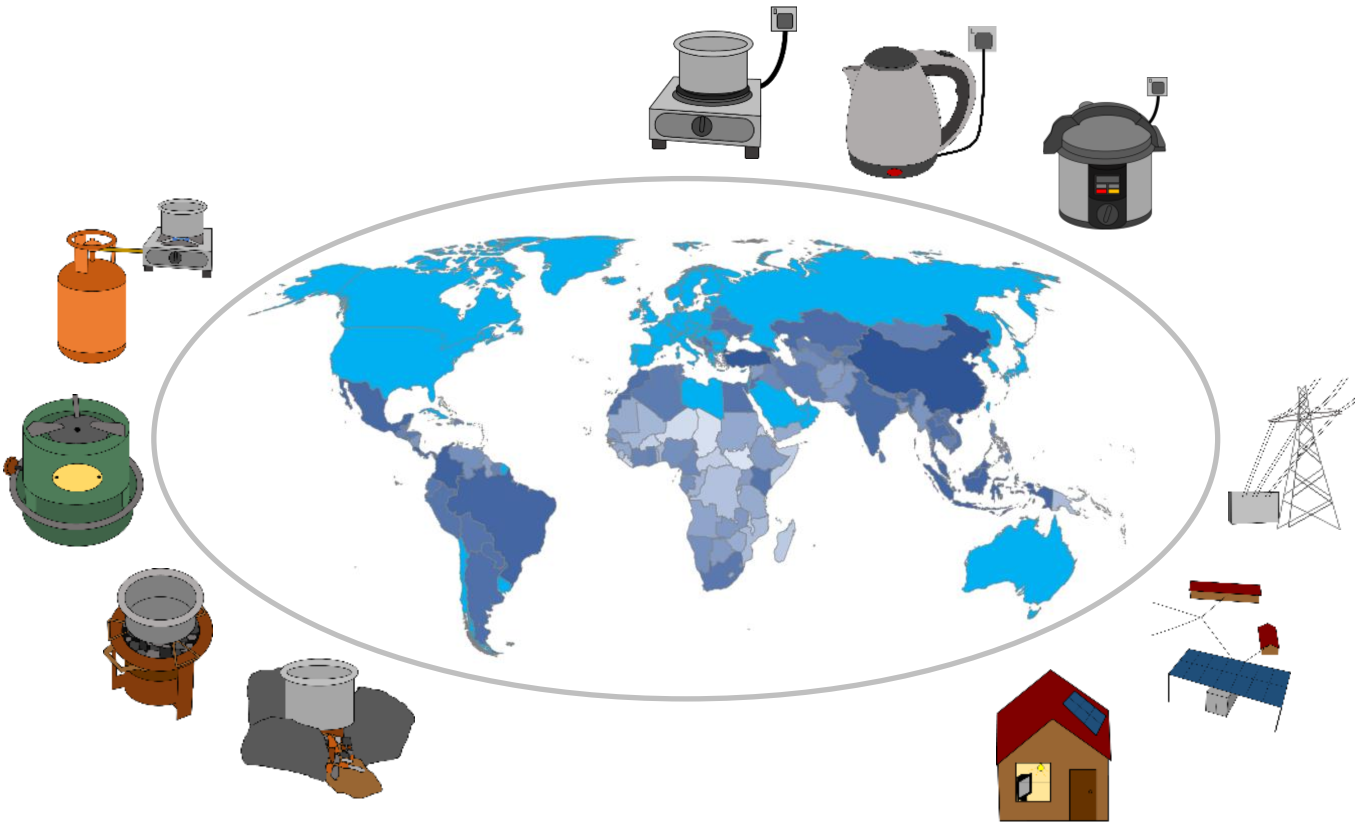
Global Market Assessment for Electric Cooking



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Executive Summary

Globally, approximately 2 billion people have access to some form of electricity but do not have access to clean cooking, the majority of which rely on the traditional use of biomass. Cooking with biomass leads to an estimated 3.8 million deaths per year attributed to household air pollution. The widespread practise of cooking with non-renewable wood fuels also contributes to ecosystem degradation and the emission of approximately 1 gigaton of CO_2/year (2% of global emissions total). According to the State of Access to Modern Energy Cooking Services report by the World Bank, ESMAP and MECS, not progressing beyond the status quo is costing the world more than US$2 trillion each year; US$ 1.4 trillion from the negative impacts on health, US$ 0.2 trillion per year from climate impacts and environmental degradation and US$ 0.8 trillion per year from its adverse effects specifically on women.

A growing body of evidence is showing that, in many settings, modern energy cooking services such as electric cooking are already cost-effective alternatives. For many countries in the Global South with a strong enabling environment (including having access to affordable, reliable electricity and the presence of a strong, active modern cooking sector) a transition to electric cooking is already taking place, mainly among the consumer class. For other countries where many households have limited or no access to modern energy, a suite of innovative business models and technologies are rapidly expanding opportunities to transition to electric cooking via mini-grid and off-grid systems.

To understand where the greatest opportunities and challenges for a scale up of electric cooking in the Global South lie, a Global Market Assessment (GMA) for electric cooking has been conducted by the Modern Energy Cooking Services (MECS) programme which seeks to “to rapidly accelerate the transition from biomass to clean cooking on a global scale”. The GMA has drawn on the experience of a range of stakeholders to identify the key factors which influence the viability of a scale up of electric cooking and represents this as a weighted score constructed from 37 indicators covering 130 countries in the Global South. As electric cooking relies on a electricity which can now be supplied in a variety of different ways, the GMA provides a score for national grid, mini-grid[1] and off-grid (standalone)[1] supported electric cooking.

Overall findings

Energy infrastructure and human development are key enabling factors for scaling up electric cooking. There are groups of key indicators which enable a strong GMA score and which are broadly similar across national grid, mini-grid and off-grid scenarios: “energy” enablers have a particularly strong effect on GMA score (including indicators on the strength of electricity infrastructure and clean cooking market), as do “development” enablers but to a lesser extent (including human development, gender inequality, ICT adoption, logistics and business indices). For all scenarios, the regulatory environment was also an enabler, while for the mini-grid and off-grid scenarios the market size and strength for these technologies were enablers, as well as aid and renewable energy finance flows.

There are a number of countries where a scale up of electric cooking is both viable and urgently needed. Comparing countries with high GMA scores, for one or more of the scenarios, and those with large proportions of people likely to already be paying significant amounts for polluting fuels (such as kerosene and charcoal) highlights China, Malaysia, Thailand, Laos, Kenya, Myanmar, Philippines, Nigeria, Tanzania, Uganda and Rwanda. Having high GMA scores and the presence of large numbers of people paying for polluting fuels suggests that pivoting to electric cooking could be both viable and affordable in these countries. With high GMA scores and very large absolute numbers of people paying for polluting cooking fuels, China and Nigeria amongst others present opportunities for transition on a huge scale.

Many countries have high GMA scores and the need to transition but ability to pay may be a challenge, as many people cook using cheap or freely gathered fuels (e.g. firewood, or waste from animals or crops). Countries with high GMA scores and many people cooking with these commonly collected fuels include China, India, Laos, Bangladesh, Nepal, Kenya, Myanmar, Afghanistan, Vietnam, Nigeria, Serbia, Uganda, Sri Lanka, Rwanda and the Philippines. These countries have large proportions of their populations in need of a transition but likely to have lower expenditures on cooking fuels and therefore less ability to pay for modern energy cooking services. The GMA also highlights India, China, Nigeria and Bangladesh amongst others which have huge absolute numbers cooking with cheap or freely gathered polluting fuels as well as strong GMA scores.

[1] In this report “mini-grid” and “off-grid (standalone)” refer to renewables powered systems (e.g. hydro mini-grids, solar home systems) only; non-renewable sources (e.g. diesel generators) are excluded from these terms.

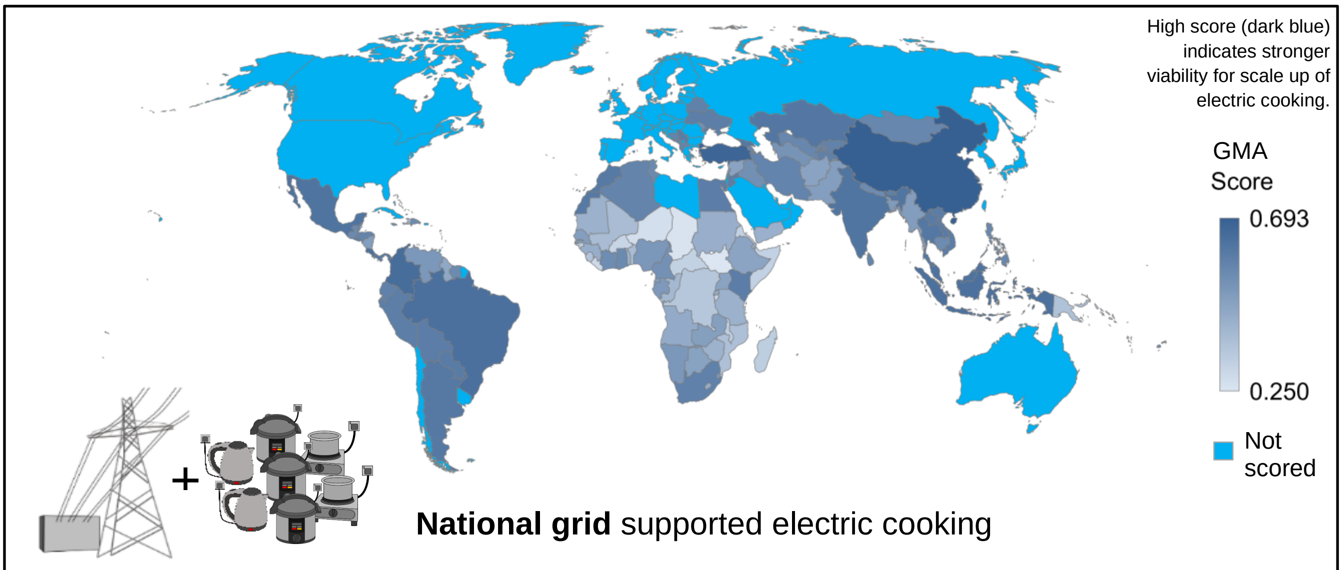
In many cases a scale up of electric cooking on the national grid needs to be coupled with decarbonisation of generation infrastructure. Many high scoring countries have relatively low renewable energy shares and as such need to couple a transition to electric cooking with decarbonisation of their generation infrastructure. This means that for a transition to electric cooking to have the most positive impact in terms of reducing air pollution and CO_2 emissions, it needs to be supported by increased investment in and focus on renewable electricity generation which is already often cheaper than generation from fossil fuels. On this basis, Kenya has particularly strong potential for a transition to electric cooking, with strong GMA score, 89% renewable grid electricity and high proportions of its population paying for polluting fuels for cooking (others include Laos, Honduras, Montenegro, Guatemala and Ghana). Conversely, other high scoring countries with significant proportions using polluting fuels have carbon intensive grids; these include China (28% renewable), Malaysia (18%), India (21%), Thailand (19%) and Vietnam (28%), and so need to couple a transition to electric cooking on the national grid with significant efforts to decarbonise generation.

The GMA calculates the viability of scale up of national grid, mini-grid and off-grid (standalone) supported electric cooking. The following sub-sections summarise these results, which are also represented as "maps", and followed by conclusions, methodology, limitations and further resources.

National grid enabled potential for scale up of electric cooking

The GMA score for the viability of scale up of national grid supported electric cooking (see figure below) is highest for countries with the highest levels of "development"; also described as "emerging markets", with strong electrical infrastructure and clean cooking fuel markets where large proportions of people are already using modern cooking fuels (including LPG and electricity). These include China, Turkey, Colombia, Brazil, Indonesia, Malaysia, Mexico, India, Thailand and Argentina. A number of other countries such as Costa Rica, Georgia, Panama, Laos, Paraguay, Serbia and Kenya also have strong viability for scale up on the national grid. Despite many high scoring countries having strong clean cooking markets and electrical infrastructure, some of these still have large numbers of people doing some, or all their cooking with polluting fuels. Through comparing national grid GMA scores and the proportion of people cooking with biomass, the top countries with not only an opportunity but also a need for scaled up transition on national grids can be shortlisted to include China, Malaysia, India, Thailand, Laos, Serbia and Kenya. These countries are where continued efforts to transition to electric cooking on the national grid is not only most viable, but also pressingly needed.

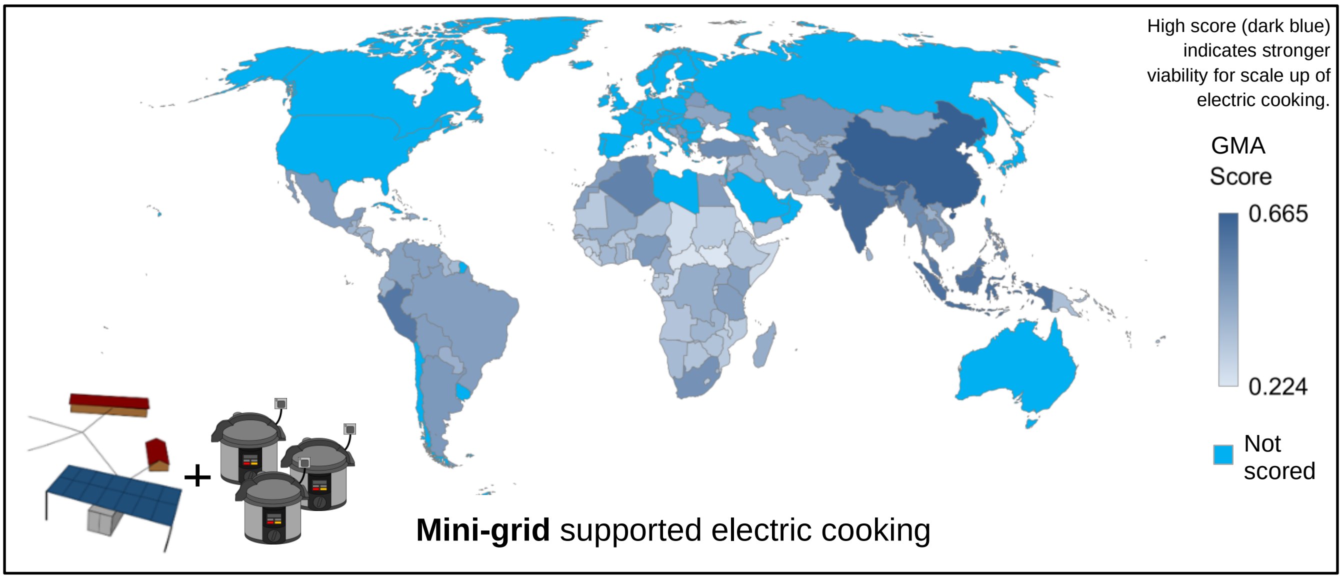
However, as previously mentioned, many high scoring countries for this scenario have relatively low renewable energy shares. As such, to most effectively reduce air pollution and CO_2 emissions many countries need to couple a transition to electric cooking with decarbonisation of their generation infrastructure.



National grid supported electric cooking

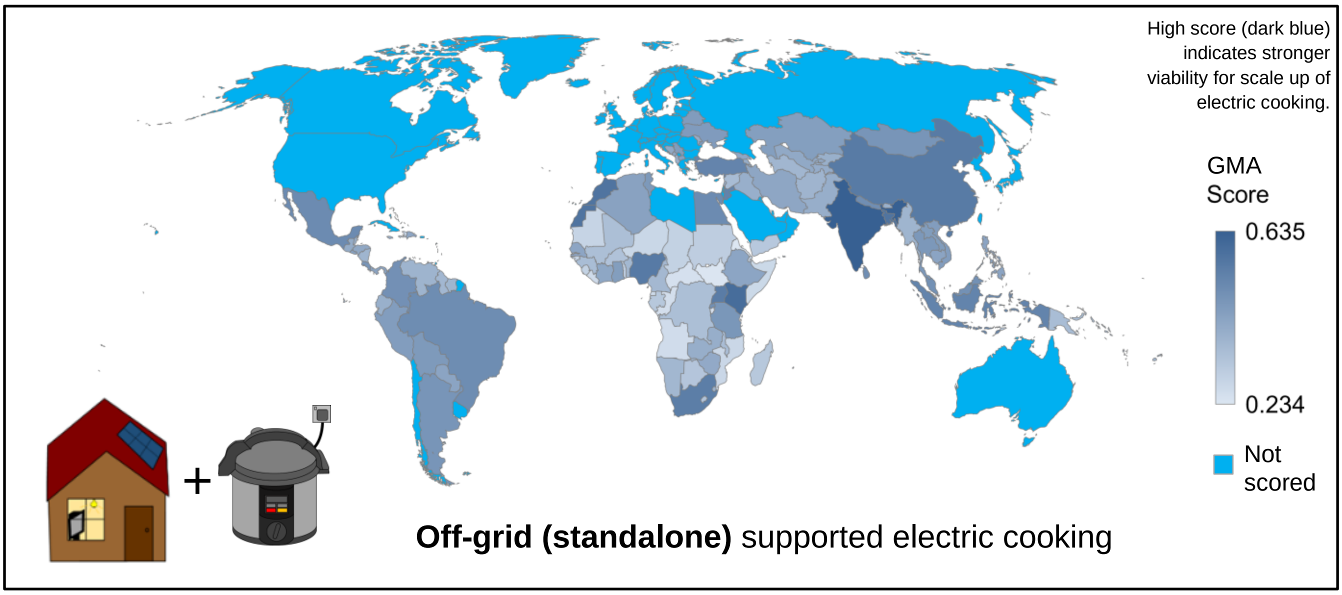
The importance of mini-grids

For the mini-grids scenario, the viability of a scale up of electric cooking is again topped by emerging markets with strong development indicators and electrical infrastructure including China, India, Indonesia, Peru, Malaysia, Thailand, Turkey, South Africa and Argentina (see figure below). However, other countries with particularly strong mini-grid infrastructure also perform well including Nepal, Bangladesh, Myanmar, Afghanistan, Nigeria and Tanzania. However, the accuracy of the scores for the mini-grid scenario is restricted due to the available data on mini-grids only covering two thirds of countries, lacking detail on energy access tier and fuels used for cooking specifically for those connected to mini-grids.



Off-grid (standalone) electric cooking

The off-grid scenario also highlights India, Kenya, Bangladesh, Nigeria, China, Uganda, Indonesia, Sri Lanka, Nepal, Rwanda, Malaysia and Tanzania as the highest scoring (see figure below), as they have strong off-grid renewables sectors and consistent development indicators. Again, the accuracy of the scores for the off-grid scenario are particularly affected by a lack of datasets on off-grid markets which adequately cover the Global South (currently available datasets only cover half of the countries in this study).



Enabling factors – energy infrastructure, human development and other key indicators

Comparing GMA scores with and without including the previously mentioned enabling indicators shows that the viability of a scale up of electric cooking, particularly on the national grid, is most significantly restricted by having poor electricity infrastructure and weak clean fuel markets, while lower levels of human development are also a hindrance but to a lesser extent. This indicates that particularly improvements in electricity infrastructure (including access and reliability), as well as growth in clean cooking markets, are strong catalysts for a scale up of electric cooking. Such improvements could come through mini-grid or off-grid (standalone) technologies, or expansion and upgraded access to the national grid. Almost by definition, those with large amounts of off-grid infrastructure, are countries where development indicators are lacking. They often have large populations, the majority of which are using polluting fuels for cooking.

Improvements in energy (i.e. access and reliability) and human development (i.e. gender equality, Ease of Doing Business, ICT/internet adoption) indicators are needed particularly in much of sub-Saharan Africa. For example, the GMA analysis indicates that improvements in energy indicators would significantly improve the viability of scaling up electric cooking in countries such as: Uganda, Zambia and Namibia (on national grids); Madagascar, Democratic Republic of Congo and Niger (on mini-grids); Zambia and Malawi (on off-grid (standalone) systems).

However, some countries in sub-Saharan Africa already present strong potential for scale up of electric cooking for one or more scenarios. Kenya is relatively less affected by the removal of enabling indicators for the national grid scenario, while the same can be said for Nigeria and Tanzania for the mini-grid scenario (this affect is less prevalent for off-grid).

Conclusion

The GMA, perhaps unsurprisingly, highlights the role of energy infrastructure and human development indicators in enabling a scale up of electric cooking. It draws attention to Asia (particularly China, India and Indonesia), which already have many of these enabling factors in place and yet still have large parts of their populations using polluting fuels for cooking. India for instance has made major gains over the last 5 years in its grid infrastructure which could enable a more rapid scale up of modern energy cooking services among its poor. China and Indonesia have very strong electricity infrastructure but still have large populations paying for polluting fuels. As the world necessarily decarbonises energy systems, from household up to national scale, there is both a need to develop, and an opportunity to harness, enabling factors in accelerating the transition to modern energy cooking services through greater uptake of electric cooking.

The last ten years have seen significant progress in pursuit of reaching SDG7 (ensure access to affordable, reliable, sustainable and modern energy for all), including improvements in finance for off-grid electricity and upgraded access to national grids. While clean cooking is sometimes considered a marginal issue, the political will for reaching SDG7 could be leveraged such that electrification planning includes cooking loads and supporting services, i.e. incorporating innovative business models and enabling policies for on- and off-grid transitions to modern energy cooking services. International Climate Finance (ICF) is likely to play an increasing role in the coming decade in enabling this transition.

As a UKAid-funded programme, MECS has focused on countries facing perhaps greater challenges regarding a transition to modern energy cooking services; i.e. predominantly those in South Asia and sub-Saharan Africa. The GMA finds that within these clusters there are some countries who have strong enabling factors that could be leveraged to drive forward the adoption of electric cooking and create substantial development impact for low-income households currently cooking with polluting fuels. For example: Kenya on national grids; Nepal, Bangladesh, Myanmar, Nigeria and Tanzania on mini-grids; Kenya, Bangladesh, Nigeria, Uganda, Sri Lanka, Nepal, Rwanda and Tanzania on off-grid (standalone) systems. Again unsurprisingly, the opportunities in these regions are comparatively greater for mini-grid and off-grid supported electric cooking. With continued and accelerated progress towards the provision of energy access for all, there are opportunities across all scenarios which will continue to grow; particularly throughout the coming decade which the European Energy Centre, and others, have referred to as the “decade of renewables”.

Ultimately the GMA is indicative and prompts more contextual examination of current and developing policies, private sector enabling environments and cooking cultures amongst other factors, to understand the possibilities around addressing the enduring problem of cooking with biomass and its associated health, environmental and gender equity challenges. The GMA highlights possibilities both now and in the coming decade for leveraging modern energy infrastructure to accelerate the transition towards electric cooking and other modern energy cooking services.

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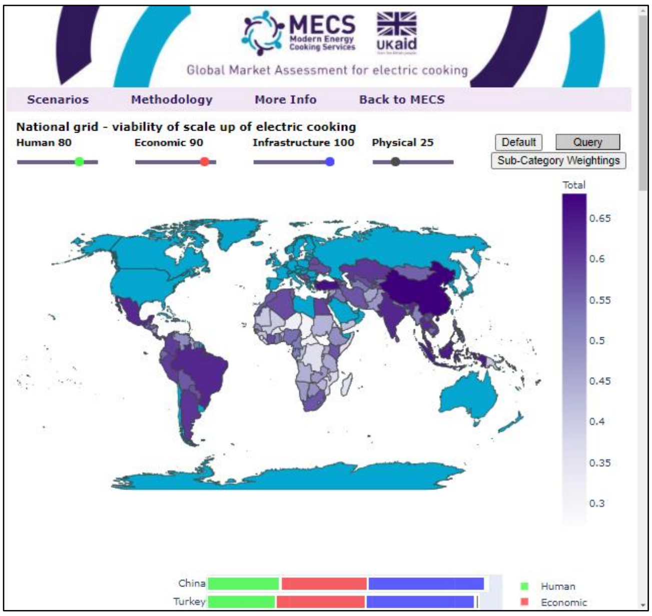
Additional resources

In addition to this report, the GMA project has also produced two other outputs:

- Online GMA visualisation tool (**link TBC**) – providing public access to the GMA data with the capability to manipulate and to display scores and rankings according to user needs (**to be released**).
- Country fact sheets (**link TBC**) – detailing information as to the opportunities for, and barriers to, a scale up of electric cooking in a number of target countries (**to be released**).

Online visualisation tool



Country fact sheets

Fact sheets image to be inserted

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Contents

1. Background

It is estimated that approximately 3 billion people globally are without access to clean cooking (the majority of which rely on the traditional use of biomass of cooking) [1]. Meanwhile, just 770 million are now without access to electricity [2], meaning that around 2 billion people have access to some form of electricity, but continue to cook with polluting fuels. Furthermore, using the expanded definition of 'modern energy cooking services'[2] as many as 4 billion do not have access to modern energy for cooking [3]. The widespread practice of cooking with non-renewable wood fuels also contributes to ecosystem degradation and the emission of approximately 1 gigaton of CO_2/year (2% of global emissions total) [4] an estimated 3.8 million deaths per year are attributed to smoke from cooking fires [5].

In some settings, using electric cooking appliances to cook with reliable grid electricity already offers a cost-effective opportunity to enable clean cooking [6]. For people with unreliable electricity access, and those not connected to the grid, a suite of new electric cooking technologies and business models is emerging to enable a transition away from biomass fuels. To understand and prioritise the opportunities and challenges for accelerating access to electric cooking in different countries, a global market assessment for electric cooking (GMA) was commissioned.

Market assessments aim to quantify the existing potential for the product or service to meet demand, and to identify the opportunities and barriers to increasing this potential through understanding of both the enabling environment and the aspirations, current practices, and characteristics of the consumers/target market. In the context of the MECS programme, a market assessment aims to understand the enabling environment surrounding modern energy cooking services and the needs and motivations of all involved stakeholders, including but not limited to end-users, manufacturers, policymakers, development partners and energy system operators.

In 2017 a GMA was carried out as part of the preliminary stages of MECS research [7], with the intention of focusing efforts in priority areas and to elaborate upon the problem statement to be addressed by the programme; "to rapidly accelerate the transition from biomass to clean cooking on a global scale". Official Development Assistance (ODA) recipient countries' favourability towards implementing grid-connected (battery supported) and standalone solar (battery supported) electric cooking were considered through using a multi-criteria decision analysis (MCDA) methodology. This provided a ranked list of countries, with their respective scores broken down by the contributing factors, along with a more detailed analysis of the most favourable/highest ranking contexts as well as others with interesting market dynamics which were not reflected in the ranked lists. The viability index was then complimented by estimates of market size for key target market segments, such as the number of people living in rural, off-grid regions. These results were used to direct intervention and to identify target countries for the current MECS programme.

Since the 2017 GMA the MECS programme has grown and developed into a large network of researchers and practitioners conducting a variety of activities. A number of national and community scale activities, including market assessments, have been conducted to better understand cooking in specific countries and regions and to direct future MECS activities [8]. This process has improved the understanding of the factors which influence the viability of modern energy cooking services in a variety of contexts and uncovered new target market segments not considered by the 2017 GMA. In addition, the cost of enabling technologies such as efficient, low-powered cooking devices, renewable energy generation and energy storage are falling while their quality and availability is improving, and traditional cooking fuels are becoming scarcer and more expensive. Concurrently, the political environment for such technologies is opening up and renewable decentralised energy generation is increasing in popularity alongside other enabling social, cultural and political factors. As such, the enabling environment for modern energy cooking services, offered through a widening variety of product offerings, is changing across the globe. Therefore, by applying the enhanced knowledge and experience of the MECS programme and drawing on the most recent information, an improved GMA has been conducted to provide an up-to-date picture of the global environment for electric cooking.

This report provides a description of the GMA methodology, followed by a review of the results and additional information on countries where a scale up of electric cooking is shown to be most viable. This is followed by further analysis to identify the key factors which influence the viability of a scale up of electric cooking and the countries/regions where these are strongest and weakest.

[2] Defined as lacking "the ability to cook efficiently, cleanly, conveniently, reliably, safely, and affordably" [3].

Additional outputs

In addition, to effectively and quickly scale-up modern energy cooking services, stakeholders from a number of non-academic sectors including the private (e.g. manufacturers, distributors, retailers, energy services), finance (e.g. microfinance/carbon finance institutions) public and third sectors (e.g. policy makers, development organisations) need to be aware of the drivers and opportunities and informed by accurate, up-to-date information. As such, two additional outputs have been produced to broaden the reach of this study's findings and provide improved accessibility to the MECS programme's growing body of context specific research:

- Online GMA visualisation tool (**link TBC**)

This study has produced a huge quantitative dataset containing a wealth of data pertinent to the aims of the MECS programme that is now available in a single location. Such a dataset presents the opportunity to perform further analysis by all stakeholders (as well as researchers) based on their needs and preferences. Therefore, an online visualisation tool has been created to provide anyone with the ability to manipulate the data through an easy-to-use interface and display the results as an attractive graphic. The source excel database including the raw datasets is also available via the tool. Screenshots of the online visualisation tool are shown in Figure 1.

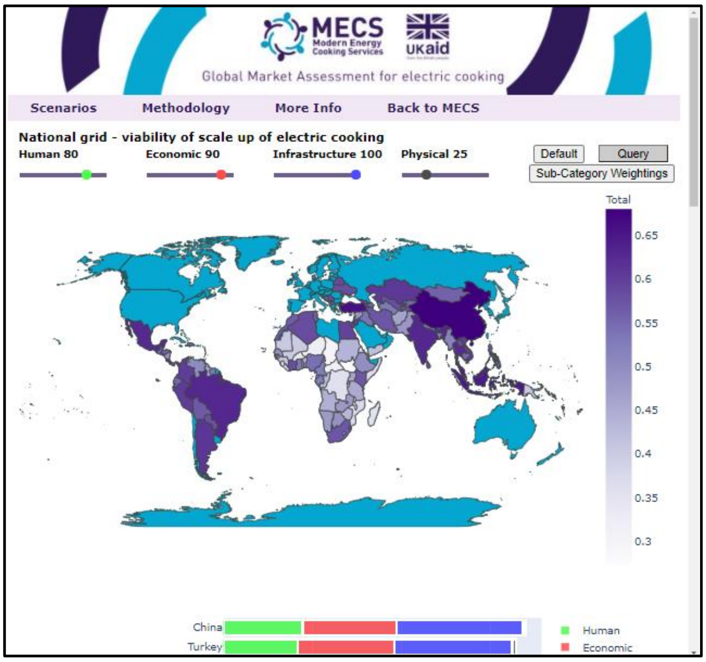

Figure 1 - Online visualisation tool screenshots

- Country fact sheets (**link TBC**)

While there was once a dearth of understanding of cooking practises and markets, MECS has developed an ever-growing knowledge base around these topics, particularly for MECS focus countries. However, so far, outputs of these activities have largely been aimed at academic audiences and used to inform the design of successive MECS activities. Therefore, to communicate the results of the GMA more effectively, alongside context-specific information about the opportunities and barriers for modern energy cooking services, detailed country "factsheets" have been created.

Insert screenshots when available

2. Methodology

The methodology used to carry out this study draws on that used by Leary et. al [7] which centres around using publicly available datasets to represent the viability of a scale up of electric cooking across the 130 countries on the Development Assistance Committee (DAC) list of Official Development Assistance (ODA) recipients [9]. These datasets are collated into a database of indicators, grouped into sub-categories and categories, weighted according to their relative importance and summed to produce a score which represents the relative viability of a scale up of electric cooking[3]. This methodology is detailed in the following sub-sections.

In addition, by drawing on the expertise of researchers and experts within and outside the MECS programme, a project steering group was set up to oversee its direction and development. This steering group included representatives from MECS, the World Bank Group's Energy Sector Management Assistance Program (ESMAP) and the Clean Cooking Alliance (CCA).

2.1. (Re)assessment of scope

Electric cooking at its most fundamental level relies on a supply of electricity which, particularly across the Global South, is provided in a variety of different ways. The first iteration of the GMA focussed on two target market segments: "PV-eCook… regions where no grid infrastructure exists (nor is it likely to in the near future), i.e. rural off-grid HHs" and "Grid-eCook… the fringes of the grid, where the infrastructure is weakest, i.e. urban slums or rural grid-connected HHs".

This study has included and supplemented these markets by expanding the Grid-eCook market to represent households on both strong and weak grids[4], and supplemented them by considering mini-grid supported electric cooking. In addition, to emphasise the need for focus on context as well as technologies, these target markets were renamed as "national grid", "mini-grid" and "off-grid (standalone)" scenarios (shown in Figure 2). These terms refer to mini-grid and off-grid (standalone) systems powered by renewable sources (e.g. hydro mini-grids, solar home systems) only; non-renewable sources (e.g. diesel generators) are excluded.

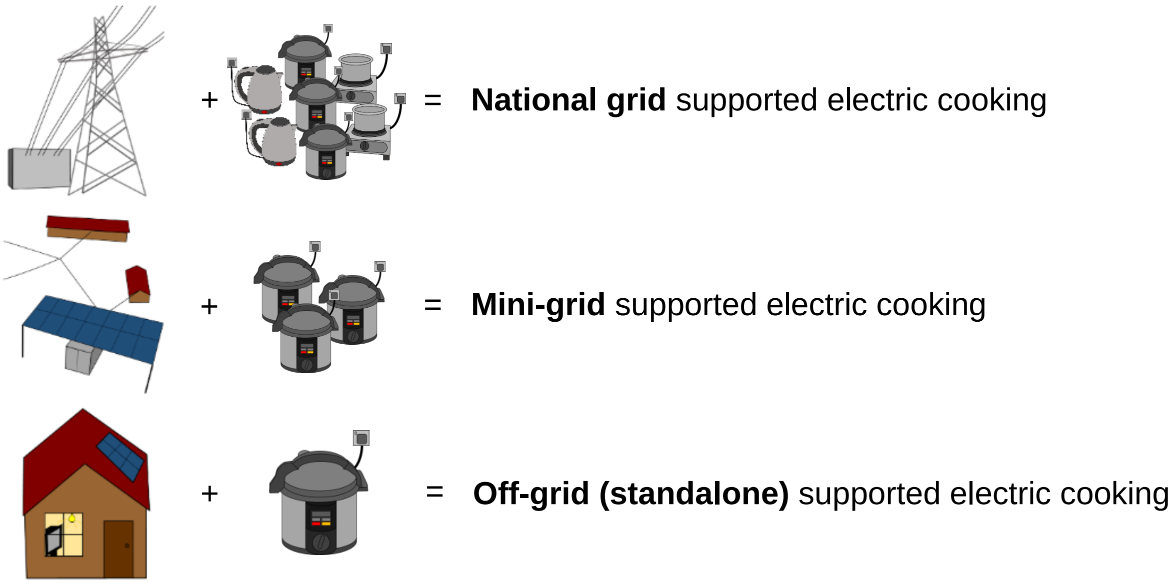

Figure 2 - GMA scenarios

[3] There are numerous examples of this overall methodology is used in the construction of multidimensional indices, including: ESMAP's Regulatory Indicators for Sustainable Energy (RISE) [31], BloombergNEF's Climatescope [32], and the World Bank's Ease of Doing Business Index [33].
[4] Separate weak and strong grid scenarios were considered, but a lack of differentiating datasets meant little distinction could be made between them. These were therefore combined into the "national grid" scenario.

2.2. Identification of factors and representative datasets

Beyond the fundamental requirement of having access to electricity, the viability of a scale up of electric cooking is reliant on a wide range of factors from spheres including the political, economic, social and technical. Using the first iteration of the GMA as a starting point, a review of these viability-influencing factors was carried out by consulting with the project steering group and a wide range of MECS researchers, MECS collaborating partners and contacts.

To represent as many of these factors within the GMA database as possible, a thorough review of publicly available datasets was performed, identifying over 100 potential indicators from over 50 different sources. The criteria for inclusion in the GMA database was based on importance (in representing the viability of electric cooking), coverage level (across the 130 DAC listed countries) and availability of equivalent or better alternatives. Finally, these datasets were given "indicator" names (describing the factor they represent) and grouped into sub-categories and categories. As shown below in Table 1, the analysis for all three scenarios included 37 indicators[5], 18 sub-categories and four categories. The sources for these indicators can be found in Appendix 1.

Table 1 – List of indicators, sub-categories and categories

Category	Sub-category	Indicator
ECONOMICS	Clean fuel users	Users of electric cooking
		Users of clean alternatives (e.g. LPG, biogas)
		Users of commercialised polluting fuels (e.g. charcoal)
	Fuel markets	Unrealised potential for electric cooking
		Affordability of electricity
	Finance	Credit rating
		Mobile money
		OECD aid flows
		Renewable energy finance flows
PHYSICAL	Solar resource	Photovoltaic power potential
	Deforestation	Tree cover loss
HUMAN	Capacity	ICT/internet adoption
	Business	Ease of Doing Business Index (EoDB)
	Policy	Regulatory Indicators for Sustainable Energy (RISE)
	Health	Household Air Pollution (HAP) attributable deaths
	Gender	Gender Inequality Index (GII)
	Demographics	Urban population growth
	Development	Human Development Index (HDI)
	Displacement	Number of displaced persons (DPs)
		DPs using clean cooking fuels (grid)
		DPs using clean cooking fuels (off-grid/mini-grid)
		DPs with unrealised potential for electric cooking
INFRASTRUCTURE	Logistics	Logistics Performance Index (LPI)
	Manufacturing and imports	Manufacturing, value added (% of GDP)
	Grid	Access to electricity (all areas)
		Access to electricity (urban)
		Electricity access projections (grid)
		Renewable energy share
		Grid reliability
	Mini-grid	Access to electricity (all areas)
		Access to electricity (rural)
		Electricity access projections (mini-grid)
		Off-grid renewables capacity (mini-grid)
		Number of mini-grid developers
		Number of people connected to mini-grids
	Off-grid	Access to electricity (all areas)
		Access to electricity (rural)
		Electricity access projections (off-grid)
		Off-grid renewables capacity (standalone)
		Off-grid lighting/appliance customers

[5] Table shows 40 indicators as two indicators appear more than once: access to electricity (rural) for both mini-grid and off-grid scenarios, and access to electricity (all areas) for all three scenarios.

2.3. Calculating indicator weightings

To represent the extent to which the above indicators contribute to the viability of a scale up of electric cooking is incorporated into the GMA, each indicator, sub-category and category is multiplied by a "weighting". These weightings represent their relative importance for each scenario while also considering the reliability and coverage of the indicators' dataset; lower weightings given to indicators with less reliable data and/or poorer coverage. A group of key stakeholders, including representatives from MECS, ESMAP, CCA and FCDO[6], was asked to provide these relative importances through employing Multi-Criteria Decision Analysis (MCDA) techniques. These were gathered initially using the Delphi method [10] and SMART technique [11] (via two rounds of anonymous questionnaires) and finally through a focus group discussion. The process is summarised below:

a) As per Delphi method, blank questionnaire distributed to group members alongside training on how to complete it. Anonymously, group members use the SMART technique to assign relative importance to indicators following the below steps (also shown in Figure 3):

    (1) Assign weight of 100 to most influential indicator in sub-category
    (2) Weight each indicator against others in sub-category, repeat for all sub-categories
    (3) Follow same process, weighting sub-categories within categories
    (4) Follow same process, weighting categories against each other.

b) Responses collated and analysed. Condensed questionnaire re-distributed, highlighting indicators, sub-categories, and categories with poor agreement or where that member's responses vary significantly relative to the rest of the group. Group members asked to revise weightings and/or provide comment or justification.

c) Focus group discussion held to agree, by consensus, on final weightings with particular focus on areas where disagreement still present.

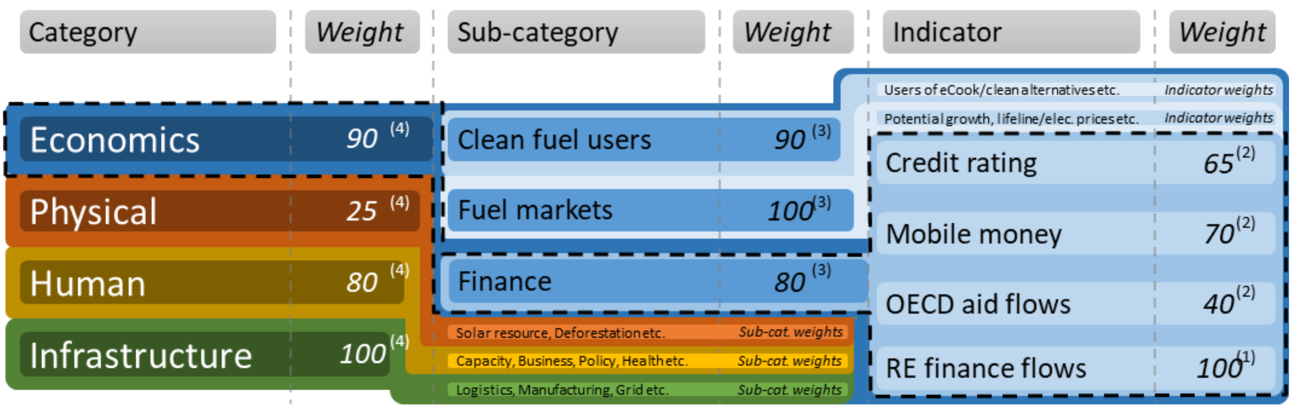

Figure 3 - Weighting process using SMART technique, highlighting the indicator weightings assigned to the Finance sub-category.

[6] Two weightings groups were originally targeted, to represent: "impact" – highlighting where electric cooking could have the greatest development impact; and "investment" – highlighting where electric cooking could present the most attractive investment or business opportunity. However, due to difficulties in fostering interest from investment stakeholders, the weighting process was only completed for the impact group.

An example of the relative importances gathered by the MCDA techniques and used for the national grid GMA scores are shown in Table 2. These were used to calculate the final weightings for multiplication with the indicators using the steps outlined in Table 3. The final weightings used in the study are represented in Figure 4.

Table 2 - Indicator, sub-category and category relative importances for national grid scenario

Category	Wt.	Sub-category	Wt.	Indicator	Wt.
ECONOMICS	90	Clean fuel users	90	Users of electric cooking	100
				Users of clean alternatives (e.g. LPG, biogas)	70
				Users of commercialised polluting fuels (e.g. charcoal)	70
		Fuel markets	100	Unrealised potential for electric cooking	100
				Affordability of electricity	70
		Finance	80	Credit rating	65
				Mobile money	70
				OECD aid flows	40
				Renewable energy finance flows	100
PHYSICAL	25	Solar resource	50	Photovoltaic power potential	100
		Deforestation	100	Tree cover loss	100
HUMAN	80	Capacity	45	ICT/internet adoption	100
		Business	80	Ease of Doing Business Index (EoDB)	100
		Policy	100	Regulatory Indicators for Sustainable Energy (RISE)	100
		Health	85	Household Air Pollution (HAP) attributable deaths	100
		Gender	50	Gender Inequality Index (GII)	100
		Demographics	95	Urban population growth	100
		Development	50	Human Development Index (HDI)	100
		Displacement	25	Number of displaced persons (DPs)	35
				DPs using clean cooking fuels (grid)	60
				DPs using clean cooking fuels (off-grid/mini-grid)	100
INFRASTRUCTURE	100	Logistics	60	DPs with unrealised potential for electric cooking	100
		Manufact. & imports	65	Logistics Performance Index (LPI)	100
		Grid	100	Manufacturing, value added (% of GDP)	100
				Access to electricity (all areas)	100
				Access to electricity (urban)	80
				Electricity access projections (grid)	75
				Renewable energy share	70

Table 3 - Process for calculating indicator weightings from relative importances

Steps	Example (grid scenario)
1) Relative importances are divided by the total of the importances in the sub-category/category/overall to calculate the “importance fraction”.	Users of electric cooking (importance fraction): 100 / (100+70+70) = 0.416… Clean fuel users (importance fraction): 90 / (90+100+80) = 0.333… Economics: 90 / (90+25+80+100) = 0.305…
2) These importance fractions are multiplied by the number of other importance fractions within the sub-category/category.	Users of electric cooking (adjusted fraction): 0.416… * 3 = 1.25… Clean fuel users (adjusted fraction): 0.333… * 3 = 1 Economics (adjusted fraction): Remains unchanged (0.305…)
3) These fractions are multiplied together and scaled so that the total of all the fractions is equal to one.	Users of electric cooking (unscaled weighting): 1.25… * 1 * 0.305… = 0.381 Users of electric cooking (final weighting): 0.381… / 8.04… = 0.0473…

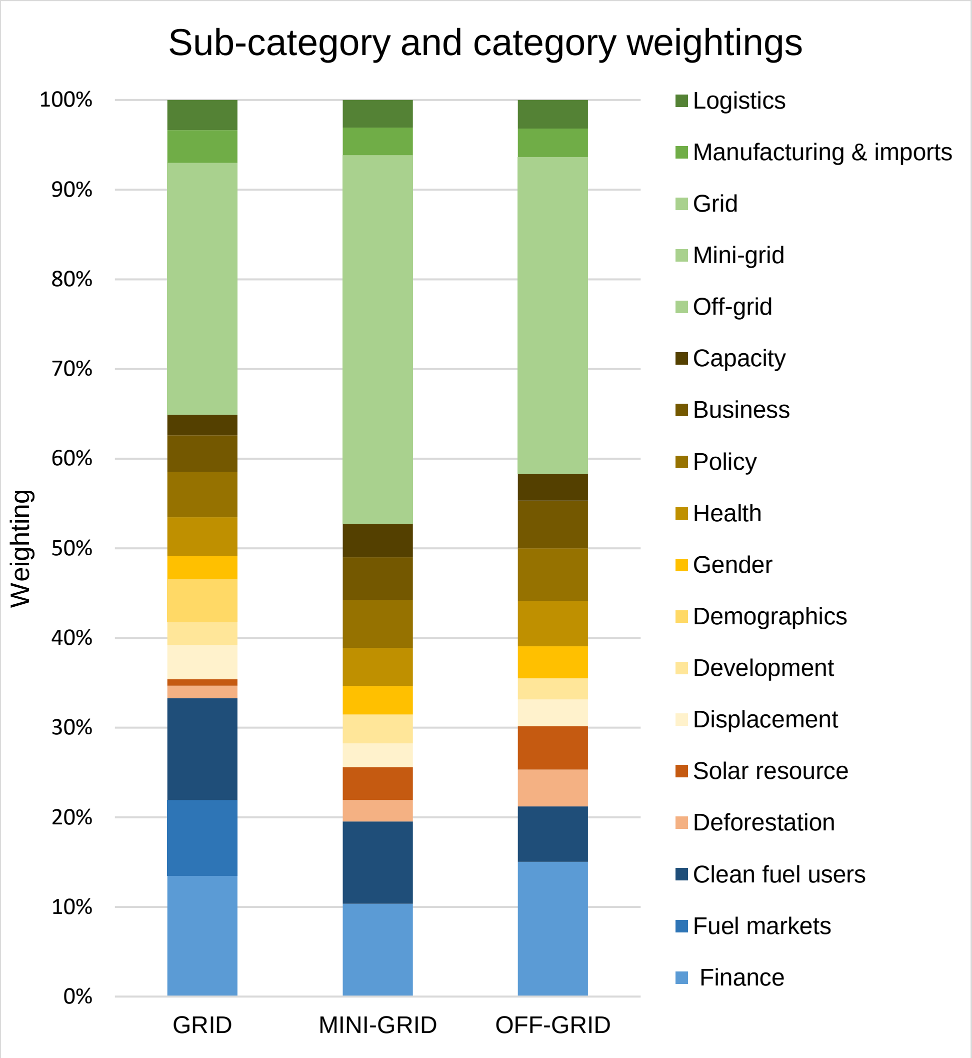

Figure 4 - Sub-category and category weightings

2.4. Data pre-processing

To calculate the score for all countries for each scenario, a weighted sum model requires a complete database without any gaps. The first step towards achieving this was to remove countries with insufficient coverage by the indicators (threshold set at 70%). As such, the initial list of 142 DAC listed countries was reduced to 130[7].

The second step was to apply upper and lower bounds to datasets. Upper bounds were set using the following criteria (bounds used for all indicators shown in Appendix 2):

- If indicator is a percentage (e.g. % users of electric cooking), set upper bound at 100%
- If indicator is an index, upper bound set at theoretical limit (e.g. Logistics Performance Index limit = 5)
- If indicator has no theoretical limit, upper bound set at the global maximum value
  - If indicator datapoint is identified as an outlier, upper bound set at 90th percentile.

[7] Removed countries: Wallis and Futuna, Saint Helena, Montserrat, Tokelau, Niue, West Bank and Gaza Strip, Kosovo, North Korea, Tuvalu, Nauru, Libya, Cuba

An example dataset is shown in Figure 5 to show the effect of gaining greater detail through applying bounds.

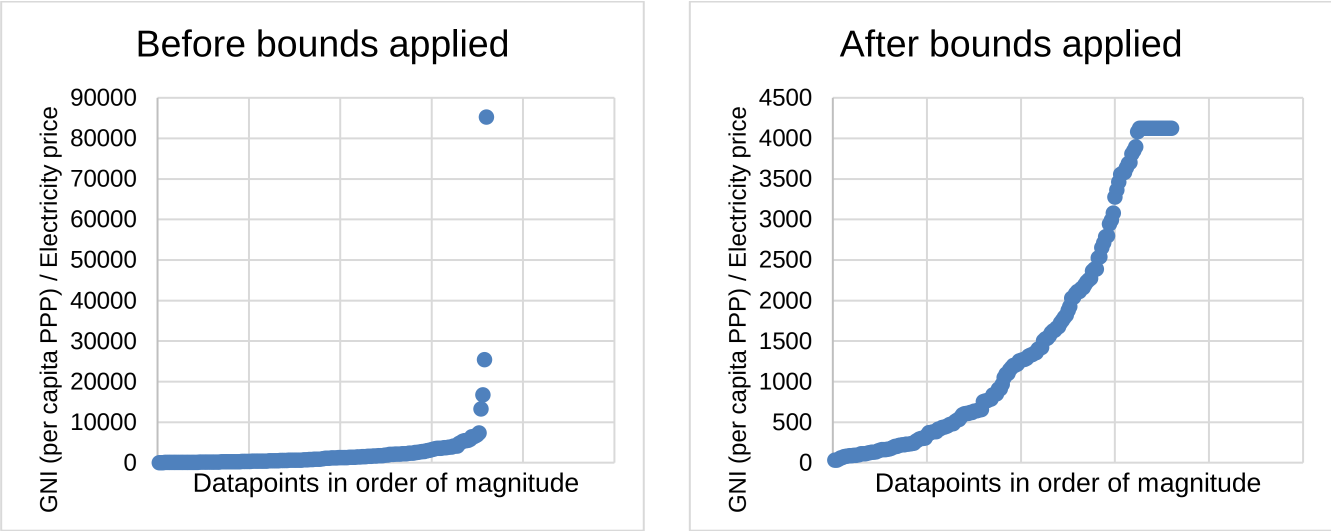

Figure 5 - Effect of imposition of bounds on affordability of electricity indicator

The third data pre-processing step normalises the indicators; scaling the datapoints so that the minimum value is zero and maximum value is one.

The final step before calculating country scores, fills all gaps in the GMA database using imputation. Although one of the three criteria for indicators' inclusion in the analysis was their level of global coverage, in some cases their importance in representing the viability of a scale up of electric cooking and a lack of appropriate alternatives meant that some with poor coverage were included (see section 2.4.2). In order to produce an accurate, but also complete database, two imputation methods were used: imputation by regression, and imputation by grouping.

2.4.1. Imputation by regression

Indicators with inadequate coverage (less than 90% of countries with datapoints) were compared with all other indicators in the database and selected additional datasets to find strong correlation. A polynomial fit using regression techniques is undertaken to characterise the relationship between pairs of variables. The coefficient of determination[8] is used to quantify the variation between pairs of variables and this provides a value between 0 and 1 that provides a 'goodness of fit' measure. Where strong enough correlation was found (R^2 the coefficient of determination) takes a value at least 0.7 imputation by regression was used to fill gaps (using interpolation) and significantly improve global coverage. Table 4 shows the results of imputation by regression indicating coverage before and after, with source and proxy used for the imputation. Figure 6 shows an example data set comparison before and after imputation.

Table 4 - Coverage, source and proxies for imputation of indicators by regression

Indicator	Coverage		Source	Proxy
	Before	After		
Mobile money	72%	97%	WB - Global Findex Database	Broadband Subscriptions * GNI per capita
Gender Inequality Index (GII)	83%	99%	UNDP - Gender Inequality Index	HDI
DPs using clean fuels (grid)	73%	100%	MEI - Refugees and Cooking	Access to clean fuels %
DPs using clean fuels (off/mini grid)	73%	100%	MEI - Refugees and Cooking	Access to clean fuels % (rural)
DPs with unrealised potential for eCook	73%	97%	MEI - Refugees and Cooking	Access to electricity %
Logistics Performance Index (LPI)	81%	100%	WB - Logistics Performance Index	E-Government Participation Index * HDI
Electricity access projections (grid)	45%	100%	GEP - Electrification Projections	Access to electricity % * HDI
Grid reliability	65%	96%	WB - Ease of Doing Business	EoDB (Getting electricity score) * HDI
Electricity access projections (mini-grid)	45%	100%	GEP - Electrification Projections	Access to electricity % * HDI
Electricity access projections (off-grid)	45%	100%	GEP - Electrification Projections	Access to electricity * HDI

[8] https://online.stat.psu.edu/stat462/node/95/

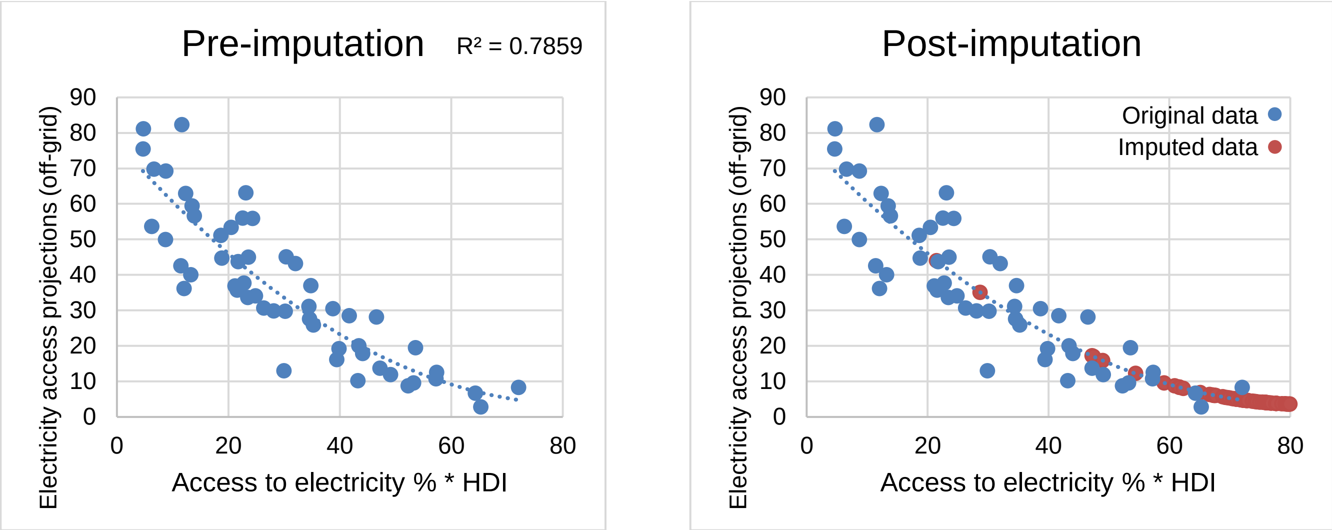

Figure 6 – Effect of imputation by regression on electricity access projections (off-grid) indicator

2.4.2. Imputation by grouping

After imputation by regression, all indicators (apart from those where no suitable proxy indicator could be found[9]) had at least 90% coverage. To complete the database to 100% coverage, a three-stage process, using loosening grouping criteria, imputed values based on the median of other countries with datapoints in the same group[10] (shown in Table 5).

The first grouping stage sees missing values replaced with an average from other countries in the same region, income group [12] and whether they are classified as heavily indebted [13], a small state [14] or fragile state [15]. The second stage sees these criteria loosened, with missing values replaced by an average from other countries in the same region and whether they are a small state or not. To fill the small number of remaining gaps, the criteria is further loosened to take an average based on the small states grouping only.

Table 5 - Imputation by grouping stages and completeness

		Pre-imputation	Imputation stage 1	Imputation stage 2	Imputation stage 3
	Completeness	97.2%	98.9%	99.7%	100.0%
Grouping criteria	Region		■	■	
	Income group		■		
	Heavily indebted		■		
	Small States		■	■	■
	Fragile state		■		

2.4.3. Calculate GMA score and rank

The final scores for each country were calculated by multiplying the datapoints for each indicator, by its respective weighting (as produced by method detailed in section 2.3). Countries were ranked for each scenario, with the highest scoring countries having the best ranking (see section 4. Results and Findings).

[9] No proxy found for six indicators. Two had moderate coverage (RISE 74%, off-grid renewables capacity (mini-grids) 80%), so were included in imputation by grouping. Four had poor coverage (no. mini-grid developers 57%, no. people connected to mini-grids 63%, off-grid renewables capacity (standalone) 48%, and off-grid lighting/appliance customers 65%); countries with no data for these indicators were given a value of zero.

[10] Groupings: Region – East Asia & Pacific, Europe & Central Asia, Middle East & North Africa, Latin America & Caribbean, South Asia, Sub-Saharan Africa; Income group – high, upper middle, lower middle, low; Heavily indebted – yes, no; Small state – yes, no; Fragile (and conflict affected) state – yes, no.

3. Limitations

The purpose of creating a composite indicator is to distil the complexity of a problem into a series of quantitative indicators which are combined into a single score which is simpler to understand, communicate and interpret for a wider range of stakeholders. Common criticisms of this approach are that it can over-simplify complex issues and be misleading or misused when poorly understood, especially when unreliable datasets are used [16] [17] [18]. To avoid some of these pitfalls, this report has provided a detailed methodology and results (with more information available via the excel tool[11]) and engaged with a multidisciplinary steering group at all stages. In addition, key limitations associated with the availability and accuracy of data are summarised below.

During the "identification of factors and representative datasets" stage (as detailed in section 2.2) a wide range of factors which influence the viability of a scale up of electric cooking were long- and short-listed through consultation with stakeholders from multiple disciplines. Through an extensive review of publicly available sources, datasets were matched with these factors to represent them in the GMA database, but for a number of factors suitable datasets were not available. Three key areas are listed below:

Cost competitiveness of electric cooking – lack of fuel prices data

To the authors' knowledge, there is no publicly available dataset for the cost of cooking fuels (LPG, charcoal and kerosene in particular) across the Global South, preventing comparison with the cost of cooking on electricity (electricity prices across the globe are available from the Ease of Doing Business database). Significant attempts to source this information were made, including via an online survey sent to Clean Cooking Alliance (CCA) networks (amongst others), but were able to collect a small number of responses from only 20 countries.

Knowledge gaps around the relationship between cuisines, cooking practices and cooking energy consumption

There is still much to be learned about the differences in energy required to cook foods on different devices, and how this varies according to the cooking processes involved for cooking "typical daily/weekly" menus across the world. For example, a diet which often includes boiling or stewing foods for long periods (e.g. tripe, beans) are well suited to energy-efficient insulated and pressurised electrical devices, while cooks often prefer LPG when quickly shallow frying.

Cooking fuels and electricity access – global datasets still lack multi-dimensionality.

Some of the highest weighted, and therefore most influential indicators relate to the cooking fuels used (drawing on the WHO household energy database [19]) and access to electricity (drawing on the World Bank DataBank [20]). However, these datasets still lack the necessary nuance to account for fuel stacking and tiers of electricity access (as highlighted by ESMAP [3]) which vary hugely across the Global South and is likely to strongly influence the viability of a scale up of electric cooking. In order to account for fuel stacking to some extent the "upper bound" (rather than the average) of household cooking fuels is used in the GMA scores, however, until a much larger number of countries have implemented data gathering methodologies such as ESMAP's Multi-tier Framework [21] or incorporated more nuance into energy and cooking questions in household censuses this will continue to hinder national, regional and global analyses.

Mini-grid and off-grid market size and strength – poor global coverage

The availability of data on the size and strength of mini-grid and off-grid markets varies significantly between countries with many having little or no data. The GMA's mini-grid and off-grid infrastructure indicators use datasets (see Appendix 1 for more information) which rely on countries voluntarily updating open access resources (such [22] and [23]), governments keeping publicly available records of their sectors or being members of an association which collects such data [24] which leads to databases of varying quality for around half of the countries included in the GMA. Given the current growth of the mini-grid and off-grid markets, and its expected continued acceleration in the coming years, significant improvements in such resources are needed, alongside understanding of which cooking fuels are currently being used by those with different tiers of energy access (perhaps more useful than current datasets which focus on the arbitrary disaggregation of rural vs urban).

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[11] **Link TBC**

4. Results and Findings

This section outlines the results of the GMA as a global ranking and score for each of the national grid, mini-grid and off-grid (standalone) supported electric cooking scenarios. A high score/ranking indicates better viability for a scale up of electric cooking, and a low score/ranking indicates a worse viability. Short descriptions of selected countries' scores (grouped when of countries' scores are similar) are also provided. This is followed by further analysis (in section 4.4) highlighting "enabling environment" indicators and comparing GMA scores with and without selected indicators.

4.1. National grid supported electric cooking

The scale up of national grid supported cooking (Figure 7 and Table 8) is most viable in China, with other strong economies (e.g. Turkey, Colombia, Brazil, Indonesia, Malaysia, Mexico and India) also inside the top 10. The ranking list suggests that national grid supported electric cooking is most viable in countries classified as "emerging markets". In fact, using Morgan Stanley Capital International (MSCI) market classifications [25], eight of the top ten countries in the ranking list are considered emerging markets, while Costa Rica and Kazakhstan make up the remainder of the top 10. The lowest scoring countries are predominantly concentrated in sub-Saharan Africa (with the bottom 14 all countries from this region). High scoring countries for the viability of scale up of national grid supported electric cooking often have widespread access to reliable electricity, but low numbers of people using it for cooking (and thus high unrealised potential for electric cooking) and usually already have large proportions of using clean alternatives to electric cooking (e.g. LPG, biogas). They also have high scores for indicators in the human and economics categories (e.g. large OECD aid and renewable energy finance flows, and high Ease of Doing Business and sustainable energy policy scores).

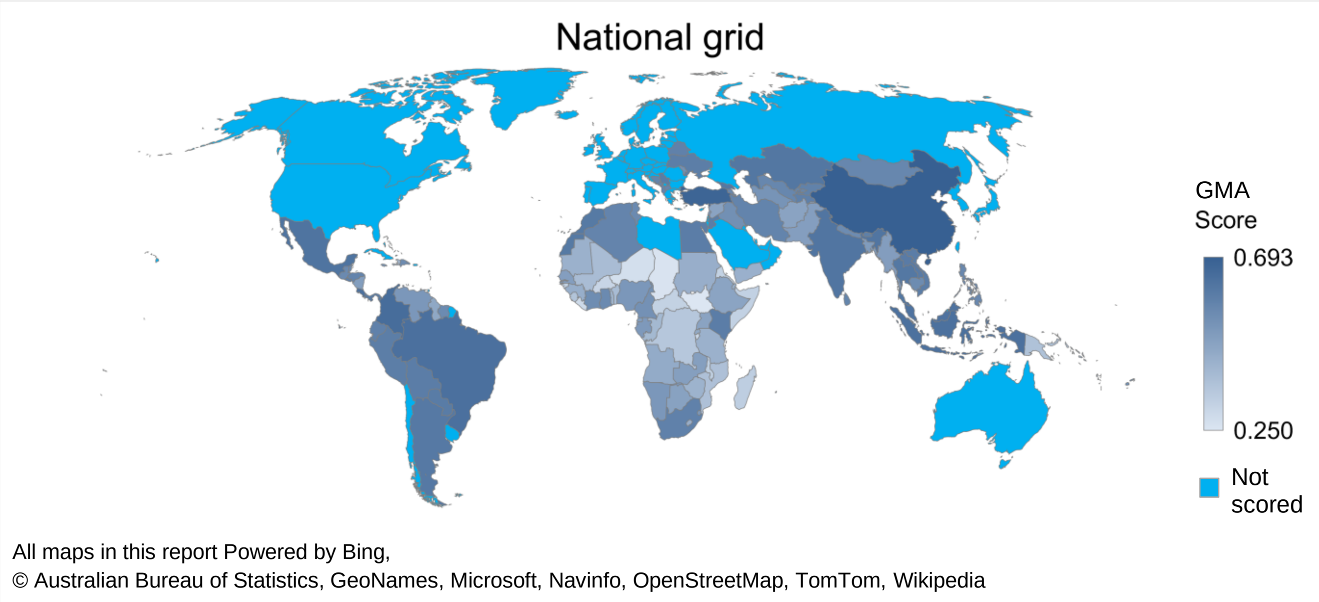

Figure 7 – Choropleth of GMA score for national grid scenario

Nevertheless, there are still significant proportions of people cooking with biomass in these countries (Table 6). For example, especially given their large populations, **China and India still have large numbers of people cooking on biomass, while they score very highly on the national grid scenario.** However, particularly in India, many of these are likely to be cooking on freely-collected biomass (as they have relatively low numbers of people using commercialised polluting fuels), so have little existing cooking energy expenditure, and are perhaps likely to have weaker energy infrastructure (due to living in remote or informal settlements).

Malaysia, Thailand, Laos, Serbia, Kenya and Vietnam (and a number of other countries shown in Table 6) **also have significant numbers in need of a transition whilst also scoring well for the national grid scenario.** More analysis relating cooking fuels and the GMA score included in section 5.3.2).

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Table 6 - Countries (from top 40) with significant proportions using commercialised polluting fuels and/or biomass for cooking

		*Commercialised polluting fuels (%)			**Biomass (%)		
Rank	Country	Lower bound	**Primary fuel**	***Upper bound***	Lower bound	**Primary fuel**	***Upper bound***
1	China	1	**7**	***21***	11	**28**	***50***
7	Malaysia	0	**0**	***30***	0	**1**	***20***
9	India	0	**2**	***10***	26	**48**	***69***
11	Thailand	4	**10**	***22***	4	**10**	***20***
16	Laos	9	**26**	***54***	41	**65**	***85***
18	Serbia	0	**0**	***8***	16	**33**	***53***
19	Kenya	9	**22**	***44***	52	**66**	***79***
23	Vietnam	0	**2**	***14***	18	**32**	***49***
27	Bhutan	0	**0**	***10***	3	**21**	***52***
34	Bosnia and Herzegovina	0	**0**	***7***	22	**54**	***89***
35	Honduras	0	**3**	***10***	17	**40**	***60***
38	Sri Lanka	0	**1**	***7***	49	**67**	***83***
39	Montenegro	0	**2**	***11***	20	**42**	***67***
40	North Macedonia	0	**2**	***27***	10	**30**	***56***
41	Mongolia	8	**15**	***27***	23	**34**	***48***
42	Uzbekistan	0	**0**	***13***	0	**13**	***50***
45	Philippines	5	**12**	***24***	26	**41**	***56***
47	Dominica	0	**1**	***48***	0	**11**	***42***
48	Guatemala	0	**2**	***16***	36	**50**	***66***
49	Ghana	21	**31**	***46***	28	**40**	***53***

*Commercialised polluting fuels = kerosene, charcoal, coal,**Biomass = wood, crop waste, dung

It is evident that high scoring countries for this scenario also often score highly across what may be called "development" indicators including HDI, GII, Ease of Doing Business, RISE and ICT/internet adoption (more in section 4.4).

However, **many high scoring countries have relatively low renewable energy shares** (average of 40% for the top 10) **and as such need to couple a transition to electric cooking with decarbonisation of their generation infrastructure;** such countries include: Thailand, Kazakhstan, India, Mexico, Malaysia and Indonesia. High scoring countries with relatively high renewable energy shares are shown in Table 7 and comparing this with Table 6 highlights the potential for a transition to electric cooking in Kenya, with strong GMA score, 89% renewable grid electricity and high proportions of its population using polluting fuels for cooking (others include Laos, Honduras, Montenegro, Guatemala and Ghana). Conversely, other high scoring countries with significant proportions using polluting fuels have carbon intensive grids; China (28% renewable), Malaysia (18%), India (21%), Thailand (19%) and Vietnam (28%), despite evidence that renewable generation is (and has been for some years) often cheaper than fossil fuels [26]–[29].

Table 7 - Countries (from top 50) with renewable energy share over 50%

Rank	Country	Renewable energy share (%)
3	Colombia	74.0
4	Costa Rica	99.2
5	Brazil	83.1
12	Georgia	76.9
15	Panama	82.1
16	Laos	57.5
17	Paraguay	100.0
19	Kenya	89.2
25	Peru	61.7
26	El Salvador	67.6
27	Bhutan	100.0
28	Tajikistan	93.1
29	Ecuador	78.9
32	Kyrgyzstan	92.4
35	Honduras	74.9
37	Albania	100.0
39	Montenegro	63.0
44	Belize	96.4
48	Guatemala	59.4
49	Ghana	50.2

4.1.1. Notable countries in the top 20 (national grid scenario)

Costa Rica – has a strong market of clean fuel users (electricity primary fuel 48% (LB 38%, UB[12] 58%)) and LPG primary fuel 46% (LB 36%, UB 56%) and universal access to reliable electricity (SAIDI[13] 0.5hrs/yr) which is almost entirely renewable (99%). There are some using biomass for cooking (primary fuel 5% (LB 2%, UB 9%)) which could be targeted as a priority to achieve a complete transition to clean cooking fuels. Although not considered an emerging economy it also has good scores across several human indicators, including HDI, ICT/internet adoption and gender inequality.

Georgia and Panama – also have strong clean fuel markets (users of clean alternatives 93% and 97% respectively) and widespread access to reliable electricity (SAIDI 4.7 and 7.8hrs/yr respectively). Their renewable energy shares are high (77% and 82% respectively) which means a transition from the dominant fuel in the countries, LPG, would be environmentally beneficial. However, transitioning the significant proportion who still use biomass for cooking in the two countries (primary fuel: Georgia 19% (LB 7%, UB 38%), Panama 11% (LB 2%, UB 29%)) should be the main priority, particularly in Georgia which has the third highest number of HAP attributable deaths in the top 33 countries. As such, there is still a need for many to reduce their reliance on polluting fuels in Georgia and Panama and both countries are well positioned for this to be realised.

Laos – has almost universal access to electricity which is reliable (SAIDI 4hrs/yr) and relatively renewable (57%) and has some of the highest levels of investment in renewables both from public and international sources despite being a relatively small country. However, almost everyone in the country cooks with biomass (primary fuel 65% (LB 41%, UB 85%)) and/or charcoal (primary fuel 26% (LB 9%, UB 50%)), it has the highest levels of HAP attributable deaths in the top 33, and one of the highest levels of tree cover loss. This indicates that Laos has an urgent need to transition its population onto modern energy cooking, and also the opportunity to harness its strong electricity infrastructure in affecting this transition.

Paraguay – has a mixture of cooking fuels, with many using clean fuels such as LPG (primary fuel 52% (LB 41%, UB 64%)) and also electricity (primary fuel 15% (LB 7%, UB 25%)). Like many others at the top of the national grid GMA rankings, Paraguay has universal access to electricity, which is relatively reliable (SAIDI 21.9hrs/yr) and affordable. In addition, the national grid is 100% supplied by renewables. However, there are still many who rely on biomass (primary fuel 25% (LB 17%, UB 34%)) and/or charcoal (primary fuel 7% (LB 4%, UB 10%)) and tree cover loss is one of the highest of any country. As such, with its completely renewable national grid, Paraguay has huge potential to increase adoption levels of electric cooking by those using traditional fuels, as well as those using LPG.

Serbia – has the highest existing level of electricity use for cooking (primary fuel 47% (LB 30%, UB 66%)) of any country in the top 26, with the electricity being accessible to all, reliable (SAIDI 3.9hrs/yr) and relatively cheap. Serbia also has good scores for human indicators (e.g. HDI, gender inequality index and Ease of Doing Business), but makes relatively little investment in renewable energy and has a national grid which is just 32% renewable. Despite being what could perhaps be considered a more developed nation than many others in the GMA analysis, the use of biomass for cooking is still common (primary fuel 33% (LB 16%, UB 53%)). As such, there is the potential for significant health, environmental and gender impacts by encouraging more widespread adoption of modern energy cooking services which would be augmented by efforts to decarbonise electricity infrastructure more broadly.

Kenya – scores highly across all GMA scenarios (particularly off-grid (2nd)) but is also 19th for the national grid scenario with a highly renewable national grid (89%) which is reliable (SAIDI 12hrs/yr). The country has strong policy (2nd highest RISE score excluding emerging markets), strong Ease of Doing Business score and finance indicators (e.g. third highest for mobile money and high levels of investment in renewables). Kenya also has the second highest proportion of people using commercialised polluting fuels (primary fuel 22% (LB 9%, UB 44%)) in the top 46 of the national grid scenario and so has large numbers of people with the need, as well as ability to pay for, a transition to electric cooking which is strongly viable in all contexts.

[12] GMA database uses UB (95% confidence interval upper bound of proportion of population with primary reliance on fuel) as proxy indicator for the proportion of households for whom the fuel is part of their 'fuel stack'; i.e. they cook with it but not necessarily as their primary fuel.
[13] System Average Interruption Duration Index (SAIDI) is the number of hours of electricity supply interruption the average customer experiences per year (as provided by Ease of Doing Business database)

4.1.2. Other top 20 countries (national grid scenario)

Kazakhstan and Morocco *– are similar to Costa Rica in that they have strong clean fuel markets (users of clean alternatives 100%, almost all LPG) widespread and reliable electricity infrastructure (SAIDI 1 and 0.5hrs/yr respectively) and high scores for most development indicators. Kazakhstan has particularly cheap electricity ($0.04/kWh) and relatively high levels of electric cooking (primary fuel 22% (LB 7%, UB 42%)), but low renewable energy share (10%). Electricity is more expensive in Morocco ($0.12/kWh), slightly more renewable (21%) and there have been high levels of public investment in renewables in recent years. As such, while Kazakhstan and Morocco have strong viability for the scale up of electric cooking, a transition away from LPG onto electric cooking needs to be supported by significant growth in the renewable share of electricity generation.*

Table 8 – GMA rankings and scores for national grid scenario (emerging markets in dark blue, frontier[14] markets in light blue)

Rank	Country	Score	Rank	Country	Score	Rank	Country	Score
1	**China**	0.693	44	Belize	0.559	88	Uganda	0.470
2	**Turkey**	0.677	45	Philippines	0.559	89	Syrian Arab Republic	0.470
3	**Colombia**	0.650	46	**Tunisia**	0.555	90	Afghanistan	0.470
4	Costa Rica	0.640	47	Dominica	0.554	91	Ethiopia	0.468
5	**Brazil**	0.639	48	Guatemala	0.554	92	Timor-Leste	0.461
6	**Indonesia**	0.637	49	Ghana	0.553	93	Comoros	0.456
7	**Malaysia**	0.630	50	Dominican Republic	0.552	94	Guyana	0.456
8	**Mexico**	0.628	51	Suriname	0.552	95	Sao Tome and Principe	0.452
9	**India**	0.623	52	Azerbaijan	0.551	96	Rwanda	0.446
10	**Kazakhstan**	0.617	53	Cambodia	0.548	97	Angola	0.445
11	**Thailand**	0.614	54	Nepal	0.547	98	Guinea	0.436
12	Georgia	0.613	55	Fiji	0.545	99	Lesotho	0.433
13	**Argentina**	0.610	56	**Côte d'Ivoire**	0.544	100	Sudan	0.433
14	**Morocco**	0.609	57	**Mauritius**	0.542	101	Yemen	0.427
15	**Panama**	0.608	58	**Jamaica**	0.535	102	Djibouti	0.426
16	Laos	0.602	59	Iraq	0.535	103	Mauritania	0.425
17	Paraguay	0.602	60	Grenada	0.535	104	Tanzania	0.424
18	**Serbia**	0.599	61	Antigua and Barbuda	0.532	105	**Zimbabwe**	0.418
19	**Kenya**	0.598	62	Cameroon	0.530	106	Micronesia	0.416
20	**Egypt**	0.597	63	Moldova	0.529	107	Togo	0.410
21	**Jordan**	0.597	64	St. Vinc. and the Gren.	0.527	108	Congo, Republic	0.400
22	Bolivia	0.596	65	Turkmenistan	0.522	109	Haiti	0.399
23	**Vietnam**	0.596	66	Saint Lucia	0.517	110	**Benin**	0.390
24	**Ukraine**	0.595	67	Maldives	0.515	111	Vanuatu	0.388
25	**Peru**	0.595	68	Marshall Islands	0.510	112	Mali	0.388
26	El Salvador	0.591	69	**Lebanon**	0.510	113	Solomon Islands	0.385
27	Bhutan	0.588	70	Namibia	0.510	114	Gambia, The	0.379
28	Tajikistan	0.587	71	Venezuela	0.510	115	Mozambique	0.374
29	Ecuador	0.583	72	**Nigeria**	0.510	116	Papua New Guinea	0.370
30	**South Africa**	0.583	73	Eswatini	0.508	117	Sierra Leone	0.363
31	Belarus	0.582	74	Cabo Verde	0.508	118	Congo, Dem. Rep.	0.353
32	Kyrgyzstan	0.582	75	Gabon	0.503	119	Madagascar	0.330
33	Iran	0.575	76	Tonga	0.497	120	Malawi	0.326
34	**Bosnia and Herzegovina**	0.574	77	**Bangladesh**	0.496	121	Somalia	0.320
35	Honduras	0.573	78	Samoa	0.492	122	Central African Republic	0.317
36	Algeria	0.573	79	Myanmar	0.490	123	Eritrea	0.317
37	Albania	0.573	80	Nicaragua	0.489	124	Guinea-Bissau	0.314
38	**Sri Lanka**	0.572	81	Equatorial Guinea	0.489	125	**Burkina Faso**	0.304
39	Montenegro	0.571	82	**Senegal**	0.487	126	Burundi	0.293
40	North Macedonia	0.570	83	**Pakistan**	0.487	127	Liberia	0.291
41	Mongolia	0.565	84	Zambia	0.484	128	Niger	0.273
42	Uzbekistan	0.564	85	Kiribati	0.477	129	Chad	0.258
43	Armenia	0.559	86	**Botswana**	0.476	130	South Sudan	0.250
			87	Palau	0.476			

[14] "Frontier markets" are the third tier of market classification given by MSCI, behind "emerging markets" and "developed markets", according to their criteria: economic development, size and liquidity, and accessibility to investment [25]

4.2. Mini-grid supported electric cooking

The top of the rankings for the viability of scale up of mini-grid supported electric cooking (Figure 8 and Table 10) is again dominated by emerging markets (e.g. China, India, Indonesia, Peru, Malaysia), although to a lesser extent than for the national grid scenario (top five classified as emerging markets and nine of the top 20). Countries which score well (particularly compared with the national grid scenario) are those with strong mini-grid infrastructure, (e.g. Algeria, Nepal, Myanmar, Philippines and Bangladesh) while the effect of having strong development indicators is less prevalent. Again, countries which score poorly are largely in sub-Saharan Africa (bottom 13 all from this region).

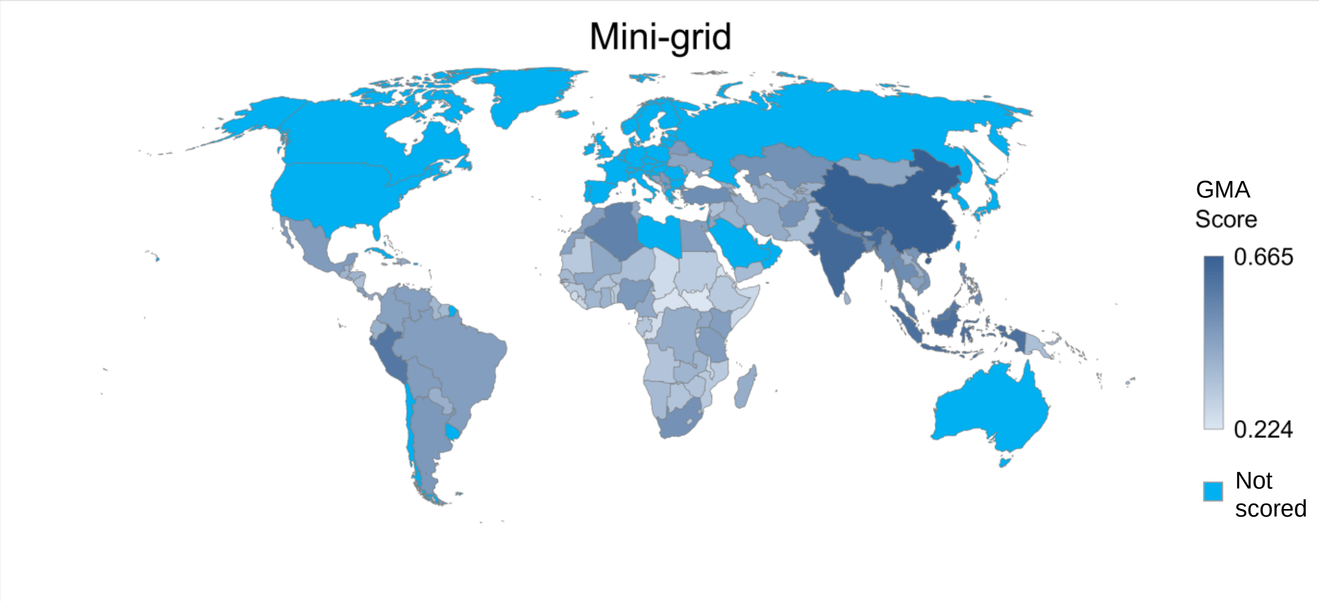

Figure 8 - Choropleth of GMA score for mini-grid scenario

Without mini-grid specific energy access and cooking fuels data (see section 3), analysis by cooking fuel (as shown for the national grid scenario) is problematic. Instead, Table 9 highlights the top countries based on mini-grid infrastructure (overcoming some limitations of mini-grid datasets also in section 3), showing countries with a GMA ranking inside the top 50 and in the top 10 for one or more of the mini-grid indicators. The top 10 countries for the mini-grid scenario remain, with all but Bangladesh having a "best mini-grid rank" of fifth or higher.

Therefore, by demonstrating strong development and electricity indicators with strong mini-grid infrastructure, **China, India, Indonesia, Peru and Malaysia are the countries with the best viability of a scale up of electric cooking on mini-grids**. These countries are closely followed by those for which the scenario score improves dramatically due to having much stronger mini-grid infrastructure than on the national grid; these include **Nepal, Bangladesh, Myanmar, Afghanistan, Nigeria and Tanzania which are also strongly viable opportunities for growth in mini-grid supported electric cooking.**

Table 9 – Top scoring countries and mini-grid indicators

Rank	Country	Mini-grid capacity (rank)	No. mini-grid developers (rank)	No. of people connected (rank)	Highest rank out of mini-grid indicators
1	China	3	17	14	3
2	India	1	13	1	1
3	Indonesia	2	19	9	2
4	Peru	9	4	19	4
5	Malaysia	4	32	23	4
6	Algeria	5	-	13	5
7	Nepal	14	2	10	2
8	Bangladesh	10	14	22	10
9	Philippines	17	17	2	2
10	Myanmar	19	1	12	1
13	Kazakhstan	7	-	-	7
15	Afghanistan	20	8	5	5
16	Vietnam	6	54	85	6
18	Nigeria	24	20	8	8
23	Tanzania	16	7	6	6
31	Cambodia	69	6	31	6
38	Mali	18	3	18	3

4.2.1. Notable top 20 countries (mini-grid scenario)

Nepal – has very strong mini-grid indicators which compensate for weak scores for finance and use of clean or commercialised polluting fuels (compared with other high scoring countries for this scenario). Nepal has the second highest number of mini-grid developers of any country and also high scores for number of people connected to mini-grids and off-grid (mini-grid) renewables capacity. The country also has a relatively high number of HAP attributable deaths but Nepal has relatively few households paying for cooking fuels and many use biomass (primary fuel 70% (LB 55%, UB 84%)) meaning that although a transition to cleaner cooking fuels is needed, ability to pay is a challenge.

Bangladesh – rises 69 places compared with the national grid scenario and has a similarly strong mini-grid sector alongside Myanmar and Nepal. Similarly to Nepal, in Bangladesh there is relatively little use of clean cooking fuels (electricity primary fuel 0% (LB 0%, UB 5%), gas primary fuel 22% (LB 13%, UB 32%)) while cooking with biomass is widespread (primary fuel 75% (LB 65%, UB 85%)) so again ability to pay for more modern cooking solutions will be a challenge. The country does however have relatively high levels of renewables investment and RISE score showing a propensity towards more modern energy use and renewable sources. This is particularly important given the environmental vulnerability of the country and its high tree cover loss. As such, in Bangladesh there is the urgent need as well as opportunity to transition to modern energy cooking through a growth in electric cooking on mini-grids.

Myanmar – also rises 69 places relative to the national grid scenario with similarly strong mini-grid infrastructure to Nepal and Bangladesh. The country has a strong proportion of people already cooking with electricity (primary fuel 25% (LB 9%, UB 46%)), and/or commercialised polluting fuels (primary fuel 12% (LB 4%, UB 29%)). This, coupled with the need to address high levels of HAP attributable deaths, make Myanmar an attractive market for scaling up electric cooking on mini-grids; particularly as it has the joint (with Nigeria) highest score of the top 20 countries for projected proportion of population accessing electricity from mini-grids in 2030 (30%).

Afghanistan – has very strong mini-grid indicators leading to a rise of 75 places compared with the national grid scenario. Similar to Nepal, Bangladesh and Myanmar, the country has relatively high numbers of HAP attributable deaths due to the widespread use of firewood, crop waste and dung as cooking fuels (biomass as primary fuel 53% (LB 43%, UB 69%)). However, the accessibility and growth potential of Afghanistan's market is hindered by having poor scores for most indicators in the human category including the lowest Ease of Doing Business in the top 27, lowest ICT/internet adoption in the top 51 and, and lowest RISE score in the top 78.

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Nigeria – despite not being able to compete with countries at the very top of the ranking list in terms of existing electricity and mini-grid infrastructure, strong human and economics indicators mean the country is in the top 20 countries for electric cooking on mini-grids. The combination of a large proportion of people using commercialised cooking fuels (primary fuel 17% (LB 8%, UB 40%)) and high numbers of HAP attributable deaths (4th highest overall) show that there is a need for transition to cleaner cooking fuels and also ability to pay for them. Nigeria also has the highest renewable energy finance flows of any country, and joint (with Myanmar) highest score of the top 20 countries for projected proportion of population accessing electricity from mini-grids in 2030 (30%) so presents a strong opportunity in the short-medium term as mini-grid infrastructure grows particularly with its very large overall population.

Tanzania – although just outside the top 20 countries (similarly for the off-grid scenario), rises 81 places relative to the national grid scenario, has very strong mini-grid infrastructure and the highest proportion of people using commercialised polluting fuels in the top 50 (primary fuel 31% (LB 19%, UB 50%)) demonstrating a need to transition as well as an ability to pay for modern cooking fuels. Tanzania's ranking is restricted by having weaker development indicators than other high scoring countries for this scenario, and poorer access to electricity. However, the country presents a growing opportunity for scale up of transition towards electric cooking on mini-grids in particular and is the second highest scoring country in sub-Saharan Africa for this scenario (behind Nigeria).

4.2.2. Other top 20 countries (mini-grid scenario)

***Algeria** – although with a carbon intensive national grid (see national grid scenario for more information), has one of the highest off-grid (mini-grid) capacities and number of mini-grid customers giving it high mini-grid infrastructure scores. However, more sub-national information would be needed to identify whether those which are connected to mini-grids are the small proportion of people who already cook with electricity (primary fuel 2% (LB 0%, UB 12%)); rather than gas which is widespread.*

***Philippines** – has strong development indicators and a fairly strong clean cooking market (gas primary fuel 44% (LB 28%, UB 61%) but also many who use biomass (primary fuel 41% (LB 26%, UB 56%) which is a likely cause for the highest HAP attributable deaths in the top 40 countries. It also has one of the highest numbers of mini-grid customers but (similar to Algeria) more contextual information is needed to know whether it is mini-grid customers who constitute the small proportion of people who already cook with electricity (primary fuel 2% (LB 0%, UB 7%).*

***Kazakhstan, Vietnam, Belarus and Serbia** – have strong development indicators and overall electricity infrastructure (see national grid scenario for more information) but lack data on mini-grids which means that further investigation is needed to know whether this scenario truly represents a strong opportunity for scaling up electric cooking in the four countries.*

Table 10 - GMA rankings and scores for mini-grid scenario (emerging markets in dark blue, frontier markets in light blue)

Rank	Country	Score
1	**China**	0.665
2	**India**	0.634
3	**Indonesia**	0.610
4	**Peru**	0.586
5	**Malaysia**	0.578
6	Algeria	0.553
7	Nepal	0.537
8	**Bangladesh**	0.528
9	Philippines	0.526
10	Myanmar	0.520
11	**Thailand**	0.518
12	**Turkey**	0.514
13	**Kazakhstan**	0.500
14	**South Africa**	0.500
15	Afghanistan	0.495
16	**Vietnam**	0.487
17	**Argentina**	0.480
18	**Nigeria**	0.478
19	**Serbia**	0.476
20	Belarus	0.473
21	North Macedonia	0.472
22	**Mexico**	0.471
23	Tanzania	0.465
24	Bolivia	0.463
25	**Egypt**	0.462
26	**Brazil**	0.461
27	**Kenya**	0.461
28	Venezuela	0.459
29	**Morocco**	0.458
30	Costa Rica	0.458
31	Cambodia	0.451
32	**Colombia**	0.450
33	**Bosnia and Herzegovina**	0.445
34	Maldives	0.445
35	**Jordan**	0.444
36	**Ukraine**	0.435
37	Mongolia	0.434
38	Mali	0.429
39	Uganda	0.427
40	Armenia	0.426
41	**Tunisia**	0.425
42	**Panama**	0.422
43	Cameroon	0.422
44	Dominican Republic	0.420
45	Montenegro	0.419
46	**Mauritius**	0.419
47	Bhutan	0.418
48	Azerbaijan	0.417
49	Albania	0.417
50	Iran	0.415
51	Tajikistan	0.413
52	Madagascar	0.411
53	El Salvador	0.410
54	Congo, Dem. Rep.	0.410
55	Georgia	0.407
56	Dominica	0.405
57	Antigua and Barbuda	0.405
58	Uzbekistan	0.404
59	Paraguay	0.404
60	Grenada	0.402
61	Cabo Verde	0.402
62	Turkmenistan	0.401
63	Laos	0.401
64	**Jamaica**	0.400
65	Ecuador	0.399
66	Kyrgyzstan	0.396
67	**Sri Lanka**	0.396
68	Iraq	0.394
69	Ghana	0.394
70	**Lebanon**	0.394
71	Moldova	0.393
72	Honduras	0.390
73	Guatemala	0.389
74	Haiti	0.388
75	Saint Lucia	0.388
76	St. Vinc. and the Gren.	0.387
77	Zambia	0.385
78	**Côte d'Ivoire**	0.382
79	Palau	0.380
80	Guyana	0.380
81	Belize	0.378
82	Fiji	0.376
83	**Senegal**	0.374
84	Suriname	0.372
85	Eswatini	0.371
86	Namibia	0.367
87	Micronesia	0.366
88	Yemen	0.366
89	Marshall Islands	0.360
90	**Pakistan**	0.357
91	Tonga	0.354
92	Niger	0.354
93	Papua New Guinea	0.353
94	Nicaragua	0.353
95	Samoa	0.348
96	Syrian Arab Republic	0.344
97	Rwanda	0.342
98	**Zimbabwe**	0.338
99	Kiribati	0.337
100	**Botswana**	0.337
101	Angola	0.334
102	**Burkina Faso**	0.333
103	Solomon Islands	0.331
104	Gabon	0.329
105	Vanuatu	0.325
106	Lesotho	0.322
107	Mauritania	0.321
108	Guinea	0.321
109	Ethiopia	0.319
110	Mozambique	0.317
111	**Benin**	0.315
112	Comoros	0.312
113	Sudan	0.308
114	Timor-Leste	0.307
115	Togo	0.297
116	Djibouti	0.286
117	Sao Tome and Principe	0.284
118	Gambia, The	0.283
119	Malawi	0.282
120	Liberia	0.278
121	Somalia	0.269
122	Equatorial Guinea	0.267
123	Chad	0.261
124	Guinea-Bissau	0.257
125	Sierra Leone	0.257
126	Congo, Republic	0.253
127	Eritrea	0.234
128	Central African Republic	0.233
129	Burundi	0.226
130	South Sudan	0.224

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4.3. Off-grid (standalone) supported electric cooking

India has the highest score for viability of scale up of off-grid electric cooking. While emerging economies still make up 10 of the top 20 countries, the top 10 is mostly made up of those with strong off-grid (standalone) sectors (e.g. Kenya, Morocco, Bangladesh, Nigeria and Uganda) which gain an average of 50 ranking places each compared with the national grid scenario.

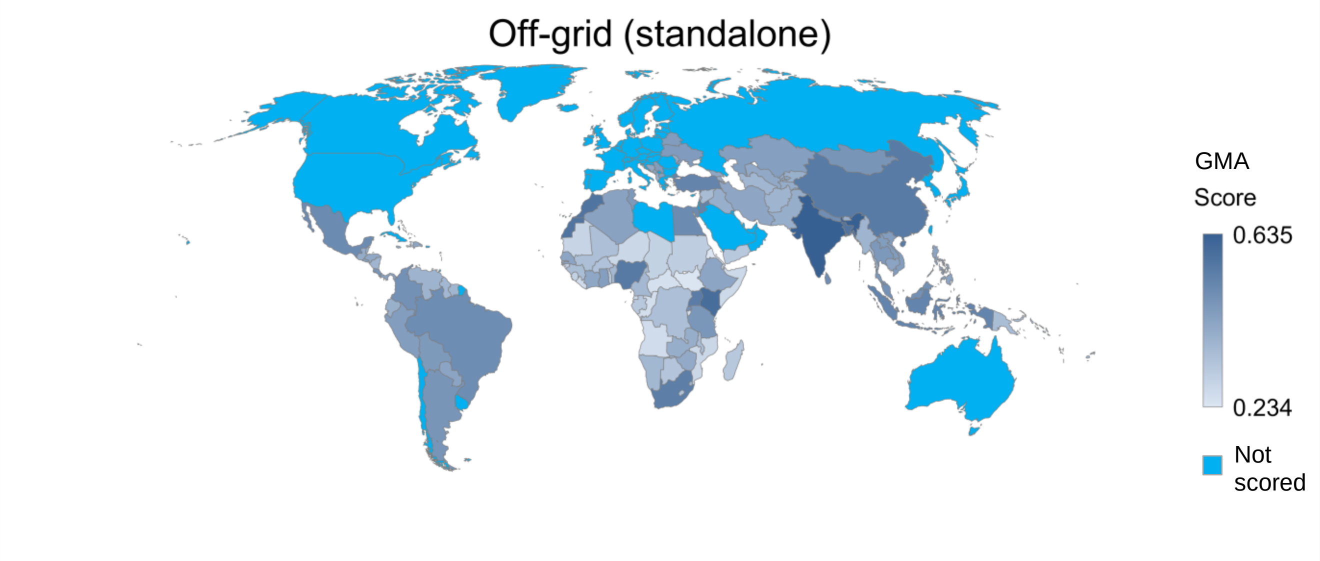

Figure 9 - Choropleth of GMA score for off-grid scenario

Table 11 shows the countries with a ranking inside the top 50 for the GMA's off-grid (standalone) scenario and inside the top 10 for one of the three off-grid (standalone) indicators: electricity access projections, off-grid renewables capacity and off-grid lighting/appliance customers. This sees Jordan removed from the top 20 alongside all other emerging economies (excluding India). By making these exclusions, **according to available data India, Kenya, Morocco, Bangladesh, Nigeria and Uganda are the most viable countries for a scale up of electric cooking supported by off-grid (standalone) systems.** Other countries with strong off-grid sectors perform well, but are restricted by development indicators, include **Sri Lanka, Nepal, Rwanda and Tanzania which also present very strong opportunities.**

Table 11 - Top scoring countries and off-grid indicators

Scenario rank	Country	Elec. access projections (rank)	Off-grid renewables capacity (rank)	Off-grid lighting/appliance customers (rank)	Best off-grid indicator (rank)
1	India	64	2	1	1
2	Kenya	45	5	2	2
3	Morocco	76	4	26	4
4	Bangladesh	61	1	3	1
5	Nigeria	40	9	7	7
7	Uganda	13	7	6	6
15	Sri Lanka	116	10	22	10
16	Nepal	55	8	10	8
17	Rwanda	18	6	8	6
23	Tanzania	22	3	5	3
43	Ethiopia	30	12	4	4

4.3.1. Notable top 20 countries (off-grid scenario)

Kenya – (see national grid scenario for more information), is 19th for the national grid scenario and also has a strong off-grid sector (2nd highest number of off-grid lighting/appliance customers and 5th highest off-grid renewables capacity) and as such has the second highest score for the off-grid scenario.

Bangladesh – (see mini-grid scenario section for more information), is in the top 10 for the mini-grid scenario but also has the third highest number of off-grid lighting/appliance customers (behind India and Kenya) and highest off-grid renewables capacity, meaning it comes 4th for the viability of scale up of off-grid electric cooking.

Nigeria and Uganda – similarly to Kenya, both have strong markets for off-grid lighting/appliances, causing both to rise significantly in the rankings relative to the national grid scenario in particular (Nigeria +67, Uganda +81). As for Nigeria in the mini-grid scenario (see previous section), Uganda also has both a need for a transition to cleaner fuels (with high HAP attributable deaths and tree cover loss) and many using commercialised cooking fuels (primary fuel 26% (LB 17%, UB 38%)) and so an existing ability to pay for cooking fuels. Policy and business environments in both countries are also relatively strong but would benefit from further development, while in Uganda 56% are projected to have access to electricity via off-grid systems in 2030, the highest of the top 54.

Sri Lanka and Nepal – have strong off-grid (standalone) sectors in addition to growing clean cooking sectors dominated by the use of LPG (primary fuel Sri Lanka 32% (LB 16%, UB 48%), Nepal 28% (LB 9%, UB 44%)). However, biomass use is still high (primary fuel Sri Lanka 67% (LB 49%, UB 83%), Nepal 70% (LB 50%, UB 84%)) and a contributing factor towards high levels of HAP attributable deaths. A major challenge for these two countries is the lack of household expenditures for cooking fuels (for more information see mini-grid scenario section for Nepal and All round high scoring countries section for Sri Lanka).

Rwanda – has a strong off-grid sector (8th highest off-grid customers and 6th highest off-grid renewables capacity) and despite relatively low public investment in renewables and many using commercialised polluting fuels (primary fuel 17% (LB 9%, UB 32%). The country has the highest RISE score of any country excluding emerging markets and 2nd highest Ease of Doing Business score in the top 18 making it attractive to investors. Therefore, Rwanda presents a strong opportunity for scaling up off-grid electric cooking.

4.3.1. Other top 20 countries (off-grid scenario)

***Morocco and Jordan** – both score well due to having a strong clean cooking sector, electricity infrastructure and development indicators (see national grid scenario for Morocco and Costa Rica) as well as some existing activity in the off-grid sector. Both countries have very low biomass use (and low HAP attributable deaths) so the opportunities for this scenario may be scaling up existing off-grid systems to support a transition away from LPG in the medium term.*

***Costa Rica –** (see national grid scenario) similarly to Morocco and Jordan has a strong clean cooking sector, energy and development indicators, but has very little activity in the off-grid sector due to having universal access to reliable electricity, so although has a high score for the off-grid scenario does not have strong potential for off-grid supported electric cooking.*

Table 12 - GMA rankings and scores for off-grid scenario (emerging markets in dark blue, frontier markets in light blue)

Rank	Country	Score
1	**India**	0.635
2	**Kenya**	0.595
3	**Morocco**	0.575
4	**Bangladesh**	0.574
5	**Nigeria**	0.557
6	**China**	0.555
7	Uganda	0.551
8	**South Africa**	0.546
9	**Jordan**	0.531
10	**Indonesia**	0.527
11	**Turkey**	0.527
12	**Egypt**	0.506
13	**Mexico**	0.505
14	**Brazil**	0.501
15	**Sri Lanka**	0.497
16	Nepal	0.497
17	Rwanda	0.491
18	**Colombia**	0.490
19	**Malaysia**	0.489
20	Costa Rica	0.477
21	Mongolia	0.477
22	**Argentina**	0.476
23	Tanzania	0.471
24	**Thailand**	0.467
25	**Tunisia**	0.466
26	Bolivia	0.462
27	**Ukraine**	0.457
28	Belarus	0.454
29	Laos	0.454
30	**Serbia**	0.454
31	**Peru**	0.453
32	**Vietnam**	0.452
33	Ghana	0.450
34	**Kazakhstan**	0.447
35	North Macedonia	0.440
36	El Salvador	0.439
37	Algeria	0.436
38	**Panama**	0.434
39	**Mauritius**	0.432
40	Philippines	0.432
41	Paraguay	0.431
42	Cambodia	0.430
43	Ethiopia	0.428
44	**Senegal**	0.427
45	Dominican Republic	0.424
46	Iran	0.424
47	Dominica	0.423
48	**Côte d'Ivoire**	0.423
49	Montenegro	0.422
50	Georgia	0.421
51	Honduras	0.420
52	**Bosnia and Herzegovina**	0.417
53	Antigua and Barbuda	0.417
54	Uzbekistan	0.416
55	**Zimbabwe**	0.415
56	Grenada	0.409
57	Guatemala	0.408
58	Tajikistan	0.406
59	**Jamaica**	0.404
60	Moldova	0.403
61	Armenia	0.403
62	Zambia	0.402
63	**Pakistan**	0.401
64	**Lebanon**	0.399
65	Saint Lucia	0.398
66	Iraq	0.398
67	Belize	0.397
68	Ecuador	0.396
69	Kyrgyzstan	0.396
70	Bhutan	0.395
71	Albania	0.393
72	St. Vinc. and the Gren.	0.391
73	Azerbaijan	0.391
74	Venezuela	0.384
75	Eswatini	0.384
76	Palau	0.383
77	Afghanistan	0.383
78	Nicaragua	0.382
79	Myanmar	0.381
80	Suriname	0.379
81	Fiji	0.377
82	Turkmenistan	0.377
83	Micronesia	0.377
84	Maldives	0.375
85	Namibia	0.374
86	Guyana	0.374
87	**Benin**	0.372
88	Cameroon	0.370
89	Cabo Verde	0.361
90	Marshall Islands	0.361
91	Tonga	0.361
92	Syrian Arab Republic	0.361
93	Malawi	0.359
94	Papua New Guinea	0.357
95	Guinea	0.357
96	Samoa	0.356
97	Kiribati	0.355
98	Mali	0.351
99	Congo, Dem. Rep.	0.351
100	Solomon Islands	0.348
101	**Burkina Faso**	0.340
102	Lesotho	0.336
103	Vanuatu	0.332
104	**Botswana**	0.332
105	Comoros	0.326
106	Madagascar	0.325
107	Gabon	0.324
108	Yemen	0.324
109	Timor-Leste	0.322
110	Togo	0.313
111	Sudan	0.307
112	Gambia, The	0.299
113	Djibouti	0.297
114	Sierra Leone	0.295
115	Chad	0.295
116	Sao Tome and Principe	0.288
117	Mauritania	0.287
118	Guinea-Bissau	0.285
119	Haiti	0.283
120	Niger	0.280
121	Mozambique	0.279
122	Somalia	0.275
123	Equatorial Guinea	0.271
124	Liberia	0.267
125	Angola	0.264
126	Congo, Republic	0.257
127	Central African Republic	0.251
128	Burundi	0.242
129	South Sudan	0.237
130	Eritrea	0.234

4.4. All round high scoring countries

Computing all round GMA scores (sum of the scores across all indicators for the three scenarios using an average where required to avoid double counting) highlights countries with opportunities for a scale up of electric cooking more generally (as shown below in Table 13). This highlights many of the countries already mentioned (particularly "emerging markets" and those with top 20 scores for one or more of the scenarios).

Table 13 - All round GMA ranks and scores (top 50) (emerging economies in dark blue, frontier markets in light blue) [colour scale: green = high rank, red = low rank]

Overall (rank)	Country	Score	Nat. Grid (rank)	Mini-grid (rank)	Off-grid (rank)
1	**India**	1.256	9	2	1
2	Nepal	1.168	54	7	16
3	**China**	1.144	1	1	6
4	**Indonesia**	1.133	6	3	10
5	**Peru**	1.076	25	4	31
6	Algeria	1.070	36	6	37
7	**Malaysia**	1.063	7	5	19
8	**Kenya**	1.058	19	27	2
9	**Bangladesh**	1.039	77	8	4
10	**Turkey**	1.026	2	12	11
11	Afghanistan	1.019	90	15	77
12	Cambodia	0.993	53	31	42
13	Philippines	0.991	45	9	40
14	**Kazakhstan**	0.988	10	13	34
15	**Thailand**	0.987	11	11	24
16	**Vietnam**	0.980	23	16	32
17	**Sri Lanka**	0.975	38	67	15
18	**Argentina**	0.969	13	17	22
19	**Brazil**	0.968	5	26	14
20	Iran	0.965	33	50	46
21	**Egypt**	0.961	20	25	12
22	Belarus	0.954	31	20	28
23	**Morocco**	0.954	14	29	3
24	**Tunisia**	0.950	46	41	25
25	**Jordan**	0.949	21	35	9
26	**Nigeria**	0.945	72	18	5
27	Mongolia	0.938	41	37	21
28	Azerbaijan	0.928	52	48	73
29	Uganda	0.928	88	39	7
30	Costa Rica	0.922	4	30	20
31	**Colombia**	0.921	3	32	18
32	**Panama**	0.918	15	42	38
33	Myanmar	0.914	79	10	79
34	Maldives	0.905	67	34	84
35	Georgia	0.904	12	55	50
36	Uzbekistan	0.903	42	58	54
37	Tanzania	0.901	104	23	23
38	Dominican Republic	0.900	50	44	45
39	**Serbia**	0.899	18	19	30
40	**South Africa**	0.899	30	14	8
41	**Mexico**	0.899	8	22	13
42	**Ukraine**	0.896	24	36	27
43	**Bosnia and Herzegovina**	0.895	34	33	52
44	Bolivia	0.889	22	24	26
45	Bhutan	0.888	27	47	70
46	Tajikistan	0.884	28	51	58
47	El Salvador	0.869	26	53	36
48	Paraguay	0.867	17	59	41
49	Venezuela	0.861	71	28	74
50	North Macedonia	0.835	40	21	35

4.4.1. Notable top 20 countries (all round high scoring)

Cambodia – has good scores across the three scenarios (ranked 12th overall) owing to its high levels of electricity access (urban 100%, rural 89%), relatively high renewable generation mix (54%) and national grid reliability (SAIDI 20.8hrs/yr). Some in Cambodia use LPG for cooking (primary fuel 19% (LB 10%, UB 29%)) and/or charcoal (primary fuel 7% (LB 4%, UB 13%)), but the majority of its population cook predominantly with biomass (primary fuel 70% (LB 60%, UB 79%)). As such, it has relatively high numbers of household air pollution attributable deaths and is in need of a transition towards modern cooking fuels but ability to pay may be a challenge; it also has one of the highest levels of tree cover loss in the global south. Mini-grids are also an opportunity for electric cooking in Cambodia; it has one of the highest numbers of mini-grid developers in the Global South.

Philippines – is in the top 10 for the mini-grid scenario (see mini-grid section) as well as scoring well for the national grid (45th) and off-grid (40th) scenarios. The country has strong human indicators and widespread access to reliable electricity (3.6hrs/yr) in all areas (urban 98%, rural 93%). Despite this, many still cook with biomass (primary fuel 41% (LB 26%, UB 56%)) and the Philippines has high levels of household air pollution attributable deaths relative to many high scoring countries, while a similar portion of the population cook with LPG (primary fuel 44% (LB 28%, UB 61%)). As such, there is significant need and potential for a transition onto electric cooking in the country while transitioning LPG users towards electric cooking would need to be coupled with decarbonisation of the national grid which is only 21% powered by renewable sources.

Sri Lanka – as well as scoring highly for the off-grid scenario, is 17th overall due to its widespread access to electricity (99.6%) which is reliable (SAIDI 4hrs/yr), and high unrealised potential for electric cooking as many use LPG (primary fuel 32%, UB 48%) and/or biomass (primary fuel 67%, UB 83%). Large amounts of biomass cooking likely contributes to its high HAP deaths so ability/willingness to pay is likely to be a challenge for those most in need of a transition to modern cooking services but with many already with access to electricity there is significant potential for a scaled up transition to electric cooking. Although the grid is already somewhat decarbonised (renewable energy share 46%) a transition would be more impactful with an increased share of renewables, an area which is being heavily invested in according to the GMA's financial indicators.

Summary of results and findings

This section has shown the GMA results for national grid, mini-grid and off-grid scenarios. Analysis has indicated that there are a number of countries where a scale up of electric cooking is both viable and urgently needed, including: China, Malaysia, Thailand, Laos, Kenya, Indonesia, Peru, Malaysia, Nepal, Bangladesh, Myanmar, Afghanistan, Nigeria, Tanzania, Uganda, Sri Lanka and Rwanda. These countries have high GMA scores and large numbers of people cooking with polluting fuels meaning that pivoting to electric cooking is of huge importance and highly viable. With high GMA scores and very large absolute numbers of people paying for polluting cooking fuels, China, India and Nigeria present opportunities for transition on a huge scale.

In addition, it has been found that in many cases a national grid supported scale up of electric cooking needs to be coupled with decarbonisation of generation infrastructure. Many countries with a high GMA score for the national grid scenario have low renewable energy shares. This means that for a transition to electric cooking to have the most positive impact in terms of reducing air pollution and CO_2 emissions, it needs to be supported by increased investment in and focus on renewable electricity generation which is already often cheaper than generation from fossil fuels. **On this basis, Kenya has particularly strong potential for a transition to electric cooking, with its strong GMA score, 89% renewable grid electricity and high proportions of its population paying for polluting fuels for cooking** (others include Laos, Honduras, Montenegro, Guatemala and Ghana).

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5. Further analysis

A number of key trends were identified through reviewing the results and ranking lists. The first of which is an apparent link between strong development indicators and a high score. Particularly for the national grid scenario, countries with high GMA scores appear to have high development indicators (e.g. HDI, GII, Ease of Doing Business, RISE and ICT/internet adoption) while, others more obviously related to electric cooking such as users of clean alternatives and access to electricity also appear to have a similar relationship. Such trends suggest that one or more sub-groups of indicators could represent a core sub-set or "enabling environment" for a scale up of electric cooking.

Development is perhaps most commonly represented by HDI, and so is shown below (Figure 10) against the GMA score for the national grid scenario. It is clear from the plot shown that a strong positive linear relationship is evident between the variables. This relationship is also present between access to electricity and GMA score, and between HDI and access to electricity demonstrating that development, electricity access/infrastructure and the viability of electric cooking are all strongly interlinked (see Appendix 6).

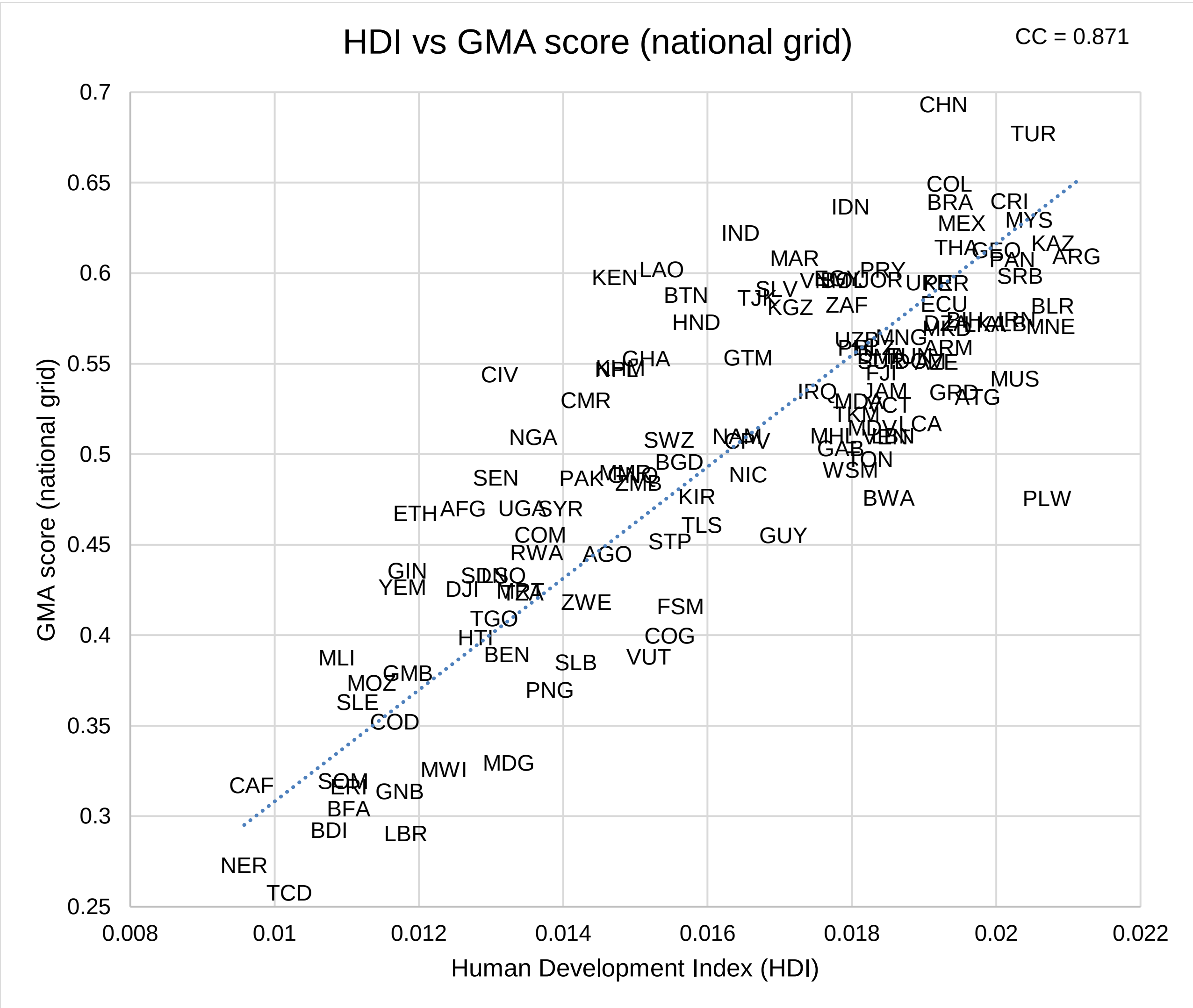

Figure 10 – HDI plot against GMA score for national grid scenario

Opposite trends, where high indicator scores appear to be related to low GMA scores, are also apparent for indicators such as renewable energy share, HAP attributable deaths and users of commercialised polluting fuels. These positive and negative correlations are investigated in detail in the following sections.

5.1. Correlation of indicators and GMA score

Each indicator was compared with the final GMA scores and the correlation coefficient[15] (degree to which the trends in the datasets match) were calculated. The strongest trends between indicators and the GMA score were found in the national grid scenario, with eight indicators having “strong correlation” (often said to be represented by a correlation coefficient (CC) greater than 0.7 or less than -0.7) while many more indicators have “moderate correlation (CC>0.5, CC<-0.5). Table 14 shows the correlation coefficients for all indicators compared with the GMA scores.

The national grid scenario GMA score was strongly correlated with: users of clean alternatives, ICT/internet adoption, GII, HDI, DPs using clean cooking fuels, access to electricity (all, urban areas), electricity access projections (grid) and grid reliability. **It was moderately correlated with:** unrealised potential for electric cooking, affordability of electricity, credit rating, Ease of Doing Business, RISE, HAP attributable deaths (negative), urban population growth (negative) and LPI. In either the mini-grid or off-grid scenario just **one indicator was strongly correlated with a high score (RISE when compared with off-grid GMA score)** but **two almost identical groups of indicators were moderately correlated:** users of clean alternatives (mini-grid only), users of commercialised polluting fuels (negative), credit rating, OECD aid and renewable energy finance flows (off-grid only), ICT/internet adoption, Ease of Doing Business, RISE, GII, HDI, LPI, access to electricity (all areas and rural), electricity access projections (negative), off-grid renewables capacity and number of people connected to mini-grids (mini-grid only).

Table 14 - Correlation between indicators and GMA scores
[coloured by CC strength: orange = moderate negative, light green = moderate positive, dark green = strong positive correlation]

	Correlation coefficient (CC)		
Indicator	Grid	Mini-grid	Off-grid
Users of electric cooking	0.34	0.24	0.19
Users of clean alternatives (e.g. LPG, biogas)	0.76	0.51	0.41
Users of commercialised polluting fuels (e.g. charcoal)	-0.55	-0.50	-0.48
Unrealised potential for electric cooking	0.69		
Affordability of electricity (grid only)	0.55		
Credit rating	0.58	0.50	0.48
Mobile money	0.48	0.35	0.42
OECD aid flows	0.44	0.46	0.64
Renewable energy finance flows	0.48	0.47	0.64
Photovoltaic power potential	-0.20	-0.11	-0.05
Tree cover loss	-0.03	0.08	0.15
ICT/internet adoption	0.80	0.63	0.58
Ease of Doing Business index	0.67	0.55	0.63
Regulatory Indicators for Sustainable Energy (RISE)	0.61	0.63	0.78
Indoor Air Pollution attributable deaths	-0.57	-0.33	-0.36
Gender Inequality Index (GII)	0.72	0.54	0.49
Urban population growth	-0.51		
Human Development Index (HDI)	0.83	0.59	0.55
Number of displaced persons (DPs) per 1000 population	-0.11	-0.08	-0.08
DPs using clean cooking fuels ([a]*grid*, [b]*off-/mini-grid*)	[a]0.72	[b]0.38	[b]0.37
DPs with unrealised potential for eCook	-0.25		
Logistics Performance Index	0.64	0.60	0.64
Manufacturing, value added	0.40	0.47	0.37
Access to electricity (all areas)	0.86	0.59	0.54
Access to electricity ([c]*urban*, [d]*rural*)	[c]0.83	[d]0.60	[d]0.58
Electricity access projections ([e]*grid*, [f]*mini-grid*, [g]*off-grid*)	[e]0.79	[f]-0.54	[g]-0.49
[h]*Renewable energy share* / [i]*Off-grid renewables capacity*	[h]0.14	[i]0.64	[i]0.58
Grid reliability (SAIDI * SAIFI)	0.74		
Number of mini-grid developers		0.34	
Number of people connected to mini-grids		0.48	
Off-grid lighting/appliance customers			0.40

[15] Correlation coefficients (CC) represent the strength and direction of agreement between two datasets as a number between -1 and 1. CC of 1 represents perfect agreement (high value in one dataset = high value in the other) while a CC of -1 represents perfect disagreement (high value in one = lower value in the other). As the CC approaches 0, the correlation between the datasets weakens to the point that the two datasets show no relationship at all if CC=0.

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Indicators which are at least moderately, and positively, correlated with the GMA scores for each scenario could be said to represent the "enabling environment" for a scale up of electric cooking, further analysis on this topic is shown in the next section. Number of people connected to mini-grids is also included despite its CC being slightly below 0.5 as this dataset is restricted by a lack of coverage.

In addition, four indicators show moderate negative correlation for at least one of the scenarios. Users of commercialised polluting fuels is consistently negatively correlated with the GMA score, while (perhaps unsurprisingly) HAP attributable deaths has a similar (although weaker) behaviour. Furthermore, urban population growth is negatively correlated with the GMA score for the national grid scenario, as are electricity access projections for mini-grids and off-grid (standalone) systems with their respective scenarios.

5.2. Enabling environment indicators

As shown in the previous section, several indicators are at least moderately positively correlated with the GMA score and through calculating the correlation coefficients between these indicators they can be grouped according to their characteristics. Carrying out this analysis (see appendix A for more detailed information) allows them to be separated into three groups: an "energy" group, a "development" group and a small number of indicators which are neither correlated with the indicators in the energy/development groups nor are correlated with each other (see Table 15).

Table 15 - Enabling environment indicators grouped

National grid	Mini-grid	Off-grid
Energy		
Access to electricity (all areas)	Access to electricity (all areas)	Access to electricity (all areas)
Access to electricity (urban)	Access to electricity (rural)	Access to electricity (rural)
Users of clean alternatives	Users of clean alternatives	
Unrealised potential for electric cook.		
DPs using clean cooking fuels (grid)		
Electricity access projections (grid)		
Grid reliability (SAIDI * SAIFI)		
Development		
Human Development Index (HDI)	Human Development Index (HDI)	Human Development Index (HDI)
ICT/internet adoption	ICT/internet adoption	ICT/internet adoption
Gender Inequality Index	Gender Inequality Index	Gender Inequality Index
Ease of Doing Business index	Ease of Doing Business index	Ease of Doing Business index
Logistics Performance Index	Logistics Performance Index	Logistics Performance Index
Credit rating	Credit rating	Credit rating
Affordability of electricity (grid only)		
Independent of other indicators		
RISE	RISE	RISE
	Off-grid renewables capacity (MG)	Off-grid renewables capacity (S)
	Number of people connected to mini-grids	
		OECD aid flows
		Renewable energy finance flows

Through comparing rankings and scores before and after removing these groups of indicators from the analysis (by setting their weights to zero) their effect on the rankings and scores can be seen. The charts below (Figure 11) show the ranking difference between GMA scores before and after the groups of enabling indicators are removed.

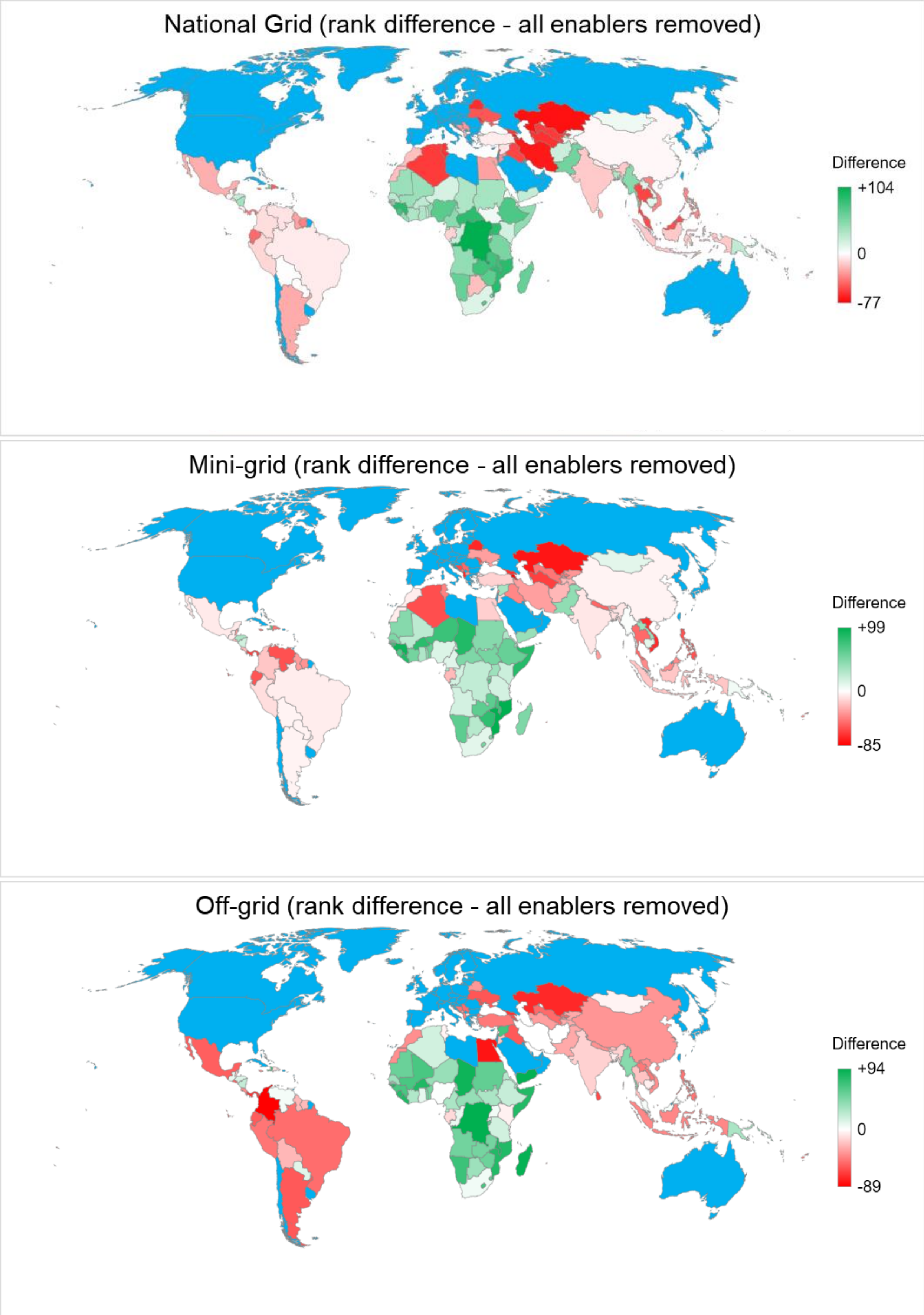

Figure 11 - Choropleths showing difference between GMA ranking with and without enabling environment indicators removed

Table 16 shows the countries in the top 65 for each scenario (with enabling indicators removed) which increase their ranking by more than 20 places.

By reviewing this data, it is clear that the viability of a scale up of electric cooking is most significantly hindered by poor enabling indicator scores in countries across sub-Saharan Africa. Other countries are similarly affected, including several from Central America/Caribbean (Honduras, Haiti, Dominica, Guatemala and Nicaragua), South/South-East Asia (Bangladesh, Pakistan, Mongolia, Laos and Myanmar), Pacific islands (Micronesia, Solomon Islands and Vanuatu) and North Africa (Syrian Arab Republic and Yemen).

There are, some exceptions to this where countries in sub-Saharan Africa already have high GMA scores: Kenya is relatively less affected by the removal of enabling indicators for the national grid scenario, the same can be said for Nigeria and Tanzania for the mini-grid scenario while this effect is less prevalent for the off-grid scenario.

Table 16 – Countries inside top 65 which increase rank by more than 20 places when enabling environment indicators are removed

National grid (adjusted rank)			
Rank	Country	Score	Diff.
2	Uganda	0.544	+86
5	Nigeria	0.487	+67
6	Zambia	0.469	+78
9	Namibia	0.464	+61
10	Guinea	0.463	+88
12	Honduras	0.458	+23
14	Congo, Dem. Rep.	0.453	+104
15	Cameroon	0.449	+47
17	Ghana	0.439	+32
19	Ethiopia	0.429	+72
23	Côte d'Ivoire	0.416	+33
26	Pakistan	0.404	+57
27	Eswatini	0.386	+46
28	Mozambique	0.385	+87
30	Lesotho	0.380	+69
31	Myanmar	0.379	+48
36	Central African Republic	0.362	+86
39	Zimbabwe	0.357	+66
40	Malawi	0.357	+80
41	Sierra Leone	0.353	+76
43	Equatorial Guinea	0.348	+38
44	Nicaragua	0.343	+36
45	Bangladesh	0.342	+32
50	Tanzania	0.339	+54
51	Burundi	0.339	+75
53	Angola	0.338	+44
54	Senegal	0.338	+28
57	Madagascar	0.330	+62
62	Mauritania	0.322	+41
64	Sudan	0.321	+36

Mini-grid (adjusted rank)			
Rank	Country	Score	Diff.
1	Uganda	0.496	+38
2	Madagascar	0.471	+50
7	Kenya	0.443	+20
9	Haiti	0.438	+65
11	Mozambique	0.426	+99
12	Mali	0.419	+26
13	Guinea	0.417	+95
14	Zambia	0.409	+63
16	Niger	0.391	+76
17	Zimbabwe	0.391	+81
19	Burkina Faso	0.389	+83
23	Namibia	0.374	+63
24	Côte d'Ivoire	0.374	+54
25	Laos	0.370	+38
30	Congo, Dem. Rep.	0.351	+24
33	Senegal	0.342	+50
34	Liberia	0.340	+86
36	Somalia	0.336	+85
37	Chad	0.332	+86
38	Ghana	0.332	+31
40	Honduras	0.329	+32
42	Eswatini	0.326	+43
43	Micronesia	0.323	+44
46	Malawi	0.319	+73
47	Pakistan	0.316	+43
48	Yemen	0.313	+40
49	Guinea-Bissau	0.313	+75
50	Ethiopia	0.310	+59
53	Benin	0.307	+58
54	Lesotho	0.306	+52
55	Rwanda	0.304	+42
57	Solomon Islands	0.293	+46
59	Sierra Leone	0.286	+66
60	Mauritania	0.286	+47
62	Syrian Arab Republic	0.283	+34
64	Burundi	0.280	+65

Off-grid (adjusted rank)			
Rank	Country	Score	Diff.
1	Zimbabwe	0.576	+54
5	Congo, Dem. Rep.	0.502	+94
8	Malawi	0.476	+85
9	Senegal	0.466	+35
11	Zambia	0.456	+51
13	Namibia	0.447	+72
14	Madagascar	0.439	+92
15	Yemen	0.432	+93
18	Burkina Faso	0.422	+83
19	Côte d'Ivoire	0.418	+29
21	Eswatini	0.412	+54
22	Ethiopia	0.409	+21
23	Syrian Arab Republic	0.409	+69
26	Chad	0.402	+89
28	Guinea	0.397	+67
31	Mali	0.383	+67
32	Guinea-Bissau	0.382	+86
33	Sierra Leone	0.382	+81
34	Lesotho	0.370	+68
35	Myanmar	0.366	+44
36	Benin	0.365	+51
39	Mozambique	0.363	+82
40	Somalia	0.362	+82
41	Liberia	0.355	+83
44	Micronesia	0.352	+39
50	Haiti	0.345	+69
53	Sudan	0.340	+58
56	Nicaragua	0.333	+22
57	Cameroon	0.332	+31
60	Togo	0.328	+50
62	Mauritania	0.325	+55
63	Papua New Guinea	0.325	+31

Comparing between the charts where enabling environment indicators for energy and development are removed independently (while also removing the independent indicators), shows that the effect of removing the development indicators is less significant than removing the energy indicators as shown in the charts below (Figure 12). Countries move an average of 8 places when the development enablers are removed, whereas they move an average of 19 places when the energy enablers are removed. The difference is particularly large between the national grid scenario with development indicators removed (average movement five places) and energy indicators removed (23 places). This does not appear to be due to weightings differences between energy and development indicators, as the average weightings of the enablers across the three scenarios are similar (41% for energy and 39% for development).

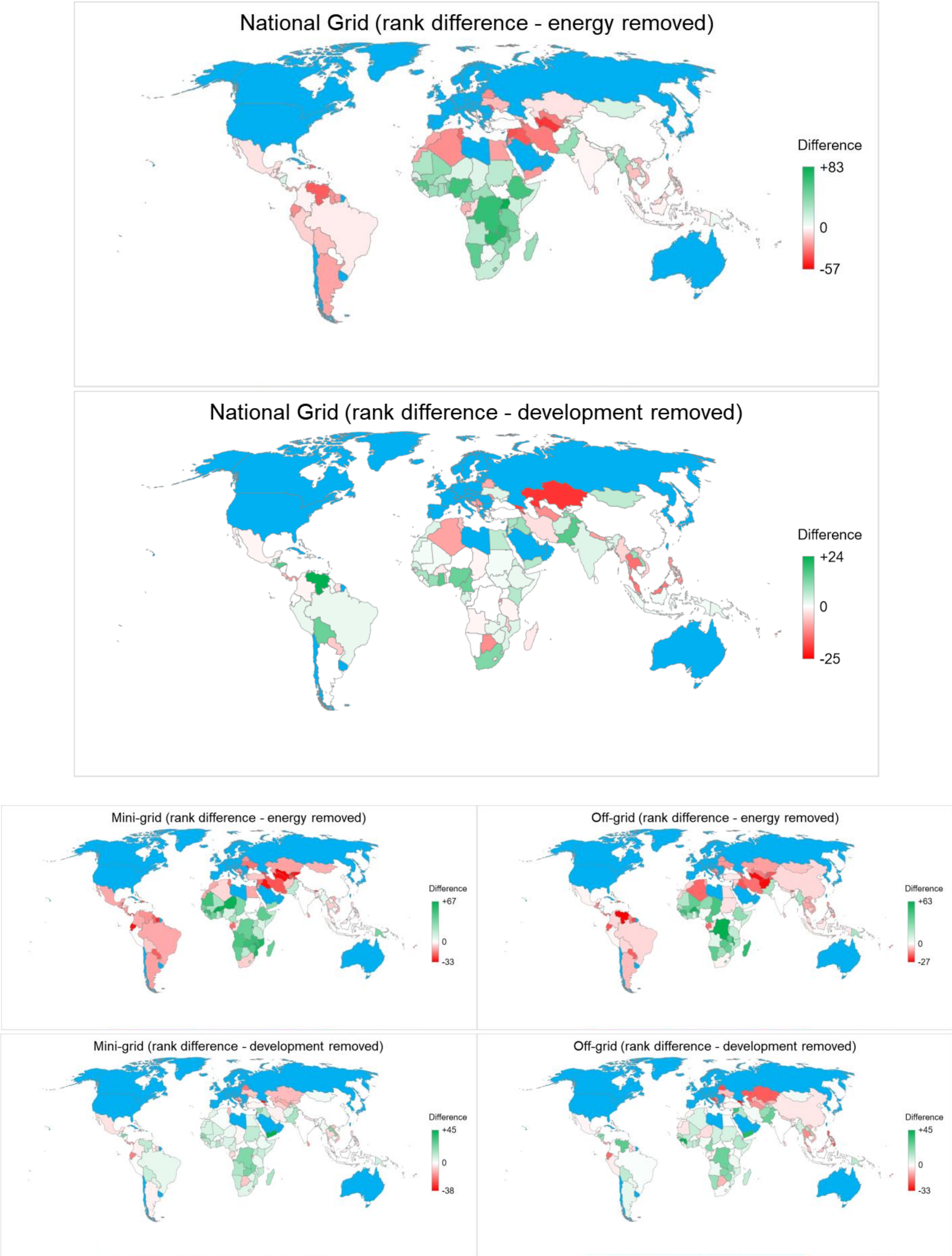

Figure 12 - Choropleths showing difference in GMA ranking for removal of development indicators and energy indicators

5.3. Negatively correlated indicators

As previously mentioned, four indicators are negatively correlated with a high GMA score. These include two key, and interrelated indicators: users of commercialised polluting fuels and HAP attributable deaths. Reducing the number of HAP attributable deaths is a strong driver for a transition towards cleaner cooking fuels; WHO estimates that 3.8 million deaths per year can be attributed to HAP [30]. The GMA score also incorporates users of commercialised polluting fuels (summing users of kerosene, charcoal and coal) as households using these fuels are exposed to the adverse health effects of cooking with them, while also paying a significant amount for them; providing some evidence of ability to pay for electricity for cooking.

5.3.1. HAP attributable deaths

As shown earlier, the GMA score was negatively correlated with HAP attributable deaths, particularly for the national grid scenario (CC of -0.58 (national grid), -0.33 (mini-grid), -0.36 (off-grid)). Therefore, although they appear to be related, there are countries where a scale up of electric cooking is viable, as well as there being a strong need for action to combat the negative effects of using cooking fuels which are damaging to human health. These countries are those furthest into the top right corner of the chart below (Figure 13) and include (across the three scenarios): Côte d'Ivoire, Nigeria, China, India, Myanmar, Nepal, Bangladesh, Laos, Bosnia and Herzegovina, Georgia and the Philippines. Countries in the bottom right corner are those with high HAP deaths and so have a pressing need for a transition to cleaner cooking fuels, but low GMA scores, so are poorly equipped to address it, these countries include (across the three scenarios): Chad, Central African Republic, Niger, Comoros, Sierra Leone, Guinea, Guinea-Bissau and Haiti.

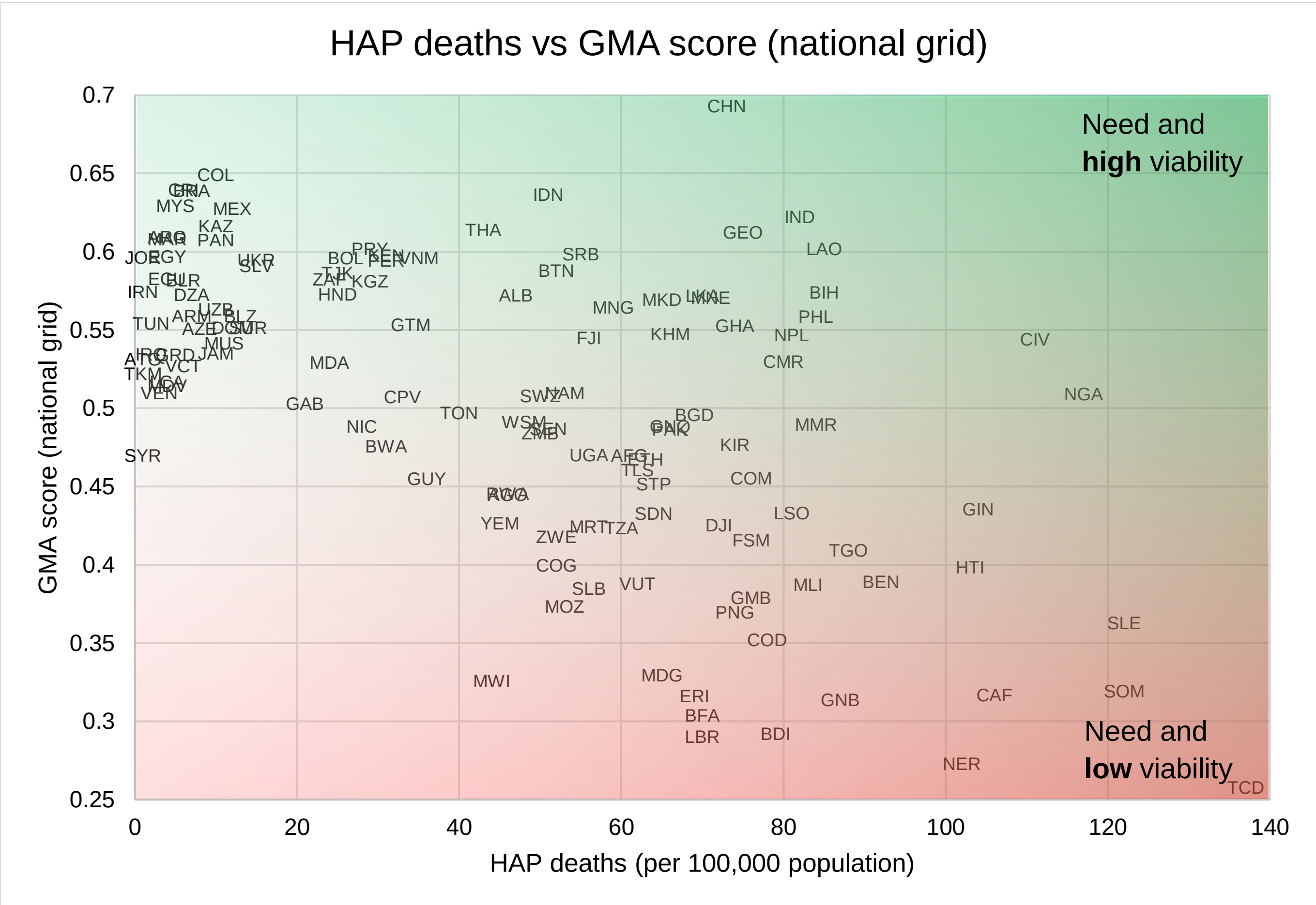

Figure 13 – Household air pollution (HAP) attributable deaths against GMA score (national grid scenario)

5.3.2. GMA scores vs cooking fuels

In countries where the use of solid fuels (defined by WHO as including charcoal, coal and biomass (wood, crop waste and dung)) is high, a transition to cleaner cooking fuels is most urgently needed, however, in the same way that HAP attributable deaths are negatively correlated with GMA score, so is users of solid fuels.

Again, there is some correlation between the GMA score and users of solid fuels (CC of -0.68 (national grid), -0.46 (mini-grid), -0.40 (off-grid)) and as such some countries present good opportunities for scale up of electric cooking, as well as having a pressing need due to large numbers of people cooking on solid fuels (see Figure 14), these include: Kenya, Laos, India, China, Sri Lanka, Ghana, Nepal, Cambodia, Côte d'Ivoire, Cameroon, Nigeria, Myanmar, Bangladesh, Tanzania, Uganda and Rwanda. However, those in pressing need of a transition, but most in need of efforts to improve its viability include: Eritrea, Burundi, Liberia, South Sudan, Central African Republic, Sierra Leone, The Gambia, Guinea-Bissau, Haiti, Chad, Somalia, Mozambique, Niger, Malawi and Burkina Faso.

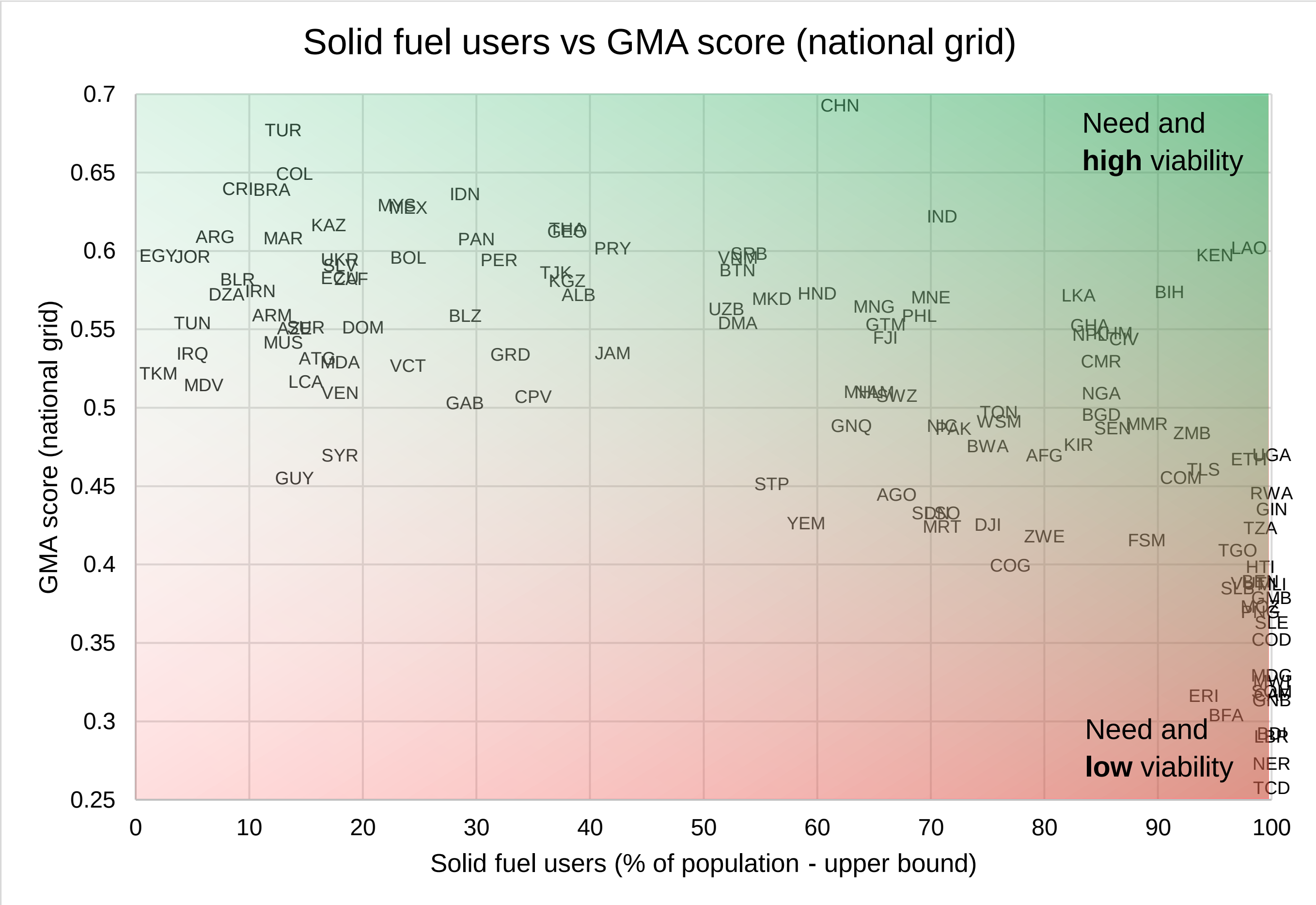

Figure 14 – Proportion of population using solid fuels against GMA score (national grid scenario)

Although to achieve universal access to clean cooking technologies as part of SDG 7, all who cook with biomass would need to transition to clean fuels. The “lowest hanging fruits” are the people who already have significant expenditures on cooking fuels (as opposed to those who gather wood, crop waste or dung for free), represented by the users of commercialised polluting fuels indicator (also moderately negatively correlated with GMA score: CC of 0.55 (national grid), 0.50 (mini-grid), 0.48 (off-grid)). Countries towards the top of the rankings with a relatively large proportion of their population using these fuels (see Figure 15) include: China, Malaysia, Thailand, Kenya, Laos, Ghana, Dominica, Grenada, Tanzania, Myanmar, Nigeria, Tanzania, Uganda and Laos.

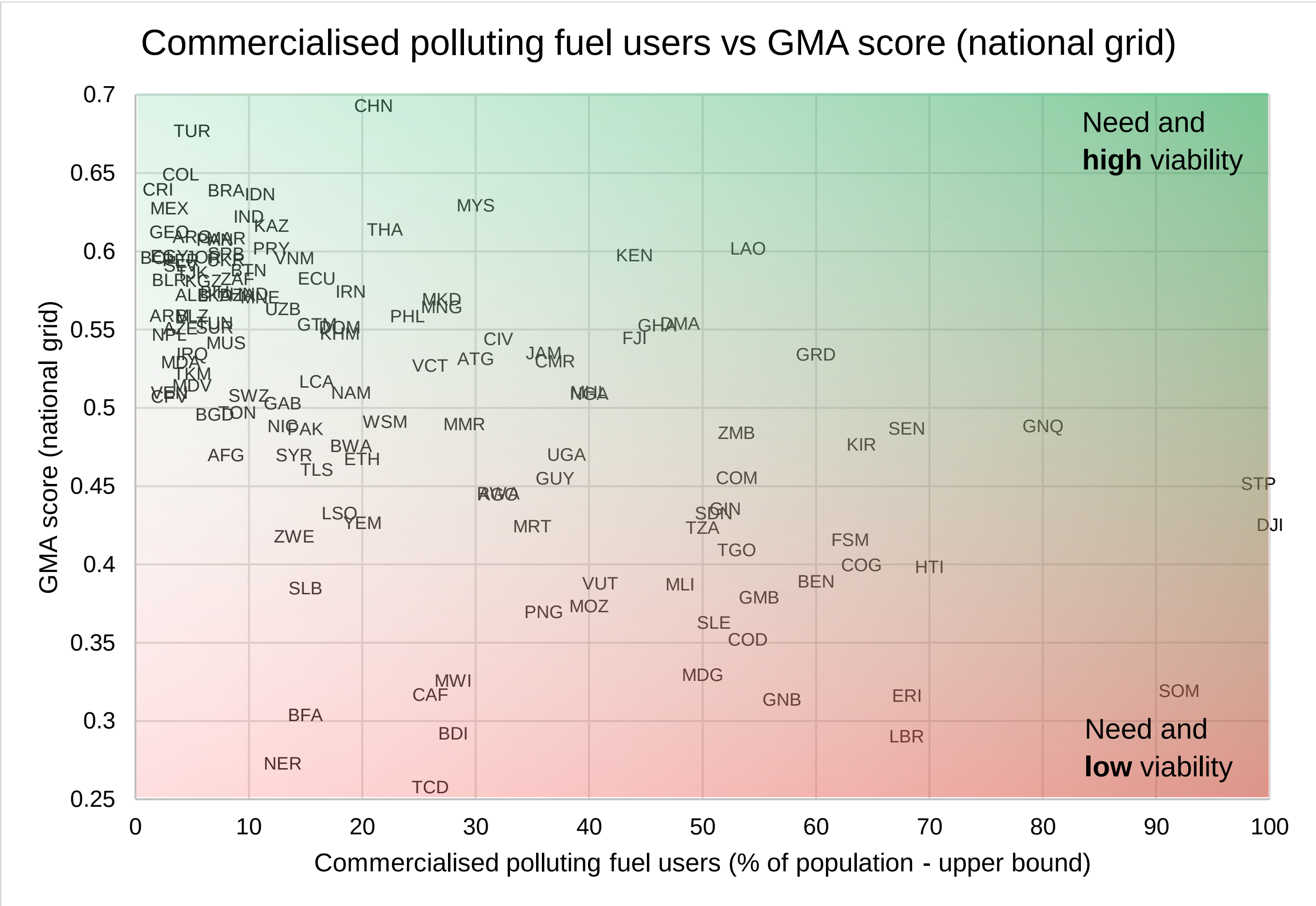

Figure 15 – Users of commercialised polluting fuels against GMA score (national grid scenario)

6. Discussion

Through bringing together a range of multi-dimensional datasets and incorporating stakeholder judgement on their relative importances, this study has created three scores and corresponding ranking lists to represent the viability of a scale up of electric cooking in the Global South. The study has also shown that energy infrastructure (in particular) and human development are key enabling factors in the viability of a scale up of electric cooking and that the countries most in need of a transition away from biomass cooking are often lacking in these areas. However, several notable exceptions have strong potential for scale up of electric cooking, as well as a pressing need to transition away from traditional fuels and as such present strong opportunities for impact by private, public and third sector actors alike.

The GMA score for the viability of scale up of national grid supported electric cooking is highest for countries with the highest levels of “development”; also described as “emerging markets”, with strong electrical infrastructure and clean fuel markets where large proportions of people are already using modern cooking fuels (including LPG and electricity). These include China, Turkey, Colombia, Brazil, Indonesia, Malaysia, Mexico, India, Thailand and Argentina. A number of other countries such as Costa Rica, Georgia, Panama, Laos, Paraguay, Serbia and Kenya also have strong viability for scale up on the national grid.

Despite many high scoring countries having strong clean cooking markets and electrical infrastructure, some of these still have large numbers of people doing some, or all their cooking on polluting fuels. Through comparing national grid GMA scores and the proportion of people cooking with biomass, the top countries with not only an opportunity but also a need for scaled up transition on national grids can be shortlisted to China, Malaysia, India, Thailand, Laos, Serbia and Kenya. These countries are where continued efforts to transition to electric cooking on the national grid is not only most viable, but also pressingly needed.

On mini-grids, the viability of a scale up of electric cooking is again topped by emerging markets with strong development indicators and electrical infrastructure including China, India, Indonesia, Peru, Malaysia, Thailand, Turkey, South Africa and Argentina. However, other countries with particularly strong mini-grid infrastructure also perform well including Nepal, Bangladesh, Myanmar, Afghanistan, Nigeria and Tanzania. However, the accuracy of the scores for the mini-grid scenario is restricted due to the available data on mini-grids only covering two thirds of countries, lacking detail on energy access tier and fuels used for cooking specifically for those connected to mini-grids.

The off-grid scenario also highlights India, Kenya, Bangladesh, Nigeria, China, Uganda, Indonesia, Sri Lanka, Nepal, Rwanda, Malaysia and Tanzania as the highest scoring, as they have strong off-grid renewables sectors and consistent development indicators. Again, the accuracy of the scores for the off-grid scenario are particularly affected by a lack of datasets on off-grid markets which adequately cover the Global South (currently available datasets only cover half of the countries in this study).

Analysis has also shown that the countries which are most in need of a transition towards modern cooking fuels – due to having large proportions of people cooking on solid fuels and/or high numbers of HAP attributable deaths – are often those where a transition to electric cooking is least viable. However, there are a number of exceptions, where countries with high GMA scores also have large proportions of people who are likely to be paying significant amounts for biomass fuels (e.g. China, Malaysia, Thailand, Laos, Kenya, Myanmar, Philippines, Nigeria, Tanzania, Uganda and Rwanda) and also where countries have high GMA scores but many who are likely to pay little or nothing for biomass (e.g. China, India, Laos, Bangladesh, Nepal, Kenya, Myanmar, Afghanistan, Vietnam, Nigeria, Serbia, Uganda, Sri Lanka, Rwanda and the Philippines) and as such will find a transition more difficult due to a lack of existing expenditure on cooking fuels.

Alongside highlighting the countries in which a scale up of electric cooking is most viable, analysis has shown that there is a group of key indicators which enable a strong GMA score which are broadly similar across the three scenarios. These enabling indicators can be organised into two sub-groups: “energy” enablers (including indicators on the strength of electricity infrastructure and clean cooking market) and “development” enablers (including human development, gender inequality, ICT adoption, logistics and business indices). For all scenarios, the Regulatory Indicators for Sustainable Energy (RISE) was also an enabler but did not fit into the energy or development sub-groups, while for the mini-grid and off-grid scenarios market size and strength as well as finance flows (aid and renewable energy related) were also enablers.

Removing these enabling indicators from the analysis shows that the viability of a scale up of electric cooking, particularly on the national grid, is most significantly restricted by having poor electricity infrastructure and weak clean fuel markets, while lower levels of development are also a hindrance but to a lesser extent. This indicates that improvements in electricity infrastructure (including access and reliability) as well as growth in clean cooking markets are key enablers in improving the viability of a scale up of electric cooking. These improvements are needed particularly in much of sub-Saharan Africa. For example, improvements in energy indicators would significantly improve the viability of scaling up electric cooking in countries such as: Uganda, Zambia and Namibia (on national grids); Madagascar, Democratic Republic of Congo and Niger (on mini-grids); Zambia and Malawi (on off-grid (standalone) systems).

Through analysis of the GMA score results it is possible to indicate relationships, trends and correlations between overall scores, groups and sub-groups of data. It is recognised that in practice the datasets are interrelated via a complex network of cause, influence and effect that are only partially captured in the measured data. For example, although the enabling indicators are separated into energy and development groups according to apparent correlations between them, they are far from independent groupings. Furthermore, a significant limitation when constructing the GMA database was the need for datasets with adequate coverage across the majority of countries in the Global South, which are particularly lacking regarding mini-grid and off-grid markets. Finally, there are a variety of important factors for which adequate datasets are not available (e.g. global cooking fuel prices) and which are particularly difficult to quantify (e.g. cultural aspects such as food preferences, device suitability and cooking practices) which could not be included, and can only be appreciated via detailed study from the national down to the individual household level.

7. Recommendations

A national grid supported transition to electric cooking (particularly when transitioning from fossil fuels e.g. LPG) needs to be coupled with decarbonisation of electricity grids.
Almost all countries with a high GMA score for the national grid scenario have very low renewable energy shares and so are likely to have carbon intensive electricity supplies. This means that for a transition to electric cooking to have the most positive impact (particularly regarding climate and the environment), it needs to be supported by increased investment in, and focus on, renewable electricity generation; often already cheaper than generation from fossil fuels.

Efforts to improve access, reliability and strength of national grid, mini-grid and off-grid electrical infrastructure must accelerate and integrate electric cooking where possible.
Some of the most influential factors as to the viability of electric cooking concern access to, and reliability of, electricity infrastructure. Although progress is being made towards universal electrification in many countries, electric cooking needs to be integrated into the planning and implementation for it to most effectively enable accelerated adoption of modern energy cooking services. Innovative solutions to cooking with electricity on mini-grid and off-grid (standalone) systems are already cost effective in some contexts and need to be developed into robust technical and business cases for electric cooking supported by these technologies. Meanwhile, continued investigation around the interface between cooking culture and the use of low-powered, efficient cooking devices such as electric pressure cookers is also essential.

Electrification needs to be coupled with accurate, up-to-date datasets on tier of access, cooking fuels and costs.
Existing data on access to electricity and cooking fuel use, which varies hugely across the Global South and strongly influences the viability of a scale up of electric cooking, still largely does not account for tiers of access (as highlighted by ESMAP [3]). Worse still is the availability of data on the size and strength of mini-grid and off-grid markets (many countries have little or no data), and there is currently minimal integration between these areas (e.g. which cooking fuels are used by mini-grid connected households vs those connected to the national grid). Given the current growth of the mini-grid and off-grid markets, and its expected acceleration in the future, improvements in such resources are needed which would provide more insight than current datasets which focus on the arbitrary rural vs urban disaggregation.

More globally complete data is needed around other cooking fuels (e.g. cooking fuel prices for charcoal, LPG and kerosene) to provide comparison with electric cooking.
The GMA does not incorporate information on other cooking fuels beyond the proportion of those using clean alternatives or commercialised polluting fuels due to a lack of datasets with adequate global coverage. For example, there is no global dataset for the cost of the other main cooking fuels (e.g. LPG, kerosene and charcoal) which has prevented the inclusion of an indicator comparing the cost of cooking with electricity and other fuels; an important factor in understanding the viability of electric cooking. Collecting such data is challenging (as experienced by this study) but a globally complete database of information on cooking fuels (as well as cooking practices and fuel stacking as below) would be hugely beneficial for actors in the clean cooking sector, as well as for future revisions to this GMA.

Contextual understanding – food preferences, cooking practices, fuel/device stacking – is an essential component around which further work is needed to most effectively accelerate the scale up electric cooking.
There is still much to be learned about the differences in energy required to cook foods on different devices, and how this varies according to the different cooking processes involved in cooking 'typical daily/weekly' menus across the world. Furthermore, important behaviours like fuel stacking are not represented by any cooking fuel datasets which cover a large number of countries, and so many still rely on collecting information on the 'main household cooking fuel'. Like the recommendations above, data gathering methodologies such as the MTF or better formulated household census questions around cooking are needed to provide more contextual understanding and better advise the sector.

Expansion of data gathering around electric cooking for RISE and others would improve opportunities.
Understanding and tracking policy developments on a global scale is challenging, but tools such as ESMAP's RISE score and BloombergNEF's Climatescope score are hugely useful in providing global insights. However, currently only RISE incorporates cooking-specific policies (a functionality available for the first time this year). Modern cooking actors would benefit from more countries being included in databases (RISE and Climatescope cover around three quarters of countries on the DAC list) and a cross-cutting policy indicator specifically for electric cooking (incorporating relevant aspects from the electricity access, renewable energy, energy-efficiency and clean cooking pillars) would be ideal.

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9. Appendices

Appendix 1

GMA indicators and sources

Indicator	Summary	Source
Users of electric cooking	% of population using electricity as primary cooking fuel (upper bound)	WHO Household Energy Database (available via email from WHO)
Users of clean alternatives (e.g. LPG, biogas)	% of population using clean alternatives as primary cooking fuel (LPG, biogas, ethanol etc) (upper bound)	WHO Household Energy Database (available via email from WHO)
Users of commercialised polluting fuels (e.g. charcoal)	% of population using kerosene, charcoal or coal (upper bound)	WHO Household Energy Database (available via email from WHO)
Unrealised potential for electric cooking	% access to electricity - % primarily cooking with electricity	WHO Household Energy Database (available via email) World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS)
Affordability of electricity (grid only)	Wealth adjusted price of electricity (GNI per capita PPP / electricity price (USD))	Electricity price from Ease of Doing Business Database GNI per capita PPP from World Bank DataBank (https://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD)
Credit rating	Sovereign Wikirating Index is a framework which evaluates the credit rating of sovereign countries/territories based on economic indicators	Wikirating (https://www.wikirating.org/wiki/List_of_countries_by_credit_rating)
Mobile money	% who used mobile money, a debit or credit card, or a mobile phone to make or receive a payment from a digital account in the past year.	World Bank Global Findex Database (https://globalfindex.worldbank.org/)
International RE finance flows	International financial flows to developing countries in support of clean energy research and development and production	ESMAP Tracking SDG 7 Energy Progress Report (https://trackingsdg7.esmap.org/downloads)
Public investment in renewables	Investment transactions for renewable energies from public financial institutions based on the project level information as collated by IRENA.	IRENA Renewable Energy Statistics https://irena.org/publications/2020/Jul/Renewable-energy-statistics-2020
Photovoltaic power potential	Takes into account solar irradiation, air temperature, terrain horizon, albedo, module tilt, configuration, shading, soiling and other factors	World Bank Global Solar Atlas (https://globalsolaratlas.info/global-pv-potential-study)
Tree cover loss	Loss of tree cover between 2017 and 2019 as % of total tree cover in 2010	Global Forest Watch (https://www.globalforestwatch.org/dashboards/global/)
ICT/internet adoption	Score based on levels of internet use and mobile and broadband (wired and wireless) subscriptions.	UN E-Government Knowledgebase (https://publicadministration.un.org/egovkb/Data-Center)
Ease of Doing Business index	Quality of environment for starting and operating a local firm	World Bank Ease of Doing Business Index (https://www.doingbusiness.org/en/data)
Regulatory Indicators for Sustainable Energy (RISE)	Strength of renewable energy favouring policies	ESMAP RISE (https://rise.esmap.org/)
Indoor Air Pollution attributable deaths	Deaths/100,000 people attributable to indoor air pollution related illnesses / causes.	WHO Global Health Observatory data repository (https://apps.who.int/gho/data/node.main.BODHOUSEHOLDAIRDTHS?lang=en)
Gender Inequality Index	Loss in potential human development due to disparity reproductive health, empowerment and the labour market.	UNDP Human Development Reports (http://hdr.undp.org/en/content/gender-inequality-index-gii)
Urban population growth	% growth in urban population compared with previous year	World Bank DataBank (https://data.worldbank.org/indicator/SP.URB.GROW)
Human Development Index (HDI)	Combines health, education and income discounting average value according to inequality	UNDP Human Development Reports (http://hdr.undp.org/en/content/inequality-adjusted-human-development-index-ihdi)
Number of displaced persons (DPs) per 1000 population	Including internally displaced, refugees etc both due to conflict and disaster	UNHCR Global Trends: Forced Displacement (https://data.humdata.org/m/dataset/unhcr-global-trends-forced-displacement-in-2019-data)
DPs using clean cooking fuels (grid)	% DPs not using biomass from "urban" and "slum" groups	Moving Energy Initiative - Energy Consumption of refugees and displaced people (https://data.humdata.org/dataset/energy-consumption-of-refugees-and-displaced-people)
DPs using clean cooking fuels (off/mini grid)	% DPs not using biomass from "rural" and "camps" groups	Moving Energy Initiative - Energy Consumption of refugees and displaced people (https://data.humdata.org/dataset/energy-consumption-of-refugees-and-displaced-people)
DPs with unrealised potential for eCook	% DPs connected to grid - % not cooking with biomass	Moving Energy Initiative - Energy Consumption of refugees and displaced people (https://data.humdata.org/dataset/energy-consumption-of-refugees-and-displaced-people)

Logistics Performance Index	Score includes: efficiency, infrastructure quality, ease, competence, track and trace, successful delivery freq.	World Bank Logistics Performance Index (https://lpi.worldbank.org/about)
Manufacturing, value added	Net output of manufacturing sector after adding up all outputs and subtracting intermediate inputs (industries in ISIC divisions 15-37)	World Bank DataBank (https://data.worldbank.org/indicator/NV.IND.MANF.ZS)
Access to electricity (all areas)	% of population with access to electricity (grid)	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS)
Access to electricity (urban)	% of urban population with access to electricity	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.UR.ZS)
Electricity access projections (grid)	Projected population connected to national grid in 2030	Global Electrification Platform (https://electrifynow.energydata.info/)
Renewable energy share	% of electricity generated from renewable sources	Our World in Data (https://ourworldindata.org/grapher/share-electricity-renewables)
Grid reliability (SAIDI * SAIFI)	Total (per year) duration of outages (in hours) / frequency of outages experienced by customers	World Bank Ease of Doing Business Database (https://www.doingbusiness.org/en/data)
Access to electricity (all areas)	% of population with access to electricity (mini-grid)	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS)
Access to electricity (rural)	% of rural population with access to electricity	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS)
Electricity access projections (mini-grid)	Projected population connected to mini-grids in 2030 (according to Global Electrification Platform)	Global Electrification Platform (https://electrifynow.energydata.info/)
Off-grid renewables capacity (mini-grid)	Total capacity of generation of electricity from off-grid renewable sources (including mini-grids and standalone off-grid)	IRENA Renewables Capacity Statistics (https://irena.org/publications/2020/Mar/Renewable-Capacity-Statistics-2020)
Number of mini-grid developers	Number of mini-grid developers in the country (planned and installed mini-grids) according to World Bank Global mini-grid Market Survey	Combined sources: ESMAP Mini-grid Database (available via email from World Bank), BNEF mini-grid asset database (https://minigrids.org/market-report-2020/), IRENA Off-grid Energy Statistics (https://www.irena.org/publications/2019/Dec/Off-grid-renewable-energy-statistics-2019)
Number of people connected to mini-grids	Number of people connected to mini-grids (planned and installed mini-grids) according to World Bank Global mini-grid Market Survey	Combined sources: ESMAP Mini-grid Database (available via email from World Bank), BNEF mini-grid asset database (https://minigrids.org/market-report-2020/), IRENA Off-grid Energy Statistics (https://www.irena.org/publications/2019/Dec/Off-grid-renewable-energy-statistics-2019)
Access to electricity (all areas)	% of population with access to electricity (off-grid)	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS)
Access to electricity (rural)	% of rural population with access to electricity	World Bank DataBank (https://data.worldbank.org/indicator/EG.ELC.ACCS.RU.ZS)
Electricity access projections (off-grid)	Projected population to standalone off-grid systems in 2030 (according to Global Electrification Platform)	Global Electrification Platform (https://electrifynow.energydata.info/)
Off-grid renewables capacity (off-grid)	Total capacity of generation of electricity from off-grid solar sources (solar lights and solar home systems)	IRENA Off-grid Renewable Capacity Statistics (https://www.irena.org/publications/2019/Dec/Off-grid-renewable-energy-statistics-2019)
Off-grid lighting/appliance customers	Off-grid solar lighting/appliances reported sold by GOGLA members, those who meet Lighting Global Quality Standards, Global LEAP or LEIA.	Combined sources: IRENA Off-grid Energy Statistics (https://www.irena.org/publications/2019/Dec/Off-grid-renewable-energy-statistics-2019) GOGLA Off-grid solar market report (https://www.gogla.org/resources/global-off-grid-solar-market-report-h2-2019-sales-and-impact-data)

Appendix 2

Bounds applied to indicators

Indicator	Lower bound	Upper bound	Reason for bounds	Other comments
Users of electric cooking	0	100	Percentage	
Users of clean alternatives	0	100	Percentage	
Users of commercialised polluting fuels	0	100	Percentage	
Unrealised potential for electric cooking	0	100	Percentage	
Affordability of electricity (grid only)	0	4126	Upper limit set at 90th percentile of global max due to outliers	
Credit rating	0	100	Percentage	
Mobile money	0	1	Percentage	
OECD aid flows	0	3241	Upper limit set at 90th percentile of global max due to outliers	
Renewable energy finance flows	0	404	Upper limit set at 90th percentile of global max due to outliers	
Photovoltaic power potential	2.51	5.38	Global max and min	
Tree cover loss	0	0.0150	Upper limit set at 90th percentile of global max due to outliers	
ICT/internet adoption	0	1	Percentage	
Ease of Doing Business index	0	100	Percentage	
Regulatory Indicators for Sustainable Energy (RISE)	0	100	Percentage	
Indoor Air Pollution attributable deaths	0	173	Global max and min	
Gender Inequality Index	0	1	Percentage	
Urban population growth	-1.58	6.00	Global max and min	
Human Development Index (HDI)	0	1	Percentage	
Number of displaced persons (DPs) per 1000	0	60.4	Upper limit set at 90th percentile of global max due to outliers	
DPs using clean cooking fuels (grid)	0	1	Percentage	
DPs using clean cooking fuels (off/mini grid)	0	1	Percentage	
DPs with unrealised potential for eCook	-0.370	1	Percentage	(negative means LPG use % higher than grid access %)
Logistics Performance Index	0	5	LPI defined max and min	
Manufacturing, value added	0	39.4	Global max for manufact %	
Access to electricity (all areas)	0	100	Percentage	
Access to electricity (urban)	0	100	Percentage	
Electricity access projections (grid)	0	100	Percentage	
Renewable energy share	0	100	Percentage	
Grid reliability (SAIDI * SAIFI)	0	4673	Upper limit set at 90th percentile of global max due to outliers	
Access to electricity (all areas)	0	100	Percentage	
Access to electricity (rural)	0	100	Percentage	
Electricity access projections (mini-grid)	0	100	Percentage	
Off-grid renewables capacity (mini-grid)	0	153	Upper limit set at 90th percentile of global max due to outliers	
Number of mini-grid developers	0	58	Upper limit set at 90th percentile of global max due to outliers	na values assumed to be 0 due to lack of coverage
Number of people connected to mini-grids	0	354490	Upper limit set at 90th percentile of global max due to outliers	na values assumed to be 0 due to lack of coverage
Access to electricity (all areas)	0	100	Percentage	
Access to electricity (rural)	0	100	Percentage	
Electricity access projections (off-grid)	0	100	Percentage	
Off-grid renewables capacity (off-grid)	0	10.4	Upper limit set at 90th percentile of global max due to outliers	na values assumed to be 0 due to lack of coverage
Off-grid lighting/appliance customers	0	1907200	Upper limit set at 90th percentile of global max due to outliers	na values assumed to be 0 due to lack of coverage

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Appendix 3

Full list of country scores and rankings for national grid, mini-grid and off-grid (standalone scenarios)

National Grid

Rank	Country	Score
1	China	0.693
2	Turkey	0.677
3	Colombia	0.650
4	Costa Rica	0.640
5	Brazil	0.639
6	Indonesia	0.637
7	Malaysia	0.630
8	Mexico	0.628
9	India	0.623
10	Kazakhstan	0.617
11	Thailand	0.614
12	Georgia	0.613
13	Argentina	0.610
14	Morocco	0.609
15	Panama	0.608
16	Laos	0.602
17	Paraguay	0.602
18	Serbia	0.599
19	Kenya	0.598
20	Egypt	0.597
21	Jordan	0.597
22	Bolivia	0.596
23	Vietnam	0.596
24	Ukraine	0.595
25	Peru	0.595
26	El Salvador	0.591
27	Bhutan	0.588
28	Tajikistan	0.587
29	Ecuador	0.583
30	South Africa	0.583
31	Belarus	0.582
32	Kyrgyzstan	0.582
33	Iran	0.575
34	Bosnia and Herzegovina	0.574
35	Honduras	0.573
36	Algeria	0.573
37	Albania	0.573
38	Sri Lanka	0.572
39	Montenegro	0.571
40	North Macedonia	0.570
41	Mongolia	0.565
42	Uzbekistan	0.564
43	Armenia	0.559
44	Belize	0.559
45	Philippines	0.559
46	Tunisia	0.555
47	Dominica	0.554
48	Guatemala	0.554
49	Ghana	0.553
50	Dominican Republic	0.552
51	Suriname	0.552
52	Azerbaijan	0.551
53	Cambodia	0.548
54	Nepal	0.547
55	Fiji	0.545
56	Côte d'Ivoire	0.544
57	Mauritius	0.542
58	Jamaica	0.535
59	Iraq	0.535
60	Grenada	0.535
61	Antigua and Barbuda	0.532
62	Cameroon	0.530
63	Moldova	0.529
64	St. Vinc. and the Gren.	0.527
65	Turkmenistan	0.522
66	Saint Lucia	0.517
67	Maldives	0.515

Mini-grid

Rank	Country	Score
1	China	0.665
2	India	0.634
3	Indonesia	0.610
4	Peru	0.586
5	Malaysia	0.578
6	Algeria	0.553
7	Nepal	0.537
8	Bangladesh	0.528
9	Philippines	0.526
10	Myanmar	0.520
11	Thailand	0.518
12	Turkey	0.514
13	Kazakhstan	0.500
14	South Africa	0.500
15	Afghanistan	0.495
16	Vietnam	0.487
17	Argentina	0.480
18	Nigeria	0.478
19	Serbia	0.476
20	Belarus	0.473
21	North Macedonia	0.472
22	Mexico	0.471
23	Tanzania	0.465
24	Bolivia	0.463
25	Egypt	0.462
26	Brazil	0.461
27	Kenya	0.461
28	Venezuela	0.459
29	Morocco	0.458
30	Costa Rica	0.458
31	Cambodia	0.451
32	Colombia	0.450
33	Bosnia and Herzegovina	0.445
34	Maldives	0.445
35	Jordan	0.444
36	Ukraine	0.435
37	Mongolia	0.434
38	Mali	0.429
39	Uganda	0.427
40	Armenia	0.426
41	Tunisia	0.425
42	Panama	0.422
43	Cameroon	0.422
44	Dominican Republic	0.420
45	Montenegro	0.419
46	Mauritius	0.419
47	Bhutan	0.418
48	Azerbaijan	0.417
49	Albania	0.417
50	Iran	0.415
51	Tajikistan	0.413
52	Madagascar	0.411
53	El Salvador	0.410
54	Congo, Dem. Rep.	0.410
55	Georgia	0.407
56	Dominica	0.405
57	Antigua and Barbuda	0.405
58	Uzbekistan	0.404
59	Paraguay	0.404
60	Grenada	0.402
61	Cabo Verde	0.402
62	Turkmenistan	0.401
63	Laos	0.401
64	Jamaica	0.400
65	Ecuador	0.399
66	Kyrgyzstan	0.396
67	Sri Lanka	0.396

Off-grid (standalone)

Rank	Country	Score
1	India	0.635
2	Kenya	0.595
3	Morocco	0.575
4	Bangladesh	0.574
5	Nigeria	0.557
6	China	0.555
7	Uganda	0.551
8	South Africa	0.546
9	Jordan	0.531
10	Indonesia	0.527
11	Turkey	0.527
12	Egypt	0.506
13	Mexico	0.505
14	Brazil	0.501
15	Sri Lanka	0.497
16	Nepal	0.497
17	Rwanda	0.491
18	Colombia	0.490
19	Malaysia	0.489
20	Costa Rica	0.477
21	Mongolia	0.477
22	Argentina	0.476
23	Tanzania	0.471
24	Thailand	0.467
25	Tunisia	0.466
26	Bolivia	0.462
27	Ukraine	0.457
28	Belarus	0.454
29	Laos	0.454
30	Serbia	0.454
31	Peru	0.453
32	Vietnam	0.452
33	Ghana	0.450
34	Kazakhstan	0.447
35	North Macedonia	0.440
36	El Salvador	0.439
37	Algeria	0.436
38	Panama	0.434
39	Mauritius	0.432
40	Philippines	0.432
41	Paraguay	0.431
42	Cambodia	0.430
43	Ethiopia	0.428
44	Senegal	0.427
45	Dominican Republic	0.424
46	Iran	0.424
47	Dominica	0.423
48	Côte d'Ivoire	0.423
49	Montenegro	0.422
50	Georgia	0.421
51	Honduras	0.420
52	Bosnia and Herzegovina	0.417
53	Antigua and Barbuda	0.417
54	Uzbekistan	0.416
55	Zimbabwe	0.415
56	Grenada	0.409
57	Guatemala	0.408
58	Tajikistan	0.406
59	Jamaica	0.404
60	Moldova	0.403
61	Armenia	0.403
62	Zambia	0.402
63	Pakistan	0.401
64	Lebanon	0.399
65	Saint Lucia	0.398
66	Iraq	0.398
67	Belize	0.397

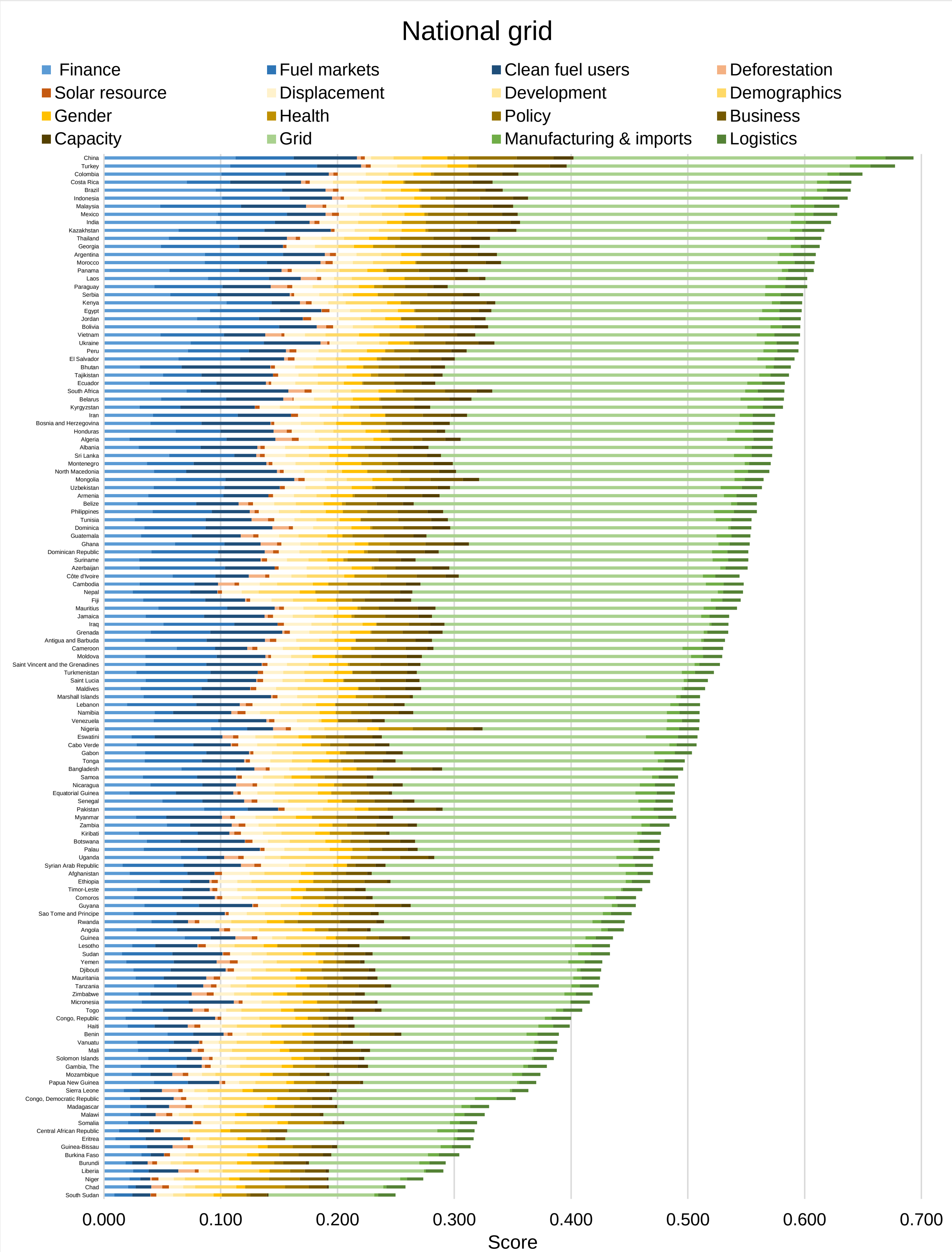
68	Marshall Islands	0.510
69	Lebanon	0.510
70	Namibia	0.510
71	Venezuela	0.510
72	Nigeria	0.510
73	Eswatini	0.508
74	Cabo Verde	0.508
75	Gabon	0.503
76	Tonga	0.497
77	Bangladesh	0.496
78	Samoa	0.492
79	Myanmar	0.490
80	Nicaragua	0.489
81	Equatorial Guinea	0.489
82	Senegal	0.487
83	Pakistan	0.487
84	Zambia	0.484
85	Kiribati	0.477
86	Botswana	0.476
87	Palau	0.476
88	Uganda	0.470
89	Syrian Arab Republic	0.470
90	Afghanistan	0.470
91	Ethiopia	0.468
92	Timor-Leste	0.461
93	Comoros	0.456
94	Guyana	0.456
95	Sao Tome and Principe	0.452
96	Rwanda	0.446
97	Angola	0.445
98	Guinea	0.436
99	Lesotho	0.433
100	Sudan	0.433
101	Yemen	0.427
102	Djibouti	0.426
103	Mauritania	0.425
104	Tanzania	0.424
105	Zimbabwe	0.418
106	Micronesia	0.416
107	Togo	0.410
108	Congo, Republic	0.400
109	Haiti	0.399
110	Benin	0.390
111	Vanuatu	0.388
112	Mali	0.388
113	Solomon Islands	0.385
114	Gambia, The	0.379
115	Mozambique	0.374
116	Papua New Guinea	0.370
117	Sierra Leone	0.363
118	Congo, Dem. Rep.	0.353
119	Madagascar	0.330
120	Malawi	0.326
121	Somalia	0.320
122	Central African Republic	0.317
123	Eritrea	0.317
124	Guinea-Bissau	0.314
125	Burkina Faso	0.304
126	Burundi	0.293
127	Liberia	0.291
128	Niger	0.273
129	Chad	0.258
130	South Sudan	0.250

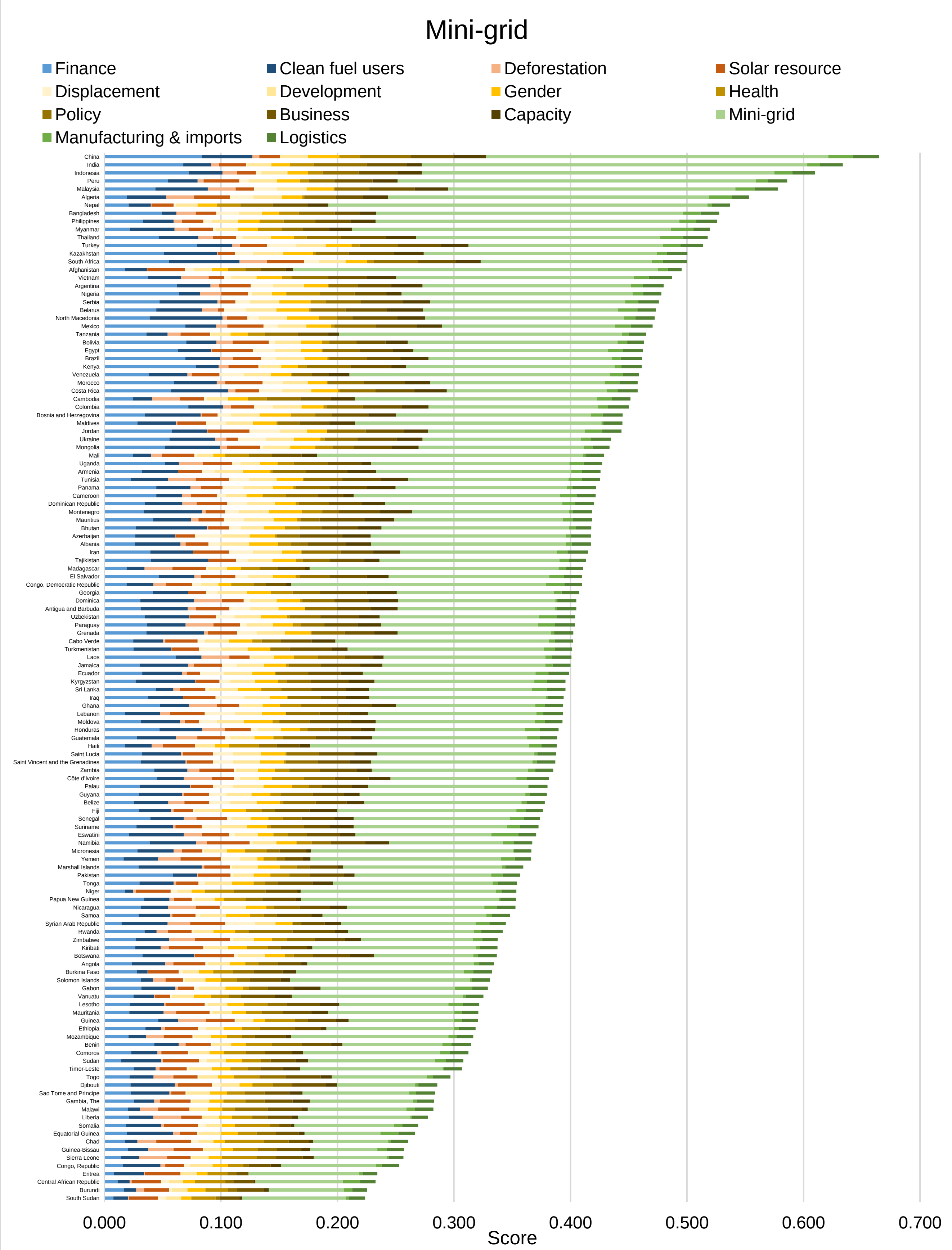
68	Iraq	0.394
69	Ghana	0.394
70	Lebanon	0.394
71	Moldova	0.393
72	Honduras	0.390
73	Guatemala	0.389
74	Haiti	0.388
75	Saint Lucia	0.388
76	St. Vinc. and the Gren.	0.387
77	Zambia	0.385
78	Côte d'Ivoire	0.382
79	Palau	0.380
80	Guyana	0.380
81	Belize	0.378
82	Fiji	0.376
83	Senegal	0.374
84	Suriname	0.372
85	Eswatini	0.371
86	Namibia	0.367
87	Micronesia	0.366
88	Yemen	0.366
89	Marshall Islands	0.360
90	Pakistan	0.357
91	Tonga	0.354
92	Niger	0.354
93	Papua New Guinea	0.353
94	Nicaragua	0.353
95	Samoa	0.348
96	Syrian Arab Republic	0.344
97	Rwanda	0.342
98	Zimbabwe	0.338
99	Kiribati	0.337
100	Botswana	0.337
101	Angola	0.334
102	Burkina Faso	0.333
103	Solomon Islands	0.331
104	Gabon	0.329
105	Vanuatu	0.325
106	Lesotho	0.322
107	Mauritania	0.321
108	Guinea	0.321
109	Ethiopia	0.319
110	Mozambique	0.317
111	Benin	0.315
112	Comoros	0.312
113	Sudan	0.308
114	Timor-Leste	0.307
115	Togo	0.297
116	Djibouti	0.286
117	Sao Tome and Principe	0.284
118	Gambia, The	0.283
119	Malawi	0.282
120	Liberia	0.278
121	Somalia	0.269
122	Equatorial Guinea	0.267
123	Chad	0.261
124	Guinea-Bissau	0.257
125	Sierra Leone	0.257
126	Congo, Republic	0.253
127	Eritrea	0.234
128	Central African Republic	0.233
129	Burundi	0.226
130	South Sudan	0.224

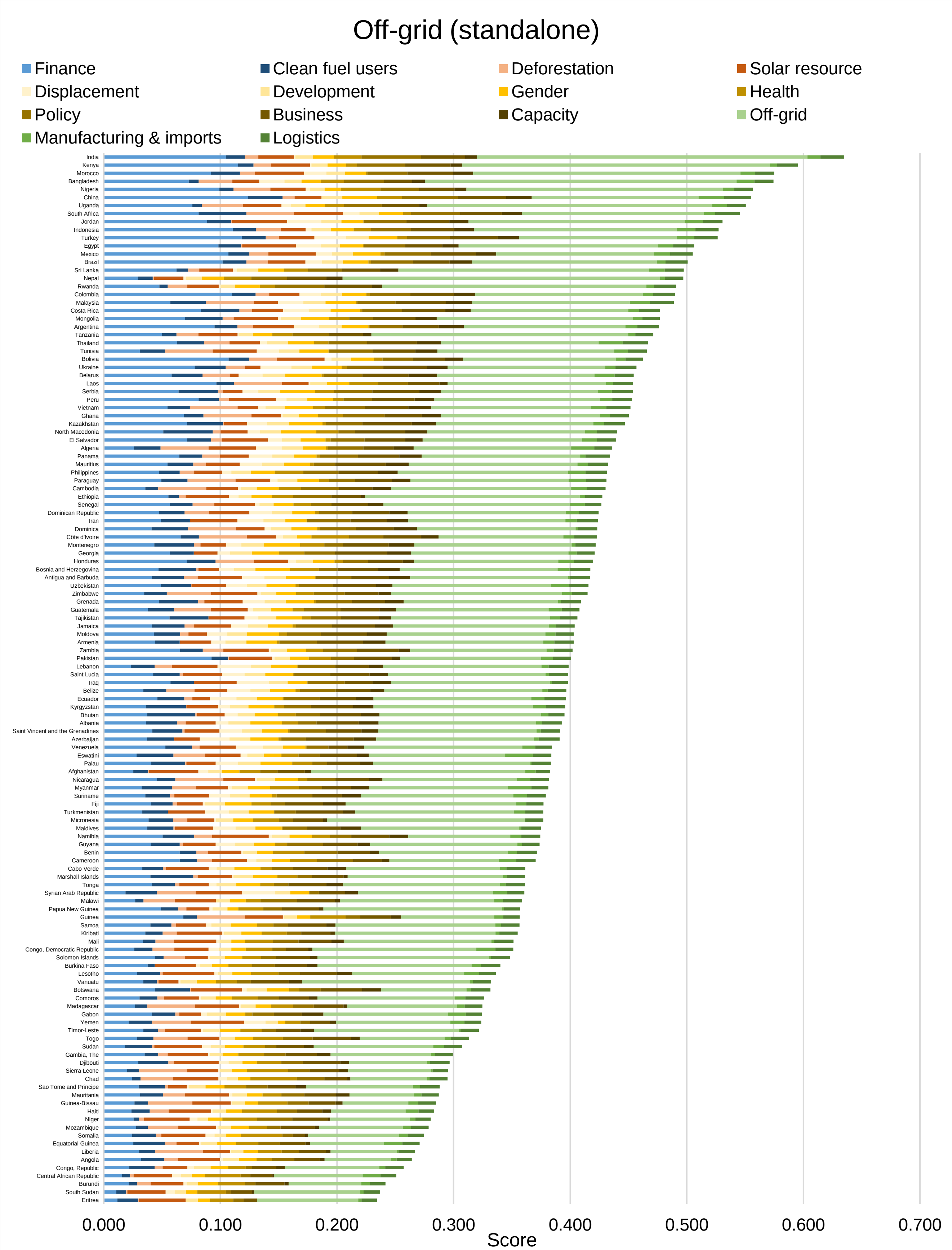
68	Ecuador	0.396
69	Kyrgyzstan	0.396
70	Bhutan	0.395
71	Albania	0.393
72	St. Vinc. and the Gren.	0.391
73	Azerbaijan	0.391
74	Venezuela	0.384
75	Eswatini	0.384
76	Palau	0.383
77	Afghanistan	0.383
78	Nicaragua	0.382
79	Myanmar	0.381
80	Suriname	0.379
81	Fiji	0.377
82	Turkmenistan	0.377
83	Micronesia	0.377
84	Maldives	0.375
85	Namibia	0.374
86	Guyana	0.374
87	Benin	0.372
88	Cameroon	0.370
89	Cabo Verde	0.361
90	Marshall Islands	0.361
91	Tonga	0.361
92	Syrian Arab Republic	0.361
93	Malawi	0.359
94	Papua New Guinea	0.357
95	Guinea	0.357
96	Samoa	0.356
97	Kiribati	0.355
98	Mali	0.351
99	Congo, Dem. Rep.	0.351
100	Solomon Islands	0.348
101	Burkina Faso	0.340
102	Lesotho	0.336
103	Vanuatu	0.332
104	Botswana	0.332
105	Comoros	0.326
106	Madagascar	0.325
107	Gabon	0.324
108	Yemen	0.324
109	Timor-Leste	0.322
110	Togo	0.313
111	Sudan	0.307
112	Gambia, The	0.299
113	Djibouti	0.297
114	Sierra Leone	0.295
115	Chad	0.295
116	Sao Tome and Principe	0.288
117	Mauritania	0.287
118	Guinea-Bissau	0.285
119	Haiti	0.283
120	Niger	0.280
121	Mozambique	0.279
122	Somalia	0.275
123	Equatorial Guinea	0.271
124	Liberia	0.267
125	Angola	0.264
126	Congo, Republic	0.257
127	Central African Republic	0.251
128	Burundi	0.242
129	South Sudan	0.237
130	Eritrea	0.234

Appendix 4

Charts showing sub-indicator scores for each scenario.




Mini-grid
Finance
Clean fuel users
Deforestation
Solar resource
Displacement
Development
Gender
Health
Policy
Business
Capacity
Mini-grid
Manufacturing & imports
Logistics
China
India
Indonesia
Peru
Malaysia
Algeria
Nepal
Bangladesh
Philippines
Myanmar
Thailand
Turkey
Kazakhstan
South Africa
Afghanistan
Vietnam
Argentina
Nigeria
Serbia
Belarus
North Macedonia
Mexico
Tanzania
Bolivia
Egypt
Brazil
Kenya
Venezuela
Morocco
Costa Rica
Cambodia
Colombia
Bosnia and Herzegovina
Maldives
Jordan
Ukraine
Mongolia
Mali
Uganda
Armenia
Tunisia
Panama
Cameroon
Dominican Republic
Montenegro
Mauritius
Bhutan
Azerbaijan
Albania
Iran
Tajikistan
Madagascar
El Salvador
Congo, Democratic Republic
Georgia
Dominica
Antigua and Barbuda
Uzbekistan
Paraguay
Grenada
Cabo Verde
Turkmenistan
Laos
Jamaica
Ecuador
Kyrgyzstan
Sri Lanka
Iraq
Ghana
Lebanon
Moldova
Honduras
Guatemala
Haiti
Saint Lucia
Saint Vincent and the Grenadines
Zambia
Côte d'Ivoire
Palau
Guyana
Belize
Fiji
Senegal
Suriname
Eswatini
Namibia
Micronesia
Yemen
Marshall Islands
Pakistan
Tonga
Niger
Papua New Guinea
Nicaragua
Samoa
Syrian Arab Republic
Rwanda
Zimbabwe
Kiribati
Botswana
Angola
Burkina Faso
Solomon Islands
Gabon
Vanuatu
Lesotho
Mauritania
Guinea
Ethiopia
Mozambique
Benin
Comoros
Sudan
Timor-Leste
Togo
Djibouti
Sao Tome and Principe
Gambia, The
Malawi
Liberia
Somalia
Equatorial Guinea
Chad
Guinea-Bissau
Sierra Leone
Congo, Republic
Eritrea
Central African Republic
Burundi
South Sudan
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
Score



Off-grid (standalone)
Finance
Clean fuel users
Deforestation
Solar resource
Displacement
Development
Gender
Health
Policy
Business
Capacity
Off-grid
Manufacturing & imports
Logistics
India
Kenya
Morocco
Bangladesh
Nigeria
China
Uganda
South Africa
Jordan
Indonesia
Turkey
Egypt
Mexico
Brazil
Sri Lanka
Nepal
Rwanda
Colombia
Malaysia
Costa Rica
Mongolia
Argentina
Tanzania
Thailand
Tunisia
Bolivia
Ukraine
Belarus
Laos
Serbia
Peru
Vietnam
Ghana
Kazakhstan
North Macedonia
El Salvador
Algeria
Panama
Mauritius
Philippines
Paraguay
Cambodia
Ethiopia
Senegal
Dominican Republic
Iran
Dominica
Côte d'Ivoire
Montenegro
Georgia
Honduras
Bosnia and Herzegovina
Antigua and Barbuda
Uzbekistan
Zimbabwe
Grenada
Guatemala
Tajikistan
Jamaica
Moldova
Armenia
Zambia
Pakistan
Lebanon
Saint Lucia
Iraq
Belize
Ecuador
Kyrgyzstan
Bhutan
Albania
Saint Vincent and the Grenadines
Azerbaijan
Venezuela
Eswatini
Palau
Afghanistan
Nicaragua
Myanmar
Suriname
Fiji
Turkmenistan
Micronesia
Maldives
Namibia
Guyana
Benin
Cameroon
Cabo Verde
Marshall Islands
Tonga
Syrian Arab Republic
Malawi
Papua New Guinea
Guinea
Samoa
Kiribati
Mali
Congo, Democratic Republic
Solomon Islands
Burkina Faso
Lesotho
Vanuatu
Botswana
Comoros
Madagascar
Gabon
Yemen
Timor-Leste
Togo
Sudan
Gambia, The
Djibouti
Sierra Leone
Chad
Sao Tome and Principe
Mauritania
Guinea-Bissau
Haiti
Niger
Mozambique
Somalia
Equatorial Guinea
Liberia
Angola
Congo, Republic
Central African Republic
Burundi
South Sudan
Eritrea
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
Score

Appendix 5

Inter-indicator correlation analysis.

National grid scenario

ID	Indicator	Correlation coefficient (CC)															
1	Unrealised potential for electric cooking	1.00	0.67	0.61	0.66	0.77	0.85	0.53	0.48	0.32	0.37	0.55	0.49	0.70	0.34	0.34	0.69
2	Users of clean alternatives (e.g. LPG, biogas)	0.67	1.00	0.91	0.74	0.73	0.82	0.59	0.40	0.48	0.40	0.75	0.69	0.84	0.61	0.35	0.76
3	DPs using clean cooking fuels (grid)	0.61	0.91	1.00	0.72	0.68	0.76	0.57	0.38	0.49	0.30	0.68	0.59	0.77	0.54	0.33	0.72
4	Electricity access projections (grid)	0.66	0.74	0.72	1.00	0.72	0.81	0.51	0.43	0.43	0.42	0.69	0.62	0.75	0.46	0.40	0.79
5	Access to electricity (urban)	0.77	0.73	0.68	0.72	1.00	0.90	0.63	0.52	0.47	0.41	0.67	0.65	0.77	0.43	0.35	0.83
6	Access to electricity (all areas (G))	0.85	0.82	0.76	0.81	0.90	1.00	0.66	0.58	0.50	0.45	0.73	0.72	0.87	0.49	0.35	0.86
7	Grid reliability (SAIDI * SAIFI)	0.53	0.59	0.57	0.51	0.63	0.66	1.00	0.47	0.53	0.44	0.63	0.59	0.66	0.43	0.38	0.74
8	Credit rating	0.48	0.40	0.38	0.43	0.52	0.58	0.47	1.00	0.64	0.54	0.56	0.60	0.65	0.24	0.34	0.58
9	Ease of Doing Business index	0.32	0.48	0.49	0.43	0.47	0.50	0.53	0.64	1.00	0.61	0.69	0.69	0.63	0.42	0.55	0.67
10	Logistics Performance Index	0.37	0.40	0.30	0.42	0.41	0.45	0.44	0.54	0.61	1.00	0.57	0.50	0.56	0.32	0.62	0.64
11	ICT/internet adoption	0.55	0.75	0.68	0.69	0.67	0.73	0.63	0.56	0.69	0.57	1.00	0.77	0.83	0.58	0.49	0.80
12	Gender Inequality Index	0.49	0.69	0.59	0.62	0.65	0.72	0.59	0.60	0.69	0.50	0.77	1.00	0.86	0.52	0.37	0.72
13	Human Development Index (HDI)	0.70	0.84	0.77	0.75	0.77	0.87	0.66	0.65	0.63	0.56	0.83	0.86	1.00	0.61	0.42	0.83
14	Affordability of electricity (grid only)	0.34	0.61	0.54	0.46	0.43	0.49	0.43	0.24	0.42	0.32	0.58	0.52	0.61	1.00	0.25	0.55
15	Regulatory Indicators for Sustainable Energy (RISE)	0.34	0.35	0.33	0.40	0.35	0.35	0.38	0.34	0.55	0.62	0.49	0.37	0.42	0.25	1.00	0.61
16	**National grid scenario score**	0.69	0.76	0.72	0.79	0.83	0.86	0.74	0.58	0.67	0.64	0.80	0.72	0.83	0.55	0.61	1.00
	ID:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**16**

Mini-grid scenario

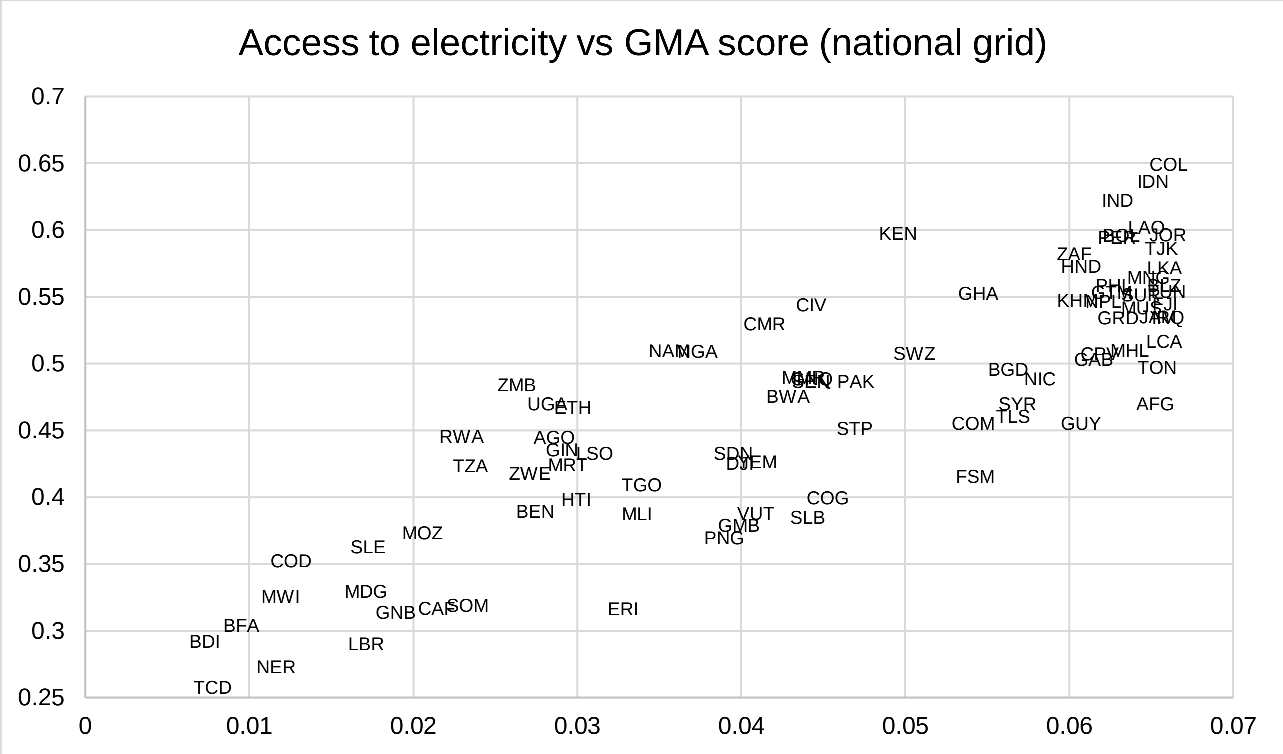
ID	Indicator	Correlation coefficient (CC)												
1	Users of clean alternatives (e.g. LPG, biogas)	1.00	0.82	0.79	0.48	0.40	0.40	0.75	0.69	0.84	0.35	0.16	-0.18	0.51
2	Access to electricity (all areas (MG))	0.82	1.00	0.96	0.50	0.45	0.58	0.73	0.72	0.87	0.35	0.14	-0.17	0.59
3	Access to electricity (rural (MG))	0.79	0.96	1.00	0.52	0.47	0.60	0.71	0.74	0.84	0.37	0.18	-0.19	0.60
4	Ease of Doing Business index	0.48	0.50	0.52	1.00	0.61	0.64	0.69	0.69	0.63	0.55	0.22	-0.14	0.55
5	Logistics Performance Index	0.40	0.45	0.47	0.61	1.00	0.54	0.57	0.50	0.56	0.62	0.31	-0.02	0.60
6	Credit rating	0.40	0.58	0.60	0.64	0.54	1.00	0.56	0.60	0.65	0.34	0.21	-0.06	0.50
7	ICT/internet adoption	0.75	0.73	0.71	0.69	0.57	0.56	1.00	0.77	0.83	0.49	0.19	-0.11	0.63
8	Gender Inequality Index	0.69	0.72	0.74	0.69	0.50	0.60	0.77	1.00	0.86	0.37	0.14	-0.16	0.54
9	Human Development Index (HDI)	0.84	0.87	0.84	0.63	0.56	0.65	0.83	0.86	1.00	0.42	0.16	-0.17	0.59
10	Regulatory Indicators for Sustainable Energy (RISE)	0.35	0.35	0.37	0.55	0.62	0.34	0.49	0.37	0.42	1.00	0.25	0.14	0.63
11	Off-grid renewables capacity (MG)	0.16	0.14	0.18	0.22	0.31	0.21	0.19	0.14	0.16	0.25	1.00	0.42	0.64
12	Number of people connected to mini-grids	-0.18	-0.17	-0.19	-0.14	-0.02	-0.06	-0.11	-0.16	-0.17	0.14	0.42	1.00	0.48
13	**Mini-grid scenario score**	0.51	0.59	0.60	0.55	0.60	0.50	0.63	0.54	0.59	0.63	0.64	0.48	1.00
	ID:	1	2	3	4	5	6	7	8	9	10	11	12	**13**

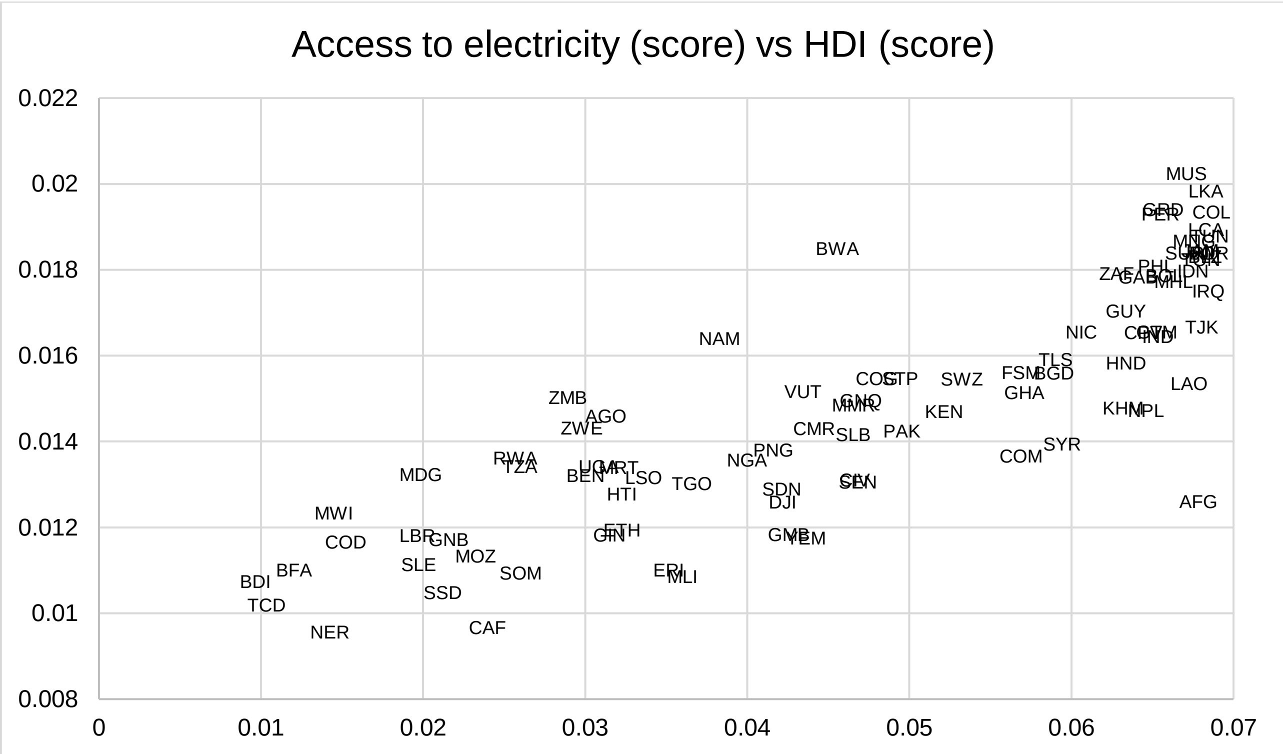
Off-grid standalone scenario

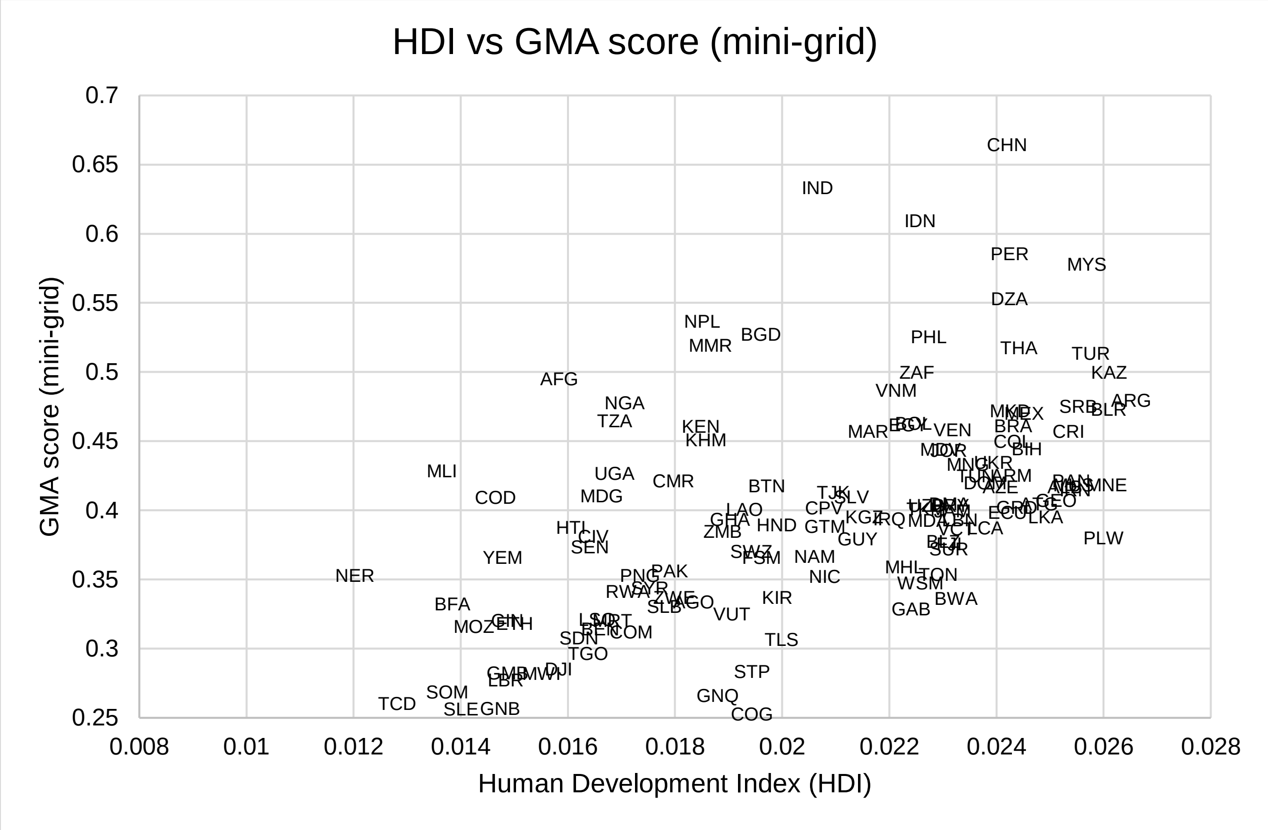
ID	Indicator	Correlation coefficient (CC)												
1	Access to electricity (all areas (S))	1.00	0.96	0.50	0.45	0.73	0.72	0.87	0.35	-0.08	0.58	0.16	0.20	0.54
2	Access to electricity (rural (S))	0.96	1.00	0.52	0.47	0.71	0.74	0.84	0.37	-0.05	0.60	0.15	0.18	0.58
3	Ease of Doing Business index	0.50	0.52	1.00	0.61	0.69	0.69	0.63	0.55	0.13	0.64	0.25	0.26	0.63
4	Logistics Performance Index	0.45	0.47	0.61	1.00	0.57	0.50	0.56	0.62	0.11	0.54	0.39	0.41	0.64
5	ICT/internet adoption	0.73	0.71	0.69	0.57	1.00	0.77	0.83	0.49	-0.07	0.56	0.16	0.18	0.58
6	Gender Inequality Index	0.72	0.74	0.69	0.50	0.77	1.00	0.86	0.37	-0.09	0.60	0.07	0.07	0.49
7	Human Development Index (HDI)	0.87	0.84	0.63	0.56	0.83	0.86	1.00	0.42	-0.11	0.65	0.15	0.16	0.55
8	Regulatory Indicators for Sustainable Energy (RISE)	0.35	0.37	0.55	0.62	0.49	0.37	0.42	1.00	0.40	0.34	0.52	0.51	0.78
9	Off-grid renewables capacity (S)	-0.08	-0.05	0.13	0.11	-0.07	-0.09	-0.11	0.40	1.00	0.05	0.35	0.36	0.58
10	Credit rating	0.58	0.60	0.64	0.54	0.56	0.60	0.65	0.34	0.05	1.00	0.07	0.12	0.48
11	OECD aid flows	0.16	0.15	0.25	0.39	0.16	0.07	0.15	0.52	0.35	0.07	1.00	0.86	0.64
12	Renewable energy finance flows	0.20	0.18	0.26	0.41	0.18	0.07	0.16	0.51	0.36	0.12	0.86	1.00	0.64
13	**Off-grid (standalone) scenario score**	0.54	0.58	0.63	0.64	0.58	0.49	0.55	0.78	0.58	0.48	0.64	0.64	1.00
	ID:	1	2	3	4	5	6	7	8	9	10	11	12	**13**

Appendix 6

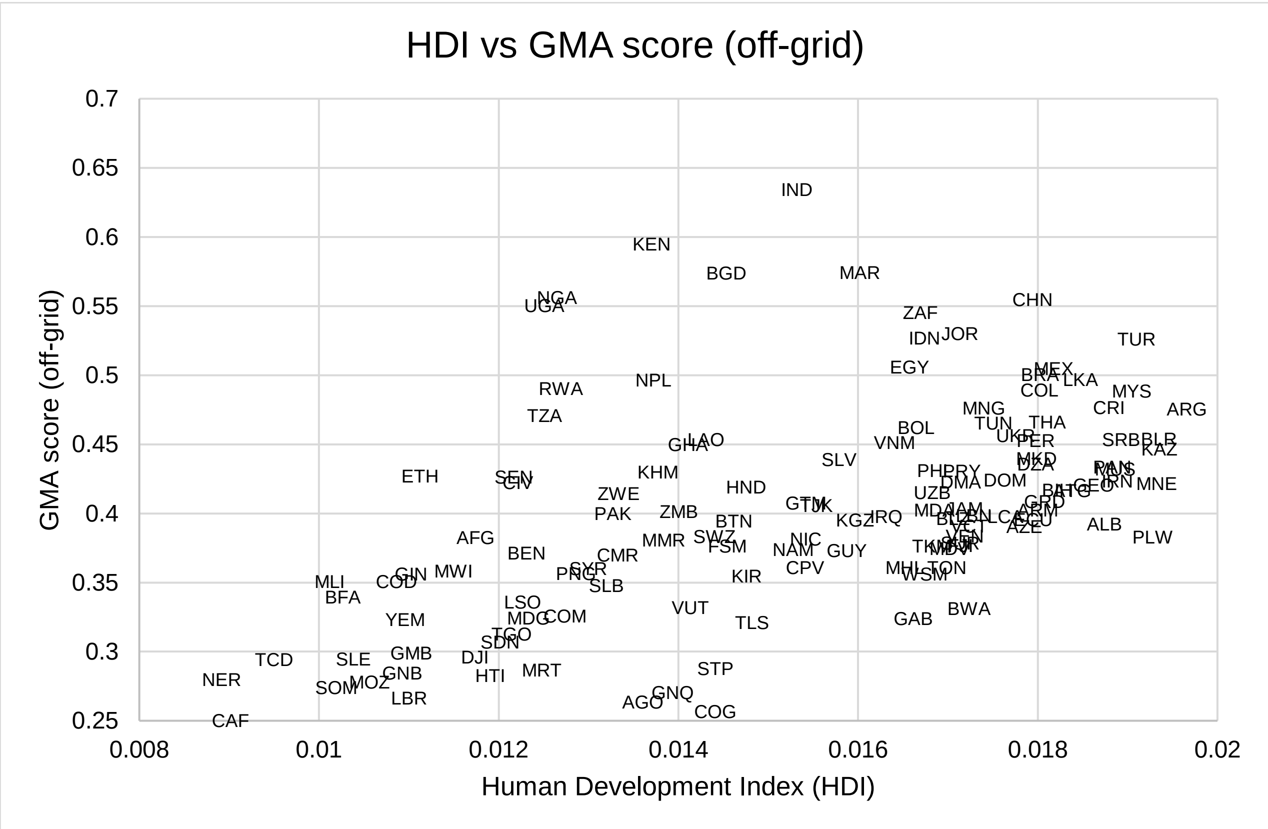
Charts showing the relationship between Access to electricity, HDI and GMA score (in addition to chart in section 4.4)







HDI vs GMA score (mini-grid)
GMA score (mini-grid)
Human Development Index (HDI)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.008
0.01
0.012
0.014
0.016
0.018
0.02
0.022
0.024
0.026
0.028
CHN
IND
IDN
PER
MYS
DZA
NPL
BGD
MMR
PHL
THA
TUR
AFG
ZAF
KAZ
VNM
NGA
TZA
ARG
CRI
KEN
KHM
MLI
COD
UGA
MDG
CMR
BTN
NER
YEM
BFA
PLW
TLS
STP
GNQ
COG
TCD
SOM
KIR
VUT
GAB
BWA
NIC
NAM



HDI vs GMA score (off-grid)
GMA score (off-grid)
Human Development Index (HDI)
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.008
0.01
0.012
0.014
0.016
0.018
0.02
IND
KEN
BGD
MAR
CHN
ZAF
TUR
EGY
NPL
RWA
TZA
MYS
CRI
ARG
ETH
KHM
HND
AFG
BEN
ALB
PLW
NER
CAF
TCD
MRT
STP
COG
VUT
TLS
GAB
BWA
KIR
CPV