Defining energy access: 2020 methodology - IEA

Introduction

Modern energy services are crucial to human well-being and to a country's economic development. Access to modern energy is essential for the provision of clean water, sanitation and healthcare and for the provision of reliable and efficient lighting, heating, cooking, mechanical power, transport and telecommunications services.

The *World Energy Outlook (WEO)* has since 2002 devoted attention to the topic of energy access, informing the international community with key quantitative analyses, including annually-updated energy access databases, projections and estimates of the investment needs and implications for global energy use and carbon-dioxide (CO2) emissions of universal energy access. A major contribution to the debate was the *Energy Access Outlook: World Energy Outlook 2017 Special Report*, which provided detailed analysis on the status of energy access in developing countries and prospects to achieving universal modern energy access to 2030. More recently, the *Africa Energy Outlook 2019*, a special focus of the *WEO-2019*, analysed in detail the present status of access to energy services in Africa and the outlook for the continent. This year, we just released our *WEO-2020*, looking in depths at how the Covid-19 pandemic is impacting current and future progress on energy access. The following methodology note describes the IEA definition of energy access, how the data for the IEA Energy Access Databases is collected, and presents the forward-looking analysis.

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Defining energy access

There is no single internationally-accepted and internationally-adopted definition of modern energy access. Yet significant commonality exists across definitions, including:

- Household access to a minimum level of electricity.
- Household access to safer and more sustainable (i.e. minimum harmful effects on health and the environment as possible) cooking and heating fuels and stoves.
- Access to modern energy that enables productive economic activity, e.g. mechanical power for agriculture, textile and other industries.
- Access to modern energy for public services, e.g. electricity for health facilities, schools and street lighting.

All of these elements are crucial to economic and social development, as are a number of related issues that are sometimes referred to collectively as "quality of supply", such as technical availability, adequacy, reliability, convenience, safety and affordability.

However, due to data constraints, the data and projections presented in *WEO* focus on two elements of energy access: a household having access to electricity and to a relatively clean, safe means of cooking. These are measured separately. We maintain databases on levels of national, urban and rural electrification rates and on the proportion of the population without clean cooking access. Both databases are regularly updated and form the baseline for *WEO* energy access scenarios to 2040.

The IEA defines energy access as "*a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average*". This energy access definition serves as a benchmark to measure progress towards goal SDG 7.1 and as a metric for our forward-looking analysis. By defining access to modern energy services at the household level, it is recognised that some other categories are excluded, such as electricity access to businesses and public buildings that are crucial to economic and social development, i.e. schools and hospitals.

Electricity access entails a household having initial access to sufficient electricity to power a basic bundle of energy services – at a minimum, several lightbulbs, phone charging, a radio and potentially a fan or television – with the level of service capable of growing over time. In our projections, the average household who has gained access has enough electricity to power four lightbulbs operating at five hours per day, one refrigerator, a fan operating 6 hours per day, a mobile phone charger and a television operating 4 hours per day, which equates to an annual electricity consumption of 1 250 kWh per household with standard appliances, and 420 kWh with efficient appliances. This service-level definition cannot be applied to the measurement of actual data simply because the level of data required does not exist in a large number of cases. As a result, our electricity access databases focus on a simpler binary measure of those that have a connection to an electricity grid, or have a renewable stand-alone system or mini-grid connection of sufficient capacity to deliver the minimum bundle of energy services mentioned above. Despite their development benefits, "pico solar" products, mainly solar lanterns which may include mobile phone chargers, are considered to be below the minimum threshold to count as having access.

Access to clean cooking facilities means access to (and primary use of) modern fuels and technologies, including natural gas, liquefied petroleum gas (LPG), electricity and biogas, or improved biomass cookstoves (ICS) that have considerably lower emissions and higher efficiencies than traditional three-stone fires for cooking. Currently, very few ICS models attain this lower emissions target, particularly under real-world cooking conditions. Therefore, our clean cooking access database refers to households that rely primarily on fuels other than biomass (such as fuelwood, charcoal, tree leaves, crop residues and animal dung), coal or kerosene for cooking. For our projections, only the most improved biomass cookstoves that deliver significant improvements are considered as contributing to energy access. The main sources are the World Health Organisation (WHO) Household Energy Database and the IEA Energy Balances.

IEA energy access databases

The WEO first constructed databases on electrification rates and the reliance on the traditional use of biomass for cooking for the *WEO* in 2002, and updated them regularly since then. Several expansions and additions have been made for the *Energy Access Outlook* special report in 2017. For the first time, we provided a historical time series for over 100 countries from 2000. This gave a first-of-its-kind assessment of country-by-country progress, including for the first time an assessment of off-grid

electricity access, sourced from government and commercial data. *WEO-2020* year-on-year and country-by-country data go up to 2019, and can be downloaded here.

Electricity Access

The general paucity of data on electricity access means that it must be gathered through a combination of sources, primarily from a network of contacts in governments. Where no government-reported data exists, data is derived from multilateral development banks and country-level representatives of various international organisations; and, other publicly available statistics, including US Agency for International Development (USAID) Demographic and Health Surveys (DHS), the World Bank's Living Standards Measurement Surveys (LSMS), the United Nations Economic Commission for Latin America and the Caribbean's (UN-ECLAC) statistical publications, and data from national statistics agencies. In the few cases where no data could be provided through these channels, other sources were used.

For many countries, data on the urban and rural breakdown was collected, but if not available an estimate was made on the basis of pre-existing data or a comparison to the average correlation between urban and national electrification rates. To estimate the number of people without access, population data comes from OECD statistics in conjunction with the UN Population Division reports *World Urbanization Prospects: the 2018 Revision Population Database*, and *World Population Prospects: The 2019 Revision*. Electricity access data is adjusted to be consistent with demographic patterns of urban and rural population. Due to differences in definitions and methodology from different sources, data quality may vary from country to country. Where country data appeared contradictory, outdated or unreliable, the IEA Secretariat made estimates based on earlier surveys.

Clean cooking access

For clean cooking, the database reports on the share of population without clean cooking access, defined as a household having primarily reliance on biomass, coal or kerosene for their cooking needs. The main source was the World Health Organisation (WHO) Household Energy Database 2018, which compiles national survey data on household cooking practices at urban and rural levels. This was cross-analysed with the IEA's *World Energy Balances 2020*, which contains data on residential energy consumption for 150 countries, as well as government sources of data. Precise numbers on stove type or quality and on secondary sources of fuel for cooking are not available for most countries. Once again, we combine this data with population estimates from OECD statistics in conjunction with the *UN Population Division* reports *World Urbanization Prospects: the 2018 Revision Population Database*, and *World Population Prospects: The 2019 Revision*.

Forward-looking scenarios for energy access

Defining the scenarios

The *World Energy Outlook 2020* (WEO-2020) makes reference to three scenarios for energy access to 2030.

The **Stated Policies Scenario** (STEPS), the IEA central scenario (identical in design to the previous New Policies Scenario), aims to provide a quantitative assessment of where existing policies as well as announced policy intentions will lead the energy sector. This scenario takes into account current progress being made: for electricity access, this is at a country-by-country level of detail. Projections also

take into account population growth, economic growth, urbanisation rate, and the availability and price of different fuels. The process of learning and cost reductions is fully incorporated into the underpinning of the World Energy Model (WEM) for both supply and demand, and applies not only to technologies in use today, but also those approaching commercialisation. While technology learning is an integral part of the *WEO* approach, the *Outlook* does not attempt to predict technology breakthroughs that produce a step-change in technologies and costs.

The **Sustainable Development Scenario** (SDS) maps out a way to meet sustainable energy goals in full, requiring rapid and widespread changes across all parts of the energy system. This scenario charts a path fully aligned with the Paris Agreement by holding the rise in global temperatures to "well below 2°C … and pursuing efforts to limit [it] to 1.5°C", and meets objectives related to universal energy access and cleaner air.

The **Delayed Recovery Scenario** (DRS) is introduced in the *WEO-2020* to reflect on the uncertainties linked to the implications of the Covid-19 pandemy on the global economy. In this scenario, the pandemic last longer and the economic recovery is weaker than assumed in the STEPS. Lockdowns in various forms are much more prolonged; periodic confinements, social distancing and other restrictive measures become part of everyday life; and the public health crisis strains the ability of many governments to provide financial lifelines to households and companies, exacerbating the slump. In this scenario, inequalities in the global economy and in the energy sector worsen, and recent progress towards universal access to energy is slowed or goes into reverse as the incomes of the poorest are hit and funding for access programmes is squeezed.

In the *WEO-2019,* an **Africa Case** (AC) was developed for the Special Focus on Africa, reflecting the Agenda 2063, in which African leaders set out their vision for the future growth and development of the continent. It also incorporated key sustainable development goals by 2030, including achieving full electricity and clean cooking access as well as significant reductions in pollution-related premature deaths. As a tangible representation of the Agenda 2063 vision, it presents a pathway to attain inclusive and sustainable economic growth and development.

Modelling the outlook for electricity access

Electrification options

Electricity access provided to a household is defined as **on-grid** if it is provided through a connection to a local network (or through grid extension) that is linked to a transmission network. Grids typically draw their power from large, centralised power plants (e.g. coal, natural gas, hydro), and increasingly from distributed generation such as solar photovoltaic (PV) or biogas units connected at a low voltage. New power generation capacity may be needed to meet additional demand to support the reliability of electricity supply. Investment in developing transmission and distribution (T&D) networks generally is most cost effective when built to serve an area with a high density of demand (e.g. concentrated services and residential load and/or energy intensive consumers). The proximity of households to the distribution system reduces the costs of extending the grid relative to other alternatives, while sparse populations, complex terrain and regulatory and institutional hurdles can make investment and maintenance of grid extensions less attractive than other solutions. Grid extension generally offers the lowest cost pathway to households for electricity access, where the option of connection is available.

Mini-grids are an option in areas not served by main grids. They are localised power networks, usually without infrastructure to transmit electricity beyond their service area. Generally, mini-grids provide electricity at a higher levelised cost than a main T&D network system. Mini-grids tend to rely on modular generation technologies like solar PV, wind turbines, small-scale hydropower and diesel generators. Like any grid, mini-grids need a stable flow of power to function properly and they often use either a small diesel generator or (increasingly) battery systems for back-up. Mini-grids require a certain demand threshold to justify the initial investment in the network, and therefore benefit from sizeable anchor loads such as public services or industrial and commercial facilities. Mini-grids can be scaled up in line with rising demand, and eventually be connected to a main T&D network, though mini-grid developers may choose not to invest in more expensive equipment that is required to meet the main T&D system standards if connection to the main grid is not foreseen. Mini-grids that are not compatible with main T&D networks can become stranded assets if the main grid is extended to the area.

In addition, electricity access can be provided through **stand-alone systems**. These are systems that are not connected to a grid and typically power single households. Today this market is dominated by diesel generators and solar PV systems (solar home systems). Off-grid systems may be the most cost-effective option (from a system cost perspective) in sparsely populated and remote areas. Both solar PV systems and batteries can be built at any scale to match the end-use service provided, which has led to innovative products coupling stand-alone generation with appliances. These products can often be scaled up as power demand grows, and can power a range of needs, from lighting and mobile phone charging to televisions and refrigerators. The upfront cost of stand-alone systems can be a critical barrier, making the availability of financing an important factor in their deployment. The levelised costs of electricity from stand-alone systems currently is the highest of the available pathways to electricity access, but rapidly falling costs for solar PV and batteries are making them increasingly attractive. The term decentralised systems is used in this report when discussing both off-grid systems and mini-grids.In order to provide an outlook for electricity access in the next decades, a model which projects country-level electrification levels to 2040 was developed. The projections are based on a country-by-country analysis of recent progress in electrification, policy commitments and investment.

Power generation

For the purpose of projections, electricity access includes a household having an electricity supply connection, with a minimum level of consumption of 250 kilowatt-hours (kWh) per year for a rural household and 500 kWh for an urban household, which increases over time to reach the national average. To estimate the additional generation needed, we match the additional demand from people getting access to the existing residential demand, total electricity generation and generation capacity. We take into account losses and own electricity use by the power sector for grid supply.

Geospatial estimation of least-cost pathway to universal access to electricity

The relative attractiveness of grid versus decentralised solutions to deliver electricity access, as well as the generation mix, depend on existing and planned network infrastructure, technology progress, local resources, population density and the distribution and growth of electricity demand. The analysis takes these factors into account, and over the years, the IEA has been working closely with several leading universities, including the KTH Royal Institute of Technology (KTH), to analyse the least-cost route to achieve full access to electricity, using the most recent tools available. Analysis was done for a few individual countries in 2014 for our first *WEO* focus report on Africa (Nigeria and Ethiopia) as well as in

2017 for the special *WEO* focus report on South East Asia (Indonesia, Philippines, Cambodia and Myanmar); it was then done for all sub-Saharan African countries in the *Energy Access Outlook 2017*.

For the *Africa Energy Outlook 2019*, the IEA refined its analysis using up-to-date datasets and the latest version of the Open Source Spatial Electrification Tool (OnSSET)1, developed by KTH. The results provide detailed coverage of 44 countries in sub-Saharan Africa. Regional results, but also national results for 11 focus countries were shown in the report.

Overall electricity access objectives and demand projections were determined by country and region in the World Energy Model (WEM) based on population dynamics and economic growth for the Stated Policies Scenario and the Africa Case. They integrated the latest policy frameworks and national targets as well as technology and energy prices. Demand related to access was initially assumed at 250 kWh a year for rural and at 500 kWh for urban households, before growing over time to reach the national average.

Demand and other key drivers (e.g. technology and fuel costs) retrieved from WEM were then used in OnSSET in combination with several open access geospatial datasets. These included demographic indicators (e.g. population density and distribution), infrastructure (e.g. existing and planned transmission and distribution networks, roads), resources availability (e.g. solar, wind, hydro) and derivative layers (e.g. distance to the grid, to the closest road or city, diesel transportation cost) among others. The geospatial model runs a least-cost analysis mainly taking into account techno-economic factors and yields electrification investment outlooks. While grid densification (connecting areas close to the existing network) is prioritised, the geospatial model does not necessarily mirror the detail of government electrification plans (where they exist) or account for the financial and technical capacities of utilities.

Investments

The investments in generating assets are a straightforward calculation multiplying the capital cost for each generating technology by the corresponding capacity additions for each modelled region and country. The investment costs represent overnight costs for all technologies. The model also calculates investment in new transmission and distribution networks.

Data visualisations

In the *Africa Energy Outlook 2019*, maps presenting the electricity access solutions to provide universal access to the population are shown for sub-Sahara Africa as a whole, as well as for 11 focus countries. This is a visual representation of the results of the geospatial modelling realised within the WEM, in collaboration with KTH University, and for the scenario Africa Case. Each pixel represents a population "settlement" that has received electricity access by 2030, and indicates whether it has been reached through grid densification/extension, through a mini-grid, or through a stand-alone system.

Modelling the outlook for access to clean cooking facilities

Taxonomy of cooking facilities

The majority of people without clean cooking access rely on the traditional use of solid biomass, which is responsible for creating harmful levels of household air pollution due to inadequate ventilation. Others use unprocessed coal or kerosene, which also produce harmful levels of household air pollution.

Kerosene, a liquid oil product, also is highly flammable and can be consumed accidentally by children. Cookstoves span a spectrum of technologies and vary widely according to local practices. This militates against neat categorisation, and therefore there is no universal definition of cookstove types. The following gives a broad overview of the terms used in our reports and highlights some of the trade-offs between stove types.

A **traditional (or basic) cookstove** is typically identified as a very cheap or no-cost device, which can include a simple open fire, built on the ground with three stones to support a pot, or a basic ceramic, clay or metal stove. It is characterised by very low efficiency and high particulate matter (PM), and burns solid biomass, including fuelwood, agricultural waste or charcoal.

An **improved biomass cookstove (ICS)** typically describes a stove which has a higher efficiency or lower level of pollution than a traditional stove, through improvements including a chimney or closed combustion chamber. Common types of improved cookstoves include a rocket stove or simple micro-gasifier, which operates a multi-stage burn (also known as wood-gas). There is ambiguity as to whether ICS are "clean" as many models are associated with household air pollution at a level harmful to human health. For this reason, people currently relying on ICS are not considered to have access to clean cooking. In our scenario, however, improved cookstoves do form an important part of the provision of access in rural areas: these cookstoves are assumed to be the best available, and by 2030, they are assumed to reach the emissions performance of advanced biomass cookstoves.

Modern stoves use liquids or gas, including LPG, biogas, electricity, ethanol or natural gas. Efficiency is high and pollution is typically very low or absent. An exception is kerosene, which produces harmful levels of air pollution and is a common source of fires and child injuries from accidental ingestion. A biogas digester is a system which produces biogas via anaerobic digestion from biomass and organic waste.

Additional population with clean cooking access

In order to provide an outlook for clean cooking access in the next decades, a model which projects country-level access levels to 2040 was developed. The projections are based on a country-by-country analysis of recent progress in clean cooking access, policy commitments and investment.

Clean cooking options

LPG stoves are judged to be more likely to penetrate as the first clean cooking solution in urban zones, where infrastructure, distribution and fuel costs can benefit from economies of scale and consumers have a relatively higher ability to pay. Thus LPG stoves are assumed to provide clean cooking services for the majority of urban zones still relying on the traditional use of biomass (with the rest reached by electricity, natural gas, or alternative solutions such as improved biomass cookstoves or ethanol), but for only a small part of rural households, depending on the country. The large majority of rural households are assumed to be provided with improved biomass cookstoves, and the remaining with biogas digesters, LPG, or other solutions such as ethanol. Those global targets are then reflected in regional allocations of the various options regarding the most likely technology solution in each region, given resource availability and government policies and measures. The analysis also takes into account the move from household use of ICS and LPG to natural gas and electricity.

Investments

Investment costs are calculated based on the unit cost of the different devices. Infrastructure, distribution and fuel costs are not included in the investment costs. Only the cost of the first stove and half of the cost of the second stove is included in our investment projections. This is intended to reflect a path towards such investment becoming self-sustaining.

Cookstove cost and efficiency

In collaboration with Politecnico di Milano, a database of cookstove costs and performance was created for the *Energy Access Outlook 2017,* through a review of all data available in the most recent scientific and grey literature, and in the GACC's *Clean Cooking Catalogue*. For regions in which data are poor, data from neighbouring regions are used as a proxy. Data on cookstove costs are in Table 1 and data on cookstove efficiencies are in Table 2.

Regarding stove efficiency, the values in Table 2 represent the estimated real-life efficiency of the device, which is in most cases lower than the efficiency assessed by laboratory tests (see Chapter 3, Box 3.2 of the *Energy Access Outlook 2017*) and more relevant for estimating future energy consumption. The estimated real-life efficiencies have been derived from laboratory-based values through the application of performance gap factors, which have been assessed separately for each stove category by Politecnico di Milano.

Health impacts and air pollution

The pollution and health impact of the scenarios were developed in collaboration with the International Institute of Applied System Analysis (IIASA) in Vienna, Austria. The WEM was therefore coupled with the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model of the IIASA. GAINS is a widely recognised model which estimates historic emissions of air pollutants by country, using international energy and industrial statistics, emission inventories and data supplied by countries. It uses this assessment of historic emissions to assess the future path of pollutant emissions by country in five-year intervals through 2050 for different scenarios and policy packages. The GAINS model also calculates the effects of these levels of emissions on ambient air quality, and the subsequent impacts on human health and ecosystems.