International Energy Agency
Secure
Sustainable
Together

Energy Access Outlook 2017

From Poverty to Prosperity

World Energy Outlook Special Report

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Luxembourg
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA.

International Energy Agency
Secure
Sustainable
Together

International Energy Agency
Website: ***www.iea.org***

For more than fifteen years, the International Energy Agency has been at the forefront of international efforts to assess and understand the persistent energy access deficit, providing annual updates on the global status of access to electricity and clean cooking. Each year, our analysis underscored that efforts were not enough to overcome the size of the problem. This year we have undertaken a new and in-depth study, and this sheds new light on progress in recent years and prospects for the future.

Our updated country-by-country data shows that the rate of new annual connections to electricity has accelerated over the last five years, and projections in our base case – which reflects policies in place as well as our assessment of the impact of new announcements and targets – show that several countries are on track to reach electricity for all by 2030. Alongside the continued expansion of grid connections, the declining cost of renewables and of decentralised solutions and the emergence of new entrepreneurs and finance streams using innovative business models are converging to boost the number and success rate of initiatives targeting access to electricity. Despite widespread global progress however, electrification efforts do not keep pace with population growth in sub-Saharan Africa, and those without electricity become increasingly concentrated in that region. By 2030, 600 million out of the 674 million people without access to electricity live in sub-Saharan Africa, a majority of them in rural areas.

India, a recent addition to the wider IEA family, stands out: half a billion people have gained access to electricity since 2000, with electricity now reaching 82% of the population, up from 43% in 2000. If this pace is maintained, India will achieve universal access in the early 2020s and achieve one of the largest successes in the history of electrification.

While there has been some progress on access to clean cooking, our analysis shows that by 2030 2.3 billion people will still lack access to clean cooking facilities, with 2.5 million premature deaths each year still attributable to the resulting household air pollution. If we are to witness the kind of progress expected on electricity, clean cooking must be placed on a par with electricity access on the policy agenda. Women spend on average 1.4 hours a day collecting fuelwood and four hours for cooking and also suffer the most from household air pollution: they must be at the heart of finding solutions.

Our ambitious strategy to achieve "Energy for All" describes how countries can build on existing successes to accelerate access at least cost. It won't be easy, but it is critically important. For access to electricity, renewables play a growing role in both grid-based electrification and the expansion of decentralised technologies that are essential for remote rural areas. For clean cooking, LPG delivers much of the access in urban areas, while in rural areas progress is achieved largely through improved biomass cooking. Though an additional $31 billion annually is needed compared to our base case to ensure that no one is left behind, it is not just a question of money – efforts on clean cooking in particular have to take account of social and cultural factors if they are to succeed. And it does not have to cost the earth: even with a minimal increase in energy demand (0.23%), achieving energy for all will not cause a net increase in greenhouse-gas emissions. The prize is huge: 1.8 million premature deaths are avoided and the reduced burden of collecting firewood for women gives them at least an additional hour each day that can be redirected to other activities.

We have many reasons for hope, and the inclusion of energy as a self-standing goal in the Sustainable Development Goals reaffirmed the international community's commitment to providing energy for all, as well as underlining the centrality of energy to the achievement of broader development objectives. But recognition of the importance of access to energy is not enough; we must take action. The agreement of the Sustainable Development Goals shows that there is worldwide acceptance that we cannot continue to accept a world where the act of preparing food is itself a cause of illness or death, or where women miss out on potential economic opportunities because of the time they spend each day collecting fuel, or where people living in rural areas do not have adequate light to secure their communities at night or allow children to do their schoolwork. We all have a stake in the success of efforts to ensure that energy for all is achieved by or before 2030. Global leaders need to work together to implement SDG 7 and foster an environment where all parties can contribute solutions and work together, making sure that local communities and especially women help shape solutions that work for them.

The IEA will enhance its efforts on sustainable energy for all, and is ready to lead on international data collection and analysis and to provide energy policy advice to its growing family and others on how to deliver sustainable energy for all and ensure that no one is left behind.

Dr. Fatih Birol
Executive Director
International Energy Agency

This study was prepared by the *World Energy Outlook (WEO)* team in the Directorate of Sustainability, Technology and Outlooks (STO) in co-operation with other directorates and offices of the Agency. It was designed and directed by **Laura Cozzi**, Head of the WEO Energy Demand Outlook Division. The principal authors were **Hannah Daly** and **Molly A. Walton**, who co-led the analysis. Principal contributors to the report were: **Law Gee Yong**, **Zakia Adam**, **Stéphanie Bouckaert**, **Olivia Chen**, **Davide D'Ambrosio**, **Luis Munuera** and **Brent Wanner**. Other contributors were Ali Al-Saffar, An Qi, Yasmine Arsalane, Elie Bellevrat, Laila El-Ashmawy, Vincenzo Franza, Timothy Goodson, Tim Gould, Han Mei, Paul Hugues, Kim Tae-Yoon, Kieran McNamara, Paweł Olejarnik, Claudia Pavarini, Toshiyuki Shirai, Glenn Sondak, Kira West and Xia Ting. Former IEA colleague **Dan Dorner** (HM Treasury, United Kingdom) played a leading role in the planning stages for this report. Jan Corfee-Morlot provided valuable inputs. **Teresa Coon** and **Eleni Tsoukala** provided essential support.

Edmund Hosker carried editorial responsibility.

The study benefited from valuable inputs, comments and feedback from the STO directors Dave Turk and Kamel Ben Naceur, as well as other senior management and colleagues within the IEA: Paul Simons, Laszlo Varro, Duncan Millard, Rebecca Gaghen, Aya Yoshida, Peter Fraser, Roberta Quadrelli, Ian Cronshaw, Heymi Bahar, Kieran Clarke, Marc-Antoine Eyl-Mazzega, Kate Dourian and Arnaud Pincet. Thanks go to the IEA's Communication and Information Office for their help in producing the final report, particularly Jad Mouawad, Chris Gully and Rob Stone for outreach and communications, Astrid Dumond for production and Bertrand Sadin for graphics. Lorcan Lyons also contributed to graphics and the website. Debra Justus was the copy-editor.

Experts from the Royal Institute of Technology, KTH-dESA, particularly Mark Howells, Dimitris Mentis, Francesco Fuso Nerini, Alexandros Korkovelos, Nandi Moksnes and Constantinos Taliotis; Politecnico di Milano, particularly Emanuela Colombo and Francesco Lombardi; and the International Institute for Applied Systems Analysis (IIASA), particularly Markus Amann, Jens Borken-Kleefeld, Janusz Cofala, Chris Heyes, Gregort Kiesewetter, Zbigniew Klimont, Peter Rafaj and Wolfgang Schöpp were key contributors to the report.

Other experts also provided key input for the report including Jem Porcaro, Monica Dean, Yasemin Erboy Ruff, Luc Seven (UN Foundation), Sarah Wykes, Hannah Mottram (both from the CAFOD), Irini Maltsoglou, Manas Puri, Luis Rincon (all from Food and Agriculture Organization of the United Nations) and Annemarije Koojiman (ENERGIA). The updating of the electricity and clean cooking access databases benefited greatly from the inputs of the Interventions for Healthy Environment Unit, World Health Organization, and numerous government and other national sources.

The work could not have been achieved without the support provided by DG Climate Action (European Commission) and the Government of Sweden.

A workshop of over 100 international experts was organised by the IEA to gather essential input to this study and was held on 27 March 2017 in Paris. The workshop participants offered valuable insights, feedback and data for this analysis.

Many experts from outside of the IEA provided input, commented on the underlying analytical work and/or reviewed the report. Their comments and suggestions were of great value. They include:

H.E. Amani Abou-Zeid	African Union Commission
Emmanuel Ackom	Technical University of Denmark
Heather Adair-Rohani	World Health Organization
Liwayway Adkins	OECD Development Co-operation Directorate
Alfred Ofosu Ahenkorah	Energy Commission, Ghana
Venkatachalam Anbumozhi	Economic Research Institute for ASEAN and East Asia
Thomas Andre	Schneider Electric
Vincenzo Antonucci	Instituto di Tecnologie Avanzate per l'Energia, France
Pepukaye Bardouille	International Finance Corporation
Philippe Benoit	Global Infrastructure Advisory Services 2050
Min Bikram Malla	Practical Action
Federico Bonaglia	OECD Development Centre
Jean-Paul Bouttes	EDF
Nigel Bruce	University of Liverpool, United Kingdom
Alessandro Casoli	The Carbon Trust
Sarah Chapman	Faro Energy
Naeeda Crishna Morgado	OECD Development Co-operation Directorate
Harry Clemens	HIVOS
Rebecca Collyer	European Climate Foundation
Christian De Gromard	Agence Française de Développement, France
Johanna Diecker	Global Off-Grid Lighting Association
Lisa Dignard-Bailey	Natural Resources Canada
Jessie Durrett	Global Alliance for Clean Cookstoves
Karabi Dutta	Household Energy Consultant
Jane Olga Ebinger	Sustainable Energy for All
Elmar Ebling	Asian Development Bank
Filip Ehrle Elveling	Ministry of the Environment and Energy, Sweden
Mikael Eriksson	Ministry of Foreign Affairs, Sweden
Alex Evans	The Global LPG Partnership
Vivien Foster	World Bank
Ashwin Gambhir	Prayas (Energy Group), India
Carlos Gascó Travesedo	Iberdrola
Olivia Gippner	European Commission
Cécile Gracy	Agence de l'Environnement et de la Maîtrise de l'Energie
Lisa Guarrera	Observatoire Mediterranéen de l'Energie
Monica Gullberg	Swedish International Development Cooperation Agency

Mansoor Hamayun	BBOXX
David Hawkins	Natural Resources Defense Council, United States
Andrew Herscowitz	Power Africa
Ijaz Hossain	Bangladesh University of Engineering and Technology
Anil K. Jain	NITI Aayog, India
Frank Jotzo	Australian National University, Australia
Michael Kelly	World LPG Association
Getahun Moges Kifle	Ethiopian Energy Authority
Vincent Kitio	UN Habitat
Hans Jørgen Koch	Nordic Energy Research
Masaomi Koyama	Ministry of Economy, Trade and Industry, Japan
Sarah Ladislaw	Center for Strategic and International Studies
Jon Lane	The Carbon Trust
Clarissa Lins	Catavento Consultancy, Brazil
Yves Maigne	Fondation Energies pour le Monde
Teresa Malyshev	Energy Consultant
Guillaume Meheut	Ministry of ecological and inclusive transition, France
Sabina Anokye Mensah	ANOMENA Ventures, Ghana
Bert Metz	European Climate Foundation
Reema Nanavaty	Self Employed Women's Association, India
Patrick Nussbaumer	United Nations Industrial Development Organization
Sheila Oparaocha	ENERGIA / HIVOS
Dorothea Otremba	GIZ, Germany
Jyoti Parikh	Integrated Research and Action for Development, India
Neeraja Penumetcha	Global Alliance for Clean Cookstoves
Ignacio Perez-Arriaga	Massachusetts Institute of Technology, United States
Koen Peters	Global Off-Grid Lighting Association
Alberto Piatti	Eni
Jesus P. Posadas	Department of Energy, Philippines
Manas Puri	Food and Agriculture Organization of the United Nations
Mark Radka	UN Environment Programme
Pippo Ranci	European University Institute
Vineet Saini	Ministry of Science and Technology, India
Carlos Salle Alonso	Iberdrola
Hans-Wilhelm Schiffer	Coal Industry Advisory Board
Andrew Scott	Overseas Development Institute
Tara Shine	Mary Robinson Foundation
Katia Simeonova	United Nations Framework Convention on Climate Change
Stephan Singer	Climate Network
Kristina Skierka	Power for All
Leena Srivastava	TERI University, India
Benjamin Sovacool	University of Sussex, United Kingdom
Lucy Stevens	Practical Action

Jeff Stottlemyer	CLASP / Global LEAP
Ørnulf Strøm	Norwegian Agency for Development Cooperation
Laura Sundblad	Global Off-Grid Lighting Association
Stacy Swann	Climate Finance Advisors, Benefit LLC
Emanuele Taibi	International Renewable Energy Agency
Minoru Takada	United Nations Department of Economic and Social Affairs
Katsushi Takehiro	Ministry of Economy, Trade and Industry, Japan
Özlem Taskin	OECD Development Co-operation Directorate
Rianne Teule	SNV Netherlands Development Organisation
Fabby Tumiwa	Institute for Essential Services Reform, Indonesia
Kevin Chika Urama	African Development Bank
Andrea Valcalda	Enel
Salvatore Vinci	International Renewable Energy Agency (IRENA)
Frank van der Vleuten	Ministry of Foreign Affairs, the Netherlands
Tom Van Ierland	European Commission
Ancha Venkata Ramayya	Jimma University, Ethiopia
David Victor	University of California, San Diego, United States
Wang Lifen	National Energy Administration, China
Marcus Wiemann	Alliance for Rural Electrification
Mary Wilcox	Practical Action Consulting
Eric Williams	OECD Development Co-operation Directorate
Felice Zaccheo	European Commission
Hisham Zerriffi	University of British Columbia, Canada
Florian Ziegler	KfW Development Bank, Germany
Cathy Zoi	Odyssey Energy, United States

The individuals and organisations that contributed to this study are not responsible for any opinions or judgements contained in this study. All errors and omissions are solely the responsibility of the IEA.

Comments and questions are welcome and should be addressed to:

Laura Cozzi
Head of the World Energy Outlook, Energy Demand Outlook Division
Directorate of Sustainability, Technology and Outlooks
International Energy Agency
31-35, rue de la Fédération
75739 Paris Cedex 15
France

Email: weo@iea.org

More information about the *World Energy Outlook* is available at www.iea.org/weo

Energy access is the "golden thread" that weaves together economic growth, human development and environmental sustainability. Energy has long been recognised as essential for humanity to develop and thrive, but the adoption in 2015 by 193 countries of a goal to ensure access to affordable, reliable, sustainable and modern energy for all by 2030, as part of the new United Nations Sustainable Development Goals (SDGs), marked a new level of political recognition. Energy is also at the heart of many of the other SDGs, including those related to gender equality, poverty reduction, improvements in health and climate change.

This year the International Energy Agency has built on its work on energy access to produce a ground-breaking and in-depth examination of the prospects for, and pathway to, modern energy access for all by 2030. The IEA has tracked country-by-country data on access for over fifteen years, providing forward-looking analysis on access to electricity and clean cooking. This year it has combined its comprehensive energy balance data with its detailed analysis of recent progress to provide a first of its kind historical analysis that covers more than 140 countries and shows not only the number of people who gained access to electricity and clean cooking since 2000 but also how they gained it. This has been combined with an in-depth review of energy access policy ambitions, and with overall energy sector modelling and geospatial analysis, to provide the global energy community with its most detailed and robust examination yet of the pathways to universal energy access by 2030, including a full assessment of costs and benefits.

A wide range of technologies and new business models are contributing to significant progress on electricity access

The number of people without access to electricity fell to 1.1 billion in 2016 from 1.7 billion in 2000. It is on track to decline to 674 million by 2030, with India reaching universal access well before then. Since 2012, more than 100 million people per year have gained electricity access, an acceleration from the rate of 62 million people per year seen between 2000 and 2012. Developing countries in Asia, led by India, have made significant progress, and the electrification rate in the region reached 89% in 2016, up from 67% in 2000. China reached full electrification in 2015, while 100 million people in Indonesia and 90 million in Bangladesh gained access since 2000. Electrification efforts in sub-Saharan Africa outpaced population growth for the first time in 2014, leading to a decrease in the number of people without access in the region. Nonetheless, despite progress in the last few years the electrification rate in sub-Saharan Africa is currently just 43%. Many developing countries in Asia are well on track to reach universal access, including India and Indonesia, and this region reaches an electrification rate of 99% by 2030. Latin America and the Middle East reach 99% and 95% electrification respectively. While several countries in sub-Saharan Africa, including Ethiopia, Gabon, Ghana, and Kenya, reach or are on track to reach universal electricity access by 2030, progress across the region as a whole is uneven, and the number gaining access fails to keep pace with population growth. By 2030, roughly 600 million of the 674 million people still without access are in sub-Saharan Africa, mostly in rural areas.

Analysis based on our unique database reveals that from 2000 to 2016 nearly all of those who gained access to electricity worldwide did so through new grid connections, mostly with power generation from fossil fuels. Over the last five years, however, renewables have started to gain ground, as have off-grid and mini-grid systems, and this shift is expected to accelerate. By 2030, renewable energy sources power over 60% of new access, and off-grid and mini-grid systems provide the means for almost half of new access, underpinned by new business models using digital and mobile technologies. Since 2000, most new access has come from fossil fuels (45% coal, 19% natural gas and 7% oil). The technologies used to provide access however have started to shift, with renewables providing 34% of new connections since 2012, and off-grid and mini-grid systems accounting for 6%. The declining costs of renewables and efficient end-user appliances and innovative business models for access are all having an impact. This combination of factors is set to transform the energy access landscape in the years to come, especially in rural areas. Over the period to 2030, new connections to the grid bring electricity to over half of those that gain access, and offer the most cost-effective means of access in urban areas, but decentralised systems are the most cost-effective solutions for over 70% of those who gain access in rural areas.

Improved access to clean cooking remains elusive

About 2.8 billion people still lack access to clean cooking, the same number today as it was in 2000. Yet, there are some notable success stories, especially in China and Indonesia as urbanisation and increased policy efforts are prompting a switch to liquefied petroleum gas (LPG), natural gas and electricity. China has seen a reduction in the share of people relying on solid fuels for cooking to 33% in 2015, from 52% in 2000. However, despite increasing awareness of the health and environmental risks, and decades of programmes targeting access to modern cooking, one-third of the world's population – 2.5 billion people – still rely on the traditional use of solid biomass while another 120 million people cook with kerosene and 170 million with coal. Most of those without clean cooking are living in developing Asia (1.9 billion), followed by sub-Saharan Africa (850 million).

In our projections, 2.3 billion people remain without access to clean cooking in 2030. Most progress comes from a switch to LPG in urban areas, especially in developing Asia. In rural areas, 370 million people gain access to clean cooking by 2030, but biomass remains a primary cooking fuel. Improved and advanced biomass cookstoves, which can be considerably more efficient and less polluting than traditional stoves, are the most common stepping stone towards clean cooking in rural areas, but are only used by one-in-ten households reliant on biomass as a cooking fuel in 2030. In developing Asia, 1.2 billion people are set to rely primarily on the traditional use of biomass for cooking in 2030. In sub-Saharan Africa, clean cooking efforts fail to keep pace with population growth: as a result, the number of people without access grows to 910 million in 2030.

India has led recent global progress in electricity access

Half a billion people have gained access to electricity in India since 2000, almost doubling the country's electrification rate. This remarkable growth puts India on course to achieving access to electricity for all in the early 2020s – a colossal achievement. The pace has accelerated in recent years, with an additional 40 million people gaining access each year since 2011. Nearly all those who gained access since 2000 have done so as a result of new connections to the grid, which has been the main focus of government measures. Coal has fuelled about 75% of the new electricity access since 2000, with renewable sources accounting for around 20%. Still, 239 million people remain without electricity access in 2016, about a quarter of the worldwide total. But India's continued emphasis on electrifying households means it is expected to reach universal electricity access in the early-2020s, with renewables accounting for about 60% of those who gain access. Progress has also been made on clean cooking, although 830 million people in India still lack access. There are clear indications however that government policy efforts targeting LPG have begun to take hold. The share of the population relying primarily on biomass for cooking fell to 59% in 2015 from 66% in 2011. By 2030, the promotion of LPG and improved biomass cookstoves by the government means that more than 300 million people gain access to clean cooking facilities, but still more than one-in-three people remain without.

Energy for all by 2030 is achievable and Africa must be at the heart of the process

Providing electricity for all by 2030 would require annual investment of $52 billion per year, more than twice the level mobilised under current and planned policies. Of the additional investment, 95% needs to be directed to sub-Saharan Africa. In our Energy for All Case, most of the additional investment in power plants goes to renewables. Detailed geospatial modelling suggests that decentralised systems, led by solar photovoltaic in off-grid systems and mini-grids, are the least-cost solution for three-quarters of the additional connections needed in sub-Saharan Africa. Scaling up investment in electricity access will require that the right policies and investment frameworks are in place. Similarly, reaping broader social and economic benefits will require a perspective on access that extends beyond household connections to include electricity for productive uses, such as businesses, agriculture and industry. This can create anchor loads to attract investment, lowering the average cost of household connections, improving food security and creating job opportunities, notably for women.

Achieving clean cooking for all relies on the deployment of LPG, natural gas and electricity in urban areas, and a range of technologies in rural areas and the involvement of local communities, especially women, when designing solutions. To achieve clean cooking for all, an additional 2.3 billion people need to gain access to cleaner fuels and technologies by 2030. The investment required for clean cooking facilities is modest, amounting to less than one-tenth of what is needed for universal electricity access. In the Energy for All Case, 800 million people gain access in urban areas. The mix of fuels and technologies for clean cooking in rural areas varies, depending on locally available resources and infrastructure, but in total around 1 billion people in rural areas gain access via improved biomass cookstoves, while LPG and biogas provide for the remaining 1 billion people. Providing funds is not enough on its own. Experience shows that past programmes can fall short if they don't take account of social and cultural factors and do not involve women from the outset.

Achieving "Energy for All" would provide significant benefits, especially for women, without having any impact on climate change

Providing energy for all would significantly improve the lives of those without access and boost their economic prospects. Women in particular stand to gain by cutting the time spent gathering fuel and cooking and avoiding household air pollution. At present, an estimated 2.8 million people die prematurely each year because of the smoky environments caused by burning solid biomass in inefficient stoves or from combustion of kerosene or coal for cooking. Women and children suffer most of the worst effects. In addition, households relying on biomass for cooking dedicate around 1.4 hours each day collecting firewood, and several hours cooking with inefficient stoves, a burden largely borne by women. Providing access to clean cooking for all lowers the premature death toll by 1.8 million people per year in 2030. It also reduces the amount of time spent gathering fuelwood and cooking - time which can be redirected to more productive activities or to acquire new knowledge and skills.

Achieving energy for all by 2030 will not cause a net increase in global greenhouse-gas emissions. Providing energy for all would have a minimal impact on global energy demand, with an increase of 0.2% (37 million tonnes of oil equivalent) relative to our base case. However, the corresponding rise in carbon-dioxide (CO_2) emissions of around 0.2% (70 million tonnes [Mt] of CO_2) in 2030, is more than offset as reducing the biomass used for cooking provides a net reduction in greenhouse-gas emissions, which would save the equivalent of around 165 Mt of carbon-dioxide equivalent from methane and nitrous oxide.

While each country will take a different route to achieving energy for all, there are some general lessons from what has already been done that will help along the way. Our analysis highlights that the following actions can help ensure "no one is left behind" – the imperative of the Sustainable Development Goals.

- *Implement policies that encourage a wide range of solutions and business models, avoiding barriers to new entrants*. Where progress has occurred, it is because policies have been clear and consistent, encouraged cost-effective investment from a wide range of financial streams and engaged a wide range of stakeholders, including the local community.

- *Facilitate rural electricity access by creating suitable conditions for off-grid investment, and by making provision for subsequent connection of decentralised solutions to the grid.* On-grid and decentralised solutions are complementary, and their relative share depends on a country's circumstances. Co-ordinated, flexible planning that encourages investment in both and makes provision to integrate them is the quickest and most resilient way to achieve access for all.
- *Make energy efficiency an integral part of energy access policies*. Efficient appliances and lighting, such as light-emitting diodes (LEDs), enable consumers to access more energy services for lower overall investment. It also facilitates the uptake of new business models and improves the affordability of off-grid solutions.
- *Take a holistic approach and include productive uses in energy access policies and targets.* Electrification strategies should take into account other development goals and opportunities to use energy access to stimulate economic activity and create jobs in addition to household electrification. Actions taken to achieve energy for all can complement those taken to address climate change.
- *Women need to be at the centre of the shift to clean cooking.* Despite the scope of the challenge, access to clean cooking receives less attention than access to electricity. For people, mostly women, to move away from solid biomass, policies and programmes need to reflect local needs and expectations, account for social and cultural factors, clearly explain the health risks, and empower women, as they are central decision-makers in household cooking matters.

The International Energy Agency (IEA) has long conducted in-depth analysis on the topic of energy access, recognising that a lack of modern energy access stifles development and amplifies inequality. The agreement of 17 new Sustainable Development Goals (SDGs) in 2015, which together make up the 2030 Agenda for Sustainable Development, underlines the importance of energy to development. For the first time, there is a goal focused specifically on ensuring access to affordable, reliable, sustainable and modern energy for all (SDG 7) by 2030. It is against this background that the IEA has produced this special report as part of its flagship *World Energy Outlook* series.

For more than 15 years, the IEA has provided annual updates of country-by-country data and forward-looking analysis on the two bellwethers of energy poverty – lack of access to electricity and clean cooking – in order to raise the profile of energy access in national and international policy circles and to provide the data necessary to inform effective decision-making and energy policies. This special report deepens and expands this analysis.[1]

- **Chapter 1** evaluates the role that energy plays in development – including its importance to meeting many of the Sustainable Development Goals – and what impact new technologies, declining costs and new business models are having on how energy and development intersect.
- **Chapter 2** provides a review of recent trends and policy efforts on access to electricity in developing countries. It also presents a global and regional electricity access outlook to 2030, and sets out what it would take to realise electricity access for all by 2030.
- **Chapter 3** covers the same ground as the previous chapter, but with a focus on access to clean cooking fuels and technologies.
- **Chapter 4** provides an in-depth focus on sub-Saharan Africa, looking at current and future trends for both electricity access and clean cooking, and how the region can achieve access to modern energy for all by 2030. In addition, it explores how enhanced energy services in the agriculture sector can boost productivity and underpin development.
- **Chapter 5** draws out the wider implications of achieving the SDG goal on access to energy for all in relation to energy demand, greenhouse gas emissions, investment, gender equality and health. It identifies key messages for policy-makers and other stakeholders to help accelerate efforts to achieve the target of ensuring universal access to affordable, reliable and modern energy services.

[1] For more information, data, and resources, see: *www.iea.org/energyaccess*.

Energy and development: the context

A renewed promise?

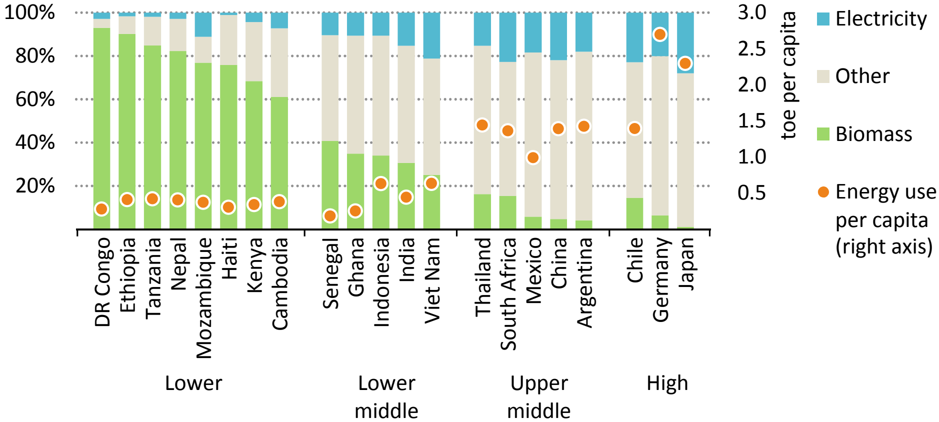
Highlights

- Energy has been long recognised as essential for humanity to develop and thrive, but the adoption in 2015 of new United Nations Sustainable Development Goals (SDGs) as part of the 2030 Agenda marked a new level of political recognition of the importance of energy to development. UN member states from 193 countries, developed and developing alike, adopted the SDGs which include, for the first time, a target to ensure access to affordable, reliable, sustainable and modern energy for all.
- The importance of energy access is not confined to this new target: it is also crucial to the achievement of many of the other SDGs, including those concerned with gender equality, poverty reduction and improvements in health. There are many important links between energy access and the other goals. Households relying on biomass for cooking dedicate around 1.4 hours each day collecting firewood, and several hours cooking with inefficient stoves, a burden largely borne by women. This time could be redirected to other activities to generate income or acquire new skills. More than 90 million primary school-aged children in sub-Saharan Africa go to a school that lacks electricity, hampering their education and their future economic prospects. And an estimated 2.8 million premature deaths per year are due to a reliance on solid biomass and coal for cooking and the use of candles, kerosene and other polluting fuels for lighting, often used in an enclosed space and without proper ventilation.
- Providing universal energy access for households, however, is not enough to ensure economic and social development. Energy also needs to be available for productive uses such as agriculture and industry to help achieve the SDG goal on poverty.
- Improvements in technologies offer new opportunities for making significant progress on the SDG goal on electricity access. The combination of declining costs for solar and decentralised solutions, cheaper and more efficient lighting and appliances, and new business models making use of digital, mobile-enabled platforms has increased the number of available solutions to cater to those currently without modern energy access. But many challenges remain, particularly for clean cooking.

1.1 What role for energy in development?

The provision of secure, affordable and modern energy for all citizens is central to poverty reduction and economic growth. Historically, the pathway to economic growth has largely been a consequence of a shift away from an agrarian based economy towards industrialisation and a knowledge-based economy. Such structural changes in an economy in turn change its patterns and levels of energy consumption and shift the types of fuels and energy technologies it utilises. Economic and social development thus tends to go hand-in-hand with energy sector transformation. As a country gets richer, its reliance on the traditional use of biomass – often non-commercial and used in inefficient stoves – tends to decline while electricity use and its per-capita energy use rise (Figure 1.1). For many countries, however, the objective of universal energy access has yet to be achieved (Box 1.1).

Figure 1.1 ▷ Final energy use per capita and fuel mix in selected low, middle and high-income countries, 2015



Energy use and fuel mix are strongly related to development

Notes: Other includes coal, oil, natural gas, heat, hydrogen and other renewables; toe = tonne of oil equivalent. Income brackets are based on the World Bank list of economies by income group by gross national income per capita: low income = $1 045 or less; lower middle = $1 046 to 4 125; upper middle: $4 126 to 12 745; high: $12 746 or more (World Bank, n.d.).

Access to modern energy is also a critical enabler of development at a household and community level. The poor and those without modern energy access are often the same, and having access to modern energy is a necessary condition for poverty alleviation which is the first Sustainable Development Goal (SDG) (see section 1.2.3 for a discussion on energy access and productive uses). For some poor households, a large share of their income may be directed towards low quality and often expensive energy sources, such as kerosene and candles for lighting, mobile phone charging at retail stations and dry cell batteries for electricity. They also have limited options to meet their basic cooking needs, and typically rely heavily on fuels and technologies which are inefficient, polluting and time consuming to provide and use.

Box 1.1 ▷ Defining energy access

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*".[1] A basic bundle of energy services means, at a minimum, several lightbulbs, task lighting (such as a flashlight), phone charging and a radio. *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)[2], as opposed to the basic biomass cookstoves and three-stone fires used in developing countries. This energy access definition serves as a benchmark to measure progress towards goal SDG 7.1[3] and as a metric for our forward-looking analysis.

The *World Energy Outlook (WEO)* electricity and clean cooking access databases contain country level data on the share of national, urban and rural households with electricity and clean cooking access since 2000. Data availability and quality limit the extent to which electricity reliability and affordability can be reported on a country basis; therefore the International Energy Agency (IEA) reports electricity access on the basis of connection only.[4] An ideal metric would measure the essential energy services that households benefit from and actually use, for example, illumination, communication, cooking and entertainment.

Moreover, this *WEO* Special Report includes a comprehensive update of each database which uses the most recent data available. For electricity access, our database includes household connections, either from a grid connection or from a renewables-based off-grid source. The approach excludes illegal connections. The data is sourced wherever possible from governments, supplemented by data from multilateral development

[1] A full description of the *World Energy Outlook* energy access methodology can be found at *www.iea.org/energyaccess/methodology*.

[2] ICS that are currently in use are not considered as clean cooking access; they have not been found to significantly improve household air pollution in most cases. For our projections, only improved biomass cookstoves which deliver significant improvements are considered as contributing to energy access.

[3] SDG 7.1 includes two specific indicators to measure progress: 7.1.1 – proportion of population with access to electricity and 7.1.2 – proportion of population with primary reliance on clean fuels and technology. This report specifically analyses what it would take to achieve SDG 7.1.

[4] The World Bank's Energy Sector Management Assistance Program is undertaking surveys in 15 countries to measure energy access according to the "Multi-Tier Framework", a methodology which measures multiple attributes of the supplied electricity and cooking fuel; this may be helpful in the future for assessing the impact of programmes and policies, though difficulties are likely to remain.

banks, various international organisations and other publicly available statistics including US Agency for International Development (USAID) supported Demographic and Health Surveys (DHS) data, the UN Economic Commission for Latin America and the Caribbean and the Latin American Energy Organization statistical publications. These sources have been used to update the historical time series for each country: together with *WEO* data gathered since 2000. This gives a first-of-its-kind assessment of progress for over 140 countries, including for the first time an assessment of off-grid electricity access, sourced from government and commercial data. People relying on "pico solar" products (see Box 2.2 in Chapter 2), mainly solar lanterns which may include mobile phone chargers, are considered to be below the minimum threshold to count as having access.[5] Nevertheless, there are significant benefits for the poor associated with pico solar products.

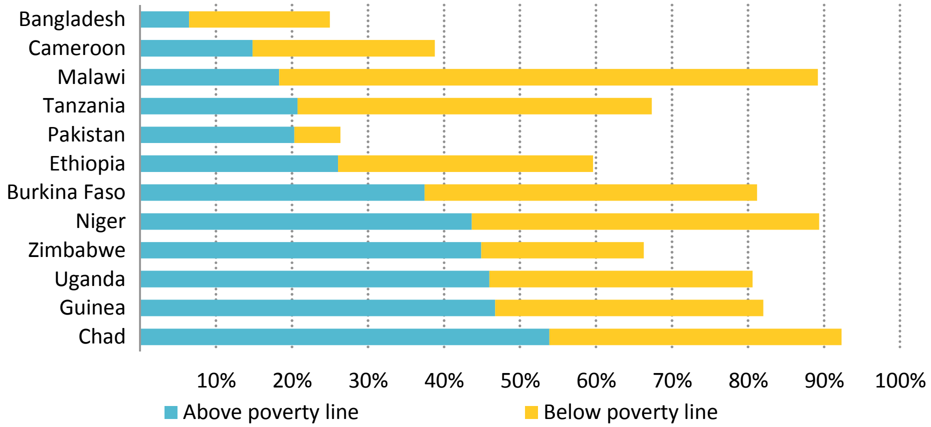
For clean cooking, a new historical analysis of reliance on cooking fuel use was undertaken for this report. The main source was the World Health Organisation (WHO) Household Energy Database 2016, which compiles national survey data on household cooking practices at urban and rural levels. This was complemented by IEA's *World Energy Balances*, which contain data on residential energy consumption, as well as government sources of data. The results give a new and fuller picture of clean cooking than has been previously available.

The relationship between income and household energy use is complex and varies by economic and geographic context. For example, while there is an inverse relationship on a global scale between gross domestic product (GDP) growth and the share of population using biomass for cooking, in several countries that relationship has not held (IEA, 2014). Cost and affordability may be the chief concerns for the poorest households, but other barriers exist, and can persist in medium- to high-income households which have affordable access to alternatives such as LPG and electricity. Evidence suggests that even when a household gains access to other fuels, such as LPG, it often continues to use biomass at least some of the time (a concept known as fuel stacking). For example in China, a survey of rural household fuel use in Hubei province found that 99% of households used at least two types of fuels, and that fewer than 10% of households had abandoned the use of biomass altogether when they could afford to do so (Peng et al., 2010). Another example is the Philippines, where reliance on biomass has increased despite growth in GDP per capita. There are a variety of reasons for this, including perceptions about the security and reliability of supply of alternatives to biomass, and cultural or social factors, including a desire to maintain traditions (Treiber, 2013).

[5] According to our definition of access, households benefiting from off-grid renewable access have at a minimum a system with battery storage that can deliver the basic bundle of energy services and that is capable of increasing the level of service over time to meet the regional average consumption.

In some developing countries, there are many people above the poverty line but without access to electricity (Figure 1.2). This signals the existence of systemic impediments such as insufficient policy, along with a lack of infrastructure and high cost of connection. In sub-Saharan Africa, at least 120 million people are living above the poverty line but are without electricity access; in developing Asia, this number is 70 million (World Bank, n.d.). In many developing countries, even when households do have access to electricity, it is often unreliable.

Figure 1.2 ▹ Share of population without electricity access above and below the poverty line in selected countries, 2016



In many countries even those who could conceivably pay for electricity still do not have access due to structural issues

Note: World Bank defines the poverty line at below $1.90 a day ($2011 at purchasing power parity).

Sources: World Bank; IEA analysis.

The transition to modern energy use is therefore a challenging one. Use of modern energy services beyond very basic needs requires those services to be technically available, affordable (i.e. at a price that does not prohibit use), adequate (i.e. sufficient supply and quality of supply), acceptable (in line with historical or cultural factors) and reliable (usable for most of the time). Even in countries that have achieved universal access to energy, such as in most high-income countries, the quality and affordability of access often remains a challenge (Spotlight).

S P O T L I G H T

Energy poverty in developed economies

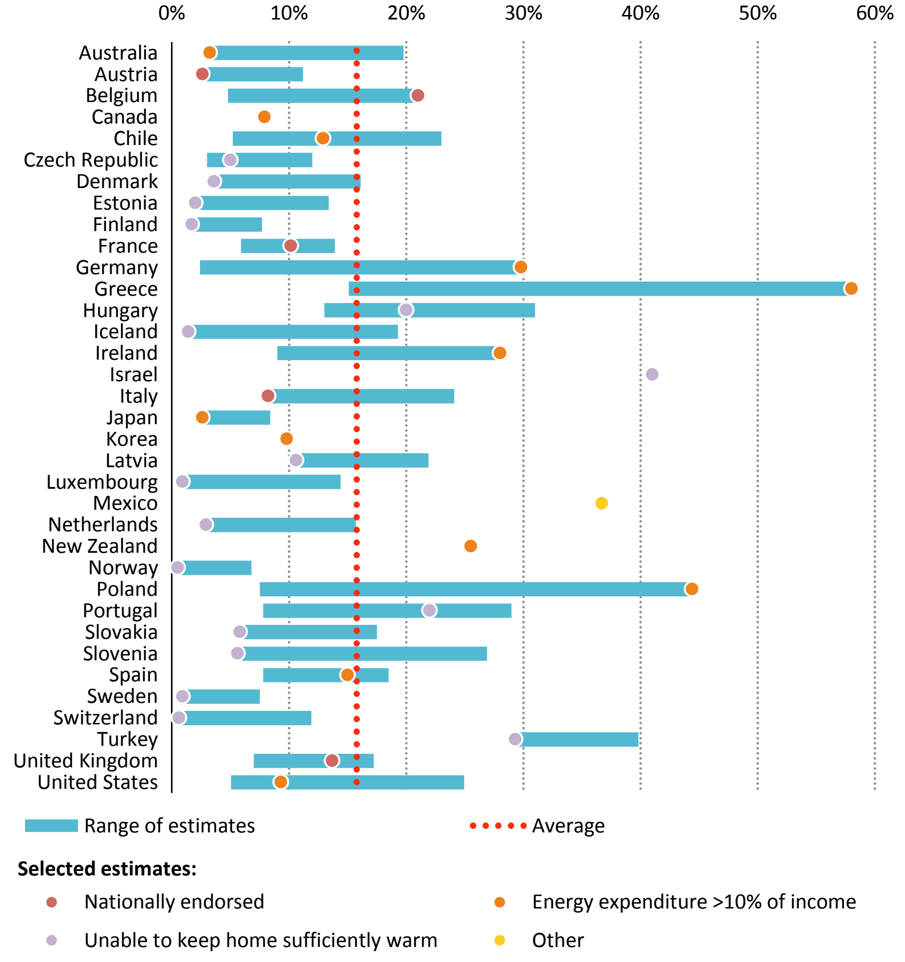
Energy poverty can take different forms, including a lack of access to modern energy services, a lack of reliability when services do exist and concerns about the affordability of access. Affordability can be an issue even in developed countries with universal and reliable access to modern energy. The United Kingdom has been the leader in investigating energy poverty, which it refers to as fuel poverty, with research going back to the 1970s. It initially established a UK Fuel Poverty Strategy in 2001 and a subsequent review in 2012 concluded that a household could be suffering from energy poverty for three main reasons, namely low incomes, high energy costs and energy inefficient dwellings. On the question of whether energy poverty is simply a side effect of income poverty, the study found that the overwhelming opinion was that income poverty is a key driver but not the sole cause or even a necessary condition for energy poverty.

To estimate the prevalence of energy poverty across developed economies, we compiled various estimates of the current level of energy poverty in each country (Figure 1.3).[6] Currently there is no internationally accepted measure of energy poverty in developed economies, although there is a growing body of analyses that points to a basket of commonly used measures (Rademaekers et al., 2016), mainly looking at household energy expenditures or subjective assessments of the affordability of energy use. Where possible, we used nationally endorsed measures (taking the average when more than one such measure exists). Where there are no such measures, we utilised or calculated using the most commonly used measure – the spending measure (proportion of households spending more than 10% of their income on energy). In addition, we took account of survey responses on whether households are able to keep their homes sufficiently warm. Based on this methodology, we calculate that an estimated 200 million people, over 15% of the total population in developed economies, suffer from energy poverty.

These are inevitably broad-brush calculations, reflecting the diversity of approaches, and the lack of commonly agreed definitions and data on the affordability of energy. In general, collecting energy affordability data does not get high-level recognition among developed countries. Only a few have a formal definition or measures to tackle energy poverty enshrined in legislation. There is a case for considering whether a common definition for energy poverty would be helpful and would spur data collection and measurement, while raising the profile of the issue and encouraging related debate.

[6] For this exercise, we have concentrated only on Organisation of Economic Co-operation and Development (OECD) countries due to the better availability of data, and focused on electricity and energy used in homes (e.g. for heating/cooling, cooking), but excluding mobility.

Figure 1.3 ▷ Share of population living in energy poverty in developed economies, 2015



Energy poverty affects a significant proportion of the population in developed countries, although estimates for each country depend on the measure used

Sources: IEA analysis based on various national sources, academic research papers and European Union Survey of Income and Living Conditions (EU-SILC, 2013).

1.2 Energy and the Sustainable Development Goals

Access to energy services is critical for advancing human development, furthering social inclusion of the poorest and most vulnerable in society and to meeting many of the SDGs. In September 2015, 193 countries – developing and developed countries alike – adopted the Sustainable Development Goals, known officially as the 2030 Agenda for Sustainable Development. The 17 new SDGs aim at ending poverty, improving health and gender equality, protecting the planet, and ensuring peace and prosperity for all. For the first time, the SDGs include a target focused specifically on ensuring access to affordable, reliable and modern energy for all by 2030 (SDG 7.1), signalling a recognition of the importance of access to modern energy services in its own right, and of the centrality of energy in achieving many of the other development goals.

The SDGs recognise the integrated nature of development. A lack of access to modern energy can make it difficult or impossible for a country to confront the myriad challenges that it faces, such as poverty (SDG 1), air pollution, low levels of life expectancy and lack of access to essential healthcare services (SDG 3), delivering quality education (SDG 4), adaptation and mitigation of climate change (SDG 11), food production and security (SDG 2), economic growth and employment (SDG 8), sustainable industrialisation (SDG 9) and gender inequality (SDG 5). Some of the key linkages are discussed in greater detail below.

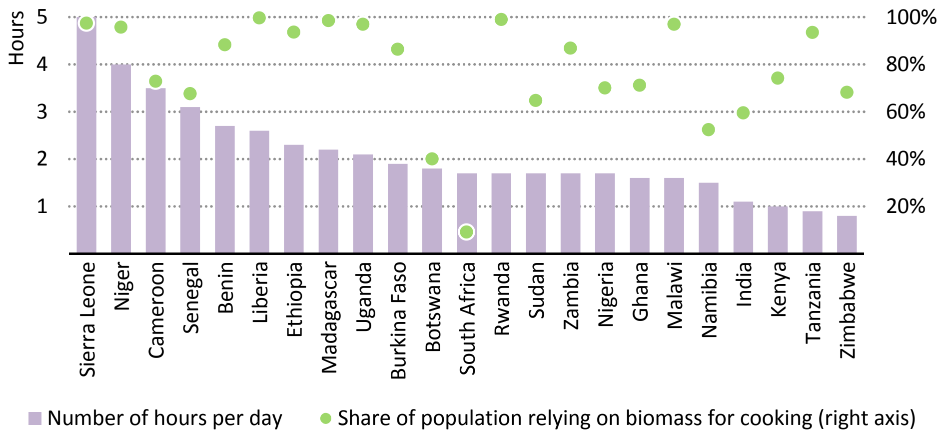
*1.2.1 **Energy access and gender equality** (SDG 5)*

There is a clear and important intersection between access to energy and gender equality. While a lack of access to modern and sustainable forms of energy impacts both men and women, inequalities in social standing, economic capability and gender-defined roles mean women often suffer from a lack of energy access in a disproportionate way.

In developing countries, women tend to bear responsibility for collecting and preparing fuel for cooking, as well as the cooking itself (Practical Action, 2016). Households dedicate an average of 1.4 hours a day collecting fuel, a burden born mainly by women and children (Figure 1.4). Moreover, the loads that they carry can have an impact on their physical well-being; in Africa, women carry loads that weigh as much as 25-50 kilogrammes (UNEP, 2017). A lack of access to clean, modern cookstoves and fuels, and a reliance on the traditional use of biomass for cooking also mean that women (and children) are the ones most impacted by household air pollution (see section 1.2.2). In rural households in South Asia, it is estimated that women spend four hours a day cooking when using traditional stoves (Practical Action, 2014). Women also bear most of the responsibility for household tasks such as cleaning and clothes washing, which take longer to do without access to modern energy.

Providing access to modern, affordable and reliable sources of energy has the potential to improve the well-being of women and children, and to provide women with new economic opportunities. Time saved through access to modern energy can be redirected towards education, social and family activities, and economic opportunities. Education has been shown to be an important driver of poverty reduction and income generation, and to enhance gender equality (ECREEE, 2015). Over 90 million primary school aged children in sub-Saharan Africa attend schools without electricity (UNESCO Institute for Statistics, n.d). In Brazil, girls with access to electricity in rural areas are almost 60% more likely to finish primary school by the age of 18 than those without, and self-employed women with access to energy have incomes that are two-times higher than those without (O'Dell, et al., 2014). In South Africa, electrification has raised female employment in newly electrified communities by almost ten percentage points because it has improved the efficiency of achieving household tasks (Dinkelman, 2010). In Nicaragua, access to reliable electricity has increased the ability of rural women to work outside the home by 23% (Grogan and Sadanand, 2013). However, there are women who generate income by selling firewood they collect, and so the provision of cleaner cooking options may reduce their income opportunities unless alternative opportunities are available.

Figure 1.4 ▹ Average number of hours spent collecting fuel per day per household



A high reliance on biomass for cooking in many countries means that women and children without clean cooking access spend an average of 1.4 hours/day collecting fuel

Sources: IEA analysis; UNEP, (2017); Practical Action, (2014).

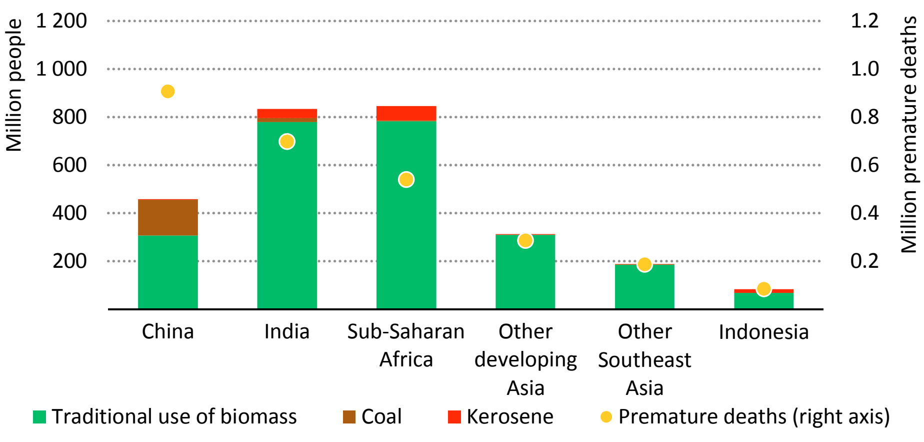
Women are often best positioned to identify, champion and deliver energy access solutions. The evidence suggests there are significant advantages in involving women from start to finish in the design of modern energy access technologies and programmes, and empowering women to become more involved in the provision of energy services (ARE, 2017; UNIDO, 2013). This is in part because they hold specific local knowledge about how different options could serve household needs, and because of their ability to influence their peers (Bonany et al., 2017 forthcoming).

Despite this, there is further to go in routinely including women when designing and implementing energy access strategies and ensuring that policies take gender into account. A number of multinational development banks, regional organisations and bilateral donors are now taking steps to mainstream gender in energy programmes and policy and methodologies and best practices are beginning to emerge. Moreover, several initiatives now bring together energy, gender, health and climate with women's empowerment, employment and representation in the energy sector, including the Global Alliance for Clean Cookstoves, SEforALL, ECOWAS Energy-Gender Policy & Regulation, ENERGIA and the Clean Energy Ministerial. These initiatives are positive steps and they should help policy-makers and institutions to better identify key barriers to improving energy access and the design of effective access programmes.

1.2.2 Energy access and health (SDG 3)

Health is another area where there is a particularly important linkage with energy access. The use of candles, kerosene and other polluting fuels for lighting has serious implications for health: so does reliance on solid biomass and coal for cooking (often in an enclosed space without proper ventilation). Together, they are responsible for an estimated 2.8 million premature deaths per year worldwide (Figure 1.5).

Figure 1.5 ▷ Population without access to clean cooking by fuel and region, and premature deaths from household air pollution, 2015



Household air pollution is responsible for 2.8 million premature deaths every year, concentrated in countries with a high reliance on biomass and coal for cooking

Sources: IEA analysis; International Institute for Applied Systems Analysis (IIASA).

Efforts to improve access to clean cooking have immense potential to improve household air quality and health, especially for women and children. The incomplete combustion of solid biomass in a three-stone fire, which is the most common traditional cooking method, releases significant particulate matter. There are alternatives such as improved or advanced biomass cookstoves (which have a chimney or a fan to aid combustion), and stoves fuelled by LPG, natural gas or solar power, which reduce household air pollution. Yet, even when these are available, households may decide they cannot afford them; or that the increased costs are not worthwhile, even if they are affordable. Moreover, the least-cost "improved" solution is not emissions free, and are often used alongside traditional alternatives, rather than entirely superseding them (known as fuel stacking).

While the challenges of providing access to clean cooking are many, so are the benefits. Clean cooking provides direct health benefits, including a reduction in the number of premature deaths. It also has the potential to help deliver other SDGs by reducing greenhouse-gas (GHG) emissions and improving the lives of women and children through a reduction in the burden of household chores related to fuel collection and cooking. In short, there are significant synergies between policies to address energy access, local air pollution, health and climate change, which underline the importance of integrating policies and local initiatives to reduce barriers to improving access to clean cooking (IEA, 2016a) (see Chapter 3, Box 3.2).

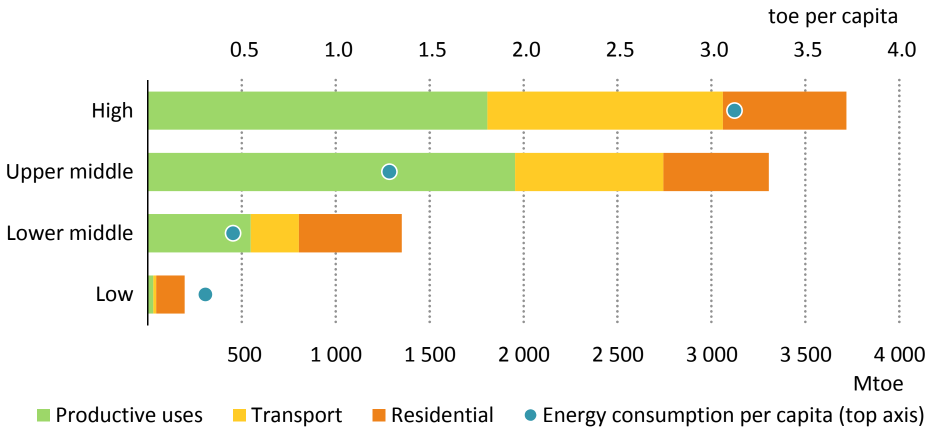
There are other synergies between energy access and health. Many people take for granted that healthcare facilities depend on energy to function and provide essential services. Almost 60% of health facilities in sub-Saharan Africa have no electricity (SE4All Africa Hub, 2014) while on average, just 34% of hospitals and 28% of health facilities in sub-Saharan Africa have reliable electricity access (WHO and World Bank, 2014). An estimated 60% of refrigerators used in health clinics in Africa have unreliable electricity resulting in a loss of almost half of vaccines while 70% of electrical medical devices used in developing countries fail, with poor power quality a major contributing factor (UNEP, 2017; WHO, 2010). Additionally, a lack of electricity means medical staff often has to work with flashlights or kerosene lamps. Moreover, the energy needs of the health sectors in low- and middle-income countries are expected to rise (Porcaro et al., 2017). The need for cold storage for vaccines, for example, is expected to increase and the growing need to fight diseases requires complex interventions that will drive additional energy requirements (WHO and World Bank, 2014).

1.2.3 Energy access for productive uses *(SDGs 1, 8, 9)*

Universal household energy access is necessary, but it is not sufficient to promote economic and social development, underscoring the need to also deliver energy access for productive uses across economies. In this *WEO Special Report*, productive uses refer to activities that create goods or services or that enhance income potential or value. This includes income generation in agriculture, industry, mining and commercial activity, but also education and health services, which can improve the potential to make economic gains.

In general, as a country undergoes the shift towards a more modern and diverse economic system that capitalises on technological advancement and a greater role for industry and services, it uses more energy and a larger share of total final energy is devoted to productive uses (Figure 1.6). That said, it is important to note that the provision of energy for productive uses cannot jumpstart an economy or a sector on its own, and that other issues, such as the development of technical and financial knowledge and capacity, infrastructure, functioning markets, and access to credit and financing are also critical.

Figure 1.6 ▹ Total final energy consumption by income group, 2016



Minimal energy use for productive uses in low-income countries highlights the economic divide and the importance of improving energy access to stimulate economic growth

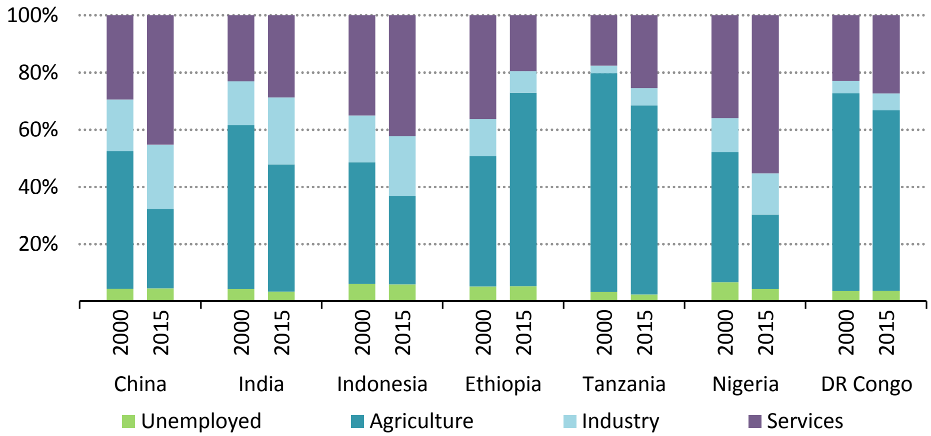
Notes: Mtoe = million tonnes of oil equivalent; toe = tonne of oil equivalent. Productive uses include industry, services, agriculture and non-energy use.

Agriculture[7]

Access to energy for agriculture is of paramount importance for economic development in most developing countries. Worldwide, agriculture accounts for just 6% of GDP (in PPP terms). While the share is around 2% in developed countries, it is much higher in some developing countries and regions: in India and sub-Saharan Africa, for example, agriculture accounts for around 18% of GDP. Moreover GDP figures often underestimate the importance of agriculture because of the difficulty of capturing the informal economy and thus the contribution of small shareholder farming. Agriculture is important for employment in developing countries. In India over two-fifths of the active population works in agriculture, and in some countries in sub-Saharan Africa the share is almost 70% (Figure 1.7). While boosting economic prospects, increased energy access may however initially decrease job opportunities in agriculture, especially for women, because of increased efficiency and mechanisation.

[7] Chapter 4 includes an analysis of the impact of providing energy access to agriculture in sub-Saharan Africa.

Figure 1.7 ▻ **Share of population employed by sector in selected developing countries**



In many low-income countries, agriculture is the largest source of employment

Source: United Nations International Labour Organization.

Many remote and rural regions in low-income countries remain without access to electricity; animal and human power provide the main energy inputs for farms, while traditional use of biomass or direct solar energy[8] provide energy for the limited processing that is done such as crop drying. No access to electricity affects food production: it also results in high levels of food loss since processing and storage options that need electricity are not available (Sims et al., 2015). High-income countries use more energy in the agriculture sector as they rely more heavily on mechanised farm equipment and a variety of technologies to process and distribute the products that enable them to have higher yields and to sell their output to markets (Box 1.2).

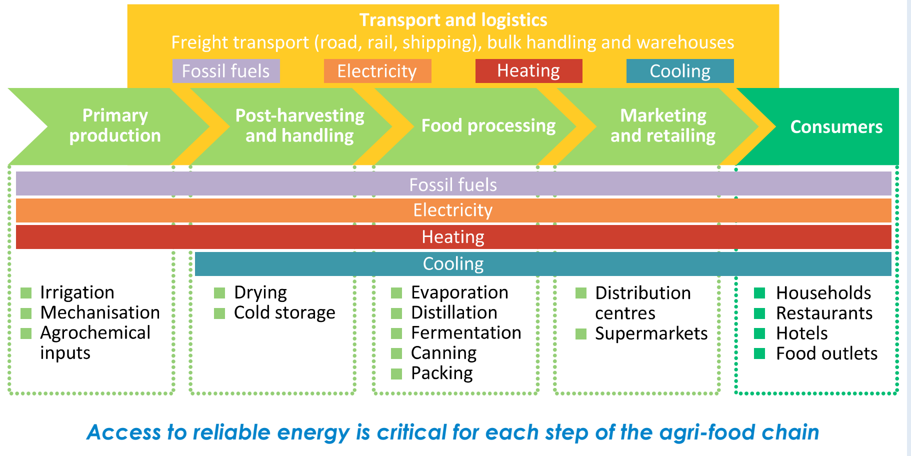
Box 1.2 ▻ **Energy access and the agri-food chain**

Access to adequate and reliable modern energy is important for food production. It can improve the productivity of every phase of the agri-food chain, from production to preparation (Figure 1.8). The pattern of energy use along the agri-food chain varies among countries, influenced by a range of factors such as the level of development, energy mix, availability of physical infrastructure and the type of products produced (cereals, rice, etc.). In developing countries, the cooking and preparation phase uses the largest share, in Africa for example, around 60% of total energy consumed in the agri-food chain is for this phase (FAO, 2011). As a country develops, its agricultural sector transitions towards higher levels of mechanisation as well as more capacity to process

[8] Not to be confused with modern sun-assisted drying or solar photovoltaic.

and store foods. This increases the total energy used within the agri-food chain, which is often generated from fossil fuels. In fact in developed countries processing and distributing food account for almost half of energy use in the agri-food chain (FAO, 2011). The use of fossil fuel energy contributes to the sector's level of GHG emissions: in 2011, the entire agri-food sector accounted for roughly 20% of global GHG emissions (FAO, 2011).

Figure 1.8 ▷ Agri-food processing chain and energy inputs



Sources: Adapted from Sims et al., (2015), Food and Agriculture Organization and USAID.

Today energy inputs are limited throughout the agri-food chain in developing and least-developed countries. This hinders efficient food production, handling and storage. The government of India estimated that the country loses over $14 billion worth of food a year, in large part due to a lack of cold storage (Ministry of Food Processing Industries, 2016). In South Asia, rice losses are over 10% higher in traditional value chains that use manual harvesting and milling compared to a mechanised value chain (Hodges et. al, 2011). The challenge is to expand access to modern energy, transition to renewable energy sources and improve the efficiency of the agri-food chain in order to bolster food security for all (Sims et al., 2015). In particular, providing energy for processing can increase the value of the products and generate economic and employment gains. To take just one example, a grain dryer introduced in Viet Nam was found to reduce the labour required to dry a tonne of rice from 46 person-hours to 7 person-hours, freeing time for farmers to engage in profitable off-farm activities and lowering the cost of drying from 10% to 4% of crop value (Hodges et al., 2011).

Sources: FAO; IEA analysis.

Irrigation is an important technique to increase agricultural productivity, though it needs to be carried out in a sustainable fashion. Irrigated cropland can be two-times more productive than rain-fed land, improving yields, and irrigation can help to manage fluctuations that occur from a dependence on precipitation (FAO, n.d.). However, the use of irrigation, especially groundwater irrigation, is often dependent on access to energy to pump and move water. Roughly seven-times more energy is needed to pump groundwater than is required for surface water extraction (IEA, 2016b). Improving access to energy for irrigation can lead to improvements in productivity. For example, in India food production has increased by around 35% since 2000, in part because of the introduction of more modern farming techniques, including the use of electric pumps for irrigation from groundwater sources. If inefficient pumps are used however, both water and electricity consumption can increase, which depending on the availability of each resource, can lead to unsustainable irrigation practices. An emphasis on irrigation infrastructure efficiency and the use of groundwater in a sustainable manner is vital to ensure that improvements in yield do not have adverse impacts.[9]

Fertiliser is another important input that can improve agricultural productivity and that also depends on energy. One study estimates that a 1 kilogramme (kg) per hectare (ha) increase in fertiliser increases cereal yields by roughly 8 kg/ha (McArthur and McCord, 2014), though it is important to note that increased use or improper use of fertiliser can have adverse environmental impacts in terms of GHG emissions and pollution from agricultural run-off (Vitousek et al, 2009).

Services

Reliable and affordable electricity is a vital input for shop owners, hospitals, schools and commercial activities. Though energy use in the services sector is small in most low-income countries, unreliable electricity often acts as a break on economic development. According to a 2016 World Bank Enterprise survey on infrastructure, business owners in some 30% of developing economies perceive unreliable electricity services as a major obstacle (Arlet et al., 2017). Sub-Saharan African economies suffered an average of 690 hours of outages in 2015 with an estimated cost to those economies of as much as two percentage points of GDP (World Bank, 2017). Many businesses have resorted to running their own generators. Where they exist, off-grid solar companies can offer an alternative to grid supplies and are providing electricity access to small businesses (Shapshak, 2016). By whatever means it is provided, reliable electricity can allow entrepreneurs to start and grow new businesses and provide services to communities that contribute to economic development and well-being.

Industry

Industry accounts for more than a third of total final energy consumption in developing countries, though it employs fewer people than agriculture. Industrial activity can serve as an anchor load for power that is provided from the grid. As industries generally place a

[9] For more information, see the *World Energy Outlook-2016,* excerpt – Water-Energy Nexus available at *http://www.iea.org/publications/freepublications/publication/world-energy-outlook-2016---excerpt---water-energy-nexus.html*.

value on the quality and reliability of power supply and are often viewed as a creditworthy customer by a power generator (utility or independent power producer), industry can foster the investment needed for larger energy infrastructure that would otherwise be uneconomic to provide electricity. This can make it more affordable to extend service to the surrounding communities and provide access to commercial enterprises and households. In low-income areas, initial industrial activity may be related to natural resources such as mining, forest products and agricultural processing.

In India, Omnigrid Power (OMC) is pioneering a plan to build 35-50 kilowatt (kW) solar projects in areas currently without a reliable grid to provide electricity to mobile phone towers. These projects will provide up to 30% more power capacity than is needed and use the excess power to serve the surrounding secondary market of households and small businesses (Oleksiw, 2016). To date, OMC is focusing on providing electricity to mobile towers because there is significant potential in India to use these towers as anchor loads. OMC is able to offset the higher costs associated with electrifying households because of a cross-subsidy provided by the anchor load. Another example is a solar-hybrid power plant built to supply electricity to a sugarcane plantation and processing factory in Zambia that is expected to produce surplus power that can serve surrounding communities as well as to export to neighbouring Angola (ESI Africa, 2017).

1.3 A shift in the energy access paradigm?

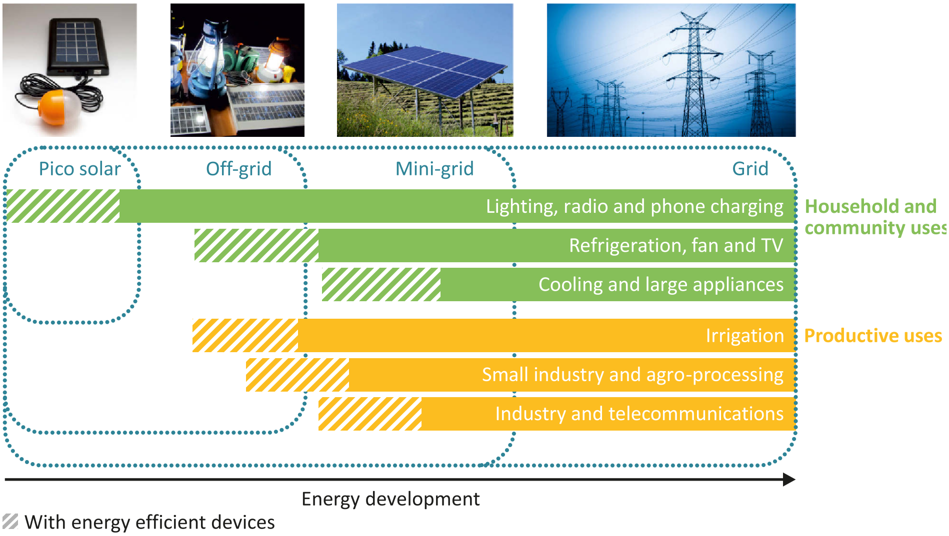
Over the last several years a new way of thinking about energy and development has been developing. New business models are starting up that take advantage of improvements in technologies, including the declining cost of renewables, and improvements in energy efficiency. Combined with existing efforts, these new business models could help accelerate progress at a scale that has the potential to transform access to electricity in the coming decade. These models have both facilitated and been supported by a variety of national and international policy efforts to support renewables and energy efficiency deployment, with a focus on holistic approaches to development that integrate economic, social, and environmental considerations.[10] So far, this shift has largely focused on access to electricity; there is a risk that clean cooking will be left behind.

The wide array of system designs now available – off-grid, mini-grid, and on-grid solutions – increases the number of pathways available to attain electricity access. Off-grid technologies (such as stand-alone solar home systems), mini-grids and energy efficient appliances are complementing efforts to provide electricity access from grid expansion. Such decentralised systems can help fill the energy access gap in remote areas to provide electricity at a level of access that is currently too expensive to be met via a grid connection and in urban areas by providing back-up for an unreliable grid supply. For both situations,

[10] For a summary of policies and regulations on energy access by country, see: the IEA's Policies and Measures Database: *www.iea.org/policiesandmeasures/* and the World Bank's Regulatory Indicators for Sustainable Energy: *http://rise.esmap.org*.

the dominant solution will depend on a range of factors, including relative costs (including per kilowatt), reliability, service levels, policies (such as subsidies), population density and household budgets. In addition, the use of more efficient appliances with these decentralised systems may allow consumers to access higher levels of energy services at lower cost, while needing less power for a given task (Figure 1.9 and Spotlight in Chapter 2).

Figure 1.9 ▹ Electricity access and illustrative technology options



The falling cost of technology and energy efficiency gains in end-use devices has increased the number of affordable options for those at the lowest levels of energy use

Notes: Off-grid refers to stand-alone systems. See Chapter 2, Box 2.1 for taxonomy of electricity technology terms.

Venture capitalists and social entrepreneurs are increasingly using new financing models to drive these new business models, capitalising on the digital revolution to provide services through decentralised renewables-based energy systems and to secure payment for those services. In most instances, these new systems do not compete directly with on-grid solutions, either in terms of market share or financing, but have instead introduced new entities and funding streams that are able to provide energy access in some places that were previously too difficult and costly to reach. To date the output from these new business models is small, but their existence is helping to bring about change. For example, some utilities are partnering with practitioners offering pay-as-you-go solutions, while other utilities are looking into electrifying telecom towers or mines with the possibility of using them as anchor loads.

In a similar fashion, the shift to approaching development from a more integrated point of view, influenced in part by the SDGs, is also changing the view of energy's role in development and the provision of energy services. Broadening the focus beyond households to include energy for productive uses and including productive uses in the focus of energy access policies and investments together can create a stronger business case for investors and a greater impetus for policy-makers to improve access to electricity.

There is also hope that progress on clean cooking can accelerate. After decades of effort with limited progress, the lessons learned from the limited uptake of improved biomass cookstoves and expanding LPG need to be applied if they are to make a difference in the coming years. Efforts to provide clean cooking are and will continue to be influenced by trends in urbanisation, and by the increasing policy attention being given to curbing the harmful impacts of household air pollution and advancing Nationally Determined Contributions and the SDGs. While many of the programmes continue to promote improved biomass cookstoves or biogas for cooking, particularly in rural areas, there is an increasing focus on the importance of LPG for clean cooking, especially in urban areas.

1.4 Defining the scenarios

This special report draws on the broader analysis and modelling in the *World Energy Outlook-2017* and makes reference to two scenarios for energy access to 2030.[11]

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, GHG emissions, local pollution and health.[12]

[11] This special report has a time horizon of 2030 as this is the target year stated in the SDGs.

[12] Note, the *World Energy Outlook-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 United Nations 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.

For the purposes 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. The relative attractiveness of grid versus decentralised solutions to deliver electricity access, as well as the generation mix, depends 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.[13] For cooking, our analysis takes into account the need for modern cookstoves and fuels. The technology characteristics of different electrification options and stove types are used to determine the investment, GHG emissions and changes in energy demand as a result of energy access in these scenarios.

[13] 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. The pollution and health impact of the scenarios were developed in collaboration with the International Institute of Applied System Analysis (IIASA) in Vienna, Austria.

Access to electricity

Flicking the switch

Highlights

- The number of people without access to electricity declined from 1.7 billion in 2000 to 1.1 billion in 2016, mainly via the expansion of the grid and with fossil fuels (45% coal, 19% natural gas and 7% oil). Progress has accelerated – more than 100 million people gained electricity access per year since 2012, compared with 62 million people per year between 2000 and 2012, and renewable sources of electricity provided 34% of this increased access.
- The majority of those without access to electricity are in developing countries in Asia and in sub-Saharan Africa. Since 2000, half a billion people have gained access to electricity in India – one of the largest electrification success stories in history. Other developing countries in Asia also registered significant progress, and the electrification rate is now 89%, compared with 67% in 2000. In sub-Saharan Africa, there are signs of promise as accelerating electrification efforts outpaced population growth for the first time in 2014, however, progress remains uneven and the electrification rate is currently only 43%.
- The country-by-country analysis of policies, investment and technologies that underpins the New Policies Scenario shows a projected electrification rate by 2030 of 99% in developing Asia and in Latin America and 95% in the Middle East. In sub-Saharan Africa, the access rate grows to 59% in 2030, however, overall progress does not keep pace with continuing population growth. Of the 674 million people still without access to electricity in 2030, 90% live in sub-Saharan Africa.
- In the New Policies Scenario, more than 60% of those who gain access by 2030 do so through generation from renewables, mostly solar and hydro. Grid extensions serve half of the newly connected, but in rural areas decentralised power systems are the most cost-effective solutions for more than two-thirds of those who gain access. Average investment costs are $24 billion per year to 2030, 1.5% of annual global energy investment.
- In the Energy for All Case, where universal access to electricity is achieved by 2030, the greatest challenge is to provide access to people living in the most remote areas in sub-Saharan Africa. New geospatial analysis shows that decentralised systems are the least-cost option to supply electricity for nearly three-quarters of those concerned, but that grid expansion also has an important part to play. The analysis also shows that almost 90% of those gaining access over and above the projections in the New Policies Scenario do so through generation from renewables. The additional annual investment cost is $28 billion per year to 2030, equivalent to 1.7% of total global energy investment.

2.1 Current status

Efforts to promote electricity access are having a positive impact in all regions, and the pace of progress has accelerated. Our analysis shows that the number of people without access to electricity fell to 1.1 billion people for the first time in 2016, with nearly 1.2 billion people having gained access since 2000 (Figure 2.1).[1] Great progress has been made in developing Asia, where the number of those who lack access to electricity fell from over one billion in 2000 to fewer than half a billion in 2016. There is also a positive trend in sub-Saharan Africa, where electrification efforts have been outpacing population growth since 2014, however, progress is uneven, and there are still more people without electricity today (588 million) than there were in 2000 (518 million). Increasingly, those who gain access are doing so via renewable sources, and decentralised systems are showing particular promise as a cost-effective way of providing access to those who lack it in rural areas (Box 2.1). However, despite the progress that has been made, 14% of the world's population still lacks access to electricity, 84% of which live in rural areas.

Box 2.1 ▷ Pathways to power: how do the solutions for electricity access differ?

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 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.

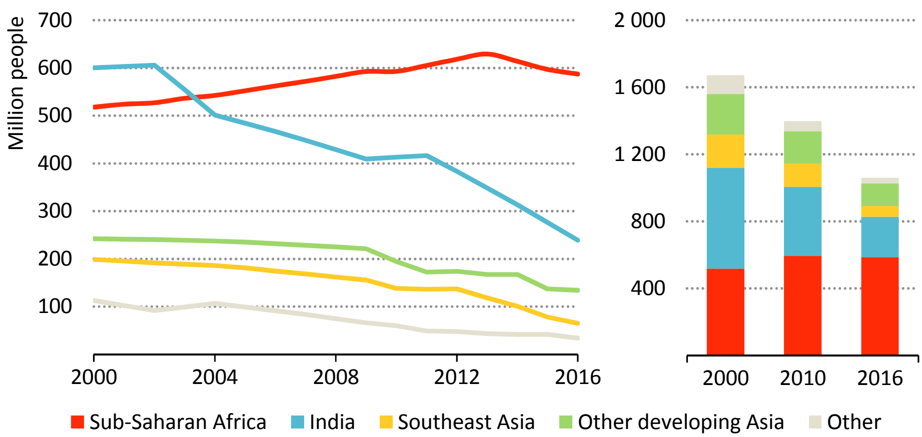
Mini-grids are an option in areas not served by main grids. They are localised power networks, usually without infrastructure to transmit electricity beyond their service area. Generally, mini-grids provide electricity at a higher levelised cost than a main T&D network system. Mini-grids tend to rely 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

[1] The *World Energy Outlook* databases on electricity and clean cooking access, which detail country-by-country access rates since 2000, are found in Annex A and *www.iea.org/energyaccess.*

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.

Figure 2.1 ▷ Population without access to electricity by region



Progress on electricity access is being made in all parts of the world, led by developing countries in Asia, in particular India

Note: Other includes Middle East, North Africa and Latin America.

2.1.1 *Regional and country developments*

Today about 89% of the population in developing countries in Asia have access to electricity, and this region accounted for three-quarters of the global population who gained access to electricity since 2000. Progress has accelerated: 75 million people gained access each year since 2012, compared with fewer than 50 million people per year between 2000 and 2012. Most developing countries in Asia have seen a sustained reduction in the number of people without electricity access such that the number of people without access has halved in the last ten years, even with population growth. China and India in particular have seen tremendous progress: China achieved universal electricity access in 2015, and half a billion people gained access to electricity in India since 2000 (Spotlight). In Bangladesh, the electricity access rate has increased by 15 percentage points over the last five years, due to a push for off-grid solar home systems and the provision of partial subsidies and loans to make these systems affordable. In Indonesia, financial support from the government to expand the grid has helped increase its access rate from 53% in 2000 to over 90% today. Sri Lanka, Bhutan and Viet Nam have reached almost full access to electricity.[2] There is still a long way to go to achieve universal access, but there is no denying the impressive progress made towards that goal.

In sub-Saharan Africa, 43% of the population now has access to electricity. There has been some encouraging progress in recent years, with 26 million people gaining access annually since 2012, an almost tripling of the rate seen between 2000 and 2012. East Africa registered significant progress. As a result, electrification efforts outpaced population growth for the first time in 2014, leading to a decline in the number of people without access since then. But progress overall has been uneven, and the number of people without access to electricity in sub-Saharan Africa remains higher today than in 2000 (see Chapter 4 for an in-depth look at sub-Saharan Africa).

In Latin America**,** 97% of the population now has access to electricity. Most of the population (17 million people) that lack access live in rural areas, often in isolated communities far from the grid and in difficult terrain. Only three countries have yet to achieve a 90% access rate: Haiti, Honduras and Nicaragua (which is just below that level). Haiti accounts for 43% of those without access in Latin America. The rate of access in urban areas is 45%, and in rural areas only 7% of the population has access. Widespread electricity theft and unwillingness to pay electricity bills in urban areas makes it very difficult for Electricité d'Haïti to maintain and provide sufficient energy to grid-connected households or to expand in to rural areas (Di Bella and Grigoli, 2016).

In the Middle East, 93% of the population has access to electricity. While near universal access has been achieved in most countries, it has proved difficult to make progress in Yemen, where over half of the population still lacks access to electricity.

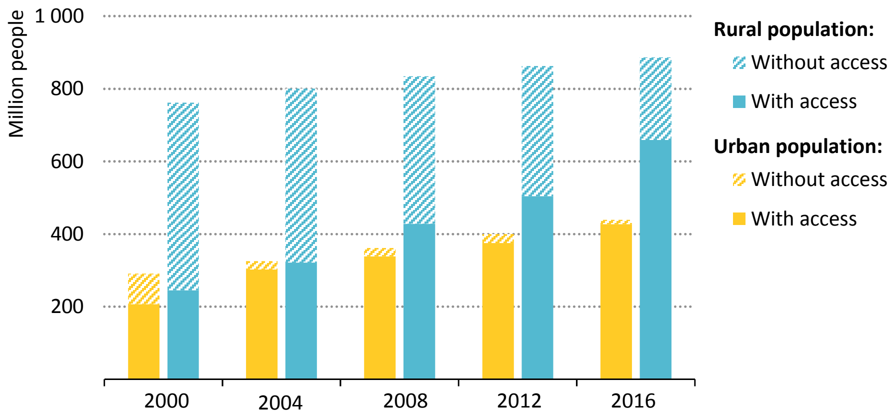
[2] For detailed information see *Southeast Asia Energy Outlook-2017*, *World Energy Outlook Special Report* (IEA, 2017b) which looks in-depth at electricity access for small island and remote communities in the region.

S P O T L I G H T

India charges ahead on universal electricity access

An estimated 239 million people were still without electricity access in India in 2016, equivalent to almost a quarter of the number of people without access worldwide. Notably, India has made significant strides in improving access, with electricity now reaching 82% of the population, up from 43% in 2000 (Figure 2.2). The pace is accelerating: the number of people gaining access has risen from 28 million per year between 2000 and 2012 to 41 million people per year in 2016. If this pace is maintained, India will achieve universal access in the early 2020s.[3]

Figure 2.2 ▷ Rural and urban populations with and without electricity access in India



Access to electricity is accelerating due to strong policy commitments in India

Universal household electricity access by 2022 was a central political commitment in India's 2014 national elections and the government has placed a high priority on delivering it. To that end it has introduced the Deen Dayal Upadhyaya Gram Jyoti Yojana scheme, which is focused on strengthening distribution networks and increasing village and household connections by co-funding network upgrades and extensions by

[3] India has electrification targets that focus on both electrifying villages (a village is considered electrified if 10% of households and community services have access) and households. It aims to electrify all villages by May 2018 and all households by 2022. On 25 September, 2017, the government announced a new commitment to achieve this target by the end of 2018. *WEO*'s analysis of all access is at the household level. India's electrification rate is derived from official national statistics which monitor rural household electrification (*https://garv.gov.in/garv2/dashboard/garv,* accessed 17 May, 2017).

the electricity distribution companies (DISCOMs). It has also entered into joint initiatives to develop detailed plans for delivering universal electricity access with individual states. Further it announced the Ujwal DISCOM Assurance Yojana (UDAY) scheme in 2015, which allows state governments, who own the DISCOMs, to take over 75% of their debt and pay back lenders by selling bonds. DISCOMs are to repay the remaining 25% through the issuance of bonds, in exchange for improvements in operational targets. By March 2017, 27 states had entered into memorandums of understanding with the government for the UDAY scheme.

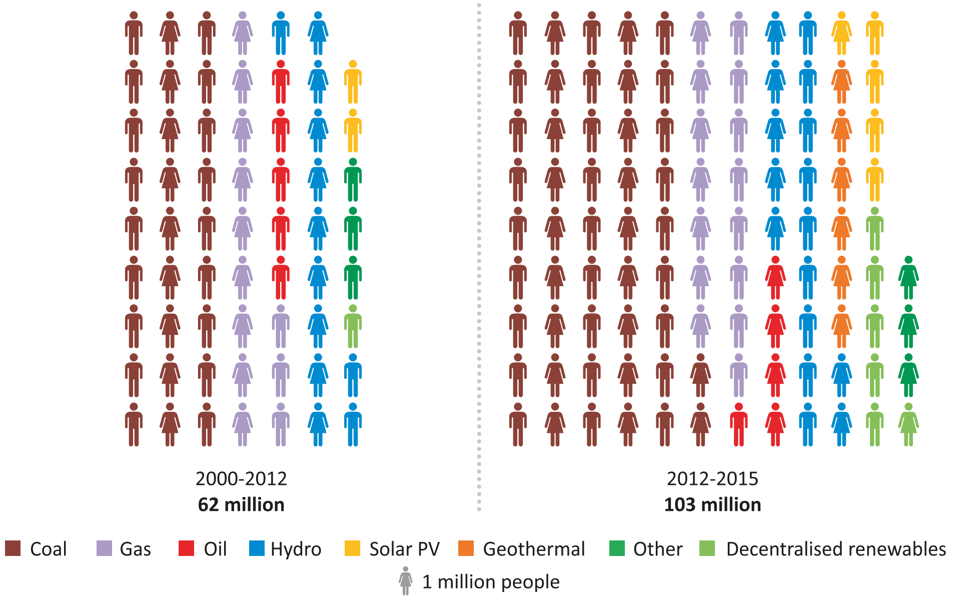
Over 99% of people who have gained access in India since 2000 have done so as a result of grid extension, which has been the focus of government measures. Coal has fuelled about 75% of the new electricity access since 2000, with renewable sources accounting for around 20%. A draft national renewable energy mini-grid policy was published in 2016 with the aim of developing 10 000 micro-grids and mini-grids with a combined capacity of 500 megawatts (MW). Although the policy has yet to be finalised, this could help boost decentralised access in the future, providing much needed clarity to potential investors; a significant barrier to increased deployment has been uncertainty about where and when the grid will be extended, increasing the investment risk. Similarly, in 2016 Uttar Pradesh enacted a policy outlining ways to facilitate the integration of mini-grids when the grid arrives, aiming to mitigate these challenges.

2.1.2 Challenges and solutions for improving access to electricity

Our country-by-country analysis shows that there has been no one-size-fits-all strategy for increasing access to electricity in recent years, reflecting the broad diversity of energy resources, infrastructure, institutions and geography across countries. Countries are using a wide array of technologies and strategies to meet their electrification goals. However, two important trends have emerged. First, the number of people gaining electricity access each year has accelerated, from 62 million between 2000 and 2012, to over 100 million since 2012. Second, the percentage of people gaining access from renewable sources (from both grid connections and decentralised systems) is slowly increasing (Figure 2.3). From 2000 to 2012, 72% of those who gained access did so via fossil fuels, with coal accounting for 44%. Renewable sources, mainly hydropower, accounted for the remaining 28%. Since 2012, the share of renewable sources has edged up to 34%. This has been driven by sub-Saharan Africa, where hydropower, geothermal and solar PV accounted for 70% of new electricity access since 2012.

The dominant pathway for providing electricity access to date has been through grid extensions, which has been the source of the vast majority (97%) of new electricity connections since 2000. Today, 33 million people, less than 1% of those with access in developing countries benefit from electricity access from decentralised solutions (excluding pico solar [Box 2.2]). However, the rapidly declining costs of solar PV, battery technologies and energy efficient appliances (especially light-emitting diode [LED] lighting) are making decentralised renewable energy systems more affordable. This is particularly the case for rural and dispersed communities not served by a main grid and where it may take years for one to arrive. Decentralised systems can also be attractive in areas with grid access but unreliable power supply.

Figure 2.3 ▷ Annual number of people gaining electricity access by fuel type in developing countries



Electricity access is accelerating and increasingly coming from renewable sources

Note: Other includes nuclear, bioenergy, wind, concentrating solar power, marine and waste.

While off-grid solutions, such as solar homes systems, make up the bulk of the decentralised systems being deployed, the role for mini-grids is expected to increase, especially when electricity access initiatives aim to provide electricity for productive and commercial activities as well as households. However, for mini-grids to be commercially viable to a developer, power demand from households and businesses has to provide an acceptable return on investment. In many cases, areas with a low density of electricity demand may be better served by off-grid systems. If they are to achieve their full potential, mini-grids need a supportive enabling environment, the key elements of which are likely to include a clear national grid extension plan, a framework that regulates how to integrate mini-grids if or when the main grid arrives, and clear rules for setting tariffs.

Box 2.2 ▷ Pico Solar: a stepping stone to household electricity access, not a long-term solution

Pico solar installations comprise a solar panel, battery, one or more LED lamps and in many cases a mobile phone charging port. Pico solar provides a level of access to electricity that is lower than the IEA's minimum threshold definition (see Chapter 1, Box 1.1), but it nonetheless provides significant benefits to those previously without any access. Pico solar has caught on rapidly because of its affordability, modularity and ease of installation and maintenance in rural regions. Over 23 million units of branded pico products have been sold since 2010, and pico products represented 94% of all off-grid solar sales in 2016, mostly in South Asia and sub-Saharan Africa (REN21, 2017).

Pico solar offers a low-cost way for people to secure an immediate improvement in their quality of life. For a payment starting at roughly $15 for the smallest device, people can own a product which provides reliable light of better quality than that from a kerosene lamp and reduces household air pollution and related health hazards (IEA, 2017a). Moreover, as pico systems are typically used to replace kerosene lamps (Rom et al., 2017), the one-time payment for the system replaces recurrent payments for kerosene, lowering expenditures on lighting from approximately 9% to 2% of total household income (Africa Progress Panel, 2017). However, even though a solar lantern may be cost effective over a longer period, the affordability of the upfront cost can still be a barrier for the poorest households.

Yet, improving the quality of life for households beyond the basics will require more power than such a system can supply. Higher levels of energy supply are needed to support a range of appliances which can reduce household chores and improve productivity. For example, pico solar cannot power refrigerators or televisions. Nor can pico solar meet energy needs at a community level or for commercial or other productive uses. Pico solar is therefore best viewed as an important near-term stepping stone for communities on the path to electrification.

A recent feature of the energy access landscape has been the way that commercially viable decentralised systems for providing electricity access are gaining momentum, aided by government policies, changing market conditions and new business models. Business models have emerged that capitalise on the widespread availability of digital and information and communication technology[4] to provide access via renewable off-grid systems at low costs, and they are already having an impact on expanding access in Africa (see Spotlight in Chapter 4). Many of these business models focus on using mobile phones to collect payment for energy services, to use and manage the service, and to monitor use

[4] *Digitalization & Energy*, a new IEA report looks at the intersection between digitalisation and the energy sector (IEA, 2017c).

of the service, making it easier to spot and deal with performance related problems and theft. So far, solar home systems, which are increasingly cost competitive with kerosene and diesel, have been the technology most widely deployed with these new mobile platforms and pay-as-you-go (PAYG) financing. PAYG helps consumers overcome the high upfront costs of the technology that traditionally has been a significant barrier to uptake in poor communities. Developments in mobile technology, such as cloud-based metering and software platforms, can also be paired with larger systems such as mini-grids, which could be used to offer households additional services, and to provide power for productive use, including, for example, irrigation. Most of the available finance so far has come from international investors (Sanyal et al., 2016). Increased access to local finance would increase the number of companies in the market, including local companies, helping to expand the market and reach more of those currently without access to electricity.

New business models providing off-grid access with solar PV are also bundling these services with efficient appliances to make them affordable to households (see Spotlight in Section 2.3). While very efficient appliances provide benefits whether they are used in households with access from a connection to the grid or from a decentralised system, they are particularly important for renewable off-grid solutions. Decreasing electricity demand can reduce the upfront cost of the system, such as a PV panel, delivering significant cost savings, even when taking into account the increased cost of appliances.

Although decentralised systems are an essential part of efforts to bring electricity access to under-served populations, they are not without challenges. On a per kilowatt-hour (kWh) basis, they are typically more expensive than grid extension. They also bring technical maintenance and management challenges, and they may still need support in the form of capacity training and subsides to support their uptake (ECA, 2017). Additionally, the limited amount of energy supplied can make it difficult to deliver a diverse and meaningful set of energy services, requiring additional capital investments.

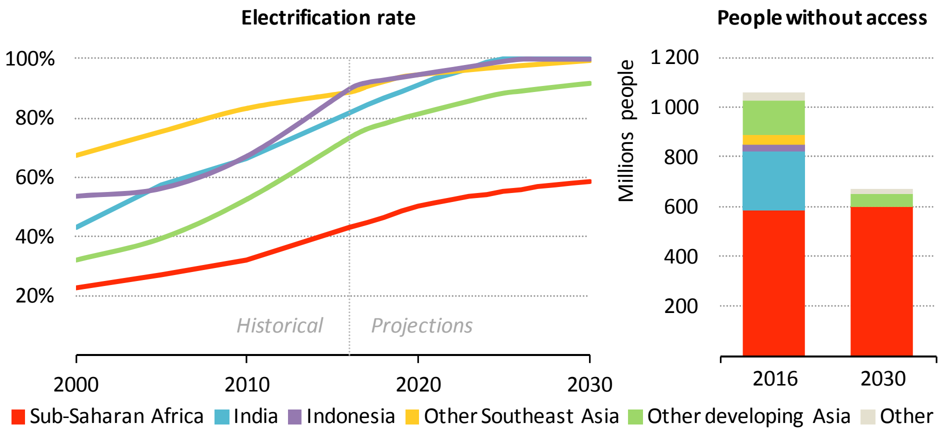
Affordability in particular remains a critical barrier to scaling up these solutions. Even though people without electricity access often pay a lot for their energy sources, such as kerosene and candles – sometimes more than they would pay for the same service if they had electricity access – the upfront costs for off-grid systems may still be higher than most consumers are willing or able to pay. As discussed, PAYG business models which bundle services and appliances offer scope for overcoming the upfront cost barriers. Governments can also help by lowering the cost for decentralised solutions by de-risking investments, by streamlining regulations for where and how mini-grid solutions can be deployed, and by providing clarity on future grid plans, so that investors and customers can plan accordingly. Targeted subsidies could also potentially help with affordability, for example by lowering connection fees or upfront costs (IEA, 2011).

2.2 New Policies Scenario

Our country-by-country analysis of national targets, investment plans, grid extensions and financial commitments points to a continued decline in the population without electricity access, with many countries expected to achieve universal access by 2030. The number of people without access to electricity is projected to fall by 36% by 2030, despite an increase in the global population. However, this still means that 674 million people (8% of the world's population) are without access to electricity in 2030, 90% of which will be in rural areas.

In the New Policies Scenario, the overall access rate in developing countries increases from 82% today to 90% in 2030, and many countries in Asia, Latin America and the Middle East achieve or come close to achieving the target for universal electricity access by 2030 (Figure 2.4 and Table 2.1).

Figure 2.4 ▷ Electricity access rate and population without electricity by region in the New Policies Scenario



By 2030, nine-out-of-ten people without access are in sub-Saharan Africa

Note: Other includes Middle East, Latin America and North Africa.

The pace of progress slows compared to the last few years, however, with 44 million people gaining access each year, rather than the 92 million needed to meet universal access by 2030. While India and other developing countries in Asia approach universal access, 80% of the population without access to electricity are concentrated in rural sub-Saharan Africa. Although there are exceptions, progress in most sub-Saharan countries is relatively slow (see Chapter 4).

The means by which access is provided over the *Outlook* period are more evenly spread among technology solutions than in recent years, with on-grid providing access for half of the population who gain access between 2016 and 2030, while mini-grid and off-grid solutions each providing access to roughly a quarter. The role of renewable sources is significant – more than 60% of those who gain access by 2030 do so with electricity generated from renewables.

In developing countries in Asia, the electrification rate increases from 89% in 2016 to 99% in 2030, bringing the population without access down from about 439 million in 2016 to 54 million in 2030. This achievement is largely the result of India's tremendous electrification effort, which sees 250 million people gain electricity access between now and the early 2020s, when it reaches full access.

2

Table 2.1 ▷ Population without access to electricity

					New Policies Scenario	
	2000		2016		2030	
	million	%	million	%	million	%
Africa	532	66%	588	48%	602	36%
North Africa	14	10%	0	0%	0	0%
Central Africa	73	90%	98	75%	122	63%
East Africa	164	90%	172	61%	135	34%
South Africa	15	34%	8	14%	1	1%
Other Southern Africa	108	86%	135	69%	156	55%
West Africa	158	67%	175	48%	188	36%
Developing Asia	1 059	33%	439	11%	54	1%
China	18	1%	0	0%	0	0%
India	600	57%	239	18%	0	0%
Indonesia	99	47%	23	9%	0	0%
Other Southeast Asia	100	33%	42	11%	2	<1%
Other developing Asia	242	68%	135	27%	52	9%
Central and South America	56	13%	17	3%	4	1%
Middle East	15	9%	17	7%	14	5%
World	**1 672**	**27%**	**1 060**	**14%**	**674**	**8%**

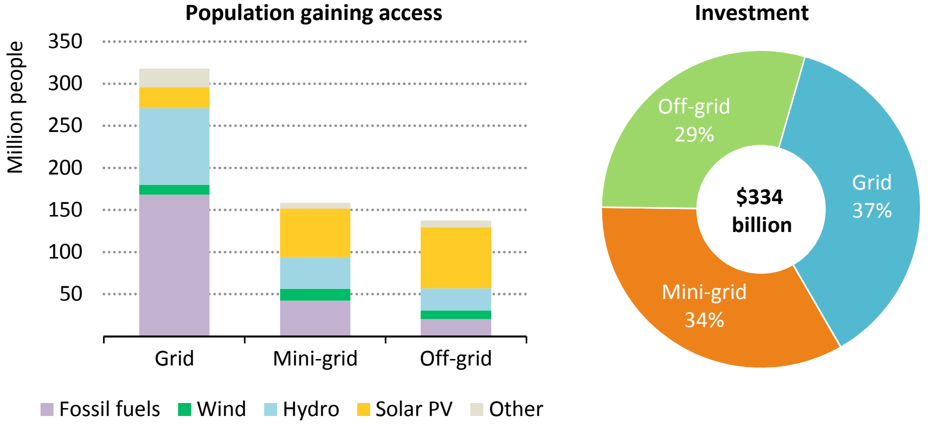
By 2025, Indonesia achieves an electrification rate of 99%. All other Southeast Asian countries, except Lao PDR, Cambodia and Myanmar, reach universal access by 2030. Afghanistan and Bangladesh both reach universal access by the late 2020s by making use of state-supported off-grid solar home systems. The rest of developing Asia is further behind, most notably Democratic People's Republic of Korea (North Korea), East Timor and Papua New Guinea.

In Latin America, nearly three-quarters of countries attain universal access by 2020 and by 2030 the region achieves near universal access, with Haiti the only country with an access rate below 90%.

Pathways for providing access

Experience from countries that have reached universal access indicates that the last 10-15% of the un-electrified population is the slowest and most costly to connect. It took countries such as China and Thailand 20 years to improve electrification rates from 30-40% to 85-90%, and another 20 years to reach universal access. Many developing countries in Asia have reached the point where electrification rates have historically slowed, but the New Policies Scenario indicates that the emergence of new solutions such as decentralised renewable systems, together with continued policy commitments and financial support, is capable of accelerating the rate of electrification for the last 10%.

Figure 2.5 ▷ Cumulative population gaining access to electricity and cumulative investment in the New Policies Scenario, 2017-2030



Half of those who gain access in the New Policies Scenario do so via the grid

Note: Other includes nuclear, bioenergy, geothermal, concentrating solar power and marine.

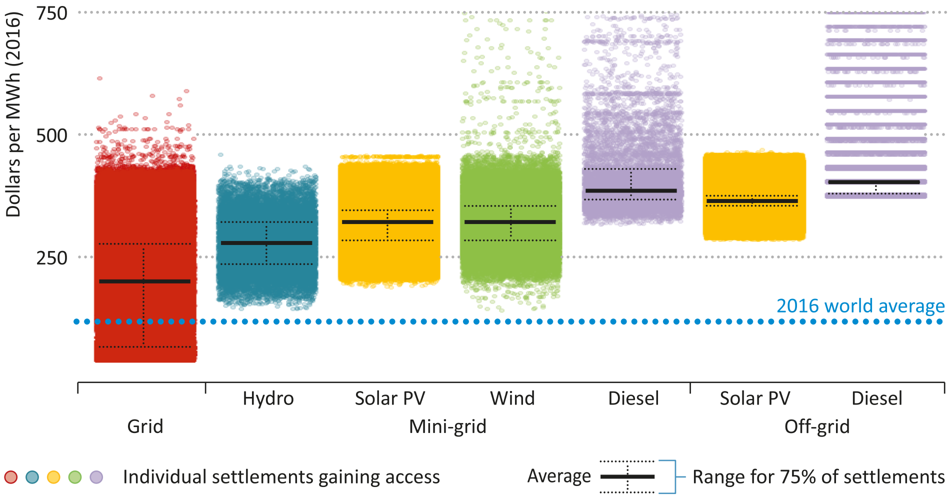
Sources: IEA analysis; KTH Royal Institute of Technology, Division of Energy Systems Analysis (KTH-dESA).

The centralised power grid remains the primary means for electrification because it is the least-cost option per kWh for the largest share of those gaining access, representing half of the total. However, the increasing concentration of those without access in rural areas and the continued challenges associated with bringing the grid to remote locations has widened the sources of supply of electricity, and this is reflected in our New Policies Scenario (Figure 2.5). By 2030, more than two-thirds of the rural population that gains access does so with decentralised solutions, with demand served by mini-grids reaching 72 terawatt-hours (TWh), a level higher than rural provision from the grid, and off-grid systems reaching over 55 TWh. Sub-Saharan Africa in particular has seen significant growth in the role that decentralised systems play in providing access in rural areas over the last few years, and by 2030, off-grid and mini-grid systems generate the majority of the electricity used to bring access to rural areas. In developing Asia, which is home to countries like Indonesia and the

Philippines with thousands of islands, two-thirds of electricity related to expanding access in rural areas comes from decentralised systems in 2030 (Box 2.3).

While fossil fuels continue to play a role in providing access via the grid, their share declines: 40% of those who gain access over the period to 2030 do so with fossil fuels, down 30 percentage points from the figure for 2000-15. Coal's role in particular declines dramatically: it provides access to 16% of those who gain it over the next 14 years, compared with 45% since 2000. Of the 375 million people who gain access from renewable sources over the next 14 years, more than 60% are from decentralised solutions, reflecting the increasing concentration of those without access in remote areas. This has significant implications for carbon-dioxide (CO_2) emissions related to energy access, an issue that is examined in detail in Chapter 5.

Figure 2.6 ▷ Levelised cost of electricity (LCOE) for electricity access solutions in the New Policies Scenario to 2030



On-grid access provides the lowest-cost pathway to electricity access, but for remote areas, mini-grid and off-grid systems are a cost-effective way to expand access

Notes: Each dot represents an individual settlement. Each settlement represents an area of one square kilometre. The least-cost option for 25 million settlements is presented. 2016 world average represents the average LCOE of the overall electricity supply for residential consumers across regions.

The system cost for providing electricity to households in sparsely populated rural areas, far from the existing grid is generally higher than that for a typical urban household (Figure 2.6). For such customers, providing access through decentralised solutions may be less costly from a system perspective than doing so through grid extension. However, people living in these areas also generally have lower incomes than those in urban areas, limiting their ability to pay. Mini-grids tend to be the lowest cost solution for remote communities far from existing grids with relatively high population densities, while off-grid solutions tend to be most cost effective for areas with low population densities.

In the New Policies Scenario, the total cumulative investment for providing electricity access amounts to around $334 billion over the period to 2030, 1.5% of global investment in the energy sector.[5] The total investment for electricity access is roughly a third each for on-grid access, mini-grids (generation and distribution) and for off-grid. Almost 90% of all investment in generation is for renewables, particularly for solar PV. Of the total investment for providing electricity access, 70% is in developing Asia, while around 25% is for sub-Saharan Africa.

Box 2.3 ▷ Electrifying the islands and rural communities in Southeast Asia

In Southeast Asia, 65 million people remain without electricity access and millions more only have access to poor quality connections, relying on costly and polluting diesel generators to meet demand (IEA, 2017a). Of those currently without access, over 95% live in four countries: Indonesia (23 million), Philippines (11 million), Myanmar (22 million) and Cambodia (6 million). How these countries meet their access needs will inevitably depend on local circumstances, which can differ widely. Two areas in Indonesia that have low access rates, East Java and Papua, serve to illustrate the point. East Java, where 4 million people lack electricity access, has a population density 80-times greater than Papua, where 1.6 million remain without electricity. It is also relatively close to the more developed regions in West Java and Bali, and has a developed grid infrastructure. Papua, on the other hand, is a large, remote, mountainous island. An analysis of current government policy to electrify villages in both areas show that, extending grid access is the least-cost solution in almost all cases for East Java, while no grid-based access is viable for Papua's interior, and access has to be extended through off-grid and mini-grid technologies.

In the New Policies Scenario, universal access is achieved across Southeast Asia in the early 2030s. Of the 57 million people who gain access in that period, 46% do so through the grid, 30% through mini-grids and the remaining 23% through off-grid technologies. Fossil fuels continue to play a part in providing access to electricity through grid connections: power generated from coal, natural gas and oil-based plants brings access to almost 29 million people.

[5] Chapter 5 provides an in-depth discussion on the investment needs for the New Policies Scenario and the Energy for All Case.

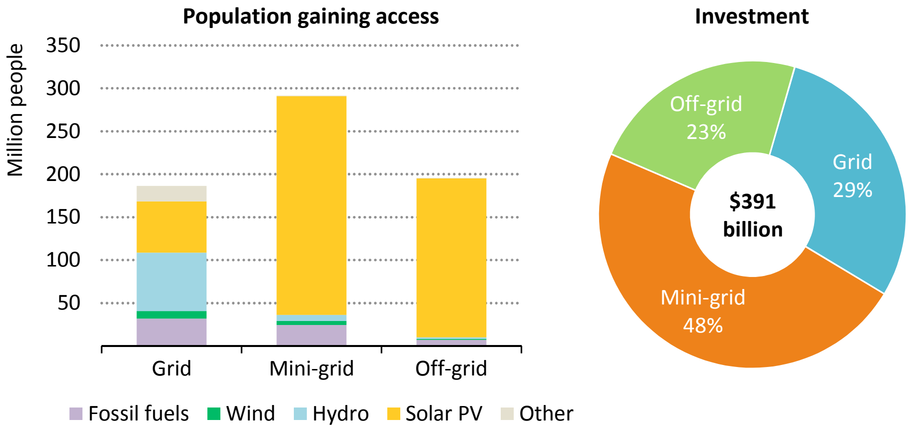
2.3 Energy for All Case

2

In the Energy for All Case, we examine how to achieve access to electricity for all by 2030 in the lowest cost manner, which means the provision of access to an additional 674 million people by 2030 compared with the New Policies Scenario (Figure 2.7).

Over 485 million, or 72%, of the additional people who gain electricity access in our Energy for All Case do so through decentralised systems. Of these, roughly 195 million gain access through off-grid solutions (predominantly solar PV), while mini-grids bring access to an additional 290 million people. Mini-grids are important because they not only provide households with access but also have the ability to ramp up generation capacity or eventually interconnect with the grid. Grid expansion continues to play a fundamental role in delivering energy access, and provides another 185 million people with access.

Figure 2.7 ▷ Additional population gaining access and additional investment in the Energy for All Case relative to the New Policies Scenario, 2017-2030



Decentralised systems make up nearly three-quarters of the additional connections to meet universal electricity access by 2030

Note: Other includes nuclear, bioenergy, geothermal, concentrating solar power and marine.

Sources: IEA analysis; KTH-dESA.

As a majority of the new population that gains access in the Energy for All Case live in rural areas, 88% of the 119 TWh of additional demand occurs there. The electricity demand from off-grid sources is 60% higher relative to the New Policies Scenario, increasing by 33 TWh, and is almost entirely comprised of off-grid solar PV systems. Capacity additions of off-grid solar PV more than double relative to the New Policies Scenario, not surprising given its modular nature and the ubiquitous availability of solar power compared with other renewable resources in the regions concerned. Mini-grids meet an additional 51 TWh of demand, while grid extensions satisfy the remaining 35 TWh of additional demand (58% of which is from rural areas). The resulting new capacity required in the Energy for All Case is 188 gigawatts (GW), an additional 70 GW relative to the New Policies Scenario.

Provision of electricity access to an additional 674 million people would require additional investment of some $391 billion over and above that in the New Policies Scenario. This is equivalent to an additional 1.7% of the total global investment in the energy sector over the period 2017-30. Nearly $280 billion of the total additional investment goes towards decentralised power systems, while around $115 billion of new investment is needed to upgrade the on-grid T&D networks and build new grid-connected generation plants, with the bulk of the investment going towards expanding the rural networks.

SPOTLIGHT

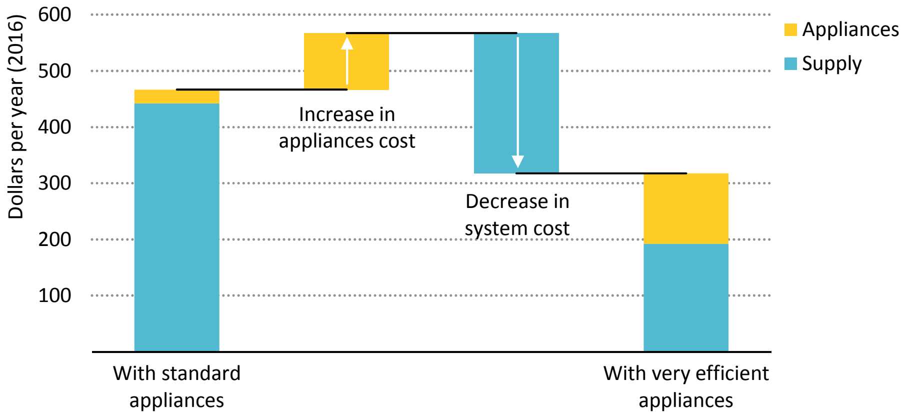
More for less: the role of efficient appliances in delivering universal electricity access

Efficient appliances can play an important role in delivering universal electricity access. Using more efficient appliances lowers the amount of electricity needed for the same bundle of energy services. In turn, this reduces the investment cost in the supply of electricity required to deliver universal energy access. Efficient appliances can make delivering electricity access with off-grid renewable solutions more affordable to households.

For example, a household that gains access to electricity in the Energy for All Case benefits from energy services delivered by four lightbulbs, a television, a fan, a mobile phone charger and a refrigerator by 2030. With standard efficiency appliances, the power demand for these services is 1 250 kWh per year. However, highly efficient appliances can deliver the same services for one-third of the electricity consumption. By bundling efficient appliances with solar PV, which is the least-cost solution for one-third of all rural households gaining access in the Energy for All Case, the higher cost of more efficient appliances is more than offset by the lower cost of supply. As a result, the average annual cost per household is reduced by 32% (Figure 2.8). This represents a reduction of $150 each year, a substantial saving, given that nearly three-quarters of Sub-Saharan African households have an annual income of less than $1 500.

Expected future improvements and cost reductions in efficient appliances further bolsters the case for the role of off-grid PV in delivering universal electricity access in rural areas. Financing models based on mobile payments, which are increasingly used to help people manage the high upfront cost of gaining access with solar PV, can also be used to help make efficient appliances more affordable for households. There is a role for governments in creating a supportive policy framework to encourage the uptake of efficient appliances, by raising awareness, putting in place standards and labelling, ensuring quality assurance, and by controlling the import of less efficient goods.

Figure 2.8 ▷ Annualised discounted cost of providing electricity access through off-grid solar PV, with and without efficient appliances, in the Energy for All Case, 2030



The cost of efficient appliances is more than offset by savings from reducing the size of a solar panel needed

Notes: Electricity consumption is based on the average of a household gaining access in the Energy for All Case in sub-Saharan Africa in 2030, equating to 1 250 kWh per household annually with standard appliances, and 420 kWh with efficient appliances. This delivers 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. The costs and performance of appliances are based on 2016 prices. The anticipated price of solar PV in 2025 is used. A discount rate of 7% is applied.

Access to clean cooking

A recipe for cleaner air and better lives

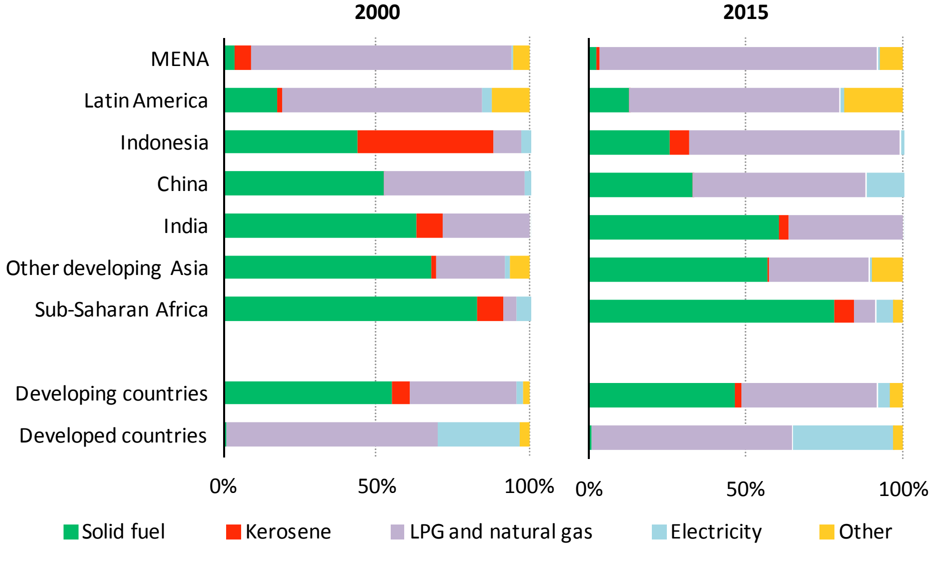
Highlights

- Today around 2.8 billion people – 38% of the global population and almost 50% of the population in developing countries – lack access to clean cooking. Most of them cook their daily meals using solid biomass in traditional stoves. In 25 countries, mostly in sub-Saharan Africa, more than 90% of households rely on wood, charcoal and waste for cooking. Collecting this fuel requires hundreds of billions of hours each year, disproportionately affecting women and children. Burning it creates noxious fumes linked to 2.8 million premature deaths annually.
- Progress on access to clean cooking has been gathering momentum in parts of Asia, backed by targeted policies focussed mainly on the use of LPG. In China, the share of the population relying on solid fuels for cooking declined from over one-half in 2000 to one-third in 2015. In Indonesia, the share of the population using solid biomass and kerosene fell from 88% in 2000 to 32% in 2015. Despite these efforts, the number of people without clean cooking access has stayed flat since 2000, with population growth outstripping progress in many countries. In sub-Saharan Africa, there were 240 million more people relying on biomass for cooking in 2015 compared to 2000.
- The world is far from being on track to achieving universal access to clean cooking facilities. In the New Policies Scenario, 2.3 billion people are projected to remain without access to clean cooking facilities in 2030, though 900 million people gain access from a range of sources. The main success comes from a switch to LPG in urban areas. In India, the country with the largest population without clean cooking access, government promotion of LPG and improved biomass cookstoves means that over 300 million people gain access to clean cooking facilities by 2030, but more than one person in three remains without. In sub-Saharan Africa, over 300 million people also gain clean cooking facilities by 2030, yet progress is not enough to keep pace with population growth, and so the number of people relying on biomass grows to 820 million in 2030, 56% of the population.
- The Energy for All Case sets out what would be needed to provide universal clean cooking access to an additional 2.3 billion people by 2030 relative to the New Policies Scenario, more than 80% living in rural areas. Of those who gain access in urban areas, LPG, natural gas and electricity are the main solutions. The path to clean cooking access for the more than 1.8 billion people who gain access in rural areas is distributed among improved and advanced cookstoves, LPG and biogas. A cumulative $42 billion in investment is needed to ensure universal clean cooking access, relative to the New Policies Scenario.

3.1 Current status

There is a long way to go to achieve the 2030 objective of universal access to clean fuels and technologies for cooking (Box 3.1). Today, an estimated 2.8 billion do not have access to clean cooking facilities. A third of the world's population – 2.5 billion people – rely on the traditional use of solid biomass to cook their meals. Around 120 million people use kerosene and 170 million use coal (Figure 3.1). There has been some progress: since 2000, the number of people in developing countries with access to clean cooking – principally liquefied petroleum gas (LPG), natural gas and electricity, has grown by 60%, and the number of people cooking with coal and kerosene has more than halved. However, strong population growth in developing countries, especially sub-Saharan Africa, has meant that the number of people relying on biomass for cooking has grown by 400 million people, despite growing awareness of the associated health risks and decades of programmes targeting access to modern cooking.

Figure 3.1 ▷ Share of population with primary reliance on various cooking fuels by region



Progress has been limited on clean cooking access in many regions

Notes: MENA refers to Middle East and North Africa. Solid fuel refers to solid biomass and coal. Other includes modern biomass and other renewables. These values report primary reliance of households on different fuels.

Sources: IEA analysis; World Health Organization (WHO) Household Energy Database, (2016).

Box 3.1 ▻ Taxonomy of cooking fuels and cookstoves

In this report, "access to clean cooking" is defined as a household primarily relying on cooking facilities which are used without harm to the health of those in the household and which are more environmentally sustainable and energy efficient than biomass cookstoves and the three-stone fires currently used in developing countries (see Box 1.1 in Chapter 1).

The majority of people who do not have 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. This box gives a broad overview of the terms used in this report and highlights some of the trade-offs between stove types (Table 3.1). The table does not include factors influenced by local culture and food availability, such as speed of cooking and taste, which are locally specific and often drive the choice of fuel for cooking. Annex B provides the average stove costs and efficiencies by region that were collected for this study and used in modelling the scenarios of investment needs.

Table 3.1 ▻ Trade-offs between different cooking fuels and technologies in a developing country context

	Stove cost	Fuel cost	Reliability	Health impact	Gender inequality	Environmental impact	Fuel availability
Biomass (traditional)	Advantage	Advantage	Advantage	Disadvantage	Disadvantage	Advantage / Neutral	Advantage / Neutral
Coal	Neutral	Neutral	Advantage	Disadvantage	Advantage	Neutral	Neutral
Kerosene	Neutral	Neutral	Advantage	Disadvantage	Advantage	Neutral	Neutral
Biomass (improved/advanced)	Neutral	Advantage	Advantage	Neutral	Advantage / Neutral	Advantage / Neutral	Advantage / Neutral
LPG	Disadvantage	Neutral	Neutral	Advantage	Advantage	Advantage	Neutral / Disadvantage
Electricity	Neutral	Disadvantage	Disadvantage	Advantage	Advantage	Advantage	Neutral / Disadvantage
Biogas, solar cookers	Disadvantage	Advantage	Neutral	Advantage	Advantage	Advantage	Advantage

Advantage ● Neutral ● Disadvantage

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.

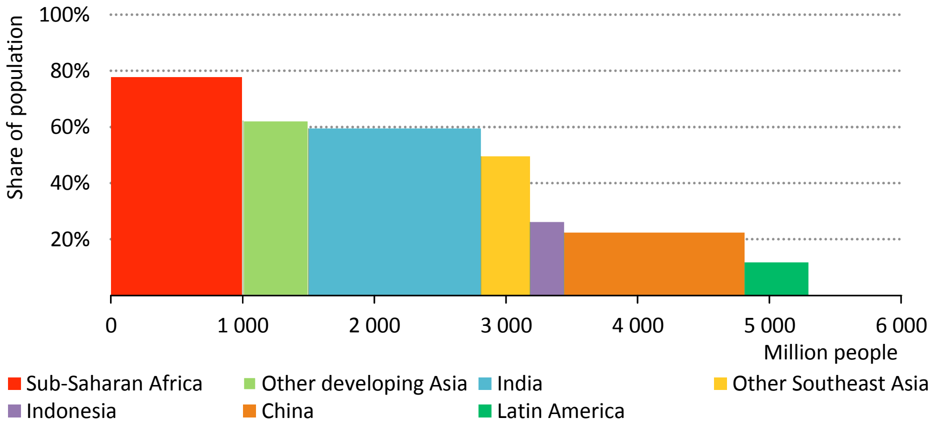
Source: IEA analysis based on Barbieri et al., (2017).

3.1.1 Regional and country developments

In developing Asia, 1.65 billion people (43% of the population) rely on biomass for cooking. This represents an increase of 160 million people since 2000 (Figure 3.2). A further 225 million people cook with coal and kerosene, a decline from 600 million in 2000, due to switching to LPG, natural gas and electricity. This fuel switch reflects a growing awareness of the harmful effects of household air pollution related to cooking, increased policy efforts to boost the uptake of LPG and natural gas and rising urbanisation, which makes it easier to access clean cooking fuels. The picture inevitably varies from country to country. Since 2010, the number of people without access to clean cooking facilities has fallen in both China (by 140 million) and Indonesia (by 46 million), but it remained flat in India (Figure 3.3). There are, however, a few countries – including Cambodia, Myanmar, Bangladesh and East Timor – where the rate of access to clean cooking is below 20%.

Overall, the share of the population with access to clean cooking has risen from 35% in 2000 to 51% today, and the number of people using LPG, gas and electricity has risen by 70% to almost 2 billion people.

Figure 3.2 ▷ Share of population and number of people relying on biomass for cooking by region, 2015



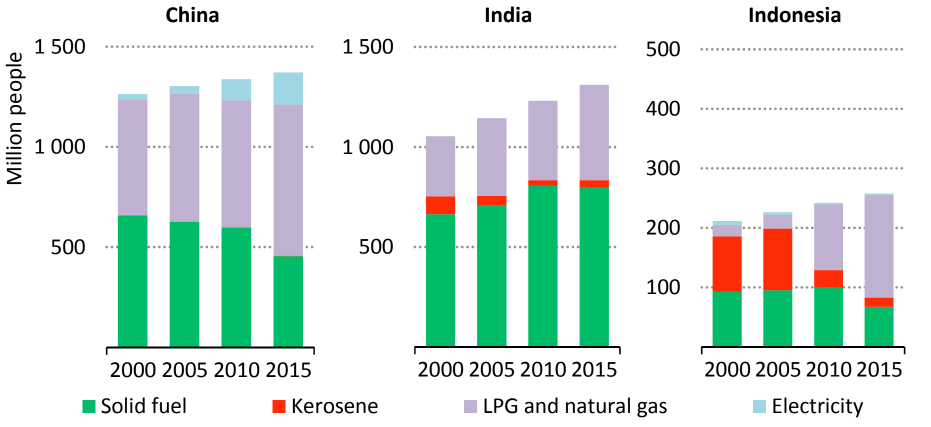
Many parts of sub-Saharan Africa and Asia rely heavily on biomass for cooking

Sources: IEA analysis; WHO Household Energy Database.

In India, an estimated 780 million people rely on biomass for cooking. In contrast with the huge strides made in electricity access in India, the number of people without clean cooking access over the last 15 years has increased by 80 million. After nearly three decades of government programmes to distribute improved biomass cookstoves, less than 1% of households use them (NITI Aayog, 2017). There are, however, indications that government policy efforts have begun to take effect: the number of people without clean cooking access has remained flat since 2010, and the share of population using biomass for cooking fell from 64% in 2010 to 59% in 2015. This seems to have been driven by an increase in domestic LPG consumption and in 2016, India became the third-largest LPG importer in the world, behind China and Japan. The government is seeking to make further progress: in 2016, it launched the Pradhan Mantri Ujjwala Yojana, a programme which aims to provide LPG access to 50 million households living below the poverty line by 2019.

In China**,** over 300 million people are estimated to rely on biomass for cooking, representing more than one-fifth of the population, although there are some uncertainties around this number. A further 150 million people are estimated to rely on coal for cooking and heating. While coal stoves are typically more efficient than biomass ones, coal is also associated with high levels of household air pollution. Overall biomass use in China's residential sector has been declining by around 6% per year since 2010, while natural gas, LPG and electricity demand have all been increasing by around 10% per year. Survey and energy balance data indicate that the number of people cooking with solid fuels has declined by 200 million since 2000. This overall decline is due to a range of factors, including a ban on the combustion of coal and wood in homes in some cities for air quality reasons, a rapid rollout of natural gas infrastructure in urban areas and the increasing use of electricity for cooking. In addition to fuel switching, policy efforts in China have targeted the provision of improved biomass cookstoves: the China National Improved Stove Programme distributed around 130 million improved stoves between 1982 and 1992 and more than two-thirds were found to still be in use in 1993.

Figure 3.3 ▷ Population relying on various cooking fuels in China, India and Indonesia



Access to LPG and electricity is replacing polluting solid fuels and kerosene in some countries in developing Asia

Note: Solid fuel is solid biomass and coal.

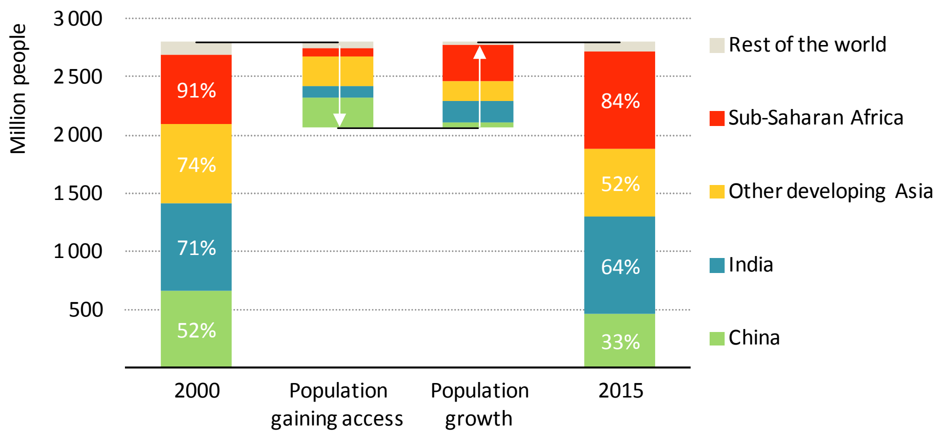
Sources: IEA analysis; WHO Household Energy Database.

In Indonesia, the number of people without clean cooking access has declined by 55% (more than 100 million people) since 2000, while the total population increased by 46 million. In part, this is due to the Kerosene-to-LPG Conversion Program launched in 2007, which saw the government shift subsidies from kerosene to LPG and provide households with a free stove, one fill and an additional 3 kilogramme LPG cylinder. As a result, the number of people using LPG has increased over four-fold to almost 100 million in urban areas and roughly 70 million people in rural areas. However, biomass remains the primary cooking fuel for those who live far away from LPG distribution networks: over 60 million people still use biomass in rural areas.

Sub-Saharan Africa is the region showing the least progress on clean cooking. Almost 80% of the population still cooks with solid biomass, a share that has declined by just three percentage points since 2000. Population growth means that, despite this small percentage decline, the number of people still cooking with solid biomass actually has increased by

240 million to reach around 780 million (Figure 3.4). Of the 25 countries in the world where more than 90% of the population cooks with solid biomass, 20 are in sub-Saharan Africa.[1] An additional 60 million people (mainly in Nigeria and Kenya) use kerosene (see Chapter 4 for more details on sub-Saharan Africa).

Figure 3.4 ▷ Impact of policies and population growth on the number of people without access to clean cooking



In many regions, the impact of policies is over-shadowed by population growth

Note: Percentages within the bar graphs indicate the share of population in each region relying on the traditional use of solid biomass for cooking.

Sources: IEA analysis; WHO Household Energy Database.

3.1.2 Challenges and solutions for improving access to clean cooking

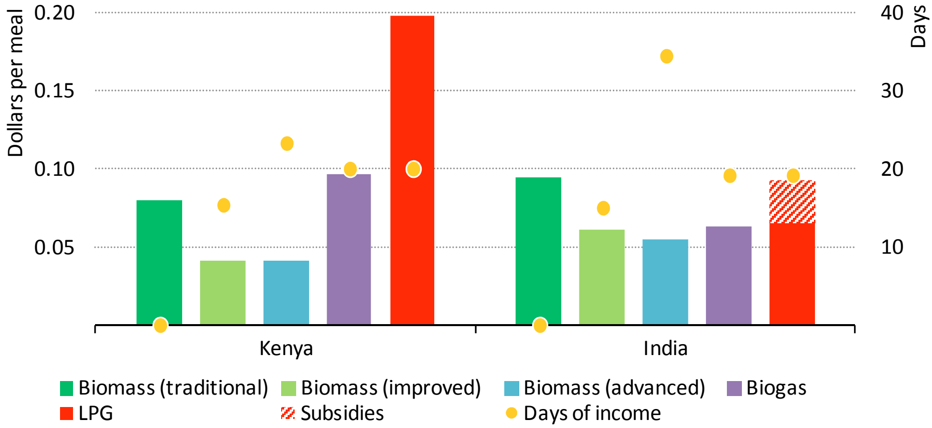
There are a variety of reasons why it has proved difficult to make progress. When taking into account the opportunity cost of gathering fuelwood, clean cooking facilities may present an overall saving compared with cooking with traditional stoves. However, even the cheapest improved cookstoves can cost a poor household several weeks of income, and they may prioritise more urgent needs such as food (Figure 3.5). Furthermore, families may not take into account the opportunity cost of time spent gathering fuelwood, especially when fuelwood is a free resource and economic opportunities are scarce. Many households do not have access to alternative fuels, like electricity or LPG. Even when they do, they may not use them, or they may continue to use biomass alongside the alternative (a practice known as fuel stacking), for reasons of culture (such as a preference for the taste of food cooked in traditional ways) or affordability (LPG cylinders cost money: solid biomass is often free, except for the time spent gathering it, and women in particular often earn money to support their households by selling collected solid biomass). Many of the programmes aimed at mitigating the harmful effects of cooking with biomass through

[1] The other five are Haiti, East Timor, Lao PDR, Myanmar and Solomon Islands.

promoting improved cookstoves have been less successful than anticipated, often because they have not taken sufficient account of cultural and affordability factors.

For those who do gain access to cleaner cooking, there are trade-offs associated with each option (Table 3.1). In several countries, including India and Thailand for example, so-called improved biomass cookstoves have the lowest upfront cost.[2] For many remote rural areas where other alternatives are unavailable or unaffordable, improved cookstoves are the only practicable option. A number of international development organisations have promoted improved cookstoves as a pathway to clean cooking, including Sustainable Energy for All (SEforAll) and the Global Alliance for Clean Cookstoves, both of which have been instrumental in researching, designing and rolling out programmes for improved cookstoves. As understanding of the health risks has grown, programmes have tended to broaden and to add the provision of other fuels like LPG.

Figure 3.5 ▷ Cost of cooking a meal, including the opportunity cost of gathering fuel, and days of income needed to purchase an improved cookstove for the poor in Kenya and India



Improved and advanced cookstoves can cost less on a per meal basis than traditional methods, but the upfront cost is a barrier for poor people

Notes: Poor in this figure is defined as a person living at the poverty line ($1.9 per day). Cost includes the stove, fuel and the opportunity cost of collecting fuelwood. Fuelwood is assumed to be collected, and the opportunity cost is calculated assuming that gathering fuelwood takes 1.1 and 1 hours per day for India and Kenya respectively (Figure 1.4), which could be redirected towards income generation, which, with the number of days' income to purchase the stove, is valued at the poverty line. A "standard" meal is defined as cooked for 45 minutes on an improved cookstove, requiring approximately 3.64 megajoules of final energy per meal. Note that the cost of attaining an LPG cylinder, typically a deposit, is not included, but can contribute to the financial barrier.

Sources: IEA analysis; Fuso Nerini et al., 2017; Politecnico di Milano; KTH-dESA.

[2] See Annex B for a range of cookstove costs and efficiencies.

Progress has been slow, however, despite all the efforts (Cameron et al., 2016). Decades of experience with a large number and a wide variety of programmes disseminating improved cookstoves have yielded limited success. Programmes that have been relatively successful, such as China's National Improved Stove Programme and Indonesia's EnDevs Programme, suggest that, while there is no single answer, there are a handful of best practices that help deliver access to clean cooking (Box 3.2). The success or failure of projects seems to hinge in particular on tailoring the design and dissemination of improved cookstoves to individual communities, each of which may have distinct cultural and geographical characteristics as well as economic and financial challenges. Other important success factors include specific ICS design features such as controllability and burn rate, and the effective design and delivery of outreach and education on the value of clean cooking.

To compound the difficulties with cookstove dissemination and uptake, improvements in pollutants from ICS have sometimes been found to be overstated (Box 3.3). Virtually no biomass cookstove currently on the market meets World Health Organization (WHO) standards for exposure to household air pollution. Recent results from randomised trials suggest that, among ICS using biomass, only highly performing forced-draft micro-gasifiers are able to ensure a statistically significant reduction in pollutant emissions in real-life conditions compared to traditional biomass use, and these improvements are still insufficient to meet the targets on exposure set by the WHO. Only cookstoves that burn LPG, ethanol, methanol, biogas or electricity meet the standards (Pilishvili et al., 2016; Quansah et al., 2017). Small-scale bio-digesters to produce gas for cooking may have a role in the remote areas where ICS has in the past been the only practicable option, though they require upfront investment for the digesters as well as space for the equipment. In Bangladesh, for example, the National Domestic Biogas and Manure Programme has been supporting the expansion of biogas technology in rural areas, and an estimated 80 000 small-scale systems that use animal waste are in operation.

LPG is a common path to access clean cooking options, especially in urban areas. In 2015, an estimated 2.5 billion people, 43% of the population in developing countries, cooked with LPG. Its use varies by region. Only 7% of people in sub-Saharan Africa have access to LPG, mainly in Sudan, Nigeria, Angola and Ghana. Access to LPG is widespread in North Africa and parts of Latin America, and is increasingly being used in Asia. LPG is produced from natural gas liquids and from refinery supply and, while not hazard-free, it is relatively safe compared to kerosene and biomass (Bruce et al., 2017). LPG is transported and sold pressurised in cylinders, and therefore needs some distribution infrastructure, together with reliable roads, the lack of which is a barrier to its use, especially in rural areas. Affordability is another major barrier with the upfront cost of the stove beyond reach for some households, and the need to buy fuel in relatively large amounts is another affordability constraint. There are signs that private enterprises are beginning to use pay-as-you-go business models to overcome these barriers: such models are already making a real difference to the provision of off-grid electricity to rural households in some countries. Subsidies are another approach to help overcome the cost barriers.

Box 3.2 ▷ Emerging best practices for clean cooking programmes[3]

- **Go local**: Undertake and build on information from a thorough evaluation of local needs and social characteristics to tailor stove and fuel type to the locality. Engage local communities and those that use the stoves to select stoves according to their preference and endorse the alternatives to be promoted. Empower local communities to self-build, self-manage and self-maintain cookstoves by supporting training, research and development and capacity building at a local level. This was a key element of success for the Chinese National Improved Stove Programme in the 1980s and 1990s.
- **Convince people of the benefits**: Increase education and awareness about the importance of clean cooking. Identify and promote improved cookstoves that are durable and affordable, and that demonstrate clear benefits to consumers, including fuel and time savings; ease of use compared to traditional cooking; reduction of indoor smoke; and an attractive design.
- **Highlight the flexibility of the device**: Identify and promote improved cookstoves that can meet a wide-range of operating conditions required by local cooking practices.
- **Engage women**: Encourage local women to lead initiatives to produce and/or distribute and maintain clean cooking devices and fuels, and to ensure the stoves and programmes are designed to better their conditions.
- **Monitor and adapt**: Continue to monitor use and stove conditions after implementation. Embed flexibility in the programme so that the cookstove types can be altered in light of feedback.
- **Use a subsidy when necessary**: Set up subsidy mechanisms, if needed, tailored to the targeted market segment, local enterprise or community in order to lower upfront costs and boost adoption rates. Social protection systems have been used as a delivery mechanism.

Sources: IEA analysis; Politecnico di Milano.

Electricity is used for cooking in only a few developing countries, notably South Africa (where more than 80% of the population cooks with electricity) and China (where the share is 12% [160 million people] and growing rapidly). Electricity use for cooking is far lower than the electricity access rate in most developing countries. It requires a large amount of power, which means that it is not suitable for off-grid power supply and is relatively expensive.

[3] As part of this report, the *World Energy Outlook*, in partnership with Politecnico di Milano, undertook an evaluation of some of the stove dissemination programmes and policies by international and regional organisations and governments (see Annex B for the list of policies covered).

Natural gas contributes to clean cooking access in those countries where it is available, and only in areas of those countries where the presence of industry, high population densities and relatively high average incomes justifies the cost of the infrastructure.

Increasing both the access to and the use of modern and clean fuels and stoves for cooking is not easy, and there are no "magic bullet" answers. Economic growth and rising incomes have not automatically led to a greater uptake of clean fuels for cooking: cultural factors matter as well as affordability. However, strong and sustained policy support has often coincided with improvements in the access rate to modern cooking facilities, underscoring that well-designed policies and programmes are crucial to improve access to clean cooking, together with sustained follow-up to promote use. New business models may help to address some of the challenges, and policy support can help encourage them to take off. Investment in access to clean cooking is still at a low level compared to investment in access to electricity access.

Box 3.3 ▹ Out of the lab and into real-life: improved cookstoves

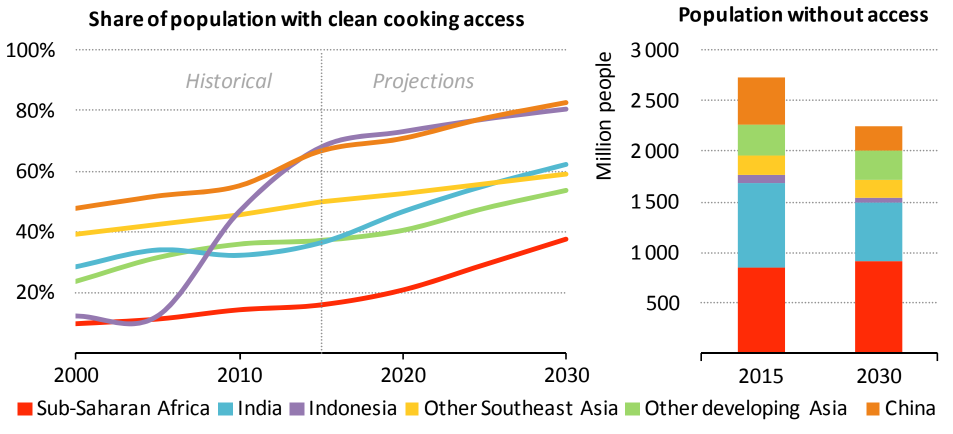
Improved and advanced biomass cookstoves are often promoted as a cost-effective way of reducing household air pollution from cooking with biomass. However, laboratory tests have overestimated emissions reductions relative to actual performance for all ICS designs, sometimes by significant amounts. The evidence from tests which compare lab and field performance suggests that results from laboratory tests are not reliable indicators of real-life average performance because laboratory-based protocols rely on a fixed "cooking system", i.e. a fixed combination of technology, fuel, pot and burn sequence (Lombardi et al., 2017). The components of the cooking system, in particular the fuel and the burn sequence, however, are in practice strongly dependent on the local context. Similarly, the room size, shape and ventilation, and the user's ability to operate the stove are difficult to capture in laboratory assessments, as is the question of how the stove is used: in practice households sometimes combine the use of traditional and improved devices for different cooking tasks ("stove stacking"). As a result, large-scale randomised control trials in the field are widely recognised as the most reliable source of evidence to assess the actual benefits provided by the introduction of a specific ICS to a particular community.

Sources: IEA analysis; Politecnico di Milano.

3.2 New Policies Scenario

Under the New Policies Scenario, the population without access to clean cooking facilities slowly declines from 2.8 billion people in 2015 to 2.3 billion people in 2030. The population relying on biomass declines from 2.5 billion to just over 2 billion, and the number of people relying on coal declines from 170 million today to around 100 million in 2030. Urban areas see a strong increase in clean cooking access, with the number of people relying on biomass declining by over 40%. In rural areas, the population relying on biomass decreases from 2 to 1.8 billion people in 2030. Solid biomass use in developing countries begins to decline slowly in the New Policies Scenario at about 0.6% annually between 2016 and 2030, and its share of residential energy drops from 54% in 2016 to 43% in 2030.

Figure 3.6 ▷ Population with and without access to clean cooking by region in the New Policies Scenario



Policies bear fruit in China and Indonesia, but universal access to clean cooking remains elusive in most of sub-Saharan Africa and many parts of developing Asia

Sources: WHO (historical); IEA analysis (projected).

In developing Asia, the share of biomass in the residential sector declines from around 50% today to 33% in 2030 as demand for gas and electricity for cooking increases in the New Policies Scenario. This decline is driven by a mix of economic growth; urbanisation, more availability of LPG, natural gas and electricity; and stronger policy efforts to promote modern fuels and improved cookstoves, motivated by the goals of reducing household air pollution and environmental degradation. Significant reductions in the population without access to clean fuels and stoves for cooking come from countries with dedicated policy initiatives, in particular China, India and Indonesia. Today, China and India account for over 40% of the global population relying on biomass for cooking, but aggressive action to provide access to clean cooking in these two countries changes the global outlook. By 2030, the number of people without clean cooking access in these two countries combined is cut by around 35%, reducing the total by around 470 million people, although over half a billion people in India remain reliant on the traditional use of biomass in 2030 (Table 3.2). China and India together account for around 80% of the population in developing Asia who gain access to clean cooking facilities.

Table 3.2 ▷ Population without access to clean cooking

	2000		2015		New Policies Scenario 2030	
	million	%	million	%	million	%
Africa	619	76%	848	71%	910	54%
North Africa	13	9%	2	1%	2	1%
South Africa	21	48%	10	17%	8	13%
Other sub-Saharan Africa	585	94%	836	88%	900	65%
Developing Asia	2 083	65%	1 874	49%	1 338	31%
China	658	52%	457	33%	247	18%
India	753	71%	834	64%	580	38%
Indonesia	186	88%	83	32%	58	20%
Other Southeast Asia	190	61%	188	50%	175	41%
Other developing Asia	296	76%	312	63%	279	46%
Central and South America	78	19%	59	12%	45	8%
Middle East	14	9%	12	5%	14	5%
World	**2 794**	**46%**	**2 793**	**38%**	**2 307**	**27%**

Sources: WHO (historical); IEA analysis (projected).

In sub-Saharan Africa, around 320 million people gain access to clean cooking facilities during the period to 2030, an estimated 100 million of them as a result of the intentions related to clean cooking pledges in countries' Nationally Determined Contributions. However, the population of sub-Saharan Africa grows by 450 million people by 2030, and clean cooking efforts do not keep pace. Therefore, the number of people cooking with biomass is projected to increase to 820 million people by 2030, increasing demand for biomass (Spotlight) (see Chapter 4 for analysis on sub-Saharan Africa).

Pathways to improve access to clean cooking

Demographics, biomass supply and policies are the main drivers of cooking fuel choice in the New Policies Scenario. The reliance on biomass becomes increasingly a rural issue: in urban areas, the penetration of access to clean cooking options reaches 95% in 2030, from 84% today, with over 500 million additional people in urban areas gaining access. Around 90% of people who gain access in urban areas do so with LPG. People in some cities, especially in China, also gain access with natural gas and electricity as infrastructure is built.

The drivers and solutions in rural areas are different than urban areas. Given the relative abundance of biomass, and the difficulty of establishing LPG supply chains in rural areas, ICS deliver access to clean cooking for half of those gaining access in rural areas, with almost 190 million people benefiting by 2030 in the New Policies Scenario. However, the number of people relying on traditional, basic cookstoves still outnumbers those with ICS almost ten-to-one in 2030.

S P O T L I G H T

Will there be enough biomass to satisfy future needs?

Biomass represents 10% of total primary energy demand. Half of it is used for cooking, mostly in the forms of fuelwood, agricultural residues and charcoal. While wood is considered renewable, it is exhaustible unless stocks are managed sustainably. In its most recent *Global Forest Resources Assessments*, the UN Food and Agriculture Organization (FAO) acknowledged positive developments in forest management over the last 25 years. However, the overall extent of forested areas continues to decline, while the global population and the number of those depending on biomass for cooking both continue to rise. Even taking into account the commitments made in many NDCs to stop deforestation by 2030, continuing population growth means further declines in forest area per capita, increasing the time that households would need to spend gathering fuelwood (Table 3.3). Even though the use of biomass for cooking is not the main factor responsible for deforestation (most of it is due to land-use change for agriculture and urbanisation), significant deforestation has been observed in countries where fuelwood consumption is greater than sustainable biomass potential. Where deforestation occurs, wood may cease to be a free good, and charcoal prices may rise. These factors underline the case for clean cooking access, particularly in areas where the decline in forests and the increase in demand for biomass are greatest.

Table 3.3 ▷ Forest area per capita

Region/country	Forest area (hectares per capita)			2010-2015
	2010	2015	2030	CAAGR*
Sub-Saharan Africa	**0.7**	**0.6**	**0.4**	**-3.1%**
Central Africa	2.3	1.9	1.3	-3.1%
East Africa	0.2	0.2	0.1	-3.3%
South Africa	0.2	0.2	0.2	-1.6%
Other southern Africa	1.5	1.3	0.8	-3.4%
West Africa	0.2	0.2	0.1	-3.6%
Developing Asia	**0.2**	**0.1**	**0.1**	**-0.9%**
China	0.1	0.2	0.2	0.3%
India	0.1	0.1	<0.1	-1.0%
Indonesia	0.4	0.4	0.3	-2.0%
Other Southeast Asia	0.3	0.3	0.3	-1.2%
Other developing Asia	0.2	0.1	0.1	-2.0%
Latin America	**1.9**	**1.8**	**1.5**	**-1.3%**
Brazil	2.5	2.4	2.1	-1.1%
Other Latin America	1.4	1.3	1.1	-1.6%

* Compound average annual growth rate.

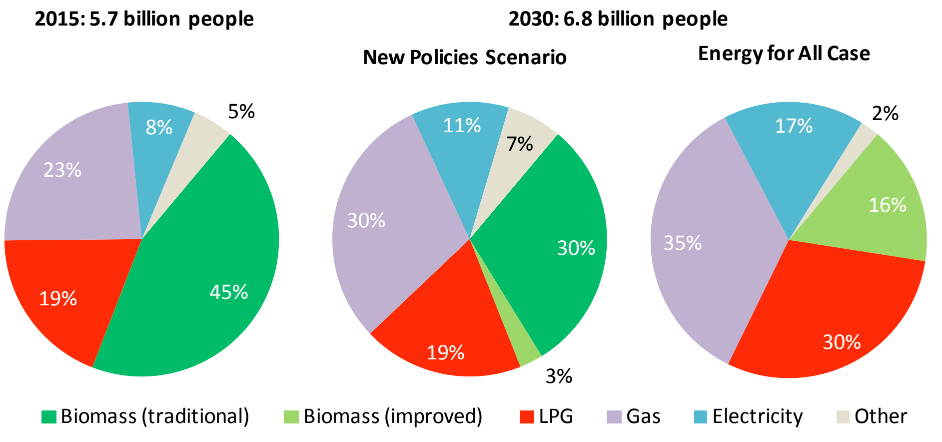
Sources: FAO (2015); IEA analysis.

Investment in access to clean cooking in developing countries reaches a cumulative \$20 billion over the period to 2030, providing cleaner cooking access for almost 900 million more people.[4] Around 60% of the estimated total investment is for LPG cookstoves, and 20% goes to biogas digesters and ICS. Almost two-thirds of total investment is directed to urban areas, where LPG is more accessible, air pollution a particular concern and biomass scarce (see Chapter 5 for in-depth analysis on investment). The cost of a clean cooking device is only around \$20 per person gaining access. Why then do more than 2 billion people continue to rely on the traditional use of biomass for cooking in 2030? The short answer is that the same barriers that have impeded progress to date persist over the period to 2030, particularly in rural areas. Significant progress is made in some parts of the world, but not everywhere, and it is insufficient to deliver access to clean cooking for all by 2030.

3.3 Energy for All Case

Our Energy for All Case maps out what would be needed to meet the Sustainable Development Goal of ensuring universal access to affordable, reliable and modern energy by 2030, replacing the traditional use of solid biomass, coal and kerosene for cooking with clean cooking facilities for everyone. Around three-and-a-half times more people gain access to clean cooking facilities relative to the New Policies Scenario, representing an additional 2.3 billion people. This requires a major shift in the cooking fuel mix (Figure 3.7).

Figure 3.7 ▷ Population relying on fuels for cooking in developing countries



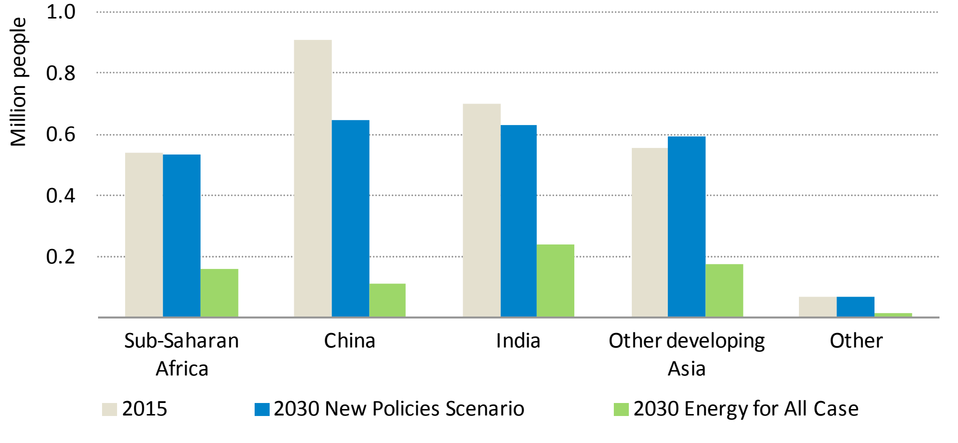
Displacing the traditional use of biomass for cooking involves a scale up of gas, LPG, electricity and ICS

Note: Other includes coal, solar and biogas. Sources: WHO and IEA analysis.

[4] Note that the cost of infrastructure related to LPG, electricity or natural gas distribution is not included. Cookstoves require replacement; improved cookstoves are typically replaced every two to four years while stoves using LPG are replaced every 5 to 15 years.

On a regional basis, the biggest increase in effort is required in developing Asia, where 1.4 billion people gain access in addition to the 570 million people who do so in the New Policies Scenario. In sub-Saharan Africa, an additional 900 million people gain access in 2030, in total four-time the number in the New Policies Scenario. Around 1.8 million premature deaths related to household air pollution are avoided in 2030 by providing access to clean cooking for all, even though the effects of pollution in earlier years mean there are still around 700 000 premature deaths in 2030 (Figure 3.8). An additional 900 million people benefit from ICS in 2030 compared with the New Policies Scenario. While the solution is relatively low cost, there are significant challenges in scaling up the use of improved cookstoves and in ensuring that they perform to higher emissions standards. A significant amount of attention would need to be paid to designing, producing, marketing and disseminating improved cookstoves that meet WHO household air quality standards: the vast majority of cookstoves currently do not meet these standards. Biogas digesters, which can provide a clean and locally sourced cooking fuel, provide access to around 200 million people in the Energy for All Case. A limited number of people living in urban areas gain access to clean cooking with electric cookstoves, mainly in countries with very well-developed electricity networks such as China.

Figure 3.8 ▹ Premature deaths from household air pollution in the New Policies Scenario and Energy for All Case



1.8 million premature deaths are avoided in 2030 by ensuring universal clean cooking access

Sources: International Institute for Applied Systems Analysis (IIASA); IEA analysis.

As in the New Policies Scenario, LPG is the most common solution to clean cooking access in the Energy for All Case, with over half of those gaining access by 2030 doing so through LPG. Around half of the total investment to achieve universal clean cooking access is for LPG stoves. Additional LPG supply required to meet this demand reaches 0.7 million barrels per day in 2030 relative to the New Policies Scenario. This poses a challenge as no refiner raises output or builds additional refining capacity just to meet growing LPG demand, because it constitutes less than 10% of refinery output. However, increased LPG demand could motivate refiners to increase LPG yields, given adequate price signals. There is also scope for demand to be shifted from those who already use LPG for cooking, where they are able to switch to using natural gas or electricity, and also for transport and industry sectors using LPG to switch to other fuels.

The Energy for All Case supposes that even the poorest, most remote and most vulnerable households obtain access to and adopt clean cooking options. While the investment cost is relatively low compared to the resulting benefits, attention needs to be paid to ensuring that the initial and continuing costs of equipment and fuel are not a barrier for poor households, and that solutions are culturally appropriate and according to the preference of those who benefit from clean cooking facilities.

Energising development in sub-Saharan Africa

Testbed for a new energy access paradigm?

Highlights

- Our analysis shows that electrification efforts surpassed population growth for the first time in 2014. The number of people without electricity access has declined in subsequent years. Renewables, mostly hydro and geothermal, are playing a larger role in providing access. In part this is spurred by emerging business models that tap into digital platforms and decentralised renewable energy technologies. Yet, sub-Saharan Africa still has 590 million people without access to electricity – more than half of the global total. Meanwhile the number of people without access to clean cooking continues rise: today around 780 million people cook with solid biomass, 78% of the population.
- In the New Policies Scenario, the number of people without access to electricity in sub-Saharan Africa remains at around today's levels in 2030. Of the 190 million who gain access by 2030, 68% do so via grid connections (of which two-thirds is from renewables) and 32% from decentralised renewables. Several countries, including Ethiopia, Gabon, Ghana and Kenya, are on track to reaching universal electricity access by 2030. East Africa achieves the fastest pace of progress as its electrification rate increases from 39% in 2016 to 66% by 2030. However, electrification efforts remain uneven and over 600 million people still are without electricity in 2030, 80% of them in rural areas. The traditional use of biomass for cooking remains entrenched in sub-Saharan Africa and the number of people without clean cooking access grows to 900 million in 2030. For both electricity and clean cooking, efforts over the period to 2030 are unable to outpace rapid population growth.
- In the Energy for All Case, decentralised technologies play a key role in delivering universal access, especially in remote and rural communities: more than three-quarters of the additional connections needed are provided by off-grid and mini-grid systems. Universal access to clean cooking is achieved principally through increased supply and use of LPG, particularly in urban areas, and improved cook stoves, particularly in rural areas. This prevents around 370 000 premature deaths per year from the effects of household air pollution in 2030. Delivering universal energy access in sub-Saharan Africa requires an additional $28 billion in annual investment over and above the level in the New Policies Scenario.
- Delivering energy access for productive uses in addition to households can boost economic growth, for instance by increasing the relatively low productivity of agriculture in sub-Saharan Africa. Our analysis shows that an increase of 6% over the electricity needed for the Energy for All Case would provide electricity for irrigation, mechanisation and better agricultural practices, improving the resilience of cereal production and increasing yields.

4.1 Context

Sub-Saharan Africa is culturally and economically diverse and it has the potential for rapid economic expansion. Six economies (Burkina Faso, Côte d'Ivoire, Ethiopia, Rwanda, Senegal and Tanzania) are projected to grow at more than 6% in 2017, but lower growth prospects for the rest of sub-Saharan Africa bring the region average down to 2.6%. Africa's relatively young population is the fastest growing in the world: over the next 15 years, an estimated 300 million young people will reach employment age, two-thirds of them in rural areas (AfDB, OECD and UNDP, 2016; EC, 2017). Sub-Saharan Africa currently accounts for 4% of global energy investment, although it contains 14% of the world's population. Many in sub-Saharan Africa do not have access to electricity: those who do consume on average 200 kilowatt-hours (kWh) per year, compared to almost 1 600 kWh in the European Union.[1] Agriculture remains a mainstay of economies in sub-Saharan Africa and its productivity is relatively low: even small increases in access to electricity could make a large difference to economic output.

New business models making use of digital platforms and decentralised power generation technologies have considerable potential for both households and for productive uses, especially in rural and remote areas. Better access to clean cooking also has potential to contribute to economic growth by freeing up the time spent on gathering and using biomass for cooking. In addition, better cooking options can improve health and reduce premature deaths from household air pollution. Improved health itself would boost economic potential, underlining how economic opportunity and health are intertwined. In this way, progress on energy access for all can contribute to reducing the pressures in Africa to migrate for better opportunities.

There is widespread recognition of the importance of affordable and reliable energy for the future of sub-Saharan Africa. Of the 53 African countries that submitted Nationally Determined Contributions (NDCs) at COP21, 34 mention energy access as a key enabler for development (Box 4.1). There are also dozens of energy investment initiatives, including the New Deal on Energy for Africa, which aims to achieve universal access by 2025 by mobilising up to $50 billion of additional funding (AfDB, 2017; Tagliapietra, 2017).

Box 4.1 ▷ Energy access and sub-Saharan Africa's NDCs

Every sub-Saharan African country submitted an NDC as part of the Paris Agreement, and many of these include specific targets on electricity and clean cooking access. This highlights the growing awareness of the importance of providing energy for all and recognition that efforts to tackle climate change and energy access are complementary and can provide significant co-benefits. Energy access measures are frequently included in the adaptation component of NDCs, highlighting the importance of access to modern energy for increasing resilience.

[1] This relates to annual residential electricity consumption per capita (for those with access).

More than half of the NDC pledges mention the importance of providing electricity, and 15 countries put in place specific targets and measures to advance electrification efforts, with small solar lamps being the most common focal point for expanding electricity access. Solar home installations, pico solar (mainly solar lanterns) and mini-grid extensions are frequently mentioned. Nigeria is targeting 100% electricity access by 2030, using both grid extension and 13 gigawatts (GW) of off-grid solar photovoltaic (PV); Sudan is planning to provide 1.1 million solar home installations by 2030; and Ghana aims to provide 2 million households with solar lanterns.

Nearly half of the NDCs pledges recognise the significance of access to clean cooking with 15 countries offering specific targets to improve access by 2025. Cape Verde and Rwanda are aiming for 100% clean cooking access by 2025. Efforts to improve household air pollution are also a catalyst for the inclusion of targets for Ethiopia and Gambia. Measures address demand (e.g. the provision of improved biomass cookstoves, biogas digesters and liquefied petroleum gas) and production (e.g. improving sustainable land use and the supply chain for charcoal). In total, the pledges would bring clean cooking access to 100 million people by 2030.

Besides specific goals for energy access, many of the NDCs include targets in other areas, such as renewables and energy efficiency, which will support and shape efforts to advance access to modern energy. Over 90% of the region's NDC submissions indicate that advancement of renewable energy is a priority, with 33 countries including specific targets to increase the share of renewables – primarily hydro and solar – in power generation. Such efforts, if realised, would mean that those who gain access via grid connections will do so increasingly with power from renewables. Energy efficiency is also recognised as being very important – 80% of submissions mention it – with 29 countries submitting specific goals. Targets in the buildings sector focus on improving the energy efficiency of lighting; as the success of India's light-emitting diode (LED) programme has shown, focusing on efficiency can have strong synergies with electricity access efforts (see Chapter 7 in IEA [2017]).

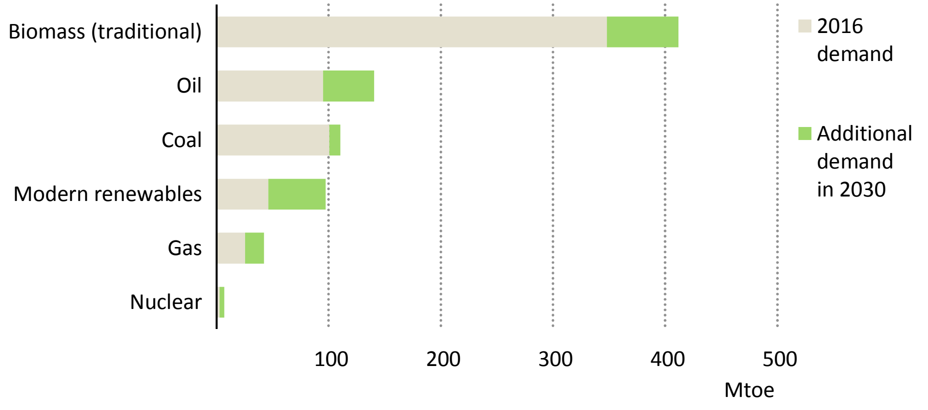
4

4.2 Sub-Saharan Africa energy outlook

Sub-Saharan Africa accounts for almost 14% of the world's population, but only 4.5% of global primary energy demand (619 million tonnes of oil equivalent [Mtoe]). Solid biomass makes up over half of total primary energy demand, mainly for household cooking. Coal and oil account for broadly equal shares and together meet a third of total primary demand. Coal demand is largely concentrated in South Africa for power generation, while oil demand of around 2 million barrels per day is more evenly distributed across the region. Modern renewables (including modern use of biomass) contribute 18%, while natural gas makes up 4% (around two-thirds of which is used in in Nigeria).

In the New Policies Scenario, total primary energy demand in sub-Saharan Africa increases by about 30% by 2030, reflecting population and economic growth (Figure 4.1). This increases its share of global energy demand to 5%, though energy use per capita remains roughly a third of the world average. The traditional use of biomass accounts for more than half of energy demand in sub-Saharan Africa in 2030, though its share drops over the period to 2030 as demand for gas and renewables increases. The share of modern renewables increases to over one-tenth of total primary energy demand, with solar PV growing fastest. Oil demand in sub-Saharan Africa registers the second-fastest pace of growth of any world region (after India), overtaking coal to become the second-largest fuel source, reflecting growing demand for transportation and liquefied petroleum gas (LPG) for cooking. Coal demand increases slightly, its share of the generation mix dropping to 31%, as coal consumption in South Africa is gradually replaced by renewables and as many of its coal mines mature and face depletion. Demand across the rest of sub-Saharan Africa more than triples. Natural gas demand is linked to resource development which helps establish or revive domestic gas markets, for example in Tanzania, Mozambique and Nigeria.

Figure 4.1 ▹ Primary energy demand in sub-Saharan Africa by fuel in the New Policies Scenario

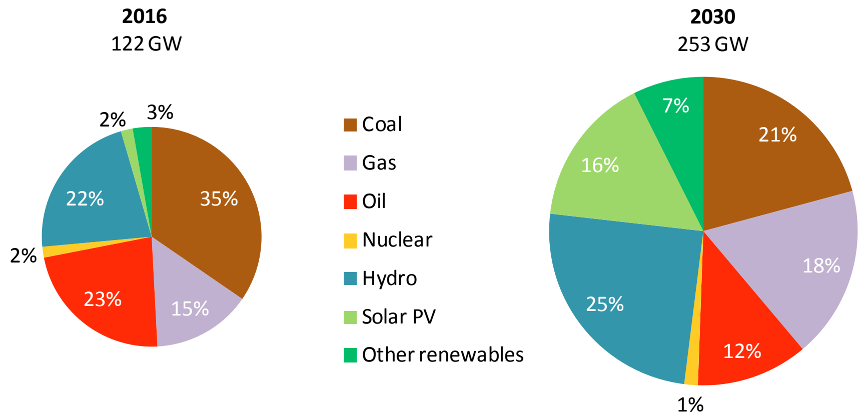


The traditional use of biomass continues to account for more than half of primary energy demand

Note: Modern renewables includes solar photovoltaic (PV), concentrating solar power (CSP), wind, geothermal, hydropower and modern use of biomass. Biomass (traditional) refers to solid biomass used for cooking in the residential sector including the energy used for the production of charcoal.

These changes affect the current balance of installed power generation capacity. Today, the total installed generation capacity in sub-Saharan Africa is 122 gigawatts (GW). Almost three-quarters it is fossil fuel-based, with coal accounting for 35%. Renewables make up about a quarter of total capacity, with large-scale hydropower accounting for the bulk (Figure 4.2).

Figure 4.2 ▷ Installed power generation capacity in sub-Saharan Africa by fuel in the New Policies Scenario

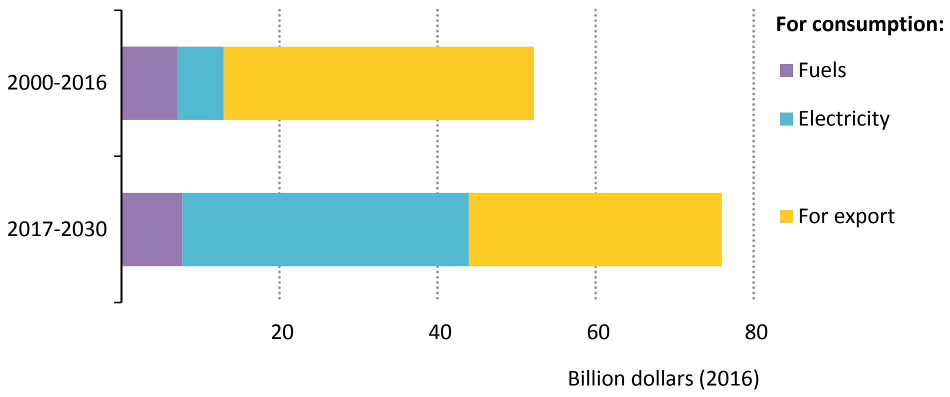


Power generation capacity more than doubles by 2030, and hydropower overtakes coal to become the largest share of installed capacity

Note: Other renewables includes bioenergy, wind, geothermal, concentrating solar power and marine.

Power generation capacity in sub-Saharan Africa is expected to more than double by 2030. By then, hydropower accounts for the largest share of total capacity, followed by coal and natural gas. Solar PV increases significantly, overtaking oil.

Figure 4.3 ▷ Average annual investment in energy supply in sub-Saharan Africa in the New Policies Scenario



More than half of investment in sub-Saharan Africa's energy supply to 2030 goes towards meeting its domestic needs

The average annual investment in energy in sub-Saharan Africa increases from $52 billion per year from 2000 to 2016 to $76 billion per year through to 2030 (Figure 4.3). To support economic growth and rising demand in all of Africa, three-quarters of new investments in energy goes towards meeting the domestic needs of consumers within sub-Saharan Africa, compared to about two-fifths in the last 15 years. This is driven by a six-fold increase in spending on electricity, which quadruples its share of total investments to nearly half of all energy investments in the next 14 years. Total annual spending on fuels remains about the same, but while two-thirds of the investment previously went towards overseas needs, more than half of future investment will go to address domestic needs.

4.3 Access to electricity

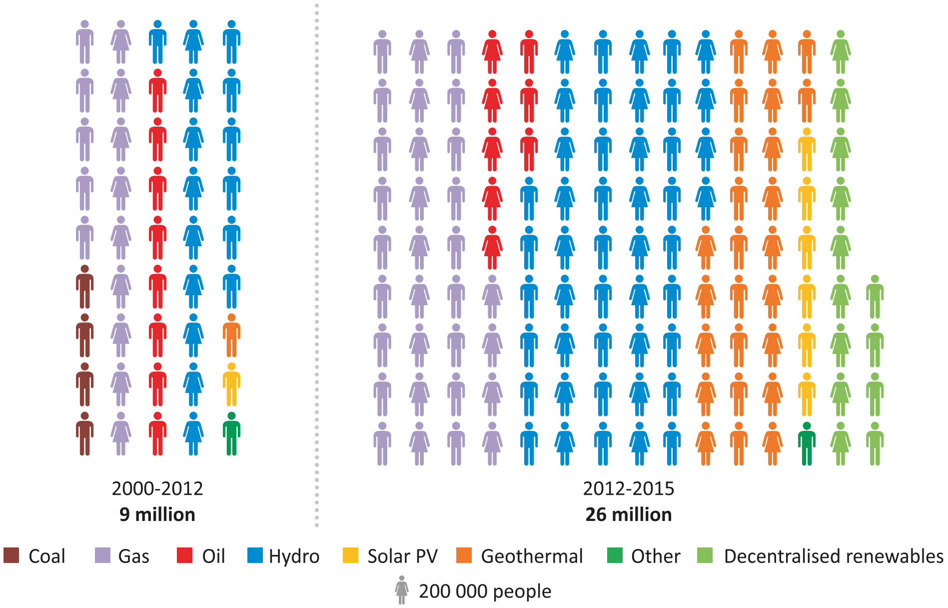
4.3.1 Current status

The number of people without access to electricity in sub-Saharan Africa stopped increasing in 2013 and has since declined, led by strong efforts in Cote d'Ivoire, Ethiopia, Ghana, Kenya, Sudan and Tanzania. Since 2012, the pace of electrification has nearly tripled relative to the rate between 2000 and 2012. East Africa in particular has made significant progress; the number of people without access has declined by 14% since 2012. Despite this turn-around, 590 million people – roughly 57% of the population – remain without access in sub-Saharan Africa, making it the largest concentration of people in the world without electricity access as efforts have often struggled to keep pace with population growth. Over 80% of those without electricity live in rural areas, where the electrification rate is less than 25%, compared with 71% in urban areas.

Grid expansion remains the primary means of bringing about electrification in the region. Sub-Saharan Africa is increasingly tapping into its renewable energy potential, especially hydropower, to provide power, resulting in an accelerated rate of the number of people gaining access from renewable sources. Between 2012 and 2015, around 18 million people gained access from renewables-based power each year, particularly large-scale hydropower and geothermal (mainly in Kenya), a considerable increase from the 3.5 million people who gained access from renewables each year on average from 2000 to 2012 (Figure 4.4). Decentralised systems, while small in share now, are also growing, particularly in areas not yet reached or too expensive to electrify by grid connections. In 2016, an estimated 2 million people gained access through solar home systems, a share which is expected to increase. Moreover, in sub-Saharan Africa, East Africa in particular has been a promising testbed for the convergence of decentralised systems, digital mobile-enabled platforms and mobile money – a trend which may accelerate the pace of progress in the years to come (Spotlight).

While the number of people in sub-Saharan Africa gaining access has increased in recent years in each of its sub-regions, progress has been uneven. In 2016, eight countries had an access rate above 80% – Gabon, Mauritius, Reunion, Seychelles, Swaziland, South Africa, Cabo Verde and Ghana – while most countries had a rate below 50% and some had a rate below 25% (Figure 4.5). Just as there is a two-speed Africa in terms of economic growth there is also, in many ways, a two-speed Africa when it comes to electricity access (Pilling and Fick, 2017). For example, at the start of 2000, Central and East Africa both had an electrification rate of 10%, the lowest in sub-Saharan Africa, which remained roughly in parallel until about 2012. Between 2012 and 2016, six times more people gained access in East Africa than in Central Africa. While each region is endowed with indigenous energy resources, a more stable investment climate and better regional interconnections made it easier for electrification efforts to advance in East Africa.

Figure 4.4 ▷ Annual number of people gaining access to electricity by fuel type in sub-Saharan Africa

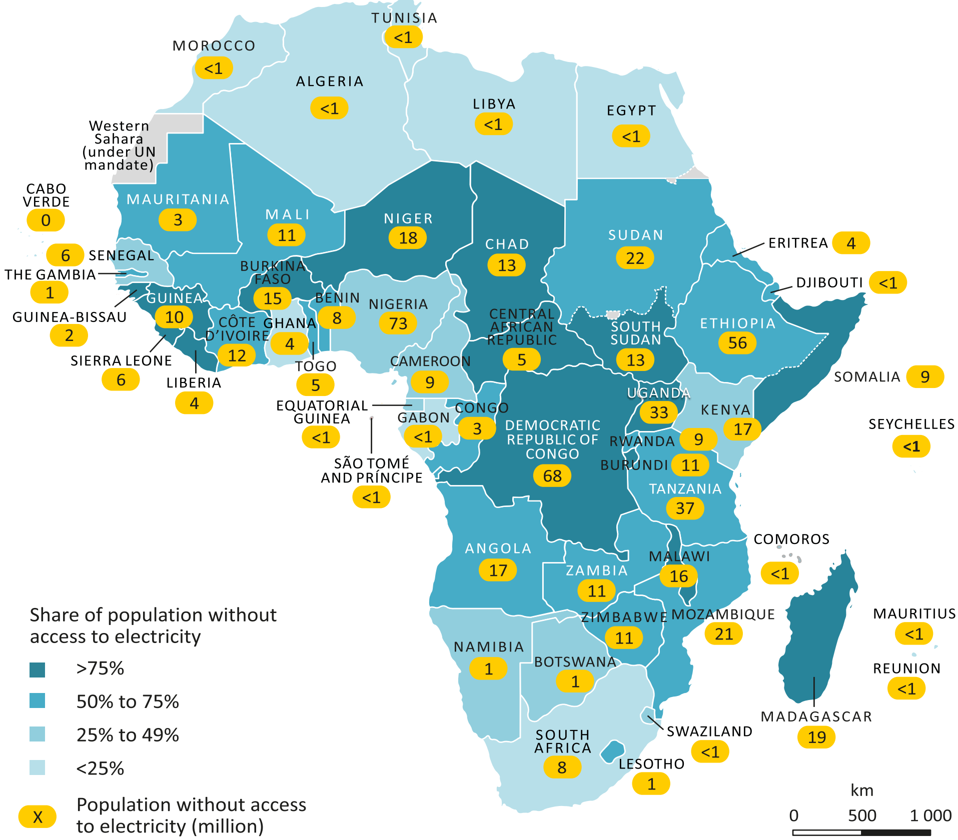


Electrification efforts have accelerated, overtaking population growth for the first time in 2014

Note: Other includes nuclear, bioenergy, wind, concentrating solar power and marine.

East Africa is the sub-region which has seen the fastest progress in electrification in recent years. The access rate is now 40%, yet more than 170 million people are still without access. Since 2000, however, the electrification rate in East Africa has increased by roughly 30 percentage points: each year, over 85 million people have gained access over this period. Its pace has picked up in recent years, and East Africa accounted for over 80% of the decline in the number of people without access in sub-Saharan Africa since 2012.

Figure 4.5 ⊳ Population without access to electricity in Africa by country, 2016



This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

In sub-Saharan Africa, 18 countries had electricity access rates above 50% in 2016

Kenya and Ethiopia in particular have shown considerable progress as a result of government initiatives, private-public partnerships and international support. The number of connected customers has more than tripled in Kenya since 2012 and the access rate increased from 20% to 65% in 2016. The Last Mile Connectivity Project in 2015-17 expanded the national grid to 1.5 million Kenyans in rural areas. In Ethiopia, the electrification rate improved from just over 20% in 2012 to 45% in 2016. Both Kenya and Ethiopia have a flourishing off-grid market providing access in rural areas – Kenya is now the largest market for off-grid solar home systems and solar lanterns in Africa (Lighting Global and BNEF, 2016). This is partly due to measures to remove value-added tax for solar imports, to regulate their quality and to implement an Off-Grid Solar Access Project (KOSAP) which is focused on 14 under-served counties. Kenya is also now tapping into its renewable resources, which include significant geothermal resources from the Rift Valley, and Ethiopia is tapping its hydropower potential.[2] There is still a long way to go however to achieve universal access to electricity: there are 56 million people in Ethiopia and 17 million people in Kenya without access, and reliability can be a problem even when grid connections are in place.

West Africa accounts for 30% of those without electricity in sub-Saharan Africa. The average access rate across West Africa is 52%, and the number of people without access has been stable since 2010, despite population growth. Ghana has been one of the most successful countries in the sub-region in expanding access. Between 2000 and 2016, its electricity access rate increased from 45% to 84%, supported by the roadmap for universal electrification by 2020 set out in the 1989 National Electrification Scheme and policies focused on rural communities, though reliability of supply remains an issue.[3] Senegal also has successfully provided access to 5 million people since 2000; its electrification rate increased by over 30 percentage points to reach 64% in 2016. Nigeria has an electricity access rate of about 61%, meaning that some 113 million people have access. However, concerns about reliability mean that an estimated 80% of those with connections also use an alternative source of electricity supply, mostly diesel generation. Nigeria is the largest African importer of diesel generators, and back-up diesel generation in Nigeria costs households and business almost $22 billion per year in fuel cost alone.

Central Africa has almost 100 million people without access, 17% of the total in sub-Saharan Africa. While electrification rates vary widely by country, as a whole its rate is the lowest of all the sub-regions, at just 25% in 2016, and just 5% of the rural population has access. Gabon has made spectacular progress, increasing its access rate from roughly 30% in 2000 to 90% today, despite having a relatively low population density. The urban electrification rate is 97%, significantly above the rural electrification rate of 38% where many localities rely on small diesel generators. In 2014, the Gabon government announced a policy that seeks to make use of a wide range of approaches to achieve universal access by the 2030s, including the development of small-scale renewable energy projects (Oxford Business Group, 2015). Cameroon has also made good progress, with its access rate reaching 63% in 2016, up from 20% in 2000. Democratic Republic of Congo (DR Congo), which has more than half of the population of Central Africa, also has one of lowest electrification rates, at just 15%. The population has grown by 66% since 2000, overtaking electricity access efforts: roughly 68 million people are without access in DR Congo, though it is now planning to tap its hydropower potential, which could speed up the pace of electrification.[4]

[2] Kenya plans to double its total geothermal capacity to more than 4 000 megawatts by 2022 (Waruru, 2016) and 6.5 GW of capacity from the Grand Renaissance dam which as of September 2017, is under construction in Ethiopia.

[3] Other notable policies include: Northern Electrification and System Reinforcement Project; Rural Electrification Program; Self-Help Electrification Scheme; Strategic National Energy Plan and the Growth and Poverty Reduction Strategy.

[4] DR Congo plans to build a 4.8 GW hydroelectric facility, Inga 3, though the output will largely serve industrial development.

Southern Africa accounts for nearly a quarter of the people without access to electricity in sub-Saharan Africa. Excluding South Africa, which has an access rate of 86%, the access rate for the Southern Africa sub-region is 31%, roughly double what it was in 2000. Tanzania has seen its access rate increase from 11% to 33% over the last 15 years. The number of people lacking access has been stable at around 37 million people since 2012, signalling that efforts to improve the access rate are just enough to keep up with population growth. Tanzania has had particular success in creating an enabling environment for off-grid access. A quarter of all households who have electricity access obtain it from off-grid solar PV: this reflects thriving solar home system and mini-grid markets. Recently there has been a sharp increase in businesses entering the mini-grid market, which serve enterprises as well as households (Tanzania Ministry of Energy and Minerals, 2017). Namibia is scaling up electrification very rapidly, with electricity now reaching 56% of the population, up from 30% in 2012. Given the disparity between urban (78%) and rural (34%) electrification rates the government's targets focus on rural electrification, aiming for 50% of rural households to have access to reliable electricity by 2020, and 100% by 2030. It is doing so through spatial planning (the Rural Electricity Distribution Master Plan of 2010 identified locations for off-grid electrification), feed-in tariffs for renewables-based generation, and action to shield the country's supply from fluctuations in the price of imports from the South Africa Power Pool.

S P O T L I G H T

Mobile phones and a world of possibilities for Africa

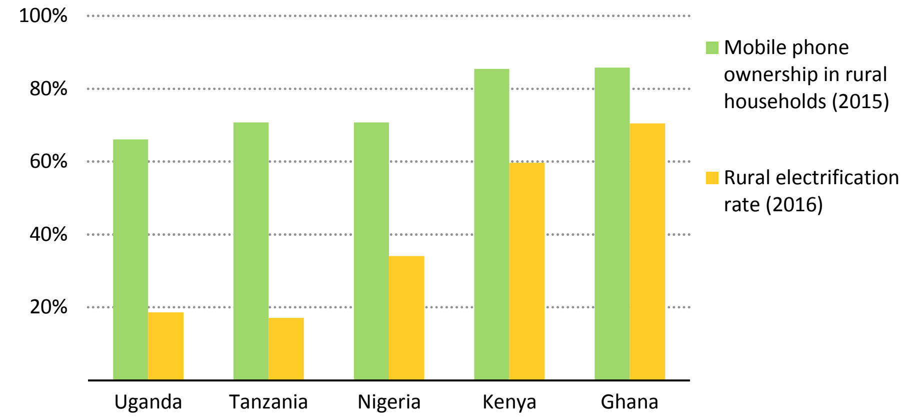
In some countries in sub-Saharan Africa, more households have mobile phones than have access to electricity and smartphones now account for more than a quarter of total connections (AfDB, 2017; GSMA, 2017b). Why does this matter for energy access? It matters because mobile phones and, in particular, smartphones, may be able to help facilitate access to a large array of energy services, especially in rural areas where the need is increasingly concentrated.

Companies such as BBOXX, M-Kopa, Off-Grid Electric and Mobisol have entered the market in Africa, bringing new business models that target areas covered by mobile networks but not electricity grids (Figure 4.6). These companies utilise mobile networks to provide energy services through pay-as-you-go (PAYG) financing and payment schemes. There are two main business models that use PAYG. The first is a rent-to-own plan, where consumers can use their phones (mobile money) to pay a fixed amount upfront for an off-grid device, such as a solar home system, and then pay it off in instalments. The other model, though it is used less and less, is where consumers pay a regular fee for the energy service but never actually own the device. For investors, mobile networks allow the company to remotely monitor products and collect usage data, disable a device when a customer misses a payment and turn the device back on when the payment has been made.

These PAYG energy service business models are most active in Kenya, Tanzania, Rwanda and Uganda, which account for the majority of sales of PAYG solar systems (GSMA, 2017a). These markets have well-established telecoms and mobile money systems and relatively business friendly markets. M-Pesa, which began in Kenya and Tanzania, is one of the most widely known and successful mobile phone-based money transfer services. Other markets in Africa are also opening, especially in Ethiopia, Ghana and Nigeria.

The most popular combination so far has been the pairing of PAYG with solar home systems (consisting of a solar module with a battery and small appliances like LED bulbs and mobile phone chargers). On average, these systems provide customers low levels of power but bundling them with super energy-efficient appliances can enhance their effectiveness and offer more energy services at lower cost (see Spotlight in Chapter 2). Some governments are entering into partnerships with companies to distribute solar home systems, such as the partnership recently forged between the Republic of Togo and BBOXX, where the goal is to distribute over 300 000 solar home systems in Togo over the next five years (ESI Africa, 2017).

Figure 4.6 ▷ Mobile phone ownership and electricity access rates in rural areas in selected sub-Saharan African countries



Mobile phones provide an opportunity to accelerate electricity access

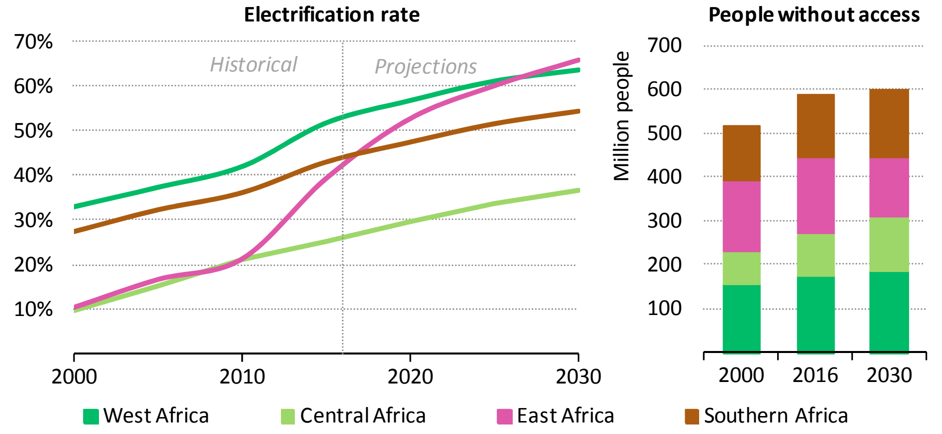
Sources: IEA analysis; USAID (2017).

4.3.2 New Policies Scenario

In the New Policies Scenario, almost 60% of the population of sub-Saharan Africa – 850 million people – has access to electricity by 2030. This represents an increase of over 15 percentage points and 410 million people since 2016. Grid extension remains the primary pathway to gain access, while renewables make up about two-thirds of total capacity additions and are responsible for three-quarters of the population gaining access.

A number of countries, including Ethiopia, Gabon, Ghana, Kenya, South Africa, Swaziland and several of the island nations reach or are close to reaching universal access. But electrification efforts remain uneven in the region as a whole, and population growth of over 420 million people means that more people in sub-Saharan Africa lack access in 2030 than today (Figure 4.7).

Figure 4.7 ▷ Electricity access rate and population without electricity access by region in sub-Saharan Africa in the New Policies Scenario

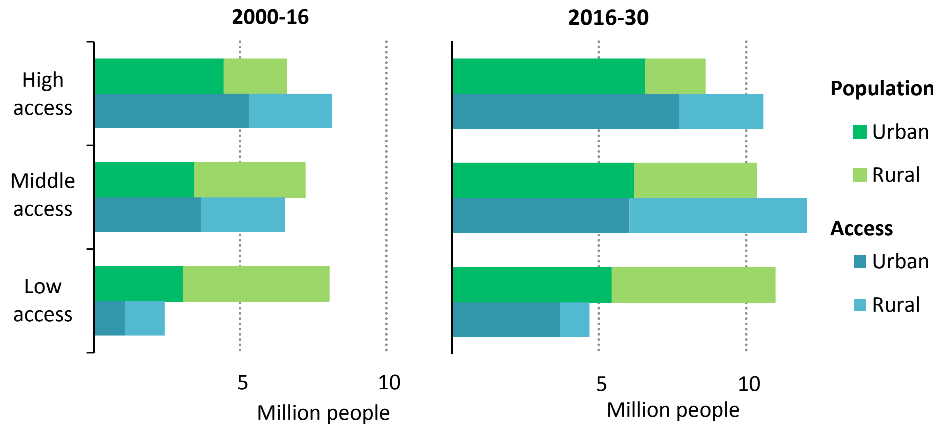


While the electrification rate improves in all sub-regions, population growth means that the number of people without electricity access rises to 600 million in 2030

Over 60% of the population growth to 2030 in the region will take place in urban areas, but over half of the population will still reside in rural areas. Roughly 40% of the population growth in sub-Saharan Africa is anticipated to occur in countries where the electricity access rate is currently below 30%, and where progress in electrification since 2000 has been very slow (Figure 4.8). In 2030, 29 countries in sub-Saharan Africa remain below the regional average access rate of 60%. Around 14 million people gain access to electricity each year, which is a quarter of what is needed to achieve universal access by 2030. As a result, just over 600 million people in sub-Saharan Africa are projected to live without electricity in 2030; almost 90% of them in rural areas. There has been significant success in the parts of sub-Saharan Africa where policy and market forces have combined to shape markets and foster new business models, and where increased investment in essential infrastructure and technologies has helped to accelerate access to electricity.

East Africa by far achieves the fastest pace of growth and is the only sub-region where efforts to provide access to electricity outpace population growth such that by 2030, the number of people without access declines by 37 million and both Ethiopia and Kenya are on track to reach near-universal access. The progress witnessed in both countries reflects tremendous policy and investment efforts to roll out grid infrastructure alongside off-grid systems in rural areas, as 6 million and 2.5 million people gain access each year respectively. South Africa is on track to achieve near-universal access in 2030, largely as a result of its Integrated National Electrification Program, which combines grid extension and solar home system strategies. The rest of Southern Africa sees access grow by almost 15 percentage points to reach 45% in 2030**.** Botswana and Namibia witness significant improvements and follow similar trajectories over the period to 2030; their access rates improve to over 70% from around 55% in 2016. Tanzania sees progress, with its electrification rate climbing to 60% in 2030 from near 30% in 2016. West Africa also sees progress. Ghana achieves universal access to modern electricity soon after 2020. After Ethiopia, Nigeria brings electricity access to the largest number of people in sub-Saharan Africa over the period (more than 80 million). Central Africa has the highest rate of growth in the number of people without access of all the sub-regions in sub-Saharan Africa, and it also has the highest rate of population growth, such that in 2030, the rural electricity access rate is 13%. There are some bright spots however, as both Gabon and Cameroon build on the progress they achieved in 2016 to reach access rates of 96% and 82% respectively.

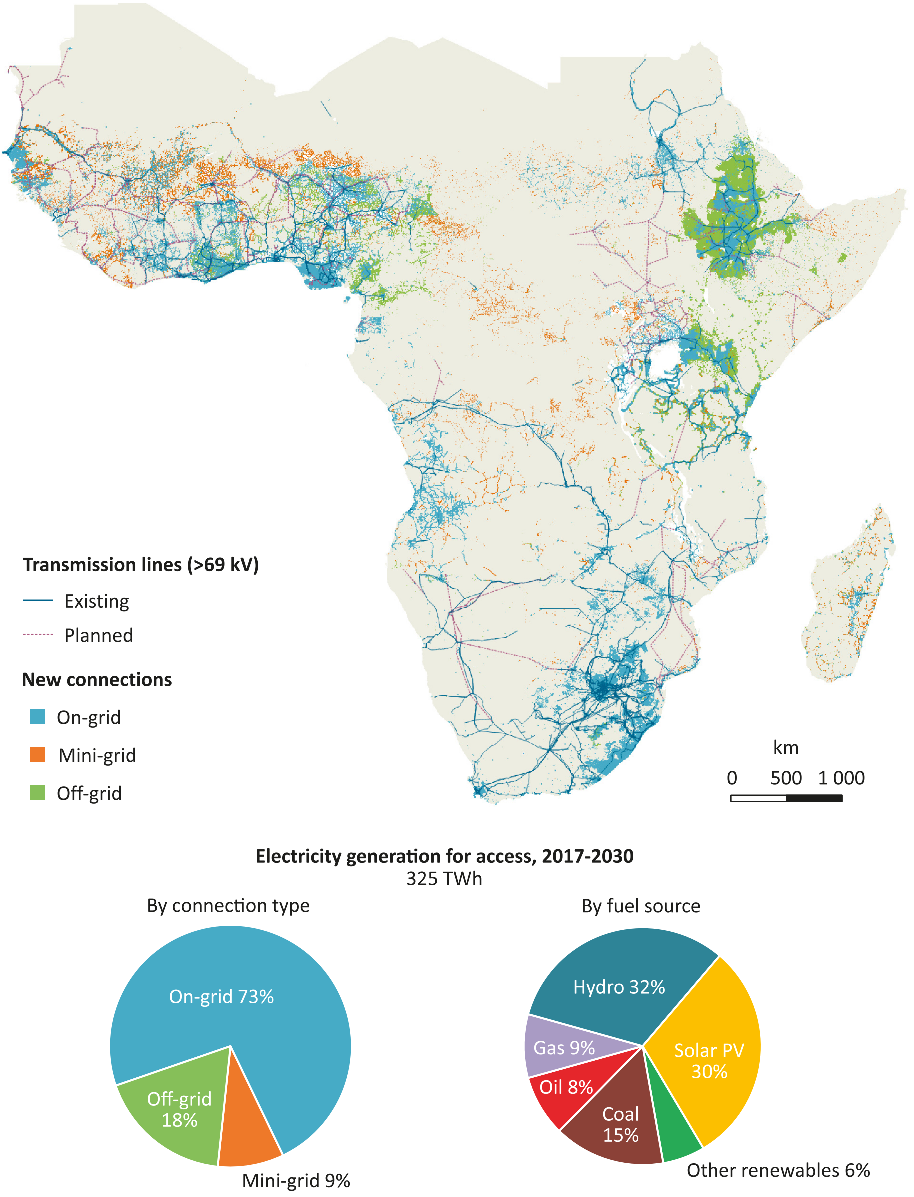
Figure 4.8 ▷ Annual additional population and people with electricity access in sub-Saharan Africa



The demographic challenge is especially acute in countries where progress has been the slowest

Note: Countries are grouped by their electrification rate in 2016. Low = access rate below 30%; middle = access rate between 30-60%; high = access rate above 60%.

Figure 4.9 ▷ New connections and power generation for electricity access in sub-Saharan Africa in the New Policies Scenario, 2017-2030



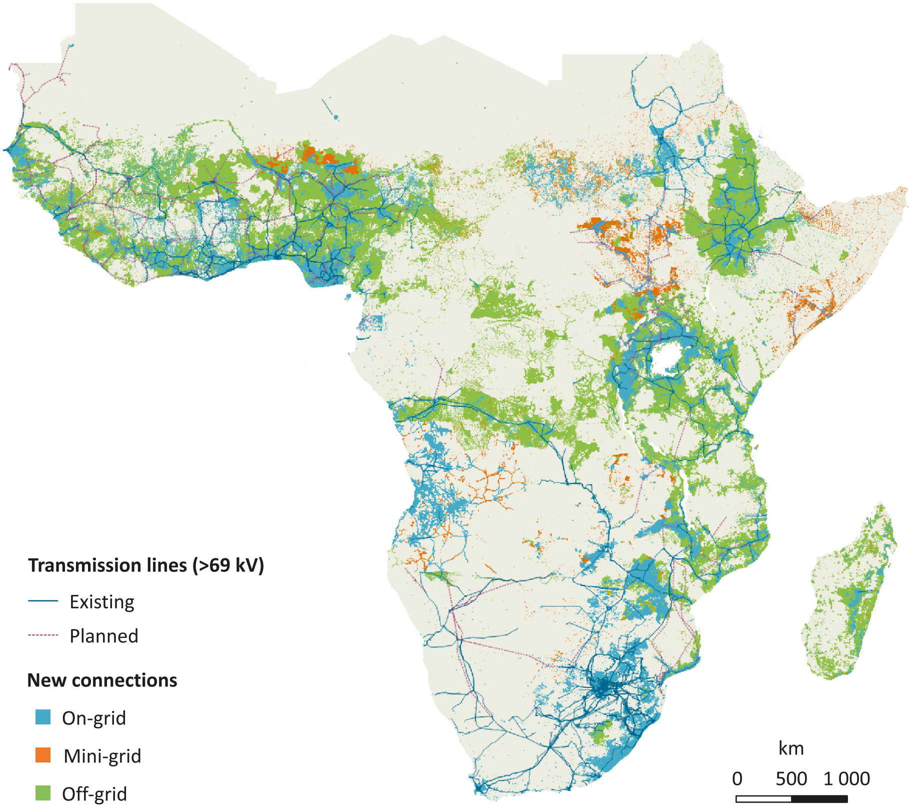
This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

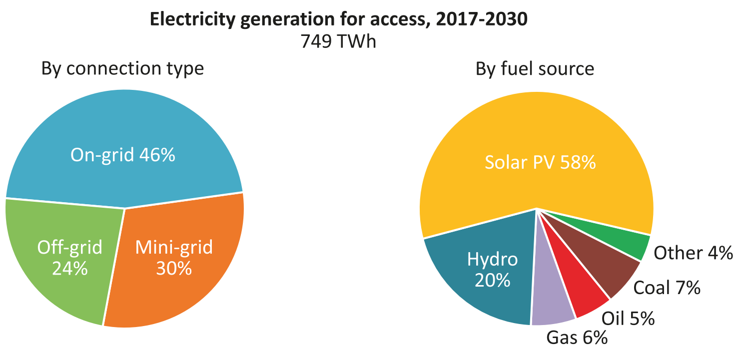
Grid extension remains the main pathway to electrification, and renewables account for an ever increasing share of new access

Note: Other includes CSP, wind, geothermal, bioenergy, marine and nuclear.

Sources: KTH-dESA; IEA analysis.

Figure 4.10 ▷ New connections and power generation for electricity access in sub-Saharan Africa in the Energy for All Case, 2017-2030





This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

More than half of those who gain access in the Energy for All Case do so through decentralised systems

Note: Other includes CSP, wind, geothermal, bioenergy, marine and nuclear.

Sources: KTH-dESA; IEA analysis.

In the New Policies Scenario, cumulative investment for providing electricity access in sub-Saharan Africa is estimated to be $84 billion over the 2017-30 period, averaging $6 billion per year. Those who gain access in sub-Saharan Africa in the New Policies Scenario do so through a range of on-grid and off-grid system options (Figure 4.9). On-grid connections remain the least-cost pathway to electrification for the majority: it accounts for 68% of the total population that gains access in 2030 and over 55% of investment. Roughly 74% of on-grid investment related to power plants is for renewables-based generation (hydropower followed by solar PV, bioenergy, wind and geothermal).

The number of people who gain access from decentralised power solutions increases over the period to 2030 as technology costs continue to decline, making off-grid systems, and to a lesser extent mini-grids, increasingly a cost-effective solution in rural areas relative to grid extensions. As a result, over 20% of those who gain access in 2030 do so from off-grid solar PV systems and 11% do so from mini-grids, accounting for almost two-thirds of those living in rural areas who gain access. Over 40% of the cumulative investment in the period to 2030 is for decentralised solutions, a majority of which is off-grid solar PV, while mini-grids account for around 15% of cumulative investment.

On-grid connections account for 15 GW of new capacity between 2017 and 2030. Decentralised solutions, including mini-grids, become a more prominent feature of access, and account for 11 GW of new capacity by 2030, providing access to electricity in rural areas that complements on-grid connections. By 2030, renewable sources account for almost 70% of electricity generation for electricity access, led by solar PV (33%) and hydro (30%). Coal, oil and natural gas combined account for 30% of generation for delivering electricity access (compared to about 40% in the current fuel mix).

Overall, the New Policies Scenario sees some progress, with a wide range of outcomes in various countries, but it falls well short of delivering access to electricity for all as there is persistent under-investment in the grids. Where grids exist, they frequently under-perform and reliability remains low. Achieving universal access will require strengthened policies, effective infrastructure planning and higher levels of strategic investment to keep pace with growing demand from strong population growth, particularly in rural areas.

4.3.3 Energy for All Case

The Energy for All Case develops a pathway that would allow sub-Saharan Africa to meet the goal of universal access to electricity by 2030. To achieve this aim, 600 million people need to gain access by 2030, over 43 million per year, in addition to the 200 million people who gain access in the New Policies Scenario. The Energy for All Case meets this increase in access mainly through an accelerated deployment of mini-grids and stand-alone systems, which together are the source of three-quarters of the additional connections (Figure 4.10).

In total, 30% of the additional people that gain access get it through off-grid solar PV, which is particularly well-suited for delivering access to rural areas where grid access is impractical or very expensive. Mini-grids experience even higher growth, an order of magnitude higher than in the New Policies Scenario, albeit from a smaller base, providing access to 44% of the additional people getting access. The Energy for All Case shows that cumulative investments between 2017 and 2030 under current policies and commitments are less than one-fifth of the level needed to achieve universal electricity access in sub-Saharan Africa. We estimate that the additional cumulative investment required amounts to $370 billion between 2017 and 2030 relative to the New Policies Scenario, an average of $26 billion per year. This is equivalent to around 1.7% of the cumulative investment in the energy sector globally over this timeframe. Around three-quarters of the additional investments go towards decentralised options: mini-grids attract half while off-grid solutions attract 23%. The resulting cumulative capacity additions in the Energy for All Case is 87 GW – an additional 62 GW compared with the New Policies Scenario – consisting of 40 GW of mini-grids, 32 GW of off-grid systems and 15 GW of additional centralised generation capacity.

4.4 Access to clean cooking

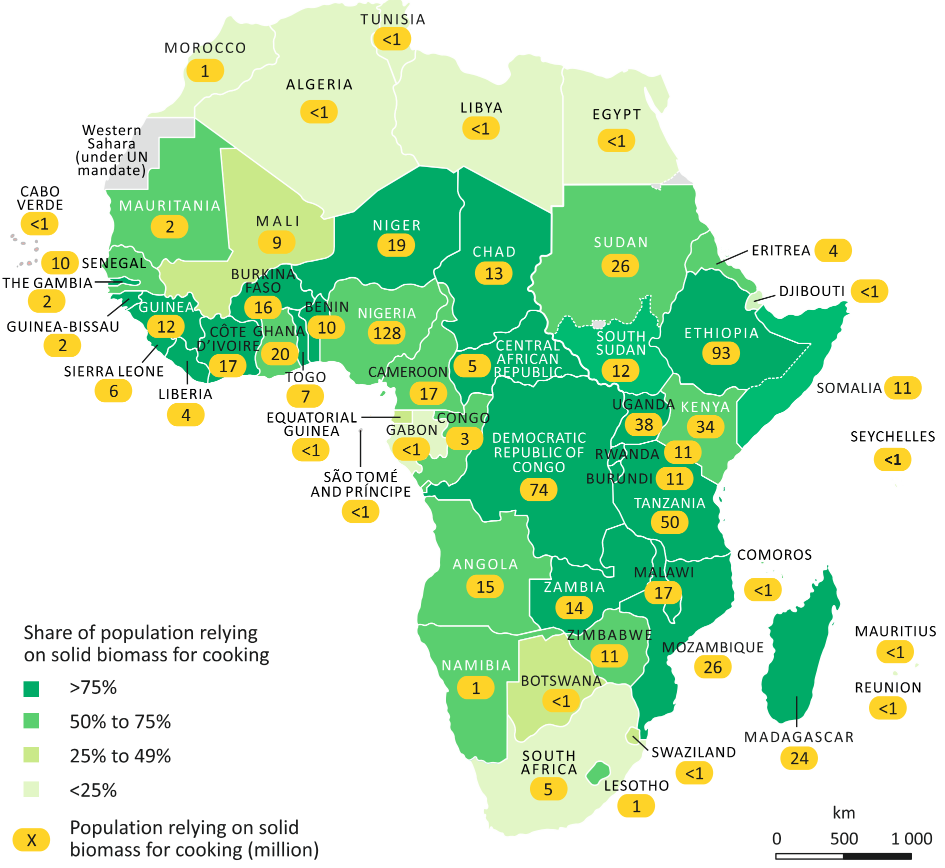
4.4.1 Current status

About 780 million people in sub-Saharan Africa, almost four-fifths of the population, rely on solid biomass for cooking. Biomass accounts for over 90% of the total population without clean cooking access. This number has grown by nearly 50% since 2000, as population growth has outpaced the number of people gaining access to clean cooking. Furthermore, 6% of the population cooks with kerosene, a cooking fuel which causes household air pollution and is used by 12% of urban households. While 32% of people living in urban areas have access to cleaner fuels for cooking, the use of biomass is deeply rooted in rural areas, where about 92% of the population cook with fuelwood, charcoal, dung and agricultural residues. Today in more than three-quarters of all sub-Saharan African countries, more than half of the population relies on solid biomass for cooking, and in many of them, the share is above 90% (Figure 4.11). Biomass dominates in sub-Saharan Africa's energy mix, where it accounts for about 60% of total energy demand, three-quarters of which is used in households. While per-capita gross domestic product (GDP) has increased by 2.6% on average since 2000, the rate of access to clean cooking has stagnated, and the number of people relying on biomass has roughly tracked population growth.

Among the sub-Saharan African countries, there are considerable variations in levels of clean cooking access and in the fuels being used, depending on the state of development, the availability of biomass and other alternatives. Only 8% of the population in South Africa relies on wood for cooking, thanks mainly to high levels of electricity access. The percentage of households that use electricity for cooking increased from 50% in 2000 to 83% in 2016. In the rest of Southern Africa, electricity is not widely used for cooking and it only extends to 5% of households and less than 1.5% in other sub-regions.

LPG is the most widely used modern cooking fuel, but even this extends to just 7% of all households in sub-Saharan Africa and only 2% of rural households (Figure 4.12). Some countries have programmes to promote its use. For example, Cameroon has developed a national LPG master plan, covering the entire value chain, with a target of 58% of the population to be using LPG, up from 17% today. Ghana has a national Action Plan for Clean Cooking that aims to have 50% of the population using LPG and at least 50% using improved biomass cookstoves. Ghana has seen some success in recent years, with 36% of the urban population having access to LPG, although the share of the rural population using biomass remains high at 90% (Box 4.2). Senegal also has ambitious policies and incentives to support switching to LPG particularly in urban areas: roughly 40% of its urban population today still relies on biomass.

Figure 4.11 ▷ Population relying on solid biomass for cooking in Africa by country, 2015

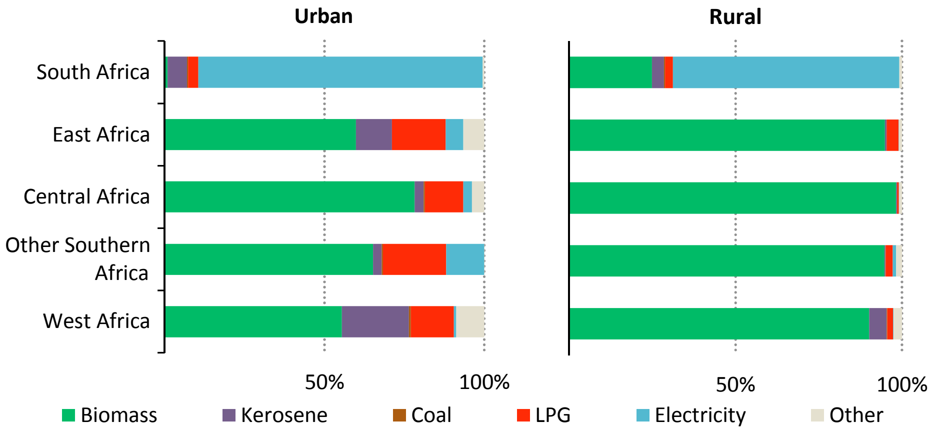


This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

More than half of the population relies on solid biomass for cooking in all but 12 countries in sub-Saharan Africa

Sources: IEA analysis; World Health Organisation (WHO) Household Energy Database.

Figure 4.12 ▷ Primary fuel used for cooking by urban and rural households by sub-region, 2015



Biomass is the main fuel for cooking, especially in rural areas

Sources: IEA analysis; WHO.

Kerosene (also known as paraffin) is the primary cooking fuel for about 60 million people living in sub-Saharan Africa. More than 40 million of them live in Nigeria, where two-fifths of urban households use kerosene for cooking. Government targets aim to replace its use with LPG, but fluctuating prices and supply has been a barrier.

Gaining access to clean cooking facilities encompasses not only switching to cleaner fuels, but also changing the way that solid biomass is used. The main pathway utilised to move people away from the traditional use of biomass for cooking has been the promotion of improved biomass cookstoves (ICS). Decades of programmes have generally failed to achieve a lasting impact (see Chapter 3). Furthermore, the health benefits of using ICS have found in many cases to not live up to expectations. However, given the large number of people in sub-Saharan Africa living in remote rural areas, ICS may well be the only immediately practicable solution in many cases.

In Kenya, where around three-quarters of the population relies on biomass for cooking, the pioneering Kenya Ceramic Jiko, an improved charcoal cookstove, was introduced in the 1980s. Around one-quarter of urban households rely on kerosene. Today a national programme targets the distribution of 5 million generic improved cookstoves to eliminate kerosene use in households by 2022 (IEA, 2014). Thus far, this programme has also supported the dissemination of over 10 000 biogas digesters. In Ethiopia, nearly all rural households and 73% of urban households depend on solid fuels for cooking. Because of unreliability of supply and fuel price fluctuations, fuel stacking is common in Ethiopian urban households. The government has implemented several improved cookstove programmes since the 1990s. The latest, the National Improved Cookstoves Program, aims to disseminate a further 9 million improved cookstoves to 4.5 million households by 2018. Biogas technology has also been promoted for cooking in rural households: as of 2013, about 8 000 domestic biogas plants have been installed under the National Biogas Program, which started in 2008.

This deep dependence on biomass for cooking has grave health, environmental and social consequences. Over half a million premature deaths each year in sub-Saharan Africa can be attributed to the poor air quality as a result of cooking on fires, higher than the number of deaths from malaria. Households in sub-Saharan Africa dedicate, on average, two hours per day gathering and hauling fuelwood (and in some countries the value is more than double this, see Figure 1.4 in Chapter 1). This is a task mainly borne by women and children, which has detrimental health impacts, and represents collectively a huge amount of time that could be used for other ends. Cooking with biomass also results in the consumption of over 300 million tonnes of fuelwood per year, which can exacerbate deforestation in stressed areas (Lambe et al., 2015).

Box 4.2 ▹ Policy turns into progress for clean cooking in Ghana

Today, 71% of the population in Ghana still relies on biomass for cooking. This has significant health impacts: an estimated 13 000 Ghanaians die annually from household air pollution, including 3 000 children (GACC, 2016). There is strong political support in Ghana for action to provide cleaner, healthier and safer forms of cooking fuels, and ultimately to reduce the number of deaths linked to household air pollution. This is evidenced by the inclusion of clean cooking initiatives in Ghana's NDC.

Promoting the use of LPG is a key plank in Ghana's efforts to boost clean cooking including a LPG programme since 1989 (SE4All Africa Hub, 2012). Today 23% of Ghana's population relies on LPG for cooking, one of the highest proportions in sub-Saharan Africa. The government has committed to a nationwide programme to increase the use of LPG further, with a target of ensuring that 15% of the population in rural areas has access to LPG by 2016 and that 50% of Ghanaians have access to LPG for commercial, industry and domestic use by 2020 (Ghana Ministry of Petroleum, 2015).

Under the rural LPG promotion programme, 70 000 cylinders and cookstoves have been distributed to households to defray the initial capital cost (GACC, 2016), with an overall distribution target of 200 000 (Ghana Ministry of Power, 2015). On the supply side, the inauguration of a new gas processing plant in 2015 helped to improve the reliability of LPG supply. A plan for recirculating LPG cylinders meant to make it easier to purchase LPG and improve safety standards is currently under consideration.

Recognising that it will take some time to build up a LPG network in rural areas, Ghana aims to have 2 million improved cookstoves in use in rural households. An initiative is underway to design cleaner cookstoves based on the local gyapa-style stoves in order to meet local needs. Another initiative promotes the use of clean cookstoves through a public awareness campaign, including the development of a school curriculum to educate students on the benefits of clean cooking and engagement with and training of women's groups on the benefits of switching to improved cookstoves. There are also plans to open test and expertise centres for cookstoves, and to develop standards and labels for end-use devices such as clean cookstoves.

A number of international organisations (e.g. SNV Netherlands Development Organisation and the German Society for International Cooperation [GIZ] and the Alliance) are working with local organisations such as the Ministry of Energy and the Ghana Alliance for Clean Cookstoves to create the right conditions for the success of these programmes, including by improving the regulatory framework and supporting the development of the market for clean cookstoves and fuels. Some of the key barriers identified are high import duties on clean cookstoves and raw materials, a lack of access to financing and capacity building on the part of local cookstove manufacturers.

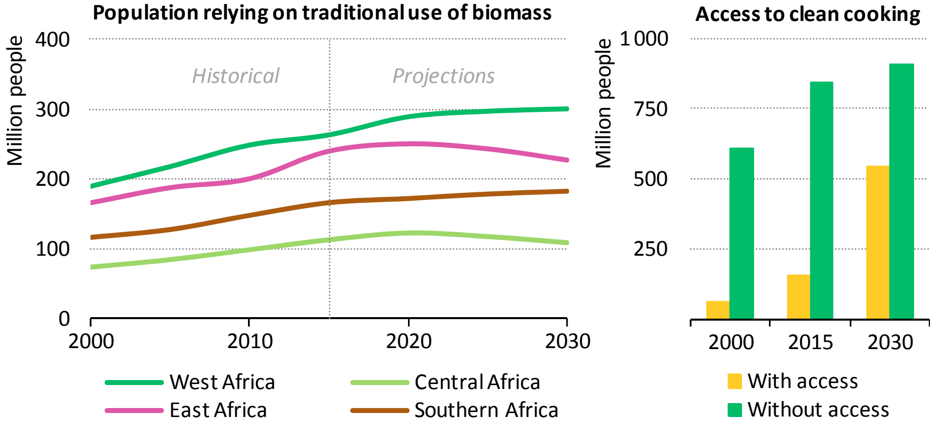
4.4.2 New Policies Scenario

In the New Policies Scenario, demand for cooking fuel increases across sub-Saharan Africa in the period to 2030, as the population continues to grow by 2.5% per year and GDP per capita by 1.9% per year. The fuel mix remains relatively constant. Bioenergy continues to provide around 90% of residential energy needs up to 2030, and demand grows by more than 1% per year. The number of people relying on the traditional use of biomass for cooking continues to increase until the early 2020s, as efforts to provide access are outmatched by population growth, but after that it starts to decline as policies start to deliver. By 2030, 900 million people are without clean cooking access in sub-Saharan Africa (Figure 4.13). The continued growth in biomass use means that household air pollution from cooking still causes an estimated 540 000 premature deaths each year in sub-Saharan Africa.

However, the progress achieved in clean cooking access under the New Policies Scenario is not negligible. The number of people with clean cooking access triples by 2030. Fifteen sub-Saharan African countries have specific targets for clean cooking in their NDCs, and our analysis shows these commitments potentially contributing to 100 million people gaining clean cooking access by 2030.

The most progress is expected in urban areas, where LPG is generally available. As a result, the number of people in urban areas using biomass in 2030 declines by around a quarter compared with 2016. Biomass remains firmly embedded in rural areas, where by 2030 over 80% of the population still does not have clean cooking access. Even though the New Policies Scenario indicates a slowing in the growth of people cooking with solid biomass in rural areas, total demand for solid biomass increases, as consumption levels per person increase, and as more people are expected to use charcoal rather than wood for cooking. This in turn puts pressure on prices in urban areas, where fuelwood and charcoal are usually commodities. In the rural areas where progress does occur, around one-third is due to LPG, around half is from a transition to improved cookstoves (i.e. cleaner and more efficient biomass use) and the remainder is due to solar and biogas devices. A lack of distribution networks and affordability of LPG remains a barrier to its uptake in rural areas, where most households do not have to pay for the biomass used.

Figure 4.13 ▹ Population relying on the traditional use of biomass for cooking, and population with and without clean cooking access in sub-Saharan Africa



Even though more than 300 million people gain clean cooking access by 2030, efforts do not overtake population growth

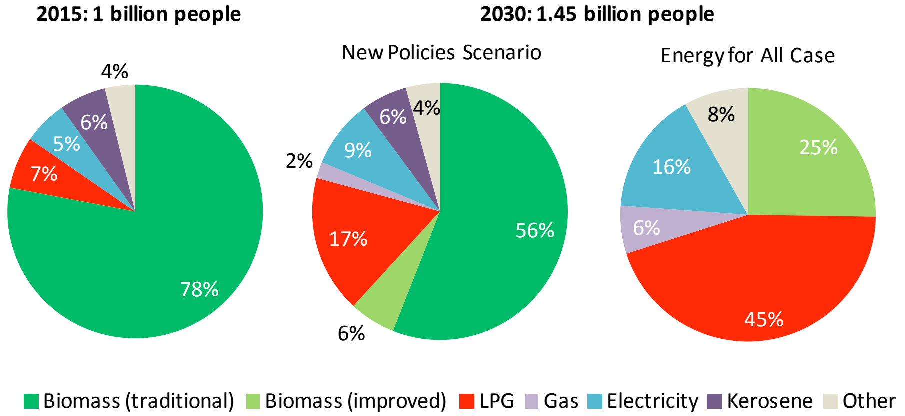
Sources: WHO (historical); IEA analysis (projected).

4.4.3 Energy for All Case

The Energy for All Case suggests that the overall cost of providing universal clean cooking access in sub-Saharan Africa by 2030 amounts to $1.7 billion per year, which compares with $77 billion invested annually in energy supply in sub-Saharan Africa under the New Policies Scenario. This investment has profound impacts on the energy mix and significantly reduces the number of premature deaths from air pollution related to the use of biomass.

In the Energy for All Case, the overall share of biomass in total primary energy demand declines to around 30% in 2030, half the level in 2016, and the residential sector fuel mix in particular changes dramatically. Total residential energy demand declines by 5.5% per year, as the inefficient use of biomass is replaced by modern fuels and improved and advanced biomass cookstoves. The share of biomass in residential energy demand declines to 62% in 2030, compared with over 90% now, with LPG, natural gas and electricity accounting for the remaining share. Around a quarter of people still use biomass for cooking in improved and advanced cookstoves (Figure 4.14). Cooking with biomass is completely eliminated in urban areas, where over 400 million people gain access to LPG, electricity and natural gas cooking facilities. LPG is the main source of new clean cooking access and the share of people relying on LPG in 2030 grows two-and-a-half times compared with the New Policies Scenario, as those who currently use LPG move to other fuels and free up supply. The biggest change compared with the New Policies Scenario is in rural areas, where around 750 million people gain clean cooking access, compared with 90 million in the New Policies Scenario, with access gains coming from a mix of improved and advanced biomass cookstoves, LPG and biogas.

Figure 4.14 ▷ Population relying on fuels for cooking in sub-Saharan Africa

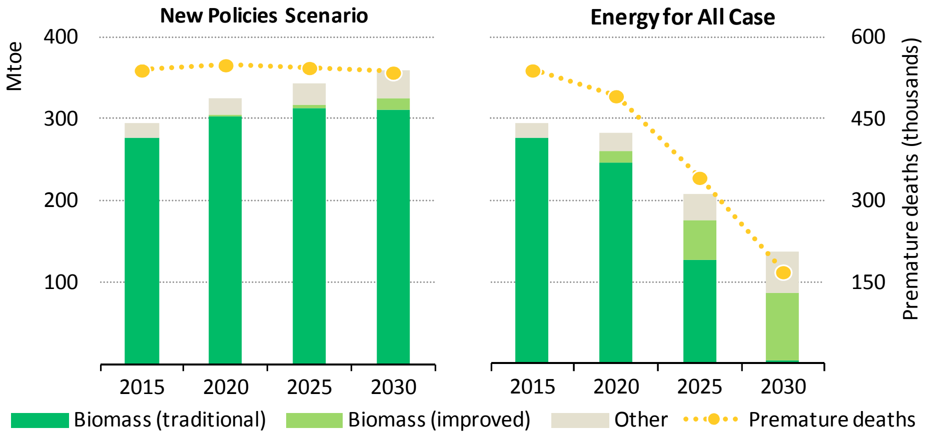


Providing clean cooking for all requires a radical shift in fuel use

Notes: Other includes coal and biogas used for cooking. Biomass (traditional) refers to the traditional use of solid biomass for cooking. Biomass (improved) refers to biomass used in improved/advanced cookstoves.

The social and environmental benefits of moving to modern fuels for cooking are dramatic. Biomass demand for cooking in the residential sector declines by 240 Mtoe (75%) in 2030 relative to the New Policies Scenario, a shift that eases deforestation and saves many billions of hours spent gathering fuelwood. The health improvements are just as striking: under the New Policies Scenario, both the number of people relying on the traditional use of biomass for cooking and the number of premature deaths from household air pollution change relatively little by 2030, whereas under the Energy for All Case, the provision of clean cooking facilities to all reduces premature deaths by around 370 000 in 2030 relative to the New Policies Scenario (Figure 4.15). However, the full realisation of these health benefits depends on increasing the effectiveness of improved and advanced biomass cookstoves in reducing pollutants, on the way they are used and especially on the adequacy of ventilation.

Figure 4.15 ▷ Fuel consumption for cooking and premature deaths from household air pollution in sub-Saharan Africa by scenario



Huge health improvements are achieved as a result of universal access to clean cooking facilities

Notes: Biomass (traditional) refers to the traditional use of solid biomass for cooking. Biomass (improved) refers to biomass used in improved/advanced cookstoves. Other refers to LPG, electricity, natural gas, kerosene, coal and biogas used for cooking.

Sources: IEA analysis; International Institute for Applied Systems Analysis (IIASA).

Box 4.3 ▷ Biogas as a clean, sustainable and locally produced cooking fuel

In many rural areas there are significant barriers to gaining access to modern fuels and stoves for cooking: in many cases, there is simply no market. Improved and advanced biomass cookstoves remain the most widely disseminated solution to clean cooking access, but the health improvements from these are limited. The use of biogas – produced in a digester from the fermentation of organic matter, including crop waste, manure, kitchen scraps, and sewage – for cooking provides many of the attractions of solid biomass, since the fuel source is typically free and sometimes abundant, with the added benefit that the gas burns efficiently with almost no pollution. A number of countries already make use of biogas for cooking and lighting in rural areas, including China, Nepal, Sri Lanka, Bangladesh, India and Kenya. By 2013, 100 million people in rural Chinese households were using biogas digesters (Xia, 2013). The Indian government has been operating the National Project on Biogas Development since 1982, which sets up biogas plants for rural and semi-urban households: to date almost 5 million biogas plants have been installed (India Ministry of Energy and Minerals, 2017).

The use of biogas brings many advantages. Biogas is a clean fuel, so it does not produce the household air pollution that biomass does, with health benefits especially for women and children. The use of biogas instead of wood also saves the time and effort of gathering wood, reduces deforestation and produces fertiliser as a by-product. As a locally produced fuel, it is relatively free from supply disruptions and price fluctuations. Biogas digesters can operate at a household or community scale, providing an opportunity for entrepreneurs to create a market for the fuel.

However, biogas digesters require a substantial upfront investment that can range from $100 to $1 000, depending on size, making them unaffordable for many rural households. Transport and storage can also be challenging, although some companies have proposed innovative ways to solve this challenge. For example, one company operating in Africa and Latin America has developed a cost-effective means to transport biogas through non-pressurised backpacks ((B)Energy, n.d.). The proper installation and maintenance of biogas digesters are critical to ensure they function properly, as well as the availability of sufficient raw feedstocks. Maintaining and removing blockages from the digester can be labour intensive. There are cultural issues too as some may not be willing to handle certain residues such as manure or to cook with it.

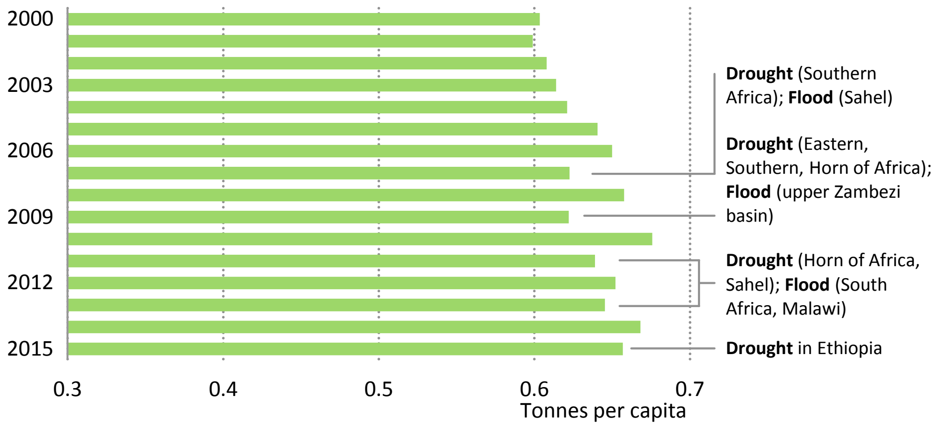
4.5 Impact of modernising agriculture

An assessment of agriculture in sub-Saharan Africa provides an illustrative example of the potential impact on development that the provision of modern energy can have. Africa's annual food import bill is around $35 billion (roughly equivalent to the amount needed to close the power deficit in Africa and roughly half of Africa's net energy import bill). The African Development Bank (AfDB) estimates that the food import bill could rise to over $110 billion by 2025. Food production per head has changed little since 2000, flat levels of energy inputs combined with unpredictable weather, including severe drought, flooding, and rising temperatures have impacted sub-Saharan Africa's agricultural productivity year-on-year, raising food security risk and causing famine in several countries including Somalia, Nigeria, Kenya, Ethiopia and Uganda (Figure 4.16).[5]

Given that a majority of people in sub-Saharan Africa are involved in small businesses, including smallholder agriculture, and that an estimated 300 million people in rural areas will reach working age by 2030, the delivery of modern energy services for agriculture would lead to widespread benefits for inclusive growth and could help create opportunities for those entering the workforce (Fox and Sohnesen, 2012). Women, in particular, stand to benefit significantly from improvements in the sector, as 62% of economically active women are working in agriculture (over 90% in countries such as Burkina Faso, Malawi and Rwanda) (AfDB, 2015).

[5] Note in some cases countries such as Ethiopia, severe famine was mitigated by food imports. However, improving yields can help lower a growing dependence on imports.

Figure 4.16 ▷ Total food production per capita in sub-Saharan Africa

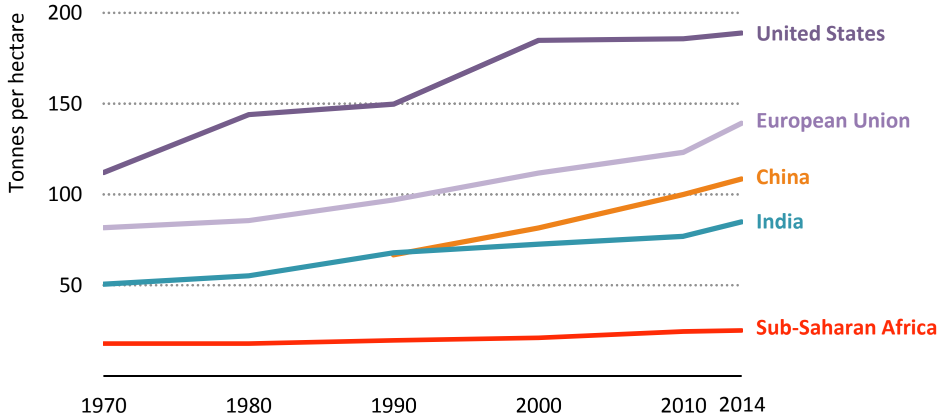


Food production has been stagnant and weather-related incidents have impacted sub-Saharan Africa's food security year-on-year

Sources: IEA analysis; FAO (n.d).

Agriculture in sub-Saharan Africa remains largely unmodernised and its productivity per unit of hectare has remained relatively stagnant, well below that of other regions (Figure 4.17). There are several reasons. First, sub-Saharan Africa's energy inputs into agriculture remain very low; agriculture is responsible for just 2% and 6% of total final consumption for electricity and diesel, respectively. For comparison, India's shares are 18% and 6%. Second, much of the uncultivated land in sub-Saharan Africa is of poor quality, characterised by limited organic matter and poor water retention capacity (AGRA, 2016). Third, its current agricultural production makes very limited use of irrigation to raise crop yields. Just 4% of the total cultivated area in sub-Saharan Africa is irrigated, most of it in Madagascar, South Africa and Sudan, compared with 37% in Asia and 14% in Latin America (UNEP, 2017; You et al., 2010). Fourth, a majority of farms in Africa are small, less than two hectares, and are used for subsistence farming. Between 40-60% of these smallholder farms are unable to produce enough food for subsistence and have to compensate by buying from the market if budgets allow (AGRA, 2016). As well, financial structures, infrastructure and government policies are not strong enough in many places to help bring about improvements in productivity. Improved access to energy would not solve all these problems, nonetheless it could make a significant difference.

Figure 4.17 ▹ Agricultural land productivity in selected countries and regions



Agricultural productivity in sub-Saharan Africa is well below that of other regions

Note: Data for China are not available before 1990.

Source: FAO (n.d).

4

4.5.1 Energy to improve agricultural productivity

By 2030, while the population in sub-Saharan Africa is expected to grow by over 40%, the self-sufficiency ratio for staple crops in the region (i.e. the percentage of food consumed that is produced domestically) is expected to be among the lowest in the world. Improving productivity to satisfy rising demand from a growing population would require an 80% increase in total agricultural production from staple crops (van Ittersum et al., 2016).

Geospatial analysis developed for this special report shows that a holistic electrification strategy that incorporates productive economic activities, particularly in agriculture, could be delivered cost-effectively. Electrification is critical to improving the productivity of agriculture in sub-Saharan Africa, though it alone cannot tip the scales so that Africa is able to feed itself. Policy action in the region also needs to ensure that functioning markets are in place, to provide or support infrastructure such as logistics and transport, and to train farmers in the use of new technology and best practices.

As well as improving the productivity of sub-Saharan Africa's agricultural sector, significant customers tied to agricultural activity could serve as anchor loads and provide a source of stable baseload demand and revenue. These customers could serve as focal points from which larger systems could be built that provide electricity access to surrounding residential and commercial areas. Anchor loads also benefit from economies of scale, reducing the unit costs of providing electricity to other customers, and generating the economic conditions that facilitate scaling up infrastructure to support more intensive end-uses through mini-grids and grid extensions.

A special case developed for our analysis of energy for all combines anchor loads from productive uses, geographic, climate, soil and terrain data with economic inputs to determine areas where agricultural productivity can be expanded through a combination of irrigation, mechanisation and improved agricultural practices. This analysis finds that by 2030, the share of irrigated areas in sub-Saharan Africa would increase from 4% today to 12%. The combined additional electricity demand for water pumping, full mechanisation and post-processing would amount to 12 terawatt-hours (TWh), just 6% more than the total electricity needs to achieve universal access in the Energy for All Case in 2030.

Realising energy for all

...doesn't cost the earth

Highlights

- Despite the progress made in recent years, the world is far from being on track to meeting the Sustainable Development Goal of energy for all by 2030. The New Policies Scenario shows that, on the basis of current policies, in 2030 there will still be 674 million people without electricity access and 2.3 billion people without access to clean cooking facilities, with those lacking access increasingly concentrated in sub-Saharan Africa.
- Realising the Energy for All Case would mean total global energy investment increasing by 1.9% between now and 2030 relative to the New Policies Scenario. To provide electricity access for all, an additional $28 billion per year is needed in the Energy for All Case between now and 2030 on top of the $24 billion invested annually for electricity access in the New Policies Scenario. An estimated 95% of the additional investment for electricity access over and above that projected in the New Policies Scenario would need to be directed to sub-Saharan Africa. This would significantly improve the lives of those without access – especially women, who are disproportionately affected – and boost their economic prospects.
- Realising the Energy for All Case for clean cooking would require an additional $3 billion a year compared to the New Policies Scenario. In 2030, the benefits would include avoiding an estimated 1.8 million premature deaths related to household air pollution, and saving over 100 billion hours each year that are currently spent gathering fuelwood, mostly by women, which could be used for more productive purposes.
- Our analysis indicates that achieving energy for all will not cause a net increase in global greenhouse-gas emissions. Meeting energy for all would have a minimal impact on global energy demand, with an increase of 0.23% in 2030 relative to the New Policies Scenario. However, the corresponding small rise in CO_2 emissions (0.2%) is more than offset by the net reduction in greenhouse-gas emissions from reducing dependence on biomass for cooking, largely arising from methane.
- Investment alone will not ensure that energy for all is realised. Further efforts are required, particularly in sub-Saharan Africa. Decentralised energy technologies and new business models offer scope for achieving faster and more affordable rural electrification, provided that governments create effective enabling environments. Strategies to deliver universal access should be diverse and tailored to local conditions and practices. They need to be underpinned by firm political commitments, supportive enabling and regulatory frameworks, engagement with the private sector, appropriate financing options and investment, capacity building and close consultation from the outset with local communities, especially women.

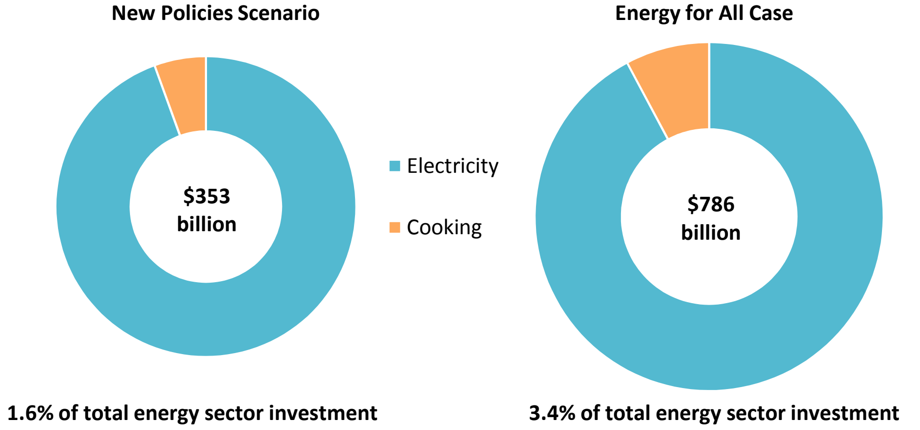
5.1 Implications of achieving energy for all by 2030

The achievement of energy for all by 2030 is a major challenge. As detailed in previous chapters, success would bring a variety of economic and health benefits to those currently without access. It would also have wide-ranging implications for many of the Sustainable Development Goals.

5.1.1 Investment

Our analysis indicates that the provision of electricity and clean cooking for all would require \$786 billion in cumulative investment in the period to 2030, equal to 3.4% of total energy sector investment over the period (Figure 5.1). This would mean an additional \$31 billion per year on top of the \$25 billion per year projected under the New Policies Scenario, with sub-Saharan Africa accounting for the largest share of additional investment, followed by developing Asia.

Figure 5.1 ▷ Cumulative investment in modern energy access, 2017-2030

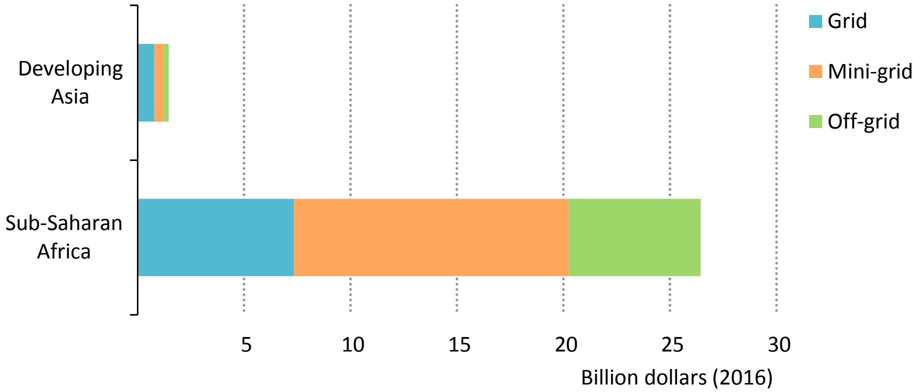


The cumulative investment of \$786 billion needed to provide energy for all would mean a 3.4% increase in total energy sector investment

Sources: IEA analysis; KTH Royal Institute of Technology, Division of Energy Systems Analysis (KTH-dESA).

Most of this expenditure relates to the provision of access to electricity. An extra \$28 billion per year is needed to achieve electricity access for all on top of the \$24 billion per year needed in the New Policies Scenario. However, the target of this investment shifts, reflecting the increased role that decentralised power generation solutions play in providing electricity access in the Energy for All Case. A majority of those who remain without access under the New Policies Scenario are in rural areas, and over two-thirds of the additional investment needed in the Energy for All Case is for decentralised renewables (Figure 5.2).

Figure 5.2 ▷ **Additional average annual investment related to electricity access in the Energy for All Case relative to the New Policies Scenario, 2017-2030**



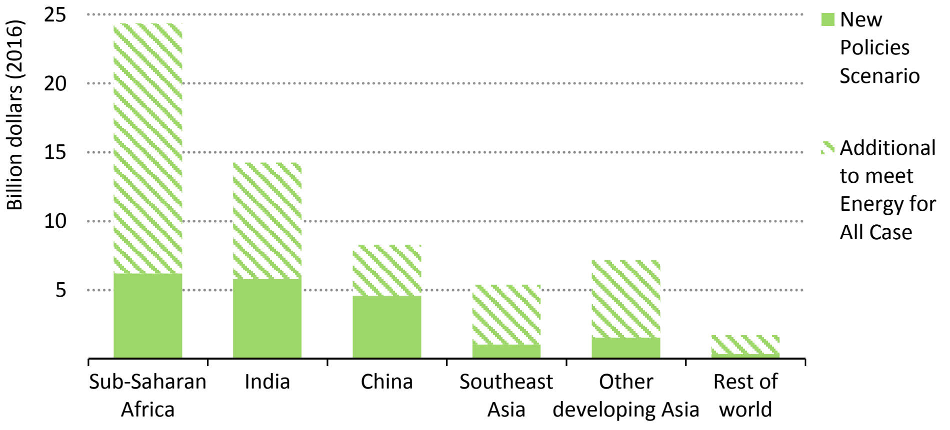
As the majority of those without access reside in rural areas in sub-Saharan Africa, a large share of the additional investment in the Energy for All Case is for decentralised solutions

Sources: IEA analysis; KTH-dESA.

Regarding access to clean cooking, the cumulative investment in the Energy for All Case is three-times higher than in the New Policies Scenario, reflecting the large number of those projected still to be without access in 2030 in the New Policies Scenario (Figure 5.3). An additional $42 billion, or roughly $3 billion per year, is needed to ensure clean cooking for all above what is invested in the New Policies Scenario. The additional increment consists of $18 billion for liquefied petroleum gas (LPG), $23 billion for improved biomass cookstoves and biogas. It is important to consider this investment in context; for instance roughly $270 billion was spent on fossil-fuel consumption subsidies in 2016 (IEA, 2017).

Providing energy for all requires an increase in financing from a range of sources, including development banks, governments, bilateral development assistance and the private sector. Encouragingly, our analysis shows that the private sector is increasingly engaged, and that new business models and creative partnerships are increasing the pool of potential investment for projects from large-scale infrastructure to targeted micro schemes. But additional investment alone will not be sufficient: the right policies, governance structures, capacity building and inclusive planning processes need to be in place to provide a predictable, efficient and effective investment climate.

Figure 5.3 ▹ Cumulative investment in clean cooking solutions in the New Policies Scenario and Energy for All Case, 2017-2030



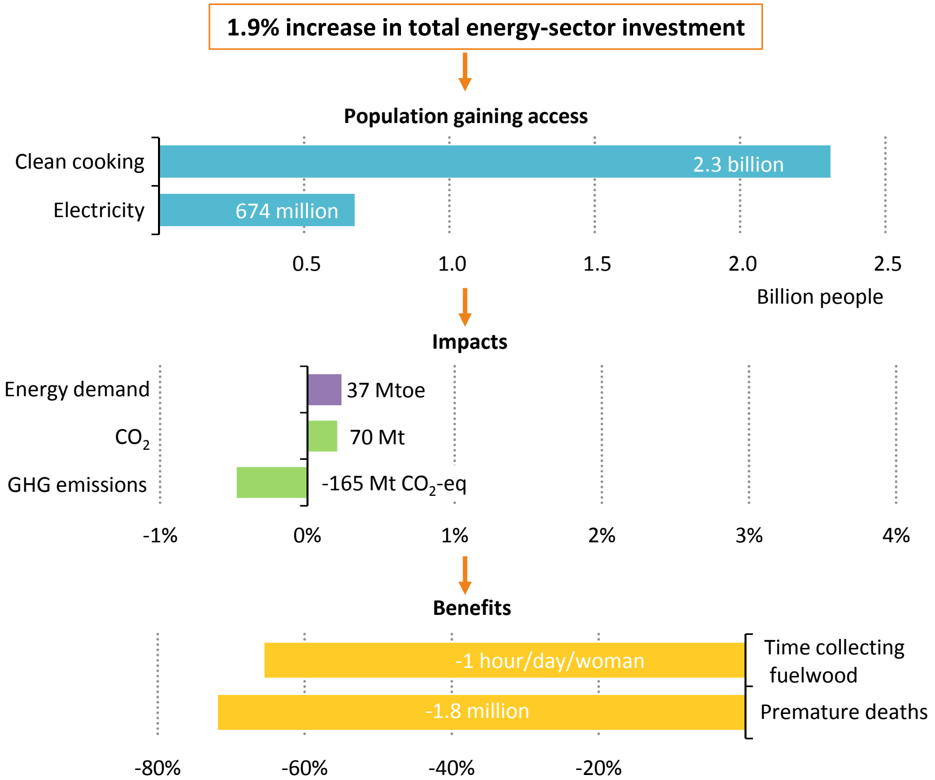
Three-times more investment is needed to provide clean cooking in the Energy for All Case than in the New Policies Scenario

5.1.2 Greenhouse-gas emissions and energy demand

Providing energy for all does not have a major impact on energy demand (Figure 5.4). In 2030, in the Energy for All Case, additional energy demand related to expanding access adds just 37 million tonnes of oil equivalent (Mtoe) to global energy demand relative to the New Policies Scenario, an increase of 0.23%, which is roughly equivalent to a week's worth of energy demand in the United States. Fossil fuels account for just over 30% of electricity generation for access in the Energy for All Case, compared with more than 40% in the New Policies Scenario, with renewables playing a greater role in the provision of electricity access from both on-grid and decentralised solutions in the Energy for All Case. Meeting the target for clean cooking in the Energy for All Case shifts the fuel mix of the residential sector. The traditional use of solid biomass for cooking is replaced by LPG, electricity, natural gas, biogas and solar. Where solid biomass remains, it is used in improved, more efficient cookstoves. Additional LPG demand increases by 0.7 million barrels per day in 2030 in the Energy for All Case relative to the New Policies Scenario.

Achieving universal energy access is not in conflict with achieving climate objectives. The relatively small increase in total primary energy demand and the central role of renewables in our Energy for All Case means that global energy-related carbon dioxide (CO_2) emissions increase by just 70 million tonnes (Mt) relative to the New Policies Scenario in 2030 (0.2% of the global level). Additional CO_2 emissions from providing clean cooking in 2030 account for most of this, primarily due to the increased use of LPG. However, the increase in CO_2 from electricity access and clean cooking access is offset by the greenhouse-gas net savings from a 75% reduction in the quantity of biomass for cooking in 2030 relative to the New Policies Scenario. The reduction in biomass combustion saves the equivalent of around 165 Mt of carbon-dioxide equivalent (CO_2-eq) from methane and nitrous oxide emissions, even without accounting for the reduced CO_2 emissions as these are assumed to be carbon neutral (IEA, 2015).[1]

Figure 5.4 ▷ Additional impact of the Energy for All Case relative to the New Policies Scenario in 2030



The benefits of achieving universal energy access by 2030 far outweigh the costs

Notes: Notes: GHG=greenhouse-gas. GHG emissions are from biomass combustion in traditional cookstoves.

Sources: IEA analysis; KTH-dESA; International Institute for Applied Systems Analysis (IIASA).

[1] The climate benefit of moving from biomass to other fuels is likely to be higher than this when taking into account the reduction in CO_2 emitted as a result of unsustainably harvested biomass and short-lived climate forcers emissions of biomass stoves. The IEA methodology does not take into account CO_2 emissions from the combustion of biomass because they are considered as non-emitting CO_2, based on the assumption that the released carbon will be reabsorbed by biomass regrowth, under balanced conditions (IEA, 2016).

5.1.3 Health and well-being

Achieving energy for all would have significant implications for human health and well-being. The New Policies Scenario reflects existing and announced policies to reduce the use of solid biomass, coal and kerosene and to provide access through cleaner alternatives. The measures are projected to lower the number of premature deaths related to household air pollution from 2.8 million in 2015 to 2.5 million in 2030. Providing access to electricity and clean cooking in the Energy for All Case would lower the number of premature deaths by an additional 1.8 million in 2030. This would benefit women and children in particular, who are often most at risk from household air pollution related to burning biomass for cooking. A shift away from the traditional use of biomass also would benefit women by reducing the number of hours needed to collect fuelwood. We estimate that the achievement of clean cooking for all would save roughly one hour per day of backbreaking work collecting and hauling fuelwood for women gaining access. Over a year, this would save more than 100 billion hours which could be re-directed to other activities. These might include, for example, leisure, enterprise endeavours, community involvement and education. Time not spent collecting fuelwood could be used in ways that lead to improvement in economic standing, particularly if supportive elements are in place and existing barriers to women's economic empowerment are addressed (see Chapter 1). In some instances, fuelwood is collected to be sold, but the loss of this income could be overcome by the involvement of women in the cookstove supply chain or in the value chain of the electricity sector.

5.2 Key messages for policy-makers

While each country will take a different route to achieve energy for all, there are some general lessons from what has already been done that will help along the way. Our analysis highlights that the following actions can help ensure that "no one is left behind" – the imperative of the Sustainable Development Goals.

Implement policies that encourage a wide range of solutions and business models, avoiding barriers to new entrants

As our analysis has shown, new sources of finance and innovative business approaches are changing established perceptions about how energy for all can be achieved. These innovations should not be seen as being in conflict with the current pathway; rather they should be viewed as complementary solutions. Nor should they be considered static or binary as continued development will entail continued improvement in quality and reliability and the provision of more energy services. Our analysis suggests that while each country will work out what mix of fuel, technology and sources of finance is best suited to its specific situation and available resources, it is vital that policy-makers engage a wide array of stakeholders, including the private sector, align government policies and objectives with local level policies and dynamics and support capacity-building at the community level to ensure that the energy access solutions delivered are absorbed and maintained long-term.

A well-designed regulatory framework is crucially important. To achieve universal energy access by 2030, $56 billion must be invested per year, a small sum when compared to the roughly $1.6 trillion per year to be spent in the energy sector over the next 14 years. Policy adjustments to provide incentives, such as the elimination of value-added tax on solar panels as was done in Kenya and Tanzania, and better clarity and transparency of policies and programmes can encourage investment. For instance, the transparency and accountability of Bangladesh's Infrastructure Development Company Ltd. (IDCOL) Solar Home Systems programme created a focal point to channel financial grants and subsidies from international donors and multilateral development banks to the sector. Additionally, it included the private sector to encourage competition and financing. As such, this model helped what is often a fragmented market reach scale. Actions like these can increase the avenues available for financing, ensuring that all potential flows are capitalised upon, including social capital, grants, impact investing, as well as commercial lenders. In some cases, different types of entities are partnering to provide solutions. In Kenya, a combination of government initiatives, public-private partnerships and international aid have worked together to increase its electrification rate from 20% in 2012 to 65% today. Additionally, small enterprises are pairing with national corporations to create integrated business-to-business arrangements to increase access to potential markets and funding and improve branding and consumer awareness. Good policy will also need to facilitate that appropriate financing mechanisms are matched with suitable projects. For example, the scale of decentralised energy systems may require a special focus on smaller projects, business models and more localised financial solutions relative to policies for power grid extensions.

Facilitate rural electricity access by creating suitable conditions for off-grid investment, and by making provision for subsequent grid connection of decentralised solutions

Decentralised off-grid systems have proven to be effective in many countries such as Nepal, Bolivia and Kenya at providing access to areas that are too expensive to electrify via the grid in the short or medium term. However, moving beyond a basic level of consumption is likely to require more energy than off-grid systems can provide, and therefore recquire either mini-grids or grid connection, which also can usually offer less expensive electricity. Mini-grids themselves can be integrated into large networks, if they use compatible equipment. This underlines the need to recognise the dynamic and integrated nature of energy access development, and for co-ordinated planning which takes account of ways to upgrade existing systems and integrate decentralised systems into the grid if it arrives, such as is being done in Tanzania and Namibia. Policy uncertainty and a lack of transparency can create the perception of risk, discouraging investment and halt the progress of decentralised energy systems and entrepreneurs.

Off-grid solar and digital technologies are having a significant impact on rural electrification in parts of Africa and developing Asia, changing the way electricity is delivered and paid for, and making electricity accessible and affordable for parts of the population for the first time. Our analysis shows that a decline in the cost of decentralised renewable energy technologies, a rise in the availability of affordable energy efficient appliances and a boom in mobile phone ownership are together making off-grid solar home systems the least-cost pathway to universal electricity access in some areas. In our Energy for All Case, almost 82% of the rural population of sub-Saharan Africa who do not currently have electricity gain access through decentralised solar photovoltaic (PV) systems. Recently private sector actors have been stepping in with business models that utilise mobile phones and pay-as-you-go schemes to lower the barriers associated with high upfront costs that have impeded many households from acquiring decentralised systems. Access to electricity in Tanzania has increased in part due to a thriving market for solar home systems, and an increase in the number of businesses entering the mini-grid market. While some of these business models are competitive without aid or subsidy; they have much greater effect if government policies provide clarity related to grid expansion plans, set appropriate tariff structures and simplify the permitting and licensing processes. Fundamentally, for these new models to be effective, they must offer services that are affordable to consumers. Rural customers may pay more for their electricity than urban users or be unable to use higher powered appliances because the unit cost of electricity is typically higher for decentralised systems than a grid tariff unless the government decides in favour of cross-subsidisation to even costs out, as has been the case historically.

Make energy efficiency an integral part of energy access policies

For energy to have an impact, it must be affordable and reliable. This is particularly challenging in areas that are sparsely populated and far from an existing grid. Energy efficiency has the potential to improve not only the economics of energy access, but also the reliability and performance of a system. However, too often, developing countries are the recipients of second-hand, inefficient appliances, which while affordable, limit the level of energy services a consumer can attain. Pairing off-grid systems with super-efficient appliances allows consumers to maximise each kilowatt-hour of electricity and improves the affordability of energy access. In all systems, energy efficiency enables consumers to access higher levels of energy services at lower costs, and reduces the size (and thereby the cost) of the system needed to support these services (see Spotlight in Chapter 2). Many policies and programmes to improve energy access currently focus solely on supply, however, and fail to optimise energy efficiency policies and opportunities. Similarly, many countries do not regulate the import of less efficient goods (see Box 7.2 in *WEO-2017*). This represents a major missed opportunity.

Take a holistic approach and include productive uses in energy access policies and targets

No country has gone from poverty to prosperity without making electricity affordable and available in bulk. Electrification strategies should be holistic, with plans to meet the targets for household electrification taking into account other development goals and opportunities to use energy access to stimulate economic activity. There is an opportunity to use the provision of energy access to create local jobs, in terms of production of technologies, especially in regard to cookstoves and their installation and maintenance; however, this will require the development of local skills and competencies. One example is

Indonesia, which has developed a micro hydropower technology cluster employing some 300 engineers, technicians and developers to help further the deployment of mini-grids (EnDev, 2017). Another project in Kenya is working with women entrepreneurs in three key value chains (improved cookstoves, solar and biomass briquettes) to support the production of quality products and help them gain access to financing and markets (ENERGIA, 2014).

Broadening the scope to include the provision of energy for productive uses such as agriculture, industry and community services can help to foster economic opportunities. As our analysis of energy for agriculture in sub-Saharan Africa shows, the amount of energy needed above what is required to provide energy for all is relatively small, yet has significant economic impacts, bolsters food security and lowers food import bills (see section 4.5 in Chapter 4). Second, it creates a strong business case for entities to invest in electricity-related infrastructure as productive uses can serve as an anchor load for power generation, which generate cash flow and provide return on investment, and can bring down the cost of electricity to households. Success on this front will require cross-sectoral planning, co-ordination and financing (for example, between the ministries of energy, water and agriculture) to ensure that the necessary infrastructure, technical and financial knowledge and capacity, and access to markets are in place.

5

Women need to be at the centre of the shift to clean cooking

Improving access to clean cooking is not just a question of money. Many programmes aimed at promoting clean cooking have fallen short of their goals because they have not taken into account the impact that cultural and social factors have on cooking preferences. Persuading people, mostly women, to stop using solid biomass requires tailoring policies and programmes to the various needs and expectations of different groups of stakeholders, taking account of social and cultural factors. For example, the threat that fuel switching poses to the livelihoods of women that currently earn some income from collecting and selling firewood or dung, or the threat that clean cooking fuels and devices may pose to commercial enterprises engaged in the manufacturing and distribution of briquettes in urban areas will need to be addressed. Attention needs to be given to campaigns to raise awareness of the health risks of burning solid biomass in improperly ventilated spaces, and to training and support programmes to help smooth the transition to cleaner cooking fuels. For example, the Ministry of Education in Ghana is undertaking efforts to teach students the benefits of clean cookstoves and fuels. China's National Improved Stove Programme supported training, research and development and capacity building at local levels to ensure that communities could build, manage and maintain cookstoves. Such support also increases the likelihood that the community will take ownership and maintain the new cooking devices and fuels. Delivering universal access to clean cooking will also require a big push to involve and empower women, as they are usually the main decision-makers in matters related to household cooking. Research suggests that engaging women in policies and programmes that design and deliver clean cooking will increase their impact, because women are well-placed to understand, champion and help deliver appropriate solutions tailored to local conditions and needs.

Energy Access Databases

The International Energy Agency's *World Energy Outlook* (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. A definition of access to electricity and clean cooking is in Box 1.1.

The general paucity of data on **electricity access** means that it must be gathered through a combination of sources. The sources for data for this report include: International Energy Agency (IEA) energy statistics; a network of contacts spanning national governments, utilities, multilateral development banks and country-level representatives of various international organisations; other publicly available statistics, such as US Agency for International Development (USAID) supported Demographic and Health Surveys (DHS), 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.

For **clean cooking**, a new historical analysis of reliance on cooking fuels use was undertaken for this report. 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.

Table A.1 ▷ Access to electricity

	Electrification Rate						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2016	2016	2016	2016
WORLD	**73%**	**76%**	**82%**	**86%**	**96%**	**73%**	**1 060**
Developing countries	64%	69%	76%	86%	94%	70%	1 060
Africa	**34%**	**39%**	**43%**	**52%**	**77%**	**32%**	**588**
North Africa	**90%**	**96%**	**99%**	**100%**	**100%**	**99%**	**<1**
Algeria	98%	98%	99%	100%	100%	97%	-
Egypt	94%	98%	100%	100%	100%	100%	-
Libya	100%	100%	100%	100%	100%	99%	-
Morocco	71%	87%	99%	99%	100%	97%	<1
Tunisia	95%	99%	100%	100%	100%	100%	-
Sub-Saharan Africa	**23%**	**27%**	**32%**	**43%**	**71%**	**23%**	**588**
Central Africa	**10%**	**15%**	**21%**	**25%**	**50%**	**5%**	**98**
Cameroon	20%	47%	49%	63%	94%	21%	9
Central African Republic	1%	2%	2%	3%	5%	1%	5
Chad	2%	3%	4%	9%	32%	1%	13
Congo	21%	23%	37%	43%	56%	16%	3
Democratic Republic of Congo	7%	7%	15%	15%	35%	<1%	68
Equatorial Guinea	22%	25%	27%	68%	93%	48%	<1
Gabon	31%	46%	60%	90%	97%	38%	<1
East Africa	**10%**	**17%**	**21%**	**39%**	**66%**	**31%**	**172**
Burundi	4%	5%	5%	10%	35%	6%	10
Djibouti	46%	48%	50%	42%	54%	1%	1
Eritrea	17%	23%	32%	33%	86%	17%	4
Ethiopia	5%	15%	23%	45%	85%	29%	56
Kenya	8%	14%	18%	65%	78%	60%	17
Rwanda	6%	8%	10%	30%	72%	12%	8
Somalia	5%	9%	14%	16%	35%	4%	9
South Sudan	n.a.	n.a.	n.a.	1%	4%	<1%	13
Sudan	30%	31%	36%	46%	71%	31%	22
Uganda	4%	9%	9%	19%	23%	19%	33

Table A.1 ▻ Access to electricity (continued)

	Electrification Rate						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2016	2016	2016	2016
West Africa	**33%**	**37%**	**42%**	**52%**	**80%**	**28%**	**175**
Nigeria	40%	47%	50%	61%	86%	34%	74
Benin	22%	23%	27%	32%	56%	11%	8
Côte d'Ivoire	50%	49%	59%	62%	88%	31%	9
Ghana	45%	51%	61%	84%	95%	71%	4
Senegal	30%	35%	54%	64%	90%	43%	6
Togo	9%	18%	28%	35%	74%	5%	5
Burkina Faso	13%	9%	15%	20%	58%	1%	15
Cape Verde	59%	65%	70%	97%	100%	89%	<1
Gambia	18%	27%	35%	48%	66%	13%	1
Guinea	16%	18%	20%	20%	46%	1%	10
Guinea-Bissau	10%	11%	12%	13%	23%	1%	2
Liberia	<1%	1%	2%	12%	16%	3%	4
Mali	12%	14%	17%	41%	83%	6%	11
Mauritania	15%	17%	19%	31%	47%	2%	3
Niger	7%	8%	9%	11%	54%	<1%	18
Sao Tome and Principe	53%	55%	57%	59%	70%	40%	<1
Sierra Leone	9%	11%	12%	9%	12%	6%	6
South Africa	**66%**	**81%**	**83%**	**86%**	**87%**	**83%**	**8**
Other Southern Africa	**14%**	**16%**	**22%**	**31%**	**65%**	**13%**	**135**
Angola	12%	17%	40%	35%	69%	6%	17
Botswana	22%	40%	45%	55%	69%	32%	1
Comoros	30%	35%	40%	71%	89%	62%	<1
Lesotho	5%	12%	17%	34%	63%	24%	1
Madagascar	8%	16%	17%	23%	52%	7%	19
Malawi	5%	7%	9%	11%	49%	3%	16
Mauritius	100%	95%	99%	100%	100%	100%	-
Mozambique	7%	7%	15%	29%	57%	15%	21
Namibia	34%	34%	44%	56%	78%	34%	1
Seychelles	50%	54%	58%	99%	99%	99%	<1
Swaziland	25%	30%	35%	84%	90%	71%	<1
Tanzania	11%	12%	15%	33%	65%	17%	37
Zambia	12%	19%	19%	34%	67%	6%	11
Zimbabwe	40%	36%	37%	34%	81%	11%	11

Table A.1 ▷ Access to electricity (continued)

	Electrification Rate						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2016	2016	2016	2016
Developing Asia	**67%**	**74%**	**83%**	**89%**	**97%**	**81%**	**439**
China	**99%**	**99%**	**99%**	**100%**	**100%**	**100%**	**-**
India	**43%**	**58%**	**66%**	**82%**	**97%**	**74%**	**239**
Indonesia	**53%**	**56%**	**67%**	**91%**	**99%**	**82%**	**23**
Other Southeast Asia	**67%**	**76%**	**83%**	**89%**	**97%**	**82%**	**42**
Brunei	99%	99%	100%	100%	100%	100%	<1
Cambodia	16%	12%	23%	60%	97%	50%	6
Lao PDR	20%	11%	63%	91%	99%	85%	1
Malaysia	97%	98%	99%	99%	100%	97%	<1
Myanmar	5%	12%	49%	59%	79%	43%	22
Philippines	87%	82%	83%	90%	98%	83%	11
Singapore	100%	100%	100%	100%	100%	100%	-
Thailand	82%	99%	99%	100%	100%	100%	-
Viet Nam	76%	95%	97%	98%	100%	98%	2
Other Developing Asia	**32%**	**39%**	**53%**	**73%**	**87%**	**65%**	**135**
Bangladesh	20%	34%	47%	75%	90%	67%	41
DPR Korea	20%	23%	26%	27%	36%	11%	18
Mongolia	90%	65%	86%	91%	98%	73%	<1
Nepal	15%	35%	76%	77%	97%	72%	7
Pakistan	53%	56%	67%	74%	90%	63%	51
Sri Lanka	62%	68%	77%	100%	100%	100%	-
Other Asia	10%	14%	30%	63%	87%	51%	17
Middle East	**91%**	**80%**	**91%**	**93%**	**98%**	**79%**	**17**
Bahrain	99%	99%	99%	100%	100%	100%	<1
Iran	98%	98%	98%	99%	100%	96%	1
Iraq	95%	29%	98%	99%	100%	95%	1
Jordan	95%	100%	99%	100%	100%	100%	-
Kuwait	100%	100%	100%	100%	100%	100%	-
Lebanon	95%	100%	100%	100%	100%	99%	<1
Oman	94%	96%	98%	100%	100%	93%	<1
Saudi Arabia	98%	97%	99%	99%	100%	98%	<1
Syria	86%	91%	93%	n.a.	n.a.	n.a.	n.a
Qatar	95%	99%	99%	99%	100%	99%	<1
United Arab Emirates	96%	94%	100%	100%	100%	100%	-
Yemen	50%	37%	40%	48%	72%	32%	14

Table A.1 ▻ **Access to electricity** (continued)

	Electrification Rate						Population without access (million)
	National				Urban	Rural	
	2000	2005	2010	2016	2016	2016	2016
Central and South America	**87%**	**91%**	**94%**	**97%**	**98%**	**86%**	**17**
Argentina	95%	96%	97%	100%	100%	85%	<1
Bolivia	60%	67%	80%	92%	98%	66%	1
Brazil	95%	97%	99%	100%	100%	97%	1
Colombia	81%	88%	97%	98%	100%	87%	1
Costa Rica	96%	99%	99%	99%	100%	97%	<1
Cuba	97%	96%	97%	100%	100%	98%	<1
Dominican Republic	67%	93%	97%	97%	98%	91%	<1
Ecuador	80%	91%	92%	98%	99%	94%	<1
El Salvador	71%	81%	92%	96%	98%	90%	<1
Guatemala	67%	79%	80%	94%	100%	84%	1
Haiti	34%	37%	20%	33%	45%	7%	7
Honduras	55%	64%	80%	76%	81%	65%	2
Jamaica	90%	88%	92%	100%	100%	96%	<1
Nicaragua	48%	70%	72%	89%	96%	70%	1
Panama	76%	86%	88%	95%	100%	82%	<1
Paraguay	75%	88%	97%	99%	100%	99%	<1
Peru	73%	75%	86%	95%	97%	89%	2
Trinidad and Tobago	99%	99%	99%	99%	100%	98%	<1
Uruguay	98%	96%	99%	100%	100%	98%	<1
Venezuela	94%	99%	99%	99%	99%	98%	<1
Other Central and South America	87%	88%	92%	96%	99%	91%	<1

Note: n.a. = not available.

Table A.2 ▷ Access to clean cooking

	Share of population without access to clean cooking				Population without access (million)	Population relying on biomass (million)
	2000	2005	2010	2015	2015	2015
WORLD	**46%**	**44%**	**42%**	**38%**	**2 792**	**2 500**
Developing countries	61%	57%	54%	49%	2 792	2 500
Africa	**76%**	**75%**	**72%**	**71%**	**848**	**784**
North Africa	**9%**	**3%**	**1%**	**1%**	**2**	**1**
Algeria	1%	1%	1%	<1%	<1	<1
Egypt	16%	4%	1%	1%	<1	<1
Libya	1%	1%	1%	-	-	-
Morocco	5%	5%	4%	3%	1	1
Tunisia	7%	6%	2%	2%	<1	<1
Sub-Saharan Africa	**91%**	**89%**	**86%**	**84%**	**846**	**783**
Central Africa	**93%**	**92%**	**92%**	**91%**	**115**	**113**
Cameroon	88%	83%	79%	77%	18	17
Central African Republic	>95%	>95%	>95%	>95%	5	5
Chad	94%	>95%	>95%	95%	13	13
Congo	94%	93%	86%	84%	4	3
Democratic Republic of Congo	>95%	>95%	>95%	>95%	75	74
Equatorial Guinea	78%	78%	78%	77%	<1	<1
Gabon	37%	42%	25%	14%	<1	<1
East Africa	**>95%**	**95%**	**86%**	**90%**	**249**	**240**
Burundi	>95%	>95%	>95%	>95%	11	11
Djibouti	>95%	>95%	94%	94%	<1	<1
Eritrea	94%	93%	92%	90%	5	4
Ethiopia	>95%	>95%	84%	94%	94	93
Kenya	>95%	>95%	93%	86%	40	34
Rwanda	>95%	>95%	>95%	>95%	12	11
Somalia	>95%	>95%	>95%	>95%	11	11
South Sudan	n.a.	n.a.	n.a.	>95%	12	12
Sudan	88%	81%	65%	65%	26	26
Uganda	>95%	>95%	>95%	>95%	38	38

Table A.2 ▷ **Access to clean cooking** (continued)

	Share of population without access to clean cooking				Population without access (million)	Population relying on biomass (million)
	2000	2005	2010	2015	2015	2015
West Africa	**>95%**	**95%**	**94%**	**87%**	**308**	**263**
Nigeria	>95%	>95%	>95%	94%	171	128
Benin	>95%	>95%	94%	90%	10	10
Côte d'Ivoire	94%	92%	80%	77%	17	17
Ghana	90%	87%	88%	71%	20	20
Senegal	72%	56%	69%	71%	11	10
Togo	>95%	>95%	>95%	91%	7	7
Burkina Faso	>95%	>95%	92%	86%	16	16
Cape Verde	33%	35%	26%	25%	<1	<1
Gambia	91%	91%	>95%	90%	2	2
Guinea	>95%	>95%	>95%	>95%	12	12
Guinea-Bissau	>95%	>95%	>95%	>95%	2	2
Liberia	>95%	>95%	>95%	>95%	4	4
Mali	>95%	>95%	92%	50%	9	9
Mauritania	80%	71%	68%	66%	3	2
Niger	>95%	>95%	>95%	>95%	19	19
Sao Tome and Principe	76%	77%	62%	40%	<1	<1
Sierra Leone	>95%	>95%	>95%	>95%	6	6
South Africa	**48%**	**36%**	**24%**	**17%**	**10**	**5**
Other Southern Africa	**86%**	**86%**	**87%**	**86%**	**164**	**161**
Angola	54%	55%	61%	61%	15	15
Botswana	54%	48%	44%	42%	<1	<1
Comoros	91%	>95%	95%	93%	<1	<1
Lesotho	79%	79%	67%	63%	1	1
Madagascar	>95%	>95%	>95%	>95%	24	24
Malawi	>95%	>95%	>95%	>95%	17	17
Mauritius	7%	6%	3%	2%	<1	<1
Mozambique	>95%	90%	>95%	95%	27	26
Namibia	64%	59%	57%	55%	1	1
Seychelles	1%	2%	2%	2%	<1	<1
Swaziland	52%	60%	72%	50%	<1	<1
Tanzania	>95%	>95%	>95%	>95%	51	50
Zambia	86%	84%	83%	87%	14	14
Zimbabwe	70%	70%	71%	71%	11	11

Table A.2 ▷ Access to clean cooking (continued)

	Share of population without access to clean cooking				Population without access (million)	Population relying on biomass (million)
	2000	2005	2010	2015	2015	2015
Developing Asia	**65%**	**60%**	**57%**	**49%**	**1 874**	**1 648**
China	**52%**	**48%**	**45%**	**33%**	**457**	**307**
India	**71%**	**66%**	**68%**	**64%**	**834**	**780**
Indonesia	**88%**	**88%**	**53%**	**32%**	**83**	**67**
Other Southeast Asia	**61%**	**58%**	**54%**	**50%**	**188**	**185**
Brunei	-	-	-	-	-	-
Cambodia	>95%	92%	88%	83%	13	13
Lao PDR	>95%	>95%	>95%	>95%	7	7
Malaysia	1%	1%	<1%	-	-	-
Myanmar	92%	93%	94%	94%	51	51
Philippines	53%	58%	64%	62%	62	61
Singapore	-	-	-	-	-	-
Thailand	33%	34%	28%	26%	18	18
Viet Nam	86%	68%	52%	41%	37	36
Other Developing Asia	**76%**	**68%**	**64%**	**63%**	**312**	**309**
Bangladesh	89%	88%	86%	83%	133	132
DPR Korea	47%	47%	47%	46%	12	12
Mongolia	77%	76%	68%	67%	2	1
Nepal	74%	81%	79%	70%	20	20
Pakistan	80%	58%	48%	50%	95	95
Sri Lanka	80%	78%	85%	83%	17	17
Other Asia	79%	80%	77%	72%	34	33
Middle East	**9%**	**9%**	**6%**	**5%**	**12**	**10**
Bahrain	1%	1%	1%	1%	<1	<1
Iran	5%	5%	2%	1%	<1	<1
Iraq	14%	14%	4%	2%	<1	<1
Jordan	-	-	-	-	-	-
Kuwait	-	-	-	-	-	-
Lebanon	1%	1%	1%	1%	<1	<1
Oman	2%	2%	2%	2%	<1	<1
Qatar	-	-	-	-	-	-
Saudi Arabia	-	-	-	-	-	-
Syria	1%	1%	1%	n.a.	n.a.	n.a.
United Arab Emirates	1%	1%	1%	-	-	-
Yemen	40%	40%	40%	39%	10	9

Table A.2 ▻ Access to clean cooking (continued)

	Share of population without access to clean cooking				Population without access (million)	Population relying on biomass (million)
	2000	2005	2010	2015	2015	2015
Central and South America	**19%**	**18%**	**15%**	**12%**	**59**	**57**
Argentina	5%	4%	3%	-	-	-
Bolivia	33%	30%	19%	17%	2	2
Brazil	12%	10%	7%	5%	10	10
Colombia	20%	18%	14%	13%	6	6
Costa Rica	13%	9%	8%	6%	<1	<1
Cuba	9%	9%	9%	6%	<1	<1
Dominican Republic	14%	14%	15%	12%	1	<1
Ecuador	2%	7%	7%	6%	<1	<1
El Salvador	27%	27%	23%	20%	1	1
Guatemala	57%	57%	45%	30%	5	5
Haiti	>95%	>95%	94%	93%	10	10
Honduras	68%	58%	54%	52%	4	4
Jamaica	16%	15%	14%	13%	<1	<1
Nicaragua	62%	60%	55%	52%	3	3
Panama	19%	17%	16%	14%	<1	<1
Paraguay	55%	51%	43%	33%	2	2
Peru	46%	42%	36%	32%	10	10
Trinidad and Tobago	1%	1%	1%	1%	<1	<1
Uruguay	2%	4%	3%	1%	<1	<1
Venezuela	3%	2%	2%	2%	<1	<1
Other Central and South America	19%	15%	13%	13%	<1	<1

Note: n.a. = not available.

Sources: World Health Organisation Household Energy Database; IEA analysis.

Cookstove costs, efficiency and programmes

The database of cookstove costs and performance was created 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 is used as a proxy. Data on cookstove costs are in Table B.1 and data on cookstove efficiencies are in Table B.2.

Regarding stove efficiency, the values in Table B.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) 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.

Clean cooking policies and programmes are summarised in Table B.3. It shows selected programmes related to access to clean cooking facilities in the period from 1982 to 2017. The information is drawn from extensive stakeholder consultations. It is classified by type, strategy (dissemination, promotion, subsidies, incentives or other) and fuel/stove. Where available, information about programme duration and targets is included.

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

	Basic		Improved		Advanced biomass	Modern stoves	Biogas digesters
	Fuelwood	Charcoal	Fuelwood	Charcoal			
West Africa	13	11	44	25	51	39	800
Central Africa	7	7	42	50	45	36	n.a.
East Africa	10	7	29	26	44	38	750
Southern Africa	13	4	39	38	60	36	n.a.
China	6	n.a.	35	57	61	36	n.a.
India	4	n.a.	29	53	65	36	300
Indonesia	8	n.a.	64	60	70	n.a.	575
Thailand	4	2	41	57	81	n.a.	180
Other Southeast Asia	9	n.a.	42	57	66	n.a.	400
Other Developing Asia	14	19	25	38	84	n.a.	n.a.
Latin America	35	16	97	34	14	25	313

Notes: n.a. = not available. Latin America includes Bolivia, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama and Peru.

Sources: Politecnico di Milano; IEA analysis.

Table B.2 ▷ Cookstove efficiencies by type and region

	Basic		Improved		Advanced biomass	Modern stoves	Biogas digesters
	Fuelwood	Charcoal	Fuelwood	Charcoal			
West Africa	18%	23%	31%	32%	39%	50%	n.a.
Central Africa	19%	22%	31%	35%	37%	50%	n.a.
East Africa	21%	24%	31%	34%	34%	48%	55%
Southern Africa	20%	21%	29%	33%	38%	50%	n.a.
China	13%	18%	25%	33%	32%	56%	52%
India	13%	18%	23%	28%	29%	53%	49%
Indonesia	8%	16%	28%	35%	37%	53%	52%
Thailand	16%	19%	27%	29%	32%	53%	n.a.
Other Southeast Asia	8%	16%	24%	28%	37%	53%	51%
Other Developing Asia	12%	22%	23%	30%	32%	46%	44%
Latin America	13%	20%	27%	34%	n.a.	51%	52%

Notes: n.a. = not available. Latin America includes Bolivia, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama and Peru.

Sources: Politecnico di Milano; IEA analysis.

Table B.3 ▹ Selected clean cooking policies and programmes

Region	Country	Policy/programme	Strategy	Fuel/stove	Target scope	Start year	End year	Resulting scope
West Africa	Ghana	Country Action Plan for Clean Cooking, Ghana Alliance for Clean Cookstoves	Promotion, incentives	LPG, ICS	50% population switch to LPG, 50% to generic ICS (equivalent to 5 million ICS)	2013	2020	
	Nigeria		Subsidies	LPG, ICS	17.5 million households			
East Africa	Ethiopia	Energising Development Programme	Promotion	ICS		2010	2013	1.3 million people
		National Improved Cookstoves Programme	Dissemination, promotion	ICS	9 million by 2018, 31 million by 2030	2013	2030	
	Kenya	Kenya Country Action Plan; Clean Cookstoves Association of Kenya	Dissemination, subsidies, promotion, incentives	ICS	5 million households	2013	2020	
	Rwanda	National Domestic Biogas Programme	Dissemination, subsidies	Biodigesters	15 000 domestic biogas plants	2007	2010	3 365 stoves
	Uganda	Uganda National Alliance for Clean Cookstoves, Renewable Energy Policy, Biomass Energy Strategy	Promotion	ICS	3 million households		2017	
Central and Southern Africa	DR Congo, Lesotho, Malawi, Mozambique, South Africa, Tanzania, Zambia	Programme for Basic Energy Conservation (GTZ ProBEC)	Promotion	ICS	125 000 stoves	2004	2010	
Southern Africa	Malawi	Energising Development Malawi	Promotion, incentives	ICS	625 000 people	2012	2016	193 million people
		National Cookstove Taskforce		ICS	2 million efficient stoves	2012	2020	
Central and South America	Haiti	Recho Mirak stove programme	Dissemination	ICS		1983	2010	50 000 stoves
	Guatemala	Social Investment Fund	Dissemination	ICS		1993	2004	90 000 stoves
		Country Action Plan for Clean Cookstoves and Fuels, Ministry of Energy and Mines Energy Policy, National Strategy for Sustainable Use of Wood	Dissemination, promotion, subsidies	ICS	650 000 stoves	2014	2023	
	Peru	"500 000 Improved Cookstoves for a Smoke Free Peru" campaign	Promotion, incentives	ICS	500 000 stoves	2009	2011	250 000 stoves by 2012

Table B.3 ▷ Selected clean cooking policies and programmes (continued)

Region	Country	Policy/programme	Strategy	Fuel/stove	Target scope	Start year	End year	Resulting scope
Asia	China	National Improved Stove Programme	Dissemination	ICS		1982	1992	180 million stoves
			Subsidies	ICS, Coal stoves	40 million households		2020	
	Mongolia	Mongolia Clean Stove Initiative	Promotion, subsidies, incentives	ICS	45 000 low emission stoves	2013		25 000 stoves by 2014
	India	National Programme on Improved Chulhas	Dissemination, subsidies	ICS		1983	2002	35 million stoves
		National Biomass Cookstoves Initiative	Dissemination, promotion	LPG, ICS	50 million LPG canisters, 2.75 million with clean cooking	2009	2017	
	Bangladesh	Bangladesh Council for Scientific and Industrial Research programme	Dissemination	ICS		1980	2001	300 000 stoves
		Country Action Plan for Clean Cookstoves	Dissemination, promotion, subsidies, incentives	ICS	30 million households	2013	2030	
	Nepal	National Rural and Renewable Energy Programme, Alternative Energy Promotion Centre	Dissemination, promotion	ICS, Biodigesters	Universal access	2012	2017	
	Laos	Improved Cookstoves Programme	Promotion	ICS	420 000 stoves	2012	2020	78 000 stoves by 2015
	Indonesia	Clean Stove Initiative Indonesia	Dissemination, promotion, subsidies, incentives	ICS, Biodigesters	10 million stoves by 2020, universal access by 2030	2012	2030	

Notes: ICS = improved biomass cookstoves, LPG = liquefied petroleum gas.

Sources: Politecnico di Milano; IEA analysis.

Definitions

This annex provides general information on terminology used throughout the *Energy Access Outlook*, including: units and general conversion factors; definitions of fuels, processes and technologies; regional and country groupings; and abbreviations and acronyms.

Units

Area	Ha	hectare
	GHa	giga-hectare (1 hectare x 10^9)
	km^2	square kilometre
Emissions	ppm	parts per million (by volume)
	Gt CO_2-eq	gigatonnes of carbon-dioxide equivalent (using 100-year global warming potentials for different greenhouse-gases)
	kg CO_2-eq	kilogrammes of carbon-dioxide equivalent
	g CO_2/kWh	grammes of carbon dioxide per kilowatt-hours
Energy	Mtce	million tonnes of coal equivalent (equals 0.7 Mtoe)
	toe	tonne of oil equivalent
	ktoe	kilotonne of oil equivalent
	Mtoe	million tonnes of oil equivalent
	MBtu	million British thermal units
	kcal	kilocalorie (1 calorie x 10^3)
	MJ	megajoule (1 joule x 10^6)
	kWh	kilowatt-hour
	MWh	megawatt-hour
	GWh	gigawatt-hour
	TWh	terawatt-hour
Gas	mcm	million cubic metres
	bcm	billion cubic metres
	tcm	trillion cubic metres
Mass	kg	kilogramme (1 000 kg = 1 tonne)
	kt	kilotonnes (1 tonne x 10^3)
	Mt	million tonnes (1 tonne x 10^6)
	Gt	gigatonnes (1 tonne x 10^9)

Monetary	$ million	1 US dollar x 10^6
	$ billion	1 US dollar x 10^9
	$ trillion	1 US dollar x 10^{12}
Oil	b/d	barrels per day
	kb/d	thousand barrels per day
	mb/d	million barrels per day
Power	W	watt (1 joule per second)
	kW	kilowatt (1 Watt x 10^3)
	MW	megawatt (1 Watt x 10^6)
	GW	gigawatt (1 Watt x 10^9)
	TW	terawatt (1 Watt x 10^{12})

General conversion factors for energy

Convert to:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388 x 10^{-5}	947.8	0.2778
Gcal	4.1868 x 10^{-3}	1	10^{-7}	3.968	1.163 x 10^{-3}
Mtoe	4.1868 x 10^4	10^7	1	3.968 x 10^7	11 630
MBtu	1.0551 x 10^{-3}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
GWh	3.6	860	8.6 x 10^{-5}	3 412	1

Definitions

Advanced biomass cookstoves: Advanced biomass cookstoves are biomass gasifier-operated cook stoves that use solid biomass, such as wood chips or briquettes. These cooking devices contain technical improvements which increase combustion efficiency and lower pollutant emissions compared to traditional cookstoves. They can include high performance micro-gasifiers and improved cookstove versions with forced-draft, which have a blower that injects air into the fire to improve combustion.

Back-up generation capacity: Households and businesses connected to a main power grid may also have some form of back-up generation capacity that can provide electricity in the event of disruption. Back-up generators are typically fuelled with diesel or gasoline, and capacity can be as minimal as a few kilowatts. Back-up capacity is distinct from mini-grid and off-grid systems, which are not connected to the main power grid.

Bioenergy: Refers to the energy content in solid, liquid and gaseous products derived from biomass feedstocks and biogas. This includes biofuels for transport and products (e.g. wood chips, pellets, black liquor) to produce electricity and heat. Municipal solid waste and industrial waste are also included.

Biogas: A mixture of methane and carbon dioxide produced by bacterial degradation of organic matter and used as a fuel.

Clean cooking facilities: Cooking facilities that are considered safer, more efficient and more environmentally sustainable than the traditional facilities that make use of solid biomass (such as a three-stone fire). This refers primarily to improved solid biomass cookstoves, biogas systems, liquefied petroleum gas stoves, ethanol and solar stoves.

Decentralised systems: Off-grid systems and mini-grids.

Electricity generation: Defined as the total amount of electricity generated by power only or combined heat and power plants including generation required for own use. This is also referred to as gross generation.

Gas: Gas includes natural gas, both associated and non-associated with petroleum deposits, but excludes natural gas liquids.

Household air pollution: Chemical, biological and physical contamination of household air.

Improved cookstoves: 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 rocket stoves or simple micro-gasifiers, which operate a multi-stage burn (also known as wood-gas).

Investment: All investment data and projections reflect “overnight investment”, i.e. the capital spent is generally assigned to the year production (or trade) is started, rather than the year when it actually incurs. Investment data are presented in real terms in year-2016 US dollars.

Investment for access to electricity: Investment for access to electricity includes finance for new transmission and distribution lines, new power generation capacity in mini-grid and off-grid systems, as well as the share of capacity additions connected to the main grid needed to meet access-related electricity demand.

Investment for access to clean cooking facilities: Investment for access to clean cooking facilities includes financing for improved biomass cookstoves and stoves using cleaner fuels such as liquefied petroleum gas, biogas and solar stoves.

Kerosene: A fuel used predominantly for lighting, and secondarily for cooking. Kerosene is considered dangerous as it produces harmful levels of air pollution and is a common source of fires and child injuries from accidental ingestion.

Mini-grids: Localised power networks, generally without infrastructure to transmit electricity beyond the service area.

Modern biomass: Includes all biomass with the exception of traditional use of biomass.

Modern energy access: Access to modern energy services includes household access to a minimum level of electricity; household access to safer and more sustainable cooking and heating fuels and stoves than traditional biomass stoves; access that enables productive economic activity; and access for public services.

Modern fuel stoves: Stoves which use liquids or gas, including LPG, biogas, electricity or natural gas. Excludes kerosene.

Modern renewables: Includes all types of renewables with the exception of the traditional use of biomass.

Off-grid systems: Stand-alone systems that are not connected to any grid.

Pico solar: Off-grid solar PV that comprises a solar panel, battery, one or more LED lamps and in many cases a mobile phone charging port. Pico solar provides a level of access to electricity that is lower than the IEA's minimum threshold definition.

Premature deaths: Deaths that are attributable to a given risk factor and are considered to have been preventable if the risk had been eliminated. All deaths are considered equally, regardless of age.

Productive uses: Energy used towards an economic purpose. This includes energy used in agriculture, industry, services and non-energy use. Some energy demand from the transport sector (e.g. freight-related) could also be considered as productive, but is treated separately.

Renewables: Includes bioenergy, geothermal, hydropower, solar photovoltaic (PV), concentrating solar power (CSP), wind and marine (tide and wave) energy for electricity and heat generation.

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

Total final consumption: Total final consumption (TFC) is the sum of consumption by the different end-use sectors. TFC is broken down into energy demand in the following sectors: industry (including manufacturing and mining), transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at world level where it is included in the transport sector.

Total primary energy demand: Total primary energy demand (TPED) represents domestic demand only and is broken down into power generation, other energy sector and total final consumption.

Traditional use of solid biomass: The traditional use of solid biomass refers to the use of solid biomass with basic technologies, such as a three-stone fire, often with no or poorly operating chimneys.

Regional and country groupings

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of Congo, Côte d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, the Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Réunion, Rwanda, São Tomé and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Uganda, United Republic of Tanzania, Togo, Tunisia, Zambia and Zimbabwe.

Central Africa: Cameroon, Central African Republic (CAR), Chad, Congo, Democratic Republic of Congo (DR Congo), Equatorial Guinea and Gabon.

China: Refers to the People's Republic of China, including Hong Kong.

Developed countries: Australia, Armenia, Austria, Azerbaijan, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Georgia, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kazakhstan, Korea, Kyrgyzstan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Russian Federation, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Turkey, Turkmenistan, United States, United Kingdom and Uzbekistan.

Developing Asia: Bangladesh, Brunei Darussalam, Cambodia, China, Chinese Taipei, India, Indonesia, the Democratic People's Republic of Korea, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Viet Nam and other Asian countries and territories (Afghanistan, Bhutan, Cook Islands, East Timor, Fiji, French Polynesia, Kiribati, Laos, Macau (China), Maldives, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu.

Developing countries: Developing Asia, Middle East, Africa and Central and South America regional groupings.

East Africa: Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, South Sudan, Sudan and Uganda.

Central and South America: Argentina, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, Venezuela and other Central and South American countries (Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands, French Guyana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname and Turks and Caicos Islands).

Latin America: Refers to Central and South America.

Middle East: Bahrain, Islamic Republic of Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, United Arab Emirates and Yemen. It includes the neutral zone between Saudi Arabia and Iraq.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

Other Southern Africa: Southern Africa regional grouping excluding South Africa.

Southern Africa: Angola, Botswana, Comoros, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, United Republic of Tanzania, Zambia and Zimbabwe.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Laos People's Democratic Republic (PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam.

Sub-Saharan Africa: Africa regional grouping excluding the North Africa regional grouping.

West Africa: Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, São Tomé and Principe, Senegal, Sierra Leone and Togo.

Abbreviations and acronyms

AfDB	African Development Bank
CO_2-eq	Carbon-dioxide equivalent
COP	Conference of the Parties
CSP	concentrating solar power
DDUGJY	Deen Dayal Upadhyaya Gram Jyoti Yojana scheme
discoms	distribution companies
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
ECOWAS	Economic Community of West African States
EnDev	Energising Development Programme
EU-SILC	European Union Survey of Income and Living Conditions
GACC	Global Alliance for Clean Cookstoves
GHACCO	Ghana Alliance for Clean Cookstove and Fuel
GDP	gross domestic product
GHG	Greenhouse-gas
GIS	geographic information systems
ICS	improved cookstoves
ICT	information and communication technology
IDCOL	Infrastructure Development Company Limited
IIASA	International Institute for Applied Systems Analysis

KOSAP	Kenya Off-Grid Solar Access Project
LCOE	levelised cost of energy
LED	light-emitting diode
LPG	liquefied petroleum gas
NDC	nationally determined contributions
NITI	National Institution for Transforming India
OECD	Organisation of Economic Co-operation and Development
OMC	Omnigrid Micropower Company
PAYG	pay-as-you-go
PM	particulate matter
PMUY	Pradhan Mantri Ujjwala Yojana
PPP	purchasing power parity
PV	photovoltaic
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SHS	solar home systems
UDAY	Ujwal Discom Assurance Yojana scheme
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFAO	United Nations Food and Agriculture Organization
USAID	United States Agency for International Development
WEM	World Energy Model
WEO	World Energy Outlook
WHO	World Health Organization

References

Chapter 1: Energy and development: the context

Arlet, J. et al. (2017), *Doing Business 2017 – Getting Electricity, Factors Affecting the Reliability of Electricity Supply*, World Bank, Washington DC.

ARE (Alliance for Rural Electrification) (2017), *Innovative Business Models / Gender & Sustainable Energy,* ARE Newsletter, ARE, Brussels.

Bonany, J. et al. (2017 forthcoming), *Social interaction and technology adoption: experimental evidence from improved cookstoves in Mali.*

Dinkelman, T. (2011), "The effects of rural electrification on employment: new evidence from South Africa", *The American Economic Review*, vol. 101/7, pp. 3078-3108.

ECREEE (ECOWAS Centre for Renewable Energy and Efficiency) (2015), *Situation Analysis of Energy and Gender Issues in ECOWAS Member States*, ECREEE, Praia, Cape Verde.

ESI Africa (2017), *BBOXX: solar innovation to light up Togo,* ESI Africa, *www.esi-africa.com/news/bboxx-solar-innovation-to-light-up-togo/* , accessed 13 July 2017.

EU (European Union) (2013), *Statistics on Income and Living Conditions* (SILC) (database), Eurostat, *http://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions*, accessed 13 July 2017.

FAO (Food and Agriculture Organization of the United Nations) (2011), *Energy-Smart Food for People and Climate*, FAO, Rome.

FAO (n.d.), *Water and Food Security*, *www.fao.org/docrep/x0262e/x0262e01.htm*, accessed 05 July 2017.

Grogan, L. and Sadanand, A. (2013), "Rural electrification and employment in poor countries: evidence from Nicaragua", *World Development*, vol. 43, pp. 252-265.

Hodges, R. et al. (2011), "Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use", *Journal of Agricultural Science*, vol. 145/S1, pp. 37-45.

IEA (International Energy Agency) (2016a), *Energy and Air Pollution: World Energy Outlook Special Report*, OECD/IEA, Paris.

– (2016b), *World Energy Outlook-2016*, OECD/IEA, Paris.

– (2014), *Africa Energy Outlook: World Energy Outlook Special Report,* OECD/IEA, Paris.

McArthur J. and McCord, G. (2014), *Fertilising Growth: Agricultural Inputs and their Effects in Economic Development,* Brookings Institution, Washington DC.

Ministry of Food Processing Industries (2016), *Annual Report 2016-17,* Government of India, New Delhi.

O’Dell, K. et al. (2014), *Women, Energy, and Economic Empowerment,* Deloitte University Press.

Oleksiw, Z. (2016), *Solar Business Models for Growth: The Private Sector Needs to Lead on India’s Rural Electrification Deficit*, The Energy Collective, *www.theenergycollective.com/ zadie-oleksiw/2376885/solar-business-models-for-growth-the-private-sector-needs-to-lead-on-indias-rural-electrification-deficit*, accessed 04 July 2017.

Peng, W. et al. (2010), “Household level fuel switching in rural Hubei”, *Energy for Sustainable Development*, vol. 14/3.

Porcaro, J. et al. (2017), *Modern Energy Access and Health*, State of Electricity Access Report Special Feature, International Bank for Reconstruction and Development/World Bank, Washington DC.

Practical Action (2016), *Poor People's Energy Outlook 2016,* Practical Action Publishing Ltd., Rugby, United Kingdom.

– (2014), *Gender and Livelihoods Impacts of Clean Cookstoves in South Asia,* Practical Action Publishing Ltd, Rugby, United Kingdom.

Rademaekers, K. et al. (2016), *Selecting Indicators to Measure Energy Poverty,* Framework Contract ENER/A4/516-2014, European Commission, Rotterdam, Netherlands.

SE4All Africa Hub (Sustainable Energy for All Africa Hub) (2014), *Powering Affordable, Reliable, and Sustainable Energy,* African Development Bank, Nairobi.

Shapshak, T. (2016), *New solar products to boost small businesses in Africa,* Forbes, *www.forbes.com/sites/tobyshapshak/2016/06/22/new-solar-products-to-boost-small-businesses-in-africa/#4b6851f4679e*, accessed 21 September 2017.

Sims, R. et al. (2015), *Opportunities for Agri-Good Chains to Become Energy-Smart,* FAO, Rome.

Treiber, M. (2012), *Fuel and Stove Diversification in the Light of Energy Transition and Technology Adoption Theory,* Norwegian University of Life Sciences, Ås, Norway.

UNEP (United Nations Environment Programme) (2017), *Atlas of Africa Energy Resources.* UNEP, Nairobi.

UNESCO (United Nations Educational, Scientific and Cultural Organization) (n.d.), *Education: Access to basic services in public schools by level of education* (database), UNESCO, http://data.uis.unesco.org/?queryid=194.

UNIDO (United Nations Industrial Development Organization) and UN Women (United Nations Entity for Gender Equality and the Empowerment of Women) (2013), *Sustainable Energy for All: the Gender Dimensions,* UNIDO, Vienna.

UNILO (United Nations International Labour Organization) (n.d.), *Statistics and Databases* (database), http://www.ilo.org/global/statistics-and-databases/lang--en/index.htm

Vitousek, P. et al. (2009), "Nutrient imbalances in agricultural development", *Science,* vol. 324/5934, pp. 1519-1520.

World Bank (2017), *Getting Electricity: Factors Affecting the Reliability of Electricity Supply*, Doing Business 2017, World Bank, Washington, DC.

– (n.d.), *Poverty and Equity Data* (database), World Bank, *http://povertydata.worldbank.org /poverty/home/.*

WHO (World Health Organization) (2010), *Medical Devices: Managing the Mismatch,* WHO Press, Geneva.

WHO and World Bank (2014), *Access to Modern Energy Service for Health Facilities in Resource-Constrained Settings: A Review of Status, Significance, Challenges and Measurement,* WHO Press, Geneva.

Chapter 2: Access to electricity

Africa Progress Panel (2017), *Lights, Power, Action: Electrifying Africa*, Africa Progress Panel, Geneva.

Di Bella, G. and Grigoli, F. (2016), "Power it up; strengthening the electricity sector to improve efficiency and support economic activity", *IMF Working Paper,* No. 16/85, International Monetary Fund, Washington DC.

ECA (Economic Consulting Associates) (2017), *Mini-Grids: Are Cost-Reflective Tariffs Necessary?,* ECA, *www.eca-uk.com/2017/02/22/mini-grids-are-cost-reflective-tariffs-necessary/*, accessed 13 July 2017.

IEA (International Energy Agency) (2017a), *Medium-Term Renewable Energy Market Report,* OECD/IEA, Paris.

– (2017b), *Southeast Asia Energy Outlook: World Energy Outlook Special Report*, OECD/IEA, Paris.

– (2017c), *Digitalization & Energy*, OECD/IEA, Paris.

– (2011), *World Energy Outlook-2011*, OECD/IEA, Paris.

REN21 (Renewable Energy Policy Network for the 21st Century) (2017), *Renewables Global Status Report,* REN21 Secretariat, Paris.

Rom, A. et al. (2017), *The Economic Impact of Solar Lighting: Results from a Randomised Field Experiment in Rural Kenya, www.dec.ethz.ch/research/solar-lighting.html*, accessed 21 September 2017.

Sanyal, S. et al. (2016), *Stimulating Pay-As-You-Go Energy Access in Kenya and Tanzania*, World Resources Institute, Washington DC.

Chapter 3: Access to clean cooking

Barbieri, J. et al. (2017), "Cooking in refugee camps and informal settlements: a review of available technologies and impacts on the socio-economic and environmental perspective", *Sustainable Energy Technologies and Assessments*, vol. 22, pp. 194-207.

Bruce, N. et al. (2017), *Liquefied Petroleum Gas as a Clean Cooking Fuel for Developing Countries: Implications for Climate, Forests, and Affordability*, Materials on Development Financing no. 7, KFW Development Bank, Frankfurt.

Cameron, C. et al. (2016), "Policy trade-offs between climate mitigation and clean cook-stove access in South Asia", *Nature Energy,* vol. 1, *http://dx.doi.org/10.1038/nenergy.2015.10*.

FAO (2015), *Global Forest Resources Assessments* (database), FAO, *www.fao.org/forest-resources-assessment/explore-data/en/*, accessed 27 July 2017.

Fuso Nerini, F. et al. (2017), "The Cost of Cooking a Meal: the Case of Nyeri County, Kenya", *Environmental Research Letters,* vol. 12/6.

Lombardi, F. (2017). "Laboratory protocols for testing of improved cooking stoves (ICSs): a review of state-of-the-art and further developments", *Biomass and Bioenergy,* vol. 98, pp. 321-335.

NITI Aayog (National Institution for Transforming India) (2017), *Draft National Energy Policy,* Government of India, New Delhi.

Pilishvili, T. et al. (2016), "Effectiveness of Six Improved Cookstoves in Reducing Household Air Pollution and Their Acceptability in Rural Western Kenya", *PLOS One*, *https://doi.org/10.1371/journal.pone.0165529*.

Quansah, R. et al. (2017), "Effectiveness of interventions to reduce household air pollution and/or improve health in homes using solid fuel in low-and-middle income countries: a systematic review and meta-analysis", *Environment International,* vol. 103, pp. 73-90.

Chapter 4: Energising development in sub-Saharan Africa

(B)Energy (n.d.), *(B)Plant*, *www.be-nrg.com/b-products/*, accessed 26 July 2017.

AfDB (African Development Bank) (2017), *The New Deal on Energy for Africa: a Transformative Partnership to Light Up and Power Africa by 2015,* AfDB, Abidjan, Côte d'Ivoire.

AfDB, OECD (Organization of Economic Co-operation and Development) and UNDP (United Nations Development Programme) (2016), *African Economic Outlook 2016: Sustainable Cities and Structural Transformation,* OECD Publishing, Paris.

– (2015), *African Economic Outlook 2015,* OECD Publishing, Paris.

AGRA (Alliance for a Green Revolution in Africa (2016), *Africa Agriculture Status Report 2016: Progress towards Agricultural Transformation in Africa,* AGRA, Nairobi.

EC (European Commission) (2017), *Panel Discussion on "Zero Hunger: Regional Commitments to Eradicate Hunger, Food Insecurity and Malnutrition",* EC, *https://ec.europa.eu/commission/commissioners/2014-2019/hogan/announcements/speech-commissioner-phil-hogan-panel-discussion-zero-hunger-regional-commitments-eradicate-hunger_en*, accessed 3 July 2017.

ESI Africa (2017), *Solar hybrid power plant moves ahead in Zambia*, ESI Africa, *www.esi-africa.com/news/solar-hybrid-power-plant-moves-ahead-in-zambia/*, accessed 13 July 2017.

FAO (n.d.), *FAOSTAT: Production* (database), http://www.fao.org/faostat/en/#data/QC

Fox, L. and Sohnesen, T. (2012), *Household Enterprises in Sub-Saharan Africa: Why They Matter for Growth, Jobs, and Livelihood,* Policy research working paper no. 6184, World Bank, Washington DC.

GACC (Global Alliance for Clean Cookstoves) (2016), *Country Factsheet: Ghana*, GACC, *http://cleancookstoves.org/country-profiles/focus-countries/1-ghana.html*, accessed 21 September 2017.

Ghana Ministry of Petroleum (2015), *Petroleum Minister Affirms Governments efforts to Reduce the Number of Ghanaians who Die from Household Air Pollution (HAP),* Government of Ghana, Accra.

Ghana Ministry of Power (2015), *Sustainable Energy for All Action Agenda for Ghana*, Government of Ghana, Accra.

GSMA (Groupe Spéciale Mobile Association) (2017a), *Global Mobile Money Dataset* (database), GSMA, *www.gsma.com/mobilefordevelopment/programme/mobile-money/global-mobile-money-dataset*.

– (2017b), *The Mobile Economy: Africa 2017,* GSMA, London.

IEA (International Energy Agency) (2017), *World Energy Outlook-2017,* OECD/IEA, Paris.

– (2014), *Africa Energy Outlook: World Energy Outlook Special Report,* OECD/IEA, Paris.

Lambe, F. (2015), *Bringing clean, safe, affordable cooking energy to households across Africa: an agenda for action*, Stockholm Environment Institute, Stockholm.

Lighting Global and BNEF (Bloomberg New Energy Finance) (2016), *Off-Grid Solar Market Trends Report 2016*, BNEF, London.

India Ministry of Energy and Minerals (2017), *Biogas,* Government of India, New Delhi.

Oxford Business Group (2015), *Gabon seeks universal power access by 2035,* Oxford Business Group, *www.oxfordbusinessgroup.com/analysis/solutions-rural-power-working-towards-goal-universal-access-2035*, accessed 18 July 2017.

Pilling, D. and Fick, M. (2017), *Sub-Saharan Africa grows at modest 2.5%, Financial Times*, Nairobi and Lagos.

SE4All Africa Hub (Sustainable Energy for All Africa Hub) (2012), *Rapid Assessment Gap Analysis: Ghana,* African Development Bank, Abidjan, Côte d'Ivoire.

Tagliapietra, S. (2017), Electrifying Africa: how to make Europe's contribution count, Bruegel Policy Contribution issue no. 17, Breugel, Brussels.

Tanzania Ministry of Energy and Minerals (2017), *Energy Access Situation Report 2016*, Tanzania National Bureau of Statistics, Dodoma, Tanzania.

UNEP (United Nations Environment Programme) (2017), *Atlas of Africa Energy Resources,* UNEP, Nairobi.

USAID (United States Agency for International Development) (2017), *Demographic and Health Surveys Programme: STATcompiler* (database), *www.statcompiler.com/en/.*

van Ittersum, M. et al, (2016), "Can sub-Saharan Africa feed itself?" *PNAS*, vol. 113/52, 14964-15969.

Waruru, M. (2016), "Kenya On Track to More Than Double Geothermal Power Production", Renewable Energy World, *http://www.renewableenergyworld.com/articles/2016/06/ kenya-on-track-to-more-than-double-geothermal-power-production.html,* accessed 20 June, 2017.

Xia, Z. (2013), *Domestic Biogas in a Changing China: Can Biogas Still Meet the Energy Needs of China's Rural Households?,* International Institute for Environment and Development, London.

You, L. et al. (2010), *What is the Irrigation Potential for Africa? A Combined Biophysical and Socioeconomic Approach,* International Food Policy Research institute discussion paper 00993, International Food Policy Research institute, Washington DC.

Chapter 5: Realising energy for all

EnDev (Energising Development Programme) (2017), *Country Project Indonesia,* GIZ, Jakarta, Indonesia.

ENERGIA (2014), *Women Entrepreneurship Delivering Sustainable Energy for All,* Newsletter of the Energia International Network on Gender and Sustainable Energy, vol. 1/15, Leusden, Netherlands.

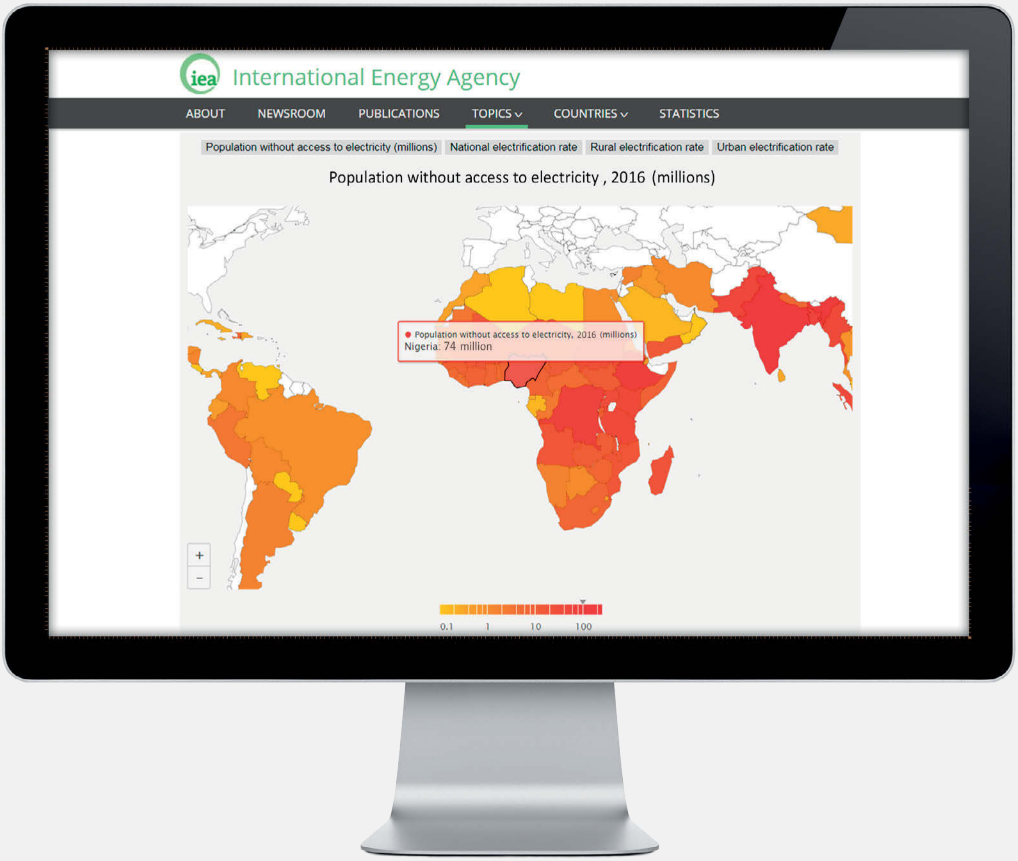
IEA International Energy Agency (2017), *World Energy Outlook-2017,* OECD/IEA, Paris.

– (2016), *CO_2 Emissions from Fuel Combustion,* OECD/IEA, Paris.

– (2015), *Energy and Climate Change: World Energy Outlook Special Report*, OECD/IEA, Paris.

Explore the data behind the

Energy Access Outlook 2017



www.iea.org/energyaccess

The IEA's *World Energy Outlook* has tracked country-by-country data on access to electricity and clean cooking for over fifteen years. Its unique database provides a historical time series from 2000 to present for over 100 countries on access to electricity and clean cooking. Please visit the free database from the *Energy Access Outlook* 2017 report at www.iea.org/energyaccess/database. There you will find data on the electricity and clean cooking access rates for more than 100 countries, including the urban and rural divide, along with much more material.

IEA Publications,
International Energy Agency

Website: www.iea.org

Contact information: www.iea.org/aboutus/contactus

IEA/OECD possible corrigenda on: www.oecd.org/about/publishing/corrigenda.htm

Layout in France by IEA, October 2017

Cover design: IEA, photo credits: ShutterStock

Energy Access Outlook 2017

Energy is essential for humanity to develop and thrive. In 2015, the new Sustainable Development Goals, adopted by 193 countries, included for the first time a target to ensure affordable, reliable, sustainable and modern energy for all, underscoring a new level of political agreement on the importance of access to modern energy services. At the same time, the declining cost of decentralised renewables, increased access to affordable energy-efficient appliances and the use of mobile platforms are changing the way we think about providing energy access. It is against this backdrop that the IEA produced this Special Report, part of its flagship *World Energy Outlook* (*WEO*) series.

This report:

- Expands and updates the *WEO*'s country-by-country electricity and clean cooking access database, and assesses the status for all developing countries, reviewing recent trends and policy efforts up to 2016.
- Presents a global and regional electricity and clean cooking access outlook to 2030, with a dedicated chapter on sub-Saharan Africa.
- Provides a pathway for achieving access to modern energy for all by 2030, identifying policy priorities, detailing investment needs, and the role that decentralised and on-grid solutions may play.
- Analyses how energy development can unleash economic growth in sectors such as agriculture, and explores how energy access intersects with other issues such as gender, health and climate change.

40 years of World Energy Outlook

for more information visit www.iea.org/energyaccess