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The potential power of different levels of energy access to reduce poverty, improve health, education and gender equality

Mirjam Harmelink, Harmelink consulting, The Netherlands mirjam@harmelinkconsulting.nl
Milou Beerepoot, United Nations Development Programme, Thailand milou.beerepoot@undp.org

ABSTRACT

Analysis of available literature shows that for every step towards energy access and clean cooking, there is a positive and progressive impact on several Sustainable Development Goals (SDGs). Findings indicate that access to electricity and clean cooking projects contribute to a range of SDGs, some of the most impactful being reduction of poverty (SDG1), improvement of health and well-being (SDG3), quality of education (SDG4) and achieving gender equality (SDG5). Findings furthermore show that social and economic benefits gradually increase when moving to higher tier levels for access to electricity and clean cooking.

The framework developed by the World Bank was applied to categorize different levels (tiers) for access to electricity and clean cooking, to illustrate the correlation between improving levels of access to electricity and clean cooking and higher social and economic impacts. In the literature we found 10 indicators positively correlating with the implementation of electricity-access projects and 5 positively correlating with the implementation of clean cooking projects. This resulted in a 'scoring' tool that can be used to see in a glance the social and economic benefits of different types of energy access projects.

Introduction

The United Nations Development Programme (UNDP) Strategic Plan 2018–2021 and its Strategy Note on Sustainable Energy emphasize the crucial role of energy access in helping countries to end extreme poverty, reduce inequalities and achieve the goals of the 2030 Agenda for Sustainable Development. UNDP's work on clean energy aligns with Sustainable Development Goal 7 (SDG7) on access to affordable and clean energy while it is acknowledged that energy is an 'intermediate' commodity: it powers appliances, equipment, and machinery as well as lighting and thermal applications. In relation to the Sustainable Development Goals in general, SDG 7 is primarily useful in that it helps to achieve other SDGs. In other words, the success of SDG 7 is a precondition for the success of many other SDGs. Especially the SDG7 goals related to energy access and clean cooking have a direct impact on SDG1 No Poverty, SDG3 Good Health, SDG4 Quality Education. and SDG5 Gender Equality (see Figure 1).

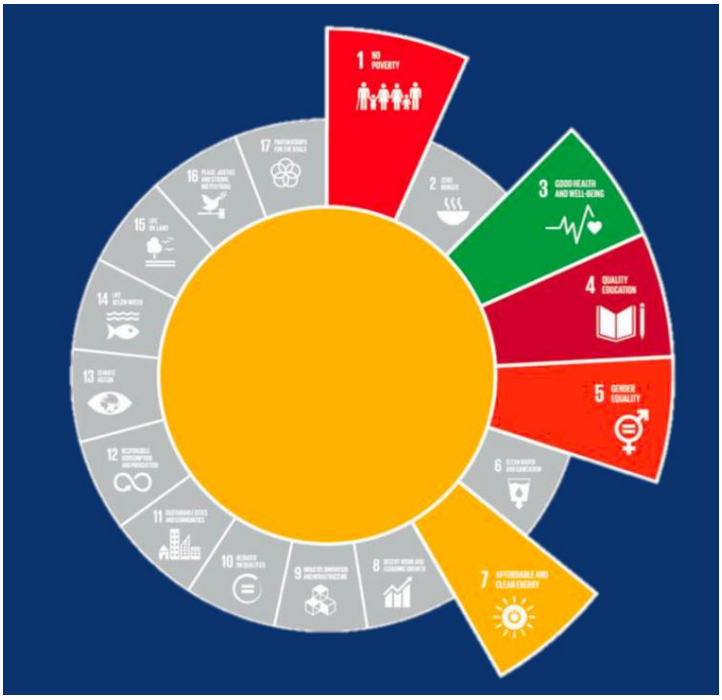

Figure 1: Four SDG directly impacted by SDG 7: SDG 1—No Poverty: End poverty in all its forms everywhere, SDG 3—Good health and well-being: Substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination, SDG 4—Quality education: Ensure inclusive and quality education for all and promote lifelong learning, SDG 5—Gender equality: Achieve gender equality and empower all women and girls

UNDP is working on improving its assessment of the social and economic benefits of its energy-access projects and the contribution of these projects towards achieving other SDGs. In 2015, UNDP conducted analysis of the non-energy benefits of its sustainable energy projects as a scoping exercise for assessing impact (UNDP, 2015). Results presented in this paper are a next step in developing a framework that can be used to assess the impact of the social and economic benefits for a specific subset of sustainable energy projects: access to electricity and clean-cooking projects.

Study objectives and approach

The study objectives were to:

- Develop a 'scoring' tool that can be used by project managers, for a straightforward scoring of the social and economic benefits of their projects.
- Provide an indication on the degree of social and economic benefits that can be observed for different types of energy access projects.
- Provide guidance for project managers, on monitoring and data collection approaches to assess the social and economic benefits of their energy-access projects.

To meet these objectives, we started with a stock taking literature review on available *approaches* to assess social and economic impacts of energy-access projects and on *actually reported impacts* of energy access and clean cooking projects. Next the results of this literature review were processed and summarized into a scoring tool for project managers and country office staff providing an indication on the degree of expected benefits for different types of energy access projects.

Background

Defining access to energy

No single internationally accepted definition of energy access exists. The International Energy Agency defines it as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average" (IEA, 2017).

UNDP includes businesses and communities in its understanding of energy access, which is thus characterized as "the need for electrical, thermal and mechanical energy for households, small and medium-sized businesses and communities, with an emphasis on clean energy for the poor" (UNDP, 2016).

Within its Energy Sector Management Assistance Programme (ESMAP), the World Bank also applies a broader scope than the International Energy Agency: "Access to energy is the ability to avail energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe, for all required energy services across household, productive and community uses" (ESMAP, 2015).

This paper assesses the social and economic benefits deriving from energy access for households, businesses and communities. This wider perspective was chosen because UNDP's energy access projects support a diverse range of activities and technologies targeted at different end users. We also accounted for differences in the type and extent of social and economic benefits with increasing levels of energy access.

Impact pathway for energy access projects

Figure 2 depicts the impact pathway for energy-access projects developed by the World Bank, referred to as the 'energy results chain' (ESMAP, 2015). The energy results chain represents how investments in energy-access projects potentially lead to social and economic benefits (impact). The model assumes that investments in energy-access projects (input) lead to project implementation (intermediate output) and the delivery of assets or policy reforms (outputs). In turn, this improves one or more attributes of energy supply (intermediate outcome), such as greater availability, improved quality or increased affordability of energy. Collectively, these attributes increase the usability of the energy supply, thus improving energy access (outcome) and, eventually, the actual use of energy services (intermediate impact). This process can subsequently contribute to the achievement of developmental goals (impact). Each step in the energy result chain can be translated into an *indicator* to measure progress towards reaching targeted results.

Higher up on the results chain, however, it becomes harder to link investments in energy to the outcomes. This indicates that when the effects of an intervention are sought at higher levels in the results chain, which is the objective for this paper, *attribution* of benefits becomes more difficult. This was an important aspect kept in mind when reviewing and analysing reported social and economic benefits of energy-access projects: Can the observed benefits be attributed to a single intervention (in the UNDP case, investment in the energy system) or should other causes be considered as well?

The framework in figure 2 was used to structure the literature review on evidence for *anticipated impacted pathways* for each of the indicator assessed in our study.

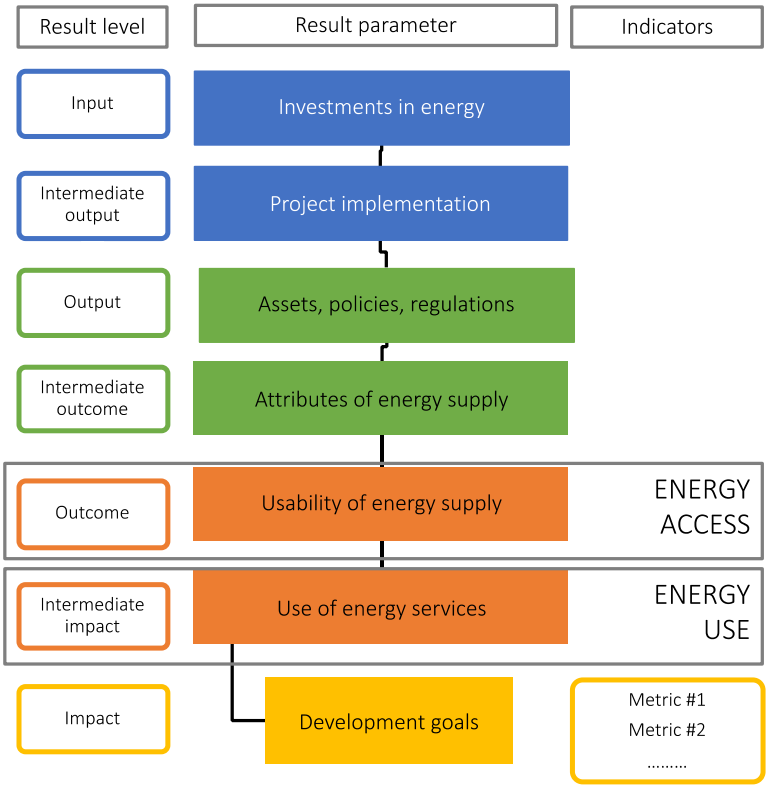

Figure 2: Impact pathway of energy access projects. Source: ESMAP (2015).

Access to electricity: levels and correlating benefits

Defined levels of access to electricity

'Access to electricity' used to be defined in a binary approach as whether a household had electricity to use or not. This characterization, however, does not account for different levels of access to electricity provided to end users. Electricity, after all, is only useful if the desired energy services become available. Energy services require different levels of electricity supply in terms of quantity, time of day, supply duration, quality and affordability. Energy systems range from the most basic pico solar system, to off-grid and local mini grids to the most advanced system, with access to an integrated electricity grid.

The World Bank developed a framework to categorize electricity-access projects. This framework distinguishes six tiers (levels) of access to electricity, with tier 0 representing the baseline situation with no access to electricity and tier 5 the most advanced level of access. The successive thresholds of supply (tiers) allow for increased use of end-use equipment (appliances) and hence access to energy services. Figure 3 shows that at tier 1 level, appliances include e.g. a radio, tasks light and a charger. When more capacity is provided and availability of electricity increased to more than 8 hours a day (tier 2 level) a television, computer and fan can be used as well. This gradually increases until we arrive at Tier 5 level.

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Capacity	No electricity	Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2000 W
Availability (hours/day)		Min 4		Min 8	Min 16	Min 23
Availability (hours/ evening)		Min 1	Min 2	Min 3	Min 4	
Reliability					Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
Quality					Voltage problems do not affect use of desired appliances	
Affordability				Cost of standard consumption package of 365 kWh/year < 5% of household income		
Legality					Legal payment of bill demonstrated	
Health and safety					Absence of accidents	

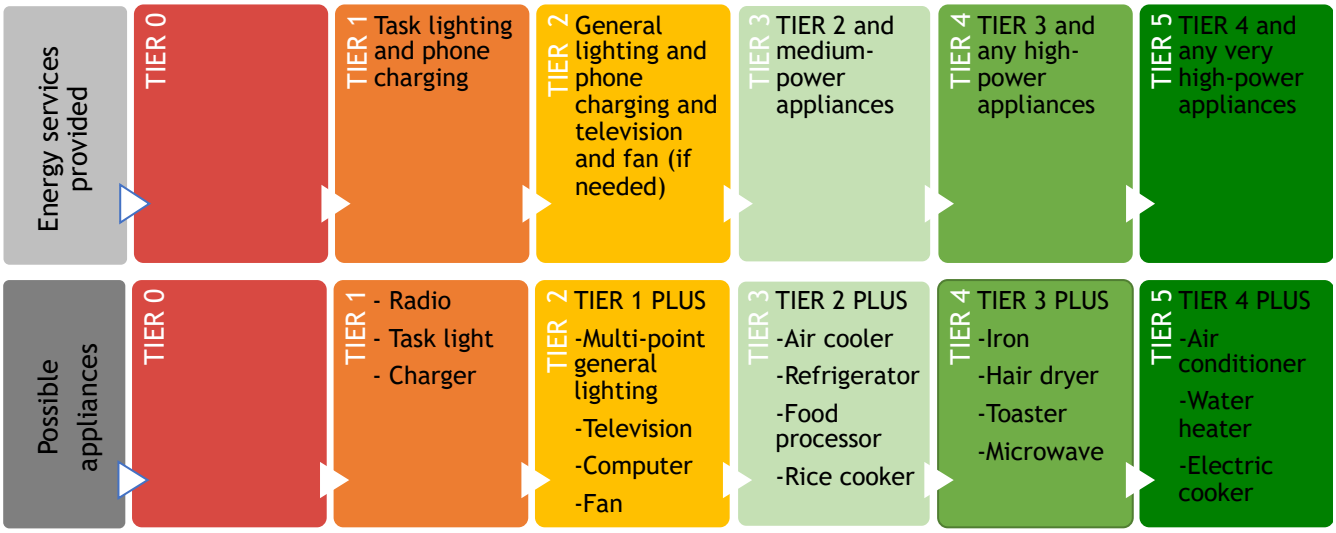

Figure 3: Multi-tier matrix for Measuring Access to Household Electricity Supply (ESMAP, 2015)

Social and economic benefits of electricity access

In total ten social and economic metrics were drawn from reports in the reviewed academic and grey literature that positively correlate with the implementation of electricity-access projects for at least one of the tier levels and can be connected to the SDG1, SDG3, SDG4 and SDG5 goals (see table 1) (IOB, 2013; Terrapon-Pfaff and others, 2014; Peters, Vance and Harsdorff, 2011; Khandker and others, 2009; IEG, 2008; Arnold, Matto and Narciso, 2006; FRES, 2013; World Bank, 2017; Jensen and Oster, 2009). We did not specifically scan the literature on potential negative correlations. We did, however, notice that for some anticipated impacts the literature is dissenting on the fact if an impact can be measured and/or what is the size of the impacts (see Harmelink et al (2018)).

Findings from the literature indicate that the degree of social and economic benefits gradually increases when moving to higher tier levels for electricity access. Table 1 shows that, for example, when a project intervention provides access to lighting and phone charging (tier 1), moderate benefit generally can be expected from the expenditure on lighting while small benefit can be expected for health and education (Harmelink et al, 2018).

The matrix in table 1 provides a basic scoring based on the relationship between level of access to electricity and the social and/or economic benefits. The following scoring level was applied, and values inserted in table 1 derived from the literature review:

- (0) No benefit is to be expected for this social or economic metric.
- (1) Degree of social and economic benefit is small, compared with tier 0.
- (2) Degree of social and economic benefit is moderate, compared with tier 0.
- (3) Degree of social and economic benefit is large or significant, compared with tier 0.

The matrix shows a gradual increase in the degree of social and/or economic benefits when moving to higher tiers for electricity access. Most of the reviewed literature focused on accessing impacts up to tier 2 or 3; it is assumed that benefits fully materialize when moving towards the higher tier levels.

The results presented in Table 1 are visualized in a radar chart (Annex I), showing the degree of social and economic benefits for different levels of electricity access projects, compared with tier 0. These radar charts can be useful for project managers of energy-access projects because they provide, at a glance, what social and economic benefits could be anticipated based on the level (or "tier") of energy access for their project intervention. Based on the results of this basic scoring, activities can be incorporated into the project plan to gather data to monitor the relevant metrics.

Table 1: Degree of expected benefits for SDG1, SDG3, SDG4 and SDG5 of five tiers of access to electricity-access, compared to tier 0 (no electricity access)

(0) No benefit
(1) *Small* benefit, compared with tier 0
(2) *Moderate* benefit, compared with tier 0
(3) *Significant* benefit, compared with tier 0

			TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
			Task lighting and phone charging	General lighting and television and fan	TIER 2 and any medium-power appliances	TIER 3 and any high-power appliances	TIER 4 and any very high-power appliances
#SDG	Metric	Indicator	Indication of the degree of the benefits, compared with TIER 0				
No poverty (SDG1)	Increase in economic activity	Household income Employment, male and female No. of new firms/year	0	0	1	2	3
	Decrease in expenditure on lighting	Expenditure on lighting	2	3	3	3	3
Good health & well-being (SDG 3)	Decrease in indoor air pollution due to access to clean lighting	Carbon monoxide concentration $PM_{2.5}$ concentration	1	2	3	3	3
	Decrease in occurrence of diseases related to indoor air pollution due to access to clean lighting	Occurrence of respiratory disease symptoms Occurrence of eye infections Averted DALYs	1	2	3	3	3
	Decrease in number of accidents with lighting	Occurrence of burn accidents Occurrence of electrocution accidents	1	2	2	3	3

(0) No benefit
(1) *Small* benefit, compared with tier 0
(2) *Moderate* benefit, compared with tier 0
(3) *Significant* benefit, compared with tier 0

			TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
			Task lighting and phone charging	General lighting and television and fan	TIER 2 and any medium-power appliances	TIER 3 and any high-power appliances	TIER 4 and any very high-power appliances
#SDG	Metric	Indicator	Indication of the degree of the benefits, compared with TIER 0				
Quality education (SDG 4)	Additional time spent on homework	Hours/day	1	2	2	3	3
	Increase in number of children finishing school	No. of children finishing school/year	1	2	2	3	3
	Increase in education level	Years at school	1	2	2	3	3
	Increase in school enrolment	No. of children enrolling in school/year	1	2	2	3	3
Gender equality (SDG 5)	Increase in time for activities other than household chores	Additional hours/day available for other activities	0	0	1	2	3

Access to clean cooking: levels and correlating benefits

Defining levels of access to clean cooking

The Word Bank also developed a framework to categorize clean-cooking projects, which distinguishes six tiers for access to clean cooking. This framework was mirrored into a classification for cookstoves ranging from improved cooking solutions (tiers 1 and 2) to clean-cooking solutions (tiers 3—5) (see Figure 4).

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Availability of primary fuel	Availability inadequate				Available at least 80% of the year	Available all year
Quality of primary fuel: Variations in heat rate that affects ease of cooking	Low quality				High quality	
Affordability	Primary solution not affordable				Levelized cost < 5% of household income	
Convenience: Fuel acquisition & preparation time (hours/week)			< 7	< 3	< 1.5	< 0.5
Convenience: Stove preparation time (minutes/meal)			< 15	< 10	< 5	< 2
Health and safety	Self-made stove	Manufactured stove	Biogas/LPG/electricity/natural gas stoves			

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
		IMPROVED SOLUTIONS		CLEAN-COOKING SOLUTIONS		
Cookstove classification		LEGACY & BASIC IMPROVED COOKSTOVE	INTERMEDIATE IMPROVED COOKSTOVE	ADVANCED IMPROVED COOKSTOVE	MODERN FUEL STOVES	RENEWABLE FUEL STOVES
Key features		Small improvements in efficiency over tier 0	Rocket style designs with highly improved fuel efficiency and moderate gains in combustion efficiency; some with high-end materials	Fan jet or natural draft biomass gasifiers with very high fuel and combustion efficiencies; may require pellet/ briquette fuel	Rely on fossil fuels or electricity, have high fuel efficiency, and very low particulate emissions	Derive energy from renewable nonwood fuel energy sources; some are supplementary rather than primary cookstoves
Typical technologies /fuels		• Legacy biomass and coal chimney • Basic efficient charcoal • Basic efficient wood	• Portable rocket stoves • Fixed rocket chimney • Highly improved (low CO2) charcoal stoves	• Natural draft gasifier • Fan gasifier/ fan jet • TChar stoves	• LPG and DME • Electric and induction • Natural gas Kerosene	• Biogas • Ethanol • Methanol • Solar ovens • Retained heat cookers

Figure 4: Multi-tier Matrix for Measuring Access to Cooking Solutions (ESMAP, 2015)

Social and economic benefits of access to clean cooking

Five social and economic metrics were drawn from the review of the academic and grey literature that positively correlate with the implementation of projects providing access to clean-cooking solutions and can be connected to the SDG1, SDG3 and SDG5 goals (see Table 2). (IOB, 2013; Terrapon-Pfaff and others, 2014; Rosenthal and others, 2017; FRES, 2013; Katuwal and Bohara, 2009; Wodon and Beegle, 2006). Again we did not specifically scan the literature on potential negative correlations. We did, however, notice that for some anticipated impacts the literature is dissenting on the fact if an impact can be measures and/or what the size of the impacts (see Harmelink et al (2018)).

Similar to the analysis on access to electricity, table 2 shows a gradual increase in the degree of social and economic benefits when moving to higher tiers in terms of access to clean-cooking projects. Most of the reviewed literature focused on assessing impacts up to tiers 2 or 3, and it was assumed that benefits fully materialize when moving towards the higher tier levels. Results in Table 2 are visualized in a radar chart too (Annex II).

Table 2 shows that when, for example, a project intervention provides access to basic improved cookstoves (tier 1), moderate benefits can be expected in relation to the occurrence of accidents because households can dispense with the use of open fires. Furthermore, a small benefit can be expected from a decrease in indoor air pollutants and related diseases. The literature is unanimous on this topic: most reviewed studies indicated positive health impacts, with only a minority of studies that did not find any positive effect on health indicators due to use of improved cookstoves. Available evidence suggests that health benefits most likely materialize when clean-cooking programmes focus on clean fuels, such as LPG, electricity, biogas or ethanol (more detail in Harmelink et al (2018)).

Table 2: Degree of expected benefits for SDG1, SDG3 and SDG5 of five tiers of access to clean-cooking, compared to tier 0 (traditional biomass cooking)

(0) No benefit
(1) *Small* benefit, compared with tier 0
(2) *Moderate* benefit, compared with tier 0
(3) *Significant* benefit, compared with tier 0

			TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
			Legacy and basic improved cookstoves	Intermediate improved cookstoves	Advanced improved cookstoves	Modern fuel stoves	Renewable fuel stoves
#SDG	Metric	Indicator	Indication of degree of benefit, compared to TIER 0				
No poverty (SDG1)	Increase in economic activity	Female employment rate Increase in household income	**0**	**0**	**1**	**2**	**3**
Good health & well-being (SDG 3)	Decrease in indoor air pollution due to access to clean cooking	Carbon monoxide concentration $PM_{2.5}$ concentration	**1**	**2**	**3**	**3**	**3**
	Decrease in occurrence of diseases related to indoor air pollution due to access to clean cooking	Occurrence of respiratory disease symptoms Occurrence of eye infections Averted DALYs	**1**	**2**	**3**	**3**	**3**
	Decrease in number of accidents with cooking	Occurrence of accidents	**2**	**3**	**3**	**3**	**3**
Gender equality (SDG 5)	Increase in time for activities other than household chores	Decrease in time for fuel collection	**0**	**0**	**0**	**2**	**3**

Monitoring social and economic benefits: from simple to advanced

The radar charts presented in Annex I enable a basic scoring on the social and economic benefits related to SDG1, SDG3, SDG4 and SDG5 that can be anticipated when the level of energy access (tier) for a project intervention is known. The charts can be useful for project managers when working on energy-access projects. In addition to this basic scoring, activities can be incorporated into the project plan to gather data ex-post and ex-ante project implementation to monitor relevant metrics.

In order to monitor the impact of energy access projects with regard to its effect on SDG1, SDG3, SDG4 and SDG5, there are several approaches possible, varying from simple monitoring to advanced monitoring methods. It may be obvious that the more advanced the monitoring method, the more detailed and reliable information can be obtained. At the same time, more advanced monitoring will require more time and resources and thus a balance will need to be sought for each project to find an optimum within the constraints of the project. Table 3 shows an overview of monitoring approaches, varying from simple to advanced monitoring methods resulting from an inventory of practical experiences within the UNDP (Harmelink et al, 2018)

Table 3: Overview of monitoring approaches, varying from simple to advanced

	Approaches
↑ Simple	*Basic scoring:* Apply basic scoring developed in this study —at four levels—based on observed social and economic benefits highlighted in the academic and grey literature for different levels of access to electricity and clean-cooking solutions.
	Rule of thumb: Applying a rule of thumb is a straightforward approach, in which observed impact factors reported in academic or grey literature are combined with basic data gathering on the project level or making use of publicly available statistics. This entails working with average impacts resulting from projects executed in divergent circumstances. In this approach, however, calculations are surrounded by large uncertainties.
	Surveys: Surveys are widely used to collect data on social and economic impacts. These can range from basic surveys, with a limited number of questions, to detailed surveys for scoring the baseline situation and project outcomes.
	Modelling: Modelling can, for example, be applied to assess economic or health impacts. Models include simplified or generalized benefit pathways derived from huge amounts of data. Combined with specific local or regional data, these models can be used to calculate economic or health impacts. Modelling is not a straightforward exercise because it requires running complex models and either collecting detailed data or making plausible assumptions.
↓ Advanced	*Measurements:* Measurements are the most detailed and most precise way to determine socioeconomic benefits. Measurements, however, can be costly because they require a well-prepared monitoring protocol, installation of measuring equipment and longer-term measurements to attain reliable results.

If there is no budget reservation in the project for monitoring impact, then the basic scoring approach with radar charts as presented in this study can be the minimum level of indicating expected impact and can be useful in: (1) Identifying the type and size of social and economic benefits associated with energy-access projects and (2) Indicating the importance of monitoring to free up resources for activities that need to be incorporated in the project to gather data to monitor relevant metrics.

If the energy access project has limited resources available for monitoring the impact on SDG1, SDG3, SDG4 and/or SDG5, then the "Rule of Thumb" approach can help in getting an indication of impact by means of multiplying simple observations (e.g. number of households affected by the project, number of children affected by the project) with previously observed impact factors. E.g. GOGLA's standardized impact metrics for the off-grid solar energy sector (Gogla, 2018)

In case of time and resources available for more serious monitoring, conduct of surveys ex-ante and ex-post project intervention can give good indications of impact of the energy access project towards the goals of the SDG1, SDG3, SDG4 and/or SDG5.

More advanced monitoring methods comprise of modelling exercises and measurements. In case energy access projects have a project component that is specifically aiming for certain impacts, e.g. improved indoor climates, then it can be justified to use project budget for advanced monitoring by means of e.g. indoor air quality measurements, ex-ante and ex-post project intervention.

Conclusions and recommendations

The analysis of expected impacts of energy access projects showed that there can be a strong relationship between the level (or "tier") of energy access and the expected impact on SDG1, SDG3, SDG4 and SDG5. This is equally valid for electricity access as well as access to clean cooking, although the impact will show in different ways. The analysis expressed these different levels of impact along the levels of energy access by means of "radar charts", where the wedges stand for SDG1, SDG3, SDG4 and SDG5. For the wedges SDG1, SDG3 and SDG4, two to four sub-segments representing specific metrics could be identified, thereby showing a more refined analysis of impact for these SDGs.

The approach developed in this study was tested on a few UNDP energy-access projects under implementation. The results illustrate that the basic scoring approach developed in this study is useful in:

- Identifying the type and size of social and economic benefits associated with energy-access projects and
- Identifying activities that need to be incorporated into the project plan to gather data to monitor relevant metrics.

Four recommendations emerged through this analysis for project managers of energy access projects to apply in the planning and inception phase of their project:

- Encourage using the basic scoring charts for energy-access projects **to identify types and sizes of social and economic benefits associated with energy-access projects** and the importance of monitoring impacts
- Encourage using the basic scoring charts for energy-access projects to **explain the importance of realizing full energy access up to Tier 5 level** since only then the full benefits for other SDGs will be realized.
- **Identify and apply an impact assessment monitoring approach as early as the inception phase** of a project to ensure that the social and economic benefits are properly monitored from the start of each project.
- Gather **feedback on the usefulness of impact assessment and different levels of monitoring (simple to advanced)** as well as problems encountered when gathering information on the social and economic indicators for energy-access projects to further develop mechanisms for assessing the social and economic benefits of completed energy-access projects.

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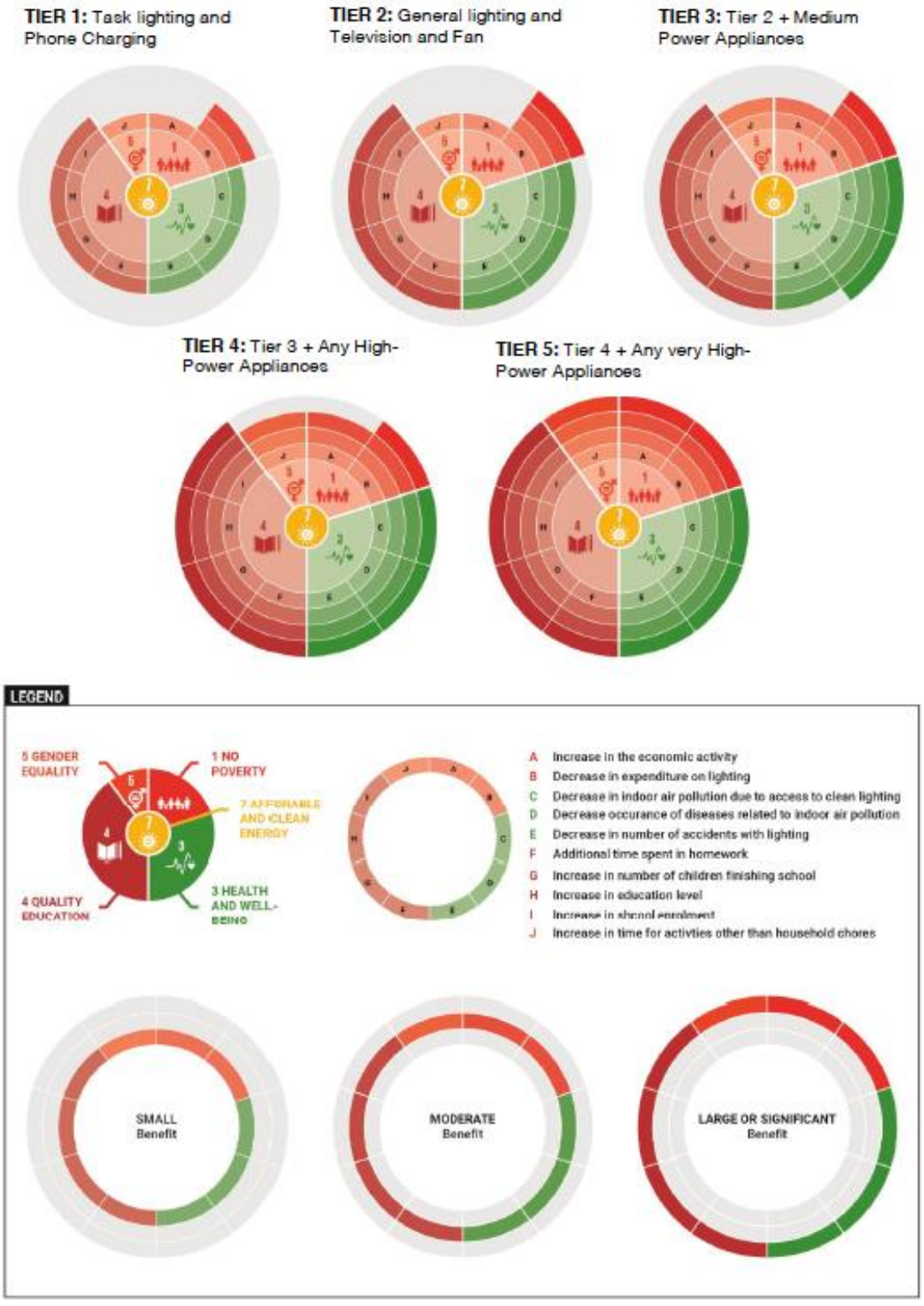
Annex I: Social and economic benefits of electricity access



Degree of expected benefits for SDG1, SDG3, SDG4 and SDG5 of five tiers of access to electricity-access, compared to tier 0 (no electricity access)

Annex II: Social and economic benefits of access to clean cooking

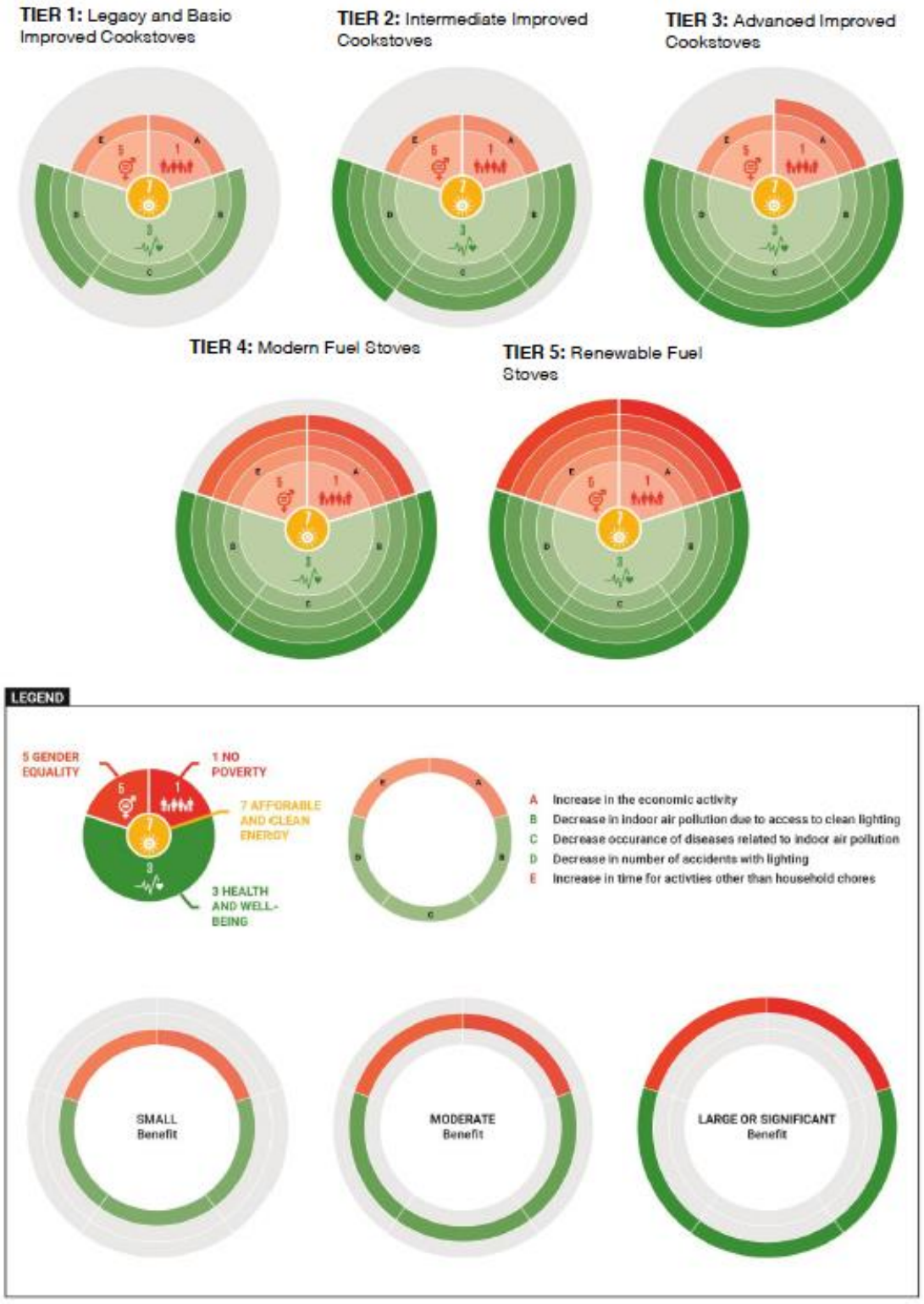


Figure 6: Degree of expected benefits for SDG1, SDG3 and SDG5 of five tiers of access to clean-cooking, compared to tier 0 (traditional biomass cooking).