Energy and Development Methodology

The **World Energy Outlook** has for many years devoted attention to the energy and development issue, developing a series of databases and publishing quantitative analysis. The latest contribution to the debate is the special early excerpt of the 2011 *World Energy Outlook*, entitled "Energy for All: financing access for the poor" released in October 2011. The report tackles the critical issue of financing the delivery of universal modern energy access.

This document explains in detail the methodology used to derive the quantitative analysis presented in the report as well as the methodology underpinning the supplementary energy and development material available at the website: http://www.worldenergyoutlook.org/development.asp

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1.1 Electricity Access: database and outlook under the New Policies Scenario

1.1.1 Electricity access database

The electricity access database shows detailed data on urban and rural electrification collected from industry, national surveys and international sources. The database was updated with the latest information for *WEO-2011* to provide the best available picture of access to electricity services by region and country. The major revision since electricity access database was published last year occurs in India.

There is no single internationally-accepted definition for electricity access. The definition used in this analysis covers electricity access at the household level, that is, the number of people who have electricity in their home. It comprises electricity sold commercially, both on-grid and off-grid. It also includes self-generated electricity for those countries where access to electricity has been assessed through surveys by government or government agencies. The data does not capture unauthorised connections. The national, urban and rural electrification rates shown indicate the number of people with electricity access as a percentage of the total population.

The analysis is a combination of desktop research and information from workshops in the area of rural development and energy poverty. If available, international statistical surveys or census data has been used in order to ensure maximum consistency and uniform methodology. In situations where country data was unavailable from international statistical sources, data has been derived from national websites, governmental bodies, the energy sector and other reports. If electricity access data was unavailable for 2009, data for the last available year before that was used. Data has been validated through consistency-checking amongst different data sources and expert judgements.

Using the electrification rate data collected, estimates of the number of people without electricity access, as well as the urban and rural breakdown, are determined based on population estimates from OECD statistics in conjunction with the United Nations Population Division report, *World Urbanization Prospects: The 2009 Revision Population Database.* Electricity access data was 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.

1.1.2 Outlook for electricity access under the New Policies Scenario

The electricity access database provides invaluable information about the current electrification rates in all countries. In order to provide an outlook for electricity access in the next decades, a model able to generate projection of electrification rates by regions has been developed under the New Policies Scenario assumptions.

The projections are based on an econometric panel model that regress 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:

- per capita income
- demographic growth
- urbanisation level
- fuel prices
- level of subsidies to electricity consumption
- technological advances
- electricity consumption
- electrification programmes

The model was developed using the same economical and demographical assumptions as that in the New Policies Scenario. This 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-energy subsidies. However, we assume that no additional policies to expand energy access, over and above those in place today, are enacted over the projection period.

1.2 Reliance on traditional use of biomass: database and outlook under the New Policies Scenario

1.2.1 Reliance on traditional use of biomass database

The database showing reliance on the traditional use of biomass is based on survey and national data sources, and refers to those households where biomass is the primary fuel for cooking. We define the term "biomass" broadly to cover the various resources like wood, charcoal, tree leaves, crop residues and animal dung. The traditional use of biomass refers to the basic technology used, such as a three-stone fire, traditional mud stoves or metal, cement and pottery or brick stoves, with no operating chimneys or hoods. As 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 more than 1.45 million premature death each year according to the World Health Organization.

The database on reliance on the traditional use of biomass combines information on percentage of people using biomass as primary fuel for cooking with country data on level of consumption of biomass by type. The latest update was for *WEO-2011* to provide the best available picture of population reliant on the traditional use of biomass for cooking by region and country.

1.2.2 Outlook for the reliance on biomass under the New Policies Scenario

In order to provide an outlook for the number of people relying on the traditional use of biomass in the next decades, a regional model was developed under the New Policies Scenario assumptions. As for the electrification rates model, the projections are based on an econometric panel model that regress reliance on biomass rates of different countries over many variables, to assess their level of significance. Variables that were determined statistically significant and consequently included in the equations are:

- per capita income
- demographic growth
- urbanisation level
- level of prices of alternative modern fuels
- level of subsidies to alternative modern fuel consumption
- technological advances
- programmes

As for the electrification model, we assume that there are no additional policies implemented to reduce reliance of households on traditional biomass for cooking, over and above those in place today.

1.3 The Energy for All Case

The outlook for energy access under the New Policies Scenario shows that worldwide the electrification rate in 2030 will not reach 100% and the number of people relying on the traditional use of biomass will rise to 2.7 billion. To illustrate what would be required to achieve universal access to modern energy services, we have developed the Energy for All Case (Referred to in *WEO-2010* as the Universal Modern Energy Access Case.

This case quantifies the number of people that need to be provided access to modern energy services and the scale of the investments required by 2030 in order to achieve universal access to modern energy services. For our analysis, we define modern energy access as *"a household having reliable and affordable access to clean cooking facilities, a first connection to electricity and then an increasing level of electricity consumption over time to reach the regional average".* Access to electricity involves more than a first supply connection to the household; our definition of access also involves consumption of a specified minimum level of electricity, the amount varies based on whether the household is in a rural or an urban area. This 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 biomass cookstoves currently used in developing countries. This definition refers primarily to biogas systems, liquefied petroleum gas (LPG) stoves and advanced biomass cookstoves that have considerably lower emissions and higher efficiencies than traditional three-stone fires for cooking.

The Energy for All Case also includes interim targets to 2015, adopted to be consistent with the achievement of the first Millennium Development Goal - eradicating extreme poverty. We interpret this, in this context, as meaning that no more than one billion people should be without access to electricity by that date and no more than 1.7 billion should still be using traditional biomass for cooking on open fires or primitive stoves (see Table). The relationship between poverty and modern energy access has been derived from a cross-country analysis covering 100 countries and the projections are based on regression analyses, which are applied to each region.

Table 1: Targets in the Energy for All Case

	2015		2030	
	Rural	Urban	Rural	Urban
Access to electricity	Provide 257 million people with electricity access	100% access to grid	100% access, of which 30% connected to the grid and 70% either mini-grid (75%) or off-grid (25%)	100% access to grid
Access to clean cooking facilities	Provide 800 million people with access to LPG stoves (30%), biogas systems (15%) or advanced biomass cookstoves (55%)	Provide 200 million people with access to LPG stoves	100% access to LPG stoves (30%), biogas systems (15%) or advanced biomass cookstoves (55%)	100% access to LPG stoves

The targets presented in the table above uses Liquefied petroleum gas (LPG) stoves as a proxy for modern cooking stoves (including kerosene, biofuels, gas and electric stoves). Advanced biomass cookstoves are biomass gasifier-operated cooking stoves which run on solid biomass, such as wood chips and briquettes. Biogas systems include biogas-fired stoves.

The Energy for All case thus has two sub-models, one for universal electricity access and one for universal access to clean cooking facilities, presented separately below.

1.3.1 Achieving universal electricity access

The Energy for All Case is based on the assumption that new policies are introduced that result in a progressive increase in electrification rates to 100% of the world's population by 2030. Achieving universal access to electricity by 2030 would result in higher global energy demand than projected in the New Policies Scenario. It would also have implications for energy investment and for energy-related CO_2 emissions. The Energy for All Case seeks to quantify these increments and is calculated in four main steps.

1. Determine the additional number of people gaining access to electricity every year to reach universal electrification in 2030

The number of people gaining access over time is estimated by the outlook for the electricity access under the New Policies Scenario. In order to reach 100% electrification by 2030, the Energy for All Case projects an exponential addition of people gaining access over time. This exponential distribution was chosen to be consistent with the system for building electricity network extensions and results in quantifying the annual additional people by region gaining access to electricity compared to the New Policies Scenario projection.

2. Calculate the consumption patterns over time of the new connected and thus the power generation needs

The Energy for All Case assumes a basic consumption for each person gaining access, as well as its evolution over time, in order to estimate the additional demand compared to the New Policies Scenario projection and needed to achieve the universal electrification by 2030. It is assumed that each person gaining access is at first going to use electricity only as a substitute for the traditional fuels used to cover basic needs (e.g. candles, liquefied petroleum gas [LPG], kerosene). To assess the extent of the additional generating capacity required to achieve universal access, we have made assumptions about minimum levels of consumption at both the rural and urban level: rural households are assumed to consume at least 250 kWh per year and urban households 500 kWh per year. 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. This higher consumption in urban areas reflects specific urban consumption patterns. The Energy for All Case assumes that the consumption per capita of an individual catches up the average consumption of their region over time. On average, consumption level of each newly connected person reaches the regional average after 10 years, but although the starting consumption is the same across regions, there is a regional difference in the "catching-up" process, depending on the average consumption of each region under the New Policy Scenario and the rural and urban disparity**.**

Once the new level of demand is determined, and therefore the generation needs are estimated, the Energy for All Case assumes a breakdown by power generation options. The generation options have been chosen according to the 100% electrification target in 2030. The Energy for All Case, as a global plan, sets the most cost-efficient and likeliest picture for 2030 and defines generation addition patterns accordingly.

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 isolated off-grid generation. 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 2030 is also projected to be supplied through the grid, as this will be the most economic option. The remaining rural generation is off-grid, divided between mini-grids and isolated off-grid generation, including PV, mini-hydro, biomass, wind, diesel and geothermal. Mini-grids, defined as village- and district-level networks with loads of up to 500 kW , will constitute the bulk of off-grid generation, while isolated off-grid options will provide electricity to the remotest populations.

3. Quantify the investment costs and distribution and transmission costs

To evaluate the cost associated with generation, the Energy for All case feeds the added required generation to 2030 into the power generation module of the *WEM* and the transmission and distribution model of the New Policies Scenario (see Chapter 5: Power and Renewables Outlook). Costs for off-grid generation are adjusted on the base of available costs for the various options (mini-grid and isolated off-grid) by region and country. Consumer density is a key variable in providing electricity access: the cost per MWh delivered through an established grid is cheaper than that through mini-grids or off-grid systems, but the cost of

extending the grid to sparsely populated areas can be very high and long distance transmission systems have additional system losses.

4. Calculate the implication of the additional electricity generation on energy-related CO_2 emissions

The Energy for All case quantifies the additional electricity generation needed to have 100% electrification rate by 2030. Generating this additional power would have an impact on energy-related CO_2 emissions. The model assume that the electricity is generated using the fuel mix set out in the New Policies Scenario for the country or region in question. Additional CO_2 emissions are then calculated using the country specific CO_2 content of the power generation. Finally, this calculation is repeated assuming that the generation fuel mix to supply the additional demand were that of the 450 Scenario.

1.3.2 Achieving universal access to clean cooking facilities

In the New Policies Scenario, 2.7 billion people in 2030 rely on the traditional use of biomass as primary source for cooking, with serious consequences for their health. The Energy for All case shows a possible path towards the progressive penetration in the next two decades of clean cooking facilities (clean cooking fuels and stoves, advanced biomass cookstoves and biogas systems) until universal access is achieved in 2030.

LPG stoves are more likely to penetrate in urban zones, where infrastructure, distribution and fuel costs can benefit from economy scale and consumers have 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 (55%) are assumed to be provided with advanced biomass cookstoves, and the remaining 15% with biogas digester. Those global targets are then reflected in regional allocations of the various options (LPG, biomass cookstoves and biogas systems) that are derived from assumptions regarding the most likely technology solution in each region, given resource availability and government policies and measures.

Once determined the number of people by country -with rural/urban split- that need to be provided with each clean cooking facility option, investment are calculated on the base of unit costs of the devices. Advanced biomass cookstoves, with emissions and efficiencies similar to those of LPG stoves, are assumed to cost $50. The assumed cost of an average-sized biogas digester varies by region. Based on 2010 data provided by SNV, the Netherlands Development Organisation, the cost is $437 for India, $473 in China, $660 in Indonesia, $526 in other developing Asia, $702 in Latin America and $924 in sub-Saharan Africa. An LPG stove and canister is assumed to cost $60. Infrastructure, distribution and fuel costs are not included in the investment costs. We assume one stove or biogas system per household over the projection period, thus replacement costs are not included.

Expanding household access to modern fuels would inevitably increase global demand for these fuels, notably oil. Using World Heath Organisation (WHO) data for developing country households currently using LPG, we have estimated an average LPG consumption of 22 kg per person per year. The additional oil demand associated with access to LPG in the Energy for All Case is calculated based on the average per capita consumption (converted into mb/d of LPG) and the estimated number of people who switch to LPG stoves by 2030.

The impact on greenhouse-gas emissions of switching to advanced biomass technologies or LPG is very difficult to quantify because of the diversity of factors involved, including the particular fuels, the types of stoves and whether the biomass used is replaced by new planting and that a sustainable forestry management programme is in place. But it is widely accepted that improved stoves and greater conversion efficiency would result in emissions reductions

1.4 The 2011 Energy Development Index

The IEA has devised an Energy Development Index (EDI) in order to better understand the role that energy plays in human development. The index, which first appeared in *WEO-2004*, has been updated and modified to better track progress in a country's or region's transition to the use of modern fuels. The 2011 EDI is calculated in such a way as to mirror the UNDP's Human Development Index and is composed of four indicators, each of which captures a specific aspect of potential energy poverty:

- *Per capita commercial energy consumption*: which serves as an indicator of the overall economic development of a country.
- *Per capita electricity consumption in the residential sector*: which serves as an indicator of the reliability of, and consumer's ability to pay for, electricity services.
- *Share of modern fuels in total residential sector energy use*: which serves as an indicator of the level of access to clean cooking facilities.
- *Share of population with access to electricity*.

The choice of indicators is constrained by the type of data related to energy poverty that is currently available. For example, the per-capita commercial energy consumption figure is one indicator of overall economic development of a country but for reasons of data deficiency it fails to take account of biomass resources, including wood, charcoal and biofuels, which are used for productive activities in developing countries. Biomass data is seldom disaggregated in a sufficient manner to capture this reality. With the introduction of low-emission, high-efficiency stoves, biomass consumption will decline in many countries. Yet the EDI cannot adequately compensate for the fact that this decline will be slower than in those countries where households switch to liquid fuels for cooking, even though the impact on energy poverty could be similar. The countries included in the EDI are those for which IEA collects energy data.

A separate index is created for each indicator, using the actual maximum and minimum values for the developing countries covered (see Table 1 for the 2011 EDI minimum and maximum values).

Table 1: The minimum and maximum values used in the calculation of the 2011 Energy Development Index

Indicator	Minimum value (country)	Maximum value (country)
Per capita commercial energy consumption (toe)	0.03 (Eritrea)	2.88 (Libya)
Per capita electricity consumption in the residential sector (toe)	0.001 (Haiti)	0.08 (Venezuela)
Share of modern fuels in total residential sector energy use (%)	1.4 (Ethiopia)	100 (Yemen, Lebanon, Syria, Iran)
Share of population with access to electricity (%)	11.1 (Dem. Rep. of Congo)	100 (Jordan, Lebanon)

Performance in each indicator is expressed as a value between 0 and 1, calculated using the formula below, and the EDI is then calculated as the arithmetic mean of the four values for each country.

$$\text{Indicator} = \frac{\text{actual value-minimum value}}{\text{maximum value} - \text{minimum value}}$$

By publishing updates of the EDI on an annual basis the IEA hopes to raise the international community's awareness of energy poverty issues and to assist countries to monitor their progress towards modern energy access.