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1 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. The latest contribution to the debate is the Energy Access Outlook: World Energy Outlook 2017 Special Report, which provides detailed analysis on the status of energy access in developing countries and prospects to achieving universal modern energy access to 2030. The following methodology note describes the IEA definition of energy access, how the data for the IEA Energy Access Databases is collected, and describes the forward-looking analysis.

2 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, WEO focuses on two elements of energy access: a household having access to electricity and to a clean cooking facilities. 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, task lighting (such as a flashlight), phone charging and a radio – 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 off- or mini-grid connection of sufficient capacity to deliver the minimum bundle of energy services, above.

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 lower emissions, 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. The main sources are the World Health Organisation (WHO) Household Energy Database and the IEA Energy Balances.

3 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. These databases have been updated regularly since then. Several expansions and additions have been made for this special report in 2017. For the first time, we provide a historical time series for over 100 countries from 2000, which can be downloaded at www.iea.org/energyaccess. In addition, we have collected data for electricity access up to 2016, a one-year lag, compared to the previous two-year lag. This gives 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.

3.1 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 2016 Revision Population Database*, and *World Population Prospects: the 2015 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.

### 3.2 Clean cooking access

For clean cooking, a new historical analysis of the reliance on different cooking fuels use was undertaken for this report. This 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 2016, 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 2017*, which contains data on residential energy consumption for 150 countries, as well as government sources of data. The results give a new and fuller picture of clean cooking access than has been available previously. 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 2016 Revision Population Database*, and *World Population Prospects: the 2015 Revision*.

### 4 Forward-looking scenarios for energy access

#### 4.1 Defining the scenarios

This 2017 *Energy Access Outlook* special report draws on the broader analysis and modelling in the *WEO-2017* and makes reference to two scenarios for energy access to 2030.

The **New Policies Scenario**, the IEA central 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, for the first time, 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 **Energy for All Case** examines the achievement of SDG 7.1. This case (first developed for *WEO-2003* and updated in *WEO-2013*) highlights what more needs to be done to put the world on course to achieve universal energy access by 2030 and what the implications might be for energy demand, supply, investment, greenhouse-gas emissions, local pollution and health.
The WEO-2017 includes a new Sustainable Development Scenario, which builds on the Energy for All Case to provide a pathway to achieve the key energy-related components of the UN Sustainable Development agenda: universal access to modern energy by 2030, urgent action to tackle climate change (the objective of WEO’s previous 450 Scenario) and measures to improve poor household air quality.

4.2 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 off-grid systems. These are stand-alone 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.

**Additional population with electricity access**
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 for the Energy Access Outlook 2017. 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.

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 includes a highly detailed geospatial analysis of sub-Saharan Africa at the level of one square kilometre, to assess the most cost-effective strategy for delivering electrification pathways in the New Policies Scenario and the Energy for All Case. The analysis integrates a Geographic Information Systems model using open-access geospatial data with technology, energy prices, electricity access and demand projections from the WEM. The geographic analysis of the type of access that contributes to electrification pathways has been developed in collaboration with the KTH Royal Institute of Technology, Division of Energy Systems Analysis (KTH-dESA) in Stockholm, Sweden.

**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**
The night sky image of Africa is a visual representation of WEO electricity access projections from the WEM, that were allocated to population centres in collaboration with KTH university. Each pixel represents a "settlement" of one square kilometre that has received electricity access by 2030. The intensity of each pixel is based on the electricity demand density and the technology mix granting access in that particular settlement.

**4.3 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 this report 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 (Box 3.3). 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.

Advanced biomass cookstoves contain technical improvements which increase combustion efficiency and lower pollutant emissions. These can include highly performing micro-gasifiers and ICS versions with a forced-draft, which have a blower injecting air into the fire to improve the stove performance.

Modern stoves use liquids or gas, including LPG, biogas, electricity 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
Historical trends show that economic development and income growth do not automatically lead to a decrease in the traditional use of solid biomass. In practice, there are numerous considerations besides income in play, particularly the relative prices and availability of the various alternatives. Clean cooking access rates are econometrically projected using several statistically-significant variables, including:

- Historical progress in clean cooking access
- Energy balance trends
- Policies and clean cooking programmes
- Population growth
- Urbanisation level
- Availability and price of fuelwood and charcoal
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 all urban zones still relying on the traditional use of biomass but for only around 30-50% 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 or solar cookstoves. 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.

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.

Table 1  Cookstove costs by type and region (year-2016 US dollars)

<table>
<thead>
<tr>
<th>Region</th>
<th>Basic Fuelwood</th>
<th>Basic Charcoal</th>
<th>Improved Fuelwood</th>
<th>Improved Charcoal</th>
<th>Advanced Biomass</th>
<th>Modern Stoves</th>
<th>Biogas digesters</th>
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<td>7</td>
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<td>50</td>
<td>45</td>
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<td>29</td>
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<td>38</td>
<td>60</td>
<td>36</td>
<td>n.a.</td>
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<td>61</td>
<td>36</td>
<td>n.a.</td>
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<td>65</td>
<td>36</td>
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<td>70</td>
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<td>Other Developing Asia</td>
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<td>38</td>
<td>84</td>
<td>n.a.</td>
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### Table 2

<table>
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<tr>
<th>Region</th>
<th>Basic Fuelwood</th>
<th>Basic Charcoal</th>
<th>Improved Fuelwood</th>
<th>Improved Charcoal</th>
<th>Advanced biomass</th>
<th>Modern stoves</th>
<th>Biogas digesters</th>
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<td>31%</td>
<td>32%</td>
<td>39%</td>
<td>50%</td>
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<tr>
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<td>35%</td>
<td>37%</td>
<td>50%</td>
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<td>33%</td>
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<tr>
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<tr>
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<td>46%</td>
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<td>34%</td>
<td>n.a.</td>
<td>51%</td>
<td>52%</td>
</tr>
</tbody>
</table>

Notes: n.a. = not available. Latin America includes Bolivia, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama and Peru.
Sources: Politecnico di Milano; IEA analysis.

### 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.