Next level sustainable energy provision in line with people’s needs

A proposal for extending the Multi-Tier Framework for monitoring the SDG7

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The Sustainable Development Goals and the productive use of electricity

In 2016, the United Nations (UN) adopted 17 sustainable development goals (SDGs) within the framework of the UN Agenda 2030. Of the 17 SDGs, the SDG7 aims to ensure universal access to affordable, reliable, sustainable and modern energy for the entire world population and to increase the global share of renewable energy and the level of energy efficiency. Enhanced access to electricity for productive uses especially is also expected to catalyse an increase in welfare and economic development across all sectors, as it constitutes a key element for job creation and increased added value.

In this context, productive use of electricity can be defined as the utilisation of electricity for activities which generate a monetary value or, based on a broader definition of the term, contribute to an enhanced productivity or increased welfare of the affected population (Kapadia 2014, Brüderle and Bodenheimer 2011). This may involve a broad range of activities such as water pumping in agriculture, water purification, processing of agricultural products, preservation or refrigeration of goods, manufacturing of durable products or provision of various types of services. Therefore, productive uses go beyond the consumption of electricity for private household applications. However, a clear separation between productive uses and household use of electricity is difficult, especially if small family-run businesses or productive activities in the informal sector are concerned. Therefore, there is a fuzzy transition between the utilisation of electricity in households and by commercial businesses or service providers in developing and emerging countries.

Economic growth and climate and energy strategies

Along with economic growth, developing and emerging economies face the formation and expansion of commercial activities and energy-intensive industrial sectors, which may lead to significant increases in greenhouse gas emissions. Economic development, the creation of jobs and the increase of welfare for the population have a high political priority, especially in developing and emerging countries. However, economic growth and increased purchasing power, the expansion of infrastructures and the emergence and extension of commercial and industrial uses of electricity are generally related to an increased energy demand. This inevitably leads to growing greenhouse gas emissions if no strategies for developing a clean and sustainable energy supply are implemented at the same time.

Especially the industrial sectors of developing countries show a remarkable growth rate, e.g. a compounded average annual growth rate of 6.1 % in non-OECD countries compared to 1.1 % in OECD countries in the timeframe 2000-2017. Further, non-OECD countries have a substantially higher energy intensity, i.e. energy consumption per unit of value added, in comparison to OECD countries. This again becomes particularly apparent when looking at the industrial sector: with 0.2 koe/$, non-OECD countries use almost twice as much energy as OECD countries, with 0.08 koe/$.

These figures highlight the significant impact that the growing productive use of electricity in developing and emerging economies can have on global CO_2 emissions and emphasise the need for an integrated framework for monitoring and managing the access to sustainable electricity sources in these countries.

The present monitoring framework for SDG7

The progress towards reaching the SDG7 is currently monitored based on a Multi-Tier Framework (MTF) for assessing the electricity access conditions on the national level. Although separate matrices exist for the assessment of energy access for households, public and productive uses, so far, the focus of the MTF has been mainly on the electricity needs of private households, for example, for the provision of lighting, clean cooking solutions or basic communication services such as mobile phone charging.

Regarding the definition of the metrics for the tiers for assessing electricity access, the MTF for productive applications is based on the same assumptions concerning connection power and daily available capacity as defined for households (see table below). For the five tiers describing the levels of energy supply for productive applications, the MTF further assumes that tiers 3-5 successively meet the requirements of commercial activities and that in tier 5, electricity access does not cause significant issues for productive activities (Bhatia et al. 2015).

However, considering the connection power and daily capacities defined for the tiers, it becomes evident that the present monitoring of the attainment of SDG7 mainly places emphasis on the fulfilment of the basic needs for the use of private household applications and does not allow for a systematic and comparable assessment of electricity access conditions for private and productive uses.

Excerpt from Multi-Tier matrix for electricity supply for productive applications

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power		≥ 3 W	≥ 50 W	≥ 200 W	≥ 800 W	≥ 2 kW
Daily capacity		≥ 12 Wh	≥ 200 Wh	≥ 1.0 kWh	≥ 3.4 kWh	≥ 8.2 kWh
Availability of electricity (daily)		Min 2 hrs	Min 4 hrs	Half of the working Hours (min 50 %)	Most of working hours (min 75 %)	Almost all working hours (min 95 %)
Reliability					Reliability issues with moderate impact	No reliability issues or little (or no) impact
Quality					Quality issues with moderate impact	No quality issues or little (or no) impact

Source: Bhatia et al. (2015)

Goal of this study

Considering the above, it is the goal of this study to review the present methodology for monitoring the SDG7 targets and to develop an approach for monitoring access to electricity which also considers the significant role of productive uses of electricity in developing and emerging economies. By adding to a better understanding of the electricity access needs of a broader range of user types (including households as well as commercial and industrial applications), the results further aim to support the implementation of sustainable energy strategies, i.e. the development of energy supply solutions which are needs-oriented and at the same time sustainable. Thus, the developed framework can be used as a tool for energy planning to safeguard that, as a basis for economic development, the requirements of various types of productive users of electricity can be met while at the same time being consistent with climate change strategies.

Review of the present MTF framework

Tier 1 covers merely very basic energy services for simple lighting applications with a strongly limited availability during the day. Even for household applications it is questionable whether the parameters defined for this tier actually represent a significant step towards enhanced energy access. A productive use of electricity in this tier cannot be assumed.

Tier 2 intends to cover the needs for electric lighting, air circulation and basic communication needs such as television and phone charging in private households. However, although a peak capacity as low as 50 W would be sufficient for charging a mobile phone, it would not suffice to provide enough electricity for powering a television or for using lighting and communication applications in parallel. Also, productive uses of electricity are likely not possible based on this definition. Therefore, in order to represent a more substantial step towards enhanced electricity access and towards the simultaneous provision of a minimum of adequate lighting and basic communication services for a significant timeframe, the definition of the parameters for this tier should be raised at least to an available minimum capacity of 100 W for 4 hours daily.

Tier 3 would allow for the simultaneous use of lighting and communication appliances as well as, for example, ventilators or other small household applications. However, for the use of electric hotplates or other fundamental domestic appliances, such as electric cooling units, this capacity and daily availability would still not be sufficient. It is also questionable whether an availability of 200 W (or 1 kWh daily) for 50 % of the working hours would be sufficient to allow for any significant productive activity.

Tier 4 is characterised by a connection capacity which would be enough to allow for the provision of lighting and communication services as well as the parallel use of several household appliances such as ventilators, but it still does not suffice to power, for example, a small electric hotplate with an average connected load of about 2.5 kW. Regarding the productive use of electricity, tier 4 assumes that for 75 % of the working hours electricity supply is available and that reliability issues only cause a moderate impact. However, with a connection power of only 800 W, only the requirements of basic applications at a small scale (such as e.g. a food blender, a rice cooker, simple tools or a sewing machine) could be covered.

Tier 5 would allow a household to use various types of domestic applications in addition to lighting and communication services but a use of basic applications with a higher connection load such as electric stoves would still not be possible.

Productive uses of electricity, for example in a small family-run workshop or a retail shop, would be possible, based on this definition. With 95 % availability and no significant quality issues, economic activities would not be severely affected. However, the assumed connection power and daily capacity would only suffice to cover small to medium scale commercial businesses but would not allow for larger-scale commercial or even industrial activities. The emergence and evolution of such productive activities in developing and emerging economies, however, is a key element for the creation of jobs and a sustained increase in value added.

Recommendations for an extended monitoring framework for SDG7

Against the background of the above, this study suggests revising and extending the current MTF in order to:

- ✓ Reflect significant steps towards an enhanced electricity access for households and small-scale family businesses;
- ✓ Take account of the important role that the productive use of electricity plays at all stages of value chains (ranging from family businesses or agricultural applications to the provision of professional services or large-scale industrial production) for climate

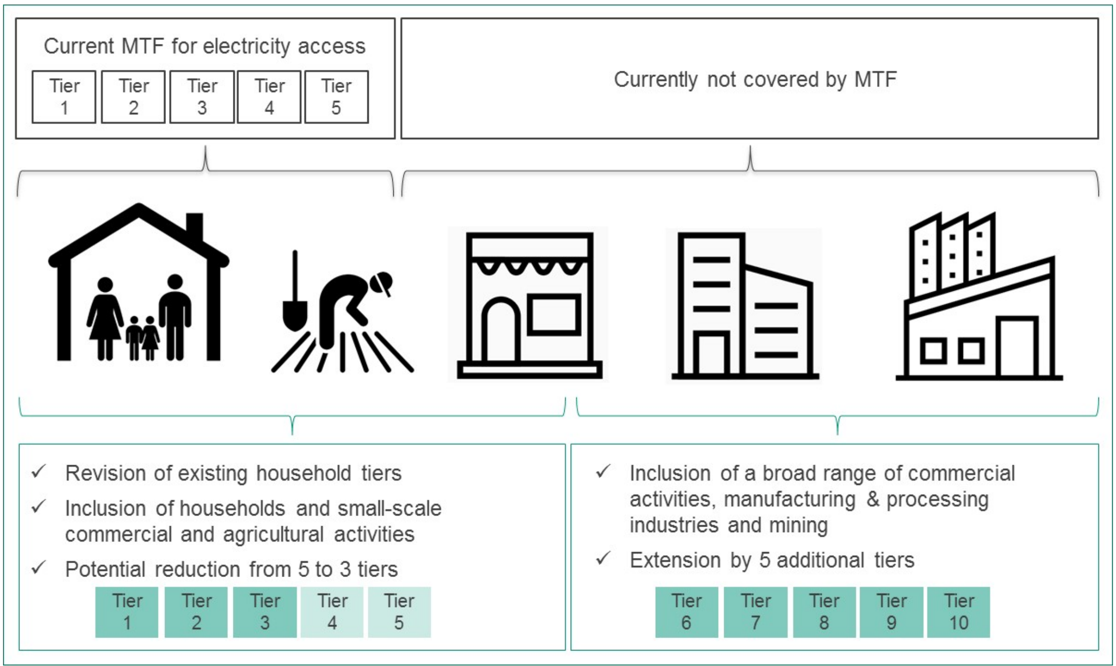
change abatement and sustainable energy strategies;

- ✓ Develop an integrated and seamless framework for monitoring and managing the access to sustainable electricity sources which considers the fuzzy transition between the needs of households and commercial or industrial applications;
- ✓ Allow for a closer link between climate change policies and strategies for economic development and sustainable energy supply to safeguard that the electricity requirements on all tiers can be met with needs-oriented but environment-friendly energy solutions. Here, especially the application of decentralized renewable energy solutions plays a major role.

This implies the following recommendations:

- ➢ Revising the current MTF tiers for the household sector in order to represent essential development steps from basic household applications and requirements for clean (electric) cooking and cooling applications to small-sized commercial activities.
- ➢ Adding 5 additional tiers for productive uses covering electricity access requirements of a broad range of business activities along value chains - ranging from processing of agricultural products to highly sensitive and energy-intensive production processes.

Overview over the proposed revision of the current MTF



Source: Own depiction IREES / Fraunhofer ISI

Instead of applying different MTF matrices for households and productive uses, the proposed framework represents an integrated scale covering the electricity access requirements of households, various commercial or manufacturing activities and industrial processes. On the one hand, the scale is extended to consider requirements of manufacturing and processing industries, on the other hand the smaller development steps of the current scale might be adjusted with a potential reduction from 5 to 3 tiers.

Thus, the approach generates a tool to evaluate electricity access not only against the background of the current economic structures as present in many developing and emerging countries, i.e. a strong focus on agricultural production and extraction of raw materials, but also from a forward-looking, development perspective. The steps defined for the revised framework represent the fuzzy transition between household electricity demand and commercial activities and allow for an assessment of electricity supply conditions as required to increase the local manufacturing share in the value-chain of products based on the productive use of electricity.

The newly developed tiers for productive uses are categorised based on a systematic analysis of a broad range of business activities and production processes. For this purpose, the European classification of economic activities, NACE, is used as it ensures transparency and comparability on a European as well as on a global level. For the analysis, the focus is laid on manufacturing and industrial production processes (including mining) to include a wide range of possible economic activities along the value chain.

For each category of productive activities, the following characteristics are described: Share of electricity consumption in total energy demand and specific energy demand in relation to turnover (as indicators for the capacity requirements and energy-intensity of the activities) and the main critical processes affected by potential power outages (as an indicator for the sensitivity of the processes to power cuts and voltage fluctuations and the potential economic impact that a power outage might have on the respective business).

On this basis, the electricity access requirements of each economic activity are evaluated as specified for the MTF, namely referring to the availability, reliability, quality and affordability of the electricity supply. The results are further clustered in order to derive groups of productive activities with similar requirements regarding electricity access. Thereby five tiers for electricity access for productive uses can be derived (see box below).

Classification of productive uses of electricity for the definition of tiers

Tier 6: Mechanical manufacturing technologies with low electrical control requirements and a low automation level, such as e.g. crop and animal production, production of wearing apparel, leather, tobacco products or furniture.

Tier 7: Mass production of consumer goods without utilisation of sensitive production technologies, such as e.g. food products, beverages, textiles, wood and wood products, print media or other manufacturing.

Tier 8: Mass production of investment goods and durable products with a relevant degree of automation and electric control systems, such as e.g. paper and paper products, metal products, electrical equipment and machinery, motor vehicles and transport equipment.

Tier 9: Manufacturing of high technology or highly sensitive products with a high degree of automation, such as e.g. production of basic pharmaceutical products or computers, electronic and optical products.

Tier 10: Mining and chemical processing of raw material with a very high energy demand, such as e.g. processing of coal, metal ores, natural gas, coke and petroleum products, chemicals, rubber and plastic products, non-metallic and metallic products.

A more detailed description of the five tiers for productive uses of electricity, including the specification of the respective NACE codes, is provided in the table below.

Even though the industry structure and the standard of production processes in developing and emerging countries obviously vary from those in developed countries, the approach is still suitable to obtain a reliable indication of the capacity requirements of a broad range of productive activities. Many economic activities, such as higher-level processing and manufacturing processes, are not yet established in developing and emerging economies as these countries still largely rely on the export of raw materials or unprocessed agricultural products. However, in order to allow for a forward-looking and development-oriented approach, the assessment of electricity access requirements should not be limited to the status quo of economic activities in developing countries but should also consider the requirements of potential future industries and orientation at world market standards.

In contrast to the MTF framework for household electricity access, the results indicate more qualitative assessments of the electricity supply requirements for each tier. This is due to the fact that business operations and company sizes within each group of activities can be highly heterogeneous. This distinguishes the commercial and industrial sector from the household sector where defining standard sizes and typical applications is more straightforward, while, for example, the electricity demand of a commercial business is almost freely scalable depending on the size of the company. A more detailed analysis of the commercial and industrial sector would require a further differentiation on the level of subgroups or even a bottom-up assessment on the company level. However, although such an approach could capture the individual characteristics of a particular country or region, it would not suffice to derive a universally applicable assessment framework for electricity access requirements. Therefore, the applied top-down method, based on the analysis of the energy intensity and process technologies of the most relevant industrial sectors, is a valid approach for deriving a holistic MTF for productive uses in the industry and service sector since the classification comprises all potential business activities.

Outlook and possible further analysis activities

Based on the results of this study a range of further activities could be pursued to verify and refine the results.

It would be particularly beneficial to make further use of the results of the still ongoing World Bank enterprise survey in order to verify and possibly refine the proposed definition of the extended MTF matrix for productive uses. This would permit to compare the systematic top-down approach applied in this study against the country-level bottom-up assessment of the World Bank survey to ensure that the definitions actually capture the requirements of the local industries and businesses.

Another focal point of further activities should be the development of methodologies and frameworks for the collection of data for country level assessments of the suggested tiers. Here, it would be particularly important to coordinate and align efforts with national climate change mitigation strategies as well as with plans for economic development and industry expansion. In this context it is particularly crucial to ensure that the institutions concerned work together in order to avoid adverse effects and to maximise policy efficiency.

Also, in order to ensure the practicability when using the proposed framework for the targeted selection and prioritisation of actual energy supply or infrastructure projects, it would be helpful to develop a more detailed definition and design of suitable technical solutions to meet the respective access requirements for the proposed tiers.

Proposal for the extension of the Multi-Tier Framework for productive uses

		Tier 6	Tier 7	Tier 8	Tier 9	Tier 10
Tier	**Definition**	Mechanical manufacturing technologies with low electrical control requirements/ low automation level, agriculture	Mass production of consumer goods without sensitive production technologies	Mass production of investment and durable products and a relevant degree of automation and electric control systems	Manufacturing of high technology or highly sensitive products with a high degree of automation	Mining and chemical processing of raw materials
	Industry sectors *NACE Code*	1, 12, 14, 15, 31, 33	10, 11, 13, 16, 18, 32	17, 22, 25, 27, 28, 29, 30	21, 26	5 - 8, 19, 20, 23, 24
Indicators	**Capacity requirements**	Low	Low - medium	Medium - high	Low	Low - high
	Availability	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)
	Reliability *Intolerance to power cuts*	▪ Power cuts during working hours acceptable ▪ No harmful impacts on machinery, processes and products	▪ Short power cuts during working hours acceptable ▪ Harmful impacts on products possible (temperature sensitive process such as food production)	▪ Power cuts during working hours critical as significant damage to products is possible	▪ No power cuts acceptable ▪ Significant impacts on products	▪ No power cuts acceptable ▪ Significant impacts on machinery, processes and products
	Quality *Intolerance to voltage fluctuations*	Low: voltage fluctuations do not significantly affect production processes	Low: voltage fluctuations do not significantly affect production processes	High: undue voltage fluctuations affect production technologies	High: undue voltage fluctuations affect production technologies	High: undue voltage fluctuations affect production technologies
	Affordability *Economic impacts of power cuts*	Low	Low - medium	Medium	High	High

1 INTRODUCTION

In 2016, the United Nations (UN) adopted 17 sustainable development goals (SDGs) within the framework of the UN Agenda 2030 (UN 2015). The goals are set equally to industrialised, emerging and developing countries. They cover interlinked targets aiming at various aspects of social and economic development for the entire global population while taking into account environmental aspects and ensuring a sustainable use of resources.

Against this background, the SDG7 aims at ensuring universal access to affordable, reliable, sustainable and modern energy for all (UNDP 2018a). This goal aims at enabling development based on energy use for the entire world population across all sectors. The objective is to ensure that this expansion of energy supply has the lowest possible impact on the environment and climate. Due to the greenhouse gas emissions from energy conversion and use, there is a close link between SDG7 and the Nationally Determined Contributions (NDCs), i.e. the greenhouse gas reduction plans submitted by all countries under the Paris Agreement.

The specific targets and related indicators as defined for monitoring the progress towards reaching the SDG7 are summarised in Table 1

Table 1: SDG7 – Targets and indicators

Targets	Indicators
7.1 By 2030, ensure universal access to affordable, reliable and modern energy services	7.1.1 Proportion of population with access to electricity 7.1.2 Proportion of population with primary reliance on clean fuels and technology
7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption
7.3 By 2030, double the global rate of improvement in energy efficiency	7.3.1 Energy intensity measured in terms of primary energy and GDP
7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil fuel technology, and promote investment in energy infrastructure and clean energy technology	7.a.1 Mobilised amount of United States dollars per year starting in 2020 accountable towards the $100 billion commitment
7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing states and landlocked developing countries, in accordance with their respective programmes of support	7.b.1 Investments in energy efficiency as a percentage of GDP and the amount of foreign direct investment in financial transfer for infrastructure and technology to sustainable development services

Source: UNDP (2018b)

The progress towards reaching the SDG7 is currently monitored based on a Multi-Tier Framework (MTF) for assessing electricity access conditions on national level. So far, the focus of the MTF has been mainly on the basic electricity needs of private households, for example for the provision of lighting, clean cooking solutions or basic communication services such as mobile phone charging.

However, economic development and the increase of welfare for the population have a high priority, especially in developing and emerging countries, and access to electricity is a key catalyst for enhancing productivity and enabling economic growth. Economic development and the emergence and extension of commercial and industrial uses of electricity are generally related to an increased energy demand. This inevitably leads to growing greenhouse gas emissions if no strategies for developing a clean and sustainable energy supply are implemented at the same time.

Therefore, strategies and monitoring frameworks for enhanced energy access should consider the needs of both, households and commercial and industrial applications, and should be closely linked to climate change policies and strategies for sustainable energy supply.

Goal of this study

Against this background, it is the goal of this study to review the present methodology for monitoring the SDG7 targets and to develop an approach for monitoring access to electricity which considers the significant role of productive uses of electricity in developing and emerging economies. By adding to a better understanding of the electricity access needs of different consumer types, the results further aim to support the implementation of sustainable energy strategies, i.e. the development of energy supply solutions which are needs-oriented and at the same time sustainable.

Structure of this report

This report is structured as follows:

Subsequent to this introductory section, chapter 2 provides an overview over the concepts and instruments which are currently used to monitor SDG7.

Chapter 3 outlines the linkages between SDG7 and global climate change strategies and highlights the significance of industrial development and productive uses of electricity in the context of climate change abatement and sustainable energy strategies.

Chapter 4 presents the major part of the analysis. It starts with a critical assessment of the existing MTF and examines to what extent the present framework suffices to represent the requirements related to the productive use of electricity in developing and emerging economies (section 4.1). On this basis, an extension of the present MTF matrix, i.e. a seamless assessment framework capturing the basic electricity access needs of households as well as the more challenging technical specifications needed for various productive uses of electricity is developed (section 4.2). To this end, as a first step, the general electricity access requirements of various commercial and industrial activities are outlined and the present electricity access conditions in developed and developing countries are contrasted. Then, to allow for a transparent and systematic classification of the large range of possible productive uses of electricity, major commercial and industrial activities are grouped according to typical production processes and the associated electricity access requirements. On this basis a possible extension of the MTF matrix is developed.

Chapter 5 concludes the study and provides an outlook on potential further activities.

2 CONCEPTS AND INSTRUMENTS FOR MONITORING SDG7

In order to monitor the progress towards achieving SDG 7 and to allow for a systematic planning of the transformation of the energy sectors and development of corresponding investment strategies on national level, suitable assessment tools are required. In this regard, different reporting formats and analytical frameworks have been developed.

On global level, the Economic and Social Council (ECOSOC) of the United Nations prepares annual reports for the UN Secretary-General to evaluate the overall progress towards the SDG targets (UN 2016, UN 2017, UN 2018a). Further, within the framework of the 'Tracking SDG7: The Energy Progress Report' (formerly known as Global Tracking Framework GTF), the progress of all countries for the three main SDG7 targets 7.1-7.3 (cf. Table 1) is assessed annually. The reports are hosted by the World Bank's Energy Sector Management Assistance Programme (ESMAP) in cooperation with the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the UN Statistical Department and the World Health Organisation. The quantification of the indicators draws upon different data sources compiled by the respective custodian agencies assigned for each indicator (see Box 1 below)

Box 1: Data sources and methodology used for monitoring the indicators for the SDG7 (Tracking SDG7)

The indicator **access to electricity** is measured based on the World Bank's Global Electrification Database (GED) (The World Bank 2016a). This database draws upon household survey data and contains data from 144 countries for the timeframe for 1990–2017. Additionally, data from the Socio-Economic Database for Latin America and the Caribbean (CEDLAS SEDLAC 2017) and the Europe and Central Asia Poverty Database (ECAPOV) (The World Bank 2016c) are regarded. The custodian agency is the World Bank.

The **access to clean fuels** is monitored based on household survey data of the World Health Organization (WHO), which are compiled in the WHO Household Energy database (WHO 2018). The survey covers household energy use for cooking, lighting and heating in 157 countries. The indicator measures the exposure of the population to pollutants released by burning fuels such as wood, charcoal, crop waste, coal, dung or kerosene. The custodian agency is the WHO.

To calculate the percentage **share of renewable energy** (RE) in total final energy consumption (TFEC), data from the IEA World Energy Balances database (IEA 2018) and the United Nations Statistics Division (UNSD) are used. The custodian agencies for this indicator are the IEA, the International Renewable Energy Agency (IRENA) and UNSD.

The **level of energy efficiency** (EE) is calculated based on the IEA World Energy Balances data and the World Bank's World Development Indicators (WDI) (The World Bank 2018b). For countries not covered by these databases, information is supplemented by the UNSD. The indicator is expressed as the ratio of TFEC to GDP (measured at purchasing power parity at constant 2011 US dollars) in order to capture the energy consumption per unit of economic output. The respective custodian agencies are the IEA and UNSD.

On the country level, member states voluntarily prepare national progress reports on the status of the SDGs (Voluntary National Reviews) which are compiled on the Sustainable Development Knowledge Platform of the UN (2018c). Beyond reporting on the progress towards the SGD targets, these national reports also include background information on national policy measures at varying levels of detail.

However, the most established initiative for tracking the global progress on energy access and the quality of energy services is the Multi-Tier Framework (MTF), which is part of the 'Sustainable Energy for All' (SEforALL) 'Global Knowledge Hub' hosted by ESMAP. The MTF provides a quantitative assessment of the status of energy access based on global survey data. Together with the Energy Progress Report, the MTF constitutes the main SEforALL access indicator and a primary source for tracking SDG7. The MTF is discussed in detail in section 4.

Beyond the direct reporting on the status quo regarding the SDG7 goal attainment, there are numerous assessment frameworks for the evaluation of national energy systems, policies and regulatory environments for sustainable energy transitions. To mention just a few prominent examples:

- The 'Regulatory Indicators for Sustainable Energy' (RISE 2018), a benchmarking tool that was developed by the World Bank to measure the progress towards establishing the necessary policy and regulatory frameworks for promoting sustainable energy. It covers 27 indicators across 111 countries.
- The 'State of the Electricity Access' report (SEAR) (ESMAP 2018a) which serves as a periodical stocktaking of the status and nature of progress on the issue of access to energy services. The SEAR was first published in 2017 and examines the critical role of energy in achieving the SDGs. It provides a snapshot of the status of electricity access worldwide, based on the GTF.
- The 'Global Renewable Energy Policies and Measures Database' hosted by the IEA and IRENA (IEA and IRENA 2018) compiles current information on energy-related policies and measures implemented in IEA member countries for the reduction of greenhouse gas emissions, the improvement of energy efficiency and the support of renewable energy deployment.
- The 'Renewables Global Status Report' (REN21 2018) published by REN21, a global renewable energy policy network, provides an overview over the trends and developments of renewable energy markets, investments and policies worldwide.
- The 'Climate Scope Index' (Bloomberg New Energy Finance 2018) published by Bloomberg New Energy Finance is a composite indicator that provides country-level data on the framework conditions for clean energy and climate-related investments as well as low-carbon technology value chains in 71 countries worldwide.

3 LINKAGES BETWEEN SDG7 AND GLOBAL CLIMATE CHANGE POLICIES

The goals of SDG7 are strongly linked with other political agendas and national policies such as climate protection and economic development, which highlights the relevance of closer alignment and coordination. The following section thus provides an overview over the relevance of the Nationally Determined Contributions (NDCs) developed in the framework of the Paris Agreement (section 4.1) and the relevance of industrial development and the productive use of energy in the context of the SDG7 (section 4.2).

3.1 The Paris Agreement and 'Nationally Determined Contributions'

In 2015, not only the '2030 Agenda for Sustainable Development' with its 17 Sustainable Development Goals (UN 2018b) was adopted by the countries of the UN General Assembly but also the Paris Agreement on combatting climate change was ratified by the members of the United Nations Framework Convention on Climate Change (UNFCCC). Both frameworks constitute significant achievements towards establishing a sustainable future and strong interlinkages exist between them. An inherently strong synergy exists between the targets of SDG7 (cf. Table 1) and climate change mitigation strategies, as energy conversion and energy use account for a significant share of global greenhouse gas emissions.

Dependence on fossil fuels for energy generation and the associated CO_2 emissions are a major driver for climate change and breaking this dependence through transition to renewable energy usage (SDG7 target 7.2) is a major component of national climate action plans. The same applies to improvements in energy efficiency (SDG7 target 7.3) which is an important climate change measure, especially if combined with the expansion of renewable energy usage. Enhancing access to energy (SDG target 7.1) especially is a main development goal for many low-income countries which aim to improve basic infrastructure supply for the population and ameliorate the basis for economic development. However, discrepancies between the two agendas might also occur if energy access is increased without considering renewable energy and energy efficiency targets or if efforts towards industrial development are not embedded in strategies for the efficient use of resources. Other potential conflicts might concern land-use for the deployment of renewable energies that could conflict with targets of ecological conservation or food security. Therefore, a careful alignment and coordination of the agendas is required.

Process and methodology for deriving NDCs

Negotiations before the Paris Agreement focused on a top-down approach to establish mandatory emission reductions but were impeded by distributional conflicts among developed and developing countries. In contrast, the bottom-up concept envisioned since the COP21 acknowledges the importance of domestic politics and a framework was created that allows the participating countries to make voluntary pledges. This allows the national governments to determine what they can contribute to the collective mitigation effort (Falkner 2016).

Prior to the COP21 and the ratification of the Paris Agreement, all countries were asked to submit national climate plans, the so-called intended nationally determined contributions (INDCs) in the Lima Call for Climate Action. The term INDC was introduced at COP19 in Warsaw in 2013 where countries agreed to "initiate or intensify domestic preparations for their intended nationally determined contributions" to be submitted by the first quarter to 2015 (UNFCCC 2013 Decision 1/CP.19, paragraph 2). In this context "nationally determined" means that contributions will be developed by countries in accordance with domestic policies, rather than determined collectively and "contribution" refers to the global objective to "achieve the stabilization of greenhouse gas concentrations in the atmosphere" according to the definition of UNFCCC 1992. Article 3 of the Paris Agreement requests the submission and implementation of ambitious NDCs and their advancement over time and also acknowledges the necessity to provide support to developing countries. Article 4 goes into detail on the NDCs. Each country should be enabled to determine the type and scope of the intended actions to combat climate change taking into account national circumstances.

The Paris Agreement subsequently established the requirement that all countries should increase their climate actions communicated in the INDCs every subsequent five years (Article 4.9) and the agreement expects new pledges to raise the overall ambition level (Article 4.3).

Since the COP23 in November 2017 there are currently 180 parties that ratified and signed the Paris agreement. At the point of ratification the INDCs turn into the nationally determined contributions (NDCs). The NDCs are recorded in the NDC registry which is publicly available (NDC Registry 2018). All participating countries are requested to submit the next round of NDCs (new or updated) by 2020.

In the Lima Call for Climate Action (UNFCCC 2014 Decision 1/CP.20) the Conference of Parties agreed on information to be provided by parties when communicating their INDCs. However, the document has provided limited guidance on NDC elaboration. Countries have been free to choose whether or not to consider adaptation (Decision 1/CP.20, paragraph 12); how to interpret 'clarity, transparency, and understanding' (paragraph 13); how to formulate a mitigation contribution (paragraph 14); and how to consider its contribution to be 'fair and ambitious' (paragraph 14).

As a result of this limited guidance, the submitted NDCs vary significantly in the information they present. Many NDCs explicitly specify GHG reductions targets in absolute or relative terms, but some only indicate general actions to be undertaken, or pledges framed in terms of technology goals (Bakkergaard et al. 2015).

The actions contained in all NDCs represent the collective global effort, which will determine whether the long-term temperature goal of the Paris Agreement will be achieved. However, the UN Environment's Emissions Gap Report 2017 concludes that the NDC pledges submitted so far cover only about one third of the emissions reductions needed to be on a least-cost pathway to reach the global target of "well below 2°C" (UNEP 2017).

Opportunities and challenges when linking NDCs and SDG7

The global gap and the lack of ambition and political commitment regarding climate action is partly due to the fact that, in many developing countries the NDC framework plays a minor role for national governments or other relevant domestic stakeholders as their priorities are focused on improving energy security, reducing poverty and strengthening the economy. Nevertheless, as these are also targets of the SDG agenda, it appears obvious that a stronger alignment of the SDGs with the NDCs carries a great potential for synergies and could enhance national action on all fronts.

Several studies have looked into the alignment possibilities of the NDCs and the SDGs (e.g. Dzebo 2017, Bouyé et al. 2018, Northrop et al. 2016, CDKN 2017). Both agendas recognise the close connection between climate action and sustainable development. More than half of the activities specified in the NDCs globally relate to increasing the share of renewable energy in the energy mix (SDG target 7.2) and more than one third relate to the improvement of energy efficiency (SDG target 7.3). However, especially low and lower middle income countries also have a strong focus on activities aiming at enhancing access to energy (SDG target 7.1) and actions specified by these countries comprise, for example, the construction of power plants, the diffusion of clean cooking solutions, technologies for decentralised energy supply or efficient appliances and lighting solutions (DIE and SEI 2018).

Therefore, the approach to the fulfilment of climate change targets has an essential impact on meeting certain targets of SDGs and vice versa (Stechow et al. 2016). Most studies thus conclude that the linkages of climate action and sustainable development objectives are co-beneficial but in some cases, the achievement of one target can also threaten the achievement of another. Especially in low income countries or lower and middle income countries with a strong emphasis on developing basic infrastructures and building the commercial and industrial sector to allow for economic growth and improved employment opportunities, rising energy demand and growing CO_2 emissions may result in drawbacks with regard to climate protection goals.

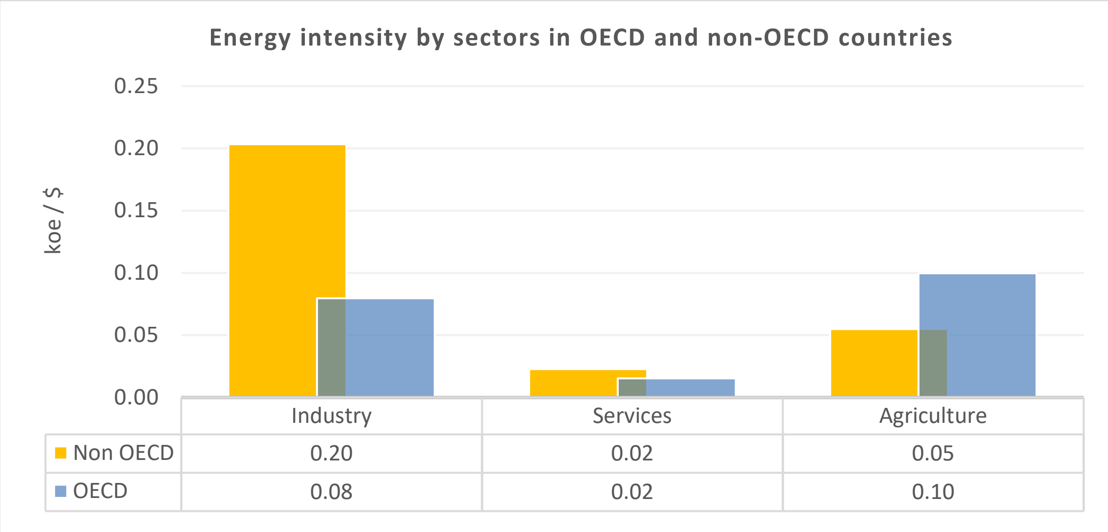
Also, challenges regarding the aligned implementation relate to institutional and procedural issues, as the SDG and NDC processes are mostly coordinated by separate national institutions and sometimes lack a consistent political backing and budget allocation (Bouyé et al. 2018, CDKN 2017). To realise potential benefits from the two agendas, countries need to undertake a systematic process to define potential benefits and co-benefits at the national and sector levels. Synergy reinforcement of both processes should be coordinated at the national level to prevent double counting and thereby reduce costs.

To align both implementation tracks it is also important to link institutional, policy, financial, monitoring and reporting frameworks that have been developed for the NDCs and SDGs. In terms of monitoring frameworks, developing indicators that help to track progress across the agendas would also be a significant step towards minimising the information management burden on countries (Bouyé et al. 2018).

3.2 Relevance of economic development and industrial growth in the context of the SDG7

Looking from a top-down perspective on at economic growth of countries or groups of countries, value added creation (i.e. GDP) primarily takes places in the industrial, tertiary and agricultural sector. With a compounded average growth rate of 6.1 % in non-OECD countries as opposed to 1.1 % in OECD countries in the timeframe 2000-2017[1], the industrial sectors of developing countries show a remarkable growth dynamic as opposed to industrialised nations.

Furthermore, non-OECD countries show a substantially higher energy intensity, i.e. energy consumption per unit of value added, in comparison to OECD countries (see Figure 1). This becomes particularly apparent when looking at the industrial sector: With a value of 0.2 koe/$[2] in non-OECD countries and 0.08 koe/$ in OECD countries, more than twice as much energy is required to produce one unit of value added in the industrial sectors of non-OECD countries compared to OECD countries.



Source: ENERDATA (2018)

Figure 1: Energy intensity in OECD and non-OECD countries in 2017

Considering both, the strong expansion of the economic output in the industrial sector of developing countries as well as its higher energy intensity, its relevance for the total energy requirements and the resulting greenhouse-gas emissions becomes evident.

Figure 2 presents the development of CO_2 emissions in non-OECD countries by sectors in the time period of 2000-2015. The graph shows that the industrial sector not only has the highest contribution to CO_2 emissions during the whole period, but also shows a considerable growth dynamic, which is consistent with the figures presented above regarding energy intensity and economic growth.

Furthermore, the development of public infrastructure and the development of an industrial sector in developing countries and emerging economies unavoidably encompasses the establishment of energy intensive industries such as, among others, primary metals manufacturing (e.g. steel, aluminium, copper), ceramic and non-

1 Calculation based on ENERDATA Global Stat after IEA Energy Statistics, last access 09/2018.

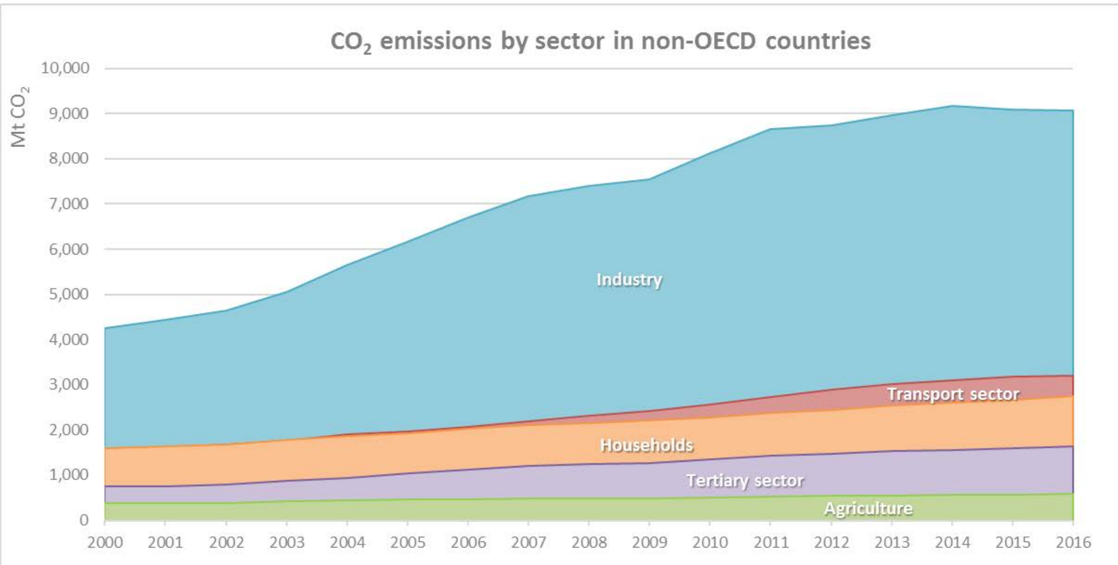
2 Calculation of energy intensity based on kilogram of oil equivalent (koe) per 2015 US$.

ceramic minerals (e.g. cement, concrete), machinery, transport equipment and others. These industries are, by nature, characterized by the dominance of energy intensive processes in their production chains, and hence the establishment and expansion of these economic branches entails a structural change that strongly affects climate change abatement and sustainability strategies.

From a bottom-up perspective, enhanced access to electricity in developing and transition countries catalyses productive uses of electricity and thus promotes economic development across all sectors.

Productive use of electricity can be defined as the utilisation of electricity for activities which generate a monetary value or, based on a broader definition of the term, contribute to an enhanced productivity or increased welfare of the affected population (Kapadia 2014, Brüderle and Bodenheimer 2011). This may involve a broad range of activities such as water pumping in agriculture, water purification, processing of agricultural products, preservation or refrigeration of goods, manufacturing of durable products or provision of various types of services. Therefore, productive uses go beyond the consumption of electricity for private household applications. However, they also cannot be clearly separated from household electricity needs, especially when small family-run businesses or productive engagements in the informal sector are concerned. Therefore, there is a flowing transition between the utilisation of electricity in households and by commercial businesses or service providers in developing and emerging countries.

Against this background and considering the above described significant impact that the growing industrial sectors in developing and emerging economies can have on global CO_2 emissions, it becomes clear that an integrated framework for monitoring and managing the access to sustainable electricity sources in these countries is necessary. Furthermore, access to sustainable electricity sources is relevant from both, the top-down perspective, i.e. for large-scale development of commercial activities and energy intensive industrial branches, and from the bottom-up perspective, i.e. to increase the access to electricity for productive engagements on all levels. Therefore, it is important to consider centralized as well as decentralized solutions for electricity supply.



Source: ENERDATA (2018) - Global Stat after IEA Energy Statistics, last access 09/2018

Figure 2: CO_2 emissions by sectors in non-OECD countries

4 THE MULTI TIER FRAMEWORK FOR MEASURING ENERGY ACCESS

The aim of SDG7 is to ensure universal access to affordable, reliable, sustainable and modern energy for all. However, defining and tracking the access to energy poses a special challenge. First, in terms of how to define affordable, reliable, and modern energy services; and second, regarding how to measure the progress toward universal access.

In order to measure progress towards reaching SDG7, the World Bank established the Global Tracking Framework, which presented an initial system for regular reporting on progress towards reaching SDG7. However, energy access used to be defined and measured using binary indicators. That means, measuring whether a household had access to electricity or not. It soon became clear, that such binary indicators do not sufficiently depict the needs of households and businesses. Therefore, a more holistic framework for measuring and defining energy access was needed.

In order to measure access to energy with a multidimensional approach that goes beyond a binary assessment, the World Bank/ESMAP developed a Multi-Tier approach of energy access. This multi-tier approach was first introduced in the GTF 2013 Report (SEfor ALL 2013).

In 2015, the World Bank, within the SEforALL initiative, finally published the Multi-Tier Framework (MTF) for measuring energy access, called "Beyond Connections, Energy Access Redefined" (Bhatia et al. 2015). The framework intends to capture not only the existence or non-existence of power supply but to assess whether the available energy actually meets the requirements as defined by the respective use case.

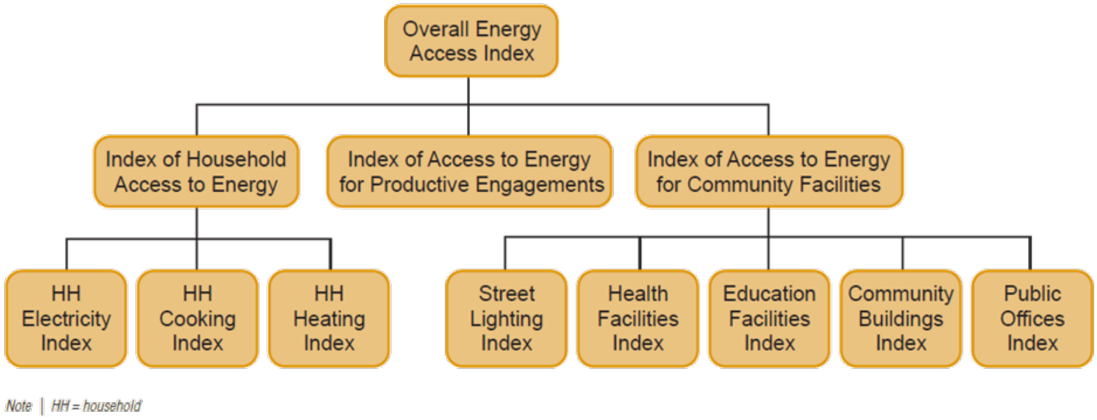
The aim of the MTF is *"to monitor and evaluate energy access by following a multidimensional approach" (ESMAP 2018b).* This is done by measuring energy access using a multi-tiered-spectrum which ranges from tier 0, which means 'no access', to tier 5, the highest level of access.

The four main objectives of the MTF are to:

- *"Establish a global baseline of energy access, starting in 10-15 high access deficit countries based on the multifaceted definition according to MTF;*
- *Transfer capacity to national statistical offices to keep tracking progress toward SE4ALL goals and SDG in the future and*
- *Continue improving tools and capacities for tracking progress towards reaching the SE4ALL objective of universal access to modern energy services by 2030, based on MTF and;*
- *Provide reliable data on energy sector that can meet the needs of multiple stakeholders, including governments, regulators, utilities, project developers, civil society organisations, developmental agencies, financial institutions, appliance manufacturers, international programs and academia" (ESMAP 2018b).*

Based on the GTF 2013, the MTF defines three broad areas of energy use. These are households, productive engagements, and community facilities (see Figure 3).

For the index covering the access to energy for households, three sub-indices are defined: access to electricity, access to energy for cooking solutions and access to energy for space-heating solutions.



Source: Bhatia et al. (2015)

Figure 3: Hierarchy of energy access indices

The attributes regarded for the assessment of energy access consider the availability, quality, adequacy and affordability of the energy and whether access and use are legal, safe and healthy.

The approach is based on the definition of tiers for different energy use applications. So far, the use cases are mainly focused on household applications such as lighting, cooking, air-conditioning or heating (see Table 2).

The scores for the different tiers are then weighted and aggregated into an overall index for energy access. The MTF aims to acknowledge progress as households move from lower to higher tiers. The data is retrieved through a bottom-up assessment based on household surveys (cf. Box 1). The survey that covered household access to electricity and clean cooking was initially implemented in 10-15 high access deficit countries and expanded to a global energy access survey in 15 countries in April 2016.

Regarding energy access for productive applications (see Table 3), the Multi-Tier Framework is based on the same assumptions concerning connection power and daily available capacity as defined for households (cf. Table 2). For the five tiers describing the levels of energy supply for productive applications the approach further assumes that tiers 3-5 successively also meet the requirements of commercial activities and that in tier 5, electricity access does not cause significant issues for productive activities (Bhatia et al. 2015).

Table 2: Excerpt from Multi-Tier matrix for access to household electricity supply

		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Capacity	Power		≥ 3 W	≥ 50 W	≥ 200 W	≥ 800 W	≥ 2 kW
	AND Daily capacity		≥ 12 Wh	≥ 200 Wh	≥ 1.0 kWh	≥ 3.4 kWh	≥ 8.2 kWh
	OR Service		Lighting of 1,000 lmhr per day and phone charging	Electrical lighting, air circulation, television and phone charging are possible			
Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
	Hours per evening		Min 1 hr	Min 2hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
Reliability						≤ 14 disruptions per week	≤ 3 disruptions per week of total duration < 2hrs
Quality							Voltage problems do not affect use of desired appliances

Source: Bhatia et al. (2015), p.6

Table 3: Excerpt from Multi-Tier matrix for energy supply for productive applications

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Availability of Electricity daily supply		Min 2 hrs	Min 4 hrs	Half of the working hours (min 50 %)	Most working hours (min 75 %)	Almost all working hours (min 95 %)
Reliability					Reliability issues with moderate impact	No reliability issues or little (or no) impact
Quality					Quality issues with moderate impact	No quality issues or little (or no) impact

Source: Bhatia et al. (2015), p.13

4.1 Review of the MTF for measuring access to electricity

As already mentioned in the 2013 Global Tracking Report (SEfor ALL 2014), measuring access to electricity is a challenging task and, so far, there is no universally accepted definition of electricity access. Fundamental electrical applications, however, comprise lighting services and clean cooking solutions for private households as well as a large variety of applications for commercial purposes.

The present monitoring of the attainment of SDG7 with the MTF matrix for measuring household access to electricity (cf. Table 3 above), however, places emphasis on the fulfilment of the basic needs for the use of private household applications. Although separate matrices exist for the assessment of energy access for public and productive uses (Bhatia et al. 2015), the assessment in the frame of the GTF, so far, focuses mainly on the requirements of private households and even the assumptions regarding connection power and daily available capacity for each tier are equivalent for households and productive uses (cf. Table 2 and Table 3). However, given the important role that the growing industrial and commercial sectors in developing and transition countries play for the economic development of these countries as well as for the attainment of the global climate change targets (cf. section 4.3) the monitoring of electricity access for these sectors appears to be particularly important.

Therefore, to obtain a consistent framework capturing the central needs of not only private households but also considering the requirements of the developing industrial and commercial sectors, the definition of the present MTF tiers could be adjusted and extended. Below the central definition parameters of the five tiers of the MTF matrix for measuring household electricity access are briefly discussed and potential adjustments to their definitions are suggested.

Tier 1 covers merely very basic energy services for simple lighting applications (3 W or 12 Wh daily) with a minimum availability of only 4 hours per day. This peak power capacity is very low and barely suffices to power small LED lamps and would be insufficient even to power a standard electric light bulb. Further, the minimum availability in the evening, when lighting is mostly needed, is only 1 hour. It is thus questionable whether the parameters defined for this tier actually represent a significant step towards enhanced energy access. Therefore, it could be considered to revise its definition in order to reflect a relevant level of energy consumption needs, i.e. to raise the definition of this tier to the next highest tier to allow for the provision of at least adequate lighting and basic communication services.

Tier 2 intends to cover the needs for electric lighting, air circulation and basic communication needs such as television and phone charging (50 W or 200 Wh/day) with a minimum availability of 4 hours per day. Although a peak capacity as low as 50 W would be sufficient for charging a mobile phone, it would not suffice to provide enough electricity for powering television or to using lighting and communication applications in parallel.

Therefore, in order to represent a more substantial step towards enhanced electricity access and towards the simultaneous provision of a minimum of adequate lighting and basic communication services for a significant timeframe, the definition of the parameters for this tier could be raised at least to an available minimum capacity of 100 W for 4 hours daily. This would allow, for example, for the parallel use of applications such as several electrical light bulbs or LEDs, a TV (depending on type and size with 30-100+ W), phone charging or air circulation (e.g. a ventilator with about 50 W).

Tier 3 is characterized by a minimum power capacity of 200 W with an availability of at least 8 hours per day. Based on this definition, this tier would allow for the simultaneous use of lighting and communication appliances as well as, for example, ventilators or other small household applications. However, for the use of electric hotplates or other fundamental domestic appliances (such as electric cooling units), this capacity and daily availability would still not be sufficient.

It is also questionable whether an availability of 200 W (or 1 kWh daily) for 50 % of the working hours (cf. Table 3) would be sufficient for any significant productive activity.

Thus, in relation to the suggested adjustment of the previous tier, this definition does not allow for a substantial increase in the possibilities for the use of electrical applications for households or commercial purposes. It could thus be considered to revise this tier, i.e. to move directly to the level of the next highest tier.

Tier 4 is defined by a minimum capacity of 800 W or 3.4 kW daily, respectively, for a minimum of 16 hours per day and with max. 14 disruptions per week. Although this connection capacity would be enough to allow for the provision of lighting and communication services as well as the parallel use of several household appliances such as ventilators, it still does not suffice to power, for example, a small electric hotplate with an average connected load of about 2.5 kW. In addition, the level of reliability of the electricity supply might be critical if longer electricity disruptions happen regularly and during times when electricity is urgently needed, e.g. for cooking or communication purposes in the evening hours.

Regarding the productive use of electricity, tier 4 assumes that for 75 % of the working hours electricity supply is available and that reliability issues only cause a moderate impact. With a connection power of 800 W, the requirements of a range of simple applications applied at a small scale (such as e.g. a food blender, a rice cooker, a sewing machine or simple tools) could be covered. This would likely suffice to cover the electricity needs of a small family-business.

However, to reflect a significant leap in the quality of electricity supply in relation to the previous tiers, the definition of this tier could be revised in order to consider the need for clean cooking solutions in addition to lighting and communication services. For example, in order to power a basic electric cook stove with two hotplates simultaneously with lighting and communication services, a minimum capacity of at least 3 kW would be required.

However, clean cooking solutions with regard to the reduction of harmful emissions can also be achieved by non-electric solutions using LPG or biomass which would reduce the minimum electric capacity of the individual households.

Assuming this adjustment of the tier definition (i.e. min. 3 kW capacity for at least 16 hours daily), would further meet the requirements of a broader range of commercial applications, such as small retail or grocery shops with food and beverage cooling applications (part time use) or, for example, the use of small to medium sized irrigation pumps (>1kW) in agriculture.

Tier 5 is defined by a minimum capacity of 2 kW or 8.2 kWh daily, respectively, for a minimum of 23 hours with no more than three disruptions (< 2hrs) per week. According to this definition a household would be able to use various types of domestic applications in parallel to lighting and communication services but still a use of basic applications with a higher connection load such as electric cook stoves would not be possible.

Productive uses of electricity, for example in a small family-run workshop or a retail shop, would be possible, based on this definition. With 95 % availability and no significant quality issues (cf. Table 3), economic activities would not be severely affected. However, the assumed connection power and daily capacity would only suffice to cover small scale commercial businesses but would not allow for medium to larger-scale commercial or even industrial activities.

Compared to the above suggested adjustment of tier 4, a more relevant addition to the quality of energy supply would thus be achieved if, in addition to lighting, communication and clean cooking technologies also reliable cooling of food and beverages would be possible. The usage of cooling technologies would significantly enhance food safety and health and could promote commercial activities. However, for powering e.g. a cook stove with four hotplates and oven in parallel to a small to medium sized fridge, a higher connection capacity (about 4-5 kW) would be required.

An even higher connection capacity (e.g. 9 kW) could be assumed if also the requirements of medium-scale commercial businesses or small cooperatives are to be included. This could cover, for example: service offices, with 2-3 computers (each ca. 100 W), telecommunication and servers (ca. 20 W) and air-conditioning (ca. 2 kW); a medium sized retail or grocery shop with 24 hour food and beverage cooling; a small workshop applying simple electrical tools such as, for example, several sewing machines (ca. 100 W) or a communal cooperative processing agricultural products. This (adjusted or additional) tier definition would allow for a seamless transition to non-household, i.e. commercial applications (see following sections).

In summary, based on the suggestions for the adjustments of the Multi-Tier matrix for measuring household electricity access discussed above, a revised tier definition for the MTF matrix for access to electricity supply could be reduced to four tiers. This adjusted framework would represent the evolution of electricity access requirements ranging from basic household needs to emerging economic activities typical for family businesses or even mediums-sized businesses or small cooperatives. Whereas the current MTF for households, and likewise the matrix for productive uses (cf. Table 2 and Table 3), measure smaller development steps that rather reflect the current situation and bandwidth of household electricity access in developing countries, the suggested new approach considers the seamless transition of electricity needs along value chains, e.g. from basic agricultural production for own consumption or sales to storing, processing and sale of processed products or provision of various services. Thereby, the proposed assessment metrics represent a shift from the household as fixed observation entity to an approach that allows for a more general examination of electricity access and whether it is suitable for the respective purpose.

4.2 Development of an assessment framework for the electricity access requirements of commercial and industrial applications

As already explained in the previous section, a central starting point for a possible further development of the SDG7 monitoring framework is the definition and categorisation of the commercial and industrial sector's requirements with regard to access to electricity. This would allow both, a stronger link with the national climate targets (i.e. significantly reducing CO_2 emissions) and a stronger consideration of future economic development in emerging and developing countries.

However, the requirements for energy supply in the industrial and commercial sector are much more complex and the applications used and their dimensions in the various sectors are much more diverse than in private households. Therefore, it is difficult to derive general usage or requirement categories.

For this reason, the subsequent analysis is structured as follows:

- In a first step, an overview over the general requirements of energy access for commercial and industrial users is given and the reasons for the varying susceptibility of different user types and sectors are highlighted (section 4.2.1).
- Section 4.2.2 provides an overview over the technical standards and framework conditions for power supply in Europe in comparison to current reliability of electricity supply in developing countries.
- To facilitate a systematic and transparent analysis of the various industrial and commercial activities, the classification of industrial and commercial uses of energy based on the Statistical Classification of Economic Activities in the European Community (NACE) is introduced (section 4.2.3).
- On the basis of the NACE-standard, an assessment of different economic sectors regarding their requirements for electricity access is performed (section 4.2.4).
- In a next step, this classification is used to derive categories (tiers) with typical use cases, practical examples and related electricity access requirements that could be used as a basis for the further development of the SDG7 assessment framework (section 4.2.5).

4.2.1 General requirements and criticality of energy access for commercial and industrial users

The industrial sector is in general highly heterogeneous regarding different aspects. This heterogeneity can be observed e.g. for the diversity of production processes with respect to inputs, procedures, technologies and outputs, as well as regarding the energy intensity of processes or products and the size of companies. Moreover, some industries are bound to continuous production processes, while others rely technologically on batch production. This will affect, for example, the tolerance towards disruptions and requirements concerning the availability of electricity supply. Therefore, it is difficult to derive a one-for-all set of monitoring criteria suitable for all kinds of industries and services regarding their requirements to power access.

Energy access and grid reliability are key for economic progress in developing countries. For example, in Sub-Saharan Africa, 79 % of all firms experienced power outages between 2006 and 2016, on average 8.6 outages per month, with an average duration of 5.7 hours (African Development Bank Group 2018). This increases unproductive down times or exposes companies to expensive isolated measures such as provisioning of generator capacities. Therefore, and also due to other insufficient infrastructures, only firms with very high returns operating in well-controlled markets can make a profit in Africa. Nearly 60 % of African firms consider underdeveloped infrastructures - power shortages or transport bottlenecks - as the most relevant barrier they face in their daily business (African Development Bank Group 2018). Typically, businesses most able to cope with these given constraints are industries which operate their own electricity capacities due to sensitive processes.

Highly critical processes and emergency power supply in case of power outages

In the event of a power outage, many companies rely on an emergency power supply which can be classified into 'uninterruptible power supply systems' (UPS) and 'emergency power systems' (EPS). Uninterruptible power supplies obtain their energy from accumulators and are used to protect highly sensitive technical systems (e.g. mainframes). They ensure uninterrupted operation in the event of a failure of the public power supply. In general, UPS systems are only configured for a short bridging time. During this time, technical systems can be reset to a safe operating state, or an emergency power supply can take over further power supply. EPS systems usually consist of generators driven by diesel engines. They are used to supply the emergency power network of the plant. The transfer of the main supply does not take place without interruption; in the best case, the start-up time of the emergency power supply is in the range of seconds. The operating time of the emergency power supply is highly dependent on an uninterruptible supply of high-quality fuel (BBK 2015).

Also in countries with high reliability of the electricity network supply, industrial consumers are recommended to have back-up capacity of several days. In Germany, the Federal Office of Civil Protection and Disaster Assistance recommends that an emergency power supply should be designed to operate for 72 hours without any additional fuel supply. The 72-hour recommendation is based on the fact that disruptions in the German public power supply can mostly be resolved within 72 hours. Should a power failure continue for a longer period of time, 72 hours is expected to provide sufficient time to initiate the supply of additional fuel and to provide refuelling (ARD 2018). However, there are areas where it is necessary to design the emergency power supply for more than 72 hours, especially if the business areas are particularly critical. Considering the current reliability of electricity supply in most developing countries (see section 4.2.2), longer periods would be necessary. However, investing in own electricity supply capacities to be able to bridge power disruptions in developing countries is not feasible for most service and manufacturing businesses due to the high cost of such facilities. Economic losses are the consequence if business operations are interrupted. Especially for energy-intensive manufacturing and high-technology enterprises this implies that investments in backup capacities with corresponding fuel storages are economically not feasible in countries with a low reliability of the public electricity supply.

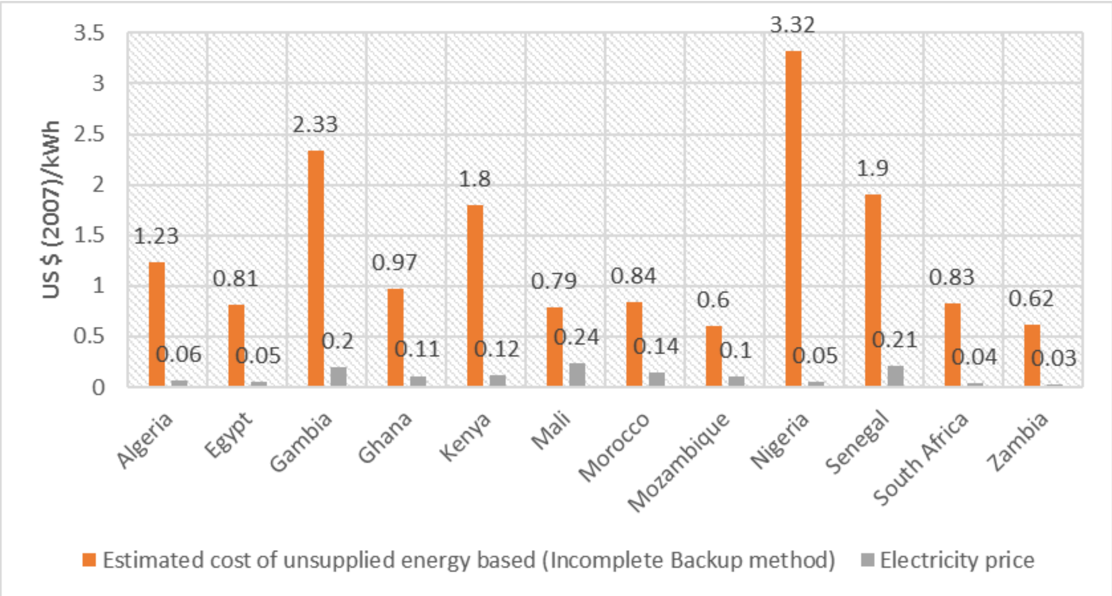
A blackout can also be highly critical in the chemical industry. Chemical production plants, such as crackers or electrolysis plants, strongly depend on a reliable power supply. If a power failure occurs in such a plant, the plant is immediately brought into a safe operating state or shut down automatically (Wirtschaftswoche 2011).

In this event, it will no longer be possible to continue production in normal operation. The restart of production after a blackout poses a special challenge for such plants. Depending on the system, it can take from one day to one week until normal operation can be re-established (RND 2018).

Economic impacts of power cuts

Power cuts are not only technologically challenging but are in many cases associated with substantial financial losses for the affected companies. Costs, as a result of the damage, are influenced by direct and indirect factors. Direct impacts on the costs could, for example, be due to loss of manufacturing and production, loss of sales, loss of value added, equipment damages or, disturbances of provided services. Those costs can be seen as direct damage costs to the manufacturer and methods to assign a monetary value to those impacts are rather straightforward. Indirect costs appear in the aftermath of the system failure with far-reaching consequences for the entire socioeconomic system. They could, for example, entail impacts on consumers or communities and are difficult to determine (Munasinghe and Sanghvi 1988).

The interruption of electricity supply is often measured in empirical studies by estimating the value of lost load (VoLL) based on macroeconomic data. This economic indicator is determined by relating the monetary value of the damage due to losses of gross value added to non-delivered electricity during the interruption. Whereas the VoLL approach only estimates average costs of non-delivered energy, bottom-up approaches based on micro analysis of firm behaviour to prevent energy outages can reveal marginal costs or the value of reliability as well as the mitigated and unmitigated costs by each customer associated with complete or incomplete back-up capacities (Oseni and Pollitt 2013). Figure 4 shows the results of estimated costs of power outages for selected African countries in 2007 derived by Oseni and Pollitt (2013) based on the World Bank business enterprise survey. Thereby, unmitigated costs of incomplete backup capacities are considered. The results reveal that the costs of power outages per kilowatt hour are by far higher than the electricity tariffs for industrial customers in all of the investigated countries.



Source: Own depiction IREES/ Fraunhofer based on Oseni and Politt (2013)

Figure 4: Estimated costs of power outages considering incomplete back-up capacity

4.2.2 Comparison of reliability and quality of electricity supply in Europe and developing countries

The transmission and distribution grids are necessary to transport the electricity from the power provider to the consumers. In Germany, the transmission grids (max. voltage of 220/380 kV) are owned by four transmission system operators (TenneT, 50Hertz GmbH, Amprion and TransnetBW). The transmission grids in the northern and eastern part of Germany, owned by 50Hertz, are part of the European grid, which is connected to Poland, Czech Republic and Denmark and have the following characterisation (50Hertz 2008):

- Utility frequency between 49.8 and 50.2 Hz
- Continuous operating voltage spectrum at the 380 kV voltage level is 360-420 kV and at 220 kV voltage level between 210-245 kV

The transmission grid operator further specifies the following acceptable voltage deviations for all relevant operating states of the customer systems, which have to be met at any time (50Hertz 2008):

- For circuits of individual units within the customer's systems: $\Delta umax \leq 0.5$ %
- For circuits of the entire system (operating circuit with advance notice): $\Delta umax \leq 2$ %
- For fault-based circuits (circuits without advance notice): $\Delta umax \leq 5$ %

In order to provide a clear legal framework for grid connections, to facilitate union-wide electricity trading, to ensure system security and to facilitate the integration of renewable electricity sources into the electricity system, the European Commission implemented comprehensive regulations. For example, the Commission Regulation 2016/1388 (EU 2016) establishes a network code on demand connection. This regulation contains requirements like the minimum time periods for which a transmission-connected consumer has to be capable of operating on different frequencies without disconnecting from the network. Table 4 shows the operating parameters for two European areas as an example.

Table 4: Minimum time periods for which a transmission-connected consumer has to be capable of operating on different frequencies without disconnecting from the network

Synchronous area	Frequency range	Time period for operation
Continental Europe	47.5 – 48.5 Hz	To be specified by each transmission system operator, but not less than 30 min
	48.5 – 49.0 Hz	
	49.0 – 51.0 Hz	Unlimited
	51.0 – 51.5 Hz	30 min
Great Britain	47.0 – 47.5 Hz	20 sec
	47.5 – 48.5 Hz	90 min
	48.5 – 49.0 Hz	To be specified by each transmission system operator, but not less than 930 min
	49.0 – 51.0 Hz	Unlimited
	51.0 – 51.5 Hz	90 min
	51.5 – 52.0 Hz	15 min

Source: EU (2016)

Quality and reliability of supply

Beyond the technical parameters defining voltage levels and frequency ranges, the quality of electricity access can be measured by indices capturing the continuity of supply. The system average interruption duration index (SAIDI) describes the average interruption duration per customer in one calendar year for the low voltage level. The system average interruption frequency index (SAIFI) describes the average number of interruptions per number of customers over the course of a year and thus gives an indication on the frequency of interruptions. Both calculations do not include planned interruptions or interruptions caused by force majeure like natural disasters. Therefore, the indices describe the general system stability and quality of the national electricity supply.

In developing countries the electricity system stability is often a major problem due to insufficient or obsolete grid infrastructures or shortages in generation capacity.

Table 5 shows a comparison of power supply quality for selected cities in developed and developing countries based on data collected in the frame of the 'Doing Business' project, carried out by The World Bank (2017b). The project monitors various framework factors for entrepreneurial activities, such as the reliability of power supply, across 190 economies worldwide. The data refers to small and medium-sized companies and selected cities at the sub-national and regional level.

Table 5: Reliability of supply for selected developed and developing countries in 2015/2016

Continent	Economy	SAIDI (interruption hours per year)	SAIFI (interruptions per customer and year)
Europe	Berlin (Germany)	0.2	0.2
	Oslo (Norway)	0.8	1.1
	Athens (Greece)	2.2	1.4
	Sofia (Bulgaria)	5.0	4.1
Africa	Dar es Salaam (Tanzania)	24.9	10.8
	Nairobi (Kenya)	80.9	17.0
	Douala (Cameroon)	103.0	26.4
	Niamey (Niger)	365.0	243.3
America	Guatemala City (Guatemala)	3.6	2.5
	Bogota (Colombia)	6.3	5.8
	Managua (Nicaragua)	73.7	39.6
	Tequcigalpa (Honduras)	257.0	19.4

Source: The World Bank (2017a)

Comparing the figures in Table 5 **Guatemala City** is a good example of how the reliability of electricity supply in a developing country can be improved. Compared to other major business cities in Latin America and the Caribbean, with an average of 13 power outages, Guatemala City had less than three outages in 2015. This is due to a number of regulatory measures, such as opening the energy sector to private investments in order to boost the power capacity in Guatemala. Today around 85 % of the installed generation capacity is operated by private companies and the capacity in total increased from 1.0 GW in 1996 to 3.7 GW in 2016. In 1996, an independent regulatory body, the national electricity commission, was established to ensure fair market competition. This commission sets the market rules, monitors power outages and imposes financial penalties on utilities when excessive service interruptions occur. Today the utility performance in Guatemala is the highest in Latin America and the Caribbean. Enabling a new connection to the electricity grid takes around 39 days, whereas the regional average is around 66 days (The World Bank 2016b).

On the contrary, the installed generation capacity in **Cameroon**, despite the liberalization of the energy sector, increased only from 0.8 GW in 2000 to 1.0 GW in 2012. In 2015 the residents of Douala experienced on average around two hours of power outages each week. Due to this high outage rate, approximately 35 % of the companies in Cameroon operate their own power generators. According to 'Doing Business' data, reliability issues in Douala are triggered more by the low diversity in the energy mix, as around 71 % of the generated electricity comes from hydropower, and a lack of infrastructure, than by insufficient utility management. A new electricity connection in Cameroon takes on average 64 days, which equals half the average time in the Sub-Saharan Africa region (The World Bank 2016b).

4.2.3 Classification of industrial and commercial uses of energy

In the European Union, economic activities are classified based on the 'Statistical Classification of Economic Activities in the European Community' which is commonly referred to as NACE. NACE is a four-digit classification providing the framework for collecting and presenting a large range of statistical data according to economic activities in the fields of economic statistics such as production, employment and national accounts, and in other statistical domains developed within the European statistical system (eurostat 2018a).

For the classification of industrial and commercial uses of energy in this study we chose to use NACE, as NACE ensures transparency and comparability on European as well as world level. The comparability at global level is due to the fact that NACE is part of an integrated system of statistical classifications, developed mainly under the auspices of the United Nations Statistical Division. NACE is derived from ISIC (the United Nations' International standard industrial classification of all economic activities), in the sense that it is more detailed than ISIC. ISIC and NACE have exactly the same items at the highest levels, while NACE is more detailed at lower levels. In order to ensure international comparability, the definitions and the guidelines established for the use of NACE within the EU are consistent with those published in the introduction to ISIC (eurostat 2018b).

NACE consists of a hierarchical structure (as established in the Regulation (EC) No 1893/2006 (EUR-Lex 2006), introductory guidelines and explanatory notes. The structure of NACE is described in the NACE regulation as follows (eurostat 2018b):

- a first level consisting of headings identified by an alphabetical code (sections);
- a second level consisting of headings identified by a two-digit numerical code (divisions);
- a third level consisting of headings identified by a three-digit numerical code (groups);
- a fourth level consisting of headings identified by a four-digit numerical code (classes).

The different levels of the hierarchical structure describe economic activities. In general, an economic activity is characterised by an input of resources, a production process and an output of products, which can be goods or services. Such an activity may consist of one simple process, but may also cover a whole range of sub-processes, each mentioned in different categories of the classification (eurostat 2018b).

4.2.4 Assessment of economic sectors regarding electricity access requirements

Based on the NACE classification, the following section provides a systematic analysis of the electricity access requirements of different economic sectors. For each economic sector, the requirements regarding the electricity supply are described, analysed and evaluated according to the dimensions of availability, reliability, quality and affordability, as regarded in the MTF. The result is presented in Table 6.

Thereby, the focus is on manufacturing and industrial production processes (including mining), i.e. NACE sections B and C. This constitutes the first step to generate a Multi-Tier matrix for the commercial and industrial sector.

Description of productive sectors

In a first step, the electricity access requirements for each activity are described using the following indicators:

Share of electricity consumption in total energy demand

The power share in the total electricity demand together with the specific energy demand per employee or per turnover can be used as an indicator to derive the relevance of electricity for the overall production process. Thereby this indicator serves as a representation of the level of the required electricity capacity, i.e. it differentiates highly electricity-intensive activities from less electricity-intensive activities. As, obviously, the absolute electricity demand depends on the company size and is thus highly scalable, this indicator can only give a relative reference on the respective capacity requirements.

The data used for this analysis are based on statistical data of the different business sectors in Germany (DESTATIS 2016), as well as on the IREES Energy Efficiency Company Network database[3].

Even though the industry structure and the standard of production processes in developing and emerging countries apparently vary from those in developed countries, the available data is still suitable to obtain a reliable indication of the capacity requirements of a broad range of productive activities. Many economic activities, such as higher-level processing and manufacturing processes, are not yet established in developing and emerging economies as these countries still largely rely on the export of raw materials or unprocessed agricultural products (cf. section 5.1.1). However, to allow for a forward-looking and development-oriented approach, the assessment should not be limited to the status quo of economic activities in developing countries but should also consider the requirements of potential future economic branches and world market standards.

Specific energy demand per turnover

As a further step to analyse the electricity-intensity of the production process, the specific energy demand is related to the production output. In order to consider the large range of possible company sizes and therewith the scalability of the requirements in each tier, again the capacity requirements are not defined in absolute but in relative terms. The relation can either be defined output or input specific. Typical references to determine the energy demand of companies are gross value added, annual turnover or the number of employees. Thus,

3 The IREES Energy efficiency Company Network database comprises detailed data on energy demand, supply technologies and efficiency measures of about 1000 industrial companies in Germany.

for the first categorisation of different business activities with regard to their energy intensity, the energy demand per annual turnover is used. The energy demand indicates how much energy is required per EUR 1,000 turnover and is used to qualitatively evaluate the electricity intensity of the economic activity.

Main critical processes affected by potential power outages

In order to determine the requirements related to the stability and reliability of the electricity supply, i.e. the sensitivity to blackouts or voltage fluctuations, the most critical processes and production facilities are identified for each business activity.

While, for example, in the chemical industry the electricity demand is mostly comparatively low, various processes such as steam cracking in a refinery or electrolysis in a chemical plant react very sensitively to network instability. This might result in high economic losses in case of power cuts as complete production batches and even the production line itself may be damaged. For example, during a power cut in a steam cracking company all systems have to be turned into a safe operating state, since an emergency power supply would not be sufficient to continue production in normal operation. Returning to normal operation can take one day to one week (RND 2018).

Other industries, such as the information and communication or the machinery industry, also react very sensitively to voltage fluctuations and power failures due to the generally high degree of automation in this sector. Here, the systems are not necessarily sensitive themselves, but they can react sensitively to unstable electricity supply due to their high degree of process automation. However, modern drive technology of new machines reacts less sensitive to voltage fluctuations.

Finally, there are also industries that are mainly characterized by mechanical processes with little or no automation, especially in countries with low labour costs, such as the textile, wearing apparel, wood or tobacco industry, which are widely established in many developing and emerging countries today. These industries are less sensitive to electricity network instabilities since machines and products are usually not damaged by disruptions in production. Nevertheless, economic losses due to production downtime (loss of sales) occur just as in industries with more sensitive processes or products.

Assessment of productive sectors

Following the analysis of the major processes that are characteristic for each of the considered economic branches, the electricity access requirements are evaluated based on expert judgements and individual interviews with industry stakeholders[4].

Thereby, the assessment of the electricity access requirements of each economic activity refers to the criteria as specified for the MTF:

1. Availability

The availability defines the power capacity requirements and is attributed to the electricity share in the total energy demand as well as the energy intensity of the different business activities expressed by the energy demand per turnover.

2. Reliability

The reliability describes the intolerance of the most characteristic processes and production facilities to power cuts. Therefore, the requirements regarding the electricity supply for different business activities are analysed based on the identified critical processes.

4 Interviews were carried out with experts from different industry branches, an energy audit expert, a provider of off-grid electricity supply solutions with a focus on developing countries and a consultant for industrial energy audits.

4. Quality

The criterion quality expresses the sensitivity of different industry sectors to voltage fluctuations. The requirements are also derived from the respective critical processes and typical production equipment applied. Particularly sensitive equipment or processes are, for instance, electroplating in metal-processing companies or automation technology.

5. Affordability

The affordability indicates the economic impact that power outages could have on the respective production process. Thereby, the economic losses can reach different levels which depend mainly on the impacts that power cuts may have on the production equipment and products.

Such negative impacts may involve:

- Economic losses due to production downtime during power outages (loss of sales);
- Economic losses due to additional time for restarting the process (loss of sales);
- Economic losses due to product damages or harmful impacts on product charge during power outages (loss of sales and material);
- Economic losses due to harmful impacts on the production technologies and the production lines itself (loss of sales, material and capital assets).

Table 6 summarises the results of the analysis for each business activity on the level of 2-digit NACE classification of economic sectors.

Since business operation and company sizes within each sector can be highly heterogeneous, which distinguishes the commercial and industrial sector from the household sector where it is more straightforward to define standard sizes and typical applications, the results need to be considered as an average, qualitative assessment of the electricity access requirements.

A more detailed analysis of the commercial and industrial sector would require a further differentiation on the level of subgroups or even a bottom-up assessment on company level. However, although such an approach could capture the individual characteristics of a particular country or region, it would not suffice to derive a universally applicable assessment framework for electricity access requirements. Therefore, the applied top-down method, based on the analysis of energy intensity and process technologies of the most relevant industrial sectors, is a valid approach to derive a holistic Multi-Tier Framework for the industry and service sector since the classification comprises all potential business activities.

Thereby, this concept also allows for a forward-looking and development-oriented approach which is not limited to the status quo of economic activities as presently established in developing or emerging countries (i.e. with a focus on agricultural production or mining and extraction of raw materials, cf. section 5.1.1) but also includes the requirements of potential future economic branches to be developed in these countries.

Table 6: Analysis of business activities regarding electricity access requirements

Description						Assessment			
NACE			Power share in total energy demand	Energy demand per 1,000 EUR turnover	Main critical processes or facilities affected by a power outage	Availability *Capacity requirements (low/medium/high)*	Reliability *Intolerance to power outages (low/medium/high)*	Quality *Intolerance to voltage fluctuations (low/medium/high)*	Affordability *Economic Impacts of power cuts (low/medium/high)*
Section	Code	Division							
A Agriculture, forestry and fishing	1	Crop and animal production, hunting and related service activities	N/A	N/A	- Water pump - Infrared heat lamp	low	low	low	low
B Mining and quarrying	5 - 8	Coal, metal ores, natural gas etc.	40 %	31.4 GJ (Coal and lignite) 5.9 GJ (petroleum and natural gas) 3.5 GJ (Other mining and quarrying)	- Drill heads - Ventilation system	high	medium	low	high
C Manufacturing	10	Food products	28 %	1.4 GJ	- Refrigerated warehouse - E/I&C (electrical instrumentation and control)	medium	medium	low	medium
	11	Beverages	N/A	1.2 GJ	-	medium	low	low	medium

Description						Assessment			
NACE			Power share in total energy demand	Energy demand per 1,000 EUR turnover	Main critical processes or facilities affected by a power outage	**Availability** *Capacity requirements (low/medium/high)*	**Reliability** *Intolerance to power outages (low/medium/high)*	**Quality** *Intolerance to voltage fluctuations (low/medium/high)*	**Affordability** *Economic Impacts of power cuts (low/medium/high)*
Section	Code	Division							
	12	Tobacco products	N/A	0.2 GJ	- Mechanical production technologies	low	low	low	low
	13	Textiles	N/A	1.4 GJ	- Mechanical production technologies - Production roads	medium	low	low	low
	14	Wearing apparel	N/A	0.2 GJ	- Mechanical production technologies	low	low	low	low
	15	Leather and related products	N/A	0.3 GJ	- Production roads - Mechanical production technologies	low	low	low	low
	16	Wood and products of wood and cork, also straw and plaiting materials	17 %	5.1 GJ	- Mechanical production technologies	medium	low	low	low
	17	Paper and paper products	26 %	7.1 GJ	- Paper machine - E/I&C	high	medium	low	medium
	18	Printing and reproduction of recorded media	N/A	1.2 GJ	- Printer	medium	low	low	low

Description						Assessment			
NACE			**Power share in total energy demand**	**Energy demand per 1,000 EUR turnover**	**Main critical processes or facilities affected by a power outage**	**Availability** *Capacity requirements (low/medium/high)*	**Reliability** *Intolerance to power outages (low/medium/high)*	**Quality** *Intolerance to voltage fluctuations (low/medium/high)*	**Affordability** *Economic Impacts of power cuts (low/medium/high)*
Section	**Code**	**Division**							
	19	Coke and refined petroleum products	6 %	6.7 GJ	- E/I&C - Steam cracking process	low	medium	low	high
	20	Chemicals and chemical products /	16 %	8.7 GJ	- Water electrolysis - E/I&C	medium	high	high	high
	21	Basics pharmaceutical products and preparations	N/A	0.5 GJ	- Hot-air sterilization - E/I&C	low	medium	high	medium
	22	Rubber and plastic products	57 %	1.2 GJ	- Injection moulding - E/I&C	medium	medium	low	high
	23	Other non-metallic mineral products	16 %	7.1 GJ	- Melting furnace for glass production - E/I&C	medium	high	low	medium
	24	Basic metals	16 % (57 % non-ferrous metals)	10.2 GJ	- Electrolysis for aluminium production - electric arc furnace for crude steel converter for crude steel - E/I&C	high	high	low	high
	25	Fabricated metal products	52 %	0.8 GJ	- Electroplating - E/I&C	medium	medium	high	medium
	26	Computers, electronic and optical products	N/A	0.4 GJ	- Mechanical production technologies	low	high	high	medium

Description						Assessment			
NACE			Power share in total energy demand	Energy demand per 1,000 EUR turnover	Main critical processes or facilities affected by a power outage	Availability *Capacity requirements (low/medium/high)*	Reliability *Intolerance to power outages (low/medium/high)*	Quality *Intolerance to voltage fluctuations (low/medium/high)*	Affordability *Economic Impacts of power cuts (low/medium/high)*
Section	**Code**	**Division**							
					- E/I&C				
	27	Electrical equipment	N/A	0.3 GJ	- Mechanical production technologies - E/I&C	low	medium	high	low
	28	Machinery and equipment	55 %	0.3 GJ	- E/I&C	medium	low	high	medium
	29	Motor vehicles and (semi-)trailers	42 %	0.4 GJ	- E/I&C - Painting process	medium	low	medium	medium
	30	Other transport equipment	N/A	0.3 GJ	- E/I&C	low	low	medium	low
	31	Furniture	N/A	0.5 GJ	- Mechanical production technologies	low	low	low	low
	32	Other manufacturing (like jewellery, sport goods etc.)	N/A	0.4 GJ	- Mechanical production technologies	low	medium	medium	low
	33	Repair and installation of machinery and equipment	N/A	0.2 GJ	- Mechanical production technologies	low	low	low	low
Q Human health and social work	86	Human health activities / hospitals	25 % (statista 2013)	N/A	- Respirator - Infusion device	low	medium	low	low

Description						Assessment			
NACE			Power share in total energy demand	Energy demand per 1,000 EUR turnover	Main critical processes or facilities affected by a power outage	Availability *Capacity requirements (low/medium/high)*	Reliability *Intolerance to power outages (low/medium/high)*	Quality *Intolerance to voltage fluctuations (low/medium/high)*	Affordability *Economic Impacts of power cuts (low/medium/high)*
Section	Code	Division							
Other services	61	Telecommunication	N/A	N/A	- Computers	low	medium	low	low
	63	Information and communication	N/A	N/A	- Network server - Climate control for server - Computers	low	medium	low	low
	77	Administrative and support service activities	N/A	N/A	- Computers - Network server	low	medium	low	low

4.2.5 Recommendations for the further development of the SDG7 monitoring framework

As second step, the results on the level of different business activities are clustered in order to derive groups of productive activities with similar requirements regarding electricity access. The result of this step is summarized in Table 7. The resulting MTF comprises 5 tiers. Each tier is defined by typical processes and product types of the respective sectors. By specifying the link to the industrial sectors, the proposed framework allows a comprehensive application to specific projects – e.g. requirements for the establishment of certain industrial sectors.

Currently, the economies of developing countries still largely depend on the primary production of agricultural products and the extraction and production of raw materials. For example, Tanzania's GDP relies roughly to 30 % on agriculture, forestry, and fishing (The World Bank 2015 - 2017). With regard to electricity access requirements, the production of agricultural products can be grouped into Tier 6 of the proposed MTF-extension.

Besides agricultural products, also mined raw materials are a major export commodity of the developing countries of the south (tier 10). Between 2002 and 2012, Africa's share of the global mining sector rose from 10 to 17 %, and in Burkina Faso, DRK, Guinea, and Mauritania, the mining sector is responsible for more than half of all exports (Bernier 2018). Even if extracting of raw materials is still conducted with simple mechanical tools in many cases, mines and quarries on an industrial scale require high power capacities and, due to the sensitive drilling technologies, a very reliable electricity supply. In some African countries, such as Liberia and Guinea, the power demand of the mining sector is even higher than the total demand of all other economic activities (Banerjee et al. 2015). As a result, the grid disposability is oftentimes insufficient for big mining facilities, forcing the companies to operate their own thermal power plants to ensure stable production conditions, although own generation is more expensive than power from the grid (Bernier 2018).

An example that illustrates the relationship between economic development and electricity supply quality on local level is the town of Moshi in Tanzania. In Moshi, grid connectivity levels are considerably higher than the national average. While electricity access is roughly 33 % across Tanzania, it is 87 % in Moshi (Kavishe 2015). Different processing industries of primary agricultural products operate in Moshi such as sugar, soft drinks, beer, animal feeds and coffee production. The latter is not only grown, but also processed and packed locally. The same applies to wood, which is not only sourced but also further processed for production of matches and furniture. All of the aforementioned products are covered by the suggested tiers 6 and 7. Here, the transition of the local value chains from basic raw material and agricultural production to processing and production of consumer products represents an important development step. This can, at least partly, be attributed to the relatively high level of power access in Moshi. However, power interruptions are also frequent in Moshi (Kavishe 2015), which may, combined with other factors, hinder the development of productions associated with tiers 8 and 9.

For Tanzania as a whole, the World Bank enterprise survey reveals that most manufacturing industries experience power interruptions on a regular basis ranging from 70 % of the surveyed companies in furniture production to 92 % in food processing (The World Bank 2018a). Interestingly, the survey disaggregates the industrial sector as follows: Food, Textiles & Garments, Furniture, and 'Other Manufacturing'. This gives a hint on the countries' current industrial structure, with a clear focus again on tiers 6 and 7.

Table 7: Proposal for extension of Multi-Tier Framework for productive uses

		Tier 6	Tier 7	Tier 8	Tier 9	Tier 10
Tier	**Definition**	Mechanical manufacturing technologies with low electrical control requirements/ low automation level, agriculture	Mass production of consumption products without sensitive production technologies	Mass production of investment and durable products and a relevant degree of automation and electric control systems	Manufacturing of high technology or highly sensitive products with a high degree of automation	Mining and chemical processing of raw materials
	Industry sectors *NACE Code*	1, 12, 14, 15, 31, 33	10, 11, 13, 16, 18, 32	17, 22, 25, 27, 28, 29, 30	21, 26	5 - 8, 19, 20, 23, 24
Indicators	**Capacity requirements**	Low	Low - medium	Medium - high	Low	Low - high
	Availability	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)	All working hours (100 %)
	Reliability *Intolerance to power cuts*	▪ Power cuts during working hours acceptable ▪ No harmful impacts on machinery, processes and products	▪ Short power cuts during working hours acceptable ▪ Harmful impacts on products possible (temperature sensitive process such as food production)	▪ Power cuts during working hours critical as significant damage to products is possible	▪ No power cuts acceptable ▪ Significant impacts on products	▪ No power cuts acceptable ▪ Significant impacts on machinery, processes and products
	Quality *Intolerance to voltage fluctuations*	Low: voltage fluctuations do not significantly affect production process	Low: voltage fluctuations do not significantly affect production process	High: undue voltage fluctuations affect production technologies	High: undue voltage fluctuations affect production technologies	High: undue voltage fluctuations affect production technologies
	Affordability *Economic Impacts of power cuts*	Low	Low - medium	Medium	High	High

TIER 6 – MECHANICAL MANUFACTURING TECHNOLOGIES WITH LOW ELECTRICAL CONTROL REQUIREMENTS AND AUTOMATION LEVELS AND AGRICULTURAL INDUSTRY

➲ **Typical economic activities / products:**

- **Crop and animal production**
- **Hunting and related service activities**
- **Tobacco products**
- **Wearing apparel**
- **Leather and related products**
- **Manufacturing of furniture**
- **Repair and installation of machinery and equipment**

Figure 5: Carpenter in a furniture factory

Tier 6 includes economic activities mainly based on mechanical production technologies with low automation levels or low requirements for electrical controls. It includes the assessed NACE divisions, which, in general, do not utilize critical production technologies or electrical control applications which are sensitive with regard to voltage fluctuations or power cuts. This includes commercial and industrial activities which are already established in many developing or emerging countries, such as production of wearing apparel or leather products or the manufacturing or repair of furniture or basic machinery.

The access to electricity infrastructure is also crucial for the development of competitive agro-industrialization in developing countries. This includes the utilization of electricity for irrigation systems in farming as well as refrigeration of vegetables and dairy products before transporting them to agro-processing plants in the next step of the value chain (see Figure 6).

In this tier the power capacity needed for value creation is relatively low. Power cuts during working hours are considered as acceptable, as no harmful impacts on machinery, processes and products can be anticipated. For instance, electricity for water pumping in agriculture can be interrupted to a certain extent without an instant damage to the products. Therefore, compared to the higher tiers, the electricity access requirements of the divisions grouped in tier 6 are rather low.

Depending on the individual location and use case, stand-alone systems or micro-grids combined with renewable energy technologies could be a suitable alternative to grid connected power supply for this tier.

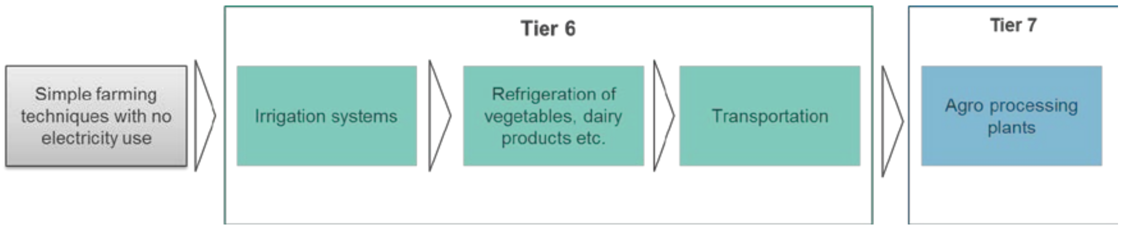


Figure 6: Examples for agro-industrialization and allocation to the proposed tier structure

TIER 7 – MASS PRODUCTION OF CONSUMPTION PRODUCTS WITHOUT SENSITIVE PRODUCTION TECHNOLOGIES

➲ Typical economic activities / products:

- Food products
- Beverages
- Textiles
- Wood and products of wood and cork, also straw and plaiting materials
- Printing and reproduction of recorded media
- Other manufacturing (e.g. jewellery, sport goods etc.)

Figure 7: Seamstress in clothing factory

Tier 7 comprises the NACE divisions related to the production of mass consumption goods without utilization of production technologies which are sensitive to voltage fluctuations or power cuts. For most of these activities, the power capacity requirements are considered to be in the medium range, with the exceptions of the very diverse NACE division 'other manufacturing', where power capacity needs relative to the respective value creation are rather low.

The requirements concerning the reliability of the electricity supply, i.e. the intolerance to power outages, range between low and medium in this tier. While short power cuts during production hours can be anticipated to be generally acceptable, harmful impacts on individual processes and products (e.g. temperature sensitive food production) are also possible.

The intolerance to voltage fluctuations is low for all sectors but 'other manufacturing', where this criterion is set to medium.

Regarding the criterion of affordability, i.e. the susceptibility to economic impacts due to power cuts, the rating for the respective NACE divisions ranges between low and medium. Box 2 below gives an example of the economic consequences of a power cut in a dairy factory, which represents a possible productive engagement in tier 7.

Based on the above definitions, tiers 6 and 7 are also suitable to describe the requirements of small commercial and industrial parks with the corresponding manufacturing companies of different sizes. Here, depending on the total capacity requirements in the respective use case, either grid–connected power supply or, for example, community-based renewable energy projects, could be deployed to safeguard a sustainable electricity supply.

Box 2: Example of a power outage in a dairy factory (tier 7)

During a power outage in a dairy factory, the production had to stop for several hours. The 15,000 litres of milk stored in tanks, machines and long pipes got wasted and, as a consequence, some of the equipment was damaged. The economic impact due to the loss of sales and material amounted to 50,000 Euros (Südwest Presse Online-Dienste GmbH 2013).

TIER 8 – MASS PRODUCTION OF CAPITAL GOODS AND DURABLE PRODUCTS WITH A RELEVANT DEGREE OF AUTOMATION AND ELECTRIC CONTROL SYSTEMS

➲ **Typical economic activities / products:**

- **Paper and paper products**
- **Fabricated metal products**
- **Electrical equipment**
- **Machinery and equipment**
- **Motor vehicles and (semi-)trailers**
- **Other transport equipment**

Figure 8: Workers in a car factory

Tier 8 groups a range of industrial sectors which are mostly producing mass capital goods and durable products (with the exception of paper and paper products, which are mass consumption products), which require a relevant level of automation and process control. The power capacity requirements relative to the economic output in these sectors range between low and medium.

However, compared to tier 6 and tier 7, the productive activities in this tier are more sensitive to power cuts during working hours as these may induce significant damages to the products due to malfunctioning of electrical controls or damages to production equipment. For the same reason, the intolerance to voltage fluctuations in this tier is rather high.

An example of the economic consequences of a power cut in a paper mill is presented in box 3 below.

Therefore, to allow for the widespread establishment of the respective industrial branches also in developing and emerging countries, a reliable and stable power supply must be ensured. This could be realized either by providing a reliable grid connection or through development of sustainable micro-grid solutions backed up by emergency power supply technologies.

Box 3: Example of a power outage in paper production (tier 8)

During a power cut, a paper mill was forced to stop operating. Due to the power failure, gas built up in an on-site pulp digester and created an explosive atmosphere, causing an explosion. Due to the substantial damage, it took about one month until the mill could return to partial operation. The economic impact amounted to an estimated 80-120 million Dollars (PapNews 2017).

TIER 9 – MANUFACTURING OF HIGH TECHNOLOGY OR HIGHLY SENSITIVE PRODUCTS WITH A HIGH DEGREE OF AUTOMATION

➲ **Typical economic activities / products:**

- **Production of basics pharmaceutical products and pharmaceutical preparations**
- **Manufacturing of computers, electronic and optical products**

Figure 9: Highly automated technology manufacturing

Tier 9 comprises high technology manufacturing sectors like electronic or chemical industries. While the specific power capacity requirements of these sectors are generally low, the quality of power supply is quite critical. Power cuts are not acceptable, as they can cause significant damages to the products. The same applies to undue voltage fluctuations.

The affordability, i.e. the potential economic damage, of power cuts in these sectors is considered as medium. However, due to the internal heterogeneity of the concerned sectors, a generalization of the affordability is difficult and the potential economic impact strongly depends on the individual use case. For some processes and products, for example in the pharmaceutical industry, the affordability of power cuts or voltage fluctuations is very low as the processes are precisely controlled and high quality standards must be met (see example in box 4 below). The same applies to high-technology production, such as electronics manufacturing, where even short power cuts may lead to significant losses of costly material and products (see box **4**).

Therefore, to enable the development of such highly sensitive economic activities in developing and emerging countries a particularly stable and high quality electricity supply must be guaranteed. This can be safeguarded by ensuring a grid-connected power supply which conforms to the European standards for electricity grids (cf. section 4.2.2) and is backed-up by additional emergency supply systems, at least for short bridging periods.

Box 4: Examples of a power outages in highly sensitive production sectors (tier 9)

Electronic production: In March 2018, a 40-minute power outage in a Samsung wafer factory in Korea damaged around 60,000 wafers, which represents about 11 % of Samsung's monthly output (Shilov 2018). The available emergency power supply could only bridge 20 minutes of the power outage. The economic damage was around 38 million Euros (Günsch 2018). The resumption of production took one day.

Basic pharmaceutical production: The pharmaceutical industry is highly sensitive to short power cuts and voltage fluctuations. The reason for this sensitivity are precisely controlled steps and the requirements for strict sterility standards (AZO Materials 2017). For example, a power outage during a fermentation process – typically lasting several weeks – will significantly or permanently affect the product (Cohen 2004).

TIER 10 - MINING AND CHEMICAL PROCESSING OF RAW MATERIALS

➲ **Typical economic activities / products:**

- **Coal, metal ores, natural gas etc.**
- **Coke and refined petroleum products**
- **Chemicals and chemical products**
- **Rubber and plastic products**
- **Other non-metallic mineral products**
- **Basic metals**

Figure 10 : Steel production with electric furnaces

Tier 10 groups industry sectors related to the extraction and the first processing steps of raw materials, as well as the basic goods industries. These branches form the physical production basis for the subsequent manufacturing value chains.

The industries grouped in this tier are highly dependent on a stable, reliable power supply and they generally have high power capacity needs due to the high energy intensity of the related processes.

Further, this tier is characterized by a range of sector-specific process technologies, like electrolysis, electric arc furnaces or steam crackers. The impacts of power outages on these and other production technologies can be severe and cause significant economic damages or even the destruction of the overall production line. Therefore, power cuts are highly critical for these industrial processes and cannot be tolerated.

Box 5 below presents an example of the consequences of a power outage during a steam cracking process in chemical production.

The establishment of tier 10 industries thus requires a particularly stable and high-quality electricity supply. Due to the extremely high capacity requirements in the concerned industries, off-grid supply solutions based on renewable energies will likely be insufficient to meet the respective needs. Also emergency supply technologies can only be used for short bridging times. Therefore, a stable and reliable grid-connected electricity supply is needed for this tier.

Box 5: Power outages in chemical production (tier 10)

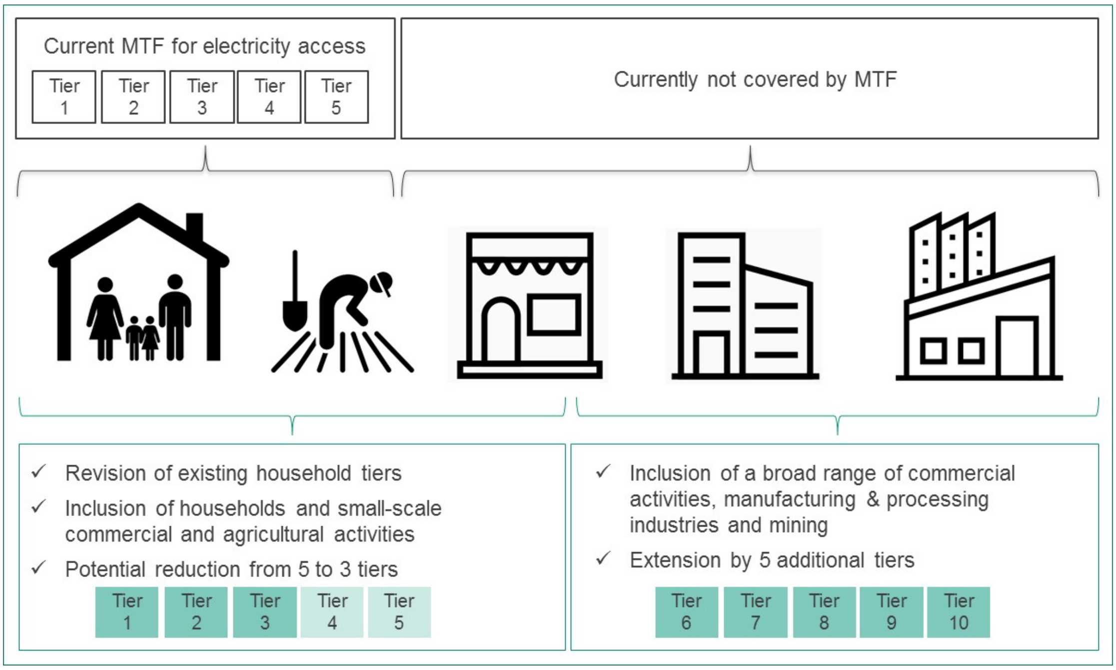
Even short power outages in basic chemical production, for example during a steam cracking process which is part of the production of e.g. ethylene and propylene for hygiene articles or in the plastic industry, cause a significant economic damage to the affected companies. For security reasons, in the event of a power failure all systems of the production plant are automatically brought into a safe operating state. In that case, normal operation is no longer possible, not even with an emergency power system. All gases in the pipes of the plant must be burned via the high flare which implies economic damage due to loss of materials. Restarting the production and returning to normal operation usually takes about a day to a week which leads to significant losses of sales (RND 2018).

5 CONCLUSION AND OUTLOOK

The MTF is a well-established approach for tracking energy supply related progress in the SDG7 context. With regard to electricity access, the framework focuses mainly on household energy demand requirements and has only a limited applicability to productive uses of electricity, such as small-scale family businesses. In order to consider electricity access requirements of small- and medium-sized manufacturing enterprises, communal cooperatives, larger industrial businesses or commercial and industrial parks, the current MTF tier scale is not sufficient. Measuring progress of electricity access conditions with regard to productive uses is, however, essential for the SDG7 goal, since only the settlement and development of enterprises leads to an economic perspective in the regions. Whereas productive uses of manufacturing and process industries are not considered yet, the household scale is rather fragmented and at a low level of ambition.

Against this background, this study suggests to revise and extend the current MTF as follows (see Figure 11):

- Adding 5 additional tiers for productive uses covering electricity access requirements of a broad range of business activities ranging from processing of agricultural products to highly sensitive and energy-intensive production processes.
- Revising the current tiers for the household sector in order to represent essential development steps from basic household applications and requirements for clean (electric) cooking and cooling applications to small-sized commercial activities.



Source: Own depiction IREES / Fraunhofer ISI

Figure 11: Proposed revision of the current MTF

Instead of applying different MTF matrices for households and productive uses, the proposed framework represents an integrated scale covering the electricity access requirements of households, various commercial or manufacturing activities and industrial processes (Figure 11). On the one hand, the scale is extended to consider requirements of manufacturing and processing industries, on the other hand the smaller development steps of current scale are adjusted with a potential to reduction from 5 to 3 tiers.

Thus, the approach generates a tool to evaluate electricity access not only against the background of the current underdeveloped industrial structures as present in many developing and emerging countries but also from a forward-looking, development perspective. The steps defined for the revised framework represent the flowing transition between household electricity demand and commercial activities and allow for an assessment of electricity supply conditions as required to increase the local manufacturing share in the value-chain of products based on the productive use of electricity.

The newly developed tiers for productive uses are categorized according to business activities and production processes from which specific electricity supply requirements result:

- Tier 6: Mechanical manufacturing technologies with low electrical control requirements and a low automation level including agriculture;
- Tier 7: Mass production of consumption products without sensitive production technologies;
- Tier 8 Mass production of investment goods and durable products with a relevant degree of automation and electric control systems;
- Tier 9: Manufacturing of high technology or highly sensitive products with a high degree of automation;
- Tier 10 Mining and chemical processing of raw materials with a very high energy demand.

Nevertheless, the proposed framework does not only indicate a developing perspective based on enterprises in industrialised countries. Examples for electricity access requirements defined by each of the tiers can be referred to major industries in developing countries. Therewith, the range well reflects the requirements which are present in developing countries already today.

5.1 Relating the proposed MTF-extension to the status quo and the challenges of developing and emerging countries

The economies of many developing and emerging countries are largely based on exporting raw materials, e.g. from the mining sector, which corresponds to a low depth of added value creation from productive activities and thus to missed economic opportunities. Further processing of raw materials to build up an industrial value chain could thus be very beneficial, maybe crucial, for the economic development of these countries.

Enhancing the level of electricity grid accessibility and other power-related requirements is decisive to enable such a progress, however, it is far from being sufficient. Other obstacles hinder a fruitful economic development, which are not directly related to electricity grid issues. These obstacles relate, for example, to governance, international trade conditions, political instability or insufficient qualification of employees.

The current industry structure in developing countries can, to a large extent, be assigned to the suggested tiers 6 and 7. However, the existing business activities associated with tiers 6 and 7, such as food processing, exploit only a fraction of the possible value creation potential today. Currently, the majority of such agro-products are used or exported unprocessed, which implies underutilized potentials for domestic value added. For instance, in Tanzania, only 4 % of the annual fruit and vegetable production is being processed and for cotton the domestic processing rate is as low as 20 % (Tanzania Country Commercial Guide 2016). Another sector with a potential for higher domestic value added in Tanzania is the production of leather, as currently only 10 % of produced raw hides and skins are being processed domestically (Tanzania Country Commercial Guide 2016).

It is obvious that a multitude of diverse barriers are responsible for the aforementioned pattern. These barriers could range from economic and political framework issues such as governance, trade regulations, openness of export markets, world-market pricing, investment-related barriers or a lack of capital as well as missing qualification of workforce or infrastructure-related barriers including the quality of electricity supply and grid disposability. Therefore, thorough analyses based on disaggregated empirical data would be needed to assess concrete drivers of the status quo of production structures and to develop targeted policy strategies and measures.

Although it is difficult to draw conclusions on an aggregated level, due to the heterogeneity of the involved sectors, affected countries, and potential barriers, it is possible to confirm the general detrimental impact of poor electricity grid quality on the productivity of manufacturing in Africa, based on data from the World Bank Investment Climate Surveys (Moyo 2013). The data has been gathered by surveying manufacturing firms, asking for the relevance of electricity disposability for the productivity of their respective business. With a regression analysis, build on a production function including quality of power infrastructure, the study showed that a general and mostly statistically significant detrimental effect of low power infrastructure quality high level of outages on productivity exists. The study used data and drew conclusions for South Africa, Mauritius, Uganda, Zambia, and Tanzania.

5.2 Relevance of the supporting framework for a sustainable energy transformation in the context of the SDGs

In order to allow for a smooth and sustainable transformation of the energy sectors of developing and transition countries, also a close monitoring of the evolution of the legal and regulatory frameworks is crucial. With the transition towards higher tiers of energy access and a growing complexity of the electricity system, a well-defined and transparent regulatory framework in the energy sector becomes even more important. Increasing shares of renewable energy and distributed electricity generation, as for example, fuelled by the development of community-driven renewable energy projects or self-supply of industrial or commercial parks (which might evolve in tiers 6-10, cf. section 4.2.5), will require the establishment of clear and equitable conditions for private stakeholders in the energy sector. Also, the growing energy demand driven by industrial development and rising standard of living will likely lead to an increase in greenhouse gas emissions (cf. section 3.2) which emphasizes the need for well-designed policies in the field of energy efficiency.

Therefore, to be able to optimally support the sustainable energy transition and to avoid negative cross-effects on other sustainable development goals, a close monitoring of the relevant political and legal framework conditions should be carried out and linked closely to the monitoring of the progress towards SDG7. In this regard, composite indicators such as RISE (Regulatory Indicators for Sustainable Energy) constitute important tools and should be liked more closely to the process of monitoring the progress towards SDG7. This would allow for an early identification of barriers related to the legal, regulatory, administrative or financial framework conditions which might lead to lock-in situations and could endanger the SDG target attainment.

5.3 Outlook and possible further analysis activities

To verify and refine the proposed MTF extension for productive uses the results of the World Bank company survey could be compared against the proposed tier definition. This would allow to compare the systematic top-down approach applied in this study with the country-level bottom-up assessment of the World Bank survey to ensure that the definitions actually capture the requirements of the local industries and businesses.

Another focal point for further activities should be the development of methodologies and frameworks for the collection of data for country level assessments of the suggested tiers. Here, it would be particularly important to coordinate and align efforts with climate change mitigation strategies as well as with plans for economic development and to make sure that the concerned institutions work together to avoid adverse effects and to maximize policy efficiency.

Also, in order to be able to use the proposed framework for the targeted selection and prioritisation of actual energy supply or infrastructure projects, it would be helpful to develop a detailed definition and design of suitable technical solutions to meet the respective access requirements for the proposed tiers.

REFERENCES

50Hertz (2008): *Netzanschluss- und Netzzugangsregeln*. https://www.50hertz.com/de/Anschluss-und-Zugang/Netzanschlus (accessed April 10, 2018).

African Development Bank Group (2018): *African Economic Outlook 2018. Macroeconomic developments and structural change - Infrastructure and its financing*.

AZO Materials (2017): *Preventing Power Outages in the Pharmaceutical Industry*. https://www.azom.com/article.aspx?ArticleID=14769 (accessed April 10, 2018).

Bakkergaard, R. K. et al. (2015): *Developing INDCs: a guidance note - DTU Orbit*. http://orbit.dtu.dk/en/publications/developing-indcs-a-guidance-note(f8df36bc-6395-4e52-8757-01121bf39ab8).html (accessed April 10, 2018).

Banerjee et al. (2015): *The Power of the Mine A Transformative Opportunity for Sub-Saharan Africa. Directions in Development—Energy and Mining*. https://openknowledge.worldbank.org/handle/10986/21402 (accessed October 12, 2018).

Bernier, A. (2018): *Artikel - LMd*. https://monde-diplomatique.de/artikel/!5480793#anker8 (accessed October 12, 2018).

Bhatia, Mikul, Angelou, Niki (2015): *Energy Access Redefined. Working Paper*. https://openknowledge.worldbank.org/handle/10986/24368 (accessed February 10, 2018).

Bloomberg New Energy Finance (2018): *Climatescope 2017*. http://global-climatescope.org/en/ (accessed February 10, 2018).

Bouyé, M., S. Harmeling, N.-S. Schulz (2018): *Connecting the Dots: Elements for a Joined-Up Implementation of the 2030 Agenda and Paris Agreement*. https://www.wri.org/publication/connectingthedots-ndc-sdg (accessed April 10, 2018).

Brüderle, A., M. Bodenheimer (2011): *Productive Use of Energy (PRODUSE)*, Eschborn. *A Manual for Electrification Practitioners*. http://www.produse.org/index.php?lang=eng&page=15&gallery=32 (accessed October 17, 2018).

Bundesamt für Bevölkerungsschutz und Katastrophenhilfe (BBK) (2015): Notstromversorgung in Unternehmen und Behörden/Band 13: 11.

CEDLAS SEDLAC (2017): *SOCIO-ECONOMIC DATABASE FOR LATIN AMERICA AND THE CARIBBEAN. This database includes statistics on poverty and other distributional and social variables from all Latin American and some Caribbean countries, based on microdata from households surveys.* http://www.cedlas.econo.unlp.edu.ar/wp/en/estadisticas/sedlac/ (accessed October 02, 2018).

Climate and Development Knowledge Network (CDKN) (2017): *REPORT: 10 propositions for success: Integrating international climate change commitments into national development planning*. https://cdkn.org/resource/report-10-propositions-success-integrating-international-climate-change-commitments-national-development-planning/?loclang=en_gb (accessed October 17, 2018).

Cohen, N. (2004): *Power: The Unregulated Utility in Pharmaceutical Environment*. https://www.rdmag.com/article/2004/05/power-unregulated-utility-pharmaceutical-environment (accessed April 10, 2018).

Das Erste Bayerischer Rundfunk (ARD) (2018): *Licht aus – Wenn in Deutschland der Strom ausfällt | Plusminus*. https://www.daserste.de/information/wirtschaft-boerse/plusminus/sendung/hr/stromausfall-106.html (accessed April 10, 2018).

DESTATIS (2016): *Wirtschaftsbereiche - Energie - Tabellen - Statistisches Bundesamt (Destatis)*. https://www.destatis.de/DE/ZahlenFakten/Wirtschaftsbereiche/Energie/Verwendung/Tabellen/TabellenEnergieverwendungVG.html (accessed October 15, 2018).

Deutsches Institut für Entwicklungspolitik (DIE), Stockholm Environment Institute (SEI) (2018): *Bridging climate and the 2030 Agenda. SDG 7: Affordable and clean energy*. https://klimalog.die-gdi.de/ndc-sdg/sdg/7/Average (accessed October 17, 2018).

Dzebo, A. (2017): *Exploring connections between the Paris Agreement and the 2030 Agenda for Sustainale Development. Policy Brief* (accessed April 10, 2018).

ENERDATA (2018): *Global Energy & CO2 Data. Research on energy efficiency, CO2 emissions, energy consumption, forecast*. https://www.enerdata.net/ (accessed Sept. 2018).

Energy Sector Management Assistance Programme (ESMAP) (2018a): *ESMAP*. http://esmap.org/sear/ (accessed February 10, 2018).

Energy Sector Management Assistance Programme (ESMAP) (2018b): *Multi-Tier Framework for Measuring Energy Access*. https://www.esmap.org/node/55526 (accessed February 10, 2018).

EUR-Lex (2006): *32006R1893*. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32006R1893 (accessed April 10, 2018).

European Commission (EU) (2016): *Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection (Text with EEA relevance), C/2016/5239*. https://publications.europa.eu/en/publication-detail/-/publication/514fd1e3-650b-11e6-9b08-01aa75ed71a1/language-en (accessed October 19, 2018).

eurostat (2008): *Europa - RAMON - Classification Detail List*. http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2&StrLanguageCode=EN&IntPcKey=&StrLayoutCode=&IntCurrentPage=1 (accessed October 12, 2018).

eurostat (2018a): *Glossary:Statistical classification of economic activities in the European Community (NACE) - Statistics Explained*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Statistical_classification_of_economic_activities_in_the_European_Community_(NACE) (accessed April 10, 2018).

eurostat (2018b): *NACE background - Statistics Explained*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=NACE_background#undefined (accessed April 10, 2018).

Falkner, R. (2016): The Paris Agreement and the new logic of international climate politics. *International Affairs* 92/5: 1107–1125.

Günsch, M. (2018): *Samsung: Zigtausend NAND-Wafer durch Stromausfall zerstört*. https://www.computerbase.de/2018-03/samsung-stromausfall-nand-wafer-zerstoert/ (accessed April 10, 2018).

International Energy Agency (IEA) (2018): *Sustainable Development Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all*. https://www.iea.org/sdg/ (accessed February 10, 2018).

International Energy Agency (IEA), International Renewable Energy Agency (IRENA) (2018): *Global Renewable Energy*. https://www.iea.org/policiesandmeasures/renewableenergy/ (accessed February 10, 2018).

Kapadia, K. (2014): *Productive uses of renewable energy*, Washington DC. *A Review of Four Bank-GEF Projects*. http://www.martinot.info/Kapadia_WB.pdf (accessed October 17, 2018).

Kavishe, T. E. (2015): *Coping with Power Interruptions in Tanzania: An Industrial Perspective A Case Study of One Small Scale Animal Food Processing Industry in Moshi Municipality*. https://www.duo.uio.no/handle/10852/49028 (accessed October 12, 2018).

Moyo, B. (2013): Power infrastructure quality and manufacturing productivity in Africa: A firm level analysis. *Energy Policy* 61: 1063–1070.

Munasinghe, M., A. Sanghvi (1988): *International Association for Energy Economics The Energy Journal // Reliability of Electricity Supply, Outage Costs and Value of Service. An Overview*. http://www.iaee.org/en/publications/ejarticle.aspx?id=974 (accessed April 10, 2018).

NDC Registry (2018): *NDC Registry*. http://www4.unfccc.int/ndcregistry/Pages/Home.aspx (accessed February 10, 2018).

Northrop, E., H. Biru, S. Lima, M. Bouye, R. Song (2016): *Examining the Alignment Between the Intended Nationally Determined Contributions and Sustainable Development Goals. Working Paper* (accessed April 10, 2018).

Oseni, M. O., M. G. Pollitt (2013): *The Economic Costs of Unsupplied Electricty: Evidence from Backup Generation among African Firms. Cambridge Working Paper in Economics 1351*. https://ideas.repec.org/p/cam/camdae/1351.html (accessed October 12, 2018).

PapNews (2017): *Officials say power failure behind International Paper mill explosion - Papnews*. https://www.papnews.com/officials-say-power-failure-behind-international-paper-mill-explosion/ (accessed April 10, 2018).

Redaktionsnetzwerk Deutschland (RND) (2018): *Blackout – welche Folgen hat ein Stromausfall im Chemiewerk*. http://www.lvz.de/Region/Borna/Blackout-welche-Folgen-hat-ein-Stromausfall-im-Chemiewerk (accessed April 10, 2018).

Regulatory Indicators for Sustainable Energy (RISE) (2018): *RISE*. http://rise.worldbank.org/ (accessed February 10, 2018).

Renewable Energy Policy Network for the 21st Century (REN21) (2018): *Renewables Global Status Report*. http://www.ren21.net/status-of-renewables/global-status-report/ (accessed February 10, 2018).

Shilov, A. (2018): *Power Outage at Samsung's Fab Destroys 3.5% of Global NAND Flash Output For March*. https://www.anandtech.com/show/12535/power-outage-at-samsungs-fab-destroys-3-percent-of-global-nand-flash-output (accessed April 10, 2018).

statista (2013): *Energieverbrauch deutscher Krankenhäusern nach Krankenhausgrößе 2013 | Statistik*. https://de.statista.com/statistik/daten/studie/425501/umfrage/krankenhaeuser-durchschnittlicher-energieverbrauch-nach-krankenhausgroesse/ (accessed October 12, 2018).

Stechow, C. von et al. (2016): 2 °C and SDGs: United they stand, divided they fall? *Environmental Research Letters* 11/3: 34022.

Südwest Presse Online-Dienste GmbH (2013): *Milch: Stromausfall in Hall - Hohenloher Molkerei muss 15.000 Liter Milch vernichten*. https://www.swp.de/suedwesten/staedte/schwaebisch-hall/stromausfall-in-hall-hohenloher-molkerei-muss-15.000-liter-milch-vernichten-19230679.html (accessed April 10, 2018).

Sustainable Energy For All (SEfor ALL) (2013): *Global Tracking Framework*. http://www.worldbank.org/en/topic/energy/publication/Global-Tracking-Framework-Report (accessed February 10, 2018).

Sustainable Energy For All (SEfor ALL) (2014): *Global Tracking Framework. Sustainable Energy For All* (accessed February 10, 2018).

Tanzania Country Commercial Guide (2016): *Tanzania - Agro-Processing | export.gov*. https://www.export.gov/article?id=Tanzania-Agro-Processing (accessed October 12, 2018).

The World Bank (2015 - 2017): *World Development Indicators | DataBank*. http://databank.worldbank.org/data/reports.aspx?source=2&country=TZA (accessed October 12, 2018).

The World Bank (2016a): *Access to electricity (% population) - Line 1990 - 2016*. https://data.worldbank.org/indicator/eg.elc.accs.zs (accessed October 02, 2018).

The World Bank (2016b): *Doing Business 2017*. http://www.doingbusiness.org/en/reports/global-reports/doing-business-2017 (accessed October 12, 2018).

The World Bank (2016c): *Europe & Central Asia*. https://data.worldbank.org/region/europe-and-central-asia (accessed October 02, 2018).

The World Bank (2017a): *About us*. http://www.doingbusiness.org/en/about-us (accessed October 17, 2018).

The World Bank (2017b): *Getting Electricity - Doing Business*. http://www.doingbusiness.org/en/data/exploretopics/getting-electricity (accessed October 17, 2018).

The World Bank (2018a): *Custom Query - Enterprise Surveys - World Bank Group*. http://www.enterprisesurveys.org/Custom-Query (accessed October 12, 2018).

The World Bank (2018b): *World Development Indicators | DataBank*. http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators (accessed February 10, 2018).

Tracking SDG7*Methodology*. https://trackingsdg7.esmap.org/methodology (accessed October 02, 2018).

United Nations Development Programme (UNDP) (2018a): *Goal 7: Affordable and clean energy*. http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html (accessed February 10, 2018).

United Nations Development Programme (UNDP) (2018b): *Goal 7: Sustainable Development Knowledge Platform*. https://sustainabledevelopment.un.org/sdg7 (accessed May 10, 2018).

United Nations Environment Programme (UNEP) (2017): *The emissions gap report 2017. A UN Environment synthesis report*. Nairobi, Kenya: United Nations Environment Programme (UNEP).

United Nations Framework Convention on Climate Change (UNFCCC) (1992): *The United Nations Framework Convention on Climate Change* (accessed October 30, 2018).

United Nations Framework Convention on Climate Change (UNFCCC) (2013): *Report of the Conference of the Parties on its nineteenth session, held in Warsaw from 11 to 23 November 2013. Part two: Action taken by the Conference of the Parties at its nineteenth session* (accessed October 30, 2018).

United Nations Framework Convention on Climate Change (UNFCCC) (2014): *Lima call for climate action* (accessed October 30, 2018).

United Nations (UN) (2015): *Transforming our world: the 2030 Agenda for Sustainable Development*. https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed February 10, 2018).

United Nations (UN) (2016): *Progress towards the Sustainable Development Goals. Report for the Secretary-General*. https://unstats.un.org/sdgs/files/report/2016/secretary-general-sdg-report-2016--EN.pdf (accessed February 10, 2018).

United Nations (UN) (2017): *Progress towards the Sustainable Development Goals. Report of the Secretary-General*. https://unstats.un.org/sdgs/files/report/2017/secretary-general-sdg-report-2017--EN.pdf (accessed February 10, 2018).

United Nations (UN) (2018a): Progress towards the Sustainable Development Goals: Report of the Secretary-General.

United Nations (UN) (2018b): *The Sustainable Development Agenda. The Sustainable Development Goals Report 2018*. https://www.un.org/sustainabledevelopment/development-agenda/ (accessed February 10, 2018).

United Nations (UN) (2018c): *Voluntary National Reviews.: Sustainable Development Knowledge Platform*. https://sustainabledevelopment.un.org/vnrs/ (accessed February 10, 2018).

Wirtschaftswoche (2011): *Energiewende: Was tun, wenn der Blackout kommt?* https://www.wiwo.de/unternehmen/energie/energiewende-was-tun-wenn-der-blackout-kommt-seite-3/5154394-3.html (accessed April 10, 2018).

World Health Organization (WHO) (2018): *WHO Household energy database*. http://www.who.int/airpollution/data/household-energy-database/en/ (accessed February 10, 2018).

ANNEX

Table 8 Abbreviations and units

EUR	Euro
GJ	Giga joule
hrs	Hours
Hz	Hertz
koe	Kilogram oil equivalent
kV	Kilovolt
kW	Kilowatt
kWh	Kilowatt hours
lmhr	Lumen-hours
min	Minutes
Mt	Mega tonnes
Δumax	Maximum voltage deviation
sec	Seconds
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index