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2 Summary

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 for more than a decade devoted attention to the topic of energy access, informing the international community with key quantitative analyses, including energy access databases, projections and estimates of the investment needs and implications for global energy use and carbon-dioxide (CO_2) emissions of universal energy access. The latest contribution to the debate is the *World Energy Outlook 2016*. This report provides detailed analysis on the status of energy access in developing countries and prospects to 2040. The first part of this methodology note discusses the *WEO* energy access databases and projections model. The second part zooms in on the methodology for our Energy Development Index. Supplementary energy access materials are available on our website:

www.worldenergyoutlook.org/resources/energydevelopment

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 *World Energy Outlook* focuses 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 that rely on the traditional use of solid biomass[1] for cooking, such as a three-stone fire. Both databases are regularly updated and form the baseline for *WEO* energy access projections to 2040. Due to differences in definitions and methodology from different sources, data quality may vary from country to country.

WEO projections for access to electricity and to clean cooking facilities are based on separate econometric panel models that regress the electrification rates and rates of reliance on solid biomass respectively over many variables at a regional level. The resulting models relate access rates to per capita income, population growth, urbanisation, fuel prices, level of subsidies, technological advances, energy consumption and energy access programmes.

The Energy Development Index (EDI) is a multi-dimensional indicator that tracks energy development country-by-country, distinguishing between developments at the household level and at the community level. In the former, it focuses on two key dimensions: access to electricity and access to clean cooking facilities. When looking at community level access, it considers modern energy use for public services (e.g. schools, hospitals and clinics, water and sanitation, street lighting) and energy for productive use, which deals with modern energy use as part of economic activity (e.g. agriculture and manufacturing). The choice of indicators used is constrained by the type of data related to energy access that is currently available. The EDI was last updated for 80 countries in 2012.

[1] Solid biomass includes fuelwood, charcoal, dung, agricultural residues, wood waste and other solid wastes.

3 Energy access methodology

The *World Energy Outlook's* activities in the domain of modern energy access consist both of analysis that is regularly updated and additional analysis on specific issues. Our general analysis consists of an update of our energy access databases, our energy access projections to 2040 and estimating the investment need and impacts on energy demand and CO_2 emissions. In this part of the methodology note we deal with the definition of energy access, data gathering for our energy access databases and the methodology for projecting future access rates.

3.1 Defining modern energy access

There is no universally-agreed and universally-adopted definition of modern energy access. For example, the UN Secretary General's Advisory Group on Energy and Climate (AGECC) defines energy access as access "to a basic minimum threshold of modern energy services for both consumption and productive uses. Access to these modern energy services must be reliable and affordable, sustainable and where feasible, from low-GHG-emitting energy sources". GIZ recommends an orientation to specific service indicators for lighting, communication and food preparation and, for instance, for electricity access defines five service levels, corresponding to a certain package and kWh per capita consumption.

For our model, we define modern energy access as "a household having reliable and affordable access to clean cooking facilities and to a minimum level of electricity consumption which is increasing over time". 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.

Access to electricity involves more than a first supply to the household; our definition of access also involves consumption of a specified minimum level of electricity, varying based on whether the household is in a rural or an urban area, which increases over time. The initial threshold level of electricity consumption for a rural household is assumed to be 250 kilowatt-hours (kWh) per year and for an urban household it is 500 kWh per year. The higher consumption assumed in urban areas reflects specific urban consumption patterns. Both are calculated based on an assumption of five people per household. In rural areas, this level of consumption could, for example, provide for the use of a floor fan, a mobile telephone and two compact fluorescent light bulbs for about five hours per day. In urban areas, consumption might also include an efficient refrigerator, a second mobile telephone per household and another appliance, such as a small television or a computer. However, we recognise that different levels are sometimes adopted in other published analysis. Sanchez, for example, assumes 120 kWh per person (600 kWh per household, assuming five people per household).[2]

Our definition of energy access also includes provision of cooking facilities which can be used without harm to the health of those in the household and which are more environmentally sustainable and energy efficient than the average solid biomass cookstove currently used in developing countries. This definition refers primarily to improved biomass cookstoves, liquefied petroleum gas (LPG) cookstoves and renewables-based cookstoves (biogas, solar) that have considerably lower emissions and higher efficiencies than traditional three-stone fires.

Our definition is intended to be supportive of the objective to conduct forward-looking projections, but data availability means that it is not viable to apply it to our estimates of the number of people that do not currently have access to modern energy services. This 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 energy access databases focus on a simpler binary measure of those that do not have access to electricity and those that rely on the traditional use of solid biomass for cooking. This is disaggregated (either with data or estimation) between those in urban and rural areas within a given country. This level of reporting is far from optimal but is driven by severe data limitations.

The number of people relying on the traditional use of solid biomass for cooking is used as a proxy for measuring those not having access to clean cooking facilities (again, due to data constraints). The traditional use of solid biomass refers to the use of solid biomass with basic technologies, such as three-stone fires, traditional mud stoves or metal, cement and pottery or brick stoves, with no operating chimneys or hoods. As

[2] Sanchez, T. (2010), *The Hidden Energy Crisis: How policies are failing the world's poor*, Practical Action Publishing, London

a consequence of the pollutants emitted by these inefficient devices, pollution levels inside households cooking with biomass are often many times higher than typical outdoor levels, leading to about 3.5 million premature death each year according to the World Health Organization.[3]

3.2 Databases

3.2.1 Electricity access

The general paucity of data on electricity access means that it must be gathered through a combination of sources, including: IEA energy statistics; a network of contacts spanning governments, multilateral development banks and country-level representatives of various international organisations; and, other publicly available statistics, including US Agency for International Development (USAID) supported DHS survey data, the World Bank's Living Standards Measurement Surveys (LSMS), the UN Economic Commission for Latin America and the Caribbean's (ECLAC) statistical publications, and data from national statistics agencies. In the small number of 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 United Nations Population Division reports *World Urbanization Prospects: the 2014 Revision Population Database,* and *World Population Prospects: the 2012 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 cross-country comparisons and earlier surveys.

3.2.2 Clean cooking access

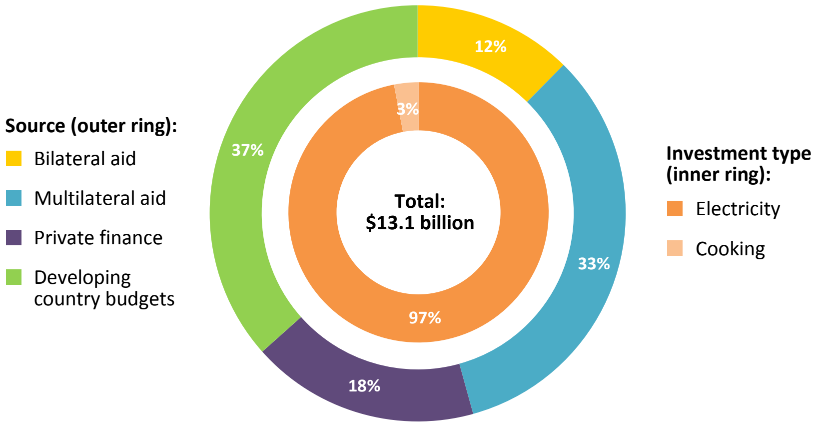
Our database on the traditional use of solid biomass for cooking mainly makes use of the World Health Organization's (WHO) Global Health Observatory estimates of reliance on solid fuels.[4] In line with the level of data available from most sources, it focuses on the population where solid fuels are the primary fuel for cooking. We make an adjustment to subtract coal use from WHO totals, based on the most recent national data.[5] 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 United Nations Population Division reports *World Urbanization Prospects: the 2014 Revision Population Database,* and *World Population Prospects: the 2014 Revision.* Reliance on solid biomass data was adjusted to be consistent with demographic patterns of urban and rural population.

3.3 Current investment in energy access

Worldwide in 2013, an estimated $13.1 billion in capital investment was directed to improving access to electricity and clean cooking facilities. Overwhelmingly, these energy access investments went to the power sector, either to increase generation capacity or to extend transmission and distribution networks, with only 3% being directed at increased access to clean cooking facilities. This figure of $13.1 billion is an increase, relative to previous *WEO* estimates ($9.1 billion in 2009), but the estimate is tentative – it may well be an under-estimate.

[3] See the World Energy Outlook Special Report – Energy and Air Pollution (2016): https://www.iea.org/publications/freepublications/publication/weo-2016-special-report-energy-and-air-pollution.html
[4] For more information, see www.who.int/gho/phe/indoor_air_pollution/en/index.html
[5] There are around 200-300 million people that rely on coal for cooking and heating purposes, which causes air pollution and has serious potential health implications when used in traditional stoves. These people are mainly in China, but there are also significant numbers in Liberia, Democratic People's Republic of Korea and Paraguay.

Figure 1: World energy access investment by type and source, 2013



Our estimate includes capital investment made to provide households with electricity access and clean cooking access. For on-grid electricity access, it includes the costs of the first connection, grid extension and the capital cost to sustain an increased supply over time. For mini-grid and off-grid systems, the estimate includes capital costs and distribution lines costs. Operating costs, such as fuel costs and maintenance costs, are not included. Broader technical assistance, such as policy and institutional development advice, is also not included.

We base our estimate of current energy access investment on several sources:

- Bilateral aid: Total Official Development Assistance (ODA) dedicated to energy access is not directly reported meaning that a set of assumptions had to be used. For the Least Developed Countries[6], the estimate includes all ODA investment flows for electricity generation, transmission and distribution. For other developing countries, only a share of these investment flows was included in the estimate, depending on the country's income. Investments for clean cooking access could not be tracked in the ODA database.

- Multilateral aid: Investment figures were collected from organisations directly, most of them reporting energy access dedicated investments. Although development banks have made progress in the past few years in their reporting of access-related investments, methodologies still differ which does not make figures between different institutions directly comparable.

- Developing countries budgets: It includes investments made directly by the governments and through state-owned utilities. It is estimated that for every $1 spent in aid on energy access, it is matched by an additional equal amount from either the private sector or developing country governments.

- Private finance: It is based on data on private sector investment in infrastructure, including public-private partnerships (PPP), sourced from the World Bank PPI database. We have assumed that the private sector component of PPP-funded projects is around 50% and that between 5% and 20% of the total investment goes towards energy access, depending on the region.

3.4 Projections under the New Policies Scenario

The *New Policies Scenario* – the *World Energy Outlook* central scenario – takes account of the broad policy commitments and plans that have been announced by countries around the world, to tackle either environmental or energy-security concerns as well as plans to phase out fossil-fuel subsidies. The New Policies Scenario assumes only cautious implementation of current commitments and plans. This is done in view of the

[6] Least Developed Countries are countries with a Gross National Income inferior or equal to $1 045 in 2013 according to the OECD list of ODA recipients

many institutional, political and economic obstacles which exist, as well as, in some cases, a lack of detail in announced intentions and about how they will be implemented.

3.4.1 Outlook for electricity access

3.4.1.1 Additional population with electricity access

In order to provide an outlook for electricity access in the next decades, a model able to generate projections of electrification rates by region has been developed. The projections are based on an econometric panel model that regresses historic electrification rates of different countries over many variables, to test their level of significance. Variables that were determined statistically significant and consequently included in the equations are:

- GDP per capita
- population growth
- urbanisation level
- fuel prices
- electricity consumption per capita
- electrification programmes
- technological advances

3.4.1.2 Power generation

To estimate the need for 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 generation sector for grid-supply. For urban-area electricity demand, the less costly choice is electricity grid extension, thus the model assumes that generation in urban areas is made entirely through grid options. In rural areas, options to increase electrification include extension of existing grids, creation of mini-grids and off-grid solutions.[7] That part of the rural area – around one-third of total rural demand – closest to urban areas and/or likely to become more densely populated by 2040 is also projected to be supplied through the grid, as this will be the most economic option. The remaining rural generation is divided between mini-grids and off-grid generation, including oil, solar PV, mini-hydro, wind and bioenergy in the mix.

3.4.1.3 Investments

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

3.4.2 Outlook for access to clean cooking facilities

3.4.2.1 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, that are in play, particularly the relative prices and availability of the various alternatives. Reliance on solid biomass rates of different countries is econometrically projected using many variables to assess their level of significance. Variables that were determined statistically significant and consequently included in the equations are:

- population growth
- urbanisation level
- availability and price of fuelwood and charcoal
- availability and cost of alternative clean fuels and cookstoves

[7] Mini-grids provide centralised generation at a local level. They operate at a village or district network level, with loads of up to 500kW. Isolated off-grid solutions include small capacity systems, such as solar home systems, micro-hydro systems, wind home systems and biogas digester systems.

- technological advances
- clean cooking programmes

3.4.2.2 Clean cooking options

LPG stoves are judged to be more likely to penetrate 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 30% of rural households. 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.

3.4.2.3 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.

Table 1: **Technology characteristics of different cooking options**

	Investment cost ($)	Efficiency	Daily hours for cooking	Consumption per household (toe/year)
Traditional cookstoves				
Charcoal	3 - 6	20%	2 - 4	0.5 - 1.9
Fuelwood, straw	0 - 2	11%	2 - 4	1.0 - 3.7
Alternative cookstoves				
Kerosene	30	45%	1 - 3	0.1 - 0.2
LPG	60	55%	1 - 3	0.08 - 0.15
Electricity	300	75%	1.2 - 2.4	0.07 - 0.13
Biogas digester	600-1 500	65%		
Improved cookstoves:				
Charcoal	14	26%	1.5 - 3	0.4 - 1.5
Fuelwood	15	25%	1.9 - 3.8	0.5 - 1.6

Note: toe = tonnes of oil equivalent.

Sources: Jeuland and Pattanaya, (2012); Department of Energy at the Politecnico di Milano; IEA analysis.

3.5 The Energy for All Case

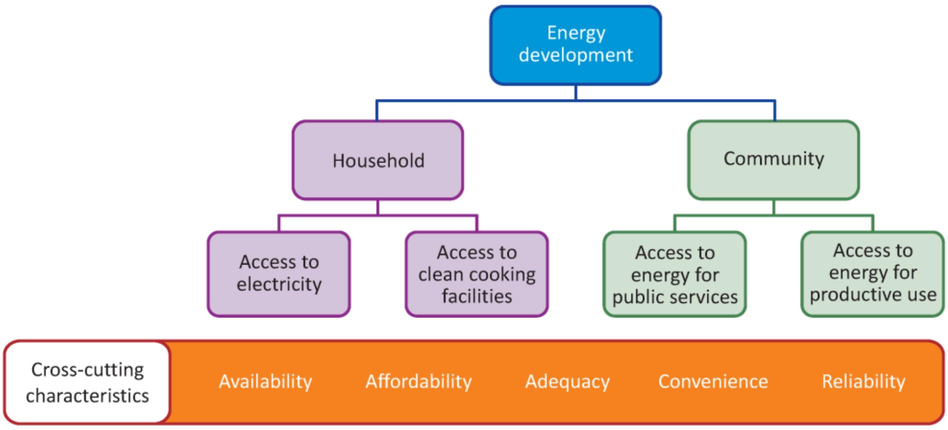
In our Energy for All Case, we examine the trajectory that would be required to achieve the goal of universal access to electricity and clean cooking facilities by 2030 and what the implications would be of doing so. The Energy for All Case quantifies the number of people that need to be provided access to modern energy services and the scale of the investments required in order to achieve universal access to modern energy access by 2030. This therefore results in a projection of the additional number of people gaining access each year compared to the New Policies Scenario, and related investments needs.

4 Energy Development Index

Tracking progress through effective energy development indicators is a critical energy access issue. The Energy Development Index (EDI) is devised as a composite measure of a country's progress in transitioning to modern fuels and modern energy services and is a means to help better understand the role that energy plays in human development. In *WEO-2012* we have built on previous work, re-examining what variables have strong explanatory value for energy access, as well as the coverage, frequency and reliability of datasets relating to these variables. We have constructed a new EDI, which includes important additional indicators – such as productive use of energy – presented in the form of country level results. We have collected a substantial amount of data, allowing us to present EDI results for 80 countries and to compare EDI results over time. Such an indicator can help ensure that policy and financing commitments achieve maximum impact.

Energy development indicators should seek to quantify availability of modern fuels, the consumption of these fuels and how this consumption contributes to basic needs and human development. However, following this path from supply through to consumption and then impacts is fraught with challenges. Instead, we take a snapshot at a country level, segregating broadly between energy development at the household level and at the community level (Figure 2). In the former, we focus on two key dimensions (as reflected earlier in this chapter), that of access to electricity and access to clean cooking facilities. Access to heating is an important additional variable that is sometimes mentioned in this context, but is often either excluded due the lack of available data or dismissed as it is strongly related to cooking (as the same means may be used for both). When looking at community-level modern energy access, the categories are broader by necessity. In the case of public services, the focus is on examining the use of modern energy in schools, hospitals and clinics, water and sanitation, street lighting and other communal institutions. In the case of productive use, the focus is often on modern energy use for activities such as agriculture (ploughing, irrigation and food processing), and micro-small enterprises, such as milling, textiles etc. The issue of modern energy for productive uses is not a new one but is rightly receiving increased recognition. An additional aspect of modern energy use captured, to an extent, within productive use is that of transport. It is valuable to capture this variable as, particularly in earlier economic development, a significant share of its energy consumption is directly or indirectly for productive economic purposes.

Figure 2: Energy development framework



Notes: Household does not distinguish energy use as part of a micro-enterprise conducted within the home (which existing energy access data is often unable to identify). While very different in nature, energy for public services and for economic/productive purposes are grouped here under the community heading.

Within these broad categories, access to modern fuel and the appliances to utilise it are considered together *i.e.* a person has adequate access only if they have access to both. However, it is recognised that, in respect to both access to energy and access to appliances, there is also a progression. For instance, in the case of electricity, the first move might be from candles and batteries to solar lanterns, solar home systems or, possibly, a mini-grid. Similarly, first access is likely to involve only a small number of basic appliances, with greater diversity coming later. In addition, there are a number of issues that are sometimes referred to generically as "quality of supply". For any energy supply to provide a genuine opportunity to use modern energy services there needs to be a technical possibility to use it (availability), a price that is not prohibitive (affordability), sufficient supply (adequacy) and a supply that is easy to use (and pay for), including being located nearby, available at desired hours of the day and safe to use (convenience). Importantly, the supply must be of the right quality (*e.g.* voltage level) and be usable for most of the time (reliability).[8] At a more sophisticated level, it is also recognised that it may be desirable to track the quality of policies, regulations and institutions involved and, certainly, whether there is sufficient funding to support realisation of the objectives.

[8] We follow the proposed characterisation proposed by Pachauri in "Reaching an international consensus on defining modern energy access", Current Opinion in Environmental Sustainability, Issue 3, Elsevier, Amsterdam, pp.235-240, 2011.