Country Deep Dive Analysis 2019:
Recommendations to include off-grid RE in the NDC update 2020 and initialize international support

Ethiopia

Authors:
Michel Köhler (the greenwerk., lead author)
Laura Brauhardt (the greenwerk.)
Christine Nettersheim (the greenwerk.)

Contributions and review by:
Till Serafimov (GIZ Ethiopia)
David Otieno (GIZ Ethiopia)
Samson Tolessa (GIZ Ethiopia)
Dorothee Merkel (GIZ Ethiopia)
Content

1 Rationale of Deep Dive ................................................................. 2
2 Background on Ethiopia ............................................................... 2
3 The Ethiopian power sector .......................................................... 3
   3.1 RE off-grid policies and the NDC ............................................. 4
   3.2 Legal framework, policies and plans ........................................ 5
   3.3 Off-grid RE investment and financing needs according to the NEP 2.0 ......................................................... 7
   3.4 Current support landscape for off-grid RE .................................. 9
4 Simulation of off-grid RE pathways until 2025 .................................. 11
   4.1 Electrification Mix ............................................................... 14
   4.2 Initial investment needs ....................................................... 15
   4.3 GHG emissions ................................................................. 17
5 Recommendations for NDC revision ............................................... 19
   5.1 NDC revision process in Ethiopia ............................................ 19
   5.2 Potential of ambition raising for the off-grid RE NDC component ......................................................... 20
   5.3 Conditional elements of the NDC ............................................. 21
6 Concluding remarks .................................................................... 22
References ..................................................................................... 24
Annexes ......................................................................................... 26
   Annex 1: Methodology for scenario development and electrification solutions ......................................................... 26
   Annex 2: Methodology for demand estimation .................................................. 30
   Annex 3: Methodology for assessment of investment needs .................................................. 31
   Annex 4: Methodology for estimation of the GHG reduction potential .................................................. 32
   Annex 5: Experts consulted ......................................................... 34
1 Rationale of Deep Dive

The overall aim of this project is to support “Strategies for Renewable Energy for Climate Protection in Developing Countries”, for which the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH nominated a consortium made up of the Reiner Lemoine Institut (RLI) and the greenwerk. The specific objective of this study is to assess the climate action relevance of the dynamically developing off-grid renewables (RE) sector with a focus on Nationally Determined Contributions (NDCs) and international support elements.

Sub-tasks include the quantification of the impact of off-grid RE technologies for providing electricity access, the overall emissions of the growing sector, their market potential in low electrified countries and the respective socio-economic benefits besides Greenhouse Gas (GHG emission reductions). Additionally, three country deep dive reports shall provide the following elements to developing country stakeholders, particularly policymakers:

- Share detailed country specific recommendations for ambition raising of NDCs;
- Share country level recommendations for inclusion of off-grid RE elements in NDCs;
- Reflect on the results from our global report in view of the 2020 NDC updates; and,
- Initialize international support to foster off-grid RE development.

2 Background on Ethiopia

With a population of ~109 million, Ethiopia is the second most populous nation in Africa after Nigeria, and the fastest growing economy in the region. However, it is also one of the poorest, with a per capita income of only USD 790 (World Bank 2019). However, Ethiopia has witnessed a significant level of economic growth over the past years: From 2006/07 to 2016/17, the country’s Gross Domestic Product (GDP) grew on average by 10.3% per year, which is relatively high compared to the East African regional average of 5.4%. While the agricultural sector represents the backbone of the local economy (47% of its GDP), most of its recent growth derived from the industry, mainly construction, and services (World Bank 2019; USAID 2019, p. 1, USAID 2016).

Advancements in economic growth have also led to some poverty reduction in both urban and rural areas. The share of the population living below the national poverty line decreased from 30% in 2011 to 24% in 2016 (World Bank 2019). Its current development path is driven by the second phase of the Ethiopian Growth and Transformation Plan (GTP II), which aims for Ethiopia to achieve lower middle income and carbon neutral status by 2025 (GoE 2015). According to this strategy, the expansion of physical infrastructure through public investments should be continued and the
country should be transformed into a manufacturing hub. This should result in an average annual GDP growth of at 11%, which goes in line with the manufacturing strategy and the desire to create more jobs (GoE 2015).

Ethiopia’s desire to lead not only on economic development, but also take climate change dynamics into consideration, also derives from the fact that the country is highly vulnerable to climate change impacts, especially heavy rainfall and drought. This affects Ethiopia’s agricultural sector in particular, as it runs on sufficient rainfall. As around 85% of the Ethiopian population directly depends on this sector, negative developments regarding the land quality or crop productivity has a significant impact on the well-being of the whole country (USAID 2016). The associated costs of climate change to the economy are not yet well documented. Estimates assume that the primary impacts of climate change on grain and livestock productivity and agricultural labor migration can be estimated at -8% of GDP. The regional economic effects of climate change range from -10% in agrarian regions (e.g. Amhara) to +2.5% in urban regions (e.g. Addis Ababa) (Yalew et al. 2017).

One sector, which combines the challenges of both increasing the country’s development status and following a low-carbon and climate-resilient pathway is the energy sector. With only 44.3% of Ethiopians electrified, the country has one of the lowest rates of electrification worldwide (IEA 2019). This is mainly a problem, which affects rural and remote areas of the country: While 96.6% of the urban population has access to electrification, only about 27% of the rural population is electrified (MOWIE 2019, p.18). To tackle the electrification challenge, the flourishing off-grid RE market has been evolving, supplying about 11% of the total population, but does not yet live up to its full potential due to existing barriers in the local context (e.g. policy and regulatory, economic, financial, capacity) (USAID 2019). With the National Electrification Program 2.0, that has been launched in 2019, the Government of Ethiopia has a new strategy guiding the development path within this sector, while considering both grid-connected and off-grid solutions (MOWIE 2019).

3 The Ethiopian power sector

Ethiopia has a final energy consumption of around 40,000 GWh. With a share of 92.4% of Ethiopia’s energy supply, waste and biomass are the country’s primary energy sources, followed by oil (5.7%) and hydropower (1.6%) (IEA 2019). Electricity is mostly used by urban households and small industry. Per capita electricity consumption was 23 kWh in 2000 and increased to about 41 kWh by 2008 and 70 kWh by 2014 which is far below the average level of per capita energy consumption across all African countries (500 kWh per capita) (Mondal et al. 2018).
According to MoWIE (2019, p. 18), 33% of the population has access to electricity through the grid, and about 11% of the Ethiopians have access through off-grid solutions. Off-grid solar solutions for households are a recent phenomenon in Ethiopia: 82% of households that use an off-grid solar solution as their primary source of electricity acquired their first solar device within the last three years. Other off-grid technologies, such as a mini-grid or pico-hydro, are currently rarely used as a primary source of electricity in Ethiopia. Off-grid solutions are more common in rural areas, where access to the grid is limited: 31.6% of rural households use an off-grid solution (17% use a solar lantern, 7.7% use a solar lighting system [SLS], and 6.5% use a solar home system [SHS]) as their primary source of electricity (Padam et. al. 2018, p. 13).

3.1 RE off-grid policies and the NDC

In its NDC, Ethiopia commits to reduce greenhouse gas emissions by 64% of the business-as-usual scenario by 2030, equalizing 255 MtCO2e per anno (FDR Ethiopia 2017, p.1). Of the envisaged GHG emissions reduction of 255 MtCO2e, 130 MtCO2e should be realized in forestry and 90 MtCO2e in agriculture, with the remaining 35 MtCO2e materialized through a combination of GHG abatement efforts in transportation, industry and buildings. The power sector is intended to remain at its current emission level of 5 MtCO2e, although this sector is expected to grow substantially in order to satisfy increasing demand for, and expand access to, electricity. Ethiopia’s NDC is based on the country’s Climate Resilient Green Economy (CRGE) Strategy, which prescribes strategies and defines objectives to tackle the effects of climate change (GoE 2011). To be able to achieve these, the following sectors require some interventions in addressing climate change: Agriculture, Forestry, Transport, Energy, Industry, Buildings including Waste. The country recognizes the importance of both mitigation and adaptation measures; as such has outlined strategies and plans to reduce and adapt to climate change impacts (GoE 2019).

Ethiopia’s NDC does not explicitly mention the promotion and implementation of off-grid technologies, however, the country aims to generate and distribute electricity from renewable sources. On the one hand, it mentions an expansion of renewable power in the mitigation part of the NDC, on the other hand the country commits itself to the development of electric power generation from geothermal, wind and solar sources to minimize the adverse effects of droughts on predominantly hydroelectric energy sector in the adaptation context (FDR Ethiopia 2017, p.6). Especially, rural areas need access to modern technologies as the rural population is still relying
on wood for fuel. Therefore, Ethiopia prioritizes renewable and aims to increase energy access in rural areas.

### 3.2 Legal framework, policies and plans

The GTP II and the national Climate Resilient Green Economy (CRGE) provide the overarching legislation for a power sector reform and private sector engagement (GoE 2011; GoE 2015). The strategy highlights solar PV technology as a key technology for rural electrification. In the same direction points the National Electrification Program (NEP 2.0) of 2019, which intends to supply 5.8 million households with off-grid electricity, mostly through solar PV (MOWIE 2019). A distinct emphasis of the NEP 2.0 is the key role of the Ethiopian private sector as well as the potential of public-private partnerships in achieving these ambitious goals. However, Ethiopia’s solar sector still faces multiple barriers which hamper a potential rapid and sustainable growth of the off-grid solar market. The market is characterized by three major challenges: low quality of products (and services), a lack of consumer awareness about additional benefits of quality products as well as a lack of access to finance for both private sector developers and operators as well as end users.

Ethiopia’s current energy policy gives a high priority to RE development and follows a climate resilient green economy strategy. The energy policy aims to reduce the role of hydrocarbon fuels in industry and transport; promotes and enhances renewable energy sources development (Hydro, solar, wind, geothermal and biomass). Furthermore, it aims at improving energy security and reliability of energy supply, at enhancing regional and global cooperation in the energy sector, at strengthening cross-border energy trade and at creating a conducive environment to the private developers.

While all on-grid power generation capacity is planned to be from renewable sources (i.e., zero emissions), there are still some off-grid power diesel gensets that create GHG emissions. Most of the emissions from off-grid electric power generation are taken into account in other sectors with the exception of rural residential fossil-fuel-based generation, which is accounted for in the electric power sector and causes the emissions to be slightly above zero. According to Ethiopian Electric Power Corporation’s (EEPC) master plan, the current diesel power plants and off-grid diesel generators have been switched off between 2012 and 2014 (EEPC 2014). From 2015 onwards, EEPC planned to generate power exclusively from renewable sources – while retaining some diesel generators as standby solutions. However, since the plan is to establish a more reliable and stable power supply throughout the country, the use of such standby facilities is expected to decrease...
dramatically to reach virtually 0% by 2030. The key targets and plans relevant to off-grid renewable energy are summarized in *Box 1*.

**Box 1: Key targets and plans for off-grid RE in recent policy documents**

**National Electrification Program (NEP 2.0) (launched in 2019)**

The main goal of the Program is the achievement of universal electricity access nationwide by 2025. Tackling the access challenge with the coordinated deployment of all technology options allows the achievement of three important goals for the nation: (i) balancing efficiency and equity in access delivery, (ii) maximizing the reach of the electrification program while minimizing the time required for all Ethiopians to have access to electricity services, and (iii) supporting economic growth and human development. The key operational action elements to reach the NEP target are:

- fast-paced ambitious grid connections rollout program implemented by the EEU, and designed for scaling up connectivity from 6.9 million households today to over 15 million households in customer count terms by 2025 (equivalent to about 65 percent of the population in 2025);
- complementary off-grid access rollout program alongside grid connections, targeted to provide access for the remaining 6 million rural and deep rural households without grid connectivity (equivalently to about 35 percent of the population in 2025) with a combination of public and private-led efforts;
- explicit cross-sectoral linkages with the productive and social services sectors and in support of vulnerable groups, for the achievement of 100 percent access at the latest by 2025 in the case of primary and secondary schools, hospitals, and primary health centers;
- NEP provides for priority connection (grid or off-grid) to locations with high economic growth potential, particularly in the agriculture sector, while ensuring gender equality in access to electricity services.

**National Adaptation Plan (NAP) (launched in 2019)**

The Plan builds on ongoing efforts to address climate change in the country's development policy framework, including the Climate Resilient Green Economy (CRGE) strategy and the second Growth and Transformation Plan (GTP II), as well as sectoral climate resilience strategies and regional and municipal adaptation plans. Its goal is to reduce vulnerability to the impacts of climate change by building adaptive capacity and resilience. It aims to strengthen holistic integration of climate change adaptation in Ethiopia's long-term development pathway, supported by effective institutions and governance structures, finance for implementation and capacity development and strengthened systems for disaster risk management and integration among different sectors.

NAP focuses on the sectors that have been identified as most vulnerable, namely: agriculture, forestry, health, transport, power, industry, water and urban. Within these sectors, 18 adaptation options (incl.
Off-grid RE under the sustainable energy supply option have been identified for implementation at all levels and across different development sectors, recognizing the considerable diversity in context and vulnerability across Ethiopia’s regions and social groups.

**Ethiopia’s Climate-Resilient Green Economy Strategy (CRGE) (launched in 2011)**

The overall goal of the strategy is that Ethiopia achieves middle-income status by 2025 while developing a green economy. Following the conventional development path would, among other adverse effects, result in a sharp increase in GHG emissions and unsustainable use of natural resources. To avoid such negative effects, the government has developed a strategy to build a green economy. It is now starting to transform the strategy into action and welcomes collaboration with domestic and international partners.

For 2020, an update of the CRGE is envisaged. By beginning of 2020, the current CRGE initiative follows a sectoral approach and is based on four pillars:

- Improving crop and livestock production practices for higher food security and farmer income while reducing emissions
- Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks
- Expanding electricity generation from renewable sources of energy for domestic and regional markets
- Leapfrogging to modern and energy-efficient technologies in transport, industrial sectors, and buildings

### 3.3 Off-grid RE investment and financing needs according to the NEP 2.0

According to the published information of the Ethiopian Government, the NEP 2.0 requires initial investments of about USD 5.75 billion for universal electrification, of which USD 1.1 billion shall be contributed by grid-connected customers and about USD 1.5 billion can be provided by the Government while the remaining USD 3.15 billion shall be sourced from Development Partners (compare Table 1, MOWIE 2019, p. 122f). The given investment volume for grid expansion excludes several elements such as ELEAP investments, some connection fees, transmission and distribution upgrades and generation capacity investments that represent about USD 7 billion of additional funds, equalizing a total of USD 10.7 billion for grid roll-out investments until 2025 (compare MOWIE 2019, p. 31).
Table 1: Breakdown of grid and off-grid investments and syndication scenarios for universal access, 2025

<table>
<thead>
<tr>
<th></th>
<th>Investment (US$ million)</th>
<th>GoE Contribution (US$ million)</th>
<th>Syndication (US$ million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Grid program</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid total investments*</td>
<td>3,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costumer contribution (→)</td>
<td>(1,100)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>2,100</td>
<td>480</td>
<td>1,620</td>
</tr>
<tr>
<td><strong>B. Off-grid program</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access to finance (with a revolving fund)</td>
<td>1,760</td>
<td>530</td>
<td>1,240</td>
</tr>
<tr>
<td>End-user subsidy</td>
<td>72</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Social institutions</td>
<td>230</td>
<td>70</td>
<td>160</td>
</tr>
<tr>
<td>MST off-grid solar</td>
<td>133</td>
<td>41</td>
<td>92</td>
</tr>
<tr>
<td>Mini-grids (MST and EPC)*</td>
<td>300</td>
<td>280</td>
<td>20</td>
</tr>
<tr>
<td><strong>Off-grid total investment syndication</strong></td>
<td>~2,500</td>
<td>~1,000</td>
<td>~1,500</td>
</tr>
<tr>
<td>Program implementation support</td>
<td>50</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td><strong>Total Investment syndication (A + B)</strong></td>
<td>~4,650</td>
<td>~1,500</td>
<td>~3,150</td>
</tr>
</tbody>
</table>

*Excludes Ethiopian Electrification Program (ELEAP) and includes regularized connections. Based on the connection cost average for the program of US$370 and excludes connection fees coming from regularized connection and lifeline customers. Numbers do not reflect investments in transmission and distribution network upgrading and modernization nor expanded generation capacity. These investment requirements will be provided by the updated of the Master Plan currently under procurement.

Source: MOWIE 2019, p. 122

For off-grid activities, the NEP 2.0 foresees investment needs of about USD 2.5 billion. From the perspective of enterprises operating in the off-grid market, the key requirement represents access to three main functional sources of funding, (i) forex – for the implementation of goods, (ii) working capital for day-to-day trading operations, and (iii) capital and operating expenditures for the establishment and expansion of the supply market infrastructure and funding of operations and logistics. Forex estimates are based on a weighted combination of Tier 1 and Tier 2 systems, for an average cost per system of USD 150. Working capital estimates are based on the markup associated with the fragmented supply chain currently characterizing the Ethiopian off-grid market, where on average importers and distributors would require an additional 30 percent (based on the information provided by the private sector), and Microfinance Institutions (MFIs) 16% based on the current interest rate). With business as usual, the access to finance requirements are significant, adding overall to USD 3.7 billion, where about USD 1.3 billion are in forex requirements, USD 1.8 billion in working capital, and about USD 600 million for capex and operating expenditures. Together with ensuring the availability of adequate financing needs for the proliferation of local entrepreneurship (including jointly with inter- national private sector enterprises), these access to finance requirements have the ultimate effect of increasing the end-customer price of off-grid solar
technologies, posing a risk for system affordability and access even with the adoption of monthly installment sales (PAYGo system) to reduce the up-front investments from the customer perspective (MOWIE 2019, p. 58f).

### 3.4 Current support landscape for off-grid RE

The government introduced an off-grid program in 2019 which will provide off-grid solutions to the 35% of the population waiting to get a grid connection, which reflects a total of 9 million beneficiary households (MOWIE 2019). The NEP off-grid program implementation framework focuses on two main technologies for service delivery to all the segments of beneficiaries: (i) Tier 1 and above solar off-grid solutions and (ii) isolated mini-grids, as well as a coordinated combination of these technology solutions. Especially, social facilities should be provided. By the end of 2018, through Government supported initiatives and private sector involvement, about 2.2 million off-grid connections have been realized.

There are various existing international support initiatives for the power sector in the country. Major programs supporting the policy, strategy and planning development are summarized in Table 2.

**Table 2: International donor programs supporting Ethiopia’s implementation of NEP 2.0**

<table>
<thead>
<tr>
<th>Support Area</th>
<th>Partner</th>
<th>Details</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Policy, strategy, and planning development</strong></td>
<td>World Bank</td>
<td>▪ Technical assistance for development and launching of NEP.</td>
<td>Fiscal year 2018 (FY 2018)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Technical assistance for revisions focusing on off-grid sector under NEP 2.0.</td>
<td>Launch in March 2019</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ National baseline survey for electrification under the Multi-Tier Framework for Access program.</td>
<td>FY 2018</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ National Geospatial Information System (GIS) platform for electrification and power sector planning.</td>
<td>FY 2018–2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ Gender and citizen engagement programs.</td>
<td>FY 2018–2023</td>
</tr>
<tr>
<td></td>
<td>European Union (EU)</td>
<td>▪ Technical assistance for NEP 2.0 development.</td>
<td>To Be Confirmed (TBC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TBC</td>
</tr>
</tbody>
</table>
In terms of financial support programs, there are also some activities that have been launched by national as well as international actors. Concerning solar lighting and SHS, the private sector and MFIs are the key players. Through a credit line at the Development Bank of Ethiopia (serving as a financial intermediary for funding provided by the World Bank), over 70,000 SHS and 1.1 million Lighting Global certified solar lanterns have been distributed to the Ethiopian population. Another initiative is the Market Development Credit Line (MDCL), a component of the Electricity Network Reinforcement and Expansion Project (ENREP) under the June 2012 financing agreement between the Federal Democratic Republic of Ethiopia (FDRE) and the International Development Association (IDA). It was created in response to growing demand for RE and products among
customers not connected to the electricity grid. The credit line was designed with two windows: 1. Retail loans to Ethiopian private sector enterprises (PSEs) and small and medium sized enterprises (SMEs), with guaranteed access to forex, for up to two years, (including a grace period of 6 months), at 12% interest; and; 2. Wholesale loans to Ethiopian MFIs in local currency, for up to six years (including a grace period of 12 months) at 6% interest. The credit line at the DBE has already underwent two phases of implementation, for an overall funding of US$40 million. Phase I was for 2012–2016 (US$20 million), whereas Phase II started in 2017 with the same amount of funding. The second phase has two key changes: A US$4.5 million collateral support facility guaranteed up to 75 percent of the loan amount; and a MOWIE policy to allocate 75% of MDCL funding for SHS, and 20% for lanterns (5%is allocated to clean cooking technologies).

The Government is also collaborating with development partners for the piloting of technology, especially mini-grids powered by renewable energy sources. USAID is conducting feasibility studies for the conversion of EEU’s diesel mini-grids to renewable energy power, five hydroelectric sites identified by Water Works Enterprise, and several clusters of unelectrified villages to evaluate mini-grid solutions for access provision. The European Union is financing six solar PV mini-grids implemented by GIZ and tests a model for renewable energy–distributed generation that is currently based on cooperatives but is aimed at scaling up the market for private or public agencies, as well as a combination of both. In collaboration with the Korean International Agency Cooperation, Ethiopia also launched two hydro mini-grids in 2017. In addition, solar, wind, and other renewable mini-grids activities are being piloted.

4 Simulation of off-grid RE pathways until 2025

We conducted a detailed study on different electrification scenarios to understand the respective electrification mix, initial investments needed and the related GHG emissions to achieve the Sustainable Development Goal (SDG) 7 on universal electricity access by 2030, in the case of Ethiopia already by 2025. Details on the methodology can be found in the Annexes. The analyzed scenarios show different ways on how to electrify the people without energy access in Ethiopia considering grid extension, mini-grids and solar-home-systems (SHS). The following table gives an overview of the three considered scenarios which are complemented by a more detailed description below.
Table 3: Overview on electrification scenarios for Ethiopia

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Business-as-Usual (BaU)</th>
<th>Universal-Energy-Access (uEA)</th>
<th>Progressive Off-Grid (prOG)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Background</strong></td>
<td>Relative values applied for people to be electrified based on New Policy scenario of IEA</td>
<td>Based on GIS analysis of current grid infrastructure and settlement patterns combined with current policy frameworks</td>
<td>Based on GIS analysis of current grid infrastructure and settlement patterns combined with most progressive policy frameworks for off-grid</td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>Focus on grid-extension SDG7 not achieved</td>
<td>Mix of off-grid and grid-extension SDG7 achieved</td>
<td>Strong focus on off-grid SDG7 achieved</td>
</tr>
</tbody>
</table>

Source: project team

The Business-as-Usual (BaU) Scenario

- **What it shows:** The Business-as-Usual (BaU) scenario quantifies the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) until 2025 by projecting current business-as-usual growth rates into the future.

- **How it is obtained:** Regional projections of electrification rates and technologies are mapped to the country-level and modelled until 2025. The BaU scenario is based on the "New Policies" Scenario of the International Energy Agency’s World Energy Outlook 2018 (IEA 2018).

The Universal-Energy-Access (uEA) Scenario

- **What it shows:** The Universal-Energy-Access (uEA) scenario estimates the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) necessary to achieve the universal access goal until 2025. These estimations account for expected population growth rates and current infrastructure and current regulatory frameworks.
How it is obtained: Existing datasets providing night lights, population densities and transmission grids are combined to estimate the number of people lacking access to electricity. Appropriate electrification options are determined based on the remoteness and density of neglected populations. In this way the model estimates the share of people that remain to be electrified by either Grid Extension, Mini-Grid deployment or Solar-Home-System adoption until 2025. The GIS-based estimates are further refined by accounting for (the lack of) favourable technology-specific frameworks through the integration of ESMAP's RISE Indicators into the model's calculations (World Bank n.d.).

The Progressive-Off-Grid (prOG) Scenario

What it shows: The Progressive-Off-Grid (prOG) scenario estimates the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) necessary to achieve the universal access goal until 2025. These estimations account for expected population growth rates and current infrastructure and progressive regulatory frameworks.

How it is obtained: Existing datasets providing night lights, population densities and transmission grids are combined to estimate the number of people lacking access to electricity. Appropriate electrification options are determined based on the remoteness and density of neglected populations. For the 2025 horizon, in this way the model estimates the share of neglected people that remain to be electrified by either Grid Extension, Mini-Grid deployment or Solar-Home System adoption. In the prOG scenario, the GIS-based estimates are modified to showcase the impact of fully favourable off-grid (Mini-Grid and Solar Home Systems) frameworks through the integration of maximized ESMAP’s RISE Indicators into the model’s calculations (World Bank n.d.).

For all scenarios, two different cases are defined:

Lower Tier Case: Starting with the number of people per electrification option, the respective minimum electricity demand is estimated. In this case, the minimum threshold for electricity access is defined as the equivalent of ESMAP’s Tier 2 (compare Figure 1) where SHS find application, and Tier 3 where Mini-Grids are deployed or Grid Extension takes place.
Higher Tier Case: Starting with the number of people per electrification option, the respective minimum electricity demand is estimated. In this case, the minimum threshold for electricity access is defined as the equivalent of ESMAP’s Tier 3 (where SHS find application, and Tier 4 where Mini-Grids are deployed or Grid Extension takes place (World Bank, 2015).

Figure 1: The Tiers of Electricity Access of the Multi-Tier Framework

4.1 Electrification Mix
As first step the electrification mix for the three scenarios was calculated. Results are shown in the following table and figure.

Table 4: People gaining electricity access in Ethiopia until 2025: different scenarios; cumulated numbers in Million

<table>
<thead>
<tr>
<th></th>
<th>BaU</th>
<th>uEA</th>
<th>prOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid extension</td>
<td>26</td>
<td>39</td>
<td>10</td>
</tr>
<tr>
<td>Mini-grids</td>
<td>8</td>
<td>4</td>
<td>25</td>
</tr>
<tr>
<td>SHS</td>
<td>17</td>
<td>38</td>
<td>47</td>
</tr>
<tr>
<td>not electrified</td>
<td>29</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: project team
Scenario BaU shows no electricity access for all in 2025 with 29 Million people being left un-electrified. The suggested electrification mix has 50% grid extension, 16% mini-grids and 34% SHS. uEA and prOG show both 100% electrification rates in 2025. In the uEA scenario a similar focus is set on mini-grids (7%) and SHS (34%). This reflects the current grid infrastructure and settlement patterns, which favour grid extension. If the most favourable frameworks for both, mini-grids and SHS, are assumed, we observe a very low grid-electrification of 12% (only about 9.5 million people) and a strong shift from grid-based electrification towards SHS (58%) and mini-grids (31%) in the prOG scenario.

Figure 2: People gaining electricity access in Ethiopia until 2025: different scenarios

4.2 Initial investment needs

The initial investments needed to achieve the electrification mix for the different presented scenarios are shown in the next figure. They reflect both cases, lower Tier and higher Tier electrification, which affects the minimum size of mini-grids and SHS. The investment costs for mini-grids and SHS include generation, storage, and – if needed – distribution. For grid extension only
the grid infrastructure costs (extension of medium voltage grid plus distribution grid and household connection are considered)\(^1\).

Table 5: Initial investment needs until 2030 in USD billion

<table>
<thead>
<tr>
<th></th>
<th>Lower Tier case</th>
<th>Higher Tier case</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BaU</td>
<td>uEA</td>
</tr>
<tr>
<td>Grid*</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Mini-Grid</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SHS</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>18</td>
<td>27</td>
</tr>
</tbody>
</table>

Source: project team

Even though in BaU remain 29 million people without access to electricity it has the second highest initial investment needs for the low Tier case. For the low Tier case, uEA is the most expensive scenario, as especially the grid investments strongly increase. The deviation of almost 100% to the NEP 2.0 numbers for grid connections (compare chapter 3.3) can be explained by the higher assumed average connection costs and a reflection of the existing transmission and distribution grid strengthening in our scenarios. Thus for the low Tier scenario, SHS remain the most cost-effective option leading to prOG as the scenario with the lowest investment needs but still enabling electricity access for all in 2025. For the high Tier case, BaU has the lowest initial investment needs but leaves 29 million people without electricity, while uEA and prOG that provide universal electification have similar initial investment needs of about USD 35 billion.

---

\(^{1}\) Common approach in electrification planning (as also applied in the NEP 2.0) is to only consider grid infrastructure investments and not investments into the central power generation. Those will follow based on the increased on-grid demand, but the costs for grid supplied electricity will remain the same.
4.3 GHG emissions

Similar to the investment needs, the related GHG emissions for all scenarios under the two cases were calculated. It needs to be notified that also emissions of non-electrified people based on the use of kerosene lamps are considered in the cumulated results. As we are looking at an electrification pathway until 2025, we can still observe a significant amount of cumulated emissions related to non-electrified people, even if in 2025 the SDG7 is achieved. The results are shown in the following table and figure. For the BaU scenario, the highest number of people cumulatively do not get access to electricity and therefore continue to use kerosene lamps that emit significant GHG emissions while the uEA and prOG scenario achieve universal electrification by 2025 leading to substantial emission reductions.

| Table 6: Cumulated GHG emissions in million tons of CO₂-equivalent (2017-2030) |
|--------------------------|-------------------|
| **Lower Tier case** | **Higher Tier case** |
| BaU | uEA | prOG | BaU | uEA | prOG |

Figure 3: Initial investment needs until 2025 in billion USD (lower Tier case)
While the grid with an emission factor close to zero can be neglected in terms of emissions, mini-grids with a small diesel share generate some minor CO₂ emissions. Thus, the prOG scenario relying on a higher share of mini-grids compared to uEA has slightly higher total emissions.

Figure 4: Cumulated GHG emissions in million tons of CO₂-equivalent, lower Tier case (2017-2025)

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini-Grid</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>SHS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No access</td>
<td>51</td>
<td>35</td>
<td>22</td>
<td>51</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>52</td>
<td>35</td>
<td>37</td>
<td>54</td>
<td>36</td>
<td>42</td>
</tr>
</tbody>
</table>

Source: project team
The overall emission reduction potential can reach up to 16 MtCO₂ between 2017 and 2025 compared to the baseline scenario (BaU_NewPol) under consideration of both Tier levels. For all scenarios, the cumulated GHG emissions related to non-electrified people are the highest. This means, the faster the electrification of all people can be achieved, the earlier those emissions can be reduced.

5 Recommendations for NDC revision

With regards to off-grid RE, only a few developing countries have provided information about targets and financial needs. According to the analysis of the project team, out of 55 submitted NDCs from African countries, only about 21 refer to off-grid solutions and only 14 of those have included off-grid targets. Despite the limited GHG reduction potential of off-grid RE, the majority of NDCs articulate off-grid RE as mitigation targets. Only three countries, including Ethiopia, reflect off-grid RE solutions in the context of adaptation and increased resilience. With regards to required support means, only three countries spelled out their related financing needs. Parties that intend to further develop RE off-grid solutions might consider reflecting related targets and support needs in their upcoming revision of the NDCs that is due by 2020 (UN 2015, Article 4.2).

5.1 NDC revision process in Ethiopia

Building on our in-depth description of the Ethiopian electricity sector and the results of the modeling, it is argued that the 2020 NDC update could be significantly enhanced and meet the scientific imperative of increased ambition. This enhancement could build on both the mitigation potential, energy access and other sustainable development benefits and the compelling financial case presented above. The revised NDCs can thus be cleaner, cheaper and smarter. In the absence of formal guidance by the Paris Agreement or technical guidance from the UNFCCC Secretariat, Parties are free to decide on the nature and form of their NDC update.

The Ethiopian NDC revision process is embedded in several parallel and synchronized planning processes (based on sights from stakeholder mission, see Annex 5). Key fundament represents the Growth and Transformation Plan (GTP) that lasts for five years and is currently in its second implementation period (GTP II). From mid of 2020 onwards follows the third implementation period, the formulation of GTP III is currently under development. In coordination with the GTP III, Ethiopia elaborates the second phase of its CRGE. Based on the currently ongoing assessment of the first CRGE, the Government of Ethiopia will formulate an updated CRGE for the decade 2021-2030 in
the first quarter of 2020, considering potentially more ambitious mitigation and adaptation objectives. Based on GTP III and the updated CRGE, Ethiopia will revise its NDC. The institutions that are in charge for mainstreaming the NDC with other planning documents provided by each Ministry are the Ministry of Finance and the Environment, Forest and Climate Change Commission (EFCCC). They elaborate the actual text and submit the final document to the UNFCCC.

5.2 Potential of ambition raising for the off-grid RE NDC component

Ethiopia has already put a number of fiscal incentives in place that support investment in off-grid RE. However, most of these are not specific to the sub-sector and to realize the full-potential of off-grid RE, especially in the rural areas, further support is required in terms of policies and regulations, access to finance as well as capacity building. Considering the climate benefits of off-grid RE in Ethiopia for both mitigation and adaptation targets, the NDC ambition raising should consider more concrete set of targets and actions relating to off-grid RE.

Within the NDC revision process, the Ministries responsible for respective sectors provide detailed information for reflection in the NDC (based on sights from stakeholder mission, see Annex 5). For renewable energies and off-grid electrification, the MOWIE will elaborate and provide relevant information. The mission findings suggest considering the following renewable energy and off-grid related elements during the NDC revision process:

- **Reflecting off-grid RE in the mitigation and adaptation section of the NDC:** In its 2015 (I)NDC, Ethiopia mainly refers to mitigation benefits of renewable technologies in a qualitative manner. As Parties can describe the (relative) mitigation potential or target of (off-grid) renewable energy solutions also in a quantitative way, Ethiopia might reflect its National Electrification Plan (NEP 2.0) targets. In addition, the resilience and sustainable development benefits of improved livelihoods (as e.g. outlined in NAP, see GoE 2019, p.58) through electricity access can be communicated more prominently in the adaptation section of the NDC.

- **Quantifying costs and financing needs:** The first round of NDC submissions delivered only limited information on costs and financing needs. In its 2015 (I)NDC, Ethiopia posits that these quantifications will be provided in future. In order to facilitate international support, the Government might consider including this information in the revised NDC based on potential financing needs and cost information defined in the GTP III and
CRGE. For the renewable off-grid sector, also the NEP 2.0 can provide helpful assumptions.

- **Conditional and unconditional elements:** NDCs represent helpful vehicles to communicate international support needs with regard to financial, technology and capacity building requirements. Parties can highlight what they achieve unilaterally and what is conditional on international support. Ethiopia is encouraged to make use of this tool and communicate key support requirements, e.g. financial support, application of market mechanisms, capacity building or technology transfer needs.

As outlined in a “Request for Support” letter from EFCCC to the NDC Partnership, Ethiopia asks for technical support to elaborate NDC updates involving strategic studies, cost-benefit analysis or CRGE target quantification. If deemed helpful, our project findings can provide some of these required elements for off-grid renewables.

### 5.3 Conditional elements of the NDC

Apart from the current support landscape for off-grid RE outline in chapter 3.4, the NDC, especially its conditional part, can provide an opportunity for Ethiopia to bring forwards its sustainable energy sector enhancements. During the mission, it became evident, that advancements in off-grid RE could be driven by the private sector, including certain support elements provided from the public sector and (international) donors. In order to overcome existing barriers in the local market for increase private sector engagement, conditional elements of the Ethiopian NDC could include the following areas of support:

- **Capacity building:** Concerning off-grid RE, Ethiopia still needs technical assistance in the areas of policy and regulatory environment as well as on capacity and knowledge among public and private sector actors.

  For the first area, private sector could be supported by defining more clearly quality standards for off-grid technology (especially SHS) and to finalize and adopt necessary regulations for mini-grids. In addition, regulatory support could entail a review of the current duties and taxation scheme for off-grid RE.

  For the second area, there is still a lack of capacity and knowledge among key actors within the public sector (e.g. Rural Electrification Fund) in order to guide off-grid RE development and to provide clear messages to the private sector and beneficiaries. In addition, the private sector faces a shortage of skilled labor, also affecting financial institutions, which are reluctant in providing necessary finance to the off-grid RE sector.
- **Finance**: Ethiopia is currently facing a shortage on foreign exchange, which has a great impact on the development of several sectors in the country, including energy. To further be able to support off-grid RE, Ethiopia is in need for financial support for dedicated off-grid RE projects or for local financial institutions to enable them for lending activities related to off-grid RE. In addition, the Government of Ethiopia lacks the resources for designing suitable subsidy programs for off-grid RE in remote areas in the county, which are needed, as the poverty level and difficult accessibility represents a great challenge for sustainable electrification. Finally, Ethiopia is in need of support for launching attractive business models for further private sector engagement in the energy sector (e.g. PAYG based on mobile money services).

- **Technology transfer**: The relevant technology for off-grid RE is mainly imported to Ethiopia, but the country is also eager to strengthen its local manufacturing sector. For the purpose a partnership program could be supported, which matches the expertise of foreign off-grid companies with the local business sector.

### 6 Concluding remarks

Based on the deep dive analysis and the various consultations and interactions with stakeholders during the deep dive mission (compare Annex 5), this section summarizes concluding remarks with regards to the revision process of the Ethiopian NDC:

- In its current package of strategies, Ethiopia has formulated very ambitious targets for achieving universal electrification. By 2025, all people shall have access and off-grid solutions are envisaged to contribute a significant share of up to 35%. However, achieving this objective will require to overcome various barriers.

- In order to achieve SDG 7 on universal electrification in Ethiopia by 2025, significant investments will be required by various players, including commercial investors such as regional and local banks. Such an increased mobilization of private funds within the next decade requires more capacity building and innovative approaches to enhance attractiveness and decrease risk of investment opportunities in the off-grid RE sector.
In this context, international support through DFIs and technical cooperation can facilitate the process through cooperation with the local and international off-grid RE private sector. This cooperation could be launched through e.g. the provision of concessional finance, guarantees, blending of resources, transparency initiatives and knowledge transfer.

So far, neither the ambitious off-grid targets nor required support are reflected in Ethiopia’s NDC. The identified international support elements could be guided towards clear provisions in Ethiopia’s NDC, which will be revised for the first time in 2020. The findings from this project can represent helpful, additional information (e.g. quantified investment needs estimations or GHG emission reductions) and provide ideas for potential solutions to address existing barriers, which should be considered by MOWIE when developing the revised targets, actions and assistance needs for the energy sector.

The deep dive analysis emphasizes to consider that off-grid RE can be included in both the mitigation and adaptation parts of the NDC. As many international support institutions such as the GCF, the Adaptation Fund, the Climate Investment Funds, bilateral support and MDBs focus on one category or have reserved volumes for specific categories, multiple reflection of the off-grid purposes allows to access additional and broader support opportunities.
References


World Bank (n.d.): Regulatory Indicators for Sustainable Energy (RISE), https://rise.esmap.org/

Yalew, Amsalu W.; Hirte, Georg; Lotze-Campen, Hermann; Tscharaktschiew, Stefan (2017) : Economic effects of climate change in developing countries: Economy-wide and regional
Annexes

Annex 1: Methodology for scenario development and electrification solutions

The methodology for calculating and quantifying different electrification scenarios for Ethiopia is explained in this annex. It was developed to answer the following main questions:

- How can different electrification scenarios for 2030 look like on a country level?
- What is their climate and economic impact?

The following figure illustrates the stepwise approach for our study.

Figure 5: Stepwise approach for quantifying electrification scenarios

We developed three different scenarios showing potential electrification pathways on how to electrify the people without energy access in Ethiopia considering grid extension, mini-grids and solar-home-systems (SHS). The following table gives an overview on the three considered scenarios which is complemented by a more detailed description below.
Table 7: Overview on electrification scenarios for Ethiopia

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>Business-as-Usual (BaU)</th>
<th>Universal-Energy-Access (uEA)</th>
<th>Progressive Off-Grid (prOG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background</td>
<td>Relative values applied for people to be electrified based on New Policy scenario of IEA</td>
<td>Based on GIS analysis of current grid infrastructure and settlement patterns combined with current policy frameworks</td>
<td>Based on GIS analysis of current grid infrastructure and settlement patterns combined with most progressive policy frameworks for off-grid</td>
</tr>
<tr>
<td>Description</td>
<td>Focus on grid-extension SDG7 not achieved</td>
<td>Mix of off-grid and grid-extension SDG7 achieved</td>
<td>Strong focus on off-grid SDG7 achieved</td>
</tr>
</tbody>
</table>

Source: project team

The Business-as-Usual (BaU) Scenario

- **What it shows:** The Business-as-Usual (BaU) scenario quantifies the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) until 2025 by projecting current business-as-usual growth rates into the future.

- **How it is obtained:** Regional projections of electrification rates and technologies are mapped to the country-level and modelled until 2025. The BaU scenario is based on the "New Policies" Scenario of the International Energy Agency’s World Energy Outlook 2018 (IEA 2018).

The Universal-Energy-Access (uEA) Scenario

- **What it shows:** The Universal-Energy-Access (uEA) scenario estimates the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) necessary to achieve the universal access goal until 2025. These estimations account for expected population growth rates and current infrastructure and current regulatory frameworks.
How it is obtained: Existing datasets providing night lights, population densities and transmission grids are combined to estimate the number of people lacking access to electricity. Appropriate electrification options are determined based on the remoteness and density of neglected populations. In this way the model estimates the share of people that remain to be electrified by either Grid Extension, Mini-Grid deployment or Solar-Home-System adoption until 2025. The GIS-based estimates are further refined by accounting for (the lack of) favourable technology-specific frameworks through the integration of ESMAP's RISE Indicators into the model's calculations (World Bank n.d.).

The Progressive-Off-Grid (prOG) Scenario

What it shows: The Progressive-Off-Grid (prOG) scenario estimates the number of new technology-specific electrifications (Grid Extension, Mini-Grids or Solar-Home Systems) necessary to achieve the universal access goal until 2025. These estimations account for expected population growth rates and current infrastructure and progressive regulatory frameworks.

How it is obtained: Existing datasets providing night lights, population densities and transmission grids are combined to estimate the number of people lacking access to electricity. Appropriate electrification options are determined based on the remoteness and density of neglected populations. For the 2025 horizon, in this way the model estimates the share of neglected people that remain to be electrified by either Grid Extension, Mini-Grid deployment or Solar-Home System adoption. In the prOG scenario, the GIS-based estimates are modified to showcase the impact of fully favourable off-grid (Mini-Grid and Solar Home Systems) frameworks through the integration of maximized ESMAP's RISE Indicators into the model's calculations (World Bank n.d.).

In order to identify the non-electrified population on country level, a night light analysis is conducted. This means, satellite images showing light emissions are taken to identify electrified areas. This is combined with spatially dissolved population data to quantify the location and number of people without energy access. The baseline year for this study is 2017. All population figures are extrapolated until 2030 according to the national population growth rates. In conclusion, for all three scenarios the same total number of people “to be electrified until 2030” is taken.
The next step is to assign the electrification mix to the total number differentiating among grid extension, mini-grids and SHS.

For the BaU scenario, the relative values of the IEA. (2017). World Energy Outlook 2017: Special Report on Energy Access are taken, which are defined in the New Policies Scenario. These values are only available in aggregated form for each continent, thus we took the African average for Ethiopia. The relative values of the electrification mix are applied to all people to be electrified, which leads to the situation that still people remain un-electrified in 2030.

For both, the uEA and prOG scenario, at first an infrastructural analysis is conducted to understand a realistic electrification mix on country level. The decisive factors for this GIS based infrastructure analysis are night lights for already electrified areas, population density to identify larger settlements and distance to existing grid infrastructure. The occurrence of nightlights determines electrified and non-electrified areas. For non-electrified areas, SHS are assigned to areas with low population density. Areas with high population densities are assigned to grid connection, if within 20km grid buffer, or to mini-grids, if outside the 20km grid buffer.

Figure 6: Illustration of geospatial input data sets for infrastructure analysis

The infrastructure analysis is exactly similar for both, uEA and prOG scenario. They bother differ in terms of the assumptions on policy and regulatory frameworks. The framework used is based on the Regulatory Indicators for Sustainable Energy (RISE) of Worldbank. We focus on 3 out of 8 Indicators within the Energy Access Indicator group reflecting frameworks for grid based electrification, mini-grids, and SHS (cf. Table 8). Taking the electrification mix from the infrastructure
analysis as baseline, the RISE indicators can create shifts towards a certain electrification option. The higher the difference between two indicators is \([0;100]\), the higher is the shift from one option to another.

Table 8: RISE scores with Sub-Indicator groups

<table>
<thead>
<tr>
<th>RISE3: Grid</th>
<th>RISE4: MG</th>
<th>RISE5: SHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Funding support for grid electrification</td>
<td>Existence of national program</td>
<td>Existence of national program</td>
</tr>
<tr>
<td>2 Funding support for customer connections</td>
<td>Financial incentives</td>
<td>Financial incentives</td>
</tr>
<tr>
<td>3 Standards of performance on quality of supply</td>
<td>Standards and quality</td>
<td>Standards and quality</td>
</tr>
<tr>
<td>4</td>
<td>Legal Framework for MG operation</td>
<td></td>
</tr>
<tr>
<td>5 Ability to charge cost-reflective tariffs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: project team

For uEA the current frameworks are taken to calculate the shift, for prOG the frameworks of mini-grids and SHS are set to the maximum value of 100 to reflect the most progressive off-grid frameworks possible.

**Annex 2: Methodology for demand estimation**

After the calculation of the electrification mix, the demand per household needs to be estimated in order to quantify the investment needs and GHG emissions per electrification option. To reflect a broader variety of future developments we defined a lower and higher demand case. The cases are calibrated along the Multi-Tier Framework of the World Bank and therefore called lower and higher Tier Case.

- **Lower Tier Case:** Starting with the number of people per electrification option, the respective minimum electricity demand is estimated. In this case, the minimum threshold for electricity access is defined as the equivalent of ESMAP’s Tier 2 (compare Figure 7) where SHS find application, and Tier 3 where Mini-Grids are deployed or Grid Extension takes place.

- **Higher Tier Case:** Starting with the number of people per electrification option, the respective minimum electricity demand is estimated. In this case, the minimum threshold
for electricity access is defined as the equivalent of ESMAP’s Tier 3 where SHS find application, and Tier 4 where Mini-Grids are deployed or Grid Extension takes place (World Bank n.d).

Figure 7: The Tiers of Electricity Access of the Multi-Tier Framework

![Figure 7: The Tiers of Electricity Access of the Multi-Tier Framework](image)

Source: ESMAP 2015

Taking the three scenarios and two cases we define six different electrification pathways. These are the baseline for calculating the investment costs and GHG emissions.

### Annex 3: Methodology for assessment of investment needs

The demand estimation leads to certain electricity consumption and peak demand for each electrification option. This is translated into capacities needed which eventually leads to the investment needs. We focus on initial investments only (re-investments / replacements of technology are not considered). These initial investments are cumulated for the year 2030 along the following metrics for each electrification option.

- **Grid extension**: Generic value of 2,500 USD per HH connection (excluding central power generation investments) is assumed. This is similar for each investigated country. For grid extension only the grid infrastructure costs (extension of medium voltage grid plus distribution grid and household connection are considered). This is a common
approach in electrification planning is to only consider grid infrastructure investments and not investments into the central power generation. Those will follow based on the increased on-grid demand, but the costs for grid supplied electricity will remain the same.

- **Mini-Grids**: Investments are based on needed capacities and relative Tier level. The costs cover generation, storage, distribution grid and household connection. Depending on Tier level / HH consumption we estimate investment costs of 1,000 to 6,000 USD per HH connection. The higher the Tier level, the higher the costs per connection as the generation and storage capacities need to be significantly increased.

- **SHS**: Investments are based on size class of SHS. Depending on Tier level / HH consumption we estimate investment costs of 300 to 1,300 USD per SHS per HH (solar PV plus storage plus DC appliances).

### Annex 4: Methodology for estimation of the GHG reduction potential

In order to determine the emission reductions (ER) caused by the assessed electrification options, elements from approved CDM methodologies, tools and standards are used. To derive the total mitigation potential of off-grid RE for Ethiopia's until universal electrification is achieved by 2025, the cumulated emissions from a “Business as Usual (BAU_New Pol) scenario” are compared with the “shift scenario” as follows:

\[
ER_y = BE_{y, BaU} - EP_{y, shift}
\]  

Equation (1)

Where:

- \(ER_y\) = Emission reductions in year \(y\) (tCO\(_2\)/y)
- \(BE_{y, BaU}\) = Baseline emissions in year \(y\) (tCO\(_2\)/y) under the BaU_NewPolicies scenario
- \(EP_{y, shift}\) = Emission path (EP) per country under shift scenario in year \(y\) (t CO\(_2\)/y)

### Determining the energy supply per technology option

Based on the numbers of people and households gaining access to energy of different types until 2030 – grid, mini-grid or SHS -, the overall energy consumption is estimated per country. Hereby
two demand cases are reflected. Under the BaU-scenario (baseline scenario) a significant number of households will not gain access to modern energy. It is assumed that these household will meet their energy demand traditionally, e.g. by using kerosene lamps for lighting. The following assumption according to CDM AMS.I-L has been applied:

\[
\begin{align*}
\text{HH consumption equiv. [kWh/a/HH] - Tier 1/2} & = 55 \text{ [kWh/a/HH]} \\
\text{Emission factor for Tier 1/2 [tCO}_2\text{/MWh}] & = 6.8 \text{ [tCO}_2\text{/MWh]}
\end{align*}
\]

**Emission determination**

Emissions are the product of amount electricity produced by the different generating types (grid, mini-grids, SHS) and an emission factor.

\[
BE_{y,BaU} = EG_{y,j,BaU} \times EF_{CO_2,j} \quad \text{Equation (2)}
\]

\[
EP_{y,shift} = EG_{y,j,shift} \times EF_{CO_2,j} \quad \text{Equation (3)}
\]

Where:

\[
\begin{align*}
BE_y & = \text{Baseline emissions in year } y \text{ (t CO}_2) \\
EG_y & = \text{Quantity of net electricity consumed under by different generating type } j \text{ under each scenario in year } y \text{ (MWh)} \\
EF_{CO_2,y} & = \text{Emission factor for different generating type } j \text{ (tCO}_2\text{/MWh) }
\end{align*}
\]

**Applied emission factors**

Emission factors for national grids are sources from either IGES’s CDM Database on Grid Emission Factors or, if not available, from IEA Data (CO$_2$-Emissions from Fuel Combustion 2017). If grid emission factors from IGES and IEA are available for the country under consideration, the IGES data are to be preferred.

For the mini-grid systems an average share of 20% of fuel oil and/or diesel fuel and 80% solar PV is assumed. The emissions are the annual electricity generated by the mini-grid unit times 20% of the emission factor for a modern diesel generating unit of the relevant capacity operating at optimal load. The emission factors for PV / diesel generator hybrid systems (tCO$_2$/kWh) derived from AMS.I-F$^2$:

\[\text{2 According to AMS-I.F, Table 2}\]
The sum of all ER for each electrification option represents the emissions path of each individual scenario. The difference between the shift and the BaU_NewPol scenarios are the potential emission reductions.

**Annex 5: Experts consulted**

The project team has conducted consultations with key stakeholders relevant for the Ethiopian NDC revision process, off-grid electrification and renewable energy implementation. Among those have been officials from the Ministry of Water, Irrigation and Energy (MoWIE), the Ministry of Finance, the Environment, Forest and Climate Change Commission (EFCCC) as well as international donor representatives and private sector actors.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Event of consultation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIZ Energising Development Ethiopia (GIZ EnDev)</td>
<td>Several Consultations</td>
</tr>
<tr>
<td>NDC Partnership</td>
<td>NDC/CRGE Multi-Stakeholder Planning Workshop</td>
</tr>
<tr>
<td>Ethiopian Solar Association</td>
<td>Bilateral Consultation</td>
</tr>
<tr>
<td>CRGE Facility Coordinator, Ministry of Finance</td>
<td>CRGE Facility Forum Meeting</td>
</tr>
<tr>
<td>Environment, Forest and Climate Change Commission (EFCCC)</td>
<td>Bilateral Consultation</td>
</tr>
<tr>
<td>World Bank</td>
<td>CRGE Facility Forum Meeting</td>
</tr>
<tr>
<td>Echnoserve</td>
<td>Bilateral Consultation</td>
</tr>
<tr>
<td>Ministry of Water, Irrigation, and Energy (MOWIE) of Ethiopia</td>
<td>Bilateral Consultation</td>
</tr>
</tbody>
</table>

Source: Authors