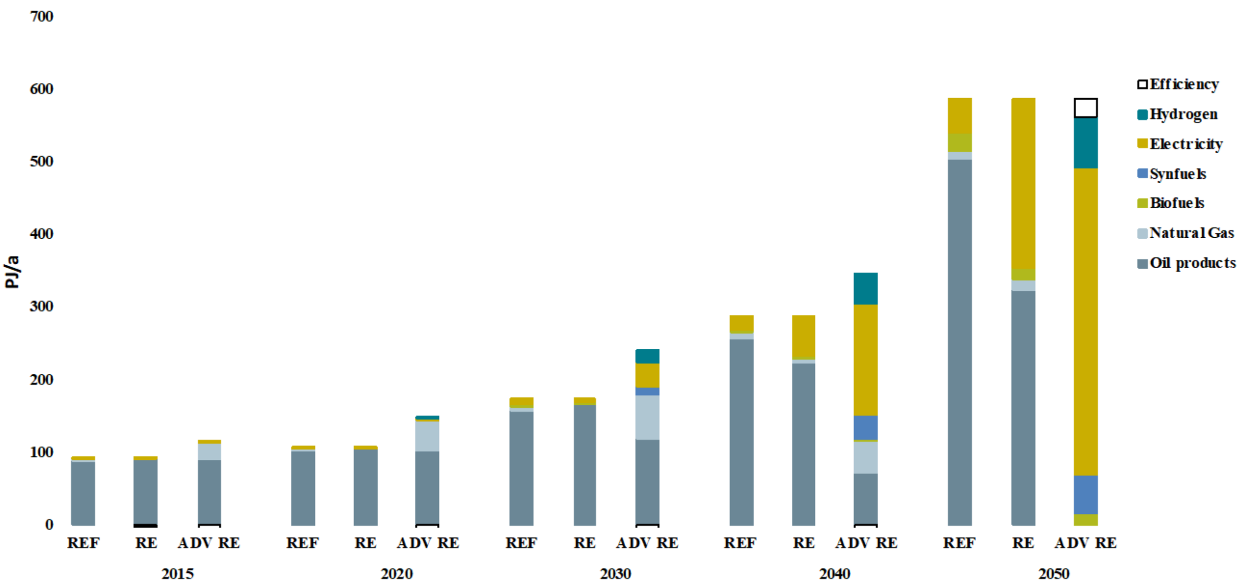
A key target is to introduce incentives for people to keep public transport as their preferred mode of transport and to significantly increase its convenience. Individual transport should rely to a large extend on smaller and more efficient vehicle concepts. In addition, it is vital to shift transport use to efficient modes like rail, light rail and buses, especially in the large and expanding metropolitan areas; a network of bike lanes for (electric) bicycles further decrease car dependency. Along with rising prices for fossil fuels, these changes limit further growth in car sales projected under the REFERENCE scenario. Due to population increase, GDP growth and higher living standards, energy demand from the transport sector is expected to increase in all scenarios by around 601 per cent to 590 PJ/a in 2050.

Additional modal shifts and technology switches lead to energy savings in the ADVANCED scenario of 4 per cent (20 PJ/a) in 2050 compared to the REFERENCE scenario. Highly efficient propulsion technology with hybrid, plug-in hybrid and battery-electric power trains will deliver large efficiency gains. By 2030, electricity will provide 4 per cent of the transport sector's total energy demand in the RENEWABLES scenario, while in 2050 the share will be 40 per cent (75 per cent in the ADVANCED scenario). Hydrogen and other synthetic fuels generated using renewable electricity are complementary options to further increase renewables' share in the transport sector. In 2050, up to 70 PJ/a of hydrogen is used in the transport sector for the ADVANCED RENEWABLES scenario.

Table 19: Projection of transport energy demand by mode

in PJ/a		2015	2020	2030	2040	2050
	REF	2	2	2	3	4
	RE	2	2	4	4	8
	ADV RE	2	2	7	17	55
	REF	89	104	173	284	581
	RE	89	104	172	283	577
	ADV RE	89	103	152	206	342
	REF	0.1	0.2	0.3	0.3	0.4
	RE	0.1	0.2	0.3	0.3	0.4
	ADV RE	0.1	0.2	0.3	0.3	0.3
	REF	0.1	0.2	0.3	0.3	0.4
	RE	0.1	0.2	0.3	0.3	0.4
	ADV RE	0.1	0.2	0.3	0.3	0.4
	REF	91	107	176	288	586
	RE	92	107	176	288	586
	ADV RE	92	105	159	224	398

Figure 23: Final energy consumption transport under the scenarios



700
600
500
400
300
200
100
0
PJ/a
REF
RE
ADV RE
2015
2020
2030
2040
2050
Efficiency
Hydrogen
Electricity
Synfuels
Biofuels
Natural Gas
Oil products

6.1.5 PRIMARY ENERGY CONSUMPTION

Taking into account the assumptions discussed above, the resulting primary energy consumption under the RENEWABLES scenarios is shown in Figure 24. Under the basic RENEWABLES scenario, primary energy demand will increase by 82 per cent from today's 1100 PJ/a to around 2000. PJ/a. Compared to the REFERENCE scenario, overall primary energy demand will be reduced by 2 per cent in 2050 under the RENEWABLES scenario (REF: around 2000 PJ/a in 2050), while the ADVANCED scenario results in additional conversion losses in a primary energy consumption of around 2200 PJ/a in 2050.

The RENEWABLES scenarios aim to phase out coal and oil as fast as technically and economically possible through expansion of renewable energies and rapid introduction of very efficient vehicle concepts in the transport sector to replace oil-based combustion engines. This leads to an overall renewable primary energy share of 72 per cent in 2030 and 82 per cent in 2050 in the basic RENEWABLES scenario, and of more than 99 per cent in 2050 in the ADVANCED case (including non-energy consumption). In contrast to the REFERENCE scenario, in both RENEWABLES scenarios no new coal power plants will be built in Tanzania.

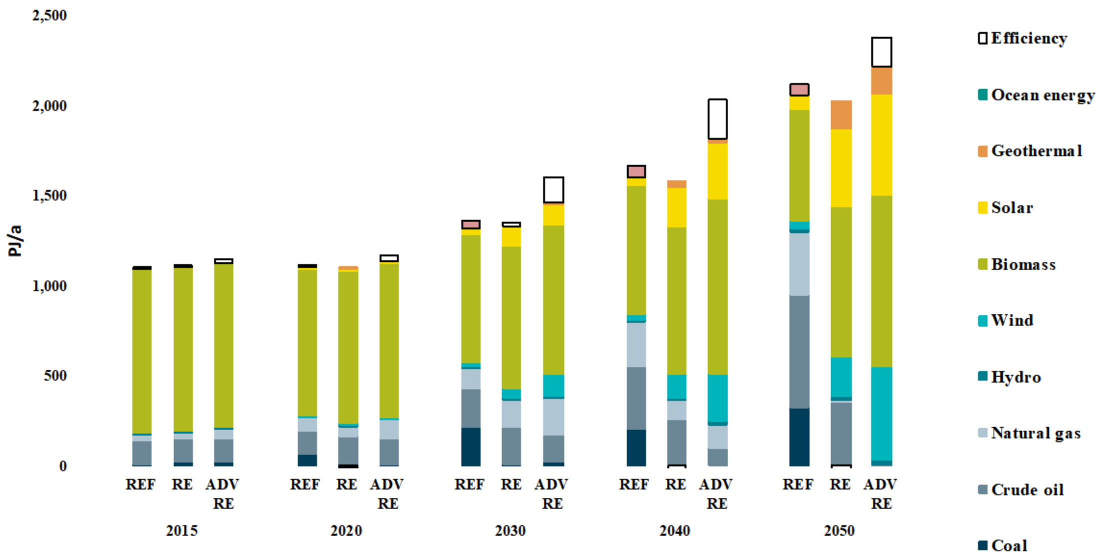


Figure 24: Projection of total primary energy demand by energy carrier (incl. electricity import balance)

6.1.6 CO_2 EMISSIONS TRAJECTORIES

Whilst Tanzania`s CO_2 emissions will increase by a factor of 7 – from 12 million tonnes to over 90 million tonnes – between 2015 and 2050 under the REFERENCE scenario, the RENEWABLES scenario will result in a moderate increase to 24.5 million tonnes with a population increase from 53 to 137 million people in the same period. As such, annual per capita emissions will remain at 0.2 tonnes. In spite of increasing power demand, CO_2 emissions will decrease in the electricity sector. In the long run, efficiency gains and the increased use of renewable electricity in vehicles will also dramatically reduce emissions in the transport sector. With a 98 per cent share of CO_2, the transport sector will be the largest source of emissions in 2050 in the basic RENEWABLES scenario. By 2050, Tanzania´s CO_2 emissions will increase by 15 million tonnes on 2015 levels in the RENEWABLES scenario, while energy consumption is fully decarbonised in the ADVANCED case.

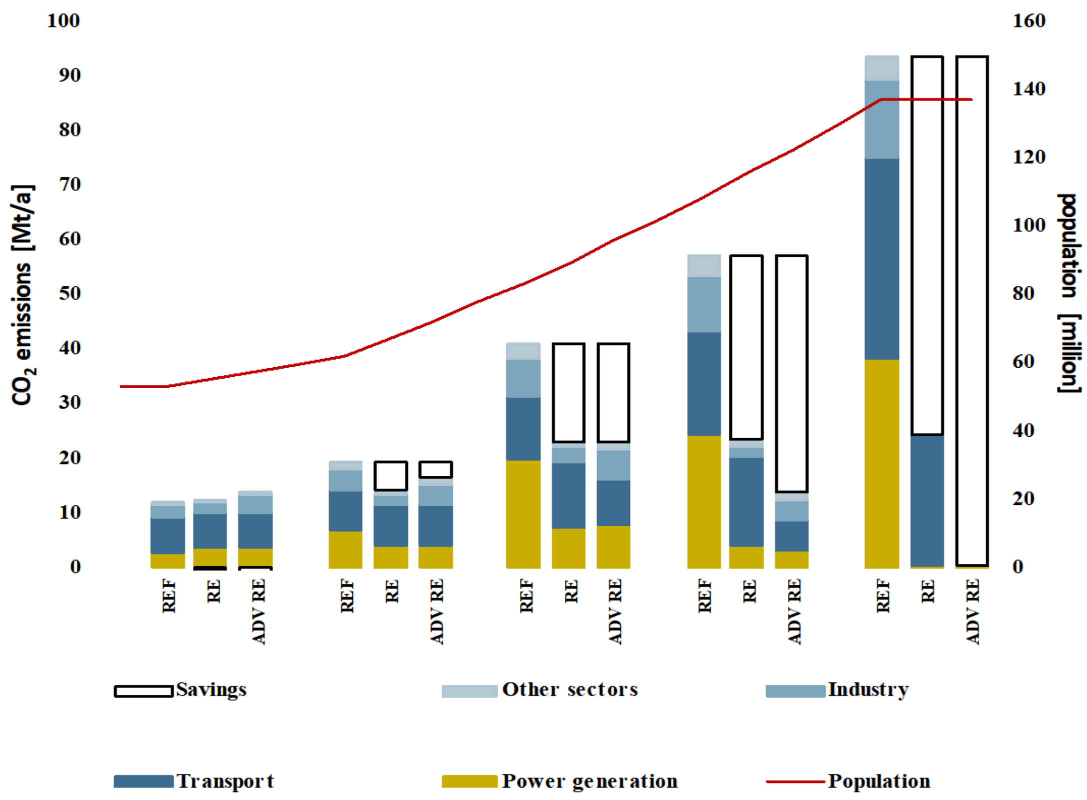


Figure 25: Development of CO2 emissions by sector under the RENEWABLES scenarios (‘Efficiency’ = reduction compared to the REFERENCE scenario)

6.1.7 COST ANALYSIS

6.1.7.1 Future costs of electricity generation

Figure 26 shows that the introduction of renewable technologies under both RENEWABLES scenarios may increase the costs of electricity generation in the future compared to the REFERENCE scenario for a short period around 2025 or 2030, depending on the assumed coal and gas price. However, this difference in the full cost of generation will be less than 1.7 cents/kWh in the basic RENEWABLES scenario and about 1.4 cents/kWh in the ADVANCED scenario, without taking into account integration costs for storage or other load-balancing measures. Because of increasing prices for conventional fuels and the lower CO_2 intensity of electricity generation, electricity generation costs will become economically favourable after 2035 under the RENEWABLES scenarios. By 2050, the cost will be 4.5 cents/kWh respectively, below those in the REFERENCE case.

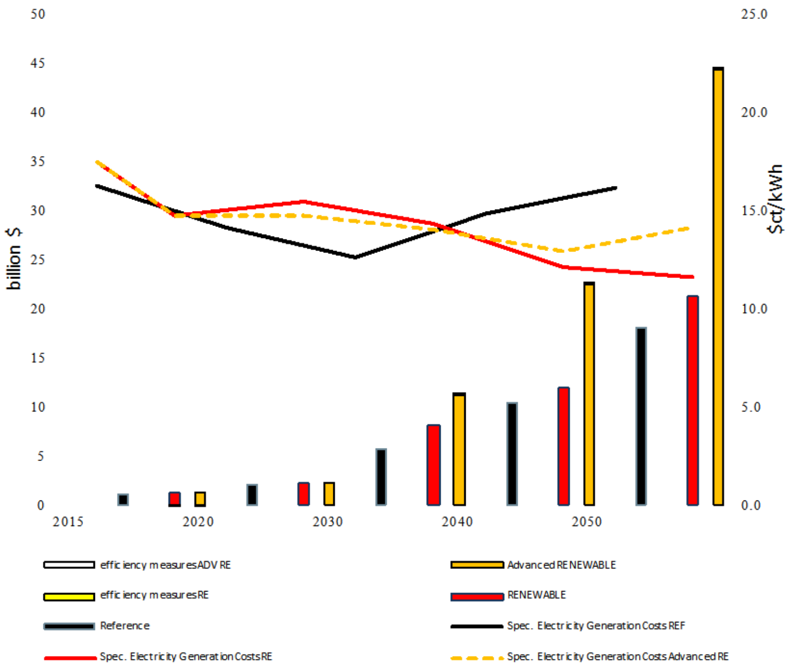


Figure 26: Development of total electricity supply costs and of specific electricity generation costs in the scenarios

6.1.7.2 Future investments in the power sector

An approximate investment of around US$160 billion is required for the RENEWABLES scenario to become reality, including investments for replacement after the economic lifetime of the plants, totalling around US$5 billion per year. The total investment required for the ADVANCED scenario to 2050 is US$310 billion, averaging US$9 billion per year. Under the REFERENCE scenario, the levels of investment in conventional power plants add up to almost 25 per cent, while approximately 75 per cent would be invested in renewable energies and cogeneration until 2050. Under the RENEWABLES scenarios, however, Tanzania would shift almost 99 per cent of the entire investment towards renewables and cogeneration. By 2030, fossil fuel's share of power sector investment would be focused mainly on gas power plants.

Because renewable energy incurs no fuel costs, the fuel cost savings for the electricity sector (excluding road transport) in the basic RENEWABLES scenario total US$80 billion up to 2050, or US$2.3 billion per year. These savings would therefore cover 70 per cent of the total additional investments compared to the REFERENCE scenario. Fuel cost savings in the ADVANCED scenario are even higher, equalling US$85 billion, or US$2.4 billion per year. Renewable energy sources would then go on to produce electricity without any further fuel costs beyond 2050, whereas costs for coal and gas will continue to be a burden on national economies.
In addition, fuel cost savings in the transport sector from modular shifts and increased electrification would increase average annual savings to US$5.3 billion in the basic RENEWABLES case, and US$8.1 billion in the ADVANCED case. However, most savings would occur after 2030.

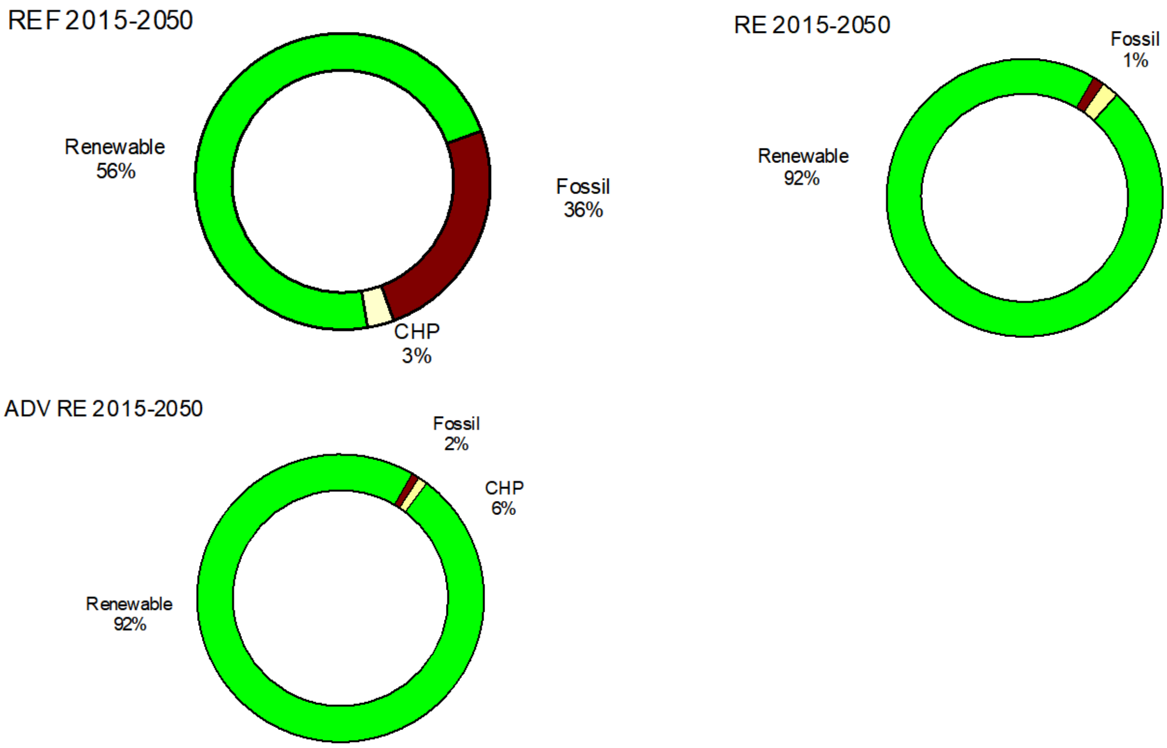
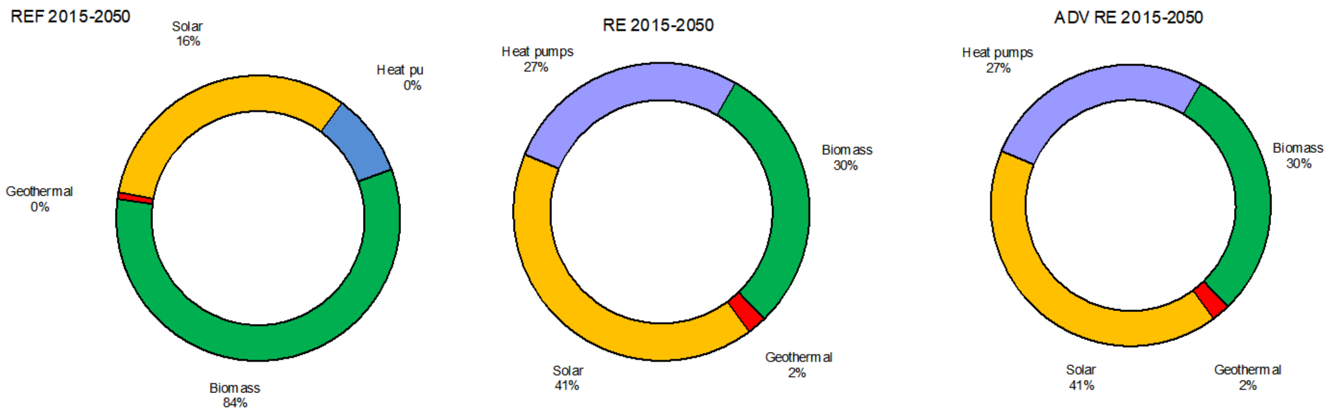


Figure 27: Share of investment between renewable, fossil and CHP technologies by scenario

6.1.7.3 Future investments in the heating sector

In the heating sector, the RENEWABLES scenarios would require a major revision of current investment strategies in heating technologies. Solar thermal, geothermal and heat pump technologies in particular require an enormous increase in installations if their heating sector potential is to be tapped. The use of biomass for heating purposes will shift , from today's dominant use of biomass to modern, efficient and environmentally friendly heating technologies in the RENEWABLES scenarios. Renewable heating technologies are extremely variable, ranging from low-tech biomass generators and unglazed flat panel solar collectors to very sophisticated enhanced geothermal and solar systems. Thus, it can only be roughly estimated that the RENEWABLES scenario requires a total investment of around US$60 billion in renewable heating technologies up to 2050 (including investments for replacement after the economic lifetime of the plants), equaling approximately US$1 billion per year. The ADVANCED scenario assumes an equally ambitious expansion of renewable technologies resulting in an average investment of around US$1 billion per year, while the main strategies in these scenarios are to substitute the remaining fossil fuel amounts with electricity, hydrogen or other synthetic fuels.

Figure 28: Share of investment for renewable heat generation technologies



6.1.8 INVESTMENT AND FUEL COST SAVINGS

Under the RENEWABLES case, the additional annual investment is estimated at $3.2 billion; compared to REFERENCE case, the fuel cost saving would add up to $5.3 billion. Thus, required additional investment cost will be more than refinanced by fuel cost savings. With high uncertainties in both future investment costs for power generation equipment and fossil fuel prices, it seems certain, that the overall cost balance is economically beneficial for the RENEWABLES case.

Table 20: Accumulated investment costs for electricity generation and fuel cost savings under the RENEWABLES scenario compared to the REFERENCE scenario (REF minus RE)

ACCUMULATED INVESTMENT COSTS difference REF minus RE		2015-2020	2021-2030	2031-2040	2041-2050	2015-2050	2015 - 2050 average per year
conventional (fossil + nuclear)	billion $	1.1	2.2	2.2	3.8	9.3	0.3
renewables (incl. CHP)	billion $	-3.2	-17.4	-30.7	-70.3	-121.6	-3.5
total	billion $	-2.2	-15.2	-28.4	-66.5	-112.3	-3.2
ACCUMULATED FUEL COST SAVINGS							
savings cumulative RE versus REF							
fuel oil (road transport)	billion $	-0.4	-1.8	2.4	24.7	24.9	0.7
fuel oil (power incl. CHP)	billion $	-0.4	-0.3	0.0	0.0	-0.7	0.0
gas	billion $	0.1	-10.6	6.1	49.0	44.6	1.3
hard coal	billion $	0.4	6.8	11.6	17.1	35.9	1.0
lignite	billion $	0.0	0.0	0.0	0.0	0.0	0.0
nuclear energy	billion $	0.0	0.0	0.0	0.0	0.0	0.0
total (power incl. CHP)	billion $	0.0	-4.1	17.7	66.2	79.8	2.3
total	**billion $**	**-0.3**	**-10.1**	**37.8**	**157.1**	**184.5**	**5.3**

Table 21: Accumulated investment costs for heat generation under the RENEWABLES scenario compared to the REFERENCE scenario

ACCUMULATED INVESTMENT COSTS difference RE minus REF		2012-2020	2021-2030	2031-2040	2041-250	2012-2050	2015 - 2050 average per year
renewable	billion $	0.8	6.5	13.6	14.4	35.2	1.0

Under the ADVANCED RENEWABLES case, the additional investment is estimated at around US$7.6 billion; compared to the REFERENCE case, the fuel cost saving would add up to $2.4 billion without the transport sector and $8.1 billion including transport fuel cost savings. Just as in the RENEWABLES case, the ADVANCED case leads to fuel cost savings that will more than refinance the investment cost for renewable power generation.

Table 22: Accumulated investment costs for electricity generation and fuel cost savings under the ADVANCED RENEWABLES scenario compared to the REFERENCE scenario (REF minus ADV RE)

ACCUMULATED INVESTMENT COSTS difference REF minus ADV RE		2015-2020	2021-2030	2031-2040	2041-2050	2015-2050	2015 - 2050 average per year
conventional (fossil + nuclear)	billion $	1.0	2.1	2.2	3.4	8.7	0.2
renewables (incl. CHP)	billion $	-3.8	-37.7	-80.6	-153.5	-275.6	-7.9
total	billion $	-2.8	-35.6	-78.4	-150.1	-266.8	-7.6
ACCUMULATED FUEL COST SAVINGS							
savings cumulative ADV RE versus REF							
fuel oil (road transport)	billion $	-0.2	4.0	26.1	82.4	112.3	3.2
fuel oil	billion $	-0.4	-0.3	0.0	0.0	-0.7	0.0
gas	billion $	0.1	-10.3	7.6	52.0	49.4	1.4
hard coal	billion $	0.4	6.6	11.9	17.1	36.1	1.0
lignite	billion $	0.0	0.0	0.0	0.0	0.0	0.0
nuclear energy	billion $	0.0	0.0	0.0	0.0	0.0	0.0
total (power incl. CHP)	billion $	0.0	-4.0	19.5	69.2	84.8	2.4
total	**billion $**	**-0.2**	**-3.9**	**65.1**	**220.7**	**281.8**	**8.1**

Table 23: Accumulated investment costs for heat generation under the ADVANCED RENEWABLES scenario compared to the REFERENCE scenario

ACCUMULATED INVESTMENT COSTS difference ADV RE minus REF		2012-2020	2021-2030	2031-2040	2041-250	2012-2050	2012 - 2050 average per year
renewable	billion $	0.8	6.5	13.6	14.4	35.2	1.0

6.2 TANZANIA ENERGY ACCESS SCENARIO

This section summarises the results of the hourly simulation of the long-term scenario projections of chapter 6.1.2.1. The [R]E 24/7model calculates demand and supply by cluster and four different voltage levels. The long-distance transmission grid (TA) serves as an interconnection across the country, while the regional transmission grid (TZ) connects to the medium (DA) and finally to the low (DZ) voltage level.

6.2.1 RESIDUAL LOAD BY REGION

The expected minimum and maximum load and generation figures for 2050 presented in Table 23 are based on calculated demand projections (see section 4) and the assumed regional distribution of population and economic activities. The year 2050 has been chosen because it shows the highest share of variable generation. It is anticipated that the majority of the load is on the distribution level preferably supplied by distributed generation. Thus, the highest values are on the DZ level. Both generation and demand vary significantly by region and time, and the variation of generation over day and time are to a large extent due to solar photovoltaics with high generation capacities around mid-day. The regional distribution is a function of solar and wind resource availability, and all regions and voltage levels show a significant mid-day generation peak, with generation low after sunset. Dispatch power plants and storage technologies secure a reliable supply for all regions.

Table 24: Maximum and minimum load and generation by cluster under assumed regional distribution for 2050

Load and Generation - maximum and minimum by cluster under assumed regional distribution			MAX			MIN		
NORTH WEST	TA TZ1	North Western Transmission Zone	[MW/h]	Date	Time		Date	Time
	North Western Transmission	Load: North Western Transmission Zone	357	1/01/2015	06:00:00	249	1/01/2015	00:00:00
		Generation: North Western Transmission Zone	771	19/12/2015	13:00:00	-238	26/05/2015	20:00:00
		Residual load North Western Transmission Zone	486	26/05/2015	20:00:00	-414	19/12/2015	13:00:00
	TA TZ1 DA1	**North Western Distribution Area**	[MW/h]	Date	Time		Date	Time
	North Western Distribution Area	Load: North Western Distribution Area	1,372	1/01/2015	06:00:00	97	1/01/2015	01:00:00
		Generation: North Western Distribution Area	2,636	18/08/2015	13:00:00	-2,167	26/05/2015	20:00:00
		Residual load North Western Distribution Area	3,539	26/05/2015	20:00:00	-1,264	18/08/2015	13:00:00
	TA TZ1 DA2	**Norther Lakes - Distribution Area**	[MW/h]	Date	Time		Date	Time
	Norther Lakes - Distribution Area	Load: Norther Lakes - Distribution Area	801	1/01/2015	06:00:00	97	1/01/2015	01:00:00
		Generation: Norther Lakes - Distribution Area	2,067	4/04/2015	12:00:00	29	19/05/2015	03:00:00
		Residual load Norther Lakes - Distribution Area	599	15/06/2015	05:00:00	-1,266	4/04/2015	12:00:00
	TA TZ1 DA1 DZ1	**Lake Zone - Distribution Area**	[MW/h]	Date	Time		Date	Time
	Lake-Zone	Load: Lake Zone - Distribution Area	3,809	1/01/2015	18:00:00	180	1/01/2015	01:00:00
		Generation: Lake Zone - Distribution Area	3,958	18/08/2015	13:00:00	-3,253	26/05/2015	20:00:00
		Residual load: Lake Zone - Distribution Area	6,430	26/05/2015	18:00:00	-1,398	26/08/2015	15:00:00
	TA TZ1 DA1 DZ2	**Western Zone**	[MW/h]	Date	Time		Date	Time
	Western Zone	Load: Western Zone	1,528	1/01/2015	18:00:00	72	1/01/2015	01:00:00
		Generation: Western Zone	1,588	18/08/2015	13:00:00	-1,305	26/05/2015	20:00:00
		Residual load Western Zone	2,580	26/05/2015	18:00:00	-561	26/08/2015	15:00:00
	TA TZ1 DA2 DZ1	**Northern Highlands**	[MW/h]	Date	Time		Date	Time
	Northern Highlands	Load: Northern Highlands	657	1/01/2015	18:00:00	31	1/01/2015	01:00:00
		Generation: Northern Highlands	908	4/04/2015	12:00:00	13	19/05/2015	03:00:00
		Residual load Northern Highlands	435	14/07/2015	18:00:00	-564	16/03/2015	15:00:00
	TA TZ1 DA2 DZ2	**Central/Capital**	[MW/h]	Date	Time		Date	Time
	Central/Capital	Load: Central/Capital	1,610	1/01/2015	18:00:00	76	1/01/2015	01:00:00
		Generation: Central/Capital	2,227	4/04/2015	12:00:00	31	19/05/2015	03:00:00
		Residual load Central/Capital	1,067	14/07/2015	18:00:00	-1,383	16/03/2015	15:00:00
SOUTH EAST	**TA TZ2**	**South Eastern Transmission Zone**	[MW/h]	Date	Time		Date	Time
	South Eastern Tran	Load: South Eastern Transmission Zone	357	1/01/2015	06:00:00	249	1/01/2015	00:00:00
		Generation: South Eastern Transmission Zone	759	5/10/2015	12:00:00	-261	9/04/2015	20:00:00
		Residual load South Eastern Transmission Zone	510	9/04/2015	20:00:00	-402	5/10/2015	12:00:00
	TA TZ2 DA1	**Highland-Coast Corridor - Distribution Area**	[MW/h]	Date	Time		Date	Time
	Highland-Coast Co	Load: Highland-Coast Corridor - Distribution Area	1,357	1/01/2015	06:00:00	97	1/01/2015	01:00:00
		Generation: Highland-Coast Corridor - Distribution Area	2,724	21/01/2015	13:00:00	-2,198	7/06/2015	20:00:00
		Residual load Highland-Coast Corridor - Distribution Area	3,555	7/06/2015	20:00:00	-1,367	21/01/2015	13:00:00
	TA TZ2 DA2	**South West to Coast: Distribution Area**	[MW/h]	Date	Time		Date	Time
	South West to Coa	Load: South West to Coast: Distribution Area	665	1/01/2015	06:00:00	97	1/01/2015	01:00:00
		Generation: South West to Coast: Distribution Area	2,344	11/11/2015	13:00:00	31	19/05/2015	03:00:00
		Residual load South West to Coast: Distribution Area	531	23/01/2015	05:00:00	-1,679	11/11/2015	13:00:00
	TA TZ2 DA1 DZ1	**Southern Highlands**	[MW/h]	Date	Time		Date	Time
	Southern Highlands	Load: Southern Highlands	1,707	1/01/2015	18:00:00	81	1/01/2015	01:00:00
		Generation: Southern Highlands	1,853	21/01/2015	13:00:00	-1,496	7/06/2015	20:00:00
		Residual load Southern Highlands	2,995	7/06/2015	18:00:00	-600	7/11/2015	15:00:00
	TA TZ2 DA1 DZ2	**Northern Coast**	[MW/h]	Date	Time		Date	Time
	Northern Coast	Load: Northern Coast	3,547	1/01/2015	18:00:00	168	1/01/2015	01:00:00
		Generation: Northern Coast	3,852	21/01/2015	13:00:00	-3,109	7/06/2015	20:00:00
		Residual load Northern Coast	6,225	7/06/2015	18:00:00	-1,246	7/11/2015	15:00:00
	TA TZ2 DA2 DZ1	**Southern Industrial Zone**	[MW/h]	Date	Time		Date	Time
	Southern Industrial	Load: Southern Industrial Zone	437	1/01/2015	18:00:00	21	1/01/2015	01:00:00
		Generation: Southern Industrial Zone	822	11/11/2015	13:00:00	11	19/05/2015	03:00:00
		Residual load Southern Industrial Zone	330	19/07/2015	18:00:00	-587	11/11/2015	14:00:00
	TA TZ2 DA2 DZ2	**South Coast**	[MW/h]	Date	Time		Date	Time
	South Coast	Load: South Coast	1,097	1/01/2015	18:00:00	52	1/01/2015	01:00:00
		Generation: South Coast	2,064	11/11/2015	13:00:00	27	19/05/2015	03:00:00
		Residual load South Coast	829	19/07/2015	18:00:00	-1,474	11/11/2015	14:00:00

6.2.2 STORAGE DEMAND BY REGION

Storage technologies – particularly decentralised batteries and pumped hydro – are used to avoid curtailment of solar photovoltaic and wind power and to guarantee security of supply. Batteries are assumed to be installed as decentralised applications on the lowest voltage level, while pumped hydro power is likely to be connected to the medium or high voltage level.

Table 24 and Table 25 show the results of the storage demand calculation for 2030 and 2050. The storage requirements are still relatively minor in 2030, and short term storage demand is required to even out day and night variations of solar photovoltaic systems . In 2050, batteries continue to shoulder more than half of the entire storage demand, mainly in connection with solar photovoltaic systems. The uneven results of charge and discharge from pumped hydro indicate a regional and seasonal storage requirement.

Both technologies play an important role: batteries for short term storage requirements, for example to balance demand and supply over a few hours or days; and hydro power is required for seasonal storage, for example wind power to bridge several weeks or months. Pumped hydro can also balance demand and supply across regions as they are connected to transmission grid. The table shows a significant regional storage demand; for example, there is a need to balance the generation difference of the Lake Zone and the Northern Coast, which have significantly higher discharge than charging rates.

Table 25: Storage demand by region in 2030

	2030	Battery charge [MW/h]	Battery discharge [MW/h]	Hydro Pumpstorage charge [MW/h]	Hydro Pumpstorage discharge [MW/h]	Total Storage Through-put [MW/h]
NORTH WEST	Lake-Zone	85,493	85,585	13,557	118,197	302,832
	Western Zone	122,746	122,902	4,830	38,520	288,998
	Northern Highlands	120,803	120,970	4,233	16,517	262,523
	Central/Capital	134,263	134,405	11,659	48,345	328,671
SOUTH WEST	Southern Highlands	131,633	131,787	5,550	45,974	314,944
	Northern Coast	89,278	89,361	13,740	117,021	309,399
	Southern Industrial Zone	127,209	127,386	5,359	10,276	270,230
	South Coast	157,738	157,874	18,651	29,951	364,214
Total		**969,161**	**970,269**	**77,578**	**424,801**	**2,441,810**

Table 26: Storage demand by region in 2050

	2050	Battery charge [MW/h]	Battery discharge [MW/h]	Hydro Pumpstorage charge [MW/h]	Hydro Pumpstorage discharge [MW/h]	Total Storage Through-put [MW/h]
NORTH WEST	Lake-Zone	674,676	674,688	497,550	1,179,574	3,026,488
	Western Zone	566,153	566,581	220,010	357,512	1,710,256
	Northern Highlands	476,318	476,485	142,348	102,376	1,197,526
	Central/Capital	600,983	601,361	395,408	392,484	1,990,236
SOUTH WEST	Southern Highlands	653,790	654,197	262,849	422,471	1,993,307
	Northern Coast	610,368	610,362	464,536	1,198,562	2,883,828
	Southern Industrial Zone	347,017	346,909	165,290	42,291	901,507
	South Coast	511,569	511,569	480,013	173,018	1,676,169
Total		**4,440,873**	**4,442,153**	**2,628,003**	**3,868,288**	**15,379,317**

Table 26 and Table 27 show that the overall supply share from storage technologies under the assumed regional demand and supply situation for 2030 and 2050. The overall share of storage technologies to ensure security of supply and to avoid un-economic curtailment for solar photovoltaics and wind power is still very minor, with an average of 6 per cent across Tanzania.

Variable power generation in some regions exceed demand, while in other regions generation cannot supply regional demand. The analysis does not include an optimisation process for regional generation, but places variable generation where demand, solar- and/or wind resources are highest. Regional difference indicates power transport demand (= transmission network expansion).

Table 27: Dispatch, storage and variable generation by region in 2030

2030		Variable Renewables	Dispatch Renewables	Storage charge	Storage discharge	Supply via Storage	Import (positive values) Export or Curtailment (negative values)
		[%]	[%]	[%]	[%]	[%]	[%]
NORTH WEST	Lake-Zone	37%	55%	1%	2%	3%	9%
	Western Zone	49%	48%	3%	4%	7%	3%
	Northern Highlands	66%	42%	6%	6%	12%	-8%
	Central/Capital	58%	44%	3%	3%	6%	-2%
SOUTH WEST	Southern Highlands	45%	50%	3%	4%	7%	4%
	Northern Coast	41%	53%	1%	2%	3%	6%
	Southern Industrial Zone	83%	37%	8%	8%	16%	-20%
	South Coast	78%	37%	4%	4%	9%	-15%
Total		**50%**	**49%**	**2%**	**3%**	**6%**	**1%**

Concentrated solar power (CSP) with 8-hour molten salt storage technologies plays an important role after 2040 and is seen as 'limited dispatchable' renewable power generation. In 2050, the assumed CSP capacity for Tanzania is 13,875 megawatts and contributes to around one fifth of the dispatchable power generation.

Table 28: Dispatch, storage and variable generation by region in 2050

2050		Variable Renewables	Dispatch Renewables	Storage charge	Storage discharge	Supply via Storage	Import (positive values) Export or Curtailment (negative values)
		[%]	[%]	[%]	[%]	[%]	[%]
NORTH WEST	Lake-Zone	55%	39%	5%	8%	13%	6%
	Western Zone	75%	43%	9%	10%	19%	-18%
	Northern Highlands	106%	43%	14%	13%	27%	-49%
	Central/Capital	90%	38%	9%	9%	18%	-28%
SOUTH WEST	Southern Highlands	70%	45%	9%	11%	20%	-15%
	Northern Coast	60%	36%	5%	9%	14%	3%
	Southern Industrial Zone	138%	48%	16%	12%	28%	-86%
	South Coast	128%	43%	12%	8%	20%	-71%
Total		**77%**	**40%**	**8%**	**9%**	**17%**	**-17%**

6.2.3 DEMAND AND SUPPLY BY VOLTAGE LEVEL

The [R]E24/7 generates demand and supply curves for each voltage level and season. This section shows an example of the South Eastern Transmission region where a significant proportion of Tanzania's industry is located. A negative residual load indicates an export to the next lower voltage level.

Figure 29: Demand and supply case: South Eastern region transmission zone / September 2050

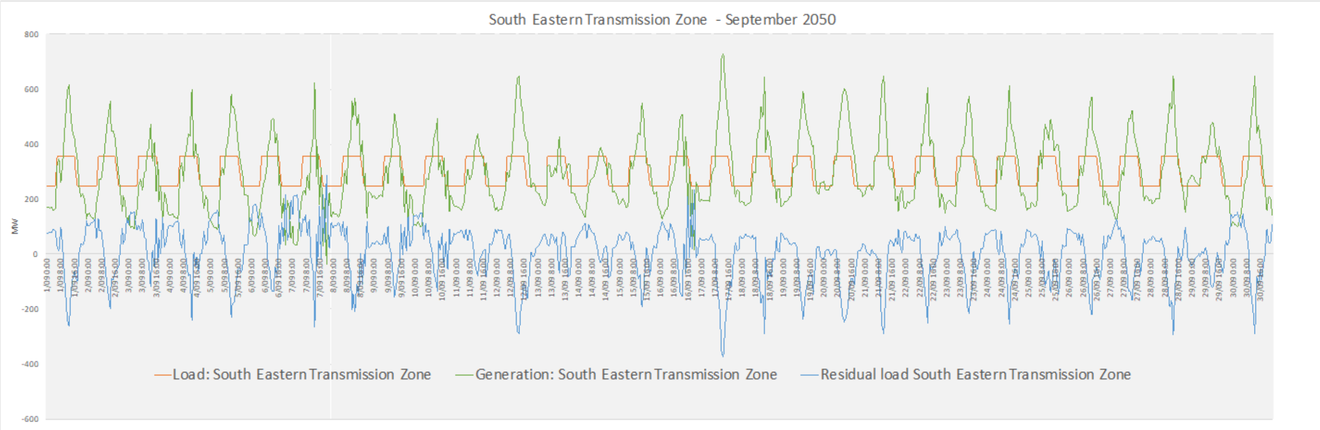


Figure 29 shows that generation in the south-eastern region exceeds demand and that power generation capacity is exported. To allocate generation capacity where demand is highest and therefore power grid infrastructure must cope with high loads makes economic sense. Load centers can therefore also operate as a 'powerhouse' for the region and/or country.

Figure 30: Demand and supply case: Highland – Coast Corridor distribution area / September 2050

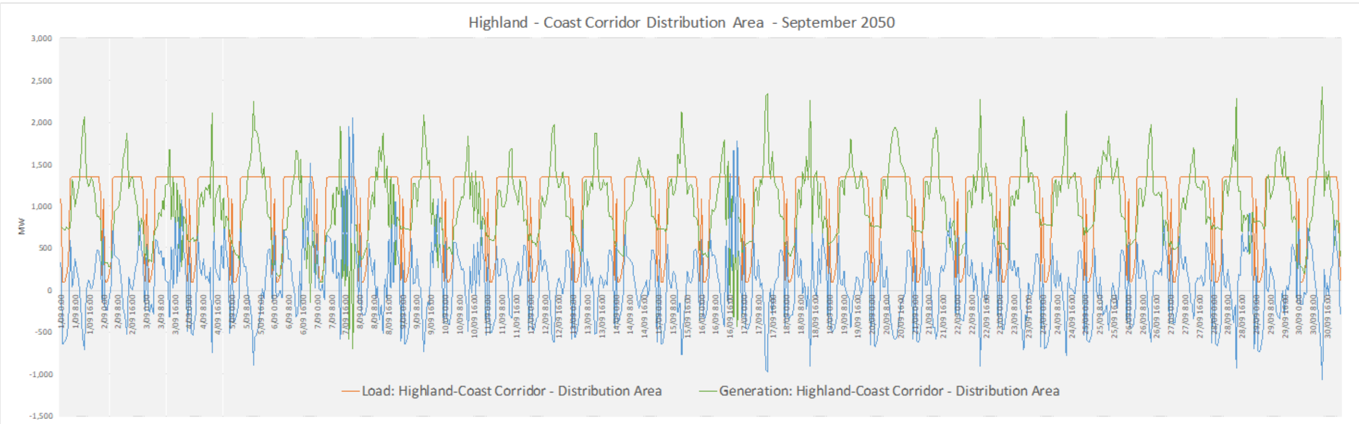
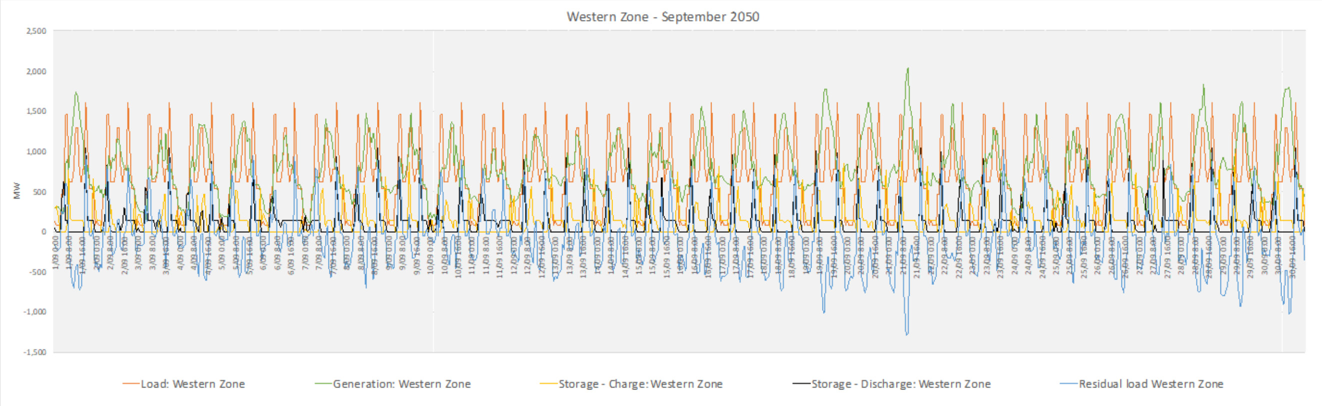


Figure 30 shows the same region as Figure 29, but for the distribution area. Demand and supply match better than at the transmission zone level, and less over-supply is exported to other voltage levels. The mid-day peak is from solar photovoltaics, while the evening generation peaks are from wind power.

Figure 31: Demand and supply case: Western zone / September 2050



The lowest voltage level – the distribution zone – of the Western Zone, which includes Tabora, Katavi and Kigoma, is shown in Figure 31. Battery storage shifts the mid-day generation peak to the early evening hours. Average load alternates between 1500 megawatts and 700 megawatts, while the storage capacity oscillates between +/- 700 megawatts with frequent peaks at around 1000 megawatts. The installed solar photovoltaic capacity in this region is assumed at almost exactly 1000 megawatts which correlates with the maximum storage demand. During the sample month of September 2050, the generation peak around 21 September is a correlation of high solar and wind generation potential. The storage capacity should not be designed for the highest generation peak, but should take into account capacities needed on a regular basis. Extreme and seldom generation surplus peaks should be curtailed rather than stored. A curtailment rate of around 5 per cent per year has proven to be economically viable.

6.2.4 CONSLUSION [R]E 24/7 MODELLING

The hourly modelling of the long term scenario shows, that the chosen mix (the basic RENEWABLES case) is suitable to guarantee security of supply, and that storage technologies in the order of 15 to 20 per cent of total generation are sufficient. Regional distribution via an interconnected power grid can reduce storage demand and curtail variable renewable power generation.

However, the development of storage costs will have a huge influence on whether or not all variable power generation will be stored, or whether the share of dispatchable renewable power generation will increase at the expense of variable power generation and storage.

Tanzania has sufficient renewable energy resources to keep storage shares well below 20 per cent while securing supply with 100 per cent renewable energy.

APPENDIX

The following tables set out the costs for power generation for the range of technologies used in the modelling. These are based on up-to-date data and current market developments, as described in section 3.3.3. The specific investment costs in $/kW are detailed in Table 28 and ongoing operation and maintenance costs in $/kW/year are shown in Table 29.

Table 29: Specific investment costs for power generation

in $/kW		2015	2020	2030	2040	2050
	Biomass and waste power plant	3,145	2,969	2,867	2,750	2,691
	Coal power plant	1,411	1,390	1,356	1,321	1,287
	Diesel generator	907	907	907	907	907
	Gas power plant	769	751	715	679	644
	Geothermal power plant	12,579	9,507	6,509	5,409	4,652
	Hydro large	3,466	3,573	3,734	3,869	3,987
	Hydro small	3,466	3,573	3,734	3,869	3,987
	Lignite power plant	1,645	1,609	1,575	1,540	1,507
	Nuclear power plant	6,615	6,615	6,615	6,615	6,615
	Ocean energy power plant	4,710	3,364	2,340	1,943	1,730
	Oil power plant	967	948	910	872	834
	PV power plant	1,817	1,682	1,305	1,059	1,079
	Solar thermal power plant	5,787	4,705	3,799	3,595	3,479
	Wind turbine offshore	5,631	3,876	3,072	2,775	2,386
	Wind turbine onshore	1,519	1,316	1,305	1,312	1,371
Hydrogen production	Electrolysis	893	844	746	746	746
	CHP Biomass and waste	5,150	4,505	3,934	3,626	3,445
	CHP Coal	1,950	1,919	1,872	1,824	1,777
	CHP Fuel cell	1,726	1,346	1,214	1,155	1,141
	CHP Gas	1,038	995	974	954	933
	CHP Geothermal	13,456	11,409	9,068	7,606	6,582
	CHP Lignite	1,950	1,919	1,872	1,824	1,777
	CHP Oil	1,340	1,312	1,259	1,205	1,153
	CHP Biomass and waste	2,545	2,486	2,443	2,418	2,391
	CHP Coal	1,949	1,919	1,872	1,824	1,777
	CHP Fuel cell	1,726	1,346	1,214	1,155	1,141
	CHP Gas	965	911	804	790	775
	CHP Geothermal	13,456	11,409	9,068	7,606	6,582
	CHP Lignite	1,950	1,919	1,872	1,824	1,777
	CHP Oil	1,339	1,312	1,259	1,205	1,153

Table 30: Operation and maintenance costs for power generation technologies

in $/kW/a		2015	2020	2030	2040	2050
	Biomass and waste power plant	189.1	178.3	172.0	165.5	162.2
	Coal power plant	30.8	29.7	29.7	29.7	29.7
	Diesel generator	112.6	112.6	112.6	112.6	112.6
	Gas power plant	23.7	22.1	20.6	18.6	17.8
	Geothermal power plant	548.6	426.6	324.4	302.9	286.7
	Hydro large	139.0	143.3	149.2	155.0	159.4
	Hydro small	139.0	143.3	149.2	155.0	159.4
	Lignite power plant	27.1	26.5	25.9	25.4	24.9
	Nuclear power plant	162.0	162.0	162.0	162.0	162.0
	Ocean energy power plant	188.7	134.7	93.0	78.2	69.0
	Oil power plant	22.4	21.7	20.3	18.8	17.4
	PV power plant	38.7	21.9	15.4	14.7	15.4
	Solar thermal power plant	350.9	270.0	233.8	215.0	196.4
	Wind turbine offshore	209.5	164.5	133.6	126.6	108.9
	Wind turbine onshore	56.5	55.9	56.8	59.8	62.6
Hydrogen production	Electrolysis	17.9	16.8	14.6	14.6	14.6
	CHP Biomass and waste	361.3	315.9	275.0	254.5	241.3
	CHP Coal	68.7	67.3	65.8	64.4	62.9
	CHP Gas	42.4	39.5	39.5	38.0	38.0
	CHP Geothermal	487.1	409.5	342.3	298.4	272.1
	CHP Lignite	81.9	80.4	77.5	76.1	73.1
	CHP Oil	48.3	46.8	43.9	42.4	41.0
	CHP Biomass and waste	93.6	83.4	74.6	68.7	62.9
	CHP Coal	68.7	67.3	65.8	64.4	62.9
	CHP Fuel cell	86.3	67.3	61.4	58.5	57.0
	CHP Gas	42.4	39.5	39.5	38.0	38.0
	CHP Geothermal	239.9	231.1	222.3	220.9	219.4
	CHP Lignite	81.9	80.4	77.5	76.1	73.1
	CHP Oil	48.3	46.8	43.9	42.4	41.0
	CHP Biomass and waste	101.7	99.5	98.0	96.5	95.1
	CHP Coal	68.0	67.3	65.8	64.4	62.9
	CHP Fuel cell	86.3	67.3	61.4	58.5	57.0
	CHP Gas	38.8	36.6	32.2	32.2	30.7
	CHP Geothermal	239.9	231.1	222.3	220.9	219.4
	CHP Lignite	81.9	80.4	77.5	76.1	73.1

Electricity generation in TWh/a	Scenario: REF 2015	2020	2025	2030	2040	2050
Power plants	**6.8**	**13.7**	**28.3**	**42.8**	**66.0**	**104.5**
- Hard coal (& non-renewable waste)	0.6	5.9	14.0	22.2	21.2	34.4
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	4.6	5.1	5.7	23.3	35.4
of which from H2	0.0	0.0	0.0	0.0	0.0	0.0
- Oil	0.9	0.3	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Biomass (& renewable waste)	0.0	0.0	0.0	0.0	0.0	0.0
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind (Onshore)	0.0	0.7	2.8	4.8	9.2	12.1
- Wind (Offshore)	0.0	0.0	0.1	0.2	0.8	1.7
- PV	0.0	0.3	1.8	3.2	4.8	8.0
- Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
- Solar thermal power plants	0.0	0.0	2.0	4.0	4.0	8.0
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat and power plants	**0.0**	**1.1**	**1.5**	**1.8**	**2.5**	**3.0**
- Hard coal (& non-renewable waste)	0.0	0.3	0.3	0.4	0.5	0.4
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.7	0.9	1.2	1.7	2.1
of which from H2	0.0	0.0	0.0	0.0	0.0	0.0
- Oil	0.0	0.0	0.0	0.1	0.1	0.1
- Biomass (& renewable waste)	0.0	0.1	0.1	0.2	0.2	0.4
- Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
CHP by producer	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
- Main activity producers	0.0	0.0	0.0	0.0	0.0	0.0
- Autoproducers	0.0	1.1	1.5	1.8	2.5	3.0
Total generation	**6.8**	**14.8**	**29.8**	**44.8**	**69.3**	**108.8**
- Fossil	4.2	11.8	20.9	29.9	47.1	72.7
- Hard coal (& non-renewable waste)	0.6	6.1	14.4	22.6	21.7	34.8
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	5.3	6.1	6.9	25.0	37.5
- Oil	0.9	0.3	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- of which renewable H2	0.0	0.0	0.0	0.0	0.0	0.0
- Renewables (w/o renewable hydrogen)	2.6	3.0	8.9	14.9	22.2	36.1
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind	0.0	0.8	2.9	5.0	10.0	13.8
of which wind for transport electricity	0.1	0.4	1.1	1.9	3.6	8.4
- PV	0.0	0.3	1.8	3.2	4.8	8.0
of which solar pv for transport electricity	0.1	0.2	0.6	0.9	1.8	4.2
- Biomass (& renewable waste)	0.0	0.1	0.1	0.2	0.2	0.0
- Geothermal	0.0	0.0	0.0	0.0	0.0	8.0
- Solar thermal power plants	0.0	0.0	2.0	4.0	4.0	0.0
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Import	0.1	0.2	5.9	11.7	16.5	16.5
- Import RES	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0
Distribution losses	1.1	2.5	6.1	9.6	14.6	21.8
Own consumption electricity	0.0	0.9	2.2	3.5	5.3	5.3
Electricity for hydrogen production	0.0	0.0	0.0	0.0	0.0	0.0
Electricity for synfuel production	0.0	0.0	0.0	0.0	0.0	0.0
Transport electricity production	0.2	0.6	1.7	2.9	5.4	12.7

final energy consumption transport in PJ/a	Scenario: REF 2015	2020	2025	2030	2040	2050
road	**88.8**	**104.3**	**138.2**	**172.6**	**284.2**	**581.5**
- fossil fuels	87.3	100.2	127.6	156.6	256.3	503.9
- biofuels	0.0	0.0	1.3	1.6	2.6	26.5
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- natural gas	0.7	2.1	3.6	5.1	8.3	9.0
- hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.7	2.0	5.7	9.4	17.1	42.1
rail	**2.0**	**2.1**	**2.5**	**2.4**	**3.0**	**3.6**
- fossil fuels	2.0	2.0	2.0	1.5	0.5	0.1
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.0	0.1	0.5	0.9	2.5	3.5
navigation	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
- fossil fuels	0.1	0.2	0.2	0.3	0.3	0.4
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
aviation	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
- fossil fuels	0.1	0.2	0.2	0.3	0.3	0.4
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
total (incl. pipelines)	**91.0**	**106.8**	**141.2**	**175.6**	**288.0**	**586.0**
- fossil fuels	89.4	102.6	130.1	158.6	257.4	504.8
- biofuels (incl. biogas)	0.0	0.0	1.3	1.6	2.6	26.5
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- natural gas	0.8	2.1	3.6	5.2	8.4	9.1
- hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.8	2.1	6.2	10.3	19.6	45.6
total RES	0.3	0.4	3.2	5.0	8.9	41.6
RES share	0%	0%	2%	3%	3%	7%

Heat supply in PJ/a	Scenario: REF 2015	2020	2025	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
- Fossil fuels	0	0	0	0	0	0
- Biomass	0	0	0	0	0	0
- Solar collectors	0	0	0	0	0	0
- Geothermal	0	0	0	0	0	0
Heat from CHP 1)	**0**	**3**	**4**	**6**	**11**	**22**
- Fossil fuels	0	3	4	5	10	19
- Biomass	0	0	0	1	1	3
- Geothermal	0	0	0	0	0	0
- Hydrogen	0	0	0	0	0	0
Direct heating	**356**	**356**	**391**	**420**	**514**	**539**
- Fossil fuels	27	37	61	85	121	163
- Biomass	323	310	317	318	368	344
- Solar collectors	2	5	8	10	14	21
- Geothermal	0	0	0	0	1	1
- Heat pumps 2)	1	1	3	4	7	7
- Electric direct heating	3	3	3	3	3	3
- Hydrogen	0	0	0	0	0	0
Total heat supply3)	**356**	**359**	**395**	**426**	**525**	**561**
- Fossil fuels	27	39	64	90	132	182
- Biomass	323	310	317	318	369	347
- Solar collectors	2	5	8	10	14	21
- Geothermal	0	0	0	0	1	1
- Heat pumps 2)	1	1	3	4	7	7
- Electric direct heating	3	3	3	3	3	3
- Hydrogen	0	0	0	0	0	0
RES share (including RES electricity)	92%	88%	83%	79%	75%	67%

Installed capacity in GW	Scenario: REF 2015	2020	2025	2030	2040	2050
Total generation	**2.0**	**3.3**	**8.1**	**10.9**	**17.6**	**27.6**
- Fossil	**1.1**	**2.2**	**4.3**	**5.0**	**8.5**	**13.0**
- Hard coal (& non-renewable waste)	0.1	0.9	2.9	3.5	3.3	5.4
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas (w/o H2)	0.7	1.1	1.2	1.4	5.0	7.5
- Oil	0.3	0.1	0.1	0.1	0.1	0.2
- Diesel	0.0	0.0	0.0	0.0	0.0	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen (fuel cells, gas power plant	0.0	0.0	0.0	0.0	0.0	0.0
- Renewables	**0.9**	**1.1**	**3.9**	**5.9**	**9.0**	**14.5**
- Hydro	0.9	0.6	0.7	0.8	1.1	2.1
- Wind	0.0	0.3	1.1	2.0	3.9	5.3
of which wind for transport electricity	0.0	0.0	0.0	0.0	0.2	0.3
- PV	0.0	0.2	1.1	2.0	3.0	5.0
of which solar pv for transport electricity	0.0	0.1	0.4	0.7	1.0	1.7
- Biomass (& renewable waste)	0.0	0.0	0.0	0.0	0.1	0.1
- Geothermal	0	0	0	0	0	0
- Solar thermal power plants	0	0	1	1	1	2
- Ocean energy	0	0	0	0	0	0
Variable RES (PV, Wind, Ocean)	0.0	0.5	2.2	4.0	6.9	10.3
Share of variable RES	0.6%	15.1%	27.5%	36.6%	39.5%	37.5%

	Scenario: REF 2,015	2,020	2,025	2,030	2,040	2,050
Total (incl. non-energy use)	947	904	970	1,036	1,258	1,586
Total energy use 1)	**945.5**	**902.3**	**967.2**	**1,032.2**	**1,251.6**	**1,578.4**
Transport	91.0	106.8	141.2	175.6	288.0	586.0
- Oil products	89.4	102.6	130.1	158.6	257.4	504.8
- Natural gas	0.8	2.1	3.6	5.2	8.4	9.1
- Biofuels	0.0	0.0	1.3	1.6	2.6	26.5
- Synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- Electricity	0.8	2.1	6.2	10.3	19.6	45.6
RES electricity	0.3	0.4	1.9	3.4	6.3	15.1
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
RES share Transport	0.0	0.0	0.0	0.0	0.0	0.1
Industry	135.5	147.1	176.2	205.2	255.1	326.8
- Electricity	3.2	8.2	14.2	20.2	33.1	61.9
RES electricity	1.2	1.7	4.3	6.7	10.6	20.5
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	7	9	14	19	27	39
- Oil products	9	11	18	25	35	45
- Gas	7	8	13	18	26	34
- Solar	0	1	2	2	3	5
- Biomass	109	110	115	120	130	140
- Geothermal	0	0	0	0	1	1
- Hydrogen	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
RES share Industry	0.8	0.8	0.7	0.6	0.6	0.5
Other Sectors	719.0	648.3	649.8	651.3	708.5	665.5
- Electricity	16.8	31.2	78.5	125.9	184.9	247.5
RES electricity	6.5	6.4	23.6	41.8	59.2	82.1
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Oil products	5.8	6.0	9.8	13.5	18.9	24.3
- Gas	3.7	10.0	16.3	22.5	31.5	41.0
- Solar	1.4	4.0	6.1	8.3	10.8	15.5
- Biomass	690.7	596.1	537.2	478.2	457.5	332.3
- Geothermal	0.5	1.0	2.0	3.0	5.0	5.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
RES share Other Sectors	1.0	0.9	0.9	0.8	0.8	0.7
Total RES	810	721	693	665	686	644
RES share	1	1	1	1	1	0
Non energy use	**2**	**2**	**3**	**4**	**6**	**8**
- Oil	2	2	3	4	6	8
- Gas	0.0	0.0	0.0	0.0	0.0	0.0
- Coal	0.0	0.0	0.0	0.0	0.0	0.0

CO2 emissions in Mill t/a	Scenario: REF 2015	2020	2025	2030	2040	2050
Condensation power plants	2.5	6.9	13.3	19.6	24.3	38.3
- Hard coal (& non-renewable waste)	0.5	4.7	11.1	17.3	15.7	25.4
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	1.9	1.9	2.1	8.4	12.6
- Oil	0.6	0.2	0.2	0.2	0.2	0.3
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
Combined heat and power plants	0.0	0.8	1.1	1.3	1.8	2.0
- Hard coal (& non-renewable waste)	0.0	0.3	0.4	0.5	0.7	0.5
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.5	0.6	0.8	1.1	1.4
- Oil	0.0	0.0	0.0	0.0	0.0	0.0
CO2 emissions power and CHP plants	2.5	7.7	14.4	20.9	26.1	40.3
- Hard coal (& non-renewable waste)	0.5	5.1	11.5	17.7	16.4	26.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	2.3	2.5	2.9	9.4	14.0
- Oil & diesel	0.6	0.3	0.3	0.3	0.3	0.3
CO2 intensity (g/kWh)	0.0	0.0	0.0	0.0	0.0	0.0
without credit for CHP heat	0.0	0.0	0.0	0.0	0.0	0.0
- CO2 intensity fossil electr. generation	598.5	650.5	690.4	699.8	554.3	553.7
- CO2 intensity total electr. generation	367.6	517.7	483.2	467.5	376.8	370.1
CO2 emissions by sector	12.0	19.1	30.0	40.7	56.9	93.4
- % of 1990 emissions (3.2 Mill t)	376.2%	596.0%	936.1%	1272.5%	1778.0%	2918.5%
- Industry 1)	1.7	2.7	4.2	5.6	7.8	10.2
- Other sectors 1)	0.6	1.0	1.7	2.4	3.4	4.3
- Transport	6.5	7.5	9.6	11.7	19.0	36.8
- Power generation 2)	2.5	6.9	13.3	19.6	24.3	38.3
- Other conversion 3)	0.8	0.9	1.2	1.4	2.4	3.8
Population (Mill.)	53.0	62.0	72.0	83.0	108.0	137.0
CO2 emissions per capita (t/capita)	0.2	0.3	0.4	0.5	0.5	0.7

Primary energy demand in PJ/a	Scenario: REF 2015	2020	2025	2030	2040	2050
Total	**1,101**	**1,106**	**1,218**	**1,326**	**1,609**	**2,064**
- Fossil	180	271	409	546	805	1,301
- Hard coal (& non-renewable waste)	13	65	143	218	210	331
- Lignite	0	0	0	0	0	0
- Natural gas	40	68	86	105	249	347
- Crude oil	127	138	180	223	346	624
- Nuclear	0	0	0	0	0	0
- Renewables	**921**	**835**	**808**	**780**	**804**	**763**
- Hydro	9	7	8	9	11	23
- Wind	0	3	10	18	36	50
- Solar	2	6	21	36	46	78
- Biomass (& renewable waste)	910	819	767	714	705	606
- Geothermal	1	1	2	3	6	6
- Ocean energy	0	0	0	0	0	0
Total RES incl. electr. & synfuel import	921	835	815	794	823	783
RES share	84%	75%	66%	58%	49%	37%

Electricity generation in TWh/a	Scenario: RE 2015	2020	2025	2030	2040	2050
Power plants	**7.9**	**13.4**	**33.3**	**50.8**	**88.2**	**159.2**
- Hard coal (& non-renewable waste)	1.7	1.5	1.4	1.5	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	3.4	10.7	11.1	6.8	0.0
of which from H2	0.0	0.0	0.0	0.0	0.0	0.0
- Oil	0.9	0.9	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Biomass (& renewable waste)	0.0	1.7	3.5	3.9	8.4	12.0
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind (Onshore)	0.0	2.0	7.0	12.0	27.0	40.0
- Wind (Offshore)	0.0	0.0	0.0	3.7	8.0	19.0
- PV	0.0	2.0	6.0	11.5	25.4	41.9
- Geothermal	0.0	0.0	0.0	0.0	0.0	3.0
- Solar thermal power plants	0.0	0.0	2.1	8.0	17.0	55.5
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat and power plants	**0.0**	**1.1**	**1.5**	**1.8**	**2.5**	**3.0**
- Hard coal (& non-renewable waste)	0.0	0.2	0.2	0.2	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.7	0.8	0.9	0.8	0.0
of which from H2	0.0	0.0	0.0	0.0	0.0	0.0
- Oil	0.0	0.0	0.0	0.1	0.1	0.0
- Biomass (& renewable waste)	0.0	0.2	0.4	0.6	1.6	3.0
- Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
CHP by producer	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
- Main activity producers	0.0	0.0	0.0	0.0	0.0	0.0
- Autoproducers	0.0	1.1	1.5	1.8	2.5	3.0
Total generation	**7.9**	**14.5**	**34.7**	**56.3**	**98.6**	**181.2**
- Fossil	5.3	6.8	13.6	14.1	8.1	0.5
- Hard coal (& non-renewable waste)	1.7	1.7	1.7	1.7	0.2	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	4.1	11.5	12.0	7.5	0.0
- Oil	0.9	0.9	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- of which renewable H2	0.0	0.0	0.0	0.0	0.0	0.0
- Renewables (w/o renewable hydrogen)	2.6	7.7	21.1	42.2	90.6	180.7
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind	0.0	2.0	7.0	15.7	35.0	59.0
of which wind for transport electricity + H2 produ	0.0	0.1	0.4	1.2	10.3	42.4
- PV	0.0	2.0	6.0	11.5	25.4	41.9
of which solar pv for transport electricity + H2 pr	0.0	0.0	0.2	0.6	5.1	21.2
- Biomass (& renewable waste)	0.0	1.9	3.9	4.5	10.0	15.0
- Geothermal	0.0	0.0	0.0	0.0	0.0	3.0
- Solar thermal power plants	0.0	0.0	2.1	8.0	17.0	55.5
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Import	0.0	0.0	0.0	0.0	0.0	0.0
- Import RES	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0
Distribution losses	1.3	2.5	6.1	9.6	14.6	21.8
Own consumption electricity	1.0	0.9	2.2	3.5	5.3	5.3
Electricity for hydrogen production	0.0	0.0	0.1	0.1	0.3	0.0
Electricity for synfuel production	0.0	0.0	0.0	0.0	0.0	0.0
Transport electricity production	0.0	0.1	0.6	1.9	15.6	64.3

final energy consumption transport in PJ/a	Scenario: RE 2015	2020	2025	2030	2040	2050
road	**89.4**	**104.3**	**137.7**	**171.6**	**283.2**	**577.1**
- fossil fuels	89.4	104.1	135.0	165.1	224.3	322.7
- biofuels	0.0	0.0	1.4	1.7	2.3	17.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- natural gas	0.0	0.0	0.0	0.0	4.0	13.8
- hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.0	0.2	1.3	4.8	52.7	223.5
rail	**2.0**	**2.1**	**3.0**	**3.5**	**4.0**	**8.0**
- fossil fuels	2.0	2.0	2.0	1.5	0.5	0.0
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.0	0.1	1.0	2.0	3.5	8.0
navigation	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
- fossil fuels	0.1	0.2	0.2	0.2	0.2	0.2
- biofuels	0.0	0.0	0.0	0.0	0.1	0.2
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
aviation	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
- fossil fuels	0.1	0.2	0.2	0.3	0.3	0.4
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
total (incl. pipelines)	**91.7**	**106.8**	**141.2**	**175.6**	**288.0**	**586.0**
- fossil fuels	91.6	106.5	137.5	167.1	225.3	323.3
- biofuels (incl. biogas)	0.0	0.0	1.4	1.7	2.4	17.2
- synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- natural gas	0.0	0.0	0.0	0.0	4.1	13.9
- hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
- electricity	0.0	0.3	2.3	6.8	56.2	231.5
total RES	0.0	0.2	2.8	6.8	54.0	248.2
RES share	0%	0%	2%	4%	19%	42%

Heat supply in PJ/a	Scenario: RE 2015	2020	2025	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
- Fossil fuels	0	0	0	0	0	0
- Biomass	0	0	0	0	0	0
- Solar collectors	0	0	0	0	0	0
- Geothermal	0	0	0	0	0	0
Heat from CHP 1)	**0**	**3**	**4**	**6**	**11**	**24**
- Fossil fuels	0	2	3	4	4	0
- Biomass	0	0	1	2	7	24
- Geothermal	0	0	0	0	0	0
- Hydrogen	0	0	0	0	0	0
Direct heating	**358**	**356**	**391**	**421**	**514**	**537**
- Fossil fuels	27	28	40	39	36	1
- Biomass	325	318	330	337	372	379
- Solar collectors	2	5	15	29	63	83
- Geothermal	0	0	0	0	1	8
- Heat pumps 2)	1	1	3	13	38	63
- Electric direct heating	3	3	3	3	3	3
- Hydrogen	0	0	0	0	1	0
Total heat supply3)	**358**	**359**	**395**	**426**	**525**	**561**
- Fossil fuels	27	31	43	44	40	1
- Biomass	325	318	332	338	379	402
- Solar collectors	2	5	15	29	63	83
- Geothermal	0	0	0	0	1	8
- Heat pumps 2)	1	1	3	13	38	63
- Electric direct heating 2)	3	3	3	3	3	3
- Hydrogen	0	0	0	0	1	0
RES share (including RES electricity)	92%	91%	89%	90%	92%	100%

Installed capacity in GW	Scenario: RE 2015	2020	2025	2030	2040	2050
Total generation	**2.2**	**4.6**	**11.8**	**18.6**	**36.5**	**62.8**
- Fossil	**1.3**	**1.5**	**2.6**	**2.7**	**2.0**	**0.2**
- Hard coal (& non-renewable waste)	0.3	0.3	0.3	0.3	0.0	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas (w/o H2)	0.7	0.8	2.1	2.2	1.8	0.0
- Oil	0.3	0.4	0.1	0.1	0.1	0.2
- Diesel	0.0	0.0	0.0	0.0	0.0	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen (fuel cells, gas power plant	0.0	0.0	0.0	0.0	0.0	0.0
- Renewables	**0.9**	**3.1**	**9.2**	**15.9**	**34.5**	**62.6**
- Hydro	0.9	0.6	0.7	0.8	1.1	2.1
- Wind	0.0	0.8	2.8	4.8	10.8	16.0
of which wind for transport electricity	0.0	0.0	0.0	0.8	1.6	3.9
- PV	0.0	1.3	3.8	7.2	15.9	26.2
of which solar pv for transport electricity	0.0	0.4	1.2	2.4	5.2	8.6
- Biomass (& renewable waste)	0.0	0.5	1.0	1.1	2.5	3.8
- Geothermal	0	0	0	0	0	1
- Solar thermal power plants	0	0	1	2	4	14
- Ocean energy	0	0	0	0	0	0
Variable RES (PV, Wind, Ocean)	0.0	2.1	6.6	12.0	26.7	42.2
Share of variable RES	0.5%	44.4%	55.7%	64.2%	73.1%	67.2%

	Scenario: RE 2,015	2,020	2,025	2,030	2,040	2,050
Total (incl. non-energy use)	948	899	965	1,042	1,268	1,607
Total energy use 1)	**946.3**	**897.2**	**962.5**	**1,038.1**	**1,262.8**	**1,600.9**
Transport	91.7	106.8	141.2	175.6	288.0	586.0
- Oil products	91.6	106.5	137.5	167.1	225.3	323.3
- Natural gas	0.0	0.0	0.0	0.0	4.1	13.9
- Biofuels	0.0	0.0	1.4	1.7	2.4	17.2
- Synfuels	0.0	0.0	0.0	0.0	0.0	0.0
- Electricity	0.0	0.3	2.3	6.8	56.2	231.5
RES electricity	0.0	0.2	1.4	5.1	51.6	230.9
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
RES share Transport	0.0	0.0	0.0	0.0	0.2	0.4
Industry	132.4	144.0	173.4	201.0	260.4	338.1
- Electricity	3.2	8.2	14.2	22.2	38.0	69.9
RES electricity	1.1	4.4	8.6	16.6	34.9	69.8
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	7	0	0	0	1	0
- Oil products	9	10	10	9	7	0
- Gas	7	9	14	18	15	0
- Solar	0	1	6	11	23	37
- Biomass	105	116	129	135	161	199
- Geothermal	0	0	0	5	14	32
- Hydrogen	**0.0**	**0.0**	**0.1**	**0.2**	**0.8**	**0.0**
RES share Industry	0.8	0.8	0.8	0.8	0.9	1.0
Other Sectors	722.1	646.3	647.8	661.5	714.5	676.8
- Electricity	16.9	31.2	78.5	126.3	188.3	253.5
RES electricity	5.6	16.6	47.8	94.6	172.9	252.8
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	0.0	0.0	0.7	-0.6	-0.4	1.4
- Oil products	5.9	6.0	6.3	4.9	3.9	0.0
- Gas	3.8	10.3	17.0	16.0	17.1	0.0
- Solar	1.4	4.0	8.5	17.7	39.5	46.1
- Biomass	693.6	593.8	534.9	493.4	451.6	352.8
- Geothermal	0.5	1.0	2.0	3.9	14.5	23.1
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
RES share Other Sectors	1.0	1.0	0.9	0.9	0.9	1.0
Total RES	808	738	740	784	966	1260
RES share	1	1	1	1	1	1
Non energy use	**2**	**2**	**3**	**4**	**5**	**7**
- Oil	2	1	2	2	2	2
- Gas	0.2	0.2	0.2	0.3	0.3	0.3
- Coal	0.1	0.2	0.5	1.1	2.5	3.9

CO2 emissions in Mill t/a	Scenario: RE 2015	2020	2025	2030	2040	2050
Condensation power plants	3.7	3.9	7.2	7.4	3.9	0.3
- Hard coal (& non-renewable waste)	1.6	1.4	1.3	1.3	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	1.8	5.6	5.8	3.5	0.0
- Oil	0.6	0.6	0.2	0.2	0.2	0.3
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
Combined heat and power plants	0.0	0.7	0.8	1.0	0.6	0.0
- Hard coal (& non-renewable waste)	0.0	0.2	0.3	0.3	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.5	0.5	0.6	0.5	0.0
- Oil	0.0	0.0	0.0	0.0	0.0	0.0
CO2 emissions power and CHP plants	3.7	4.6	8.1	8.4	4.5	0.4
- Hard coal (& non-renewable waste)	1.6	1.6	1.6	1.6	0.2	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	2.2	6.1	6.4	4.0	0.0
- Oil & diesel	0.7	0.8	0.3	0.3	0.3	0.3
CO2 intensity (g/kWh)	0.0	0.0	0.0	0.0	0.0	0.0
without credit for CHP heat	0.0	0.0	0.0	0.0	0.0	0.0
- CO2 intensity fossil electr. generation	692.9	676.3	593.0	592.3	560.0	772.8
- CO2 intensity total electr. generation	463.3	315.6	232.3	148.5	45.9	1.9
CO2 emissions by sector	12.6	14.4	20.9	23.2	23.5	24.5
- % of 1990 emissions (3 Mill t)	420.1%	479.8%	695.7%	773.3%	785.0%	817.8%
- Industry 1)	1.7	1.8	2.2	2.4	1.9	0.1
- Other sectors 1)	0.6	1.1	1.6	1.3	1.4	0.1
- Transport	6.6	7.7	9.9	12.0	16.4	24.0
- Power generation 2)	3.7	3.9	7.2	7.4	3.9	0.3
- Other conversion 3)	0.0	0.0	0.0	0.0	0.0	0.0
Population (Mill.)	53.0	62.0	72.0	83.0	108.0	137.0
CO2 emissions per capita (t/capita)	0.2	0.2	0.3	0.3	0.2	0.2

Primary energy demand in PJ/a	Scenario: RE 2015	2020	2025	2030	2040	2050
Total	**1,107**	**1,101**	**1,257**	**1,340**	**1,581**	**2,027**
- Fossil	190	223	337	375	377	371
- Hard coal (& non-renewable waste)	25	18	20	19	5	6
- Lignite	0	0	0	0	0	0
- Natural gas	37	61	145	153	111	14
- Crude oil	128	145	173	203	260	351
- Nuclear	0	0	0	0	0	0
- Renewables	**917**	**877**	**920**	**965**	**1,204**	**1,656**
- Hydro	9	7	8	9	11	23
- Wind	0	7	25	57	126	212
- Solar	2	13	44	99	215	434
- Biomass (& renewable waste)	906	850	841	792	822	834
- Geothermal	1	1	2	9	29	153
- Ocean energy	0	0	0	0	0	0
Total RES incl. electr. & synfuel import	917	877	920	965	1,204	1,656
RES share	83%	80%	73%	72%	76%	82%

Electricity generation in TWh/a	Scenario: ADV 2015	2020	2025	2030	2040	2050
Power plants	**7.9**	**14.6**	**37.4**	**64.6**	**135.2**	**239.1**
- Hard coal (& non-renewable waste)	1.7	1.7	1.7	1.8	0.0	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	3.4	10.7	11.1	6.8	2.5
of which from H2	0.0	0.0	0.1	0.3	0.9	2.5
- Oil	0.9	0.9	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Biomass (& renewable waste)	0.0	1.7	3.5	6.4	16.4	18.8
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind (Offshore)	0.0	3.0	7.0	21.0	39.0	75.0
- Wind (Onshore)	0.0	0.0	7.0	13.0	36.0	68.0
- PV	0.0	2.0	8.0	13.5	44.0	71.8
- Geothermal	0.0	0.0	0.0	0.0	0.0	3.0
- Solar thermal power plants	0.0	0.0	4.0	8.0	25.6	61.3
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Combined heat and power plants	**0.0**	**1.1**	**1.5**	**1.8**	**2.5**	**3.0**
- Hard coal (& non-renewable waste)	0.0	0.2	0.2	0.2	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.7	0.8	0.9	0.8	0.0
of which from H2	0.0	0.0	0.0	0.0	0.1	0.0
- Oil	0.0	0.0	0.0	0.1	0.1	0.0
- Biomass (& renewable waste)	0.0	0.2	0.4	0.6	1.6	3.0
- Geothermal	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.0	0.0	0.0	0.0
CHP by producer	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
- Main activity producers	0.0	0.0	0.0	0.0	0.0	0.0
- Autoproducers	0.0	1.1	1.5	1.8	2.5	3.0
Total generation	**7.9**	**15.7**	**45.9**	**79.4**	**173.7**	**310.1**
- Fossil	5.3	6.9	13.7	14.1	7.0	0.5
- Hard coal (& non-renewable waste)	1.7	1.8	1.9	2.0	0.1	0.1
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	2.6	4.1	11.4	11.7	6.5	0.0
- Oil	0.9	0.9	0.3	0.3	0.3	0.4
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen	0.0	0.0	0.1	0.3	1.1	2.5
- of which renewable H2	0.0	0.0	0.1	0.2	1.0	2.5
- Renewables (w/o renewable hydrogen)	2.6	8.7	32.1	65.0	165.7	307.1
- Hydro	2.6	1.8	2.2	2.5	3.2	6.3
- Wind	0.0	3.0	14.0	34.0	75.0	143.0
of which wind for transport electricity	0.0	0.4	2.2	6.3	27.6	77.6
- PV	0.0	2.0	8.0	13.5	44.0	71.8
of which solar pv for transport electricity	0.0	0.2	1.1	3.2	13.8	38.8
- Biomass (& renewable waste)	0.0	1.9	3.9	7.0	18.0	21.8
- Geothermal	0.0	0.0	0.0	0.0	0.0	3.0
- Solar thermal power plants	0.0	0.0	4.0	8.0	25.6	61.3
- Ocean energy	0.0	0.0	0.0	0.0	0.0	0.0
Import	0.0	0.0	0.0	0.0	0.0	0.0
- Import RES	0.0	0.0	0.0	0.0	0.0	0.0
Export	0.0	0.0	0.0	0.0	0.0	0.0
Distribution losses	1.3	2.5	6.1	9.6	14.6	21.8
Own consumption electricity	1.0	0.9	2.2	3.5	5.3	5.3
Electricity for hydrogen production	0.0	0.6	3.2	8.3	24.9	40.4
Electricity for synfuel production	0.0	0.0	5.4	7.1	24.1	34.8
Transport electricity production	0.0	0.6	3.3	9.6	41.8	117.6

final energy consumption transport in PJ/a	Scenario: ADV 2015	2020	2025	2030	2040	2050
road	**89.4**	**102.6**	**122.8**	**141.7**	**170.6**	**290.3**
- fossil fuels	89.4	101.0	113.3	117.6	72.6	0.0
- biofuels	0.0	0.0	1.4	1.7	2.4	17.0
- synfuels	0.0	0.0	7.2	9.9	35.0	51.9
- natural gas	0.0	0.0	0.0	0.0	0.0	0.0
- hydrogen	0.0	0.9	3.8	10.4	28.1	70.3
- electricity	0.0	0.7	4.3	12.0	67.5	203.0
rail	**2.0**	**2.4**	**4.2**	**6.6**	**17.3**	**55.5**
- fossil fuels	2.0	1.8	1.5	1.0	0.2	0.0
- biofuels	0.0	0.0	0.0	0.0	0.0	0.0
- synfuels	0.0	0.0	0.1	0.1	0.1	0.0
- electricity	0.0	0.6	2.5	5.5	17.0	55.5
navigation	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.4**
- fossil fuels	0.1	0.2	0.2	0.2	0.2	0.0
- biofuels	0.0	0.0	0.0	0.0	0.0	0.1
- synfuels	0.0	0.0	0.0	0.0	0.1	0.3
aviation	**0.1**	**0.2**	**0.2**	**0.3**	**0.3**	**0.3**
- fossil fuels	0.1	0.2	0.2	0.2	0.2	0.0
- biofuels	0.0	0.0	0.0	0.0	0.0	0.1
- synfuels	0.0	0.0	0.0	0.0	0.1	0.2
total (incl. pipelines)	**112.3**	**146.7**	**196.5**	**241.2**	**347.3**	**563.4**
- fossil fuels	91.6	103.2	115.3	119.0	73.2	0.0
- biofuels (incl. biogas)	0.0	0.0	1.4	1.7	2.4	17.2
- synfuels	0.0	0.1	7.3	10.2	35.3	52.4
- natural gas	20.6	39.8	54.6	60.3	42.7	0.0
- hydrogen	0.0	1.3	6.1	15.6	43.1	70.3
- electricity	0.0	2.3	11.8	34.5	150.5	423.5
total RES	0.0	2.1	19.1	51.2	222.1	562.5
RES share	0%	1%	10%	21%	64%	100%

Heat supply in PJ/a	Scenario: ADV 2015	2020	2025	2030	2040	2050
District heating plants	**0**	**0**	**0**	**0**	**0**	**0**
- Fossil fuels	0	0	0	0	0	0
- Biomass	0	0	0	0	0	0
- Solar collectors	0	0	0	0	0	0
- Geothermal	0	0	0	0	0	0
Heat from CHP 1)	**0**	**3**	**4**	**6**	**11**	**24**
- Fossil fuels	0	2	3	4	4	0
- Biomass	0	0	1	2	7	24
- Geothermal	0	0	0	0	0	0
- Hydrogen	0	0	0	0	0	0
Direct heating	**358**	**356**	**391**	**421**	**514**	**537**
- Fossil fuels	27	28	40	39	33	1
- Biomass	325	318	330	337	372	379
- Solar collectors	2	5	15	29	63	83
- Geothermal	0	0	0	0	1	8
- Heat pumps 2)	1	1	3	13	38	63
- Electric direct heating	3	3	3	3	3	3
- Hydrogen	0	0	0	1	4	0
Total heat supply3)	**358**	**359**	**395**	**426**	**525**	**561**
- Fossil fuels	27	31	43	43	37	1
- Biomass	325	318	332	338	379	402
- Solar collectors	2	5	15	29	63	83
- Geothermal	0	0	0	0	1	8
- Heat pumps 2)	1	1	3	13	38	63
- Electric direct heating	3	3	3	3	3	3
- Hydrogen	0	0	0	1	4	0
RES share (including RES electricity)	92%	91%	89%	90%	93%	100%

Installed capacity in GW	Scenario: ADV 2015	2020	2025	2030	2040	2050
Total generation	**2.2**	**5.0**	**13.9**	**25.0**	**59.5**	**112.9**
- Fossil	**1.3**	**1.5**	**2.6**	**2.8**	**1.8**	**0.2**
- Hard coal (& non-renewable waste)	0.3	0.3	0.4	0.5	0.0	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas (w/o H2)	0.7	0.8	2.1	2.1	1.6	0.0
- Oil	0.3	0.4	0.1	0.1	0.1	0.2
- Diesel	0.0	0.0	0.0	0.0	0.0	0.0
- Nuclear	0.0	0.0	0.0	0.0	0.0	0.0
- Hydrogen (fuel cells, gas power plant	0.0	0.0	0.0	0.1	0.3	0.6
- Renewables	**0.9**	**3.5**	**11.3**	**22.2**	**57.5**	**112.1**
- Hydro	0.9	0.6	0.7	0.8	1.1	2.1
- Wind	0.0	1.2	2.8	8.4	15.6	30.0
of which wind for transport electricity	0.0	0.0	1.4	2.6	7.3	13.8
- PV	0.0	1.3	5.0	8.4	27.5	44.8
of which solar pv for transport electricity	0.0	0.4	1.7	2.8	9.1	14.8
- Biomass (& renewable waste)	0.0	0.5	1.0	1.3	3.1	3.9
- Geothermal	0	0	0	0	0	1
- Solar thermal power plants	0	0	2	3	10	31
- Ocean energy	0	0	0	0	0	0
Variable RES (PV, Wind, Ocean)	0.0	2.5	7.8	16.8	43.1	74.8
Share of variable RES	0.5%	48.6%	56.0%	67.2%	72.4%	66.3%

	Scenario: ADV 2,015	2,020	2,025	2,030	2,040	2,050
Total (incl. non-energy use)	969	939	1,020	1,108	1,328	1,586
Total energy use 1)	**966.9**	**937.0**	**1,017.7**	**1,103.9**	**1,322.7**	**1,579.3**
Transport	112.3	146.7	196.5	241.2	347.3	563.4
- Oil products	91.6	103.2	115.3	119.0	73.2	0.0
- Natural gas/biogas	20.6	39.8	54.6	60.3	42.7	0.0
- Biofuels	0.0	0.0	1.4	1.7	2.4	17.2
- Synfuels	0.0	0.1	7.3	10.2	35.3	52.4
- Electricity	0.0	2.3	11.8	34.5	150.5	423.5
RES electricity	0.0	1.3	8.3	28.3	144.4	422.9
- Hydrogen	0.0	1.3	6.1	15.6	43.1	70.3
RES share Transport	0.0	0.0	0.1	0.2	0.6	1.0
Industry	132.4	144.0	173.4	201.2	260.9	339.1
- Electricity	3.2	8.2	14.2	22.5	38.8	71.3
RES electricity	1.1	4.6	10.0	18.5	37.2	71.1
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	7	0	0	0	1	0
- Oil products	9	10	10	9	7	0
- Gas	7	9	14	17	14	0
- Solar	0	1	6	11	23	37
- Biomass	105	116	129	135	161	199
- Geothermal	0	0	0	5	14	32
- Hydrogen	**0.0**	**0.0**	**0.1**	**0.4**	**2.2**	**0.0**
RES share Industry	0.8	0.8	0.8	0.8	0.9	1.0
Other Sectors	722.1	646.3	647.8	661.5	714.5	676.8
- Electricity	16.9	31.2	78.5	126.3	188.3	253.5
RES electricity	5.6	17.4	55.0	103.7	180.7	253.1
- Public district heat	0.0	0.0	0.0	0.0	0.0	0.0
RES district heat	0.0	0.0	0.0	0.0	0.0	0.0
- Hard coal & lignite	0.0	0.0	0.7	-0.6	-0.4	1.4
- Oil products	5.9	6.0	6.3	4.9	3.9	0.0
- Gas	3.8	10.3	16.8	15.6	14.7	0.0
- Solar	1.4	4.0	8.5	17.7	39.5	46.1
- Biomass	693.6	593.8	534.9	493.4	451.6	352.8
- Geothermal	0.5	1.0	2.0	3.9	14.5	23.1
- Hydrogen	0.0	0.0	0.2	0.4	2.4	0.0
RES share Other Sectors	1.0	1.0	0.9	0.9	1.0	1.0
Total RES	808	740	765	840	1148	1576
RES share	1	1	1	1	1	1
Non energy use	**2**	**2**	**3**	**4**	**5**	**7**
- Oil	2	1	2	2	2	2
- Gas	0.2	0.2	0.2	0.3	0.3	0.3
- Coal	0.1	0.2	0.5	1.1	2.5	3.9

CO2 emissions in Mill t/a	Scenario: ADV 2015	2020	2025	2030	2040	2050
Condensation power plants	3.7	4.0	7.4	7.6	3.3	0.4
- Hard coal (& non-renewable waste)	1.6	1.5	1.5	1.6	0.0	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	1.8	5.6	5.6	3.0	0.0
- Oil	0.6	0.6	0.2	0.2	0.2	0.3
- Diesel	0.1	0.1	0.1	0.1	0.1	0.0
Combined heat and power plants	0.0	0.7	0.8	0.9	0.6	0.0
- Hard coal (& non-renewable waste)	0.0	0.2	0.3	0.3	0.1	0.0
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	0.0	0.5	0.5	0.6	0.4	0.0
- Oil	0.0	0.0	0.0	0.0	0.0	0.0
CO2 emissions power and CHP plants	3.7	4.7	8.2	8.5	3.9	0.4
- Hard coal (& non-renewable waste)	1.6	1.7	1.8	1.9	0.1	0.1
- Lignite	0.0	0.0	0.0	0.0	0.0	0.0
- Gas	1.4	2.2	6.0	6.2	3.5	0.0
- Oil & diesel	0.7	0.8	0.3	0.3	0.3	0.3
CO2 intensity (g/kWh)	0.0	0.0	0.0	0.0	0.0	0.0
without credit for CHP heat	0.0	0.0	0.0	0.0	0.0	0.0
- CO2 intensity fossil electr. generation	692.9	681.6	598.5	601.1	560.1	0.0
- CO2 intensity total electr. generation	463.3	301.3	178.7	107.0	22.5	1.2
CO2 emissions by sector	13.7	16.4	22.3	23.1	13.8	0.5
- % of 1990 emissions (3 Mill t)	457.0%	547.9%	744.2%	769.0%	460.9%	17.0%
- Industry 1)	1.7	1.8	2.2	2.4	1.7	0.0
- Other sectors 1)	0.6	1.1	1.6	1.3	1.2	0.1
- Transport	6.6	7.4	8.3	8.6	5.3	0.0
- Power generation 2)	3.7	4.0	7.4	7.6	3.3	0.4
- Other conversion 3)	1.1	2.1	2.9	3.2	2.3	0.0
Population (Mill.)	53.0	62.0	72.0	83.0	108.0	137.0
CO2 emissions per capita (t/capita)	0.3	0.3	0.3	0.3	0.1	0.0

Primary energy demand in PJ/a	Scenario: ADV 2015	2020	2025	2030	2040	2050
Total	**1,128**	**1,142**	**1,328**	**1,466**	**1,826**	**2,222**
- Fossil	210	261	369	382	237	13
- Hard coal (& non-renewable waste)	25	20	22	22	4	6
- Lignite	0	0	0	0	0	0
- Natural gas	57	100	198	209	136	0
- Crude oil	128	141	149	151	97	7
- Nuclear	0	0	0	0	0	0
- Renewables	**917**	**881**	**959**	**1,083**	**1,590**	**2,209**
- Hydro	9	7	8	9	11	23
- Wind	0	11	50	122	270	515
- Solar	2	13	58	106	313	562
- Biomass (& renewable waste)	906	850	841	837	966	956
- Geothermal	1	1	2	9	29	153
- Ocean energy	0	0	0	0	0	0
Total RES incl. electr. & synfuel import	917	881	959	1,083	1,590	2,209
RES share	81%	77%	72%	74%	87%	99%

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