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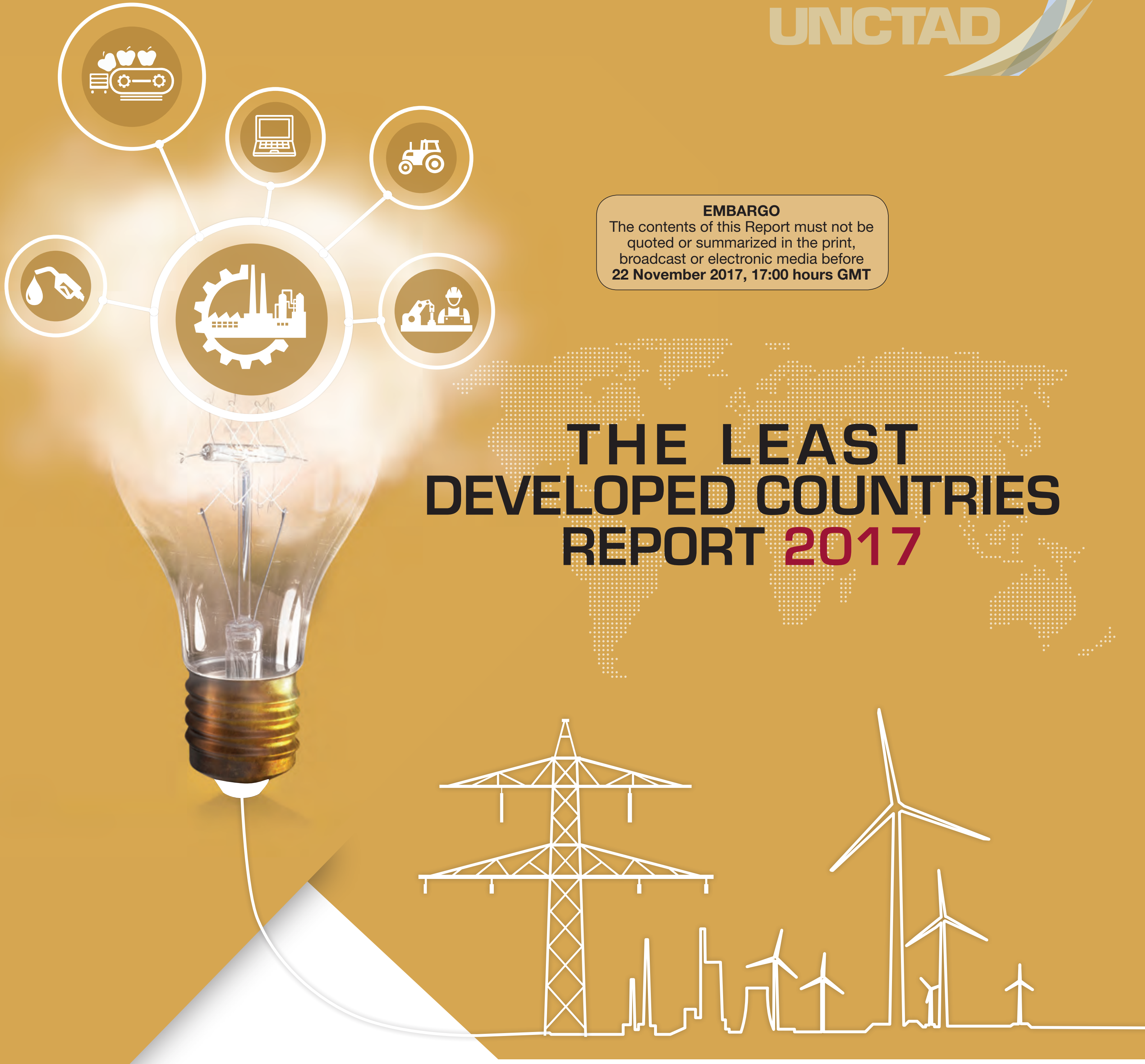

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THE LEAST DEVELOPED COUNTRIES REPORT 2017

Transformational energy access

UNITED NATIONS

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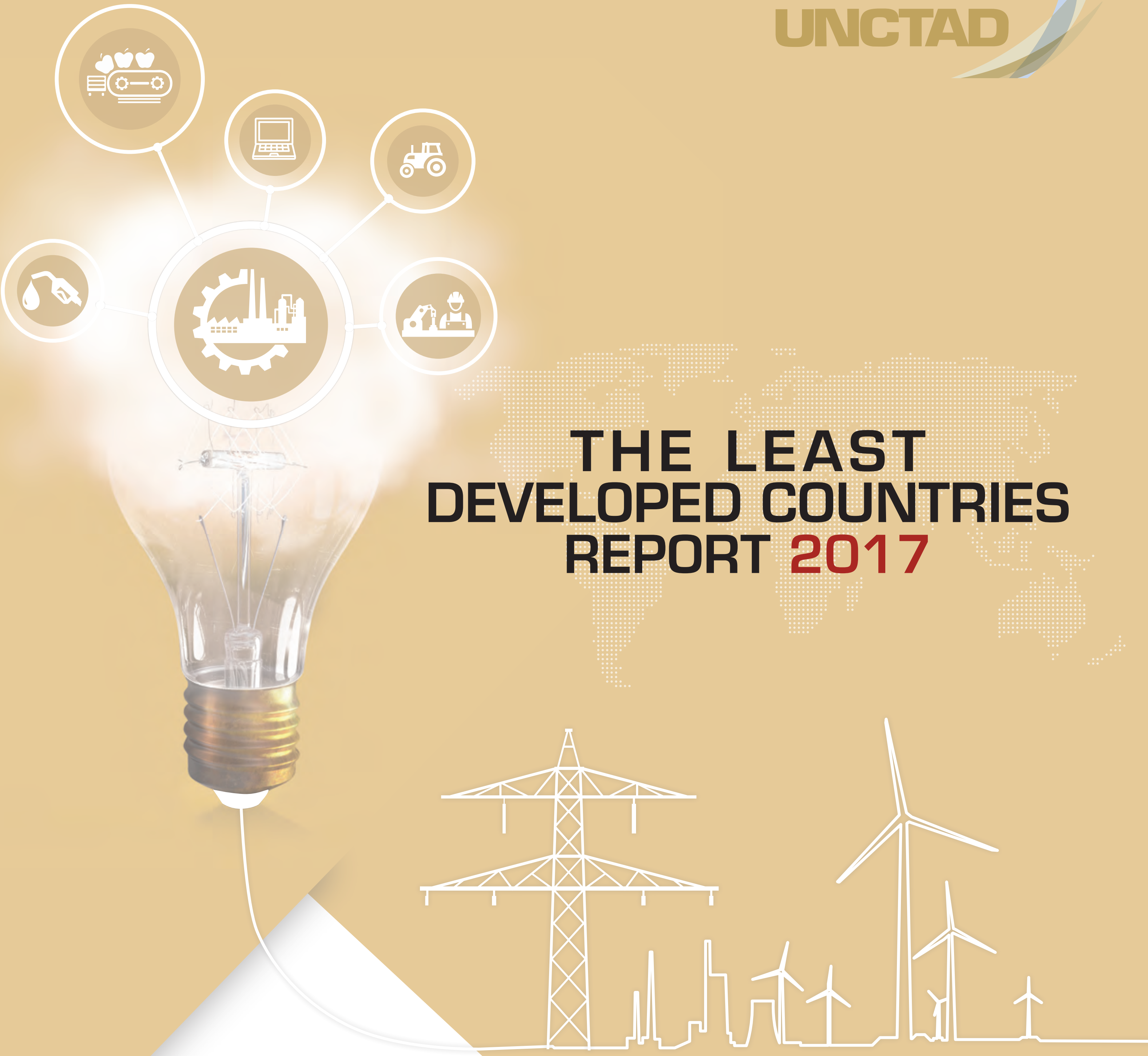

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Transformational energy access

UNITED NATIONS
New York and Geneva, 2017

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Foreword

Unlike the Millennium Development Goals, the 2030 Agenda for Sustainable Development includes an explicit goal for energy — Sustainable Development Goal (SDG) 7, to “ensure access to affordable, reliable, sustainable and modern energy for all”. Access to modern energy plays a major role in economic structural transformation — a critical issue both for the least developed countries (LDCs) and for the 2030 Agenda more generally.

This year’s edition of UNCTAD’s *Least Developed Countries Report* focuses on transformational energy access for the LDCs, where 62 per cent of people have no access to electricity, compared with 10 per cent across other developing countries. Today, the majority of people worldwide who lack access to electricity live in LDCs — a proportion that has grown steadily from less than one third in 1990.

Importantly, this year’s Report finds that “energy for all” in LDCs requires more than access to energy for basic household needs. It requires that access to energy in LDCs also serves productive capacities directly, by powering the structural transformation of LDC economies and the development of more productive, modern activities and sectors with adequate and reliable energy supplies. Structural transformation, in turn, has a role in increasing energy access, by generating sufficient additional demand for electricity for productive uses to make viable the infrastructure investments required for universal access more broadly. Yet strengthening this energy-transformation nexus remains a massive challenge, given that installed generating capacity per person in LDCs is barely one twelfth of that even in other developing countries, and one fiftieth of that in developed countries.

The LDCs are the battleground on which the 2030 Agenda will be won or lost. The central role of access to modern energy in achieving the other SDGs means that meeting SDG 7 will be central to the success or failure of the 2030 Agenda as a whole. It is our intention that this Report will serve as a valuable input to the deliberations of the 2018 High-level Political Forum, which will review progress on Goal 7. Greater international support and more concerted collective action towards realizing transformational energy access in the least developed countries could be key catalysts for implementing the entire 2030 Agenda.

Mukhisa Kituyi
Secretary-General of UNCTAD

Acknowledgements

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A meeting was held in Geneva on 13–14 June 2017 to peer-review the Report and its specific inputs. It brought together specialists in the fields of energy, development policies, international trade, finance, the least developed countries, employment, social policies, industrial development and capacity-building. The participants were: Matthias Brückner (United Nations Department of Economic and Social Affairs – Secretariat of the Committee for Development Policy), Charles Gore (independent consultant), Marek Harsdorff (International Labour Organization), Yasuhiko Kamakura (International Labour Organization), Dunja Krause (United Nations Research Institute for Social Development), Mauricio Alejandro Pinzón Latorre (Graduate Institute of International and Development Studies), Ana María Pueyo (Institute of Development Studies), Simona Santoro (United Nations Capital Development Fund), Youba Sokona (International Institute for Environment and Development), Taffere Tesfachew (independent consultant), Djiby Racine Thiam (University of Cape Town), as well as the members of the LDC Report team and the following UNCTAD colleagues: Lisa Borgatti, Milasoa Cherel-Robson, Junior Roy Davis, Mussie Delelegn, Amelia dos Santos Paulino, Pilar Fajarnes, Tamara Gregol de Farias, Kalman Kalotay, Benjamin McCarthy, Nicole Moussa, Jane Muthumbi, Patrick Nwokedi Osakwe, Henrique Pacini, Daniel Poon, Antipas Touatam and Anida Yupari.

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Mauricio Alejandro Pinzón Latorre prepared a background paper for the Report.

Erica Meltzer edited the text. Nadège Hadjemian designed the cover and the infographics.

Madasamyraja Rajalingam did the overall layout, graphics and desktop publishing.

What are the least developed countries?

47 countries

Currently designated by the United Nations as “least developed countries” (LDCs).

These are: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Cambodia, the Central African Republic, Chad, the Comoros, the Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, the Gambia, Guinea, Guinea-Bissau, Haiti, Kiribati, the Lao People’s Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, the Niger, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Solomon Islands, Somalia, South Sudan, the Sudan, Timor-Leste, Togo, Tuvalu, Uganda, the United Republic of Tanzania, Vanuatu, Yemen and Zambia.

Every 3 years

The list of LDCs is reviewed every three years by the Committee for Development Policy (CDP), a group of independent experts reporting to the United Nations Economic and Social Council (ECOSOC). The CDP, in its report to ECOSOC, may recommend countries for addition to, or graduation from, the list of LDCs. The following three criteria were used by the CDP in the latest review of the list, in March 2015:

1. **A per capita income criterion,** based on a three-year average estimate of the gross national income (GNI) per capita, with a threshold of $1,035 for identifying possible cases of addition to the list, and a threshold of $1,242 for possible cases of graduation from LDC status;
2. **A human assets criterion,** involving a composite index (the Human Assets Index, or HAI) based on indicators of: (i) nutrition (percentage of undernourished population); (ii) health (child mortality ratio); (iii) school enrolment (gross secondary school enrolment ratio); and (iv) literacy (adult literacy ratio);
3. **An economic vulnerability criterion,** involving a composite index (the Economic Vulnerability Index, or EVI) based on indicators of: (i) natural shocks (index of instability of agricultural production; share of victims of natural disasters); (ii) trade-related shocks (index of instability of exports of goods and services); (iii) physical exposure to shocks (share of population living in low-lying areas); (iv) economic exposure to shocks (share of agriculture, forestry and fisheries in gross domestic product (GDP); index of merchandise export concentration); (v) smallness (population in logarithm); and (vi) remoteness (index of remoteness).

For all three criteria, different thresholds are used for identifying cases of addition to the list of LDCs, and cases of graduation from LDC status. A country will qualify to be added to the list if it meets the thresholds for addition under all three criteria and does not have a population greater than 75 million. Qualification for addition to the list will effectively lead to LDC status only if the Government of the relevant country accepts this status. A country will normally qualify for graduation if it has met the graduation thresholds under at least two of the three criteria in at least two consecutive triennial reviews of the list. However, if the three-year average per capita GNI of an LDC has risen to a level at least double the graduation threshold, and if this performance is considered durable, the country will be deemed eligible for graduation regardless of its score under the other two criteria. This rule is commonly referred to as the "income-only" graduation rule.

In a resolution adopted in December 2015, the General Assembly endorsed the CDP recommendation of 2012 to graduate Vanuatu. In doing so, the Assembly took into consideration the setback that Vanuatu had suffered as a result of Tropical Cyclone Pam in March 2015. The General Assembly decided, on an exceptional basis, to delay the country’s graduation to December 2020.

5 countries have so far graduated from LDC status:

Botswana in December 1994, Cape Verde in December 2007, Maldives in January 2011, Samoa in January 2014 and Equatorial Guinea in June 2017.

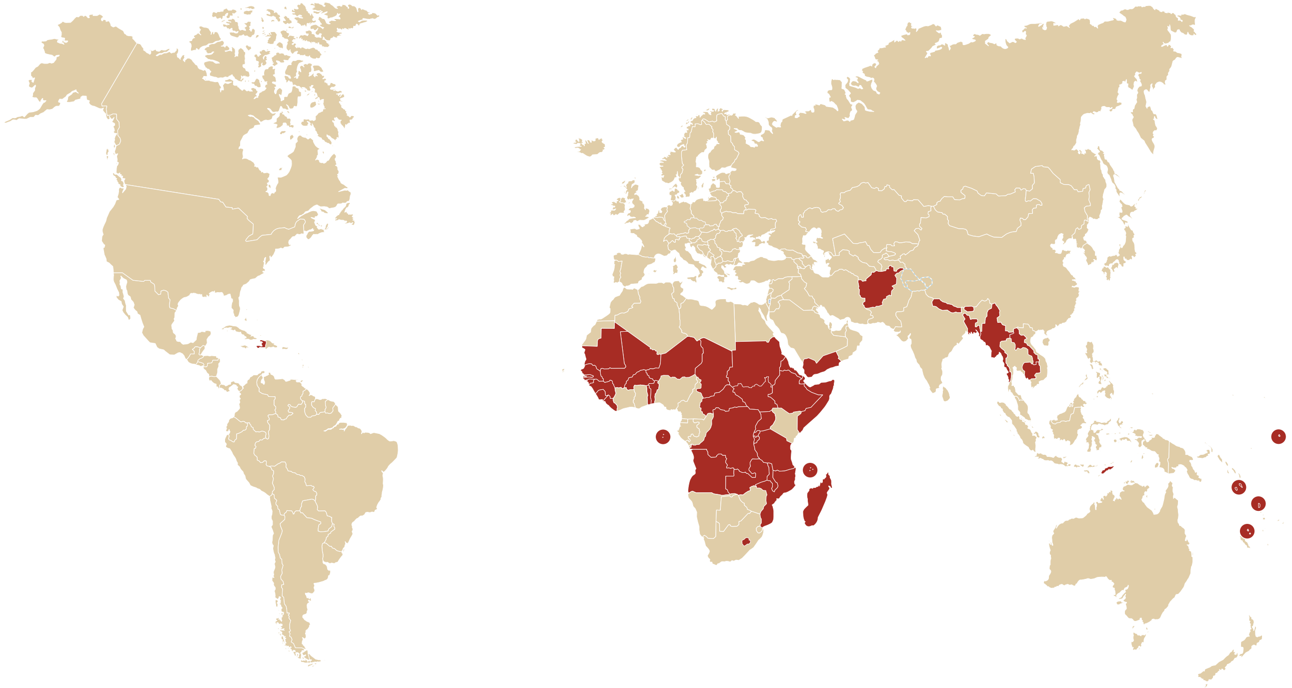
In a resolution adopted in December 2015, the General Assembly endorsed the CDP recommendation of 2012 to graduate Vanuatu. In doing so, the Assembly took into consideration the setback that Vanuatu had suffered as a result of Tropical Cyclone Pam in March 2015. The General Assembly decided, on an exceptional basis, to delay the country's graduation to December 2020.

The Committee's 2015 recommendation to graduate Angola was endorsed by the General Assembly in February 2016 through a resolution that set February 2021 as the country's graduation date. This decision was an exceptional measure to take into account the high vulnerability of the commodity-dependent Angolan economy to price fluctuations.

In a June 2015 resolution, ECOSOC recalled the CDP's 2012 recommendation to graduate Tuvalu from LDC status, and deferred to 2018 the Council's consideration of this potential graduation case.

Once a recommendation to graduate a country has been endorsed by ECOSOC and the General Assembly, the graduating country benefits from a grace period (normally three years) before graduation effectively takes place.

This period, during which the country remains an LDC, is designed to enable the graduating State and its development and trading partners to agree on a "smooth transition" strategy, so that the planned loss of LDC status does not disrupt the country's socioeconomic progress. A smooth transition measure generally implies extending to the graduated country, for a number of years after graduation, a concession to which the country had been entitled by virtue of its LDC status.



The graduation of Equatorial Guinea

Equatorial Guinea was the fifth country to graduate (as mentioned above), but the first ever to do so based on the "income-only" criterion. Its GNI per capita – $16,089 – was almost six times the income-only graduation threshold of $2,824. Notwithstanding such an impressive level of per capita income – the highest on the African continent – substantial challenges remain for Equatorial Guinea on its long road to sustainable development and the achievement of the Sustainable Development Goals (SDGs). The country did not meet the graduation threshold for the HAI or the EVI in the last review of the LDC category.

Equatorial Guinea faces challenges, such as high concentration of its economy in the oil sector, and associated difficulties in diversifying production and exports. The extractive industry is by far the largest in the economy, accounting for 41 per cent of GDP (together with utilities industries) in 2014. This is double the share of manufacturing and is also higher than the contribution of the services sector to GDP (28 per cent). Agriculture, by contrast, contributes just 1 per cent of the country's economic activities.

This high degree of concentration is reflected in the country's exports. In 2015, Equatorial Guinea had an exports product concentration index of 0.69, compared to an average for LDCs of only 0.26. There were 37 other LDCs with more diversified merchandise exports that same year. This level of export concentration makes the country highly vulnerable to oil price-related and other external shocks.

A key priority for Equatorial Guinea is to accelerate structural transformation significantly in order to diversify its economic base and reduce dependence on oil exports, as otherwise current high levels of income may not be sustained. Known oil reserves are expected to be depleted by 2035. Oil-spurred economic growth has so far failed to translate into substantial employment creation. With unemployment at 22 per cent, job creation should be a priority to ensure a more equitable distribution of oil-related wealth. To achieve economic and social progress, the country will also have to invest its oil rents productively in infrastructure and human-resource development, matched by an upgrading of the agricultural sector, diversification of rural activities and proactive efforts to develop new export sectors and sources of job growth.

Explanatory notes

The term "dollars" ($) refers to United States dollars unless otherwise specified.

The term "billion" signifies 1,000 million.

Annual rates of growth and changes refer to compound rates.

Exports are valued f.o.b. (free on board) and imports c.i.f. (cost, insurance, freight) unless otherwise specified.

Use of a dash (–) between dates representing years, e.g. 1981–1990, signifies the full period involved, including the initial and final years. An oblique stroke (/) between two years, e.g. 1991/92, signifies a fiscal or crop year.

The term "least developed country" (LDC) refers, throughout this report, to a country included in the United Nations list of least developed countries.

The terms "country" and "economy" refer, as appropriate, also to territories or areas.

In the tables:

Two dots (..) indicate that the data are not available, or are not separately reported.

One dot (.) indicates that the data are not applicable.

A dash (-) indicates that the amount is nil or negligible.

Details and percentages do not necessarily add up to totals, because of rounding.

Abbreviations

AGECC	Advisory Group on Energy and Climate Change
ASEAN	Association of Southeast Asian Nations
BRICS	Brazil, Russian Federation, India, China and South Africa
COP	Conference of the Parties
DAC	Development Assistance Committee of the OECD
EDI	Energy Development Index
EMEAP	Executives' Meeting of East Asia and Pacific Central Banks
ESMAP	Energy Sector Management Assistance Program
FDI	foreign direct investment
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GHG	greenhouse gas
GNI	gross national income
GPT	general-purpose technology
GWh	gigawatt hour
ICT	information and communication technology
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IOM	International Organization for Migration
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent power producer
IRENA	International Renewable Energy Agency
IT	information technology
kWh	kilowatt hour
LCOE	levelized cost of electricity
LDC	least developed country
MVA	manufacturing value added
MWh	megawatt hour
ODA	official development assistance
ODC	other developing country
OECD	Organisation for Economic Co-operation and Development
PerSIST	Poverty Eradication through Sustainable and Inclusive Structural Transformation
PES	primary electricity supply
PPA	power purchase agreement
ppm	parts per million
PPP	public-private partnership
PV	photovoltaic
R&D	research and development
RERA	Regional Electricity Regulators Association of Southern Africa
SDG	Sustainable Development Goal
SE4All	Sustainable Energy for All
SHS	stand-alone home system
SME	small and medium-sized enterprise
STI	science, technology and innovation
T&D	transformation and distribution
TES	total electricity supply
TPES	total primary energy supply
UN DESA	United Nations Department of Economic and Social Affairs
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistics Division
WDI	World Development Indicators
WTO	World Trade Organization

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Classifications used in this Report

LEAST DEVELOPED COUNTRIES

Geographical/structural classification

Unless otherwise specified, in this Report the least developed countries (LDCs) are classified according to a combination of geographical and structural criteria. The small island LDCs that are geographically in Africa or Asia are thus grouped with the Pacific islands to form the island LDCs group, due to their structural similarities. Haiti and Madagascar, which are regarded as large island States, are grouped together with the African LDCs.

Equatorial Guinea graduated from the LDC category in June 2017. However, data for this country are still included in the group aggregates (though not shown individually), because the country was still an LDC during the period covered by the data. The resulting groups are as follows:

African LDCs and Haiti: Angola, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, the Gambia, Guinea, Guinea-Bissau, Haiti, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, the Niger, Rwanda, Senegal, Sierra Leone, Somalia, South Sudan, the Sudan, Togo, Uganda, United Republic of Tanzania, Zambia.

Asian LDCs: Afghanistan, Bangladesh, Bhutan, Cambodia, Lao People’s Democratic Republic, Myanmar, Nepal, Yemen.

Island LDCs: the Comoros, Kiribati, Sao Tome and Principe, Solomon Islands, Timor-Leste, Tuvalu, Vanuatu.

OTHER GROUPS OF COUNTRIES AND TERRITORIES

Developed countries:
Andorra, Australia, Austria, Belgium, Bermuda, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Greenland, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, San Marino, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom of Great Britain and Northern Ireland, United States of America, Holy See, Faeroe Islands, Gibraltar, Saint Pierre and Miquelon.

Other developing countries (ODCs):
All developing countries (as classified by the United Nations) that are not LDCs.

PRODUCTS

Trade data for energy products are grouped according to the categories below. The figures provided are the codes of the Standard International Trade Classification (SITC), revision 3.

Coal: Coke, coal and briquettes: Division 32.

Crude oil: Petroleum oils and oils obtained from bituminous minerals, crude: Group 333.

Petroleum products: Petroleum oils or bituminous minerals (other than crude): Group 334, and Residual petroleum products, n.e.s., and related materials: Group 335.

Gas: Gas, natural and manufactured: Division 34.

Electricity: Electric current: Division 35.

Uranium: Uranium or thorium ores and concentrates: Group 286.

OVERVIEW

Energy, the lifeblood of development

Access to modern energy, especially electricity, has gained ever greater attention globally in recent years, which partly reflects its critical importance to all three pillars of sustainable development — economic, social and environmental. This growing global concern is embodied in Sustainable Development Goal (SDG) 7: to ensure access to affordable, reliable, sustainable and modern energy for all.

Previous editions of *The Least Developed Countries Report* have argued that the least developed countries (LDCs) are the battleground on which the SDGs will be won or lost, and SDG 7 is no exception. The LDCs have made extraordinary progress in increasing access to electricity, which has more than tripled from 12 per cent to 38 per cent since 1990. But this leaves 62 per cent of their people without access. Together with still more limited access to modern fuels for cooking and heating, this gives rise to two distinctive features of energy use in LDCs. First, it is dominated by residential use, which accounts for two thirds of the total; and second, it is heavily reliant on traditional biomass, such as fuelwood and charcoal, which accounts for 59 per cent of the total.

As access to electricity has increased to much higher levels in other (non-LDC) developing countries (ODCs), this has also resulted in an increasing concentration of energy poverty in LDCs in terms of lack of access to modern energy. By 2014, the majority (54 per cent) of people without access to electricity worldwide were living in LDCs — more than four times their share in the world population (13 per cent) and approaching double the proportion in 1990 (30 per cent).

Achieving universal access to modern energy globally is therefore critically dependent on achieving it in LDCs. But for most of them, doing so by 2030 — the target year for achieving the SDGs — will be an enormous challenge. Despite an impressive rate of progress in recent years, only four of the 47 LDCs could achieve universal access to electricity by 2030 without an acceleration of the rate of increase in access, while only seven more could do so even if they doubled their current rate of progress. In nearly a quarter of the LDCs, by contrast, achieving universal access by 2030 would require the number of persons gaining access annually to be 10 times higher in the coming years than over the past decade.

Energy access is particularly important to rural development, which, as the *Least Developed Countries Report 2015* highlighted, is central to poverty eradication. In the initial stages electrification typically occurs mainly in urban areas, while rural areas catch up only later. Consequently, access is much greater in towns and cities than in rural areas, and 82 per cent of people without access to electricity in LDCs live in rural areas.

This highlights what has historically been a key obstacle to electricity access in most LDCs: they have a characteristic combination of limited urbanization and sparsely populated rural areas, which makes conventional centralized generation systems economically unviable for most of the population, especially in a context of low incomes and limited resources for investment.

But this is now changing. Rapid technological progress in renewable energy technologies, and associated cost reductions, are opening up an unprecedented opportunity for electrification of rural areas through decentralized generation and mini-grids. The potential this creates for “win-win” scenarios across the social and environmental pillars of sustainable development is another reason for recent attention to the energy issue.

However, recent studies and initiatives have too often neglected the third potential “win” — the economic benefits of access to modern energy. At the heart of the 2030 Agenda for Sustainable Development is the inseparability and interdependence of the three pillars of sustainable development; and achieving its overarching goal of poverty eradication requires a coherent and holistic approach encompassing all three. This is the foundation of the PErSIST (Poverty Eradication through Sustainable and Inclusive Structural Transformation) framework presented in this Report.

The economic “win” of access to modern energy lies in its potential contribution to structural transformation of the economy, increasing productivity and providing new opportunities for the development of higher-value-added activities. This is essential to realizing in full its potential contribution to achieving the wider ambitions of the 2030 Agenda.

Central to this is ensuring that electricity is available, not only to meet such basic domestic needs as lighting, but also for use in productive processes. Equally, productive use of electricity is essential to making investment in electricity generation and distribution economically viable. The high capital costs require a certain level of demand to make investments viable; and productive use can both increase demand directly and strengthen residential demand by raising incomes.

This two-way relationship — from access to electricity, through productive use, to structural transformation, and from structural transformation, through increased demand, to increased investment in electricity supply and distribution — is central both to economic development and to the goal of universal access.

This has important implications for the approach to universal access. Focusing only on allowing households sufficient access to meet their basic needs will not be enough. Realizing the full benefits means taking account also of access by public facilities, such as schools and clinics, and by businesses; and ensuring that their needs are met, in terms of the level, continuity and reliability of supply. Energy access alone will not be enough; what is needed is *transformational* energy access, meeting the needs of producers for reliable and affordable supplies of the kinds of energy they need on an adequate scale.

This will require narrowing the "generation gap" with other developing countries. Despite strong growth since 2000 (following a decade of stagnation in the 1990s), LDCs' electricity generation capacity per person has failed to match either the increase in access to electricity or capacity growth in ODCs. Consequently, capacity has fallen by half, relative both to the number of people with access and to other developing countries. By 2014, LDCs' generation capacity per person was just one twelfth of the average for ODCs, at 50 watts compared with 600 watts.

Globally, a major concern in relation to increasing energy use is the potential effect on climate change. However, the starting point for greenhouse gas (GHG) emissions from electricity generation in LDCs is very low; and most LDCs have set themselves very ambitious targets for further reductions in the context of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) (2015). As well as being limited by the use of renewable energy technologies, additional emissions from increasing electricity use will be substantially offset by the effects of reduced burning of traditional biomass, which will also help to slow forest degradation and deforestation. This highlights the importance, from an environmental perspective, of pursuing universal access to electricity as part of a broader agenda of access to modern energy, also encompassing modern fuels for cooking and heating.

Universal access to modern energy can contribute as well to the 2030 Agenda's core principle of inclusivity — "leaving no one behind". Besides allowing all those currently excluded from access to electricity and modern fuels to secure their benefits, it can make a major contribution to narrowing the gap between cities and the rural areas where most people in LDCs live.

Energy and structural transformation

Patterns of energy use are closely linked to incomes at the household level, and to stages of development at the country level. As incomes rise and countries develop, they climb an "energy ladder", from the use of traditional biomass, through fossil fuels to more advanced energy sources, such as electricity — although in each case, multiple fuels coexist at any point in time. LDCs remain close to the bottom rung of this ladder. As previously mentioned, two thirds of their energy use is by households; and households rely primarily on traditional biomass, which therefore remains the main energy source in most LDCs. In all but a few cases, the great majority of the remainder is oil products, largely for transportation.

Five LDCs (Angola, Chad, South Sudan, the Sudan and Timor-Leste) rely heavily on exports of fossil fuels — and here, the energy sector is a major source of value added, foreign exchange earnings and public revenues, although its role in employment is more limited due to the capital intensity of extractive industries. In other LDCs, the sector is limited largely to the supply of electricity and fuels for domestic use and transportation, which represents only a small share of value added and employment, while imports of refined petroleum products are a major foreign exchange expense. But a few LDCs without fossil-fuel reserves have some exports either of electricity or of refined petroleum to regional markets.

However, despite this limited direct contribution to value added, employment and exports in most LDCs, the energy sector is of central importance to development, and particularly to structural transformation through its effects on other productive sectors. More reliable, affordable and efficient energy supplies can allow for the adoption of new production techniques and technologies, raise productivity and facilitate the introduction of new economic activities.

Electricity in particular is the quintessential general-purpose technology, opening up new opportunities across all sectors, so that innovations in electricity provision are propagated throughout the economy. It is also essential to other general-purpose technologies, such as information and communications technologies (ICTs), and plays a key role in technological development and innovation.

Conversely, failings in the electricity system can act as a brake on structural transformation — and nearly half of all firms in LDCs identify electricity as a major constraint on their full operation. Weak electricity systems in most of these countries result in unreliable supplies and frequent power outages, giving rise to income losses for producers and additional costs for imported back-up generators. Moreover, electricity costs are very high in African and especially in island LDCs, further increasing production costs.

Accessible, affordable and reliable electricity supplies can make a major contribution to all economic sectors. In agriculture, they can facilitate irrigation, reducing reliance on rain-fed production, as well as increasing value added through improved processing, while refrigeration can reduce crop losses. The limited availability of reliable and affordable electricity has conditioned the industrial structure of LDCs. Their limited manufacturing is dominated by light industry, which has relatively low energy intensity. A possibility for the expansion and diversification of manufacturing often recommended for LDCs is natural-resource processing — smelting and refining of metals, production of metal products, processing of fossil fuels, etc. However, these industries are energy-intensive and therefore require an adequate electricity supply. Therefore, improving the quantity and quality of electricity supply can foster industrial development in LDCs. Modern service activities, especially those linked to ICTs, are also critically dependent on adequate and reliable electricity supplies, and are important for supporting the development of other sectors.

The role of energy in promoting structural transformation has a notable gender dimension. The availability of modern energy, at both the household and the community level, can significantly reduce the time spent on domestic activities, including fuelwood collection — and such time savings are likely to benefit women disproportionately. However, such savings are not automatically translated into increased productive activity, or therefore into women's economic empowerment. This depends in large measure on the creation of new productive opportunities that are accessible to women, and on targeted policies to address the constraints women face in economic activities. Structural transformation provides the means of creating income-generating opportunities in sectors such as textiles and horticulture, which can often provide substantial benefits to women in particular.

Thus, access to electricity is essential to structural transformation. Equally, however, structural transformation is essential to electricity access, as the productive use of electricity that it engenders generates the demand needed to make investments in electricity access viable. This two-way relationship — the energy-transformation nexus — is central to the development process; and productive use of electricity is central to that relationship. It provides both the means by which access is able to transform the economy, and the additional demand that strengthens the viability of investments in the electricity sector.

However, harnessing this relationship effectively requires moving beyond a goal of universal access based on minimal household needs to a goal of transformational energy access. This in turn calls for an economically viable energy system able to access clean energy on the scale required for productive activities, with the reliability they require, at an affordable cost.

Technological opportunities – and challenges

As well as providing access to nearly four times as many people by 2030 in order to achieve universal access, realizing the potential of modern energy to stimulate structural transformation in LDCs will require a massive increase in electricity generation.

While 82 per cent of those without access to electricity in LDCs live in rural areas, as previously mentioned, rapid urbanization represents an important challenge to universal access even in urban areas, and has led to an increase in the absolute number of urban dwellers without access. For them, and for those without access in surrounding rural areas, grid extension remains the primary means of increasing access.

In more remote rural areas, the logistical challenges of electrification are much greater. However, recent technological advances have stimulated increasing interest in off-grid systems as a faster and more cost-effective alternative to grid extension beyond a certain "break-even" distance from existing grids. These include stand-alone home systems and pico-solar devices (which use small compact and light-weight solar photovoltaic panels to generate just a few watts of power in a wide range of small and portable applications) as well as mini-grids. However, while mini-grids provide greater transformational potential, stand-alone systems offer more limited potential for productive use and are more viable in dispersed communities unsuited to mini-grids.

Overall, achieving universal access in LDCs by 2030 would require grid extension to reach an estimated 571 million more people, mini-grids to serve 341 million, and stand-alone systems for 114 million.

Mini-grids are thus likely to play a key role in rural electrification in LDCs — for which there are favourable historical precedents in India and China. However, despite the potential offered by recent technological advances, parallels with the "ICT revolution", and the associated opportunity for technological leapfrogging, appear premature. The market for off-grid systems in LDCs remains relatively limited, often skewed towards small-scale low-end products, and its dynamism is partly dependent on external support. Mini-grids also face significant financial, technical, economic and institutional obstacles, including large upfront costs; tariffs that are often higher than those charged to on-grid consumers; the need for tailoring to site-specific conditions; and institutional arrangements to minimize regulatory uncertainty, manage potential conflicts and ensure adequate maintenance.

There is also some ambiguity as to the extent to which off-grid solutions are a stepping stone towards, or an alternative to, grid extension, giving rise to potential tensions between the two, if off-grid systems reduce the demand for on-grid electricity below the level needed to make the necessary investment viable. This highlights the need for a carefully planned and forward-looking approach to widening electricity access. With appropriate planning (including consistent technical standards and protocols for grid interconnection), mini-grids can be integrated into larger networks, as has been done in China and India.

LDCs' transmission and distribution (T&D) networks also need to be strengthened, to reduce the high incidence of T&D losses in these countries and to enhance energy efficiency. Weak T&D infrastructure also means that firms in LDCs suffer twice as many outages as those in ODCs, causing double the financial losses and forcing the majority to rely on their own back-up generators, at additional cost. In some African LDCs, the economic impact of these inefficiencies is estimated at up to 6 per cent of GDP. Over time, progress towards universal access, structural transformation and increasing reliance on variable renewable technologies will further increase the need for improvements in T&D infrastructure.

The increase in generation capacity required for wider access to electricity to contribute effectively to structural transformation is considerable. Across LDCs as a whole, raising electricity production to the minimum level needed for productive use would mean an increase by a factor of between 3.4 and 6.8, while reaching the minimum threshold for modern societal needs would require production to increase by a factor of 13.5.

Currently, LDCs have a distinctive dualistic pattern in their power mix for electricity generation. About half rely almost entirely on fossil fuels for electricity generation, a quarter rely mostly on hydroelectric power supplemented by fossil-fuel generation, and a quarter have a more even balance between the two. Unlike most other country groups, fossil-fuel generation in most LDCs mainly uses oil products, although gas products are the primary fuel in a few large LDCs, making this the predominant source across the group as a whole.

Given the scale of the increase in generation required by 2030, and the minimal contribution of generation in LDCs to global GHG emissions, fossil fuels are likely to remain an important part of the generation mix in most of these countries. However, a progressive move towards renewable technologies, for both grid and mini-grid systems, could make a substantial contribution to transformational energy access as well as offering environmental benefits. As yet, the uptake of renewable technologies (other than large-scale hydro) remains incipient in most LDCs, especially for utility-scale generation; but 24 LDCs have pledged, as members of the Climate Vulnerable Forum, to achieve 100 per cent renewable generation by 2050.

Structural transformation depends on appropriate technology choices for electricity generation and distribution, in order to provide suitable, reliable and affordable energy services to enhance labour productivity and foster the emergence of higher value added activities and the diffusion of ICTs.

At the project level, the choice among alternative energy systems is determined primarily by their relative cost-effectiveness, which depends on local energy-resource potential and the technical performance of alternative technologies. The standard measure of the relative cost-effectiveness of such technologies — the levelized cost of electricity — provides a useful metric from a private investor point of view. But this alone is insufficient for policy decisions on the roles of different technologies in a country's power generation mix. In particular, this measure typically reflects only private costs, and not wider social costs and benefits. It is also very sensitive to assumptions about technological performance, prices for fuels and other inputs, the cost of capital and the internalization of environmental externalities, which may differ significantly between LDCs and other contexts.

Important as appropriate technology choices at the project level are, the systemic dimension of technology choices is also critical — and this is largely beyond the scope of cost-effectiveness comparisons. It requires attention to the interactions and complementarities among technologies and to their appropriate roles within the electricity supply system, given their different time profiles of generation, location, cost structures and resilience to shocks. From this perspective, the choice is not of a single optimal technology, but of a set of technologies which, together, will provide the basis for meeting national energy needs.

System-wide considerations suggest four priorities for LDCs:

- Becoming "early followers" of new energy technologies;
- Diversifying the power generation mix, while taking account of each country's resources and comparative advantages;
- Strengthening grid flexibility and upgrading monitoring and control capabilities, to ensure grid interoperability and manage the increasing complexity of power flows;
- Adopting system-wide approaches to electricity markets, including energy-efficiency practices and demand-side management.

Harnessing the opportunities offered by recent technological advances in energy for development will thus require a stepped-up policy effort and long-term policy commitment, while maintaining the flexibility to respond to further changes in the technological landscape. Since increasing access will not automatically bring increases in productive use, this requires additional policy attention.

Technology transfer is also essential to this process. While LDCs have gained broader access to energy technologies through expanding international trade in related equipment, effective technology transfer also requires the acquisition of related knowledge and capabilities, both by actors in the energy supply chain and by end users. However, international technology-transfer mechanisms have a rather inadequate track record in this regard. Weak local absorptive capacities and innovative capabilities in LDCs thus highlight the need for greater emphasis on capacity development in energy-related projects; robust science, technology and innovation (STI) policy frameworks; greater involvement of local research institutions in energy-related activities; and efforts to promote experience-sharing and mutual learning in energy-related research. South-South and triangular cooperation may play a leading role in this area, given the similarities in energy-related challenges faced by LDCs and ODCs and the increasing importance of South-South trade for LDCs' access to electricity-related technologies.

Conducting electricity: Market structures and governance

Historically, the principal model of the electricity sector worldwide has been one based on provision by publicly owned utility companies with legal monopolies in the generation and distribution of electricity. The considerable economies of scale of the main generation technologies (fossil-fuel-based generators and in some cases hydroelectric power) led to strongly centralized electricity systems, which relied on extensive transmission and distribution systems for delivery to users. With scale economies in both generation and distribution effectively acting as barriers to entry, electricity supply in this context was effectively a natural monopoly — a market which, by its very nature, can be served at a lower cost by a single supplier than by multiple suppliers.

Although electricity consumption itself is a private good, the energy distribution network is a public good, as well as being essential to other public goods, such as street lighting. It is also essential to the fulfilment of many of the rights enshrined in the Universal Declaration of Human Rights and to the achievement of the SDGs, and is widely acknowledged as a basic need for human development.

The essential nature of electricity, and of energy more generally, has also made energy security — the uninterrupted availability of energy sources at an affordable price — a central policy concern. This encompasses a safe and reliable supply of electricity, guaranteed access and affordability. In many fuel-importing LDCs, additional concerns are vulnerability to changes in international energy prices and the resilience of the energy system to supply shocks.

These factors — the essential nature of electricity, its strategic importance and its natural-monopoly and public-good aspects — together with the historical (and in many countries continuing) role of the State in the provision of electricity, have led to a widespread view of electricity supply as a public service. Starting in the 1970s, however, a combination of technological changes and shifts in attitudes to the roles of the public and private sector have led to a move away from the predominant role of public-sector monopolies in electricity production and distribution.

Through the 1980s and 1990s, a wave of reforms spread from developed countries across much of the developing world. These reforms centred on "unbundling" electricity supply through various forms of separation between generation, transmission and distribution, together with an increase in the role of private companies, under an independent regulator. However, the results of the reforms were mixed, largely reflecting differences in motivations and starting conditions, particularly between developed and developing countries.

While relatively few LDCs engaged in reforms during the 1980s and 1990s, many more have done so since 2000. This partly reflects changes in international development finance, latterly including the reaffirmation of the role of the private sector in the delivery of development outcomes in the Addis Ababa Action Agenda (adopted in 2015 at the Third International Conference on Financing for Development), the policies of multilateral lenders and bilateral donors' energy programmes. However, while an increasing role for the private sector remains a common feature of reforms, they have evolved in the light of widespread recognition of the shortcomings of the approach promoted in the 1980s and 1990s. A range of market structures, based on vertical integration or partial unbundling, are now recognized as potentially suitable to the limited access and structural challenges characteristic of LDCs.

Consequently, electricity market structures vary widely across these countries, partly reflecting differences in country circumstances and the stage reached in ongoing reform processes. While some LDCs retain vertically integrated systems combining generation, transmission, distribution and retail under a single entity, others are partially or wholly disaggregated. Some are locally disaggregated, with systems fragmented by locality (notably between islands in many island LDCs); and others have hybrid systems, combining one or more of these structures. The extent of plans and policy frameworks is similarly varied, as are regulatory arrangements.

The environment for the electricity sector is evolving rapidly, with major shifts in technologies and their relative costs, coupled with climate change and increasing emphasis on environmental goals. Together with the goal of universal access and rapidly rising demand with serious capacity constraints, this is creating a number of challenges to sectoral governance in LDCs.

As mentioned above, successful development of the electricity sector in this context requires a system-wide approach, encompassing planning, coordination and effective regulation. Planning is particularly important to the electricity sector because of the mismatch between the time required to build distribution networks and that required to build generation facilities, and the complementarities among generation technologies; furthermore, the timescale of planning needs to be commensurate with the 30-to-40-year time horizon of investments in new facilities. Given the large number of stakeholders involved, maximizing the contribution of increasing access to other development goals requires strong coordination, under the clear leadership of a lead agency.

The need for effective regulation is reinforced by the need to increase the resilience of electricity systems while integrating variable renewable energy sources. However, regulatory capacity in most LDCs remains limited, reflecting in part the time needed to build such capacity and the recent establishment of many regulatory agencies, most of which have been in existence only since 2005. While experience of sectoral reform is an important aspect of building capacity, even some LDCs with long-standing reforms still face major challenges in this regard.

Trade in electricity can play a supplementary role, helping to lower prices, mitigate shocks, relieve shortages and facilitate the transition to renewable energy sources; and many LDCs have bilateral, regional or multilateral approaches to coordinating and pooling their efforts in the sector.

A key consideration in electricity policy and planning is the relationship between rural-urban linkages and migration, rural electrification and structural transformation of rural economies, and the role of this relationship in inclusive and sustainable development. “Energy sprawl” — the impact of energy technologies on land use — is an important factor to bear in mind in the deployment of such technologies in both rural and urban areas.

Circular rural-urban-rural migration is increasing the expectations of rural communities with respect to electricity access, and urban-rural remittances make a substantial contribution to their purchasing power. This is contributing to the growing perception of rural electrification as a commercial opportunity. In LDCs, however, it is primarily the private sector that is involved in providing household stand-alone systems and devices in rural areas. Purely commercial models for grid electrification remain rare, reflecting high costs and limited demand, and rural electrification schemes emphasizing cost recovery and financial viability have proved neither affordable nor sustainable.

Investing in electricity for transformation

Current global estimates suggest that the investments required to achieve universal access to electricity in all LDCs by 2030 are of the order of $12 billion to $40 billion per year. However, domestic resources for investment in LDCs fall far short of these levels, and even after a rapid increase over the past decade, official development assistance (ODA) to the electricity sector in LDCs is barely one tenth of this level, partly reflecting the continued serious shortfalls from donor commitments in successive Programmes of Action for the LDCs.

This mismatch between investment needs and the financing available from domestic and external official sources has contributed to increasing emphasis on a potential role for external commercial financing of electricity-sector (and other infrastructure) investment needs for sustainable development. However, there are important tensions between the nature of the investments required in the electricity sector and the motives and appetites for risk of private investors.

Private investors typically seek safe long-term investments that generate a favourable rate of return on capital. However, investments in electricity infrastructure, particularly in LDCs, do not fit well with these criteria. Investments also have a particularly long time horizon, with asset lives of typically 25-to-60 years preceded by long pre-construction processes and construction periods. Considerable investments are required, giving rise to substantial sunk costs, before any cash flow is generated; and the nature of production and distribution systems means that they cannot readily be sold, making investment decisions difficult to reverse. This leaves investors seriously vulnerable to risks, which are especially high in LDCs. Such risks are both highly complex (encompassing a combination of political, regulatory, macroeconomic, business and technical risks) and difficult to assess, particularly due to the lack of transparency that often characterizes infrastructure projects, in particular because of their one-off nature and dependence on context-specific factors. This combination of large sunk costs, long project lives and high and uncertain risks both deters private investment in electricity infrastructure and creates a strong incentive for investors to delay such investments.

Reliance on private provision also reinforces the tension between the affordability of electricity supply — a key aspect of universal access – and the financial viability of investments in its provision. If investments are to be viable, tariffs for electricity need to cover (at least) the full costs of generation, transmission and distribution. However, the tariffs that can be charged are constrained by high rates of poverty and limited purchasing power, while investment costs in rural areas are increased by the geographical and logistical challenges of power supply. Similar issues arise where a public utility acts as a single buyer of electricity from independent power providers: while the utility serves as a buffer between users and suppliers, its financial viability depends on its ability to charge tariffs that adequately reflect the costs of generation and distribution; and any risk to its financial viability is reflected in higher premiums in its purchasing contracts. To date, however, only one of the 47 LDCs (Uganda) has reported the successful adoption of such cost-reflective tariffs.

Reducing or eliminating subsidies for fossil fuels is increasingly seen as a potential source of funding for renewable energy, with the additional benefit of reducing incentives for fossil-fuel use. However, such subsidies are generally relatively limited in LDCs, and the potential for them to follow certain developed countries in achieving a revenue-neutral switch of subsidies from fossil fuels to renewable energy is questionable, particularly as this might well have adverse effects on some low- and middle-income households.

In light of the constraints on other potential sources of financing, some LDCs have resorted to external commercial borrowing to meet the considerable needs for infrastructure investment if the ambitions of the 2030 Agenda are to be fulfilled, in some cases using their natural resources as collateral. However, as the experience of the 1980s and 1990s clearly demonstrates (particularly in the case of African LDCs), a great deal of caution is required in this regard to avoid the risk of financial crises, as the attendant adjustment process can have serious detrimental effects on economic and human development. This risk is intensified by the fact that the lion's share of ODA to the electricity sector in LDCs is in the form of concessional loans rather than grants, and that much South-South financing (and some other official financing) is non-concessional lending.

The need for massive injections of capital in LDCs to achieve universal energy access (and the other SDGs) comes at a time of marked uncertainty in the international development finance architecture. Political developments and continued economic stress in some traditional donor countries are giving rise to pressure on ODA budgets and funding of some multilateral agencies, while there is increasing emphasis on the use of ODA to catalyse private financing and movement towards making multilateral funding for electricity conditional on private-sector involvement. At the same time, the implementation of the Basel III international regulatory framework for banks is expected to act as a brake on investment and lending by banks and other institutional investors in view of the illiquid nature of infrastructure-related investments. However, the prospects for South-South financing, notably from China, appear more favourable.

There has also been an explosive growth in the number of international funds offering infrastructure and climate finance; but they are generally insufficiently focused on LDCs, and the resulting fragmentation of the international development finance architecture gives rise to a complexity that is difficult to navigate, particularly for LDCs with limited institutional capacity.

There may be some potential to increase domestic financing, to the extent that countries are able to reduce illicit financial flows, and to augment that financing from diaspora direct investment. However, generating substantial resources from domestic resources is likely to require the development of domestic instruments for infrastructure-related debt. While some initiatives are under way to support domestic resource mobilization, their coverage of LDCs is variable and beneficiaries have been mainly ODCs.

Overall, the prospects for increasing financing for electricity infrastructure needs are mixed. They also fall far short of what is required to achieve universal access to electricity by 2030. Increasing the resources available for investment in LDCs' electricity sectors will thus be critical to the fulfilment of SDG 7, and still more so to achieving transformational energy access. However, this is only one aspect of a much greater set of challenges, for LDC Governments and the international community alike.

Policies for transformational energy access

Increasing access to electricity has the potential to stimulate structural transformation of LDCs' economies. Conversely, however, pursuing an approach to universal access that fails to address energy needs for structural transformation adequately risks locking them into a sub-optimal development path for decades to come. This has important implications for energy policy, for development strategies, and for the articulation between the two.

The complexities of the electricity sector make long-term system-wide planning essential, especially if it is to achieve transformational energy access. Such planning needs to be based firmly on the particular circumstances and resource potential of each locality. It must also maintain the flexibility needed to respond to a rapidly evolving technological environment, to adjust to unpredictable changes in the pattern of demand as access is increased, and to respond to changes in the business landscape as structural transformation progresses. Equally, however, predictability and transparency are needed to attract private investment into the sector.

Since the development of the electricity sector in LDCs necessarily starts from an existing (inadequate and often financially unsustainable) energy system, an evolutionary approach is needed, strengthening and building on this base. Scaling up generating capacity is a major policy priority, to ignite and sustain structural transformation. As new capacity is added (and outdated plants are replaced), the planning process should steer the energy mix towards a progressively more diversified and balanced combination of energy sources suited to the country's resources and future needs, taking account of the technical and economic characteristics, and the environmental and social impacts of different technologies. While this is likely to entail a continued role for fossil-fuel generation, given the context of sharply rising electricity demand, increasing renewable generation can make a substantial contribution. However, close attention to system-wide interdependence is needed as diversification of the energy mix brings a wider range of energy technologies, in order to build additional system flexibility and resilience, and to harness complementarities across different technologies.

In parallel with increasing generation, a second key priority is grid extension and upgrading. Improving electricity distribution requires a combination of grid extension and mini-grid development, together with deployment of stand-alone solutions for dispersed rural populations. The scope and rate of grid extension is a primary consideration for planning, in light of its greater transformational impact, supplemented by the identification of priority areas for mini-grid deployment. Sound planning, transparency and policy coordination are essential to avoid uncertainty deterring private investors and to allow future interconnection.

Regional integration of LDC energy markets could allow for more intensive exploitation of lower-cost energy sources and could increase flexibility by creating greater scope for diversification, geographically and possibly across energy sources. For some LDCs, importing electricity from neighbouring countries through regional power pools may provide a viable alternative to domestic generation, although effective integration into international or regional energy markets hinges on significant progress being made in upgrading grids and interconnections.

Effective sectoral governance frameworks are essential to successful development of electricity systems. There is no one-size-fits-all model for market structure or for transition to low-carbon electricity systems, as both are heavily dependent on country-specific factors. While LDCs should continue their efforts to increase supply capacity in collaboration with the private sector, it is important to avoid market structures that are overly demanding relative to their institutional, financial and human-resource constraints.

Financial sustainability through cost-reflective tariffs is a critical factor for the viability and quality of electricity systems. However, this needs to be balanced with affordability, in a context characterized by widespread income poverty, a major shortfall in access to modern energy and burgeoning demand associated with structural transformation. Incentives and regulation can play an important role in this regard; and changes in tariff design, if carefully crafted and backed by political will, can offer a means of matching tariff structures to the structure of electricity supply costs. However, distributional impacts require particular attention. Well-designed auctions for electricity from renewable sources could provide a means of fostering greater penetration of utility-scale renewables, without unduly burdening the public budget, and capacity development in this area is a priority for international support.

The central role of the energy-transformation nexus in sustainable development highlights the importance of integrating electrification and access to modern energy fully into development strategies. This means ensuring that the nature, quantity and quality of energy supply and access meet the needs of structural transformation, and that development policies generate the demand for electricity needed to make the necessary investments in generation, transformation and distribution viable.

Rural development is critical to structural transformation in LDCs, as well as to energy access. By unlocking opportunities in rural non-farming activities and strengthening their linkages with agriculture, an ambitious programme of rural electrification can provide a substantial boost to the transformation of rural economies. At the same time, the use of labour-intensive methods in building electricity infrastructure can provide a corresponding demand-side “kick start”. However, the transition is unlikely to be smooth, and leveraging electrification for rural transformation is likely to require complementary interventions to facilitate the adoption of modern technologies and the emergence of new economic activities. Facilitating access to intermediate (non-electrical) technological options, such as solar water pumps and evaporation fridges, can also make an important contribution prior to electrification, as well as providing opportunities for local production.

Reaping the full benefits of the energy-transformation nexus also requires complementary policies to foster economic diversification and job creation, which can furthermore help to offset the effects of the “creative destruction” brought about by electricity access and reduced employment in charcoal and fuelwood supply chains. Priorities include fostering the emergence of a domestic supply chain in modern energy and fuel-efficiency business, and capitalizing on electrification to foster the rise of new higher value added activities.

The transformational impact of modern energy access can be further enhanced through complementary interventions in skill and technological upgrading, business development, access to credit and financial services, small and medium-sized enterprises and women’s economic empowerment. STI policies can also contribute to harnessing the energy-transformation nexus, by strengthening local absorptive capacities and domestic capabilities for both radical and incremental innovation. Appropriate measures in this area include incentivizing collaboration between research institutions and broader stakeholders, to promote technology adaptation and diffusion, as well as investing in education and vocational training.

The considerable cost of universal access, and still more of transformational access, highlights the importance of efforts to mobilize and channel domestic and foreign financial resources towards these goals. In the current international environment, enhancing domestic resource mobilization is an imperative. There is thus a strong case for prioritizing public funding and the development of domestic capital markets to drive needed investment in national electricity sectors. Efforts in this area should focus on increasing the availability of de-risking instruments, including insurance and guarantee products, while avoiding excessive accumulation of contingent liabilities. LDC efforts to nurture domestic debt markets therefore merit increased priority in the development community. Leveraging foreign direct investment more effectively will depend on the ability of LDCs to attract investors strategically in ways supportive of their industrial and energy policy objectives.

While international borrowing could represent an additional source of capital, debt sustainability remains an important concern, especially in light of the current volatility of global financial markets and exchange rate fluctuations. Already high financing costs associated with perceptions of high risk in LDCs may be increased further by impending changes in the international financial regulatory environment.

There is a clear case for increased ODA to fill the financing gap for electricity infrastructure investment; and fulfilment of donors' long-standing and long-unmet aid commitments towards LDCs would make a major contribution. For renewable technologies particularly, grant financing would be appropriate, reflecting the principle of "common but differentiated responsibilities"; but despite clear pledges in the context of the UNFCCC and the Paris Agreement, climate finance for LDCs falls far short of their needs, as well as being fragmented among multiple channels, funds and sources.

The international community could also strengthen its support to the LDCs through transfer of technology. The current framework for the transfer of energy-related technologies is underfunded, and its effectiveness at best uneven; and bilateral, South-South and triangular cooperation initiatives have yet to play a decisive role. The recently established Technology Bank for LDCs could potentially improve this situation, by acting as a hub for these countries. The United Nations Conference on Trade and Development (UNCTAD) could play a role in collaboration with the Bank on issues related to the transfer of energy technologies, from the perspective of productive use of energy and structural transformation.

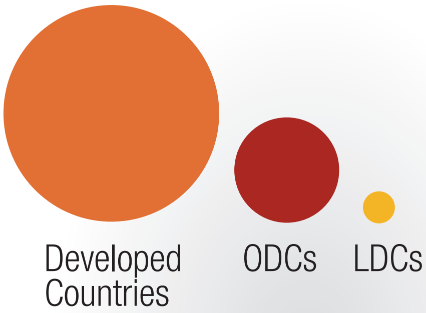
ENERGY AND SDGs

Universal access to modern energy is important **to other SDGs** across the economic, social and environmental fields

Electricity generation capacity per person in LDCs is

1/12 of that **in other developing countries** (ODCs) and

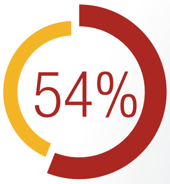
1/50 of that in **developed countries**



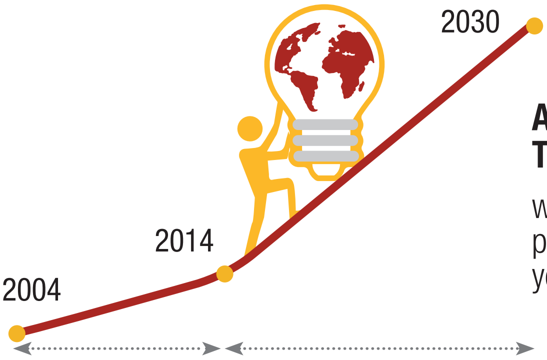
62% of people living in LDCs

have no access to electricity

compared with 10% in ODCs



of people without access to electricity worldwide **live in LDCs**



17.3 million people

61 million people

ACHIEVING UNIVERSAL ACCESS TO ELECTRICITY BY 2030

will require 3.5 times as many people in LDCs gaining access each year as in the last decade

CHAPTER 1

Energy: The lifeblood of sustainable development

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Energy: The lifeblood of sustainable development

A. Introduction

Access to modern energy, and particularly to electricity, has gained ever greater attention as an issue since around 2000, and has been the subject of numerous high-profile reports and initiatives, focused on developing countries as a whole or on African countries in particular.[1] Although not included explicitly among the Millennium Development Goals, access to energy was recognized as essential to their achievement (Modi et al., 2005; IEA, 2010); and it has been given greater prominence in the 2030 Agenda for Sustainable Development (United Nations, 2015). Sustainable Development Goal (SDG) 7 establishes universal access to modern energy by 2030 as an agreed commitment of the global community.[2]

Although the terminology of "access to modern energy" is widely used, it remains a nebulous concept. On a conceptual level, according to the International Energy Agency (IEA) (IEA, 2016a: 2):

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

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

In practical applications, however, consideration is generally limited to the first two of these elements — including, for example, the IEA flagship *World Energy Outlook* report (IEA, 2016a) — partly as a result of data limitations. Similarly, the access targets under SDG 7 relate only to the proportion of the population with access to electricity and "with primary reliance on clean fuels and technology".

The increase in attention to modern energy access partly mirrors the shift towards a more holistic approach to sustainable development embodied in the 2030 Agenda, and the major implications of access to energy in all three pillars (economic, social and environmental).

- The central role of energy in economic development is well established historically, starting with the role of coal and the development of the steam engine as drivers of the British industrial revolution in the late 18th and early 19th centuries (Wrigley, 2010).
- Equally, households' access to modern energy is a critical element of their basic needs and social well-being, reflected in the concept of energy poverty (Nussbaumer et al., 2012).
- Both traditional biomass and electricity generation have major implications for the environment, in terms of greenhouse gas (GHG) emissions and ambient and indoor air pollution.

The role of energy in transforming LDC economies is a critical issue that merits greater attention

Consequently, energy access has a prominent place on the agendas of actors across in all three pillars.

Increased access to energy in development discourse also reflects technological progress and associated cost reductions in renewable energy, which are widely seen as having the potential to provide unprecedented opportunities for increasing access to electricity, particularly in rural areas, and for "win-win" scenarios in terms of social and environmental goals.

However, the focus of recent studies and initiatives has been overwhelmingly on the social and environmental dimensions of energy access. The primary emphasis has been on the *intrinsic* benefits of *household* access to modern energy, in terms of electric lighting, access to information and connectivity, and to a lesser extent the potential time savings and health benefits of access to non-solid fuels for cooking and heating. In a context of growing global concern about climate change, renewable energy options have been highlighted as a means of responding to this unmet notional demand without compromising efforts to reduce global GHG emissions.

While these issues are undoubtedly important, this focus has led to a relative neglect of the economic dimension of the issue: the *instrumental* importance of access to modern energy for *productive sectors*, through its contribution to economic development and structural economic transformation. This is a critical issue: only through faster and more solidly based economic development can least developed countries (LDCs) hope to achieve the extraordinarily ambitious goals set out in the SDGs; and limited, unreliable and often expensive access to modern energy is a critical constraint on such development. Although by no means the only aspect of modern energy access for productive use (as discussed in section C3 below), the versatility of electricity as an energy source (chapter 2) makes it the central issue.

54 per cent of people without access to electricity globally live in LDCs

This provides the primary focus of this Report: how LDCs can realize the potential of access to electricity and its use in productive sectors to accelerate the structural transformation of their economies, in the context of SDG 7 and developments in renewable energy and off-grid (particularly mini-grid) technologies.

Section B of this chapter provides a brief overview of LDCs' access to, and production and use of energy, highlighting the gap between LDCs and other developing countries (ODCs) in energy access and production, the obstacles to increasing access and the interrelationship between access and rural-urban differences. Section C discusses the contribution of energy to structural transformation, focusing on implications for the definition of access and the mechanisms that link access to structural transformation. Section E addresses energy issues related to sustainability and inclusivity in the context of the 2030 Agenda.

B. Energy and access in LDCs

This section provides data and analysis on issues relating to energy access and use in LDCs. Like the data and analysis presented in other chapters, this is based on widely used and accepted sources. However, it is important to emphasize that there is a serious lack of reliable and consistent data on most aspects of energy, especially in LDCs, and that there are major discrepancies between different sources (box 1.1). These caveats should be kept in mind in interpreting the data in this section and elsewhere in the Report.

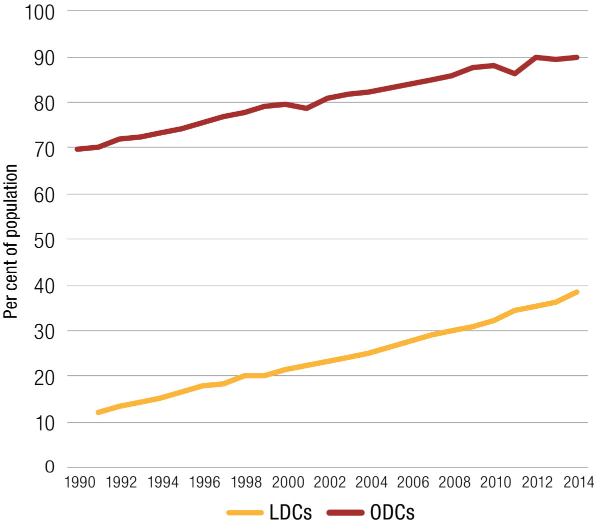
1. The energy access gap

As in other aspects of infrastructure, there has long been a very wide gap between LDCs and ODCs in terms of access to electricity (UNCTAD, 2006).[3] Since 1990, LDCs have made considerable progress in increasing such access, which more than tripled overall from 12 per cent in 1991 to 38 per cent in 2014 — an increase of 460 per cent, or nearly 300 million, in the number of people with access. However, the very low starting point, combined with relatively rapid population growth in many LDCs, resulted in an increase in the absolute number of people in LDCs without access to electricity, from 521 million people in 2000 to 578 million in 2014.

The 26-percentage-point improvement in electricity access in LDCs between 1990 and 2014 represents a greater absolute increase than the 20-point increase achieved by ODCs, reflecting a slowdown in ODCs from 1.0 per cent per annum in 1991–2009 to 0.4 per cent in 2009–2014, possibly as a result of the 2008 financial crisis (figure 1.1). In terms of the proportion of households without access, however, the gap is wider than ever. In 1991, nearly three times as many people were without access to electricity in LDCs as in ODCs (88 per cent as against 30 per cent). By 2014, the gap had increased to a factor of more than six (62 per cent as against 10 per cent).

Figure 1.1

Proportion of population with access to electricity: LDCs and ODCs, 1990–2014



Source: UNCTAD secretariat estimates, based on World Bank, World Development Indicators database (accessed May 2017).

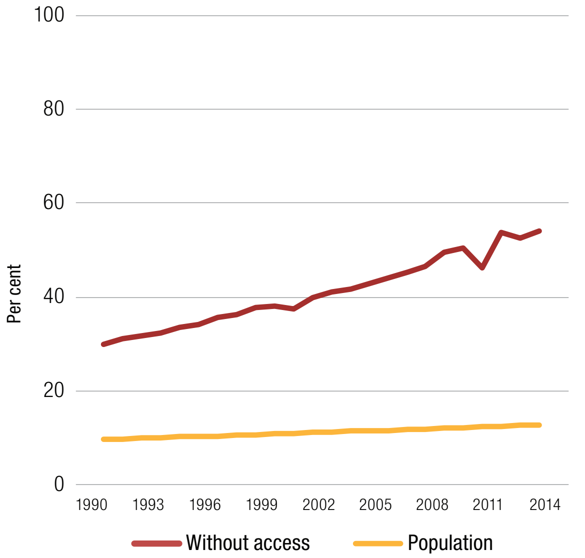
This widening gap is reflected in a major increase in the proportion of people without access to electricity globally who live in LDCs, which almost doubled from 30 per cent in 1991 to 54 per cent (577 million of 1.066 billion) in 2014, while LDCs' share in world population rose only from 10 per cent to 13 per cent (figure 1.2).[4] Of the 20 countries with the largest absolute numbers of people without access to electricity in 2014, 16 were LDCs (the others being India, Nigeria, Kenya and Democratic People's Republic of Korea) (Sustainable Energy for All, 2017). Thus, in energy as in other contexts:

> The LDCs are the battleground on which the 2030 Agenda will be won or lost: This is where shortfalls from the SDGs are greatest and improving most slowly, and where the barriers to further progress are highest.
>
> (UNCTAD, 2015: 35)

Figure 1.3 demonstrates the considerable scale of the access gap for the great majority of LDCs. Among the 35 LDCs with reliable data (box 1.1), only one (Bhutan,

Figure 1.2

Share of LDCs in worldwide population without electricity access and in total world population, 1991–2014



Source: UNCTAD secretariat estimates, based on data from World Bank, World Development Indicators database (accessed May 2017).

at 100 per cent) has access to electricity above the ODC average of 90 per cent, while one more (Nepal, at 84.9 per cent) is close to this level. In six LDCs (including the two other Asian LDCs with reliable data), access is between 50 per cent and 80 per cent, indicating that between two and five times as many people lack access as in ODCs as a whole. In all but one of the LDCs in the Africa and Haiti group (Senegal), as well as three of the five island LDCs with reliable data, only a minority of people have access. In the majority of the African LDCs with reliable data, less than a quarter of the population has access to electricity, and in South Sudan the figure is less than 1 in 20.

The energy access gap between LDCs and ODCs also extends to clean fuels for domestic use, although the attention devoted to this issue does not reflect the importance of domestic heating and cooking in energy demand in LDCs (Bhattacharyya, 2013). In only four LDCs (Angola, Bhutan, Mauritania and Yemen) do more than 40 per cent of people have access to clean fuels, compared with 80 per cent of ODCs for which data are available. In half of ODCs, access to clean fuels is greater than 90 per cent.[5]

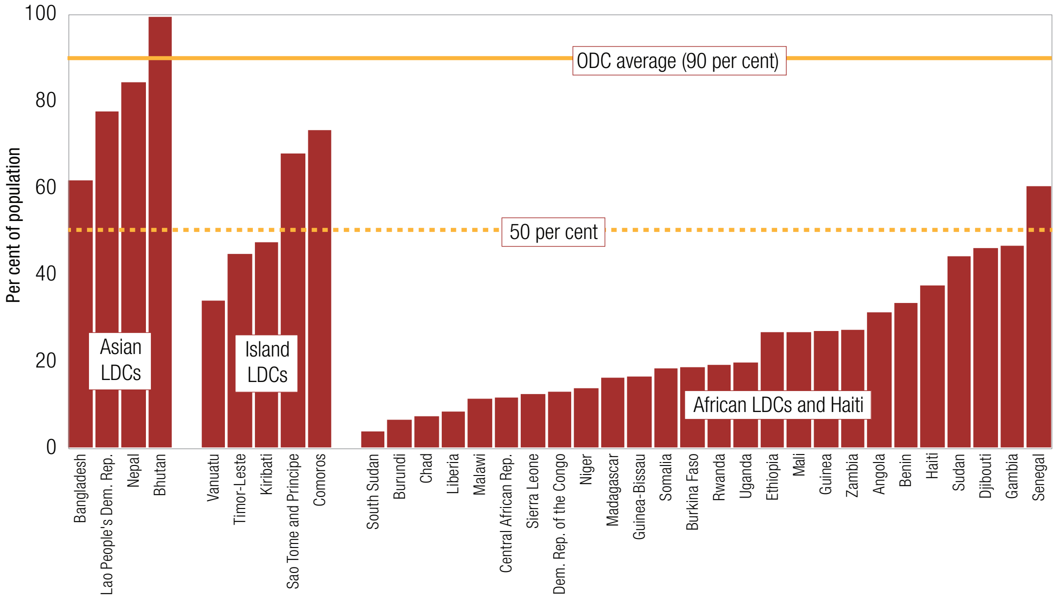
2. Electricity access and the rural-urban divide[6]

The relatively early stage of the electrification process in most LDCs, particularly in Africa, has critically important implications for the evolution of access, notably in terms of the rural-urban balance. As shown in figure 1.4, increasing access to electricity follows a distinctive trajectory as development progresses. Initially, electrification is generally focused strongly in urban areas, at least partly reflecting the (historically) much greater ease and lower cost of provision in these areas through grid extension and the greater concentration of demand in urban areas. With only a handful of exceptions, it is only after urban access exceeds 80 per cent that rural access surpasses 20 per cent.

This gives rise to a relationship between overall access and rural-urban differences analogous to the Kuznets curve (showing an increase in income inequality as per capita incomes increase in the early stages of development, which is reversed at higher income levels). As overall access to electricity increases, rural-urban differences in energy access first increase

Figure 1.3

Access to electricity in LDCs, 2014



Source: World Bank, World Development Indicators (WDI) database (accessed May 2017).
Note: Excludes LDCs for which major discrepancies exist between WDI and IEA data (box 1.1).

Box 1.1 Choice of data and related limitations

Despite the growing availability of energy data and ad hoc estimations, including those produced by private firms and research institutions, there is a dearth of comprehensive, reliable and internationally comparable time-series data on energy issues in LDCs (IEA, 2014a). This applies across a wide range of issues, including electricity access and energy balances. These limitations should be taken into account in interpreting the data presented in this Report.

In the case of energy access (the proportion of people with access to electricity in each country), there are wide differences in the estimates provided by the two primary sources, IEA (http://www.worldenergyoutlook.org/resources/energydevelopment/energyaccessdatabase/) and the World Bank (http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators&preview=off). The estimates for LDCs in 2014 from these two sources are shown in box figure 1.1.

For the purposes of this Report, World Bank (World Development Indicators (WDI)) data are used, first, because these have comprehensive coverage of LDCs, whereas published IEA data include only 42 of the 47 LDCs; and second, because they provide historical data. However, discrepancies between these two sources are used as a quality control: countries for which the absolute difference between estimates exceeds 10 percentage points (indicated by the shaded area in box figure 1.1) are excluded from country-specific figures and text discussions relating to overall access to electricity, as this is taken to indicate a particularly high level of uncertainty regarding its true level. These countries are Afghanistan, Cambodia, Eritrea, Lesotho, Mauritania, Mozambique, Myanmar, Solomon Islands, Togo, the United Republic of Tanzania and Yemen.

With respect to energy balances, aside from regional aggregates, three main data sources are used in the literature:

1. The World Energy Balances, produced by IEA;
2. The Energy Statistics Database of the United Nations Statistics Division (UNSD).
3. The World Bank's Sustainable Energy for All (SE4All) database (also partly included in the WDI).

Their comparison in terms of country and time coverage is summarized in box table 1.1 below.

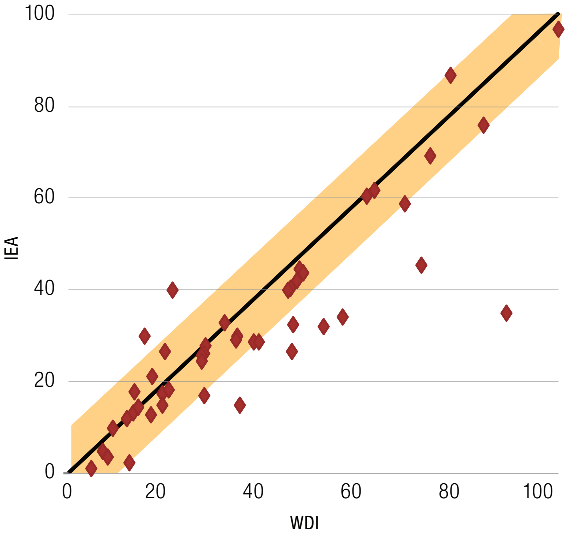
Data quality and reliability are often disputed in the literature and remain an area of concern, in the LDC context more than anywhere else. In addition to definitional issues regarding the various concepts and technologies, a particular challenge is capturing the evolving picture of distributed generation for residential purposes, including off-grid and mini-grid solutions.

The IEA World Energy Balances is generally regarded as the most dependable and internally consistent data source. For the purposes of the current Report, however, its coverage of LDCs is clearly unsatisfactory. A comparison of UNSD and SE4All (for the 19 LDCs covered by IEA, and taking IEA data as a benchmark), discrepancies across the two remaining databases do not indicate a clear preference for either (box table 1.2).

For the purposes of this Report, the UNSD database is used for energy and electricity production, in light of its better country coverage and its use of official data submitted by LDCs through the annual UNSD Annual Questionnaire on Energy Statistics. Where necessary, this is supplemented with data from other sources.

Box figure 1.1

Comparison of IEA and WDI estimates of electricity access, 2014 (per cent of population)



Source: World Bank, World Development Indicators database and IEA Energy Access database (http://www.world energyoutlook.org/resources/energydevelopment/energyaccessdatabase/) (both accessed August 2017), supplemented with unpublished data provided by IEA.

Note: The solid line represents the position of all observations if estimates from the two sources corresponded exactly. The shaded area represents discrepancies in either direction up to ten percentage points.

Box table 1.1

Comparison of coverage across data sources

	IEA World Energy Balances	UNSD Energy Statistics	WB Sustainable Energy for All
Country coverage	19 LDCs	47 LDCs	46 LDCs
Time window	1980–2015	1990–2014	1990–2012

Source: UNCTAD secretariat compilation.

Box table 1.2

Discrepancies in gross electricity production across data sources (per cent)

	UNSD Energy Statistics	WB Sustainable Energy for All
Average discrepancy*	1.82	8.82
Median discrepancy*	0.00	0.00
Per cent of matching observations	53.21	75.92

Source: UNCTAD secretariat compilation.

Note: * Discrepancies are expressed as share of the corresponding IEA figure for the same year.

(as urban access expands, with little improvement in rural access), but then decline once urban access reaches around 80 per cent and begins to level off, while rural access grows more rapidly (figure 1.5). This pattern highlights the critical role of energy access in the emergence of urban bias in the early stages of development.

Figures 1.4 and 1.5 also highlight the implications of the access gap between LDCs and ODCs for the rural-urban divide. The great majority of ODCs are in the later stages of the process, clustered in the top right corner of figure 1.4 and the bottom right corner of figure 1.5, with overall access of 80 per cent, urban access near 100 per cent, and relatively small urban-rural differences. At this stage of the process, increasing electrification tends to narrow rural-urban differences, as rural access converges towards already very high levels of urban access. This is shown by the downward-sloping red ODC trend line in figure 1.5.

Most LDCs in the Africa and Haiti group, by contrast, remain in the initial phase, with urban access well below the 80-per-cent threshold, wherein increasing overall access tends to widen rural-urban gaps (shown by the upward sloping orange trend line in figure 1.5). Their overall access is generally below 50 per cent, rural access below 20 per cent, and urban-rural gaps between 20 and 60 per cent.

In the average LDC, 90 per cent of the rural population lack access to electricity

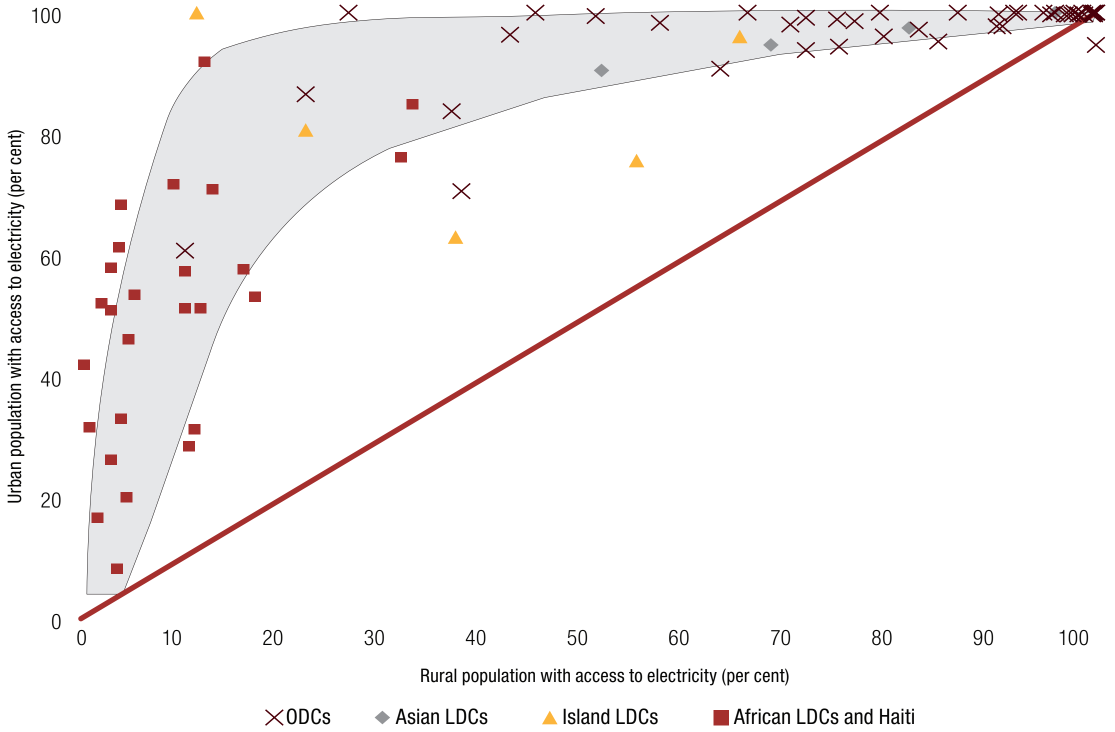
Most Asian and island LDCs are close to or above the 80-per-cent urban access threshold, so that further increases in overall access can be expected to narrow rural-urban gaps. With the exceptions of Kiribati and Vanuatu, they are also below the overall trend line in figure 1.5, indicating more limited urban-rural differences than suggested by their overall access.

This has two implications. First, access to electricity is systematically greater in urban than in rural areas (figure 1.6A). While 41.2 per cent of the urban population lacks access to electricity in the median LDC, in rural areas it is 89.3 per cent (and 94.9 per cent in the Africa and Haiti group). Access to non-solid fuels also shows substantial urban bias, but with lower overall access: only 13.1 per cent of people have access even in urban areas, and 2.4 per cent in rural areas (figure 1.6B).

Such wide rural-urban differences in access to electricity are a major factor in urban bias in LDCs, not only lowering living standards in rural areas, but also reinforcing other disadvantages of rural populations, for example by impeding the retention of health

Figure 1.4

Rural and urban population with access to electricity, LDCs and ODCs, 2014

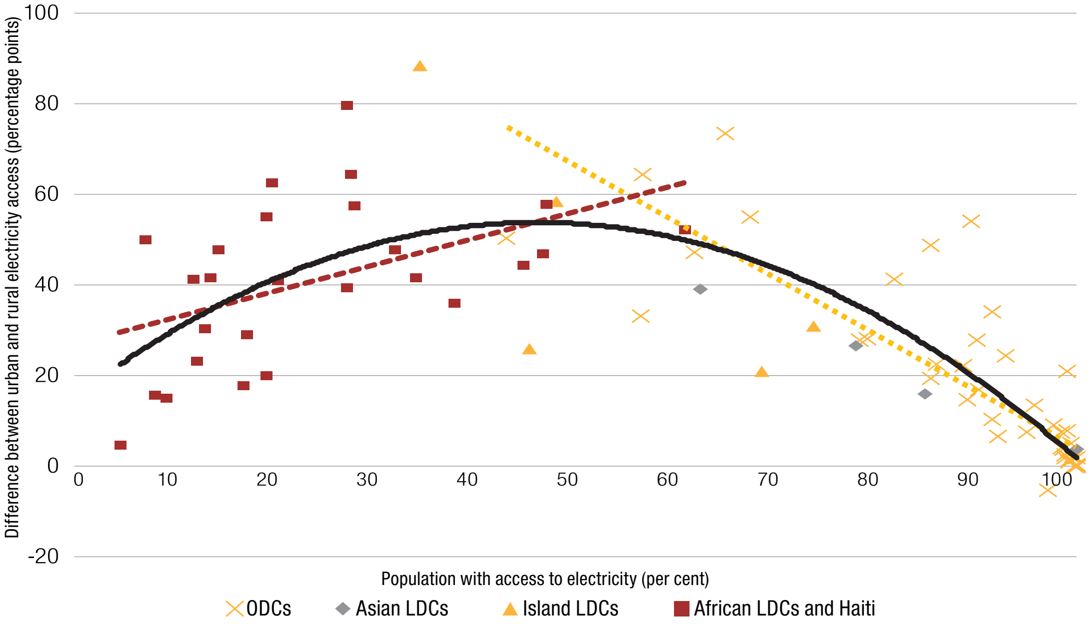


Source: World Bank, World Development Indicators database (accessed May 2017).

Note: Excludes LDCs and ODCs for which major discrepancies exist between WDI and IEA data, as described in box 1.1 (and those not included in IEA data, for which no consistency test is possible). The solid line represents the 45-degree line, corresponding to equal rates of access in rural and urban areas. The shaded area indicate the broad range of paths followed by actual observations in most LDCs and ODCs.

Figure 1.5

Electricity access and rural-urban access gap, LDCs and ODCs, 2014

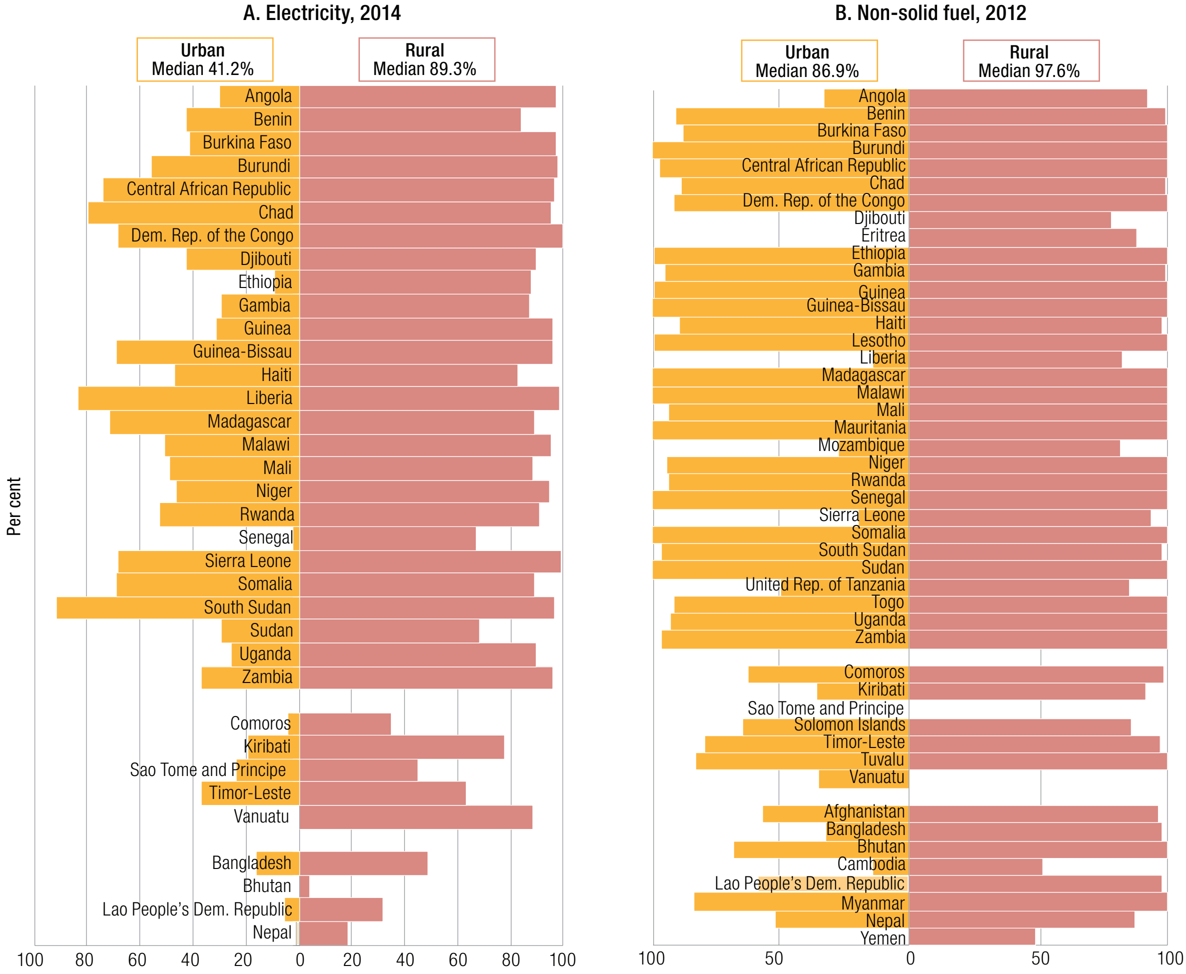


Source: World Bank, World Development Indicators database (accessed May 2017).

Note: Excludes LDCs for which major discrepancies exist between WDI and IEA data (box 1.1). The solid black line represents the polynomial trend line across all observations (degree two), that is, of the form y = ax2+bx+c. The dotted lines represent the linear trend lines for African LDCs (in red) and for ODCs (in orange).

Figure 1.6

Rural and urban population without access to electricity and non-solid fuel, LDCs



Source: World Bank, World Development Indicators database (A: accessed May 2017; B: accessed March 2017).

Note: At the time of writing, separate urban and rural estimates for population with access to non-solid fuels are no longer available in WDI. LDCs for which major data discrepancies exist between WDI and IEA data are excluded from A (box 1.1).

professionals and teachers. Rural electrification is thus an important contributory factor in ensuring that rural-urban migration is driven by choice rather than necessity, and in keeping the rate of urbanization within the bounds of sustainability (UNCTAD, 2015).

Second, the combination of urban bias in electricity access with predominantly rural populations in LDCs means that a large majority (82 per cent overall) of those without access to electricity are in rural areas (figure 1.7). In only one of the LDCs with reliable data (Djibouti) are a majority of those without access to electricity in urban areas, while two (Bhutan and Vanuatu) are estimated to have already achieved universal access in urban areas, so that all those without access are rural residents. In all three other Asian LDCs with reliable data, more than 90 per cent of those without access live in rural areas, reflecting very high levels of urban access, while the rural proportion is above 75 per cent in all island LDCs except Sao Tome and Principe (51 per cent). In the African LDCs and Haiti group, the rural dominance is relatively limited in Guinea-Bissau, Haiti and Liberia, at 55-60 per cent, but above 80 per cent in 12 of the other 23 cases. Since rural areas are also where electrification is most costly and problematic, this adds yet further to the challenge of electrification.[7]

3. Obstacles to extending access to electricity in LDCs

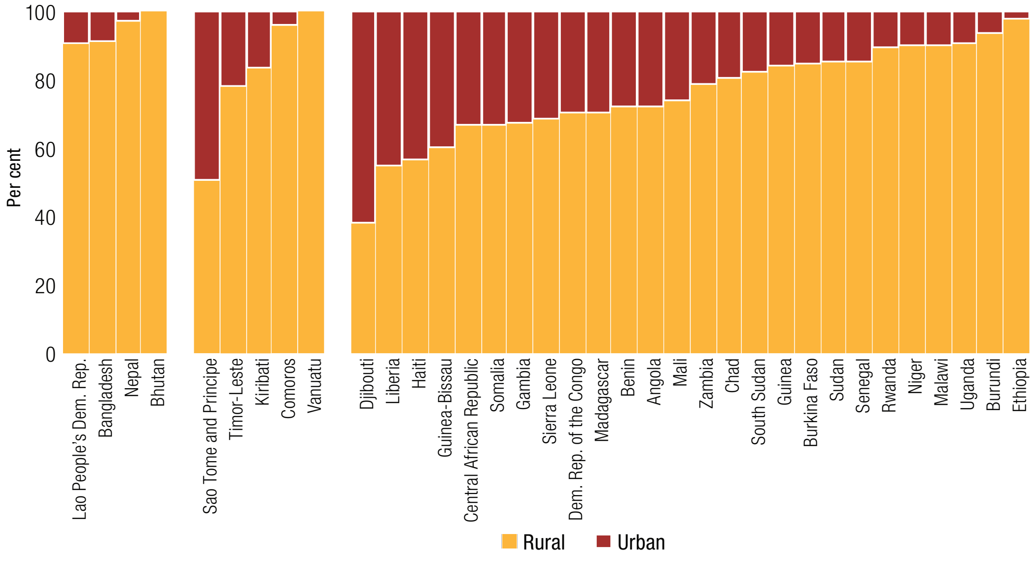
The electricity access gap is part of a broader infrastructure divide between LDCs and ODCs, largely reflecting the financial obstacles to their infrastructure development (UNCTAD, 2006). However, in the case of electrification, these constraints are compounded by serious logistical challenges arising from a combination of limited urbanization and low population density in rural areas (figure 1.8). In 40 of the 46 LDCs for which data are available, the majority of the population lives in rural areas, compared with only 30 of 103 ODCs with available data. Moreover, LDCs generally have substantially lower rural population densities than most ODCs with similarly limited rates of urbanization. Consequently, 34 of the 47 LDCs, but only 10 of the 103 ODCs, have a combination of more than 50 per cent of their population living in rural areas and population density below 75 people per km^2.

Limited urbanization, low rural population density and lack of demand in LDCs are major challenges to universal access

This settlement pattern has historically represented a particular obstacle to electrification. Until recently, electricity supply (other than households and firms using their own generators) depended almost entirely on power plants using fossil fuels (coal, gas or oil) and/or on hydroelectric power. Since these have considerable economies of scale (partly reflecting high fixed costs), these technologies depend on a large market for their viability. Consequently, they are well suited to urban and immediate peri-urban markets, but particularly ill suited to sparsely inhabited rural areas: accessing a market of sufficient scale in this context requires transmission over a very considerable area, which greatly increases capital costs for the distribution network.

Figure 1.7

Proportion of people without access to electricity living in rural and urban areas, LDCs, 2014



Source: UNCTAD secretariat estimates, based on World Bank, World Development Indicators database (accessed August 2017).
Note: Excludes LDCs for which major data discrepancies exist between WDI and IEA data (box 1.1).

In recent years, this obstacle has become less absolute as costs have fallen for renewable generation technologies that are viable on a smaller scale, increasing the potential for rural electrification using village-level mini-grids and off-grid generation. While such models have as yet had little penetration in most LDCs, they could in principle represent a historic opportunity for a major acceleration in access to electricity, if the obstacles to their widespread use can be overcome (chapter 3).

However, settlement patterns are only part of the story: access in urban areas is also much lower in most LDCs than in ODCs (as seen in figure 1.6A), while ODCs with similarly sparsely inhabited rural areas have achieved much higher rural electrification rates. The other aspects of the issue, as in other infrastructure sectors, relate to financial constraints and state capacities.

Low household incomes limit domestic demand for electricity, while the lack of industrialization and other modern activities in most LDCs limits demand for electricity by productive sectors. This lack of demand in turn limits the financial viability of commercial investments in electricity generation and distribution, especially in rural areas: here, incomes are lower and poverty more widespread and deeper, reducing demand; and this compounds the effect of thinly spread populations in increasing investment costs.

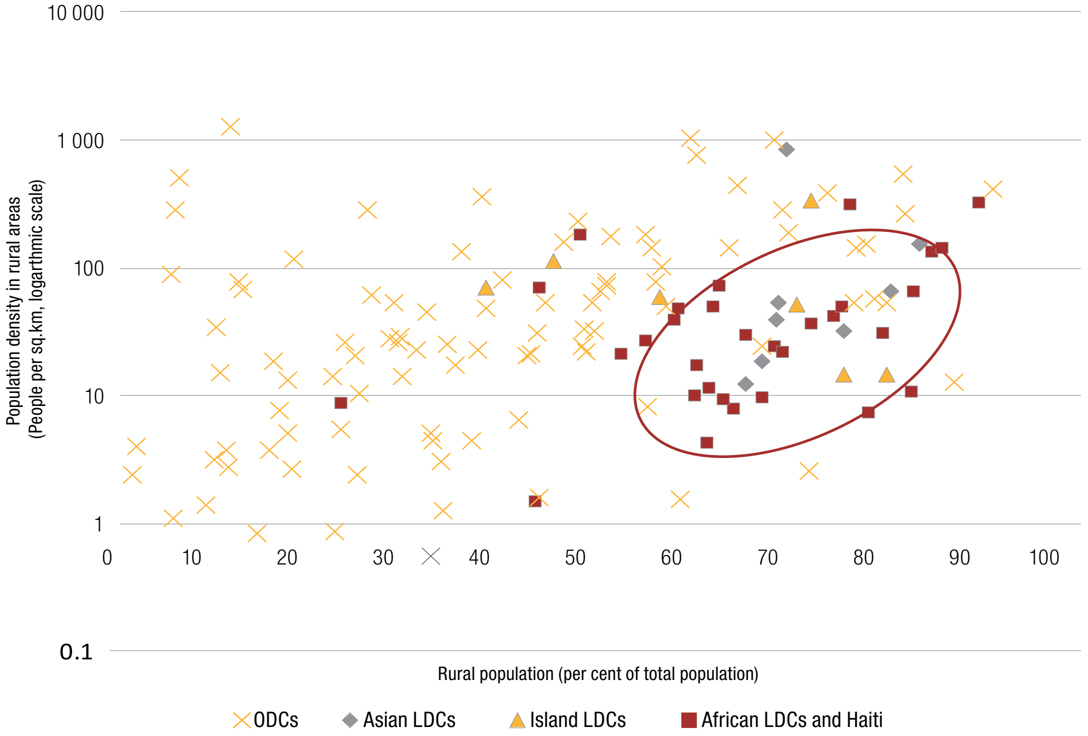
At the same time, the domestic resources available for public investment in electricity production and supply are limited by low overall incomes, narrow tax bases and weak tax collection capacity, while borrowing capacity is limited by considerations of debt sustainability. This leaves public investment in electrification critically dependent on official development assistance (ODA); but this has been limited by persistent large shortfalls from the target level of 0.15-0.20 per cent of donor gross national income (GNI) (chapter 5). Issues in the financing of energy infrastructure are discussed in greater detail in chapter 5.

4. Universal access: A mountain to climb

Figure 1.9 highlights the scale of the challenge facing most LDCs in seeking to achieve universal access to electricity by 2030.[8] Among the LDCs with reliable data, two Asian countries — Nepal and Bhutan — appear well on track towards this target, which requires substantially fewer new connections per year than over the last decade for which data are available. Lao People's Democratic Republic could also achieve universal access by 2030 with around 10 per cent fewer new connections per year than over the last decade. While this understates the scale of the challenge (as those still requiring connections are likely to be the most problematic logistically or otherwise), the target

Figure 1.8

Rural share of population and rural population density, LDCs and ODCs, 2010

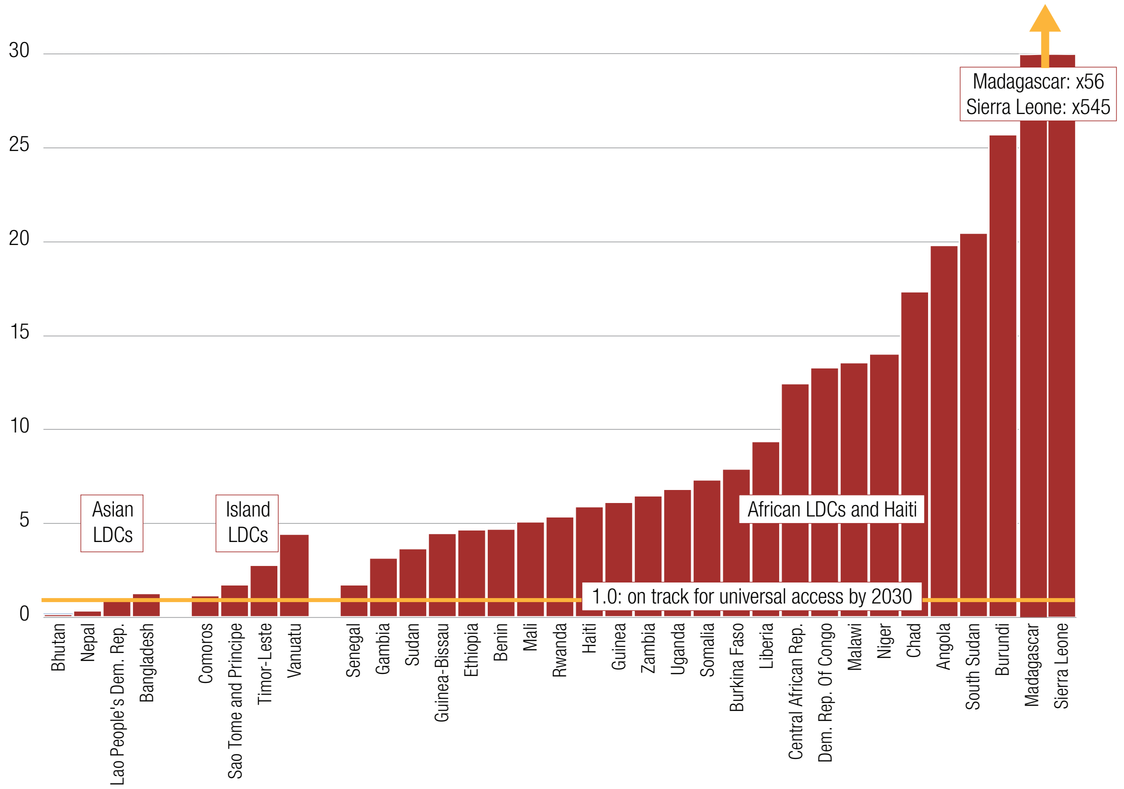


Source: UNCTAD secretariat estimates, based on World Bank, World Development Indicators database (accessed May 2017).

Note: For 18 of the 150 countries included in the graph, separate data are not available for rural land area. In these cases, rural population density was approximated by dividing rural population by total land area. It should be noted that there are marked differences in national definitions of rural and urban areas (UNCTAD, 2015: box 1.2), which affect the comparability of observations between countries.

Figure 1.9

LDCs: increase in new electricity connections required in 2014–2030 as multiple of new connections in 2004–2014



Source: UNCTAD secretariat estimates, based on access estimates from World Bank, World Development Indicators database and on population projections from UN DESA, World Population Prospects: The 2015 Revision database (both accessed May 2017).

Note: The baseline for Eritrea is 2001–2011, due to the unavailability of estimates for 2012–2014. In Djibouti and Kiribati, the number of people with access to electricity is estimated to have declined between 2004 and 2014, making estimation of a ratio impossible.

of universal access should nonetheless be achievable with an increase in policy attention and investment. The challenge will be substantially greater in Bangladesh and the Comoros, which require some 20-30 per cent more new connections per year, and still more so in Senegal and Sao Tome and Principe, where the increase required is around 75 per cent.

Elsewhere — and particularly in other African LDCs — the challenge is of an altogether greater order of magnitude. Only six LDCs in the Africa and Haiti group could achieve universal access by 2030 with less than a fivefold acceleration in their rate of progress, while 10 require a more than twelvefold acceleration. In the most extreme cases, Madagascar and Sierra Leone, annual connections need to increase by factors of 56 and 545 respectively. In Djibouti and Kiribati (not included in the figure), a reversal of the last decade's reduction in access will be required to achieve the 160-170-per-cent increase needed for universal access.

5. Electricity production: LDCs' power generation gap

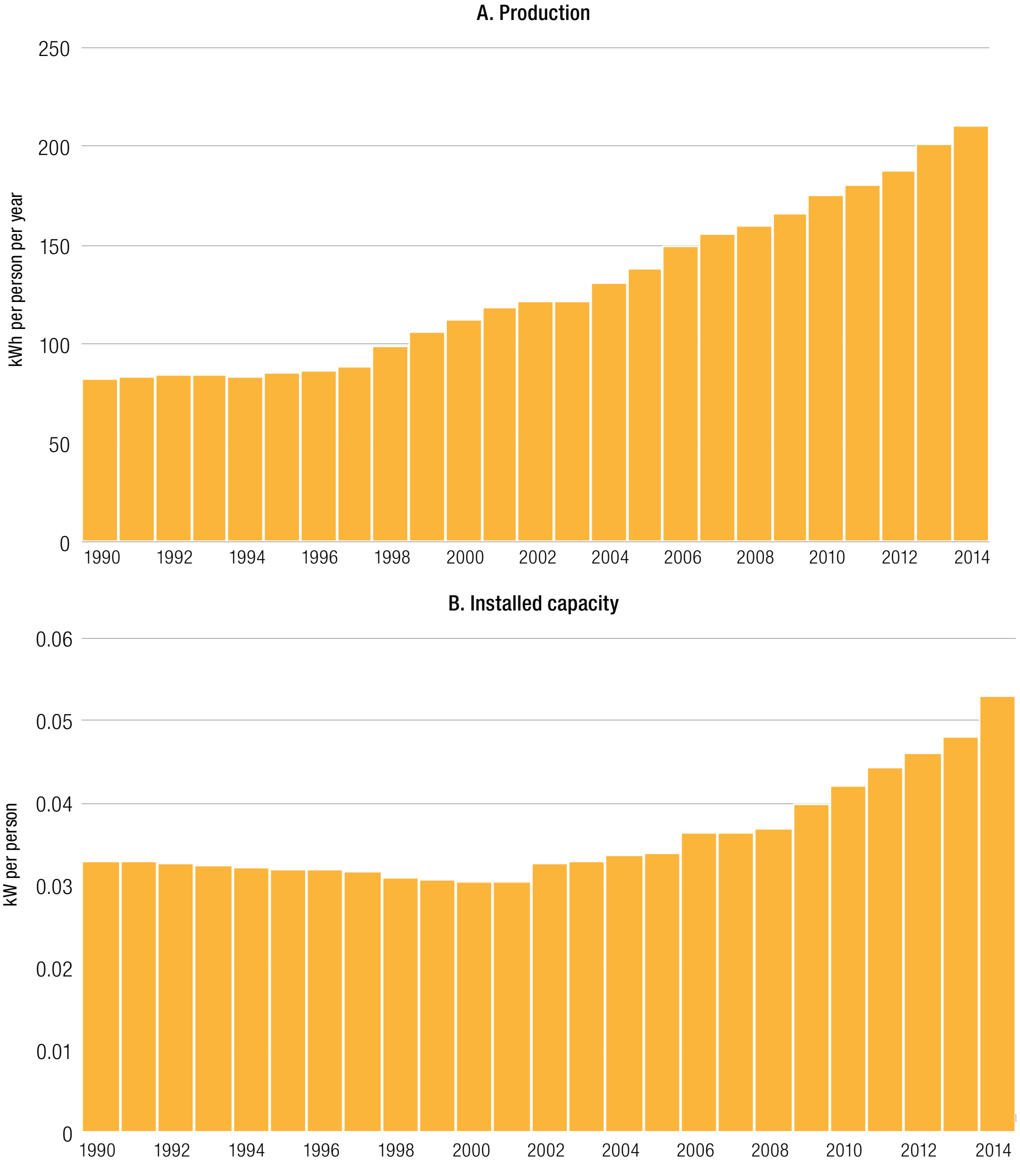
After stagnating in per capita terms through most of the 1990s, electricity production in LDCs has grown robustly since, more than doubling from 89 kilowatt-hours (kWh) per capita in 1997 to 210 kWh per capita in 2014 (figure 1.10A).[9] This increase stemmed from a combination of increasing installed capacity, which nearly doubled from 0.030 kW per capita to 0.053 kW per capita between 2001 and 2014 after a progressive decline through the 1990s (figure 1.10B), and a broad improvement in the utilization of this capacity, demonstrated by an increase in the overall capacity factor from around 30 per cent to nearly 50 per cent.

The recent expansion of power generation has also been very broad-based (figure 1.11), gross electricity output rising between 2004 and 2014 in all 47 LDCs, with a median annual growth rate of 4.7 per cent, and double-digit rates in several cases (including both fossil-fuel exporters such as Angola, the Sudan and Timor-Leste, and other LDCs such as Bhutan, Cambodia, Ethiopia, Myanmar and Rwanda). Generating capacity also expanded significantly over the same period in almost all LDCs, with slight declines only in Afghanistan, Eritrea and Malawi.[10]

Impressive as this growth may appear, however, both capacity and production have failed to keep pace with the 460-per-cent increase in the number of people with access to electricity since 1991 (figure 1.12). Both fell

Figure 1.10

Gross electricity production and installed capacity per capita, LDCs, 1990–2014



Source: UNCTAD secretariat estimates based on data from UN DESA, Energy Statistics Database and World Population Prospects: The 2015 Revision database (both accessed February 2017).

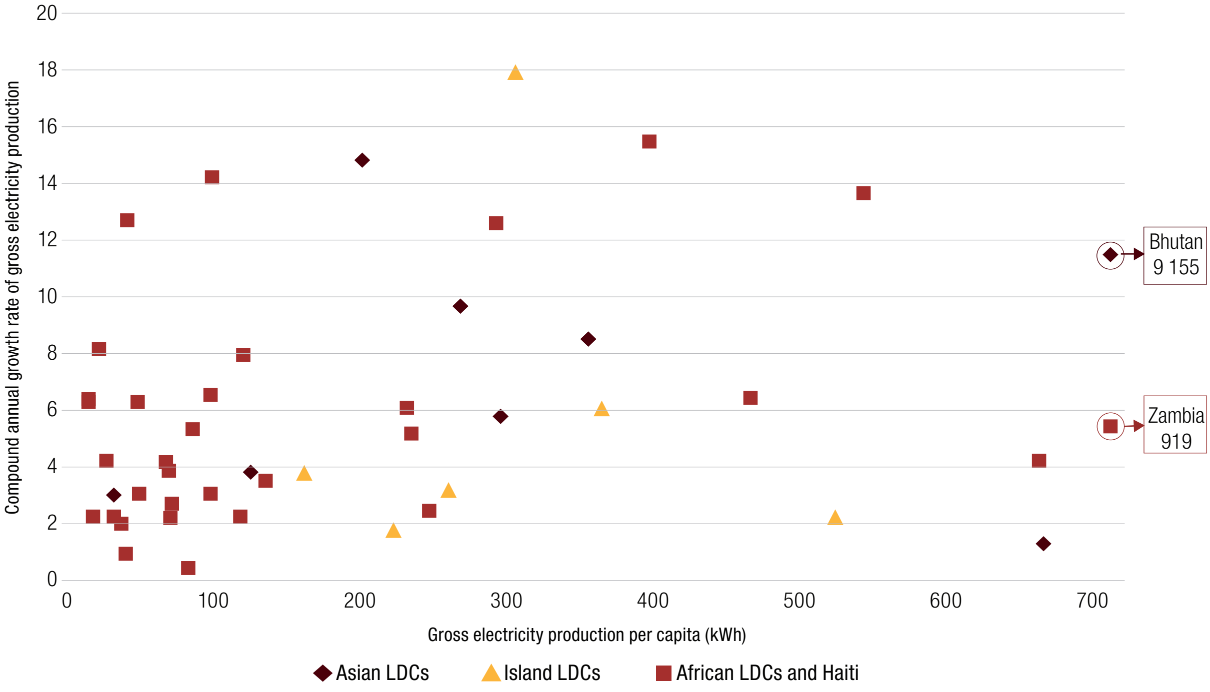
sharply relative to the population with access until 1996, installed capacity continuing to decline until 2008. Both recovered only slowly and partially thereafter, so that, by 2014, installed capacity per person with access was barely half its 1991 level, while electricity production per person with access was one fifth below its 1991 level.

Equally, while the increases in electricity capacity and installed capacity from the 1990s onwards represented a convergence towards the world average, LDCs' share in world electricity production remained only 0.8 per cent in 2014, compared with their 13-per-cent share in global population.[11] The increases were also insufficient to prevent a rapidly widening gap between LDCs and ODCs (figure 1.13). In 1990, LDCs' installed capacity per capita was 17.8 per cent of the ODC average, and their electricity production was 11.5 per cent of the ODC average. By 2014, these figures had fallen respectively by more than half to 8.7 per cent and by more than a quarter to 8.5 per cent. This represents a very considerable gap between LDCs and ODCs — and the gap between LDCs and developed countries is much wider still (figure 1.14).

As can be seen in figure 1.11, the overall figures for electricity production also conceal considerable heterogeneity among individual LDCs. Only five countries in the group (Bhutan, Lao People's Democratic Republic, Mozambique, Tuvalu and Zambia) had electricity production in excess of 500 kWh per person per year in 2014, while 20 were between 100 kWh and 500 kWh, and 22 below 100 kWh (of which 12 were 50 kWh).

Figure 1.11

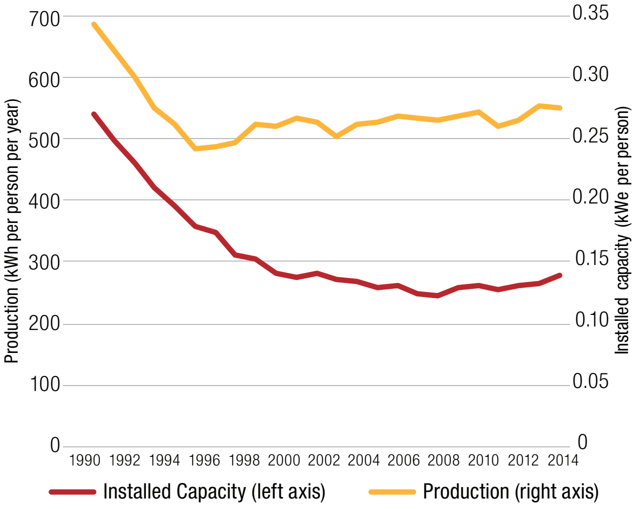
LDCs: Gross electricity production per capita, level (2014) and growth rate (2004–2014)



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database (accessed February 2017).

Figure 1.12

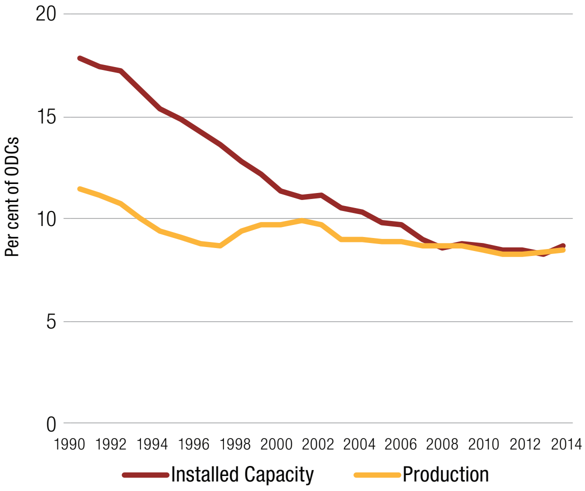
Gross electricity production and installed capacity per person with access, 1990–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database and World Population Prospects: The 2015 Revision database (both accessed February 2017).

Figure 1.13

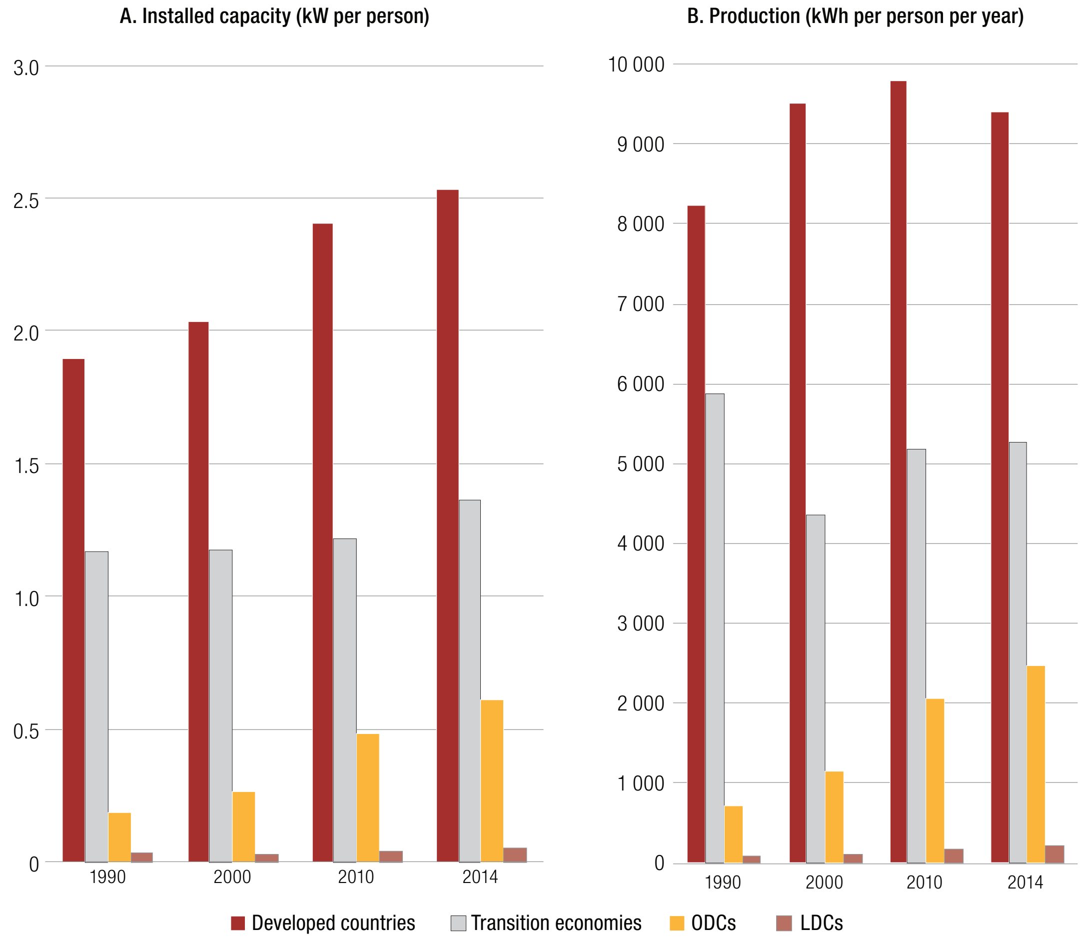
Gross electricity production and installed capacity per capita, LDCs, 1990–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database and World Population Prospects: The 2015 Revision database (both accessed February 2017).

Figure 1.14

Gross electricity production and installed capacity per capita: LDCs, ODCs, transition economies and developed countries, 1990–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database and World Population Prospects: The 2015 Revision database (both accessed February 2017).

C. Energy and structural transformation

1. Structural transformation and productive capacities

Development is not merely a matter of economic growth. Rather, it is about structural economic transformation – a progressive shift of the structure of the economy from that which characterizes LDCs (low overall productivity, limited industrialization and a predominance of traditional agriculture and low-value services) towards higher productivity and a greater role of manufacturing and higher-value services. It is akin less to the growth of an organism than to the metamorphosis of a caterpillar into a butterfly — a change, not only in the scale of the economy, but also in its nature (UNCTAD, 2014).

The core of this process is increasing overall levels of productivity, in two dimensions:

- Increasing productivity within existing economic activities;
- Shifting productive resources from sectors and activities with relatively low productivity (notably traditional agriculture and low-value services, especially in the informal sector) to those with higher productivity (particularly manufacturing and high-value services).

This requires the continual generation of new dynamic activities characterized by higher productivity and increasing returns to scale, through successive waves of introduction and diffusion of new economic activities, in order to diversify the economy into progressively more technology-intensive and higher- productivity activities and production processes. This is not a passive outcome of the growth process, but rather an active determinant of growth potential.

Of particular importance in the early stage of development that characterizes LDCs is the structural transformation of rural economies, through a parallel process of agricultural upgrading and the complementary development of rural non-farm activities (UNCTAD, 2015a). Given LDCs' predominantly rural populations and agrarian economies, such a process is essential to a broad-based transformation of the national economy as a whole, and to limit rural-urban migration to a rate at which migrants can be productively absorbed by reducing the underlying economic "push" factors.

Structural transformation requires, in particular, the development of productive capacities (UNCTAD, 2006), which may be categorized as:

- Productive resources (natural and human resources, and financial and physical capital);
- Entrepreneurial capabilities (core competencies and technological capabilities);
- Production linkages (including forward and backward linkages, information and resource flows, production clusters, global value chains and links between firms of different types and sizes).

Central to structural change and the development of productive capacities are capital accumulation, through investment to increase stocks of natural, human and physical capital; and innovation, through the introduction of new products, production methods, equipment and skills.

While access to modern energy can make an important contribution to structural transformation (chapter 2), it is clearly not enough. Lack of access to energy is only one of a range of constraints to the development of productive capacities, in terms of physical infrastructure (for transport, information and communication technology (ICT), water supply, waste disposal, etc.); institutional weaknesses (notably in relation to firms, financial systems and knowledge systems); and demand constraints (UNCTAD, 2006). Successful structural transformation therefore requires carefully planned and coordinated action to overcome all these constraints, and to address other essentials for development, particularly education and training to provide the necessary human resource base; the development of effective public institutions; and improvements to domestic resource mobilization.

2. (Re)defining access to modern energy

In practice, as discussed in the introduction to this section, access to modern energy is often defined, explicitly or implicitly, as physical connection of households to the electricity grid and their use of clean non-solid fuels for cooking. However, this definition is unduly narrow and potentially misleading. In particular, it does not address issues relating to agents other than households, to the amount of energy to which households have access, to attributes of the energy supply to which they have access, or to the use of energy for productive or other non-domestic purposes (Culver, 2017; Bazilian et al., 2010).

"Transformational energy access" for productive sectors is important as well as universal household access

More recently, however, there have been efforts in the context of the Sustainable Energy for All (SE4All) initiative to broaden understanding of access to energy in various dimensions (Bhatia and Angelou, 2015):

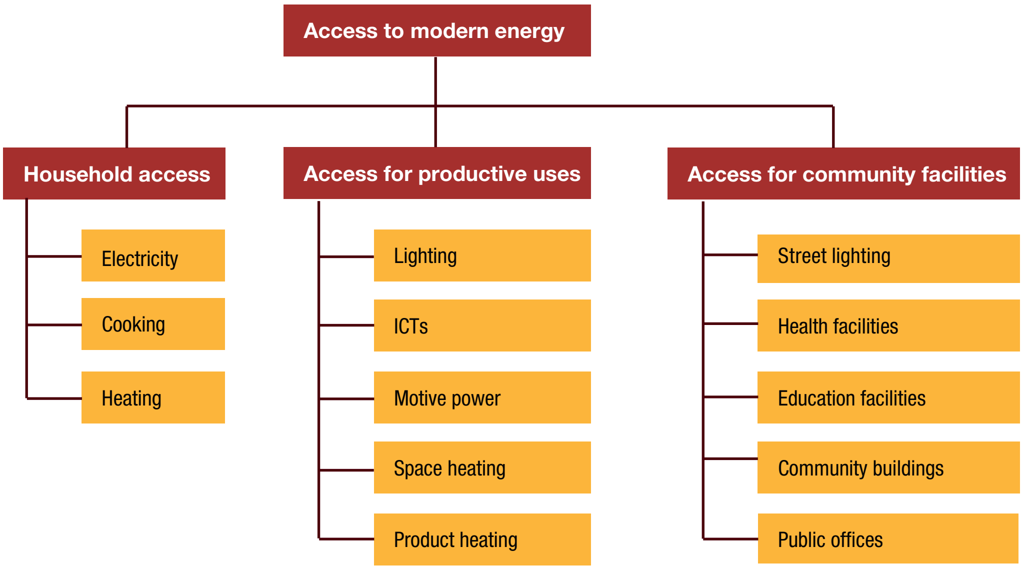
- From a focus on households to encompass businesses and public and community facilities;
- From electricity supply to encompass modern fuels for cooking and (where needed) heating;
- From access to energy to technologies for its use (particularly improved and energy-efficient stoves);
- From a binary definition (of having or not having access) to a continuum, reflected in several tiers of access;
- From physical connection or availability to include attributes of supply, including quantity, reliability, continuity and safety;
- From physical supply to affordability;
- From access at a point in time to a progressive upgrading in access over time.

Figure 1.15 sets out an adapted version of the typology of modern energy access proposed in a recent conceptualization report published by the SE4All Knowledge Hub (Bhatia and Angelou, 2015), elaborating the "access for productive uses" component in line with the other two components on the basis of the discussion in that report.

The same report also proposes five tiers of access, defined by various criteria, including for productive access (Bhatia and Angelou, 2015: table ES.6). While a much-needed move in the right direction, however, it is not clear that the criteria for these tiers of access adequately represent what is required for structural transformation. This largely reflects the basis of the approach "on the energy access experienced by individuals rather than enterprises", so that data can be collected through household surveys rather than enterprise surveys (Bhatia and Angelou, 2015). Specifically, the capacity criteria are the same as for households, while the availability criteria are significantly less demanding. Tier 1 allows no more, and tier 2 little more, than lighting and telephone charging. The daily supply criterion for tier 3 would not be sufficient for a domestic refrigerator; and even that for the highest tier (5) is well below what is required for a domestic oven. These thresholds appear low relative to electricity needs for the type of productive activities entailed in

Figure 1.15

Typology of modern energy access



Source: Adapted by UNCTAD secretariat from Bhatia and Angelou (2015), figure ES.1 and chapter 9.

a substantial economic transformation; and reliability, quality, affordability, convenience and safety are not considered at all below tier 4.

Such relatively undemanding thresholds appear oriented towards a development process characterized by a proliferation of household-level microenterprises, and may offer some benefits in this context. Typically, such a process arises as “entrepreneurs by necessity” are driven by lack of employment opportunities and/or inadequate farm incomes to resort to low-productivity survivalist activities in the informal sector. While characteristic of the current situation of many LDCs, however, achieving the SDGs will require a much more transformative development process in LDCs, founded upon the dynamic growth of enterprises run by “entrepreneurs by choice”, generating productive employment opportunities, which can be expected ultimately to form the basis of a vibrant formal sector (UNCTAD, 2015). This is likely to require an altogether more demanding framework for energy access for productive use.

While practical limitations to data collection may confine monitoring of energy access to this framework, it is therefore important that policies should be oriented towards a much more ambitious concept of access for productive use — what might be termed “transformational energy access”. This concept is discussed in greater detail in chapter 2. In particular, due attention should be given to the energy needs of enterprises as well as households. Even for households engaged in productive activities, more demanding standards may be appropriate for capacity, availability and reliability if energy is not to be a constraint on productive potential.

3. Energy for structural transformation before electrification

Like the SDGs as a whole, universal access to modern energy is an immensely ambitious goal, and nowhere more so than in the LDCs. Even if universal access is achieved by 2030 — which is far from certain — this will leave many households without access to modern energy for the next 13 years. Escaping the constraint that limited access to energy imposes on economic development and structural transformation thus requires consideration of the energy needs of productive enterprises ahead of access to electricity (Karekezi, 2002). This is of particular importance in rural areas, as it is here that lack of access to electricity represents the greatest obstacle to structural transformation.

The energy needs of many rural enterprises are for motive, mechanical or thermal energy, which can be provided by non-electrical technologies before electricity is available. Woodfuel (firewood and charcoal) plays a substantial role, often being used as an energy source by bakeries, restaurants, food stalls, breweries and forges and for brick-making (Schure et al., 2010). Key contributions can be made by the adoption of improved and fuel-efficient stoves, solar stoves, ovens, kilns and water heaters, and more purpose-specific technologies such as solar tunnels for drying agricultural produce. Potentially important technologies for motive and mechanical energy include animal traction (in agriculture), wind or hydraulic pumps (e.g. for irrigation), water-driven equipment for food processing, etc., while evaporation fridges can allow refrigeration without access to electricity.

Much of this equipment can also be produced locally, allowing it to be tailored to local needs and preferences, as well as potentially making a significant contribution to employment creation, structural transformation and the diversification of rural economies.

Programmes such as the multifunctional platform programme operated in several African countries by the United Nations Development Programme (UNDP) can also make a contribution. The multifunctional platform is a small diesel- or biodiesel-driven engine mounted on a platform, operated commercially at the village level by women's cooperatives, which is capable of powering various equipment for milling, de-husking, pressing, etc., directly, or of generating electricity to charge batteries for lighting, water pumps and productive equipment such as drills and saws.

4. Mechanisms connecting energy with structural transformation

The energy sector is an important part of the economy in its own right. This is most obvious in the case of fuel-exporting LDCs, where fossil-fuel production makes a major contribution to national income, the balance of payments and public finances; and to a lesser, but nonetheless substantial, extent in electricity-exporting countries such as Bhutan and Lao People's Democratic Republic (chapter 2). But even in other LDCs, the energy sector is a significant source of value addition and employment. Its expansion, as electricity production and access are expanded, thus represents a significant part of structural transformation in its own right; and the shift from reliance on traditional biomass to modern forms of energy represents a considerable upgrading within the sector, from predominantly low-productivity activities (collection, processing and distribution of traditional fuels) to much higher-productivity activities (production and distribution of electricity and modern fuels).

However, the role of energy in promoting structural transformation across the economy as a whole greatly exceeds the direct contribution of employment and production in the energy sector itself. This role can be divided into four broad categories of effects: direct impacts of energy access; secondary effects; synergies; and feedback effects.

Direct impacts relate to effects of energy use or access on the sectoral composition of production and productivity within activities. Access to electricity, in particular, can have a major direct impact on structural transformation of the economy, notably by:

- Allowing the adoption of production technologies that increase labour productivity within existing activities;
- Allowing the production of new goods and services that would not otherwise be viable;
- Allowing individuals and enterprises to work for longer or more flexible hours, through the use of electric light.

Access to energy can promote structural transformation through direct and secondary effects, synergies and feedback effects

Secondary effects are those which operate through the availability or increased efficiency of ancillary and support services. Such effects can also be important, both across the economy as whole — as in the case of business support services, whose development can be facilitated by the greater availability of ICTs following electrification — and for individual sectors. In agriculture, for example, the availability of refrigeration can greatly increase the efficiency of agriculture by reducing post-harvest losses, while electric, hydraulic or wind-driven pumps can facilitate irrigation.

Both direct and secondary effects depend on the scale, continuity and reliability of electricity supply, as well as on access.

Synergies with structural transformation arise from the production of modern energy itself, or from measures to reduce biomass use, some of which can also make a substantial contribution to structural transformation. Such synergies arise most notably in the agricultural sector: conventional hydroelectric power generation can provide irrigation, while production of biogas can produce organic fertilizer as a byproduct, both of which help to increase agricultural productivity. Likewise, reduced use of crop residues for energy allows them to be used to fertilize and replenish agricultural land. As well as avoiding or reducing the financial cost of purchasing mineral fertilizers, such use of organic matter provides a much wider range of nutrients, including in particular the organic carbon essential to microorganisms that enhance nutrient cycling (Sanchez, 2002; Modi et al., 2005: box 6.1).

Other examples of synergies beyond the agricultural sector include the use of lakes and reservoirs created by large-scale hydroelectric dams for leisure or tourism facilities; and local production of improved and energy-efficient stoves.

Feedback effects are positive effects on structural transformation that arise over the long term as a result of the effects of access to modern energy on poverty, environmental sustainability and inclusivity:[12]

Energy plays an important role in structural transformation, sustainability, inclusivity and poverty reduction

- Reductions in time devoted to collection of fuelwood and domestic activities free up time, some of which may be devoted to productive activities.
- Improvements in health (as a result of reduced ambient and household air pollution, electrification of health facilities, increased access to information and increased time for rest and recreation) increase labour productivity.
- Improvements in education (through improved child health, reduced time devoted to fuel collection and electrification of schools) increase human capital formation and future labour productivity.
- Reduced income poverty can reinforce these effects by further improving health and education.
- More sustainable use of forest resources can increase the long-term economic contribution of the forest sector.
- Reduced ambient air pollution in rural areas through reduced use of biomass can improve agricultural productivity, particularly in the vicinity of homes.

While these effects are subject to very long and uncertain time lags, and are therefore unlikely to be reflected in empirical analyses of energy and structural transformation, their long-term contribution to structural transformation may be considerable.

D. Energy, sustainability and inclusivity

Sustainability and inclusivity are as central to the 2030 Agenda as economic development. However, structural transformation and the development of productive capacities in LDCs will not, in and of themselves, ensure inclusivity. Equally, while they play a central role in promoting the economic sustainability of development and of poverty eradication, additional consideration is required of other dimensions of sustainability in the environmental, financial, social and political spheres.

Integrating these considerations is thus vital to a coherent approach to achieving the SDGs. This objective provides the basis for the PErSIST (Poverty Eradication through Sustainable and Inclusive Structural Transformation) framework (box 1.2), which seeks to develop a comprehensive and coherent framework for the assessment of the development needs and policies of LDCs in the new and different context presented by the 2030 Agenda.

1. Energy, environmental sustainability and climate change

Globally, the key issue in energy and sustainable development is climate change. However, LDCs have very low CO2 emissions from electricity generation and industrial fossil-fuel use — the main sources globally. They account for 42 of the 50 countries with the lowest such emissions in per capita terms in 2014, with median per capita emissions less than one fiftieth of some developed countries and major oil exporters (Boden et al., 2017).

Nonetheless, most LDCs have set themselves extremely ambitious emission-reduction targets in their intended nationally determined contributions (INDCs) under the United Nations Framework Convention on Climate Change (UNFCCC) (Australian-German Climate and Energy College, 2016). Three quarters (35) of the LDCs have set targets entailing a reduction in their per capita GHG emissions from their 2010 level by 2030, half by between 14 per cent and 48 per cent (excluding land use, land-use change and forestry). If all countries fulfilled their INDCs, 32 LDCs would rank lower in 2030 than in 2010 in terms of emissions per capita, and the number of LDCs among the 30 countries with the lowest per capita emissions globally would rise from 21 to 24.[13]

For some LDCs, particularly fossil-fuel producers, fossil-fuel-based generation is likely to play an important role in generation for grid extension, increasing their GHG emissions (although off-grid solutions based on renewable generation will be more appropriate in many rural areas, as discussed in chapter 3). However, such increases can in principle be offset by emissions reductions through increased access to modern fuels and/or adoption of more fuel-efficient stoves to reduce the use of traditional biomass. While carbon emissions from burning dead wood are offset by those that would otherwise have arisen from its decomposition, this is not the case where trees are cut down or wood is cut from live trees, as is more often the case for urban supply. Moreover, other emissions (of black carbon (soot), methane, carbon monoxide and volatile organic compounds) account for 58-66 per cent of the total on climate forcing (Bailis et al., 2015); and these only occur if wood is burned. Thus the net reduction in GHG emissions resulting from reduced burning of traditional biomass is substantial.

The scale of GHG emissions from traditional biomass in LDCs means that a large-scale substitution towards modern fuels could achieve a meaningful reduction in their overall emissions. GHG emissions from woodfuel in the 37 LDCs for which estimates are available total

Box 1.2. The PErSIST framework

The PErSIST (Poverty Eradication through Sustainable and Inclusive Structural Transformation) framework represents an attempt, on the one hand, to adapt UNCTAD's traditional focus on structural economic transformation to the greater emphasis on the social and environmental pillars of sustainable development embodied in the 2030 Agenda; and, on the other hand, to highlight and make more explicit the essential role of structural economic transformation in the achievement of the SDGs in LDCs.

The PErSIST framework comprises four closely interrelated elements:

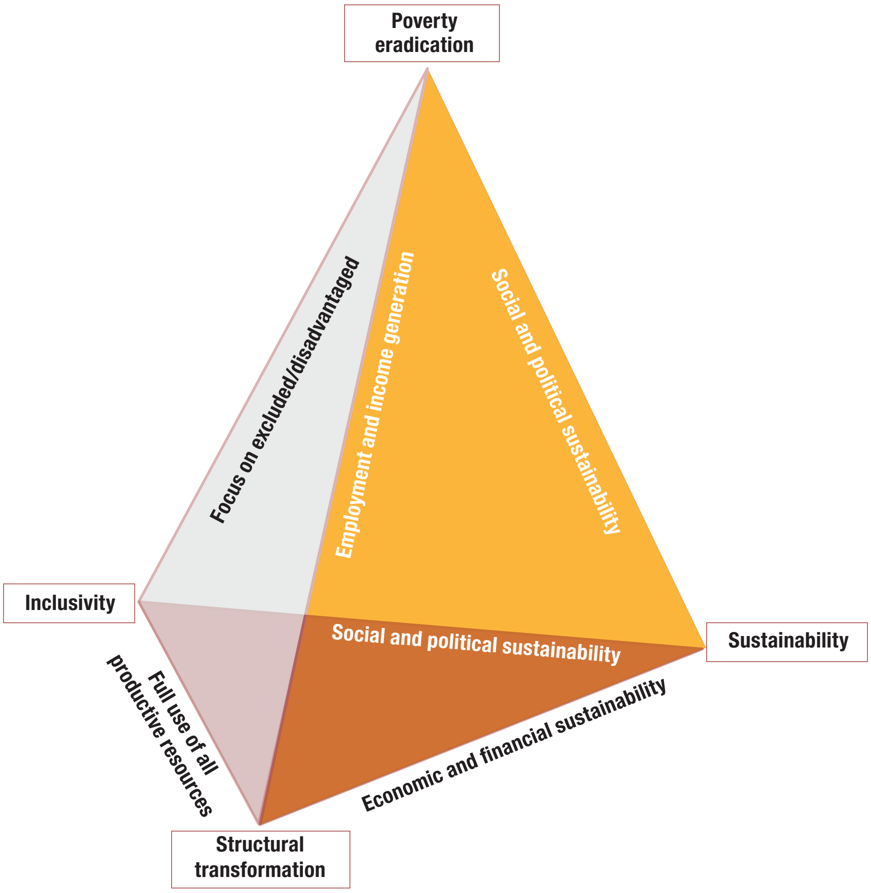
- **Structural transformation** of the economy through the development of productive capacities (section C1);
- **Poverty eradication**, encompassing income poverty (highlighting the need for full employment at incomes above the poverty line), time poverty and multidimensional poverty, based on the capabilities approach (Nussbaum and Sen, 1993) underlying the human development index developed by UNDP;
- **Inclusivity**, in terms of equality of economic opportunities and equity of outcomes for all, irrespective of gender, rural or urban residence, age (including youth and the elderly), race and ethnicity, including people with disabilities and chronic illnesses, refugees and displaced people;
- **Sustainability**, broadly defined to include not only environmental sustainability (based on the concept of ecosystem services and distinguishing between sustainability of national strategies and global environmental externalities), but also economic, financial, social, political and functional[a] sustainability.

The framework highlights a number of requirements for sustainable development (as defined by the SDGs) within each of these areas (box table 1.3), while emphasizing the critical interdependence of the different elements (box figure 1.2).

The PErSIST framework, and its application to energy, is elaborated in a background paper for this Report.

Box figure 1.2

The PERSIST Framework: Interdependence of the core components



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[a] Functional sustainability is defined, within the PErSIST framework, as the ability of systems, facilities, installations, equipment, etc., to remain fully operational over the long term.

Box 1.2 (contd.)

Box table 1.3

The PErSIST Framework: Key principles

	Component			Requirements
Sustainable and inclusive structural transformation	**Structural transformation**			Increasing productivity within economic sectors
				Shift of productive resources from sectors and activities with lower productivity to those with higher productivity
	Sustainability	Environmental	National	Resource use and environmental impacts should remain within or fall progressively towards (nationally) sustainable limits, defined as a level of use of ecosystem services that does not impair the capabilities of future generations
			Global externalities	Generation of global environmental externalities, fully supported by additional external finance and technology transfer
		Economic		Structural transformation
				Effective use of the proceeds of non-renewable resource exploitation to promote the broader development process, so as to reduce dependence on them
		Financial		Essential services provided on a commercial basis should generate an adequate rate of return whilst ensuring affordability to users, including those below the poverty line
				Recurrent costs to the public sector arising from the development process should not exceed its financial capacity
				Limitation of public sector liabilities, including contingent liabilities, in line with capacity to service them
				External liabilities should not exceed the country's long-term capacity to service them
				Dependency on ODA should be progressively reduced over time
		Functional		Systems, facilities, installations, equipment, etc, should remain fully operational over the long term
		Social/ political		The development process should not undermine political stability, and the risk of social tensions (eg as a result of increasing vertical or horizontal inequality or serious economic, human or social costs for particular areas or population groups) should be minimized
	Poverty	Income		Full employment, with minimum labour productivity sufficient to generate incomes above the poverty line, taking account of household size and composition and the labour share in value added
		Time		Limitation of working time (including domestic work) to allow adequate time for rest and leisure
		Multidimensional capabilities		Minimum hourly incomes sufficient for all households to reach the income poverty line while limiting working hours sufficiently to ensure adequate time for rest, recreation and reproductive activities
				Creating a political, social and economic environment which allows material resources to enhance capabilities
	Inclusivity			Progressive improvement in the incomes and capabilities of all disadvantaged groups relative to the remainder of the population and to identifiable advantaged groups
				Progressive reduction in vertical inequality of income and wealth distribution

Source: Woodward (forthcoming).

some 260-390 Mt of CO2 equivalent, around 30 per cent of the world total from this source. This represents some 20-50 per cent of total emissions in Burkina Faso, the Gambia, Guinea-Bissau, Malawi, Mozambique, Somalia and the United Republic of Tanzania; and 50-80 per cent in Bhutan, Burundi, Eritrea, Ethiopia, Haiti, Lesotho, Liberia, Nepal, Rwanda and Uganda (Bailis et al., 2015).

Burning of traditional biomass is also an important source of ambient (outdoor) and more particularly household (indoor) air pollution, respectively the sixth and eighth greatest risks to health globally (Forouzanfar et al., 2016). Both exposure levels and health impacts are especially high in non-island LDCs,[14] two thirds of which are among the top one third of all countries in terms of exposure, while the associated burden of disease is on average twice as great in non-island LDCs as in ODCs.

The difference between LDCs and ODCs is still greater in terms of indoor air pollution, of which traditional biomass is the main source. LDCs account for 39 of the 45 developing countries with the greatest health burden, and suffer an average health impact 10 times that in ODCs. Health effects can be reduced by switching from traditional biomass to modern fuels or through the use of improved stoves, although the latter may not lower household air pollution below the threshold level at which health risks are substantially reduced (Tielsch et al., 2016; Mortimer et al., 2017).

While it plays a limited direct role in deforestation, woodfuel use is a potentially important cause of forest degradation (reducing biomass density within forests), which can contribute to later deforestation, as well as having substantial direct implications for climate change (Hosonuma et al., 2012). Forests typically account for between 10 and 50 per cent of the land area of LDCs; and the great majority of them experience a significant degree of deforestation, with reductions of forest area generally between about 5 per cent and 25 per cent between 1990 and 2010. Woodfuel typically accounts for between 85 and 95 per cent of total wood production in LDCs (FAO, 2011: tables 2 and 4; FAO, 2014: annex 3). In woodfuel "hotspots" across LDCs in East Africa and South Asia, and in Haiti, less than 50 per cent of total fuelwood use is estimated to be replaced by natural growth (Bailis et al., 2015).

Woodfuel supply to urban areas, being larger in scale and more commercialized in nature than collection for domestic use in rural areas, gives rise to more intensive wood extraction, contributing to forest degradation across a radius as wide as 200-300 km around major cities such as Bamako, N'Djamena and Kinshasa (Hansfort and Mertz, 2011; van der Plas and Abdel-Hamid, 2005; Schure et al., 2010).

Thus, integrating wider access to electricity with more efficient use of biomass and access to modern fuels as part of a broader agenda for universal access to modern energy can generate synergies, rather than tensions, between energy access and environmental goals. Not only are potential increases in GHG emissions from increased electricity generation limited by the use of renewable technologies, but they are also offset by emissions reductions and avoidance of deforestation and forest degradation from reduced reliance on traditional biomass.

However, this hinges in part on transformational energy access raising incomes through structural economic transformation. When households gain access to modern fuels, they typically substitute only partly for traditional biomass — a process known as "fuel stacking" (Sepp, 2014; Sepp et al., 2014). A decisive reduction in the use of traditional biomass requires the availability of modern fuels to be accompanied by higher incomes (Nilsson et al., 2012; Pachauri et al., 2012; Sepp, 2012, 2014). It also depends on access to the external finance, technology transfer and technical support needed to facilitate the adoption of renewable energy technologies, as discussed in later chapters.

Access to modern energy can reduce poverty through effects on job creation, productivity and structural transformation

2. Energy, inclusivity and poverty

The core principle of the 2030 Agenda is one of inclusivity — "leaving no one behind" — and this applies as much to universal access to modern energy as to other SDGs. Universal access means access for all socially excluded or disadvantaged population groups, whether defined by age (youth and the elderly), gender, race, ethnicity, religion or residence, and equally encompassing people with disabilities and chronic illnesses, indigenous peoples, migrants, refugees and displaced people. Access to energy is of particular importance in terms of the rural-urban divide (section B3).

Access to modern energy also has the potential to reduce poverty in various dimensions. The two-way relationship between income poverty and limited access to basic energy services gives rise to a potential energy-poverty trap — a vicious circle that contributes to the poor remaining poor (Karekezi et al., 2012) in many respects, a vicious cycle in which people who lack access to cleaner and affordable energy are often trapped in a re-enforcing cycle of deprivation, lower incomes and the means to improve their living conditions while at the same time using significant amounts of their very limited income on expensive and unhealthy forms of energy that provide poor and/or unsafe services. Access to cleaner and affordable energy options is essential for improving the livelihoods of the poor in developing countries. The link between energy and poverty is demonstrated by the fact that the poor in developing countries constitute the bulk of an estimated 2.7 billion people relying on traditional biomass for cooking and the overwhelming majority of the 1.4 billion without access to grid electricity. Most of the people still reliant on traditional biomass live in Africa and South Asia. Limited access to modern and affordable energy services is an important contributor to the poverty levels in developing countries, particularly in sub-Saharan Africa and some parts of Asia. Access to modern forms of energy is essential to overcome poverty, promote economic growth and employment opportunities, support the provision of social services, and, in general, promote sustainable human development. It is also an essential input for achieving most Millennium Development Goals. Access

> **Access to modern energy can empower women to participate more effectively in structural transformation**

to energy is constrained by lack of income, but itself constrains income by limiting economic opportunities, productivity, time budgets and mobility, especially in rural areas.

The primary effect of access to modern energy on income poverty occurs through its contribution to job creation, increased productivity and structural transformation.[15] However, the net effect depends on the balance between employment creation effects, increased capital intensity of production arising from greater use of mechanical equipment in production, and reduced income opportunities in woodfuel supply, particularly to urban areas. Thus, promoting favourable labour market outcomes is a key policy issue in relation to modern energy access, particularly in the context of the 2030 Agenda.

For many households, especially in rural areas, access to modern energy also has important implications for time poverty, due to the time spent in collecting traditional biomass, particularly fuelwood (Woodward, forthcoming). Reducing biomass consumption can thus free up time, either for income-generating activities (where opportunities exist) or for rest and recreation.

Health benefits from reduced indoor air pollution are important as well (section E2); and education may also be enhanced by increased access to information (through radio, television and ICT), freeing up children's time from fuel collection, and allowing study in the evenings. Additional benefits to health and education may arise from the electrification of facilities, and in rural areas from improved retention of health professionals and teachers. These effects are reflected in a positive correlation between electricity access and the human development indicator among LDCs (figure 1.16). Limited energy access is thus an important mechanism underlying the vicious circle of economic and human underdevelopment that constrains the development of LDCs (UNCTAD, 2014: 47, chart 20).

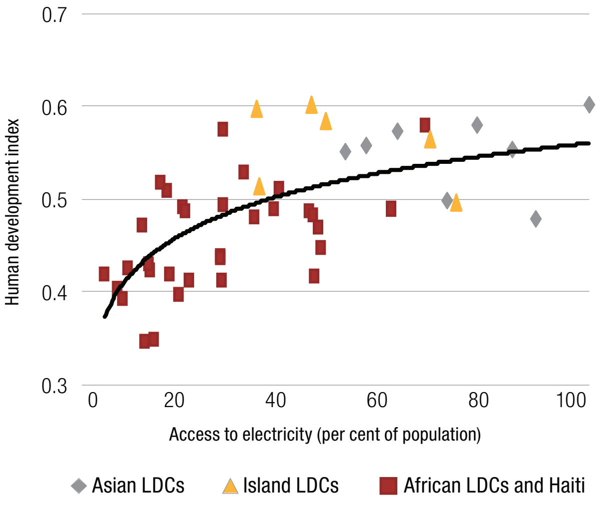
Many of these effects, particularly exposure to indoor air pollution and time poverty, vary significantly by gender — another important dimension of inclusivity. However, discussion of the gender aspects of these issues is often subject to oversimplification and overgeneralization. This highlights the complexities of gender issues, whose critical dependence on local cultures makes careful consideration of the specific context essential.

While women often bear a disproportionate share of the time costs of collecting fuelwood, evidence from LDCs suggest that this pattern is by no means as universal or as pronounced as is sometimes assumed.[16] It also appears to be limited to adults in rural areas, and is subject to marked local and seasonal differences. National analyses suggest that the overall amount of time spent collecting wood is relatively limited (between 8 and 32 minutes per person per day, even among rural women); but time costs are much greater in particular localities and for the minority of people engaged in wood collection.

Of greater importance may be the less direct impacts of energy access on the time spent on other domestic activities. Lack of access to electricity (and deficiencies in basic services more generally) may reinforce gender differences in time use within households and in labour allocation, by increasing the time required for domestic activities which are traditionally undertaken by women. For example, access to modern fuels or improved biomass stoves can reduce cooking times; household access to electricity can reduce food preparation times by allowing mechanized processing;[17] and availability of electricity at the community level can contribute to access to water, reducing the time required for water collection. Such changes can have a significant effect in freeing up women's and girls' time for other activities (Energia, 2017). Cooking, for example, is a more universal household activity, takes substantially more time overall, and is more strongly and more consistently gendered across cultures and contexts, for both children and adults (e.g. Kammila et al., 2014: figure 9), and has the additional benefit of reducing women's (and men's) exposure to household air pollution.

Figure 1.16

Access to electricity and the human development index, LDCs, 2014



Source: World Bank, World Development Indicators database and UNDP Human Development Index database (accessed June 2017).

Notes: The solid line indicates the logarithmic trend across all observations.

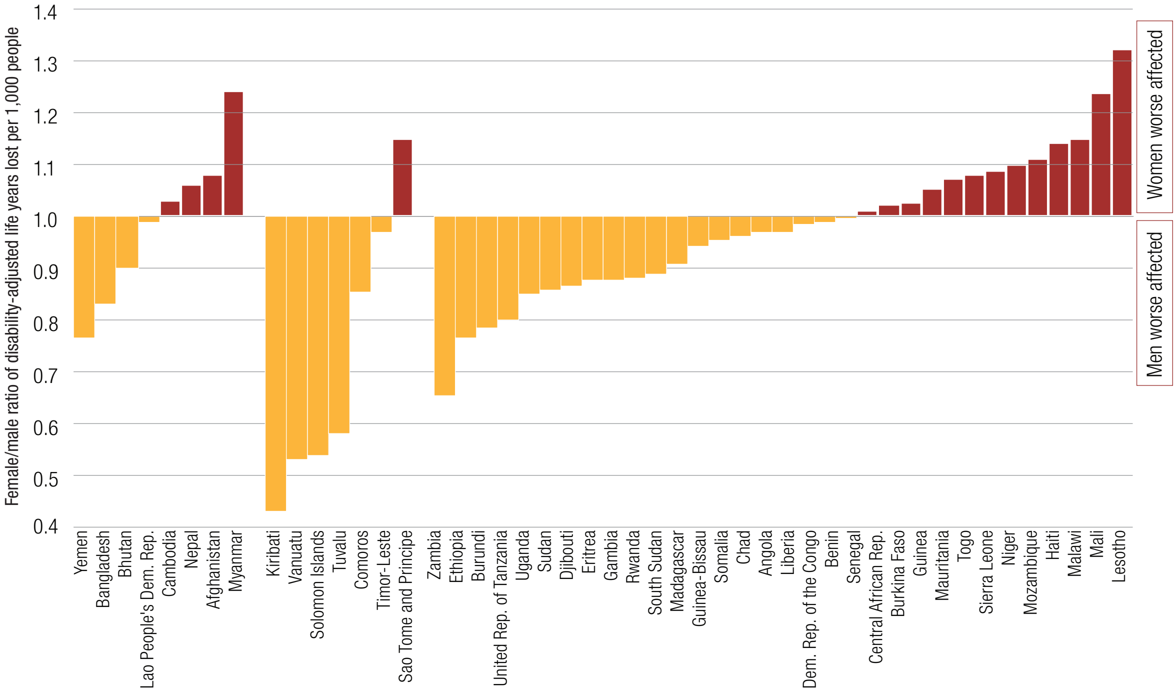
While there is little doubt that women are more exposed than men to indoor air pollution, estimates of the associated burden of disease suggest that this greater exposure is not translated into systematically greater health impacts. Asian LDCs are equally divided between those where the burden of disease from household air pollution is greater for women and those where it is greater for men; and it is greater for men in a majority of the Africa and Haiti group and all but one (Sao Tome and Principe) of the island LDCs (figure 1.17). This appears to be because men have higher background levels of the major diseases involved (lung cancer, cardiovascular disease and chronic obstructive pulmonary disease), so that a given level of exposure is more likely to result in chronic illness, disability or death (less serious health effects not being reflected in the data) (Smith, 2012).

Two other aspects of electrification have particularly important gender dimensions. First, access to electricity can increase access to information through radio, television and ICT, which may benefit women's empowerment and well-being, particularly in rural areas, by exposing them to information, ideas and influences beyond their communities. This may contribute to changing social norms, improve women's health and increase their educational opportunities through distance learning, especially in areas where there are constraints to their access to formal education. Second, the availability of electricity is essential to street lighting, which can increase women's freedom of movement (and potentially their options for participation in economic activities) by improving their physical security.

Gender roles in decision-making are also critical to the adoption of new energy-using technologies such as stoves, as women are typically the primary users of energy within the home, while men are the primary decision makers on technology adoption. Gender sensitivity is thus particularly important in promotion and marketing, as is engagement of women in the design of improved stoves, to ensure that designs meet women's (culturally specific) needs and expectations (Puzzola et al., 2013).

Figure 1.17

Gender balance of burden of disease from household air pollution



Source: UNCTAD Secretariat estimates, based on data from World Health Organization: Household air pollution burden of disease by country, 2012: All countries, http://apps.who.int/gho/data/view.main.HAPBYCAUSEBYCOUNTRYv, and population data from World Bank, World Development Indicators database (both accessed March 2017).

Note: The burden of disease is an estimate of the premature death and disability caused by different diseases and risk factors, expressed as disability-adjusted life years lost. The number of years for which people are affected by a disability is weighted according to the severity of the disability.

By increasing demand, transformational energy access can help make investments in energy systems more viable

E. Conclusion

SDG 7 establishes universal access to modern energy as an agreed goal of the global community. This has profound implications for the LDCs, which account for the majority of people worldwide without access to electricity, reflecting a very wide and growing access gap between LDCs and ODCs. In large measure, this in turn reflects the historical effects of LDCs' particular geographical and economic circumstances — a characteristic combination of limited urbanization, low rural population density and lack of resources that represents a serious impediment to the establishment of centralized generation systems. New and emerging renewable energy and mini-grid technologies (and associated reductions in their costs) have a revolutionary potential to overcome these challenges, if the obstacles to their widespread application can be overcome; and universal access by 2030 remains an immensely ambitious goal, whose achievement will be critically dependent on action by the global community commensurate with this ambition.

Access to energy plays a critical role in the sustainable and inclusive structural transformation that is essential to poverty eradication and the achievement of the other SDGs. Central to this role is the productive use of electricity, which both translates access into structural economic transformation and helps to generate the demand needed to make investments in generation and distribution viable. However, this requires going beyond an exclusive focus on social and environmental aspects of energy that results in a neglect of its economic role, and beyond definitions of access that are limited to the physical connection of households to sources of electricity for domestic use. Realizing the full developmental potential of access to modern energy requires "transformational energy access" — energy supplies and technologies that meet the needs of producers and of structural economic transformation.

Notes

1 Major initiatives include Sustainable Energy for All (SE4All); Power Africa, initiated by the United States Agency for International Development; and the Energy Africa initiative of the United Kingdom Department for International Development. Major reports on the subject in recent years have included the 2011 edition of the International Energy Agency's flagship World Energy Report (IEA, 2011), which included a section on Energy for All; the Africa Progress Panel's 2015 Africa Progress Report and their follow-up study Lights, Power, Action: Electrifying Africa (Africa Progress Panel, 2015, 2017); and the World Bank's State of Electricity Access Report (World Bank, 2017b).

2 As well as "ensur[ing] universal access to affordable, reliable and modern energy services" (7.1), the SDG targets for 2030 include "enhanc[ing] international cooperation to facilitate access to clean energy research and technology… and promot[ing] investment in energy infrastructure and clean energy technology" (7a) and "expand[ing] infrastructure and upgrad[ing] technology for supplying modern and sustainable energy services for all" (7b).

3 The definition, concept and measurement of energy access are discussed in section D1 of this chapter.

4 The irregularities in the trend shown in figure 1.2 reflect changes in the estimated worldwide figures, largely as a result of apparent year-to-year inconsistencies in the recorded level of access in India. In particular, the recorded access rate fell from 59.6 per cent in 2000 to 55.8 per cent in 2001, and from 76.3 per cent in 2010 to 67.6 per cent in 2011.

5 Based on data from WDI (accessed May 2017).

6 It is important to note, in interpreting statistics which disaggregate between rural and urban areas, that there is no internationally agreed definition of the distinction between the two, and that there are significant differences between national definitions. Among LDCs, the broadest definitions of rural areas are in Cambodia, Ethiopia and Liberia, which classify all settlements with more than 2,000 inhabitants as urban (with additional criteria relating to population density and agricultural production in Cambodia). Other countries use definitions based on administrative status, the narrowest definition being in Burundi, which considers only the capital, Bujumbura, to be urban, classifying the remainder of the country as rural. These variations give rise to inevitable issues of cross-country comparability in all data relating to rural and urban areas, especially in the latter category, as relatively large towns and areas of an urban nature outside the administrative boundaries of designated towns may be classified as rural (UNCTAD, 2015a: 21; UN DESA, 2016a: 118–122).

7 It should be noted that these figures do not accurately reflect the rural-urban split of the increase in access

required for universal access by 2030, which will also be affected by rural-urban migration in the years leading up to then. However, this issue is complicated, as the rate of rural-urban migration is itself likely to be affected by changes in rural and urban access to electricity.

8 It should be emphasized that this assessment is indicative of the order of magnitude of the acceleration required in the rate of increase in access, rather than as providing precise estimates. Aside from the high level of uncertainty regarding current access levels even in those countries excluded from the analysis (box 1.1), this also depends on population projections, which are inevitably subject to uncertainties. In addition, it implicitly assumes that the average household size in each country will change at the same rate in 2014–2030 as in 2004–2014, although in practice this may be affected by changes in the evolution of demographic variables.

9 For comparison, one hour of light with a typical 60-watt incandescent bulb requires 0.06 kWh, and keeping it lit continuously requires 500 kWh per year.

10 The time trend of net installed capacity typically combines long static periods with occasional abrupt jumps, corresponding to the deployment or decommissioning of large-scale generators. Consequently, growth rates, even over long periods, can be highly sensitive to the precise period considered.

11 For comparison purposes, generating capacity across all LDCs is only slightly higher than the total net installed capacity of Sweden (about 40 Gigawatts in 2014), and somewhat lower than that of Thailand (53 Gigawatts).

12 These are the other elements of the PErSIST (Poverty Eradication through Sustainable and Inclusive Structural Transformation) framework outlined in box 1.2.

13 UNCTAD secretariat estimates, based on INDC targets from Australian-German Climate and Energy College (2016).

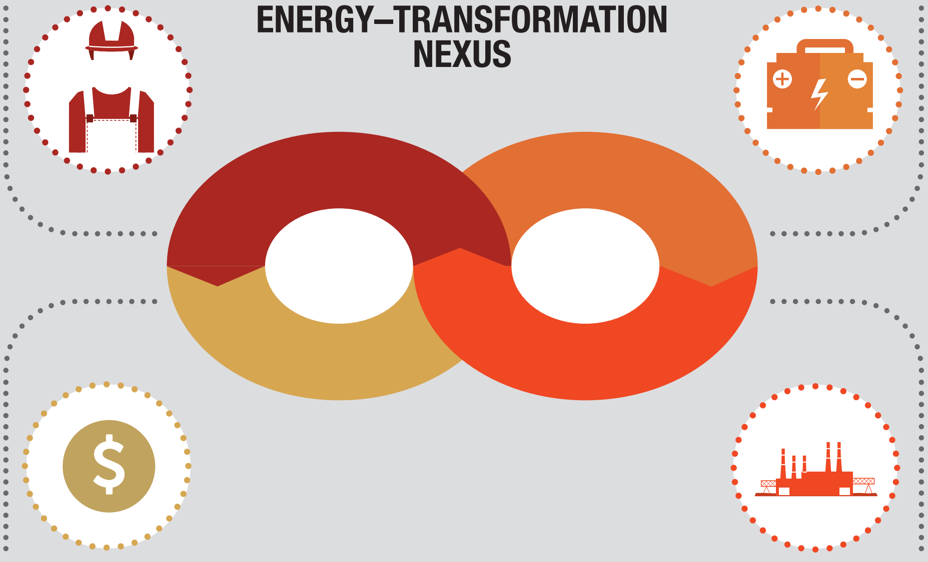
14 Most island LDCs have low levels of ambient air pollution, reflecting their particular geography, with populations widely spread across multiple islands far from external sources of pollution.

15 Additional benefits in terms of income poverty may arise from financial savings, where electricity becomes available at a lower cost than existing means of lighting (primarily kerosene).

16 Men have been found to spend more time collecting fuel in Madagascar, three of four areas studied in Bangladesh, and by a particularly wide margin in Tigray (Ethiopia) (Charmes, 2006; Practical Action, 2016; Kammila et al., 2014). A more detailed picture of the available evidence on gender patterns of time use in wood collection in LDCs is provided in Woodward (forthcoming).

17 It should be noted, however, that domestic electrical appliances are often unavailable in rural markets, even where there is access to electricity, reflecting the dominance of men in decision-making (Cabraal et al., 2005).

ENERGY–TRANSFORMATION NEXUS



Demand for electricity

Transformational energy access

Investment in electricity infrastructure

Productive uses of electricity

42% of LDC firms identify electricity as **a major constraint**

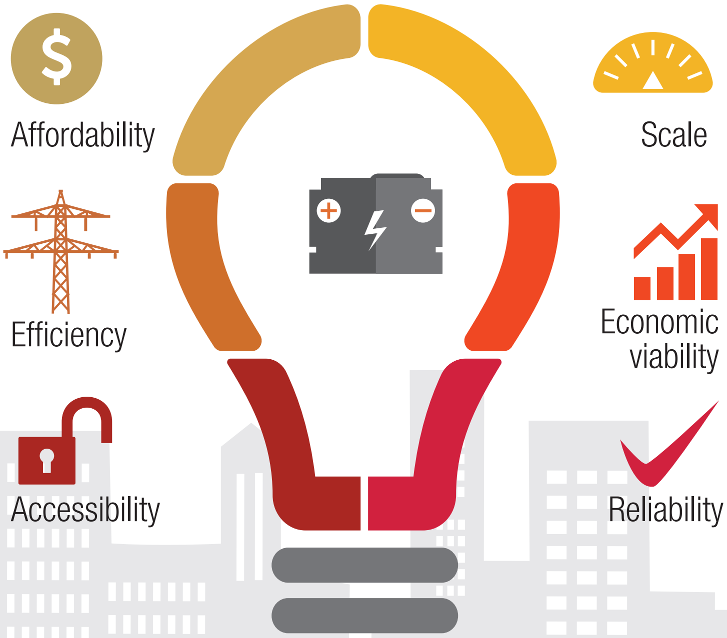
3/4 experience an average of **10 outages per month, lasting 5 hours each**

7% revenue **lost due to outages**

TRANSFORMATIONAL ENERGY ACCESS

=

sufficient, reliable and affordable energy for all types of productive use



CHAPTER 2

Energy and inclusive economic structural transformation

CHAPTER 2

Energy and inclusive economic structural transformation

A. Introduction

Energy plays a key role in economic structural transformation, especially through its indirect effects on production possibilities and productivity in other sectors. At the same time, structural transformation is critical to economically sustainable growth and rising incomes. Together, structural transformation and rising incomes provide the means of overcoming one of the key constraints to development of the electricity sector — the inadequacy of demand. Rising household incomes increase domestic demand; and structural transformation leads to expanding demand for productive uses. This circular relationship — the energy-transformation nexus — is central to the development process.

This chapter analyses the complex interaction between energy systems and energy services on the one hand and the changing composition and level of sophistication of output, employment and exports, on the other. It discusses the linkages between energy supply and sustainable and inclusive structural transformation. Following an examination of the patterns of energy supply and demand in least developed countries (LDCs) and their differences from other groups of countries in section B. Section C elaborates on the energy-transformation nexus. This is followed by a discussion of the enabling role of modern energy in relation to other sectors in section D, and of the direct contribution of the energy industry to LDC economies in section E, while section F presents the interaction between gender, energy and development. Section G concludes by presenting the requirements for the energy sector to fully realize its potential contribution to sustainable development through transformational energy access.

The electricity-transformation nexus is central to development

B. Energy sources and applications for productive use

1. Energy transition and economic development

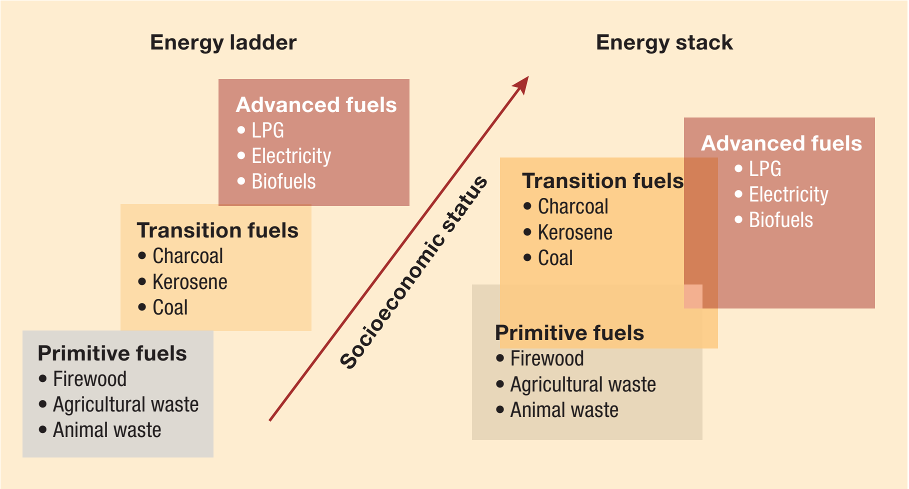
The relationship between energy and economic development is complex. It is often described as an "energy ladder" (as shown in figure 2.1) that characterizes changes in energy sources as development progresses and incomes rise.

At low levels of income and economic development, economies rely predominantly on traditional biomass, such as fuelwood, charcoal, dung, and agricultural or household waste, for cooking and space heating, and on human power for productive agricultural and industrial activities. These sources are replaced gradually by processed biofuels (charcoal), kerosene, animal power and some commercial fossil energy in the intermediate stages of the evolution and eventually by commercial fossil fuels and electricity in more advanced stages of structural transformation and economic development (Barnes and Floor, 1996).

However, this process is not a simple linear progression from one type of fuel to another. Rather than clearly switching from one energy source to another, households and productive units typically combine different types of fuels along the development path.

Figure 2.1

The energy transition process



Source: Bhatia and Angelou (2015: 48).

They continue to use the same energy sources as their incomes rise, but add new and more modern sources for particular purposes. The concurrent use of these different types of fuel at any given point in time is called "fuel stacking" or "energy stacking", as shown in the right side of Figure 2.1. Households and productive units use a progressively wider range of sources as their incomes and energy use increase, initially without necessarily reducing their absolute use of sources at lower levels of the energy ladder (Toole, 2015). Combined with wide variations in household incomes, rural-urban differences and the coexistence of different types and scales of enterprises, this means that a broad range of energy-use patterns prevails within the economy at any point in time during the energy transition.

The higher rungs of the energy ladder are characterized by the predominance of cleaner and more efficient fuels, such as electricity, liquid fuels and modern biomass. Another important feature of the energy transition is that the sources of primary energy become progressively diversified to include hydroelectric power (hereafter hydro), fossil fuels, nuclear power and modern renewables (solar, wind, tidal).

Electricity is the most versatile form of energy, providing means of lighting, motive power, product heating and cooling, space heating, and information and communication technologies (ICTs) and entertainment (table 3.1). It is also considered to be one of the best forms of energy commodities to deliver modern, economically viable, affordable, efficient and reliable energy services. Therefore, electricity occupies the highest position on the energy ladder and is regarded as the cleanest (to end-users) and most efficient of all fuels on the ladder (table 2.1) (Toole, 2015). It is also expected to play an even greater role in the future worldwide energy matrix as its use for transport services expands.

The different features of energy sourcing according to development level are illustrated by the composition of total primary energy supply (TPES) of different country groups. TPES is a measure of the energy inputs to an economy. It equals production of energy products plus imports minus exports minus international bunkers plus or minus stock changes. Typically, developed countries have a more diversified energy mix between coal, oil products, natural gas, nuclear and renewables.

Table 2.1

Productive application and energy source matrix

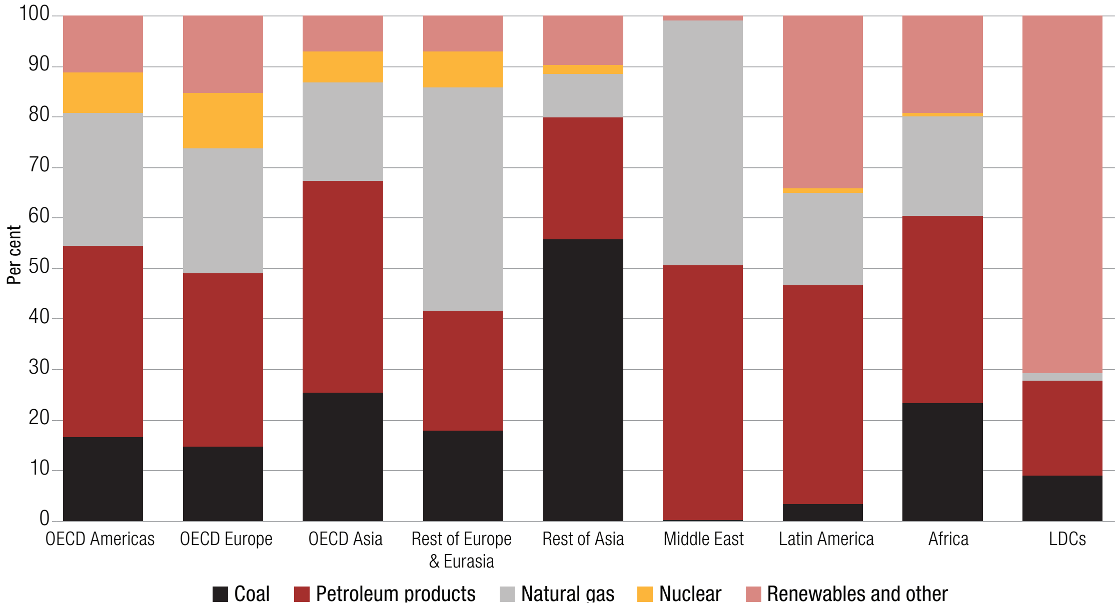
		Lighting[a]	ICT & entertainment	Motive power	Space heating	Product heating
Energy Source	Electricity	✓	✓	✓	✓	✓
	Fuel			✓		
	Renewable mechanical energy			✓		
	Renewable thermal energy			✓		
	Animal power			✓		
	Human power			✓		

Source: Bhatia and Angelou (2015: 139).

Note: a - Only electrical lighting is considered here – candles, kerosene lamps, and other solid- or liquid-based lighting fuels are considerd as no access.

Figure 2.2

Composition of total primary energy supply by country groups, 2014



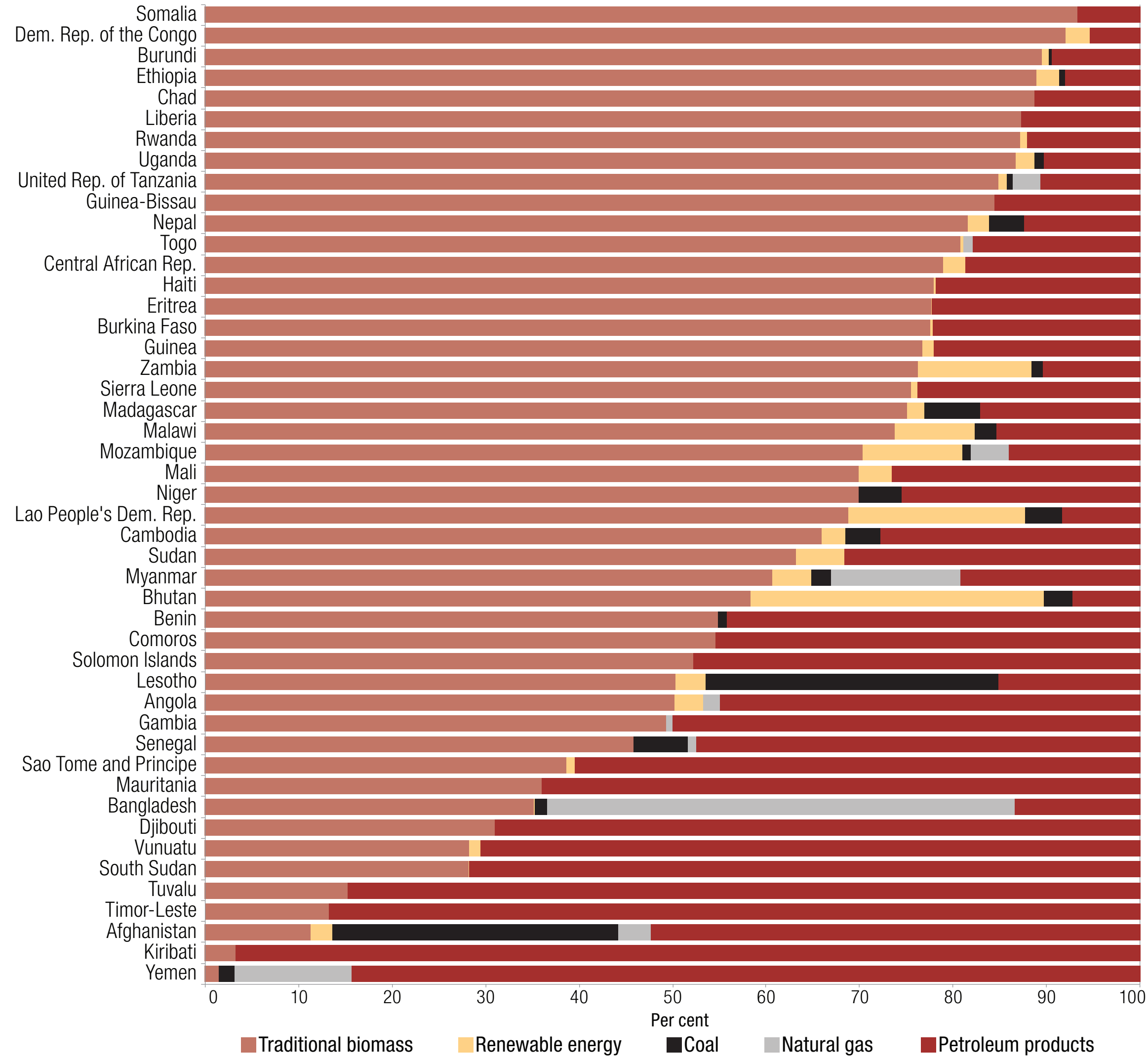
Source: IEA (2016b); UN DESA (2016b).

By contrast, as a group, LDCs have a much less diversified energy supply than other country groups, both developing and developed (figure 2.2). Across LDCs as a whole, traditional biomass accounts for 59 per cent of the TPES, being used mainly domestically for cooking and heating, while 9 per cent of TPES is from renewable energy sources, almost entirely from hydro. The remainder consists of fossil fuels, mainly oil products (19 per cent) and coal (9 per cent), while natural gas represents only 2 per cent of TPES. Only the Middle East, where almost the entire primary energy supply is derived from oil products and gas (but is equally divided between the two), shows a comparable lack of diversification. Apart from LDCs, only in Latin America and the Caribbean do biomass and renewables account for more than one fifth of energy supply, partly reflecting widespread use of biofuels.

Traditional biomass (wood, agricultural waste, dung) is the main source of energy in LDCs, unlike developed countries and other developing countries (ODCs), where the group “renewables and other” consists mostly of modern renewable energy sources. In a quarter of LDCs, traditional biomass accounts for more than 80 per cent of total primary energy use; in half it is between 50 per cent and 80 per cent. This leaves only a quarter of LDCs in which it does not represent the majority of primary energy used. In most cases, the remainder is made up mainly of oil products, though with significant contributions in a few cases from natural gas (particularly in Bangladesh and to a lesser extent Myanmar and Yemen), coal (most notably in Lesotho and Afghanistan) and renewable energy (mainly hydroelectricity, particularly in Bhutan and Lao People’s Democratic Republic, with smaller contributions in Malawi, Mozambique and Zambia). In the remaining 37 LDCs, sources of energy other than traditional biomass and oil products account for less than 10 per cent of the total, and in half of all LDCs less than 2.5 per cent (figure 2.3).

Figure 2.3

Structure of total primary energy supply in LDCs, 2014



Source: UN DESA (2016b).

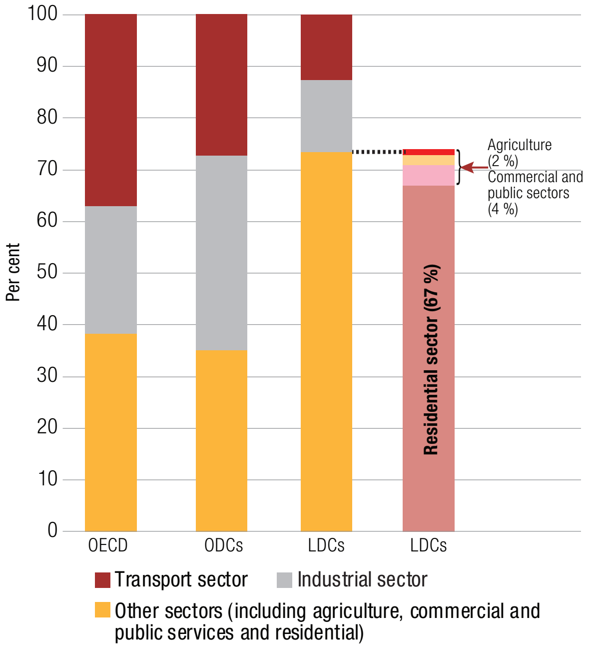
2. Patterns of energy use in LDCs

The relationship between energy, development and structural transformation is reflected not only in the combination of energy fuels used at each stage of the process, but also in the composition of energy demand. At lower levels of development, households account for the bulk of energy consumption, given scant levels of industrialization and the more limited use of energy for transportation. In LDCs the residential sector is responsible for two thirds of total final energy consumption, as compared with less than 40 per cent in ODCs and developed (Organisation for Economic Co-operation and Development (OECD)) countries (figure 2.4).

While electricity is a minor component in total energy supply of most LDCs, it is destined mainly for productive uses. Industry accounts for 45 per cent of total final electricity consumption, and other productive sectors (such as the commercial sector and the energy sector itself) for 19 per cent. At the same time, households generate approximately one third of final electricity demand (figure 2.5).

Figure 2.4

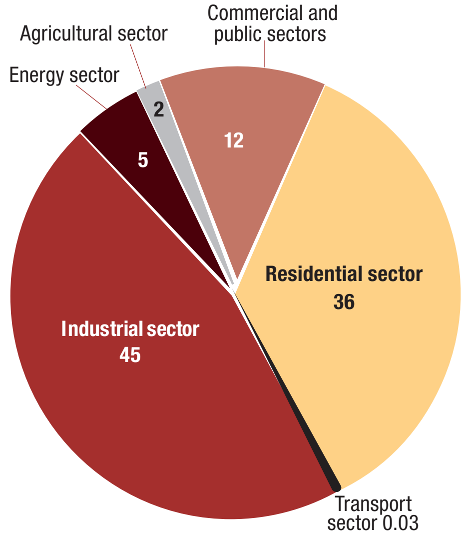
Total final energy consumption by sector, LDCs, ODCs and OECD countries, 2014



Source: IEA (2016b); UN DESA (2016b).

Figure 2.5

Total final electricity consumption per sector in LDCs, 2014



Source: UN DESA (2016b).

C. The energy-transformation nexus

The expansion of production — economic growth — requires increased energy inputs (given an unchanged level of energy efficiency). At the same time, economic growth means higher demand for energy, especially in low- and middle-income countries. There is therefore an association between economic growth and higher energy use, which, in turn implies higher energy production.

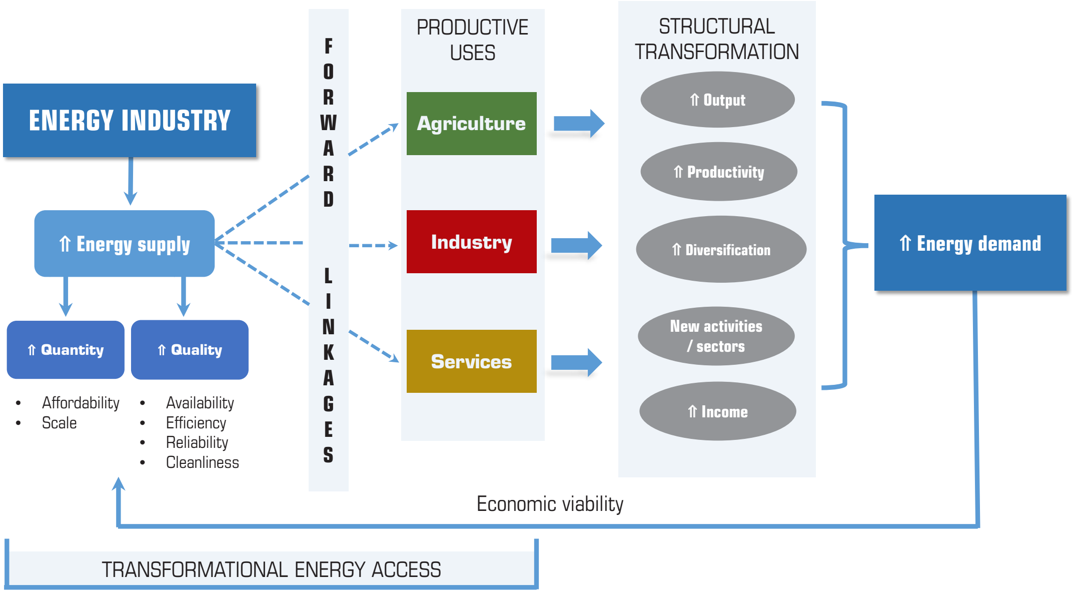
A similar two-way relationship arises in the case of economic structural transformation. This process entails the expansion and diversification of production – through the production of new goods and services and the establishment of new sectors and industries – the adoption of new technologies, and gains in productivity (chapter 1). These changes require additional energy use, both for ongoing production and for fixed investment in new productive capacities. Structural transformation also increases domestic energy use by raising household incomes. This two-way relationship is encapsulated in the energy-transformation-nexus represented in figure 2.6.

The question that arises is: does economic growth and/or structural transformation cause energy consumption to increase (by increasing energy demand)? Or does higher energy consumption or production bring about economic growth (by allowing the expansion of output) and/or structural transformation (by allowing the adoption of new technologies and the development of new economic activities? In other words, is there causality between energy consumption or production on the one hand, and growth and/or structural transformation on the other?

The issue of the existence and direction of causality between energy and economic growth has been extensively researched, as reviewed below. The association between energy and structural transformation, by contrast, has received relatively little attention. UNCTAD has accordingly undertaken original research in order to better understand it.

Figure 2.6

The energy-transformation nexus



Source: UNCTAD secretariat.

1. Causality between energy and economic growth

The literature on the existence and direction of causality between economic growth (gross domestic product (GDP)) and energy has proposed — and tested — four hypotheses (Omri, 2014):

- *The growth hypothesis:* unidirectional causality running from energy consumption to GDP growth. This implies that energy plays an important role in economic growth both directly and indirectly in the production process as a complement to labour and capital. Energy may thus be both an enhancing and a limiting factor in the growth process.
- *The feedback hypothesis:* two-way causality between energy consumption and GDP growth. This implies that the two are interrelated and may serve as complements to one another.
- *The conservation hypothesis:* unidirectional causality running from GDP growth to energy consumption. This implies that economic expansion raises energy consumption, but the process could possibly produce inefficiencies and a reduction of demand for goods and services, including energy.
- *The neutrality hypothesis:* no link between energy consumption and GDP growth. This hypothesis considers energy consumption to be a small component of GDP expansion and thus to have little or no effect on growth.

Numerous empirical studies have been made using different datasets, time frames, country coverage and econometric techniques and have reached contrasting conclusions. Recent literature reviews have been made summarizing the findings of these studies. Eggoh et al. (2011) and Lemma et al. (2016) survey studies on the relationship between energy and growth in developing countries, while Omri (2014) does this for both developed and developing countries (but only the latter are reported here), spanning different periods from 1950 to 2009. Their findings are summarized in figure 2.7.

Between 50 per cent and 63 per cent of the studies indicate an important contribution of energy to the process of economic growth, as they find evidence to support either the growth or the feedback hypotheses. The conservation hypothesis finds less supporting empirical evidence, in 28 per cent to 29 per cent of the studies. Finally, the hypothesis of no causality between energy and economic growth is indicated by just 13 per cent to 22 per cent of the studies under review.

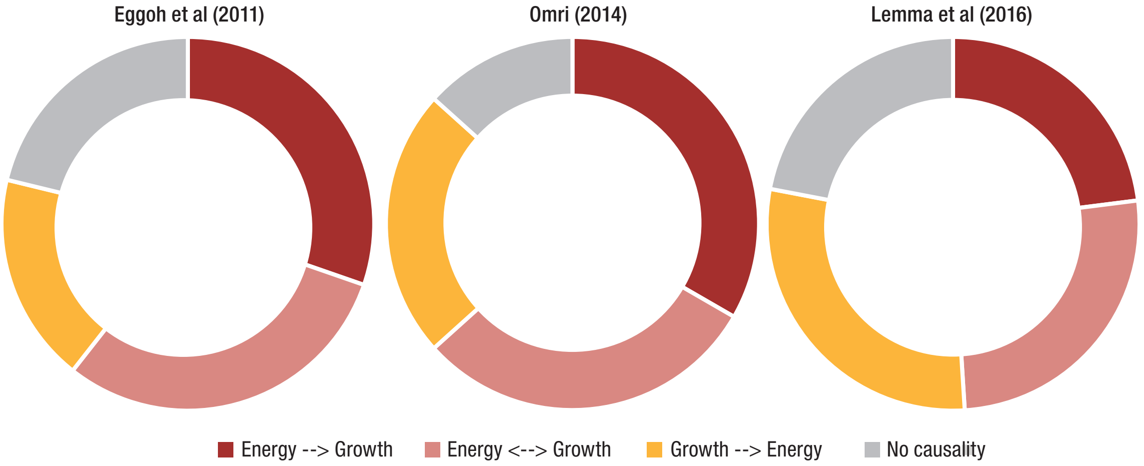
Pueyo et al. (2013) and Omri (2014) perform a similar exercise for electricity and growth. The former concentrates on developing countries, and this report presents the results of the latter solely for these countries. The findings are summarized in figure 2.8.

The role of electricity in contributing to economic growth seems to be stronger than that of all other forms of energy, as the finding of no causality is less frequent in the former case (just 14 per cent in one of the reviews and not at all in the other – figure 2.8) than in the latter (figure 2.7). A direction of causality from electricity to growth, or reciprocal causality between them, is backed by 63 per cent to 72 per cent of the studies. The conservation hypothesis is supported in 23 per cent to 28 per cent.

Figure 2.7

Findings of studies on causality between energy and growth

(Share of studies surveyed by type of causality found, per cent)

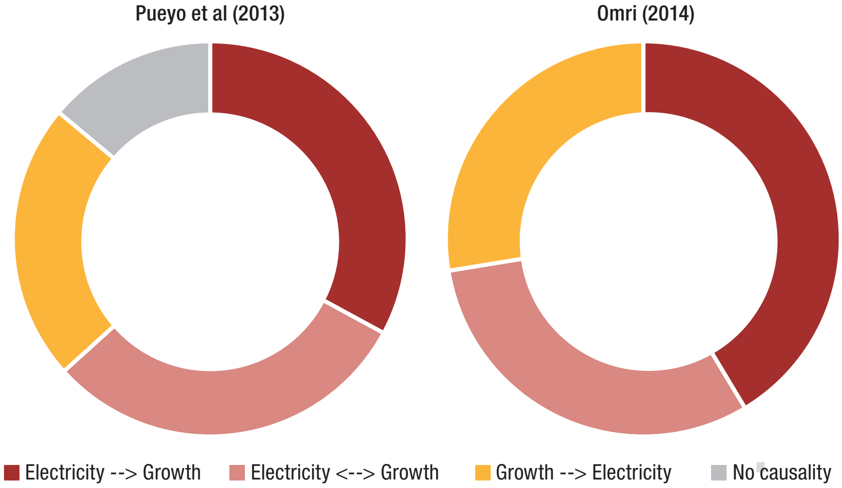


Source: UNCTAD secretariat elaboration, based on the cited references.

Figure 2.8

Findings of studies on causality between electricity and growth

(Share of studies surveyed by type of causality found, per cent)



Source: UNCTAD secretariat elaboration, based on the cited references.

It is likely that the relationship between energy consumption — and particularly in electricity access and use — and growth may differ across different levels of development, and consequently differ between LDCs and ODCs. Since a large majority of the population of ODCs already has access to electricity, increases in use are overwhelmingly attributable to existing users consuming a greater quantity. In LDCs, by contrast, a much greater part of any increase in electricity consumption is due to households and enterprises starting to use electricity for the first time. This might be expected to make the effect of increasing energy use on growth stronger at earlier stages of development. Moreover, it is likely that such growth is more transformational, since it allows the use of technologies that could not previously be used, and the emergence of previously impracticable or unviable economic activities.

The conservation hypothesis, from growth to energy use or electricity consumption, also has a particular significance in LDCs. There, the net environmental costs from increasing electricity demand, in the wider context of a transition to universal access to modern energy sources, are much more limited; and increased demand plays a key role in promoting investment in electrification.

2. Causality between energy and structural transformation

The use of energy in productive sectors, and economic structural transformation, together play a key role in the potential virtuous circle of increasing energy supply and demand. They are therefore at the heart of the energy-transformation nexus (figure 2.6). On the one hand, it is primarily through productive use and structural transformation that access to electricity generates economic growth. On the other hand, given the limited potential for domestic use at current levels of income in LDCs, a substantial increase in productive use (e.g. by agriculture and industry) is needed if demand is to be increased sufficiently to raise rates of return to a viable level.

In order to deepen the discussion of the previous session while focusing on LDCs and building on that line of research, UNCTAD has made estimates to gauge the existence and direction of causality between energy supply, and economic growth and structural transformation in both LDCs and ODCs. Economic growth is measured by GDP per capita, while structural transformation is proxied by the labour productivity of the major economic sectors — agriculture, industry and services — and of manufacturing as a subsector of industry. The analysis is based on a panel regression of data for 25-37 LDCs and 48-66 ODCs (with country coverage differing between definitions of energy use according to data availability for each) between 1990 and 2015.[1]

Three energy variables are used: TPES, total electricity supply (TES) and primary electricity supply (PES).[2] TPES includes both traditional and modern forms of energy, and is overwhelmingly dominated by traditional biomass in LDCs, but not in ODCs (figure 2.3). The electricity variables (TES and PES), by contrast, are a proxy for modern energy supply. In the LDC context, electricity accounts for the bulk of modern energy supply.[3] The results of the exercise are reported in table 2.2.

The econometric results indicate a direction of causality from economic growth to energy (the conservation hypothesis) in LDCs for TPES. They also show causality in both directions (the feedback hypothesis) for the two electricity variables (TES and PES). This indicates a stronger role for modern energy in LDCs in two respects. First, electricity plays a stronger role in LDCs than other forms of energy, since the reciprocal causality is found only in the case of electricity (TES and PES), but not for TPES. Not only does electricity supply allow economic growth, but at the same time economic growth also creates demand, which stimulates electricity supply. Second, this latter relationship is found in LDCs, but not in ODCs (table 2.2).

Modern energy affects structural transformation more in LDCs than in ODCs

The results for the relationship between energy supply and structural transformation show a similar pattern, i.e. first, a stronger role for modern energy than for other forms of energy in the LDCs, and second, a more intense relationship between energy and structural transformation in LDCs than in ODCs, given the more frequent causality links found. There is a reciprocal causality between electricity supply (TES and PES) and structural transformation in LDCs, as indicated by the confirmation of the feedback hypothesis for labour productivity of agriculture and industry (including manufacturing). Policies targeting the development of modern energy supply would thus have an impact on these sectors of the economy.

In the case of TPES, by contrast, the results indicate that structural transformation in agriculture increases energy supply, but TPES does not cause structural transformation. This is likely due, again, to the weight of traditional forms of energy in the prevailing energy matrix of LDCs, especially in rural areas. They do not have as strong a transformational potential as electricity. In the case of industry and its manufacturing subsector structural transformation, TPES brings about structural transformation, which is explained by the fact that in these sectors the share of modern forms of energy in TPES is larger than in other types of economic activity or in households.

Table 2.2

Type of causality between different forms of energy and economic growth or structrural transformation in LDCs and ODCs

	Form of energy					
Causality between different forms of energy and:	Total primary energy supply		Total electricity supply		Primary electricity supply	
	LDCs	**ODCs**	**LDCs**	**ODCs**	**LDCs**	**ODCs**
GDP	conservation	conservation	feedback	conservation	feedback	conservation
Agricultural labour productivity	conservation	feedback	feedback	feedback	feedback	feedback
Industrial labour productivity	growth	feedback	feddback	feddback	feedback	feedback
Manufacturing labour productivity	growth	growth	feedback	neutral	feedback	neutral
Services labour productivity	feedback	feedback	growth	neutral	growth	neutral

Source: UNCTAD secretariat estimations.
Note: For the meaning of the types of causality, the econometric methods and data sources, see main text.

Energy facilitates the transformational innovations, structural change and productivity growth that drive structural transformation

The services sector has a different pattern from agriculture and industry. Modern energy contributes to structural transformation of the sector in LDCs, while there is a reciprocal causality in the case of total energy. This is likely explained by the characteristics of the services sector in LDCs, wherein a large part consists of traditional and mostly informal services, which tend to consume more traditional forms of energy and fuel as compared with modern forms of energy.

The relationship between energy supply and structural transformation is stronger in LDCs than in ODCs. The reciprocal causality between electricity supply and structural transformation is found for agriculture and industry for both LDCs and ODCs. For those sectors which are most dynamic in ODCs — manufacturing and services — however, there is a difference between these groups of countries. LDCs experience the same two-way relationship for manufacturing and electricity causing structural transformation in services. In ODCs, however, no causality was found. This is likely due to the fact that electricity access is much more widespread among ODCs than LDCs and it thus has less of a transformational impact. Still, there seems to be a stronger role for total energy supply in these sectors in ODCs.

There is sufficient evidence to postulate that energy and electricity matter for enhancing sectoral labour productivity and, by extension, for promoting structural transformation in LDCs.[4] This finding underscores the crucial importance of developing wider and more reliable energy and electricity services in these countries. There are significant feedback effects running from increased access to and use of energy services on the supply side, to sectoral productivity improvements that in turn strengthen demand for increased and more efficient energy services, as encapsulated in the energy-transformation nexus (figure 2.6). However, for that nexus to operate fully, LDCs need to attain transformational energy access, as explained in the following analysis.

D. The energy sector and economic structural transformation

1. The enabling role of modern energy in structural transformation

The crucial importance of energy in the process of economic structural transformation stems from its role as an input to most production processes. Energy can be considered as a production factor alongside labour and capital (physical and human). Energy has increasing returns not only in the production and distribution of energy products (i.e. in the energy industry per se), but especially when energy products are used as inputs by other sectors and industries. This means that the rise in the use of modern energy has multiplier effects on the productivity of the other factors of production (e.g. electricity and industrial machinery, petroleum products and highways) (Toman and Jemelkova, 2003).

The transformational role of the historical energy transition from traditional to modern forms of energy in the United States has been described in the following terms:

> Energy was not only cheap and abundantly available but increasingly in forms (i.e. electricity and fluid fuels) that were flexible in their use compared to solid fuels that had previously dominated energy supply … These characteristics of energy supply — low cost, abundance and enhanced flexibility in use — provided a rich soil for the discovery, development and use of new processes, new equipment, new systems of production and new industrial locations. The most important effect of these imaginative new applications was to quicken the pace of technical advance, and this showed up in improvements in the efficiency of productive operations …. [E]lectric motors and improvements in electrical control equipment brought with them a flexibility in industrial operations previously impossible to achieve.
>
> (Schurr, 1984: 415, 419)

More recent research has confirmed the continuing fundamental role of energy in productivity growth at an economy-wide level (Murillo-Zamorano, 2003).

Similarly, in developing countries — including LDCs — more reliable, affordable and efficient energy supply can make viable the adoption of new technologies, production techniques and the making of new products, and can raise productivity. This is true for industry, but also for agriculture and services. In other words, adequate supply of modern energy can allow the structural transformation of the rural economy, industrialization and the establishment or expansion of a modern services sector.

The pervasiveness of adequate energy as a condition, enabler and multiplier of the effects of the development of productive capacities highlights the role of energy — and especially electricity — as a quintessential form of general-purpose technology (GPT). GPTs can trigger innovations that have enormous transformational powers by leading to innovational complementarities in other downstream and upstream sectors (David and Wright, 2003).

> Most GPTs play the role of enabling technologies, opening up new opportunities rather than offering complete, final solutions. For example, the productivity gains associated with the introduction of electric motors in manufacturing were not limited to a reduction in energy costs. The new energy sources fostered the more efficient design of factories, taking advantage of the newfound flexibility of electric power … This phenomenon involves what we call Innovational complementarities (IC), that is, the productivity of R&D [research and development] in a downstream sector increases as a consequence of innovation in the GPT technology. These complementarities magnify the effects of innovation in the GPT, and help propagate them throughout the economy.
>
> (Bresnahan and Trajtenberg, 1995: 84)

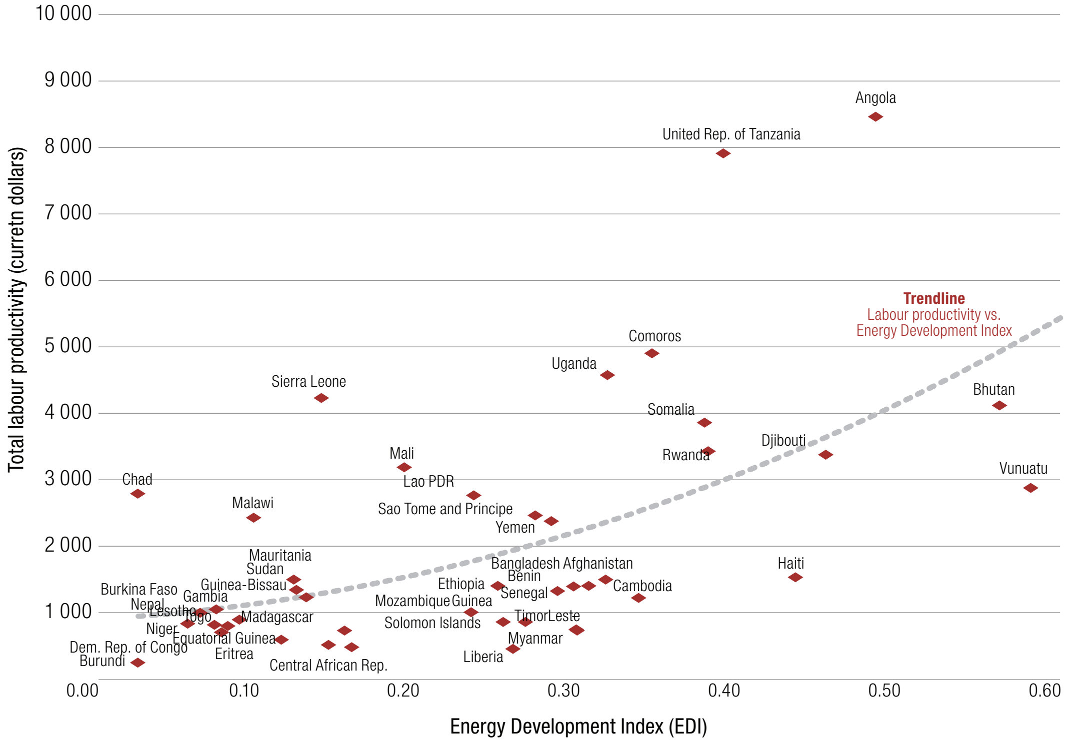
Electrification and the increased use of electrically operated equipment and machinery can enable a reallocation of resources towards higher-productivity sectors and activities (in a process of structural change), while enhancing the productivity of existing economic inputs, thus contributing to aggregate productivity growth. An essential feature of economic structural transformation is productivity growth, both at an aggregate level and at a sectoral level. There is a strong correlation between labour productivity (an indicator of partial productivity) and the Energy Development Index (EDI) in LDCs,[5] as shown in figure 2.9, indicating a close association between the level of energy development and productivity.

As well as being a GPT itself, electricity allows the utilization and diffusion of other GPTs that can lead to significant structural change matched by productivity surges, as in the case of ICT in the 21st century.

Modern energy also plays a role in technological development and innovation, which are essential components of economic structural transformation. Elements of infrastructure (especially electricity and ICTs) are considered to be components of developing countries' technological absorptive capacities, as "a greater level and quality of infrastructures … increases the country's capability to absorb, adopt and implement foreign advanced technologies" (UNCTAD, 2014a: 8). Absorptive capacity and innovative capability are major dimensions of national innovation systems.

Figure 2.9

Energy development and labour productivity, 2014



Source: UNCTAD secretariat calculations, based on data from UN DESA (2016b) and UNCTAD, UNCTADStat database (accessed May 2017).
Note: For the definition of the EDI, see footnote 5.

Therefore, modern energy plays a major role in allowing technological learning and diffusion throughout the economy.

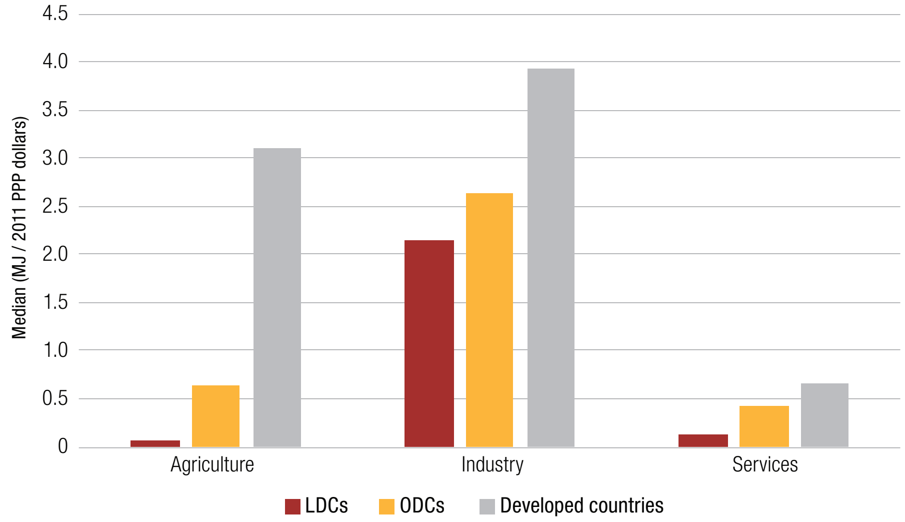
2. Energy as an essential input to production

By supplying affordable, reliable and abundant energy services to all other economic sectors and industries, the energy industry can help to realize its potential for creating increasing returns and fostering innovation and rising productivity and thereby contribute to economic structural transformation, as analysed above. The consequences are that the energy intensity of economies rises in tandem with the process of structural transformation, which can also be observed on a sectoral basis. The energy intensity in the three major economic sectors is systematically higher in ODCs than in LDCs and higher in developed countries than in ODCs (figure 2.10).

On the other hand, if the energy industry is not capable of supplying energy services in adequate quantity and quality, it can act as a brake on structural transformation. This is often the case in LDCs. Scant reliability of electricity supply means that on average three fourths of LDC firms experience electrical outages, as opposed to 60 per cent in ODCs and less than 20 per cent in developed countries. The negative consequences of the absence of reliable electricity supply are especially felt by Asian LDCs, which are more industrialized than other LDCs and therefore suffer more from outages. Asian LDCs also experience more frequent outages than other country groups (typically 17 outages per month), and although their outages are shorter (3.4 hours, as compared with 5.4 hours in African LDCs), they suffer more losses: 8 per cent of annual sales, higher than in other country groups (Table 2.3). Since the impact of unreliable electricity supplies on competitiveness is likely to vary with firm size, sector, capabilities and context (Scott et al., 2014), and

Figure 2.10

Sectoral energy intensity by country groups, 2014



Source: UNCTAD secretariat calculations, based on data from the Global Tracking Framework (accessed August 2017).

Table 2.3

Selected indicators related to electricity in enterprise surveys

(Latest year available, 2005–2016)

	Percent of firms experiencing electrical outages	**Number of electrical outages in a typical month**	**If there were outages, average duration of a typical electrical outage (hours)**	**If there were outages, average losses due to electrical outages (% of annual sales)**	**Percent of firms owning or sharing a generator**	**If a generator is used, average proportion of electricity from a generator (%)**
Least developed countries	74.4	9.9	4.8	7.0	51.2	30.0
of which:						
African LDCs and Haiti	79.5	9.0	5.4	6.7	52.7	28.5
Asian LDCs	65.8	17.2	3.4	8.0	43.4	32.5
Island LDCs	67.6	2.4	2.8	4.9	50.6	15.3
ODCs	60.0	6.1	5.0	4.3	33.0	20.5
Developed countries	19.4	0.3	3.0	0.5	5.4	4.0

Source: UNCTAD secretariat calculations, based on data from World Bank, Enterprise Surveys (accessed July 2017).
Note: Figures for country groups are unweighted averages of country figures.

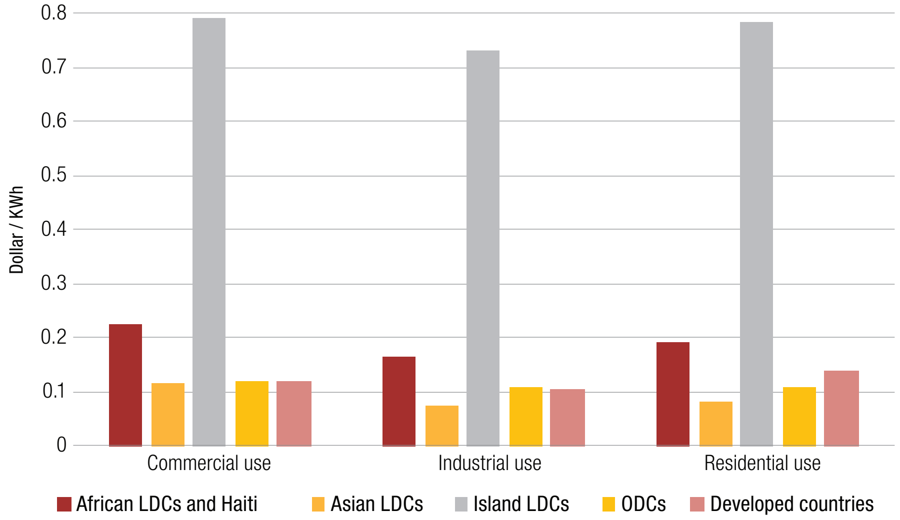
enterprise surveys tend to focus on larger enterprises, these figures may understate the challenges to micro and small enterprises, which tend to face higher costs in purchasing generators (Bhatia and Angelou, 2015).

The response of enterprises to unreliable energy supply is to sink part of their capital into back-up equipment: more than half of LDC firms own or share a generator (as opposed to one third among ODCs and just 5.4 per cent in developed countries). This equipment is indispensable for the running of LDC companies, as it generates almost one third of their total electricity consumption (well above ODCs' one fifth and a scant 4 per cent in developed countries) (table 2.3).

Another crucial failing of the energy system in most LDCs is its high electricity prices. On average, industrial and commercial consumers pay twice as much for electricity as the corresponding consumers in ODCs or in developed countries. Still, there are considerable

Figure 2.11

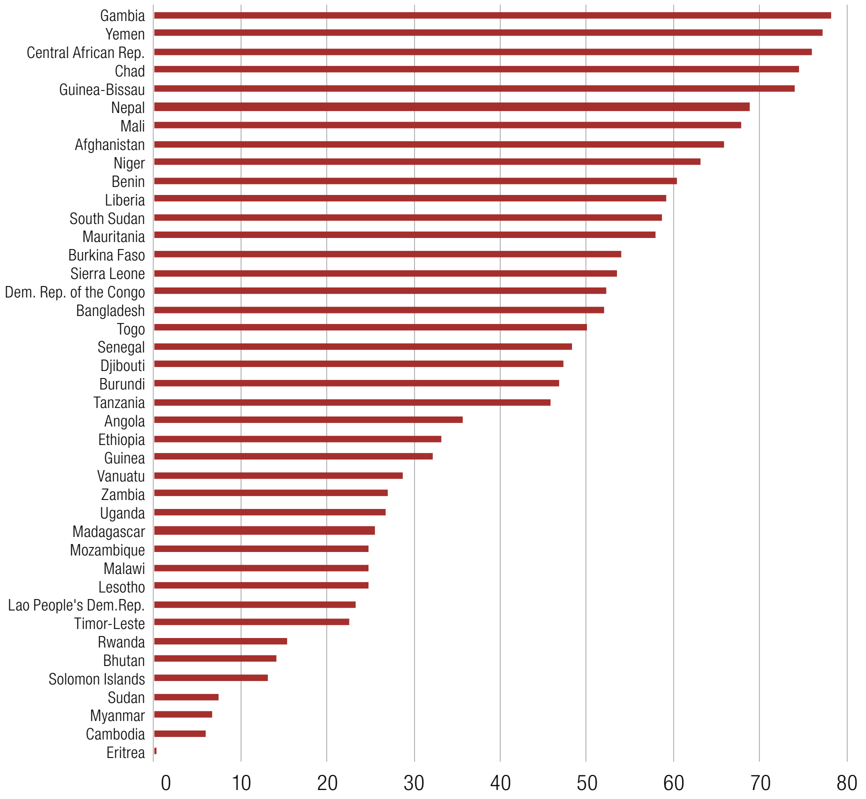
Average retail electricity tariff by end-use, latest available data



Source: UNCTAD secretariat calculations, based on data from World Bank RISE database (accessed May 2017).

Figure 2.12

Per cent of firms identifying electricity as a major constraint, latest available year



Source: World Bank, Enterprise Surveys (accessed July 2017).

Energy can promote productivity growth and structural change across all economic sectors

variations among LDC subgroups. Firms in African LDCs and Haiti face tariffs similar to those of the LDC group average, while those in island LDCs are some four times higher. By contrast, retail tariffs in Asian LDCs are similar to those of ODCs and developed countries (figure 2.11).

One consequence of the failure of most LDC energy systems to supply affordable, reliable and accessible electricity in the required quantities is that 42.1 per cent of LDC firms identify electricity as a major constraint to their business operations (as opposed to one third in ODCs and some 15 per cent in developed countries). In 18 LDCs more than half of all firms do likewise (figure 2.12).

The failings of the energy system have major adverse consequences for the running and competitiveness of LDC firms, especially those operating in the tradables sector. They face higher energy costs than their competitors, due to: 1. Higher energy prices; and 2. The presence of capital sunk into back-up equipment, which has not only a direct cost, but also an opportunity cost, since the corresponding amounts could otherwise be more productively invested. These challenges also hamper LDC firms' expansion, employment generation and moving up the value chain. The state of infrastructure is a key pillar of a country's overall competitiveness. In the face of unreliable access to electricity, domestic and foreign investors are discouraged from investing in economic sectors that are capital- and energy-intensive, including manufacturing and especially its higher value added branches. In other words, the present state of energy systems in LDCs slows down their economic structural transformation. Some sectoral aspects of the energy-transformation nexus are analysed below.

a. Agriculture / Rural activities

In rural areas, productive and household activities evolve towards more modern, efficient and diversified forms of energy as incomes rise (reflecting the energy transition outlined in figure 2.1). A faster transition from traditional energy sources (traditional biomass and use of human and animal labour) to modern energy forms can potentially accelerate rural development and rural economic transformation in LDCs. The introduction and scale-up of electrical energy, and of electrically or modern fuel-operated machinery and equipment, can enhance agricultural productivity and increase rural production and food security through its effects on irrigation, land preparation, fertilization, harvesting, agroprocessing, and food and inputs storage and conservation. Access to irrigation through electric pumps can reduce the dependence of LDCs on rain-fed agriculture and lessen their vulnerability to weather and climatic shocks. This potential is especially important for African LDCs, which have the world's lowest proportion of irrigated agriculture (UNCTAD, 2015a). Increased access to high-quality energy services also enables farmers to move up the agricultural value chain and explore production and trade opportunities in its higher value added segments. Infrastructure constraints (including inadequate electricity) have been identified as major impediments to farmers investing in processing along the livestock value chain (IFAD, 2010).

The lack of access to a reliable and affordable source of either electricity or diesel fuel hampers the development of adequate cooling and refrigeration systems in developing countries, especially in rural areas, leading to food losses and food waste.

In order to reduce food losses along the agricultural value chain, investments in post-harvesting technologies are needed to allow small farmers to better produce, process and store agricultural commodities. Energy, especially electricity, plays a pivotal role in this regard. Access to low-cost but dependable energy in LDCs has the following potentials: 1. Facilitating investment in superior post-harvesting technologies, e.g. cold chains; 2. Reducing food losses along the agricultural value chain; and 3. Upgrading production, e.g. from harvest of raw agricultural produce to processed foodstuffs (FAO, 2016). Table 2.4 provides examples of energy use patterns according to stages of agricultural value chains.

Historically, increased electrification has often induced positive productivity shocks in agriculture, which in turn have had substantial positive spillover effects on manufacturing and industrialization (Matsuyama, 1992; Johnson, 1997).

b. Industry

At present, industry accounts for a relatively small share of final electricity demand in LDCs, thanks to the combination of two factors. First, manufacturing — the foremost component of industry — represents a small share of GDP: 2.4 per cent in island LDCs, 8.1 per cent in African LDCs and Haiti, and 15.7 per cent in Asian LDCs in 2014, as compared with 20.7 per cent in ODCs. The second factor is the structure of the manufacturing industry in LDCs, which reflects the abundance in labour and land of most LDCs (but not the abundance of several of them in minerals), and also their scarcity of adequate energy supply. LDC manufacturing is dominated by low-technology,

Table 2.4

Classification of agricultural value chains by technology

Categories	Commodities /Technologies	Energy sources
Low tech (<5 kWh/day)	Field packing of leafy, stem, or fruit vegetables, root, tuber and bulb crops, fruits and berries	Electric grid; solar power with battery back-up
Basic tech (5 to 25 kWh/day)	Packinghouse operations and pre-cooling for tropical and subtropical fruits and vegetables; evaporative cool storage. (Temperature range 15°C to 20°C)	Solar water heater, electric grid; generator (diesel or gas); hybrid PV / generator systems with battery back-up
Intermediate tech (25 to 200 kWh/day)	Cooling and cold storage for temperate fruits and vegetables. (Temperature range 0°C to 7°C)	Electric grid; generator (diesel or gas)
Modern tech (>100 kWh/day)	Automated packinghouse operations,pre-cooling and cold storage for any kind of fruits and vegetables. (Temperature range down to 0°C)	Electric grid; diesel back-up generators

Source: Puri (2016).

labour-intensive and non-energy-intensive sectors. Apparel, food and beverages, and wood products together account for more than half of manufacturing value added (MVA) in these countries (figure 2.13). By contrast, energy-intensive sectors, such as basic metals, non-metallic minerals, paper and paper products, coke and petroleum refining, contribute just 28 per cent of the group's combined MVA. The problems of energy supply in LDCs have not prevented the establishment and persistence of some types of manufacturing, but have been an obstacle to their expansion and upgrading.

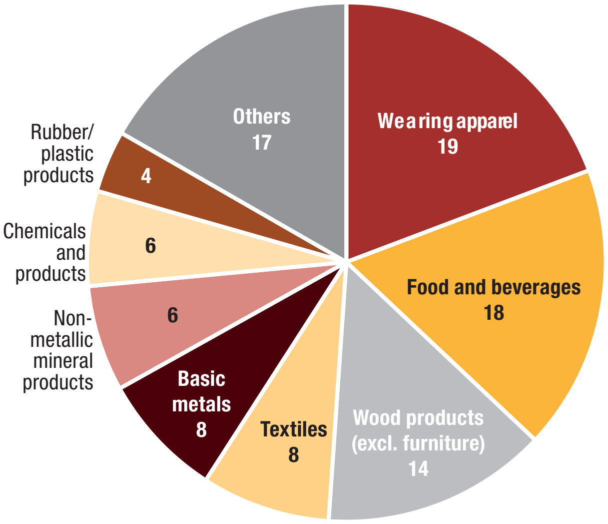
The relative contribution of factors (capital, labour, natural resources, energy and productivity) to manufacturing growth varies according to the technological intensity of sectors and the economy's stage of development. The decomposition of the long-term growth of the manufacturing sector in both developing and developed countries has shown that at low income levels, the growth of output in low-tech, labour-intensive sectors (e.g. apparel, textiles, leather goods) tends to be driven by labour. This is likely the situation of LDCs, most of which are low-income countries (UNIDO, 2016).[6] As economic growth progresses and economies reach middle-income status, energy becomes a stronger contributor to growth than either capital or labour. It can thus be expected that energy inputs will become even more critical for the growth of low-tech industries in LDCs as they develop and reach middle-income status.

The long-term expansion of medium-tech resource-based sectors (e.g. non-metallic minerals, rubber and plastics) in middle-income countries is pushed by natural resources and energy (UNIDO, 2016). As mentioned above, such sectors are energy-intensive, and currently account for a lesser part of MVA in LDCs. However, one possibility for the expansion and diversification of manufacturing often recommended for resource-rich LDCs is natural-resource processing. This applies to LDCs in both Africa (Page, 2015; UNECA and AUC, 2013; Ramdoo, 2015) and Asia (Myanmar, Yemen). It would mean stepping into the transformation of raw materials like fuels, metals and other minerals, and establishing forward linkages from the extractive industries through activities like smelting and refining of metals, refining of crude oil, processing of gas, basic processing and further value addition of metallic raw materials, etc.[7] These are all options that contribute to economic structural transformation, diversification and job creation. However, they are also energy-intensive activities and industries. Therefore, this route of industrialization depends on reliable and affordable energy (especially electricity) in order to become viable to a much greater extent than the currently dominant low-tech manufacturing sectors. The quantum leap and qualitative shift in energy requirements brought about by this type of structural transformation are embodied in the notion of transformational energy access (section F).

Figure 2.13

Structure of LDC manufacturing industry, 2011–2014

(Per cent of total manufacturing value added)



Source: UNCTAD secretariat calculations, based on data from UNIDO, INDSTAT2 - Industrial Statistics Database (accessed July 2017).

Note: Based on data for Bangladesh, Burundi, Eritrea, Ethiopia, Malawi, Myanmar, Nepal, Senegal, the United Republic of Tanzania and Yemen, which together account for 58 per cent of LDC manufacturing value added.

c. Services

Energy plays a role in enabling the development and productivity and efficiency rise in several services sectors, especially some of the more modern and higher value added ones. This is obvious in the case of transport services (land, air and water), which depend heavily on the availability, reliability and affordability of fuels. The complementarities between fuels and infrastructure operated by the sector (roads, airports, railways, gas stations, etc.) can allow it to provide efficient transport services to other sectors (e.g. bringing agricultural and manufacturing products to market). Logistics services share several of these features with transport services.

There is also strong synergy between energy and ICT services (two GPTs), as mentioned above: electricity is required for the continued operation of the ICT industry and enables innovation therein. Energy also has an impact on the performance of two services sectors that are crucial for the long-term formation of an economy's human capital: education and health, as shown in section C.4 below.

As the services sector progresses towards a greater relative weight of knowledge-intensive sectors, the energy intensity increases somewhat, given that the use of ICT hardware and the Internet becomes more pervasive. This long-term trend can be observed from the energy intensity of the sector, which in developed countries is five times higher than in LDCs (figure 2.10). However, more important than the quantity of energy consumed by the services sector at higher stages of development is its quality. Here, power disruptions can lead to data losses, supply disruptions and communication interruptions, just as it does in manufacturing; hence, the importance of reliable and affordable energy supply.

The development of the services sector is part of the process of structural transformation, through several mechanisms:

- The process of structural transformation entails not only the growth of the share of services in output and employment, but also the diversification within the services sector itself, especially the transition from low value added and often informal services (e.g. personal services, street vending) towards higher value added services (e.g. business services, engineering services).
- The transformation of the services sector entails rising labour productivity in the sector, which contributes to higher economy-wide labour productivity.
- Increasingly, services provide an outlet for the diversification of LDC exports. The share of services in the total exports of goods and services of LDCs rose from 12.5 per cent in 2005 to 19.1 per cent in 2016. For two African LDCs, for instance, energy-related or energy-powered services have become export growth sectors. Ethiopia has successfully become an international provider of air cargo services; Lesotho has become a provider of hydro transmission services to South Africa (Balchin, 2017).
- As structural transformation progresses, specialized services increasingly become an indispensable input to other activity sectors, including agriculture and manufacturing, as intersectoral linkages become more dense and complex. Services are most likely to have a supporting role in accelerating structural transformation in countries that have a dynamic manufacturing industry with fast productivity and income growth (UNCTAD, 2016a). In Ethiopia, the availability of efficient air transport services has been instrumental in diversifying the country's merchandise exports towards flower and horticultural products (Balchin, 2017). Generally, efficient transport and logistics services are a precondition for the operation and expansion of manufacturing and agriculture.

3. Backward linkages

The energy industry establishes backward linkages with providers of inputs of goods and services, both in the investment phase (i.e. when energy production, transmission and distribution facilities are being built) and in the operations phase of these facilities (i.e. when they are performing the operations of energy generation, transmission and distribution for which they have been built). Most LDCs do not have the productive capacities necessary to produce major equipment inputs, such as turbines, solar panels, control and measurement equipment, ICT hardware, etc., all of which typically need to be imported. Backward linkages established in the form of equipment purchases are thus not very intense. Nevertheless, the emergence of modern renewables as a new source of energy has begun to provide some opportunities for the establishment of new backward linkages (box 2.1).

Additionally, the construction/installation phase has the potential to generate backward linkages with the construction industry. This initial phase is also much more labour-intensive than the operation phase. Tendering can target certain local inputs for which supply capacity can be fostered (for instance, through policies favouring small and medium-sized enterprises (SMEs)), and thereby stimulate local entrepreneurship (UNCTAD, 2013).

During the normal operation phase of its facilities (especially production, transmission and distribution of electricity), the energy industry can create backward linkages in LDCs with providers of relatively simple goods and services (e.g. consumables, insurance, Box 2.1. **Asian LDC experiences of developing domestic solar photovoltaic industries**

Bangladesh has had some success in developing a domestic solar industry, which accounted for an estimated 140,000 jobs in 2016. While jobs in solar home systems are now plateauing, employment in mini-grid and solar pumping is increasing as the Government is devoting greater attention to these areas. Rahimafrooz Renewable Energy, for example, manufactures rechargeable solar batteries, charge controllers and fluorescent lamps and has also developed a solar-powered irrigation system. Bangladesh's success can be ascribed in part to on-the-job training and vocational education programmes, promotion of domestic research, and strengthened coordination among firms, regulators and universities.

Lao People's Democratic Republic has also had some success in the development of domestic assembly of imported solar components. SunLabob, a domestic company licensed since 2011, has grown to supply renewable energy services in rural areas not covered by the public electricity company, and also operates in Myanmar, where it recently completed the installation of solar-powered mini-grids in remote communities.

Source: UN DESA (2011); IRENA (2012, 2017).

transport and logistics services, etc.), but also more knowledge-intensive services (maintenance, engineering, ICT services). Again, this has the potential to foster local entrepreneurship. Moreover, operation of the industry's facilities generates direct jobs that are both relatively unskilled and skilled (as they include technicians, engineers, etc.).

While these two different phases of backward linkage generation play a relatively minor role at present, they are likely to be strengthened in future by the expected increase in investments in energy to achieve universal access and transformational energy access (section F).

The energy mining industry could also potentially develop a wide array of backward linkages — linkages that have so far been poorly exploited in mining LDCs (UNECA and AUC, 2013; Ramdoo, 2015).

4. Productivity and human capital

Modern energy access is especially critical for two services sectors that have a direct impact on human capital-building. Access by schools to modern energy of sufficient quantity and quality enhances the productivity of education. At present, some 90 per cent of children in sub-Saharan Africa attend primary schools that lack electricity and thus electric lights, refrigerators, fans, computers and printers (UN DESA, 2014). Electricity is needed, especially in rural schools, to enable the application of modern learning technologies to educational curricula and to provide access to online teaching and training courses. It is also necessary for using computers and tablets, providing lighting for adult education and literacy classes in the evening, and enabling access to educational audio and video media, as well as helping to retain teachers (Humanitarian Technology Challenge, n/d). Electrified schools have better staff retention, outperform non-electrified schools on key educational indicators, and can in some cases contribute to broader community development (UN DESA, 2014).

Modern energy can have a positive impact on the productivity of health services. In 11 countries in sub-Saharan Africa, around a quarter of all health centres lack any access to electricity, and only around 28 per cent have access to reliable electricity, with great variations across countries (ECREEE and NREL, 2015). Such access allows for improved medical facilities, especially in rural areas, effective cold chains and safe storage of medicines and vaccines. It also raises incentives for doctors to settle and work in rural areas.

As discussed in chapter 1, additional benefits for health and education arise from the effects of modern energy in reducing time poverty and increasing flexibility in time use; reducing health risks arising from exposure to household air pollution and lack of access to clean water and refrigeration; and diffusion of information, knowledge and learning.

By increasing productivity and human capital, such benefits are an integral part of the process of sustainable and inclusive structural transformation. As the economy diversifies and the productive structure is upgraded, firms move to more knowledge-intensive products and processes, which increases their demand for skilled workers. The educational system thus needs to co-evolve with the productive structure of the economy, so as to provide the qualified workforce required by increasingly demanding productive processes.

LDCs, however, are still far from reaping the benefits of more and better energy services in terms of human capital formation. The contribution of energy to raising the productivity of the education and health systems is hampered by the deficiencies of their energy systems. Even the education and health targets of the Millennium Development Goals (much less ambitious than those of the Sustainable Development Goals (SDGs)) have not been met in most LDCs. Most LDCs still lack the human resources required to contribute to structural transformation. A survey in 45 African countries — both LDCs and ODCs — found that half the respondents cited a lack of skills as a major obstacle to the competitiveness of African firms (Newman et al., 2016). Structural transformation in many LDCs thus continues to be impeded both by failings of the energy industry and by an insufficient pool of skills.

Energy production and distribution also contribute directly to the economy, generating employment and value added

E. The direct contribution of the energy industry to LDC economies

The energy industry (or sector) comprises the extraction of energy commodities and carriers; their processing, transformation, refining, manufacturing and distribution; and the production, transmission and distribution of electricity. As well as its enabling role in relation to other sectors examined in the previous section, the industry — like other sectors of economic activity — contributes to a country's economy and structural transformation directly, by generating value added, jobs and foreign trade, and through its capacity to generate and adopt technological innovations and thereby raise productivity. This section analyses the role of the modern energy industry in LDC economic activity, employment, international trade and public finance.

1. Value added

Systematic, reliable and comparable data on the different value steps of the energy industry along its production and distribution chains are not available for most LDCs.[8] However, the industry's direct contribution to economic activity and employment in LDCs can reasonably be proxied by the share of energy-related mining and the public utilities sector in total value added.[9] The industry's importance in these areas varies greatly among LDCs, and this is mainly a reflection of the differentiated weight of energy-related extractive activities. Unlike utilities, whose contribution to total value added is fairly slim and similar across LDCs (i.e. below 5 per cent, except in Bhutan), energy-related extractive industries play a disproportionate role in those LDCs where fuel resource endowments are exploited (figure 2.14).[10] This is especially the case in traditional fuel-exporting LDCs like Angola, Chad and Timor-Leste,[11] where these industries account for up to 75 per cent of the total value added, but also — albeit to a lesser extent — in countries less heavily specialized in fuels (Guinea, Mozambique, Myanmar, the Sudan) or uranium exports (the Niger). This general indication of the weight of the energy value chain in the overall economy is inevitably contingent on each country's energy resource endowment.

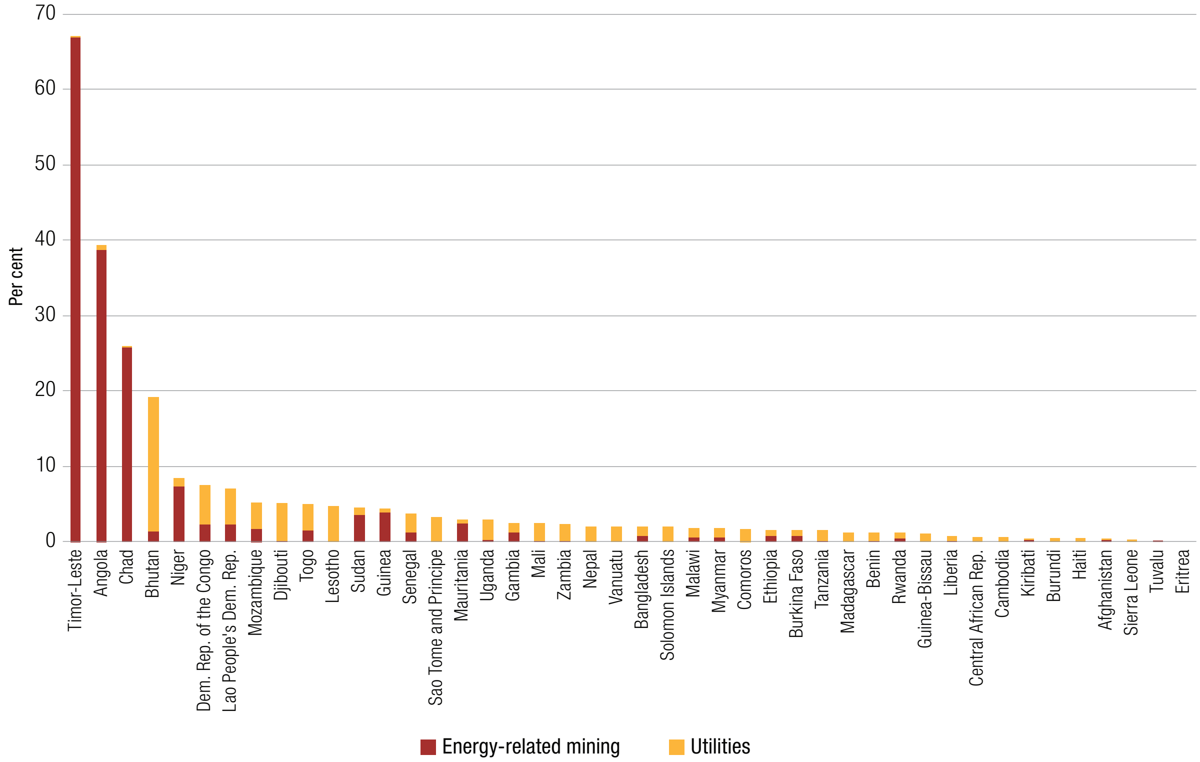


Figure 2.14

Contribution of the energy industry to total value added, 2013–2015

Source: UNCTAD secretariat calculations, based on data from African Development Bank, Socio-Economic Database; Asian Development Bank, AsDB Statistics database; UNCTAD, UNCTADStat database (accessed July 2017).

Note: To net out the effect of non-energy commodities, mining-related data have been weighted by a coefficient reflecting the overall weight of energy-related commodities in total minerals exports.

An important aspect of value generation by the energy industry is that it has increasing returns to scale in both the production and distribution of modern energy (e.g. grid electricity), and in the transformation of primary to deliverable energy (electricity production, petroleum refining). Therefore, the use of additional inputs leads to a more than proportional rise in output by the energy industry (Toman and Jemelkova, 2003). These effects become evident when economies undertake an energy transition from traditional biomass (with a strong component of self-production) to organized markets for energy products (e.g. electricity, combustible fuels). The resulting specialization and economies of scale mean rising availability of energy services at falling prices. As seen in the previous section, individual LDCs are at different stages of this transition.

The pursuit of universal energy access called for under SDG 7, and especially the need to achieve transformational energy access, will require massive investment in the energy industry (chapter 6). Its direct contribution to overall economic activity in the LDCs is therefore likely to expand in the future.

2. Employment

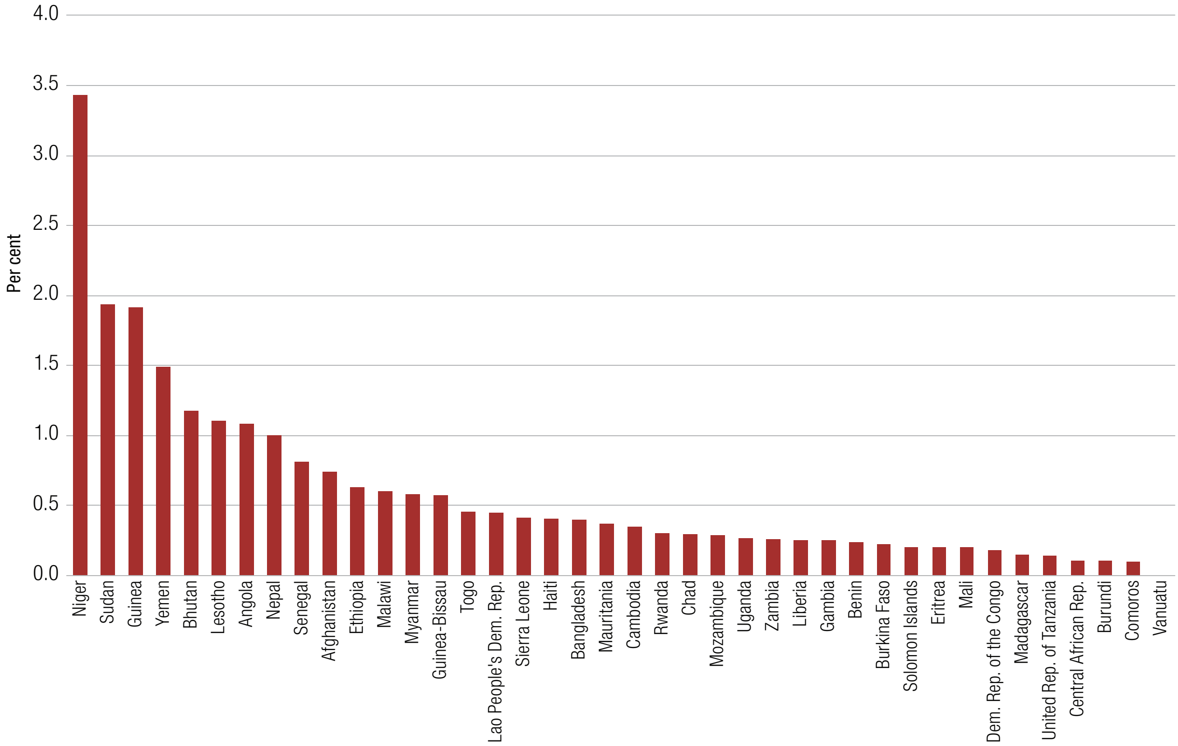
Overall, the contribution of the energy industry to employment is much smaller than its share of value added, implying a much higher level of labour productivity than other industries and sectors, reflecting its greater capital intensity. In Senegal and Zambia, for instance, utilities — including electricity, gas, steam and hot water supply, and collection, purification and distribution of water — are the sector with the highest labour productivity in the economy (Diao et al., 2017). The overall employment share of the energy industry (as defined at the beginning of section D) is highest in the Niger, at 3.5 per cent, but below 1 per cent in 32 of the 41 LDCs for which data are available (figure 2.15). The operation of electricity supply also provides employment opportunities, primarily at higher skill levels, for system maintenance and repairs and for billing and administration, as well as for power plant operation. However, taking advantage of these opportunities, and ensuring the efficient operation of energy systems, depends upon the availability of the necessary skills.

The mining segment appears to generate more jobs than the utilities segment in less than one third of the 41 LDCs, reflecting on the one hand the uneven distribution of fuel resource endowments, and on the other the capital-intensive nature of extractive industries, especially in the case of oil and gas.

The available figures somewhat underestimate the contribution of the energy industry to employment, since they do not take into account workers who are active in energy products distribution (e.g. wholesalers

Figure 2.15

Weight of the energy sector in total employment, latest available years



Source: UNCTAD secretariat calculations, based on data from ILO. ILOSTAT database (accessed July 2017) and World Employment and Social Outlook - Trends, 2015 supporting data sets.

Note: To net out the effect of non-energy commodities, mining-related data have been weighted by a coefficient reflecting the overall weight of energy-related commodities in total minerals exports.

The energy sector is a significant part of merchandise trade and a major source of public revenues in some LDCs

and retailers of vehicle fuels or gas canisters). In statistics these are part of wholesale and retail trade employment, but detailed data are not available.

Looking to the future, progress towards universal access and a transition towards a more modern energy sector have important implications for employment in the energy industry (as is also expected to happen with its value added generation). The scale of the investment required in the electricity sector to achieve universal access by 2030 means that the construction, installation and operation of electricity generation, transmission and distribution will be important sources of employment in their own right.

The development of transmission and distribution systems (grid extension and mini-grids) can provide considerable potential for employment — especially for cable installation, including digging channels for underground cables and producing poles to carry overhead cables — as can investment in increased generation capacity, particularly, but by no means exclusively, in traditional hydro. If accompanied by measures to achieve a parallel kick-start on the supply side, this can provide a major stimulus to rural economic transformation (UNCTAD, 2015a).

Further employment and income opportunities will arise in the supply chains for modern fuels, particularly given the considerable expansion in supply implied by progress towards universal access from the very limited access levels currently prevalent in LDCs. The expansion of these supply chains will imply the decline of value chains associated with traditional biofuels (e.g. firewood and charcoal), which are currently an important productive sector, particularly for the supply of urban markets. Managing this decline as access to modern energy increases, and ensuring that new income opportunities are created for those active in this sector, will therefore be a significant issue in poverty eradication.

3. International trade

The role of energy in the international trade of LDCs is much stronger than its direct contribution to output and employment: energy products account for almost 39 per cent of the group's total merchandise exports and more than 12 per cent of their imports. The importance, composition and direction of trade in energy products vary considerably between countries.

a. Exports

LDC energy exports are dominated by crude petroleum (also called crude oil), which represents 84 per cent ($57 billion of $68 billion — table 2.5) of these countries' annual energy export receipts (figure 2.16). However, these exports are concentrated in a handful of countries, mainly in Africa. Crude-oil exports contribute between one third and almost the totality of the merchandise exports of Angola, Chad, the Sudan, Timor-Leste and Yemen. The bulk of the crude oil sold by African exporters goes to Asia, Europe and North America. Exports of Asian crude-oil producers (including Timor-Leste) are mainly directed to developing East Asian markets.

Table 2.5

Energy exports of LDCs, 2014–2016

(Annual average)

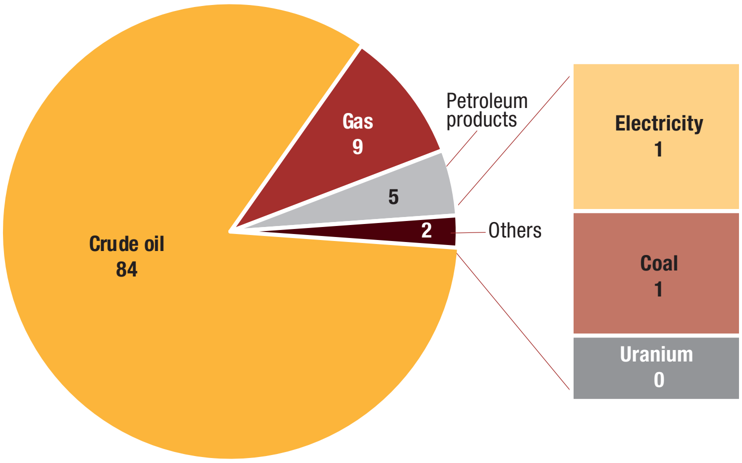
	Petroleum and products			Gas	Coal	Uranium	Electricity	Total
	Total	*of which:*						
		Crude oil	Petroleum products					
Value ($ million)								
Least developed countries	60 565	57 351	3 214	6 446	572	299	684	68 566
of which:								
African LDCs and Haiti	59 041	56 046	2 995	2 224	476	299	359	62 399
Asian LDCs	1 514	1 296	218	4 218	96	1	325	6 154
Island LDCs	10	9	0	4	0	0	0	14
Per cent of total merchandise exports								
Least developed countries	34.4	32.6	1.8	3.7	0.3	0.0	0.4	38.8
of which:								
African LDCs and Haiti	51.3	48.7	2.6	1.9	0.4	0.0	0.3	53.9
Asian LDCs	2.5	2.1	0.4	7.0	0.2	0.0	0.5	10.2
Island LDCs	1.7	1.6	0.1	0.8	0.0	0.0	0.0	2.5

Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).
Note: For the definition of the energy products, see p.xi.

Figure 2.16

LDC energy exports, 2014–2016

(Per cent)



Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).

The second most important energy commodity exported by LDCs is gas. Unlike crude oil and petroleum products, gas is produced and exported mainly by LDCs in Asia, accounting for between one quarter and one half of the exports of Myanmar, Timor-Leste and Yemen. Their exports are mainly absorbed by East Asian markets.

Refined petroleum products (hereafter petroleum products) are the third most important group of energy exports for LDCs, representing just 5 per cent of the total. They generate more than 10 per cent of the merchandise exports of a group of African LDCs that are not producers of crude oil, namely, Benin, Djibouti, Niger, Rwanda and Senegal. One half of these exports are absorbed by other countries in their respective subregions, and the other half goes outside the continent.

LDC coal exports are even more concentrated than those of crude oil, the major exporter being Mozambique. As new mines came into operation, the country's exports leapt fivefold in 2012 with respect to the previous year and rose further thereafter. Coal exports, two thirds of which are directed to Asian markets, now account for 12.6 per cent of the country's merchandise exports.

LDCs trade electricity internationally much less than other energy commodities. Exports of electricity are especially important for some Asian LDCs, accounting for about 13 per cent of the total exports of both Bhutan and Lao People's Democratic Republic, where hydro represents the bulk of electricity supply (figure 3.3). Among African LDCs, only Mozambique, Togo, Uganda and Zambia report significant values of electricity exports, varying from $22 million to $210 million; and Mozambique's exports are virtually matched by its imports. Because of the nature of electricity transmission, all of these exports are to neighbouring countries, often in the context of regional power pools (chapter 4).

Disaggregating the figures of table 2.5 at country level allows for two additional observations. First, only in a limited subset of LDCs does the energy value chain account for a significant share of total merchandise exports, but in those countries it typically plays a disproportionate role (figure 2.17). Its weight exceeds 25 per cent of the total in only 8 LDCs of the 44 for which data are available; but in those countries it accounts for an average of almost two thirds of the merchandise export revenues. Second, with few exceptions (most notably Liberia, Mozambique and Togo), energy-related exports appear to be largely concentrated in one or two main products per country, with oil and gas often exported jointly. This concentration, which is largely a reflection of different natural resource endowments, points to the vulnerability of LDCs to adverse terms-of-trade shocks.

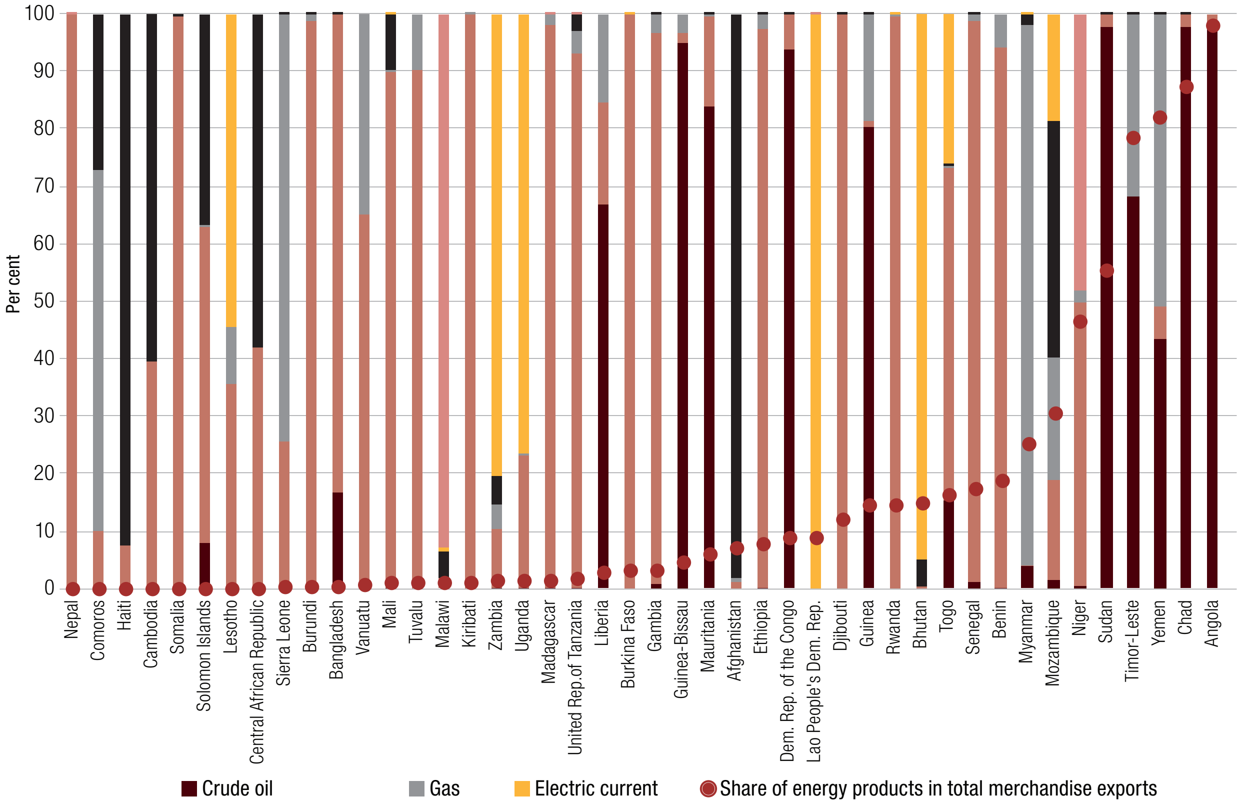
b. Imports

LDCs' energy imports are less than half of their energy exports in value terms, and account for a much smaller share (12.4 per cent) of their total merchandise imports (table 2.6). They are undertaken by all LDCs and have a product composition that is very different from that of their exports.

The bulk of LDC energy imports — 87 per cent — consists of refined petroleum products, accounting for $26 billion of their total annual energy import bill of $30

Figure 2.17

Distribution of energy exports by main type of product, 2014–2016



Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).

Table 2.6

Energy imports of LDCs, 2014–2016

(Annual average)

	Petroleum and products			Gas	Coal	Uranium	Electricity	Total
	Total	*of which:*						
		Crude oil	Petroleum products					
Value ($ million)								
Least developed countries	27 601	1 295	26 306	1 013	1 083	0	576	30 273
of which:								
African LDCs and Haiti	17 212	816	16 396	530	12	0	392	18 325
Asian LDCs	10 047	480	9 567	475	891	0	184	11 597
Island LDCs	343	0	343	7	0	0	0	350
Per cent of total merchandise exports								
Least developed countries	11.4	0.5	10.8	0.4	12.4	0.0	0.2	12.4
of which:								
African LDCs and Haiti	12.1	0.6	11.6	0.4	12.9	0.0	0.3	12.9
Asian LDCs	10.1	0.5	9.6	0.5	11.7	0.0	0.2	11.7
Island LDCs	15.7	0.0	15.7	0.3	16.1	0.0	0.0	16.1

Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).
Note: For the definition of the energy products, see p.xi.

billion in 2014–2016. All LDCs import these products, which are used for transport, but also for electricity production and heating in many of these countries, and which are therefore part of all their energy mix (figure 2.3). In some cases they also become inputs to the chemical industry, which is the seventh largest manufacturing subsector in LDCs as a group (figure 2.13). While African LDCs import these products largely from outside the continent, Asian LDCs source them mainly from Asia.

Gas is also imported by all LDCs, primarily for use as cooking fuel, but it accounts for only 3 per cent of their total energy imports. For African LDCs, 41 per cent of these imports originate on the continent, mainly in northern Africa and West Africa, while Asian LDCs' gas imports are sourced mainly from South and South-East Asia.

Other energy products are imported by only a small number of LDCs. Crude oil is mainly imported by a few LDCs that have oil-refining capacity but no crude-oil production (Bangladesh, Myanmar, Senegal and Zambia); these countries account for 90 per cent of LDCs' total crude-oil imports. Similarly, coal imports are also concentrated in a few mostly Asian LDCs, with Afghanistan, Bangladesh, Cambodia and Nepal representing 77 per cent of the total. For these countries, coal is one of their primary sources of energy (figure 2.3).

The major LDC (net) importers of electricity in 2014–2016 — sourcing from neighbouring countries — were Burkina Faso, Cambodia, Democratic Republic of the Congo and the Niger.

c. Trade balance

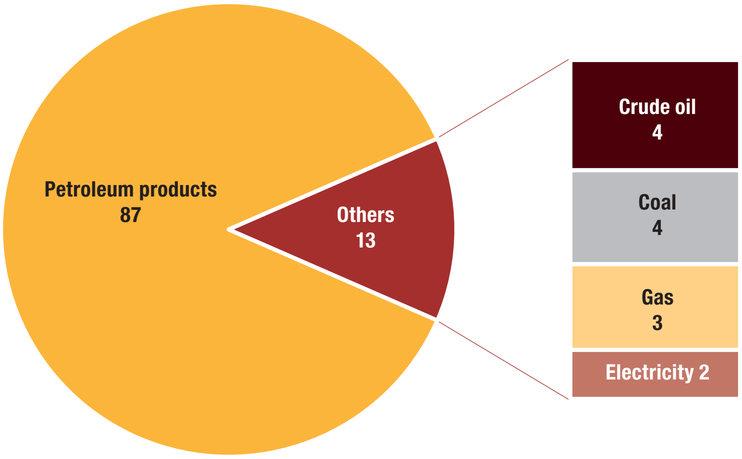
The vast majority of LDCs (38 of 46 for which data are available) are net importers of energy products (figure 2.19), reflecting the asymmetry between concentration of energy exports in a few LDCs while all are energy importers. For those which import primary energy sources for electricity generation, this situation makes electricity costs vulnerable to international price fluctuations. Price instability has to be reflected in domestic electricity prices or to be absorbed either by domestic electricity producers or by the national budget. The energy trade deficit comes mainly from petroleum products, which have higher value than energy raw materials. For the producers of crude oil, which do not refine most of their production, this represents a foregone possibility of value addition in the country and of economic diversification.

For some countries, the energy trade deficit can represent a heavy burden on the current account. For seven LDCs, including five island LDCs, this deficit exceeds the total value of merchandise exports; for 16 more, it exceeds one fifth of their merchandise export revenues.

Figure 2.18

Composition of LDC energy imports, 2014-2016

(Per cent)

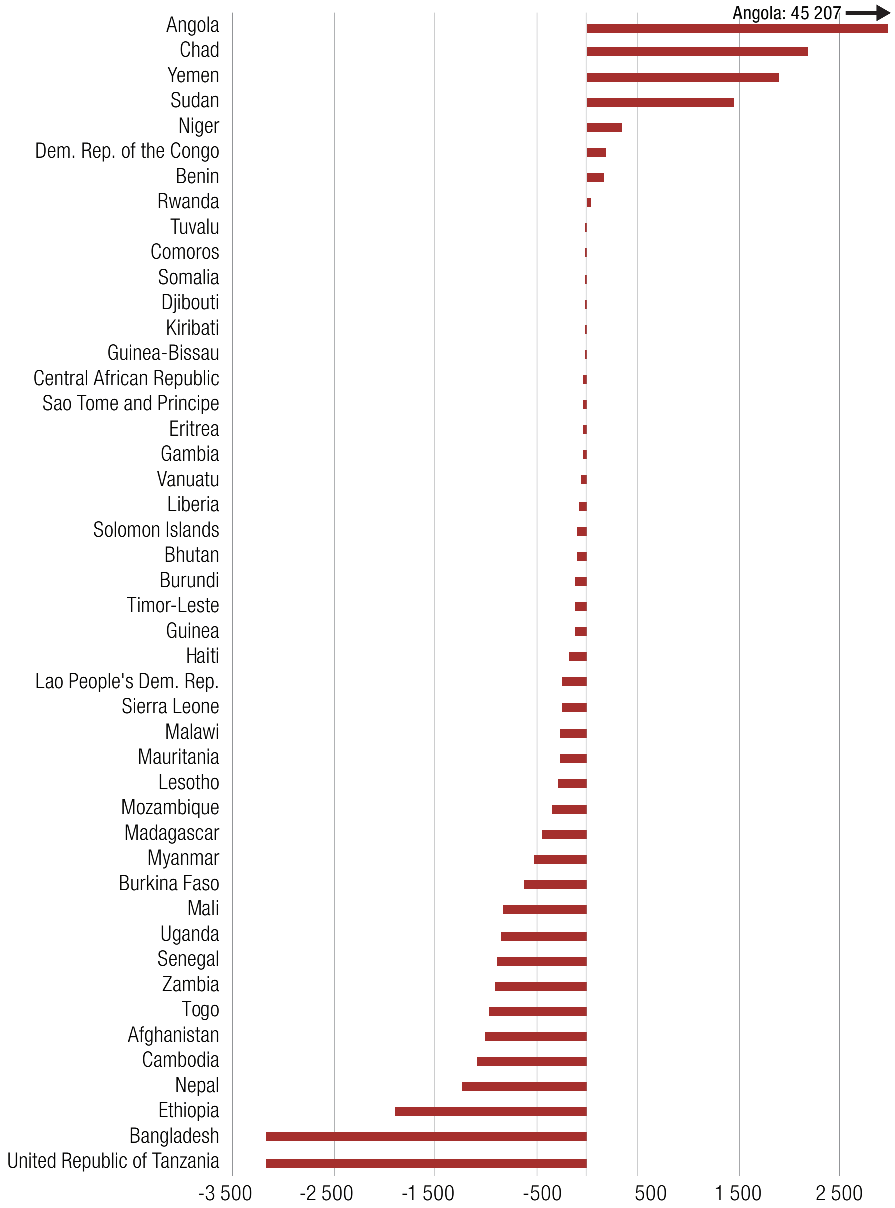


Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).

Figure 2.19

LDC energy trade balance, 2014-2016

(Annual average, million dollars)



Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).

Table 2.7

Fuel-exporting LDCs: Central government revenues from the fossil fuel sector, latest year

Country	Year	Per cent of central government revenues	Per cent of GDP
Angola	2014	67.5	23.8
Chad	2014	55.5	11.7
South Sudan	2014/15	81.2	16.7
Sudan	2014	20.6	2.4
Yemen	2011	59.3	14.1

Source: UNCTAD secretariat estimates based on IMF (2014, 2016a, 2016b, 2016c, 2016d, 2017b).

The future evolution of energy trade balances in most net-importing LDCs depends on their ability to make the transition from an energy mix dominated by fossil fuels (figure 2.3) to a greater reliance on renewable energy sources, and on the extent to which this compensates for the expected growth in energy demand.

Only eight LDCs have a surplus in energy trade. They are exporters of crude oil (Angola, Chad, Democratic Republic of the Congo, Sudan, Yemen), petroleum products (Benin, Rwanda) or uranium (Niger). Angola's energy surplus is by far the largest, amounting to $45 billion annually in 2014–2016 — three times the combined trade balance of all other surplus LDCs.

4. Public finance

In fuel-exporting LDCs, the energy sector is a disproportionately important source of public revenues. In these countries, the fossil-fuel sector generally provides more than half of all central government revenues (and more than 80 per cent in South Sudan), equivalent to some 10-25 per cent of GDP. The sole exception is the Sudan, where oil-sector revenues amount to only 2.4 per cent of GDP, although even here this represents 20.6 per cent of central government revenues (table 2.7).

However, while these revenues strengthen the fiscal position of fuel exporters substantially relative to other LDCs, they also give rise to a high level of instability and uncertainty, as revenues are subject to wide fluctuations in line with world energy prices. This makes it difficult for Governments to plan their expenditure over the medium and long term and may force spending cuts in times of declining fuel prices. Angola — the largest exporter among the LDCs — had to take a $1.4-billion loan from the International Monetary Fund (IMF) in 2009 to stabilize its macroeconomic balance following the steep fall in oil prices after the outbreak of the international economic crisis. A new decline in prices reduced revenues from oil taxes from 23.8 per cent of GDP in 2014 to 15.4 per cent in 2015 (IMF, 2016b).

Resource rents from primary fuel production (captured partly through public revenues) can provide a basis for the diversification of economic activities — one of the major features of economic structural transformation — provided the country can avoid the so-called “resource curse” or “commodity trap” (UNCTAD, 2016b).

Another important relationship between energy and public finance stems from taxes on petroleum products, which are often a critical source of government revenue. Such taxes are implemented by most Governments because raising fuel taxes is easier than collecting income and other taxes, and fuel consumption is weakly price-elastic (Kojima, 2016). A recent survey of fuel prices classified countries according to whether their prices indicate net taxation or net subsidization of fuels. Considering gasoline prices, 12 LDCs of 37 were classified as practicing “high taxation” of fuels and 22 others as undertaking an average degree of taxation. Only three LDCs (all oil producers) were classified as enacting fuel subsidies (GIZ, 2015). Beyond liquid fuels, electricity pricing and its consequences for public finance in LDCs are discussed in chapter 5.

It is essential to integrate gender considerations into energy projects and policies

F. Gender aspects of energy and development

As in other aspects of development, there are important — though complex and context-specific — interactions between energy and structural transformation on the one hand and gender inequality on the other. There is increasing recognition that men and women access, demand and use energy differently and are differently affected by energy use, and also that the social and economic effects of energy services and levels of access differ between men and women. This makes the integration of gender considerations essential to energy projects and policies (UNIDO and UN Women, 2013; Dutta et al., 2017).

Equally, there is a strong interrelationship between gender-based constraints and structural transformation. On the one hand, gender-based constraints can act as a brake on the structural transformation process, while the converse — the removal of such gender-based biases — can catalyse the whole process of structural transformation and economic diversification. Gender equality does not come about automatically as a result of economic development, but requires targeted policy action (Duflo, 2012). A better understanding of the differing needs of men and women with respect to energy access is thus critical. However, systematic, credible and independent empirical evidence on gender-differentiated impacts remains limited.

An important channel through which access to energy affects men and women differently is through changes in gender-differentiated roles within households. The traditional gender division of labour within households, especially in rural areas, typically entails women being overburdened with household and unpaid work, including fetching water, gathering firewood, and food preparation (Lele, 1986). In Cambodia women spend 30 per cent more time than men on housework and six times more in Guinea (Duflo, 2012). This limits their time availability for income-generating and productive activities.

While time savings from fuelwood collection may be more limited in aggregate and less consistently gendered than is often assumed,[12] modern energy access may provide greater time savings for women through reductions in the time spent on other activities, such as cooking, water collection and food processing (chapter 1). In many rural communities in LDCs, most domestic-related travel (e.g. for water collection) is undertaken by women (ECREEE and NREL, 2015), and the availability of transport using modern fuels can also provide substantial time savings.

Such time savings may be translated into increased economic activities among women and more education for girls (Toman and Jemelkova, 2003), although they may also be reflected in increased time spent on other domestic activities or reductions in time poverty. However, women in LDCs, especially in rural areas, face multiple constraints on accessing land, credit, agricultural inputs, extension services, labour markets and education; and these constraints limit their ability to engage productively in both farm and non-farm activities (UNCTAD, 2015a) and to access the means to upgrade their productivity and diversify their range of economic activities.

As well as cultural norms, the gender division of labour within households is influenced by a multiplicity of other factors, including economic incentives, the extent and nature of labour markets, rural or urban location, social status and age. To the extent that limited productive activity by women reflects differences between men and women in economic opportunities, and hence in the opportunity cost of time, the translation of time savings into productive activities is likely to be limited as well. This makes gender differences in the economic opportunities created by improvements in energy access, supply and reliability at least as important as the gender distribution of time savings that such improvements allow.

It should also be noted, however, that an increase in the time women spend on economic activity does not necessarily translate into greater control over resources, particularly in rural areas (where those without access to modern energy in LDCs are concentrated), as additional time may be devoted to the production of crops whose proceeds are controlled by male household members or to unpaid work in household enterprises (UNCTAD, 2015a).

In Burkina Faso, for example, reduced cooking times following the introduction of improved cook stoves under the Foyers Améliorés au Faso (FAFASO) project funded by GIZ, the German development agency, allowed housewives to engage in small-scale income-generating activities, such as selling roasted maize, while fuel savings enabled brewers and restaurant owners to increase spending on school and medical fees (IRENA, 2012). Electrification in Bangladesh has been found to increase the evening time women allocate to income-generating activities and their probability of employment (Kohlin et al., 2011).

There is stronger evidence of the gender distribution of the benefits of structural transformation enabled by energy access than of the direct benefits of higher energy access accrued at the household level. Access to reliable modern energy supply is a precondition for establishing modern food supply chains in LDCs, which “comprise the production and trade of high-value produce, usually destined for export to high-income markets or for supermarket retail in high-income urban market segments” (Maertens and Swinnen, 2012: 1412). Although these supply chains are gendered, their growth is associated with reduced gender inequalities in rural areas (Maertens and Swinnen, 2012). The boom in horticultural exports in Senegal has generated a dramatic increase in female off-farm wage employment, leading to increased female bargaining power in the household. The resulting increase in female wage income has also benefited primary-school enrolment, both for girls and for boys (Maertens and Verhofstadt, 2013).

Where increased and more reliable access to electricity allows the development of labour-intensive manufacturing growth, this can be expected to contribute to greater gender equality and women’s empowerment, as such access has often been associated with increases in female labour-force participation (Atkin, 2009). Research suggests that the expansion of the textile sector in Bangladesh, Cambodia, Lesotho and Madagascar provided opportunities for female employment (Fox, 2015). In Lesotho, the expansion of the apparel industry has meant employment and income-earning opportunities for relatively unskilled women who otherwise had few chances of formal employment (UNCTAD, 2014c). Apart from the countries just mentioned, in other sub-Saharan African countries manufacturing expansion has been dominated by food and agricultural processing and building materials. These industries also require access to reliable energy, but their gender impact is different, since they provide fewer female wage employment opportunities (Fox, 2015). This recalls the importance of the diversification of economic activities in the course of development, so as to provide economic opportunities and empowerment for both women and men.

G. Transformational energy access

The previous sections of this chapter have shown that energy — and especially electricity — can play an important role in economic structural transformation in LDCs both directly and indirectly in the production process as a complement to labour and capital. In other words, energy and structural transformation in LDCs are complementary and characterized by strong synergies.

As discussed in chapter 1, **this requires transformational energy access** in LDCs, which means going well beyond providing households with sufficient access for their minimal domestic needs. Transformational energy access can be defined as the availability to productive units (firms and farms) and to state and community institutions of the modern energy sources — including electricity – that they need to expand and upgrade their productive capacities, so as to drive the process of economic structural transformation. This concept builds on the broader notions of energy access proposed by Sustainable Energy for All (SE4All) (section D of chapter 1), and is the productive-use complement of (universal) access for households called for under SDG 7 (figure 2.6).[13]

Transformational energy access requires, in particular, accessibility, scale, reliability, economic viability, affordability, efficiency and environmental sustainability.[14]

Accessibility. If energy is to contribute to structural transformation, a first prerequisite is that producers should have access to the forms of energy that they need to allow them to raise productivity, adopt new technologies and production methods and develop new products.

Scale. Structural transformation requires an increase in both the quantity and the quality of energy supply, in line with producers' demand and needs, to avoid it acting as a constraint on the development of new and existing productive activities.

Reliability. The enabling role of energy in structural transformation requires a continuous and reliable supply of energy for productive uses. This means, in particular, high-quality and well-maintained infrastructure for electricity generation, transmission and distribution.

Economic viability. Energy systems need to be economically viable and financially sustainable if they are to operate effectively and expand to meet future demand for both domestic and productive uses. This means that investments need to generate an adequate rate of return, and that operational and maintenance costs need to be fully covered.

Transformational energy access requires accessibility, scale, reliability, economic viability, affordability, efficiency and environmental sustainability

Affordability. Since energy is a key element of production costs, limiting costs to end-users is important, to ensure competitiveness. In the electricity sector in particular, however, this must be balanced with the need for financial sustainability, as discussed in chapter 5. Increasing demand through productive use can help reconcile these issues, by allowing economies of scale, lowering production and distribution costs and harnessing network externalities.

Efficiency. Transformational energy access requires both ensuring that producers have access to forms of energy that are efficient for end-uses in the productive process, and ensuring efficiency in the production and distribution of energy itself. In the electricity sector particularly, efficiency in production and distribution can also help reconcile affordability with financial sustainability, as well as being closely linked to reliability.

Environmental sustainability. As discussed in chapter 1, the production and use of energy is closely connected with issues of environmental sustainability, most notably greenhouse gas (GHG) emissions and climate change, indoor and ambient air pollution, and deforestation and forest degradation. This is an important consideration both in the substitution of modern energy for traditional biomass, which can have substantial environmental and health benefits, and in technology choices in electricity production.

These aspects of transformational energy access have significant implications for choices of electricity technologies, policy frameworks, market structures and pricing arrangements, as discussed in the following chapters.

H. Conclusion

LDCs remain close to the bottom of the energy ladder, using energy mainly for domestic purposes and relying primarily on traditional biomass. Moving up to higher rungs of the ladder, through increased use of modern energy and electricity in particular, is a key part of the development process. More reliable, affordable and efficient energy supplies can allow the adoption of new production techniques and technologies, raise productivity and facilitate the introduction of new economic activities, with important benefits across all economic sectors.

At the heart of this process is the energy-transformation nexus — the two-way relationship between energy access and structural transformation — and the productive use of electricity that underpins it. The use of electricity in productive processes provides both the means of translating wider access into structural transformation, and the demand for electricity that can help make investments in electricity infrastructure more viable.

However, harnessing this relationship effectively means moving beyond a goal of universal access based on minimal household needs to a goal of transformational energy access. This calls for an economically viable energy system able to provide access to energy of the nature and the scale required for productive activities, with the reliability they need, at an affordable cost, in a way that is economically viable and environmentally sustainable. As the most versatile and potentially transformative form of energy, and at the highest rung of the energy ladder, electricity is at the centre of transformational energy access. The electricity sector is therefore the focus of the following chapters.

Notes

1 The LDCs included in the analysis are: Afghanistan, Angola, Bangladesh, Benin, Bhutan, Burkina Faso, Burundi, Central African Republic, Chad, the Comoros, Equatorial Guinea, Ethiopia, the Gambia, Guinea, Guinea-Bissau, Haiti, Lao People's Democratic Republic, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Nepal, the Niger, Rwanda, Senegal, Sierra Leone, Solomon Islands, the Sudan, Togo, Uganda, United Republic of Tanzania, Yemen and Zambia. The ODCs included are: Algeria, Argentina, Bahamas, Barbados, Belize, Botswana, Brazil, Brunei Darussalam, Cameroon, Chile, China, Colombia, Congo, Costa Rica, Côte d'Ivoire, Cuba, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Gabon, Ghana, Guatemala, Guyana, Honduras, Hong Kong (China), India, Indonesia, Iraq, Jamaica, Jordan, Kenya, Kuwait, Lebanon, Libya, Macao (China), Malaysia, Maldives, Mauritius, Mexico, Mongolia, Morocco, Nicaragua, Nigeria, Oman, Panama, Seychelles, Singapore, South Africa, Suriname, Syrian Arab Republic, Taiwan Province of China, Tonga, Trinidad and Tobago, Tunisia, Turkey, United Arab Emirates, Venezuela (Bolivarian Republic of) and Viet Nam.

2 TPES is defined in the main text (section A. 1. above). TES is thermal electricity plus PES. PES is electrical energy of geothermal, hydro, nuclear, tide, wind, wave/ocean and solar origin. The data sources are: United Nations Energy Statistics Database (UNSD Energy), UNCTADstat and the World Bank World Development Indicator database (WDI). Labour productivity for agriculture, industry, manufacturing and services is calculated as the ratio of gross value added per sector over sectoral employment. Unit root tests indicate that variables are not stationary in levels and consequently all estimations are done using first differences in variables.

3 For most countries, particularly LDCs, long time-series are not available. In order to address this issue, the alternative was to use existing tools to analyse stationarity of the series and causality in a panel setup. The Dumitrescu-Hurlin (2012) test, an extended version of the Granger (1969) test, was applied to detect causality in panel data. It requires that variables satisfy the stationarity condition, which was tested according to Im-Pesaran-Shin (2003). The null hypothesis of absence of causality was tested using an F-test. The alternative hypothesis states causality for some individuals but not necessarily for all of them.

4 The estimations do not allow for gauging the dimension of the effect in each sector.

5 The Energy Development Index (EDI) has been calculated by UNCTAD for LDCs as the simple average of the following indicators: 1. Per capita commercial energy consumption; 2. Per capita electricity consumption in the residential sector; 3. Share of modern fuels in total residential sector energy use; 4. Share of population with access to electricity. Each indicator was normalized to the 0–1 range using the min-max method.

6 The analysis referred to here is based on input-output tables and includes only ODCs and developed countries, but not LDCs.

7 As mentioned below in footnote 9, some LDCs have some limited oil refining capacity, but the capacity is well below domestic demand for oil products and below the potential offered by crude-oil production.

8 Due to methodological difficulties and their often non-market nature, activities related to traditional biomass are either not included or not detailed separately in national accounts data.

9 Regardless of whether they refer to value added or employment, mining-related data include activities pertaining to both energy commodities (coal, crude petroleum, natural gas and uranium) and other minerals, such as metals (other than uranium), precious stones and the like. To net out the effect of non-energy commodities, mining-related data have been weighted by a coefficient reflecting the overall weight of energy-related commodities in total minerals exports. In most LDCs, output and employment data are unavailable for such processing activities as the production of

coke, refined petroleum products and nuclear fuels, but these activities are likely to represent only a small proportion of the energy industry. Only 14 LDCs have even limited oil-refining capacity, the output of which is overwhelmed by that of the other manufacturing sectors. Similarly, available national accounts and employment data typically group together energy-related utilities — electricity and gas — and water supply, with no further breakdown.

10 Bhutan can be considered an outlier in this case, given the weight of its hydro-based electricity exports.

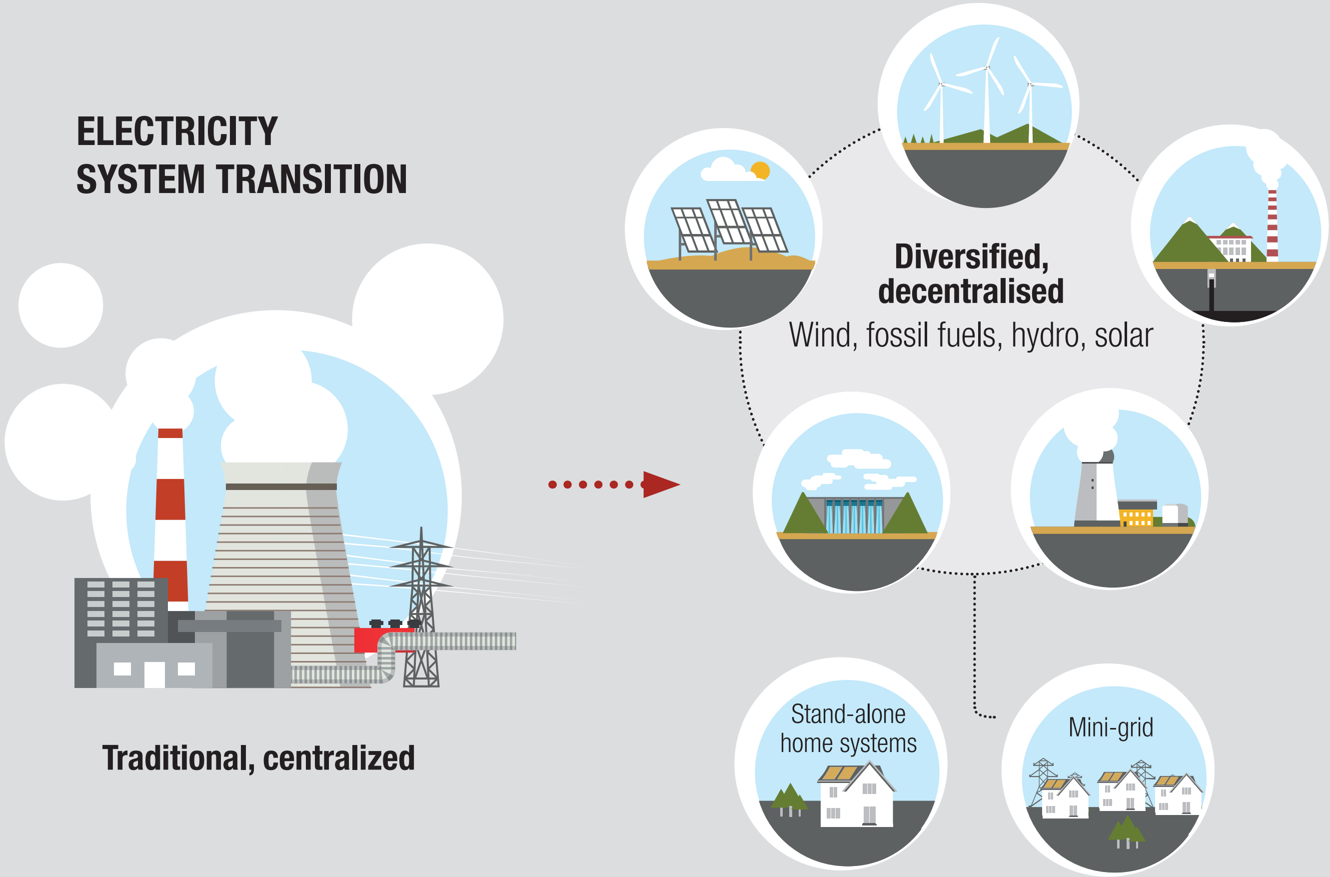
11 Data for Yemen are not available for the period concerned.

12 In households where both women and men are engaged in wood collection, the gender distribution of time savings may also differ significantly from that of time allocation: even if women spend more time than men collecting wood, a greater share of the time savings may accrue to men.

13 The 2010 Report of the United Nations Secretary-General's Advisory Group on Energy and Climate Change recommended low-income countries to expand access to modern energy services and to do so in a way that is economically viable, sustainable, affordable and efficient and that releases the least amount of greenhouse gas (GHG) emissions. This should be achieved through both centralized and decentralized energy technologies and systems, combining the three general models of grid extension, mini-grid access and off-grid access (AGECC, 2010).

14 These features are akin to the attributes of energy supply of the Sustainable Energy for All (SE4All) initiative (capacity, duration and availability, reliability, quality, affordability, legality, convenience, health and safety), but with a greater focus on the needs for sustainable and inclusive structural transformation than on the universal access aspect.

ELECTRICITY SYSTEM TRANSITION



Traditional, centralized

Diversified, decentralised
Wind, fossil fuels, hydro, solar

Stand-alone home systems

Mini-grid

5.5 billion

LDC imports of power-generating machinery and equipment in 2016

of which 47% is South–South trade

and they grew 18% annually between 2000–2016

52%

of LDC electricity generation is **based on renewables**

of which 51% is hydro

1% is solar and wind

CHAPTER 3

Harnessing technologies for transformational electricity access in LDCs

CHAPTER 3

Harnessing technologies for transformational electricity access in LDCs

A. Introduction

The previous chapters have highlighted the critical role of the energy sector in realizing the ambitions of the 2030 Agenda, and particularly in structural transformation. Many energy sources can be applied to productive uses, from animal traction to electricity and from conventional fuels to renewable energy; but electricity is uniquely versatile, powering all types of productive applications – lighting, information and communication technology (ICT), motive power, and space or product cooling/heating (Bhatia and Angelou, 2015). Hence, this chapter focuses on the links between the technological challenges and opportunities in electricity supply and the transformation of the economies of least developed countries (LDCs).

The chapter has four sections. Section B takes stock of recent trends in LDCs' electricity generation, assessing the role of renewables in the context of recent technological advances. Section C considers challenges in electricity distribution, particularly in rural areas, and the potential for leapfrogging to off-grid technologies to foster synergies between low-carbon energy systems and rural development. Section D looks at alternative technological choices from the perspective of electricity costs and systemic synergies and complementarities. It highlights the need for a systemic long-term approach to the electricity sector, progressively diversifying the national system by integrating a diversified portfolio of technologies, to enhance the provision of adequate, reliable and affordable electricity, in line with the needs of structural transformation. Section E discusses the scope and challenges for energy-related technology transfer; and section F concludes.

> **Structural transformation in LDCs will require increased use of modern energy in productive sectors**

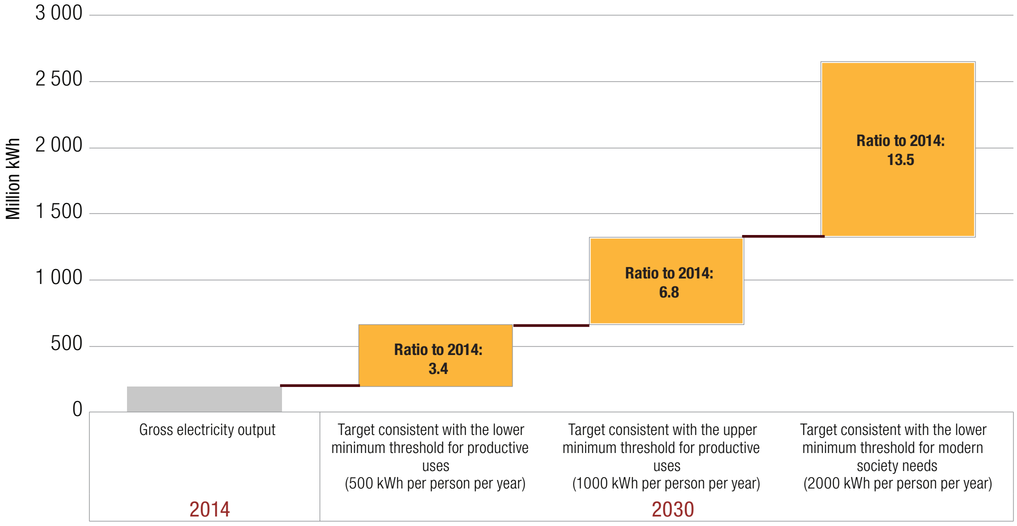
B. Taking stock of the electricity sector in LDCs

As noted in chapter 1, energy consumption in LDCs is strongly skewed towards the residential sector, with a heavy reliance on traditional biomass in total primary energy supply. Structural transformation will require a radical change in this pattern of energy consumption, with a major expansion of demand for productive purposes, and a parallel shift towards modern energy (as defined in chapter 1) — particularly as improvements in energy efficiency are unlikely to lead to less energy-intensive development paths in LDCs than in other developing countries (ODCs) or developed countries in the past (van Benthem, 2015).

Achieving universal access to modern energy by 2030, closing the long-standing "electricity divide" between LDCs and ODCs (chapter 1), and harnessing electricity technologies to stimulate sustainable structural transformation will require an enormous increase in LDCs' power generation. Combining estimates of per capita electricity supply requirements from Sovacool et al. (2012) with United Nations population projections to 2030, LDCs' combined electricity generation would need to increase to 3.4 times its 2014 level to reach the lower minimum threshold, and 6.8 times this level

Figure 3.1

LDC combined electricity output: 2014 value and various notional targets for 2030



Source: UNCTAD secretariat estimates,based on data from UN DESA, Energy Statistics Database (accessed February 2017) and Sovacool et al. (2012).

to reach the upper minimum threshold for productive uses. Reaching the minimum threshold for "modern society needs" would require an increase by a factor of 13.5 (figure 3.1).

This requires a greater expansion in electricity generation than in the period 1990–2014, and in less time. The scale of this challenge will demand enormous financial investments, considerable political will and consideration of all the available technological options.

1. LDCs' power generation mix

Different generation technologies have different characteristics (box 3.1); and the combination of energy sources used to produce electricity (the power generation mix) differs markedly between LDCs and ODCs.

Unlike other country groups, LDCs have traditionally displayed a dualistic power generation mix, relying on combustible fuel generation (overwhelmingly from fossil fuels) and hydroelectric power generation (henceforth "hydro") for nearly all their electricity needs (figure 3.2).[1] Hydro has long played a disproportionate role in these countries, accounting for more than half their combined power generation in 2014, reflecting the enormous potential of some countries in the group (notably Democratic Republic of the Congo, Ethiopia, Myanmar, Mozambique and Zambia). This further underlines the minimal role of LDC electricity generation in global greenhouse gas (GHG) emissions (chapter 1). The share of combustible fuel-based generation has increased steadily, but remains below that of ODCs and developed countries alike. Despite recent deployment of bioenergy, solar and wind technologies (section B2), the role of non-hydro renewables in grid-connected generation remains marginal, at less than 1 per cent.[2] More complex and/or less mature technologies, such as nuclear, tidal, wave and ocean power, are virtually absent from the LDC generation mix, even though several LDCs are considering the development of nuclear capacity, or exploring its feasibility (typically with the assistance of the International Atomic Energy Agency).[3]

Box 3.1 Major power-generation technologies: an overview

Several technologies are available to produce electric power from primary energy sources. This box outlines the main technologies, some of which may also be combined in hybrid systems.

Among the most widely used technologies is **combustible fuel-based generation**. This relies on a turbine driven by high-pressure steam or exhaust gas produced by the burning of *fossil fuels* (mainly coal, natural gas, and fuel oil, or diesel for small-scale generators) or *bioenergy* (solid biomass, such as agricultural waste, fuelwood, and municipal waste, or alternatively liquid biofuels or biogas). Since production is dispatchable — i.e. it can be increased or reduced to match demand with limited additional costs (except where coal is used) — oil- and gas-based generation are well suited to peak generation, back-up and system balancing. However, fuel-based generation has negative environmental effects in terms of GHG emissions and ambient air pollution.

The technologies below are generally deemed to be low-carbon in that they produce limited GHG emissions during operation. (Bioenergy is also considered as low-carbon, as it reduces the emissions associated with fossil-fuel generation).

Hydroelectric power uses the energy of flowing water to spin turbine blades, which drive a generator to produce electricity. While this most commonly uses a dam on a river to store water in a reservoir, it may also use a small canal to channel river water through a turbine.

Solar power takes two forms. *Solar photovoltaic* (PV) uses photovoltaic cells (specialized semiconductor devices with adjacent layers of different materials) to convert sunlight directly into electricity. These cells are interconnected, mounted, sealed and covered with a protective glazing to form modules or panels, which are combined into an array producing a single electrical output. *Solar thermal* energy uses concentrated solar power (focused using mirrors) to heat a fluid, powering a turbine that drives a generator.

Wind power uses the wind to drive turbines, which are generally interconnected through a system of transformers and distribution lines to form a wind power plant or wind farm. Electricity output varies with (the cube of) wind speed, so that doubling the wind speed increases power by a factor of eight. A distinction is often made between *offshore wind* and *onshore wind*.

Geothermal power generally generates electricity using turbines driven by steam extracted from geothermal reservoirs in the Earth's crust by drilling and/or pumping (or produced from hot water generated by such reservoirs) .

Marine power encompasses several distinct technologies. *Tidal power* harnesses the power of ocean tides, capturing water behind a dam or barrage at high tide, and channelling it through turbine as the tide ebbs. *Ocean thermal energy conversion* (OTEC) exploits the temperature difference between cooler deep and warmer shallow or surface seawaters to run a heat engine. *Wave power* uses a variety of methods to convert the motion of ocean waves into electricity.

Nuclear generation generally uses the heat generated by splitting atoms of radioactive materials, such as uranium, to drive steam turbines, producing radioactive waste as a by-product. While life-cycle GHG emissions are low, nuclear power poses serious challenges in terms of radioactive waste management, risks of nuclear contamination and security-related concerns.

Box figure 3.1 presents a schematic assessment of the main technologies for utility-scale electricity generation.

Box 3.1 (contd.)

Box figure 3.1

Schematic assessment of main electricity generating technologies

Attribute	Coal	Coal w/CCS*	Natural Gas	Nuclear	Hydro	Wind	Biomass	Geothermal	Solar PV
Construction Cost New plant construction cost for an equivalent amount of generating capacity	◕	◔	●	○	◑	◕	◑	◔	◕
Electricity Cost Projected cost to produce electricity from a new plant over its lifetime	◕	○	●	◕	◔	◔	◔	◑	◕
Land Use Area required to support fuel supply and electricity generation	◑	◑	◕	●	◑	◔	○	◕	◔
Water Requirements Amount of water required to generate equivalent amount of electricity	○	○	◑	○	◑	●	○	◑	●
CO_2 Emissions Relative amount of CO_2 emissions per unit of electricity	○	◕	◑	●	●	●	◕	◕	●
Other air emissions Relative amount of air emissions other than CO_2 per unit of electricity	○	○	◑	●	●	●	◔	◕	●
Waste Products Presence of other significant waste products	○	○	●	◔	●	●	◔	◕	●
Availability Ability to generate electricity when needed	●	●	●	●	◑	○	●	●	○
Flexibility Ability to quickly respond to changes in demand	◑	◑	●	◔	●	○	◑	◕	○

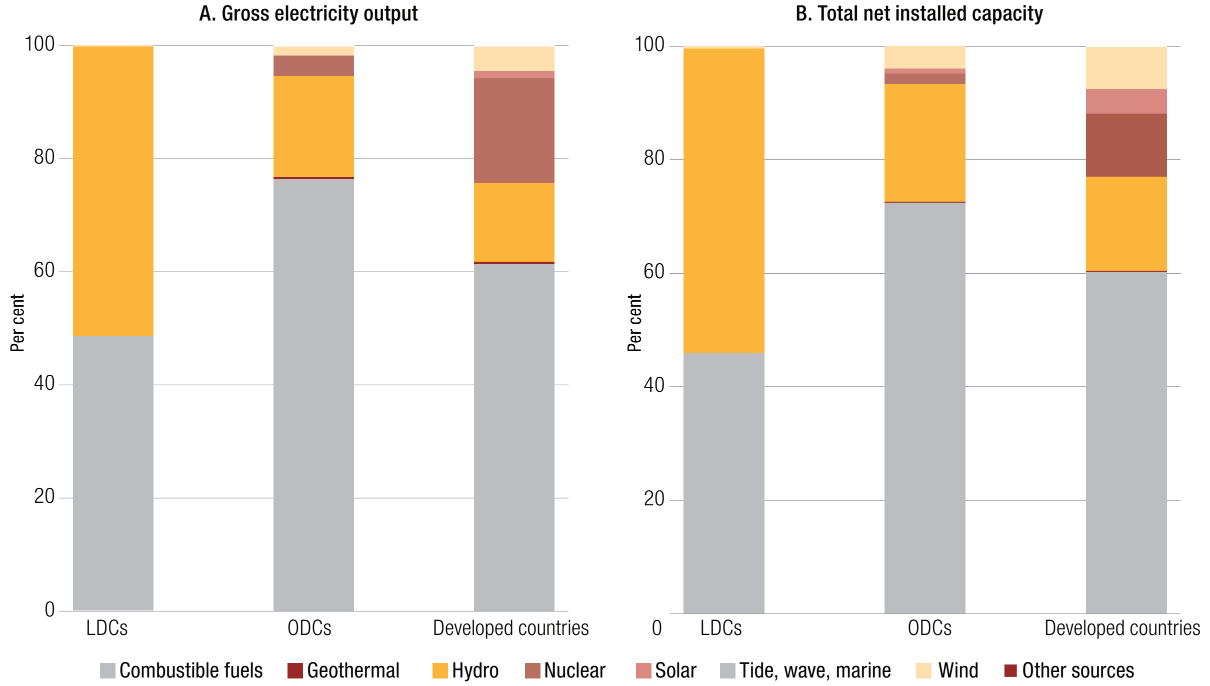
* CCS: carbon capture and storage

Advantage ● ◕ ◑ ◔ ○ Challenge

Source: Adapted from http://sites.epri.com/refcard/comparison.html

Figure 3.2

Power generation mix in different country groups, 2012–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database (accessed February 2017).

LDCs have a dualistic power generation mix, based on fossil fuels and hydroelectric power

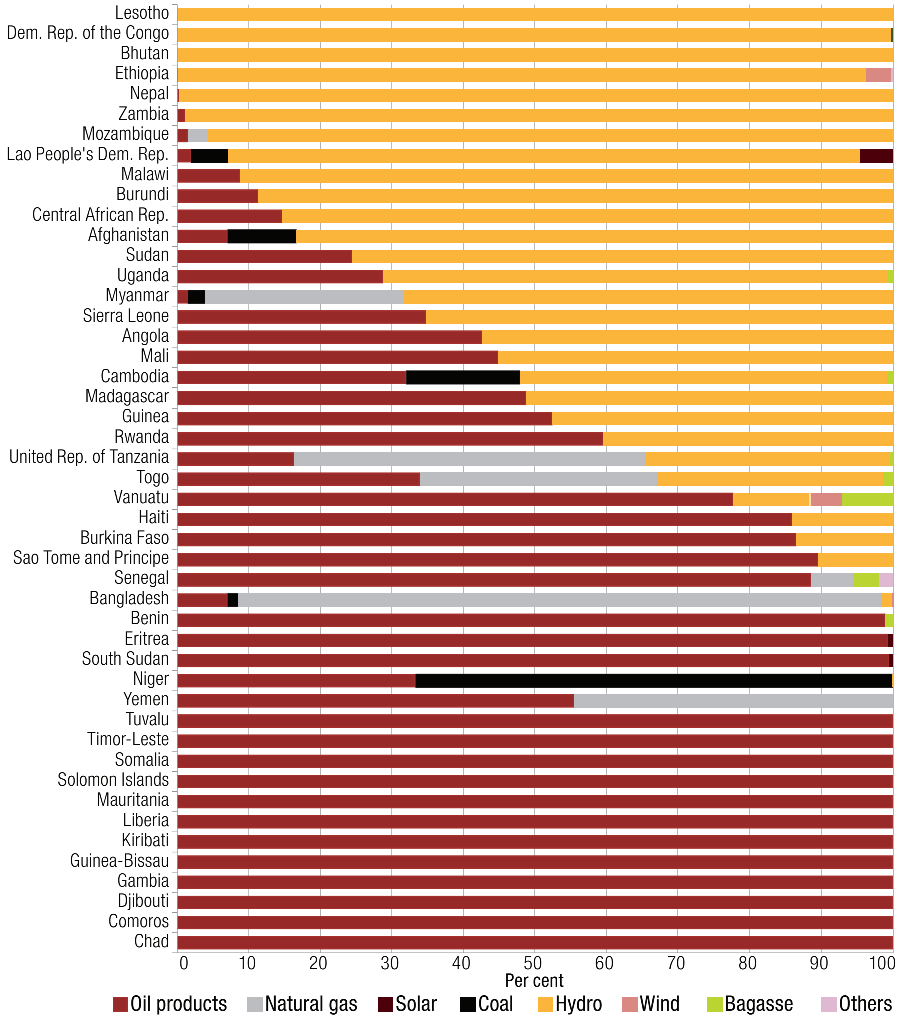
In ODCs, by contrast, combustible fuel-based generation accounts for nearly 75 per cent of electricity production and 70 per cent of capacity, while non-hydro renewables, and to a lesser extent nuclear power, play a greater and rapidly expanding role. The contrast with developed countries is still sharper. There, only 60 per cent of generation and capacity are combustible fuel-based, as much faster deployment of nuclear and non-hydro renewables has led to a more diversified generation mix.

As shown in figure 3.3, the relative importance of hydro and fossil fuel-based generation varies widely among LDCs, which can be divided into three broad groups. In the first (which comprises 12 countries, including large electricity producers such as Democratic Republic of the Congo, Ethiopia, Mozambique and Zambia), hydro accounts for more than 75 per cent of gross electricity production, the remainder being fossil-fuel and, to a lesser extent, solar or wind generation. The second group, in which hydro and fossil fuels each comprise 25–75 per cent of the generation mix, includes 13 LDCs encompassing both larger economies, such as Angola, Cambodia and the Sudan, and smaller ones, such as Malawi and Togo. The remaining 23 LDCs rely almost entirely on conventional fossil fuel-based generation, with minor contributions from hydro, solar and/or bioenergy.

Fossil-fuel-based generation is dominated by natural gas, reflecting a progressive shift towards gas-based technologies among major electricity producers. However, while oil-based generation has waned globally, it is widely used in LDCs and is the only fuel used in generation in many of the smallest LDCs. Most of the island LDCs, in particular, are heavily dependent on conventional thermal generation using

Figure 3.3

Power generation mix in LDCs: Composition of gross electricity production by energy source, 2012–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database (accessed February 2017).

Notes: LDCs are ranked in increasing order of relevance of combustible fuel generation. The decomposition of the latter across different fuels has been computed as a weighted average of each country's fuels inputs, with weights being given by the mean efficiency rates of electricity plants, as reported in UN DESA source above.

imported fossil fuels (Dornan, 2014; Kempener et al., 2015). Conversely, coal has played a relatively limited role in LDCs' electricity generation mix, although its weight may expand somewhat as recently planned investments in new coal-based plants come online.

As of 2012–2014, aside from hydro projects, the contribution of renewable technologies to generation in LDCs remained very limited (figure 3.3): bioenergy exceeded 3 per cent of generation only in Senegal (5 per cent) and Vanuatu (10 per cent), solar only in Lao People's Democratic Republic (4.6 per cent), and wind only in Ethiopia and Vanuatu (in each case 3.6 per cent). As discussed in the next subsection, however, there is evidence of an acceleration of non-hydro renewable energy deployment in LDCs since 2014, and utility-scale plants currently under construction will increase their weight in the near future.

2. The broadening array of renewable technologies[4]

Recent technological advances, together with mounting concern about climate change, have stimulated growing interest in the opportunities offered by (non-hydro) renewable-energy technologies in LDCs and ODCs alike. At the 22nd Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) (COP22), the Climate Vulnerable Forum (including 24 LDCs[5]) pledged to achieve 100 per cent renewable energy by 2050. Thus, half of the 47 LDCs — including island LDCs dependent on fossil-fuel generation as well as others with a larger share of renewable energy — consider a transition to a low-carbon power sector a strategic long-term objective. Other LDCs, such as Lao People's Democratic Republic, Mozambique and Uganda, are also experimenting with the deployment of various renewable-based generation technologies.

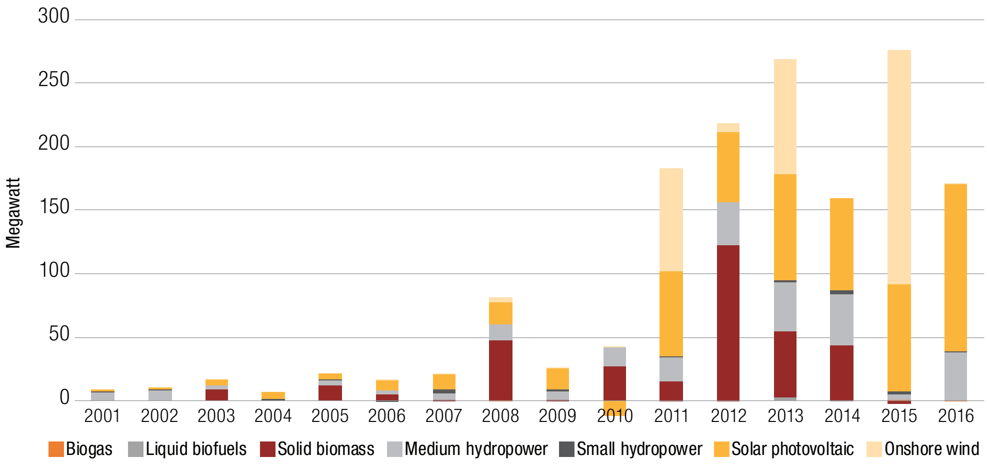
While their relative importance has contracted slightly as other renewable technologies are deployed, **large hydro plants** (defined by the International Renewable Energy Agency (IRENA) as those with capacity greater than 10 Megawatts (MW) continue to account for more than 90 per cent of LDCs' renewable-based capacity and some 80 per cent of their renewable-based generation. Since large hydro also comprises the overwhelming majority of prospective net capacity additions, this predominance is set to continue over the medium term. Moreover, large hydro is the backbone of the generation mix not only in major hydro producers, but also in several smaller LDCs, such as Burundi, Cambodia and Rwanda.

Despite the continued prevalence of large hydro, there is an incipient but accelerating uptake of other renewable technologies in LDCs, including smaller-scale hydro, bioenergy, wind and solar (figure 3.4). Net capacity additions using these technologies have increased strongly since 2010, by more than 200 MW annually, exploiting a broad range of energy sources.

Medium and small-scale hydro (with capacity of 1-10 MW and below 1 MW respectively) have long been present in LDCs, though on a limited scale. However, LDCs' combined installed capacity for medium hydro nearly doubled between 2000 and 2016, from 257 MW to 495 MW, while small hydro also increased from 45 MW to 63 MW. Electricity output from medium hydro rose by more than 80 per cent from 9,723 GWh in 2000 to 17,887 GWh in 2014, while small hydro output increased from 159 GWh to 203 GWh. At the forefront of this increase have been Democratic Republic of the Congo, Lao People's Democratic Republic, Madagascar, Mozambique, Nepal, Rwanda, Uganda and Zambia. While these technologies generally still account for a relatively minor proportion of total generation, there is growing evidence of their effectiveness in serving rural

Figure 3.4

Net capacity additions for renewable-based generation in LDCs, 2001–2016 (excluding large hydro)



Source: UNCTAD secretariat estimates, based on data from IRENA database (accessed March 2017).

Meeting LDC energy needs will require more hydro and fossil-fuel generation as well as faster deployment of other renewables

communities, especially where population is sparse and electricity demand weak (Murray et al., 2010; Sovacool et al., 2011; Gurung et al., 2012).

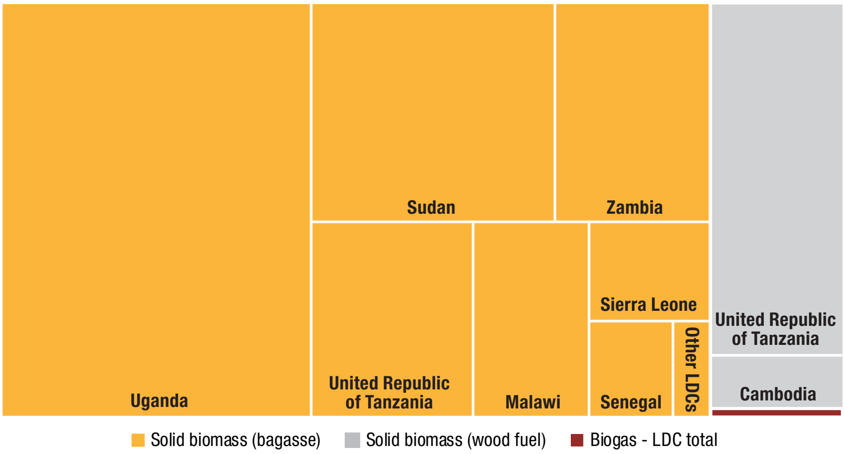
Though dwarfed by large and even medium-sized hydro, **bioenergy** generation has been scaled up significantly in a number of LDCs, notably in East Africa. Net installed capacity in LDCs as a whole more than doubled between 2009 and 2016, to 500 MW, while generation surpassed 750 GWh in 2014 (the latest available year), with Uganda leading the way (figure 3.5). Solid biomass (bagasse and to a lesser extent fuelwood) accounted for most of this output, while other technologies (including agricultural or urban waste, biogas, liquid biofuels, etc.) have been introduced too recently to make a significant contribution.[6]

The diffusion of solar and wind in LDCs is also increasing rapidly, but again from a very low base and so far only based on solar PV and onshore wind technologies (box 3.1).[7] The number of LDCs reporting **solar** capacity rose from 10 in 2000 to 40 in 2016, while their total solar generation increased from just 6 GWh to 446 GWh in 2014. Bangladesh leads the group in PV generation (figure 3.6), accounting for nearly half of their total output, largely due to widespread use of solar home systems (section C).

Despite a later start (in 2006, according to IRENA data) and as yet less widespread application (in 11 countries), **wind** technologies in LDCs have witnessed even stronger growth, surpassing 500 GWh in 2014. As shown in figure 3.7, this mainly reflects investments in utility-scale wind farms in Ethiopia, where three plants are already operating and five more are under construction (Monks, 2017), with more limited use in Bangladesh, Cambodia, Eritrea, Madagascar, Mauritania, Somalia and Vanuatu (although only in Vanuatu is the contribution to the energy mix significant).

Figure 3.5

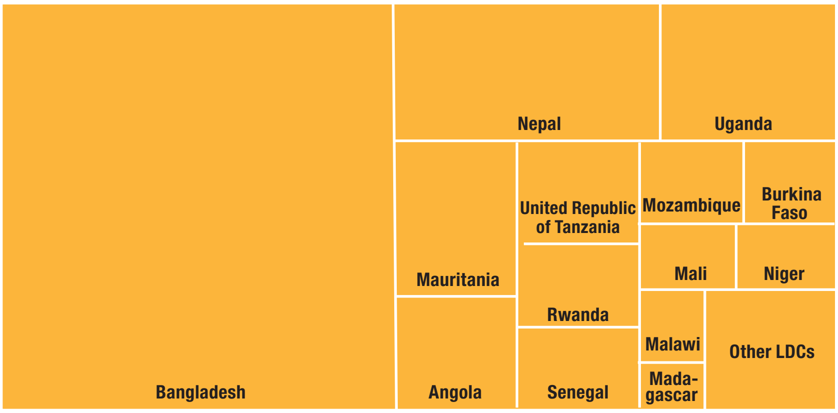
Distribution of bioenergy electricity generation across LDCs, by main technology, 2014



Source: UNCTAD secretariat estimates, based on data from IRENA database (accessed March 2017).

Figure 3.6

Distribution of solar PV electricity generation across LDCs, 2014



Source: UNCTAD secretariat estimates, based on data from IRENA database (accessed March 2017).

Figure 3.7

Distribution of onshore wind electricity generation across LDCs, 2014

Source: UNCTAD secretariat estimates, based on data from IRENA database (accessed March 2017).

Thus, while a growing number of LDCs have started to exploit non-hydro renewable generation technologies, their penetration remains very limited, and only a handful have yet moved beyond small-scale demonstration projects or off-grid energy systems into utility-scale renewable generation. Similarly, despite their proven technical potential, no LDC has yet experimented with concentrated solar power or offshore wind. While new technologies for bioenergy, solar-based generation and storage systems could change this picture, this limited progress highlights the important barriers to technology adoption. Such constraints include the limits to scale economies arising from limited demand, tight financing conditions and institutional weaknesses, especially for technologies that entail relatively high capital expenditures (Labordena et al., 2017).[8]

This situation is consistent with an S-shaped pattern of penetration of new energy technologies, with a relatively long initial period of cost discovery through small-scale demonstration projects before larger-scale deployment of the most appropriate technologies (Lund, 2010). In-depth understanding of the technical and economic dimensions of the new technological options needs to become entrenched, through imitation, network effects and/or conscious policy measures, before industry-level economies of scale can be harnessed to create a critical mass that spurs energy transition further (Grubler, 2012; UNCTAD, 2014b).

Overall, meeting LDCs' growing energy needs will likely require both an expansion of hydro and fossil-fuel-based generation — traditionally the backbone of LDCs' power generation mix — and an accelerated deployment of other (non-hydro) renewables at utility scale.[9] Continued policy commitment is hence critical to accelerate the penetration of renewable-based generation, as LDC players identify and adapt the technologies that best suit the local context. However, as discussed later in the chapter, challenges and trade-offs remain, technically, economically, socially and environmentally.

Distribution systems need to be upgraded as electricity production is increased

3. The conundrum of electricity distribution in LDCs

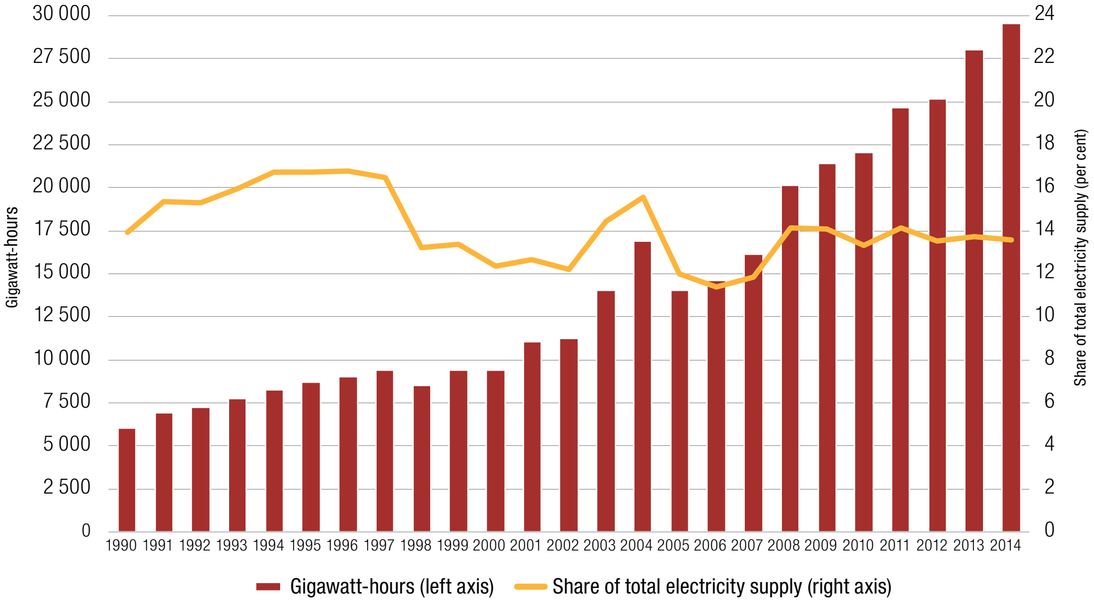
While universal access and powering structural transformation in LDCs will require a colossal scaling-up of electricity production, distribution systems are at least as important, both for outreach and for efficiency (Eberhard et al., 2011). The ability of LDCs to reap the benefits of technological progress depends critically on the grid's quality in terms of voltage levels and reliability as well as its extension. Equally, the appropriate portfolio of energy technologies depends on each country's own initial conditions, including the technical and economic potential for electricity generation and its location relative to consumers, as well as the existing distribution system. However, transmission and distribution (T&D) has often been neglected both in the policy discourse and financially (Hogarth and Granoff, 2015).

Power grids in LDCs typically reflect the legacy of traditional structures oriented towards large centralized electricity generators serving urban customers and large industrial clients (particularly exporters) (IEA, 2014a; Africa Progress Panel, 2017). Despite recent progress, the density of transmission lines remains extremely low by international standards, and local grids remain poorly interconnected internationally (and sometimes even nationally). While Africa provides the classic example of fragmented electricity markets, with low density of transmission lines and a plethora of different specifications (UNEP, 2017), LDCs in other regions face similar challenges. In Afghanistan, for instance, the interconnection of regional grids has been envisaged only since 2013 (ADB, 2013).

As discussed in chapter 1, distribution networks in most LDCs are also dilapidated, resulting in high T&D losses, which undermine the reliability of electricity supply and reduce energy efficiency. On average, T&D losses have hovered at around 14 per cent of LDCs' combined electricity supply since 1990 (figure 3.8), compared with a world average of 7–8 per cent. Moreover, the lack of progress in reducing loss rates implied, in light of the growth in electricity generation, that losses have actually skyrocketed in absolute terms, reaching in

Figure 3.8

Transmission and distribution losses in LDCs, 1990–2014



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database (accessed February 2017).

2014 the order of 30,000 GWh (roughly the combined electricity output of Mozambique and the Sudan). These inefficiencies, coupled with the additional costs faced by producers owing to outages and unreliable electricity supply, give rise to substantial impacts at the macroeconomic level, estimated at between 0.5 and 6 per cent of gross domestic product (GDP) in 12 African countries, including 8 LDCs (Eberhard et al., 2011: 10).[10]

Without a decisive improvement in energy efficiency, the magnitude of T&D losses (compounded by non-technical losses and demand-side inefficiencies, such as low-quality components and inefficient appliances) could push the ambitious Sustainable Development Goal (SDG) targets out of reach, especially in the context of climate-change mitigation and adaptation (IPCC, 2014; Ouedraogo, 2017).[11] Efforts to boost electricity generation in LDCs thus need to be complemented with upgrading of the T&D network. Moreover, the importance of the latter will be further amplified by progress towards universal access and structural transformation, and as increasing penetration of variable renewables increases the need for system balancing and flexibility of the supporting transmission infrastructure. This gives rise to a risk that the poor quality of existing grids might constrain the viability of some technologies, interfering with the choice of the most appropriate power generation mix.

C. Distributed generation: On the verge of leapfrogging?

1. The challenges of grid extension

Efforts to address energy poverty are inevitably shaped by the spatial dimension of the existing grid network. As discussed in chapter 1, 82 per cent of people without access to electricity in LDCs live in rural areas, where electrification rates are particularly low; and this rural predominance is likely to persist (figure 3.9). However, urbanization represents an additional challenge. Rapid increases in urban electrification rates in recent years have not matched the absolute increase in urban population, so that the number of urban dwellers without access to electricity has continued to rise. The continuation of such rapid urbanization, together with progress towards universal access, is likely to result in still greater pressure on the (already poor) T&D infrastructure, reinforcing the need for upgrading.

This twofold challenge requires a pragmatic and flexible approach integrating the deployment of electricity generation technologies with improvements to the distribution network. Given the current technological landscape, grid extension remains the primary means of satisfying LDCs' energy needs for domestic use and structural transformation. T&D networks also need to be upgraded to harness the potential benefits of utility-scale renewable technologies (IEA, 2016b).

However, the costs of grid extension increase with distance from the existing grid and sparsity of population, making extension to rural areas particularly expensive. Moreover, simultaneously increasing centralized electricity generation, and extending and upgrading grids entails considerable upfront costs, which need to be matched by demand if investments are to be viable, while demand is constrained by limited purchasing power. This represents a serious obstacle to grid extension in rural areas, especially at a scale and pace consistent with the attainment of SDG 7 and the needs of structural transformation.

2. The promises of off-grid energy systems in LDCs

Off-grid technologies are increasingly regarded as offering a cost-effective solution to the challenge of rural electrification, conducive to faster deployment than grid extension and giving rise to a leaner distributed generation model, as opposed to a centralized one (Murray et al., 2010; Szabó et al., 2011; Deshmukh et al., 2013; Harrison et al., 2016; Onyeji-Nwogu et al., 2017).[12] They also have the potential to promote greater equity and inclusiveness in electrification and ease the push factors underlying unsustainable urbanization, by allowing earlier access to electricity for rural communities and supporting the development of non-farm activities.

Off-grid energy systems, in themselves, are nothing new: diesel and gasoline generators are widely used worldwide, with an estimated installed capacity of 22.5 GW globally, two thirds of which is in developing countries (Kempener et al., 2015). However, technological advances in renewable-energy and storage technologies have stimulated renewed interest in off-grid systems, bolstered by their potential contribution to decarbonization of the power sector, including through the hybridization of diesel-based generators and the islanding of local grids (Kempener et al., 2015).[13]

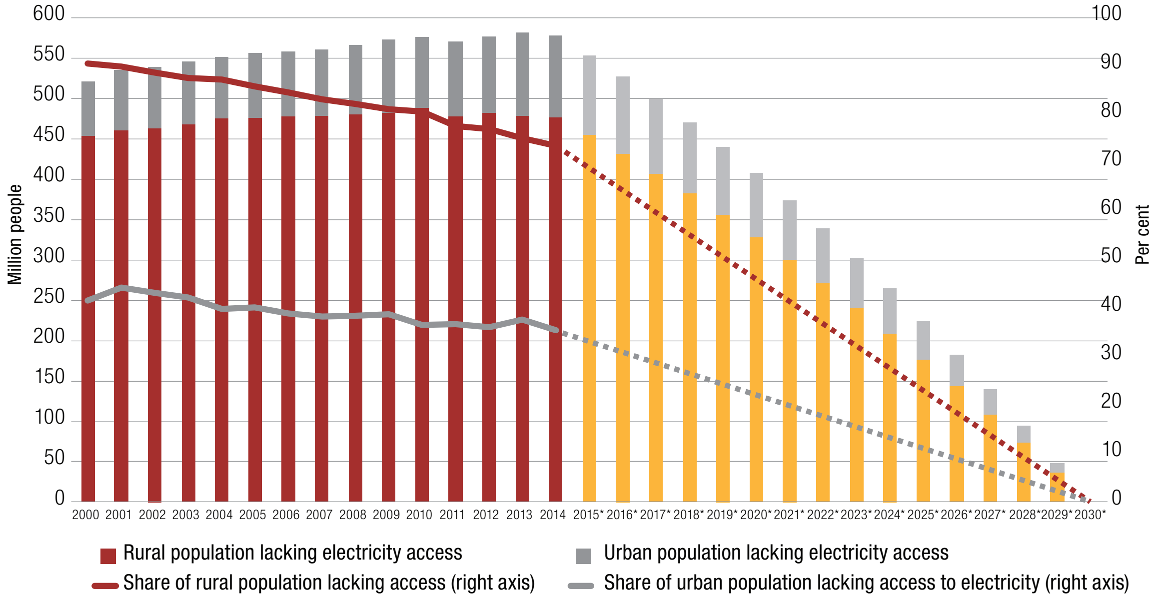
Off-grid technologies may be particularly relevant for rural electrification in LDCs

LDCs' limited urbanization and (in general) sparse rural population makes off-grid energy systems particularly relevant (figure 3.10). Beyond a certain break-even distance from the existing grid, capital costs may be lower for off-grid solutions than grid extension and conventional generators, as may operating costs, due to reduced transmission losses and potential fuel savings (Murray et al., 2010; Deshmukh et al., 2013). However, their cost-effectiveness also depends on demand, the type of load, available energy sources and technical specifications.[14] Identifying the optimal technology thus requires an in-depth analysis of the specific context, and is sensitive to assumptions on the future costs of alternative fuels, demand, load type, etc.

Despite the lack of a commonly agreed definition of off-grid technologies, they generally encompass three broad groups of technologies:

Figure 3.9

Population lacking access to electricity in LDCs by rural/urban status (2000–2014 plus forecast based on SDG 7)

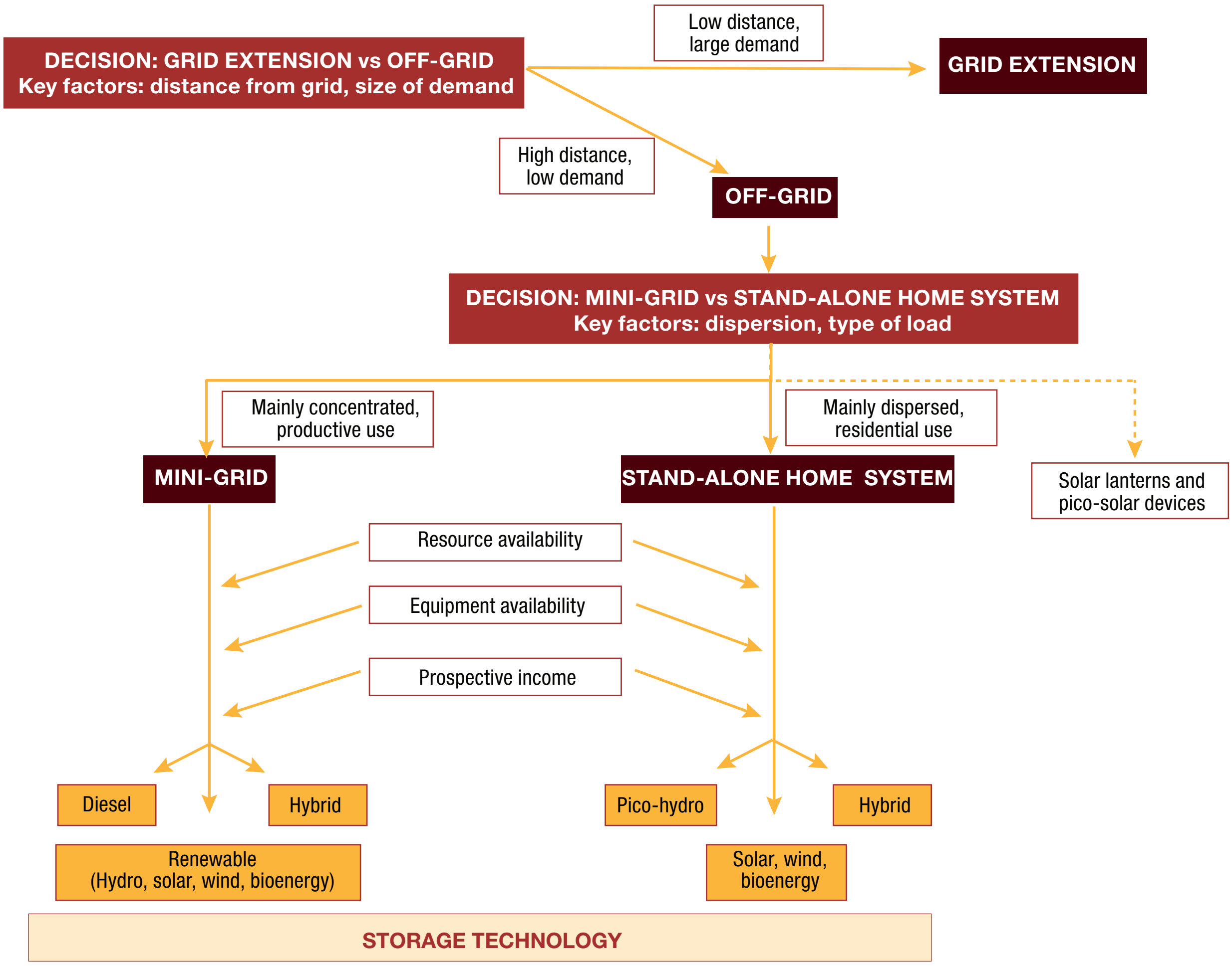


Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database and World Population Prospects: The 2015 Revision database, and World Bank, World Development Indicators database (all accessed February 2017).

Note: * Figures after 2014 are forecasted utilizing UN DESA population projections, and assuming a linear decline in the share of rural (urban) population lacking access to electricity, consistent with the achievement of universal access by 2030. They hence take into account differential trends of demographic growth in rural and urban areas, as well as urbanization treds, as incorporated in the UN DESA population projections.

Figure 3.10

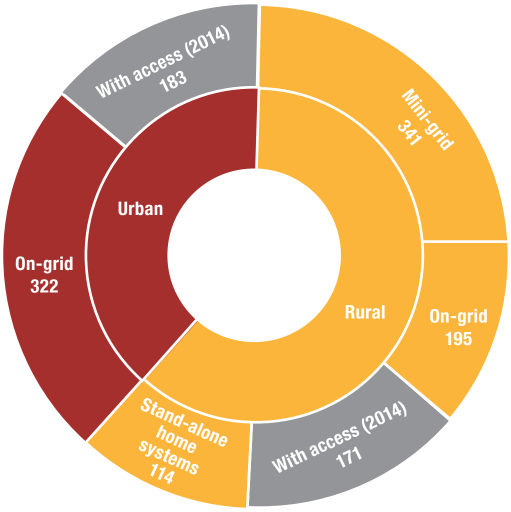
Stylized decision tree for rural electrification: On-grid vs. off-grid solutions



Source: Adapted from NORAD (2009: 3-3).

Figure 3.11

Indicative targets for LDC population gaining electricity access by 2030 (million people)



Source: UNCTAD secretariat estimates, based on data from UN DESA, Energy Statistics Database, and World Bank, World Development Indicators database (both accessed February 2017).

- *Solar lanterns and pico-solar devices*, which typically provide limited energy services (task lighting and phone charging) and often fail to meet the criteria identified by the Sustainable Energy for All (SE4All) initiative for Tier 1 energy access, but are regarded as "an important first step toward household access to electricity" (Bhatia and Angelou, 2015: 59);
- *Stand-alone systems,* consisting of a generation subsystem of small-to-medium capacity and a user's electrical installation (e.g. solar home systems);
- *Mini-grids*, with a larger capacity (from 1 kW to 10 MW), provide centralized electricity generation and a distribution subsystem at a local level, and are capable either of operating in isolation or of being interconnected with a wider grid.

In its "Energy for All" scenario, based on universal access by 2030, the International Energy Agency (IEA) envisages that all urban populations and 30 per cent of rural populations worldwide could be connected to grids, while three quarters of the remaining rural dwellers would need to be supplied through mini-grids, and the rest through stand-alone systems (IEA, 2010). Applying these estimates to United Nations

Table 3.1

Off-grid energy systems and Sustainable Energy for All tiers for energy access

		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Peak power capacity	Watt	-	Min. 3 W	Min. 50 W	Min. 200 W	Min. 800 W	Min. 2,000 W
	Daily supply capacity	-	Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
Availability	Hours per day	-	Min 4 hours	Min 4 hours	Min 8 hours	Min 16 hours	Min 23 hours
	Hours per evening	-	Min 1 hour	Min 2 hours	Min 3 hours	Min 4 hours	Min 4 hours
Energy services		Task light only	Task light AND phone charger	General lighting AND television AND fan	Tier 2 AND any other low-power appliances	Tier 3 AND any medium-power appliances	Tier 4 AND any high-power appliances
Typical technology			**Solar lantern**				
				Solar home system			
					Mini-grid		
					Fossil-fuel based generator		

Source: UNCTAD secretariat compilation, based on EUEI PDF (2014); Bhatia and Angelou (2015).

Statistics Division (UNSD) population forecasts for LDCs suggests that universal access by 2030 would require 571 million more people to be connected to grids and 341 million people to mini-grids, while 114 million would require stand-alone systems (figure 3.11). While these projections are only indicative, it is clear that achieving universal electricity access in LDCs by 2030 will depend heavily on both distributed generation and grid extension. As well as for countries with limited urbanization and sparsely populated rural areas, distributed generation is particularly important for small island developing States (SIDS), where off-grid systems may offer cheaper and cleaner solutions than the prevailing diesel-based generators (Dornan, 2014; Kempener et al., 2015).

While vibrant and multifaceted markets for renewable-based off-grid energy systems in LDCs have emerged only recently — apart from mini-hydro technologies, which have a more established tradition — they might have wide-ranging implications for rural electrification. The scope for off-grid technologies — notably solar ones — has been greatly increased by process and product innovations, which have driven down their costs, reduced their minimum efficient scale and are increasingly enhancing their potential for combination with appropriate storage or hybrid technologies. This has both increased the cost-competitiveness of off-grid technologies and broadened the range of technologies available to satisfy different energy needs (table 3.1).

At the low end of the spectrum, increasing penetration of solar lanterns and pico-solar devices (notably in East Africa) is allowing more people at the “bottom of the pyramid” to reach the first rung of the energy ladder (Bhatia and Angelou, 2015; Scott and Miller, 2016), while stand-alone home systems (SHSs) are emerging as a means of meeting slightly larger and more varied energy requirements, for example for low- to medium-power appliances. Increasingly, larger SHSs are also being used by community facilities, such as schools and rural health centres in unelectrified rural areas (Bhatia and Angelou, 2015).

The diffusion of these solar technologies has occurred mainly through markets, driven primarily by a sharp fall in the costs of PV modules (by 85 per cent in the last decade) and batteries, as well as a shift towards light-emitting diodes (LEDs) (Kempener et al., 2015; Orlandi et al., 2016; Scott and Miller, 2016). However, policies have also played a critical role, particularly through awareness-raising, quality-assurance programmes, grants and soft loans, and tariffs and tax reductions (Scott and Miller, 2016; Africa Progress Panel, 2017).[15]

While by no means transformational, household ownership of basic energy systems can provide meaningful savings and welfare improvements. Surveys in several LDCs suggest that solar lighting leads to significant reductions in lighting spending, lower CO_2 emissions, health benefits (especially for women and children, who typically spend more time indoors) and educational improvements (by allowing longer or more flexible study time)[16] (Grimm et al., 2014; Harrison et al., 2016; Hassan and Lucchino, 2016). They can also make some contribution to productive use, for example by allowing smallholder farmers to use ICTs, thereby improving access to market information, agricultural extension and basic financial services (UNCTAD, 2015b; Bhatia and Angelou, 2015). SHSs also play an important role for micro and small enterprises, notably in the services sector — shops, bars or hair salons — where energy requirements and needs for complementing end-use investments are typically

Mini-grids can provide a cost-effective means of transformational energy access in remote rural areas

lower than in manufacturing (Harsdorff and Bamanyaki, 2009; GIZ, 2013).[17] Larger SHSs can also be used for productive appliances, such as egg incubators, milking or sewing machines, huskers and polishers, as well as for renewable-based water pumps and irrigation systems (GIZ, 2016; Africa Progress Panel, 2017). Prior to electrification, renewable energy can be harnessed directly to diversify income sources and enhance labour productivity in non-farming activities and food processing through non-electrical technologies, such as solar tunnels for drying and evaporative refrigerators. (UNCTAD, 2015a). While the take-up of similar devices would likely be constrained by the availability of funds for end-use investments, LDCs' producers, including small and medium-sized enterprises (SMEs), might benefit significantly from harnessing the scope for technological adaptation and "frugal innovations" in the field of end-use productive technologies, including those compatible with off-grid systems (Prahalad, 2006).

A growing number of LDCs are pursuing the deployment of SHSs under rural electrification programmes, often supported by development partners, notably Bangladesh (which supports deployment with installation subsidies and credit), Rwanda (which has adopted a "rent-to-own" model) and the United Republic of Tanzania (Kumar and Sadeque, 2012; Deshmukh et al., 2013; Kempener et al., 2015). However, sustained penetration will depend on continued technological advances aimed at reducing high capital costs, space requirements and maintenance needs (IRENA, 2015; Kempener et al., 2015; Harrison et al., 2016). The availability of appropriate storage technologies and energy-efficient appliances will also be important to support SHSs for productive uses and rural non-farming activities.

Despite their undoubted welfare benefits, however, SHSs have limited effects in terms of transformational energy access, as they reach only the lowest rungs of the energy ladder. While different off-grid devices provide different levels of energy access (table 3.1), many appliances for productive use, particularly in higher value added stages of production, require medium or high power, and thus upper-tier access. Other productive uses (notably in food processing) call for a viable "cold chain", and thus reliability of electricity supply, highlighting the importance of combining variable renewables with appropriate storage and/or hybrid technologies. These considerations are in line with recent simulations on electrification options for Africa, suggesting that greater levels of energy demand — consistent with the prospects for structural transformation — move the optimal electrification option from stand-alone systems to mini-grid and to grid extensions (Mentis et al., 2017).

SHSs are also primarily suited to the energy needs of dispersed rural communities — some 11 per cent of LDCs' population in 2030, based on the IEA estimates referred to above. Survey evidence reinforces this view, suggesting that a substantial proportion of SHS owners ultimately aspire to higher tiers of electricity access (Harsdorff and Bamanyaki, 2009; Lee et al., 2016). Moreover, the development impact and sustainability of underlying business models, including energy-related microfinance and pay-as-you-go systems, deserve careful consideration (chapter 5).

This highlights the importance of mini-grids, which, if appropriately designed and operated, can in principle afford a cost-effective means of transformational energy access in remote rural areas, while also enhancing system reliability, incentivizing demand-side management and generating local employment (Deshmukh et al., 2013; EUEI PDF, 2014; Kempener et al., 2015). This can promote rural development, by addressing a key constraint to the development of non-farming activities (UNCTAD, 2015a) and stimulating investment in rural electricity provision, as well as supporting a transition towards a low-carbon growth path.[18]

Looking ahead to 2030, mini-grids are therefore likely to play a more prominent role in LDCs' rural electrification, echoing the historical experience of developing countries such as China and India, where diesel- and hydro-based mini-grids have long been deployed in rural areas. These experiences also highlight the potential of mini-grids to pave the way towards grid extension, through interconnection and progressive integration into the national system (Deshmukh et al., 2013; Kempener et al., 2015). Mini-grids may be particularly important in mountainous countries and archipelagos (Sovacool et al., 2011; Dornan, 2014).

However, the smooth deployment of mini-grids on the scale required for universal access in LDCs is hindered by financial, technical, economic and institutional obstacles. First, as discussed in chapter 5, their large upfront costs make the availability of financing critical, particularly in the early phases of their roll-out, often making deployment dependent on grants or soft loans from national or international sources (EUEI PDF, 2014; Deshmukh et al., 2013). Second, the design of mini-grids needs to be tailored to site-specific

Box 3.2 **Lessons from Micro-Hydro Village Electrification in Nepal**

Started in the early 2000s, with the long-term financial support of large institutional donors, Nepal's Micro-Hydro Village Electrification (MHVE) programme has emerged as a successful scheme for scaling up the deployment of mini-hydro systems. Building on the earlier Rural Energy Development Programme of the United Nations Development Programme (UNDP), the MHVE aimed at deploying community-based micro-hydro systems ranging from 10 kW to 100 kW. Project implementation was decentralized to local governments, District Development Committees and Village Development Committees setting up Micro-hydro Functional Groups in each targeted community. By 2014, more than 1,000 micro-hydro systems had been installed, with total generating capacity of 22 MW, providing off-grid electricity access to 20 per cent of the population.

Researchers and practitioners have proposed drawing the following lessons from this experience:

Sound design of mini-grid specifications and technical standards play a key role in fostering the adoption of locally appropriate technologies matching the scale of local demand.

Robust monitoring frameworks are needed to ensure that appropriate technical standards are met and maintenance and aftersales services regularly provided.

Strong emphasis is warranted on capacity development, including activities to improve the local provision of maintenance and aftersales services (backward linkages), and to stimulate demand for energy services through productive end-uses (forward linkages), so as to embed energy projects in the local economic fabric.

Commitment to long-term cost-recovery is important for sustainability, including effective revenue collection and promotion of efficiency-enhancing technologies (hybridization, smart load limiters, energy-efficient appliances, etc.).

Clear determination of the roles of different stakeholders, and focus on institution-building components, is fundamental, to deal promptly with unforeseen circumstances, ensure social acceptance of the business model and foster a strong involvement of targeted communities. Credible long-term policy commitment, with flexible approach to implementation and reduced administrative burdens, is essential to sustaining mini-grid deployment.

Source: Sovacool et al. (2011); Gurung et al. (2012); EUEI PDF (2014); http://www.worldbank.org/en/news/feature/2015/09/26/ensuring-sustainable-rural-electrification-in-nepal.

conditions, notably resource potential (for hydro and variable renewables) or fuel-supply conditions[19] and the dynamics of demand and load profiles, so as to optimize generation and storage capacities and ensure high-quality electricity provision. In this respect, the availability of a potential anchor load — i.e., a consumer of a large and possibly stable proportion of the power generated (for instance a small factory, hospital or farmer cooperative) — supplementing households' electricity demand is usually critical to support mini-grid profitability and increase capacity utilization. Third, higher tariffs than what corresponding on-grid consumers pay have often resulted from the pressure to cope with relatively low capacity factors, substantial sunk costs, costly maintenance and revenue collection. In addition to generating grievances and pressure to be connected with the central grid, this has typically raised equity concerns and issues of cross-subsidization.[20] Fourth, given the long-term nature of mini-grid investments, regulatory uncertainty and lack of transparent planning for grid extension tend to deter mini-grid developers. This aspect, coupled with the need for community involvement and mobilization, has often generated complex institutional challenges, resulting in the lack of a proven and easily replicable business model for mini-grid installation and operation (Deshmukh et al., 2013; Africa Progress Panel, 2017).

Notwithstanding the above challenges, country experiences in mini-grid deployment, including in LDCs, offer ample scope for mutual learning and experience-sharing (box 3.2). They also point to a huge scope for South-South cooperation in stimulating technology transfer and adaptation to context-specific realities.

3. Key considerations in a changing technological landscape

The previous two sections have highlighted two mutually supportive trends with the potential to shape rural electrification in LDCs: the surge in distributed generation, and technological advances in renewable-based generation. These trends can be expected to continue, as innovations and learning effects continue to push down the cost of renewable electricity technologies and facilitate their deployment. Moreover, the modularity of renewable off-grid technologies suggests that an incremental approach to their deployment is at least feasible, and arguably desirable.

However, the parallels sometimes drawn between distributed generation and the "ICT revolution" that allowed the rapid penetration of mobile telephony in the developing world appear premature. While it has expanded significantly, the market for larger off-grid energy systems in LDCs remains limited, and is largely dependent on external support from development partners, philanthropic organizations and public utilities. Equally, while the penetration of smaller-scale off-grid systems appears to have occurred relatively smoothly in some LDCs, the diffusion of more transformational higher-power technologies such as mini-grids still faces a number of important challenges.

There is also some ambiguity as to whether off-grid solutions are an *alternative* to the main transmission grid, indicating a complete leapfrogging akin to that witnessed in the ICT sector, or a *stepping stone* towards grid extension. This is a critical issue, as it gives rise to potential tensions and time inconsistencies between support for off-grid solutions and grid extension. For potential mini-grid operators, the prospect of future competition with on-grid electricity providers with different cost structures might be a significant deterrent to investments that entail substantial sunk costs. This highlights the importance of transparency and integrated planning of grid extension and mini-grid deployment, and of appropriate regulatory frameworks, so as to avoid discouraging private investors and ensure the viability of an incremental approach.

With appropriate planning, mini-grids can be integrated into larger networks rather than being supplanted by them, on the one hand supplying electricity to the larger national grid, and on the other enhancing system reliability by preserving the capacity to operate in isolation during central grid failures. While the experiences of China, India and Nepal suggest that this option is technically viable (Deshmukh et al., 2013), it requires appropriate guidelines, including consistent technical standards and protocols for grid interconnection. Another modality is that adopted in Cambodia, where a consolidated licence provided by the national regulator allows mini-grid operators to play a small distribution role in the event of central grid extension by the public utility.

Although it has as yet received less attention, an analogous tension would appear possible between the widespread use of SHSs and the development of mini-grids (or potentially grid extension). Households with SHSs may have little incentive to purchase electricity from a mini-grid, particularly where this also entails a connection charge; and this could potentially reduce prospective demand below the minimum efficient scale for investment to be viable. While SHSs may be necessary in the context of dispersed settlement patterns, their widespread adoption in villages might thus prove an impediment to the subsequent development of mini-grids, which are likely to provide a more sustainable and lower-cost means of ensuring transformational energy access and satisfying growing electricity demand.

This highlights the importance of a carefully planned and forward-looking approach to increasing electricity access. Planning and coordination are needed between mini-grid development and grid extension, to ensure appropriate prioritization of investments, to avoid deterring potential investors, and to allow mini-grids to be interconnected and/or integrated into an overall grid as appropriate at a later stage.

While the whole array of off-grid technologies offers considerable potential for LDCs, harnessing the opportunities they provide will thus require a stepped-up policy effort and long-term policy commitment, including transparent and forward-looking plans for grid extension, and clear strategic guidelines to ensure the adoption of compatible technology standards. In light of the pace of innovation in the energy market, this calls for a flexible approach that avoids locking in particular technological solutions that may be inappropriate to the country's needs in later years. It will also require a proactive policy framework that supports and facilitates a gradual technological upgrading process, by:

- Leveraging the regulatory framework to promote the adoption of appropriate technological standards;
- Emphasizing capacity development, both for grid developers and operators and for end-users, whose behaviour can strengthen the energy system value;
- Harnessing the scope for both North-South and South-South cooperation and technology transfer, and favouring experimentation and diversification across energy sources;
- Preserving an integrated approach to energy policies.

Regardless of how rural electrification is achieved, however, experience warns against naïve presumptions about its impact on productive activities. By shaking up traditional business practices, rural electrification can provide significant new opportunities for economic diversification into non-farming activities, with knock-on effects on employment, productivity and value addition. In the short run, however, it is likely to give rise to a process of "creative destruction", with winners and losers, according to the energy requirements and intensity of each business, the availability of alternative energy sources and the need for complementary investment in end-use devices (GIZ, 2013). Moreover, the impact of electricity on enterprise profitability is subject to other bottlenecks, for example in transport infrastructure, market access and formalization, as well as depending on the adequacy of local demand (GIZ, 2013; UNCTAD, 2015a). This highlights the need for complementary policies and integration of electrification strategies into wider development strategies (chapter 6).

D. Towards a systemic approach to the electricity sector

The portfolio of technologies deployed for electricity generation, distribution and even end-use devices have wide-ranging implications for a country's power generation mix, electricity costs and power-sector performance. Appropriate technology choices therefore play a critical role in structural transformation, by allowing transformational energy access and providing suitable, reliable and affordable energy services to enhance labour productivity and foster the emergence of higher-value added activities and the diffusion of ICT. This further underlines the importance of mutually supportive development and energy policy frameworks, as the path dependence resulting from investments in energy-related infrastructure gives rise to a risk of technological lock-in, unless the dynamics of structural transformation and future energy needs are duly accounted for. In this context, while some elements of irreversibility are inevitable — since the life cycle of generating technologies spans between 20 and 60 years — risks of technological lock-in can be minimized, inter alia, by adopting a forward-looking approach to future needs against which to assess the appropriateness of the technology, leveraging modularity/scalability, allowing for easy retrofit options and ensuring interoperability. Equally, the systemic interdependence of different energy systems underscores the need for a systemic approach to the electricity sector, and related planning.

Harnessing the potential of off-grid technologies requires long-term policy commitment and integrated approach

1. Resource potential and cost-effectiveness of energy technologies

The choice among alternative energy systems is determined primarily by their relative cost-competitiveness, which depends on the interaction between energy resource potential and the technical performance of each technology. Quantifying resource

Tabe 3.2

Proven reserves of selected fossil fuels in LDCs, 2016 (estimates unless otherwise stated)

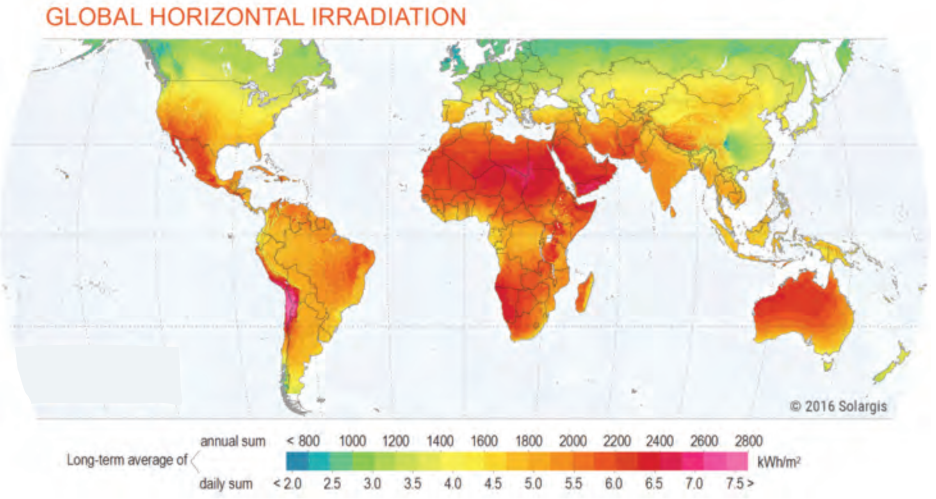
	Natural gas		Crude oil		Coal*			
					Hard Coal		Lignite	
	Million cubic meters	Share of world total (per cent)	Million barrels	Share of world total (per cent)	Million tonnes	Share of world total (per cent)	Million tonnes	Share of world total (per cent)
Mozambique	2 832 000	1 44	-	-	1.79	0.26	-	-
Yemen	478 500	0 24	3 000	0.18	-	-	-	-
Angola	308 000	0 16	8 400	0.50	-	-	-	-
Myanmar	283 200	0 14	50	0.00	3	0.00	3	0.00
Bangladesh	233 000	0 12	28	0.00	293	0.04	-	-
Timor-Leste	200 000	0 10	-	-	-	-	-	-
South Sudan	63 710	0 03	3 750	0.22	-	-	-	-
Rwanda	56 630	0 03	-	-	-	-	-	-
Afghanistan	49 550	0 03	-	-	66	0.01	-	-
Mauritania	28 320	0 01	20	0.00	-	-	-	-
Ethiopia	24 920	0 01	0	0.00	-	-	-	-
Sudan	21 240	0 01	5 000	0.30	-	-	-	-
Uganda	14 160	0 01	2 500	0.15	-	-	-	-
Senegal **	9 911	0 01	-	-	-	-	-	-
United Rep. of Tanzania	6 513	0 00	-	-	269	0.04	-	-
Somalia	5 663	0 00	-	-	-	-	-	-
Madagascar **	2 010	0 00	-	-	-	-	-	-
Benin	1 133	0 00	8	0.00	-	-	-	-
Dem. Rep. of the Congo	991	0 00	180	0.01	88	0.01	-	-
Chad ***	-	-	1 500	0.09	-	-	-	-
Niger ***	-	-	150	0.01	-	-	6	0.00
Nepal	-	-	-	-	1	0.00	-	-
Malawi	-	-	-	-	2	0.00	-	-
Lao People's Dem. Rep.	-	-	-	-	4	0.00	499	0.17
Central African Rep.	-	-	-	-	-	-	3	0.00

Source: UNCTAD secretariat calculations, based on World Energy Council (2016); CIA (2016).

Notes: * All data for coal reserves are based on 2014 estimates. ** Data for natural gas proven reserves are based on January 2012 estimates.
*** Data for natural gas proven reserves are based on January 2014 estimates.

Figure 3.12

Solar irradiation map



Source: http://solargis.com/assets/graphic/free-map/GHI/Solargis-World-GHI-solar-resource-map-en.png

potential is inherently complex, and the existing mapping of the various energy resources is far from exhaustive or accurate. Nonetheless, an increasing body of research highlights LDCs' abundant and largely untapped potential, spanning a wide spectrum of energy sources (Gies, 2016; UNEP, 2017).

With respect to fossil fuels, LDCs account for approximately 2.3 per cent of worldwide proven reserves of natural gas, 1.5 per cent of oil reserves, and 0.3 per cent of coal reserves (table 3.2).[21] However, these endowments are unevenly distributed, only about half of LDCs having any proven fossil-fuel reserves, while many others (notably most island LDCs) depend on imports. Import dependence for electricity generation is not only rooted, however, in natural resource endowments, but often also in the weakness of the refining and transformation sector further down the energy value chain (chapter 2). Besides, there appears to be significant scope to shift from emission-intensive fuels, such as coal and oil, towards natural gas for generation in a number of LDCs.

Evidence on renewable-energy potential should be treated with caution, as its quantification is complicated by spatial and technical-performance considerations. However, the available evidence suggests that LDCs could in principle harvest enormous amounts of power from renewable sources, potentially relaxing the energy constraints imposed by fossil fuel scarcity (Africa Progress Panel, 2015; Gies, 2016; UNEP, 2017). Africa, for example, has enormous renewable-energy potential, only a fraction of which is currently utilized (UNEP, 2017). Solar — the most abundant energy source in most LDCs — epitomizes this paradox. The shift towards solar electricity in LDCs is barely incipient despite much greater horizontal irradiation in most LDCs than in countries such as China or the United States with much stronger solar sectors (figure 3.12).

Several programmes, such as the Renewable Energy Resource Mapping Initiative of the Energy Sector Management Assistance Program (ESMAP) and IRENA's Global Atlas for Renewable Energy, have recently been established to assist countries in accurately mapping their resource potential as a basis for future investments. Resource potential, however, is only one side of the coin; technological advances are equally important to technology choices, not only by changing the relative efficiency of alternative energy systems, but also by potentially allowing the exploitation of previously unviable resources.

One of the most widely used metrics for cost comparison across different power-generating technologies is the levelized cost of electricity (LCOE), which represents the minimum price of electricity consistent with a given project breaking even financially over its expected lifetime.[22] However, it requires detailed knowledge of the energy sector and context, is sensitive to a set of underlying assumptions, and is generally limited to private costs (investment expenditures, operations and maintenance, fuel and decommissioning if applicable) (IRENA, 2016a). The limitation to private costs has the advantage of being very transparent in terms of the underlying assumptions, and relatively easy to understand and apply to a wide array of technologies in different contexts. However, it might be inadequate to capture all relevant dimensions, from a societal point of view.

Global LCOE trends indicate a marked improvement in the cost-competitiveness of renewable-based generation technologies since 2010, converging with conventional fossil-fuel generation (figure 3.13). This reflects technological advances in solar (and to a lesser extent onshore wind), improving technical efficiency, coupled with increasing scale economies in upstream activities. Further economies of scale and learning effects are expected to reduce costs further, according to one estimate by 59 per cent for solar PV and 26 per cent for onshore wind by 2025 (IEA, 2016b; IRENA, 2016a).[23] Other technologies, such as solar thermal and offshore wind, also have significant potential for learning effects, although this depends on their wider deployment.

Despite the increasing competitiveness of renewables globally, it is important to note the very wide variation in LCOE estimates across contexts. This implies that competitiveness advances at the global level do not automatically translate into improved competitiveness in a particular location. It should also be noted that LDCs often face particular challenges in adopting the most efficient technologies, especially where these require complex and information technology (IT)-intensive support infrastructures.

Moreover, LCOE computation is inevitably sensitive to key assumptions related to:

- Technological performance;
- Expected prices for fuels and other costs;
- Weighted average cost of capital;
- Pricing mechanisms for environmental externalities (when applicable).

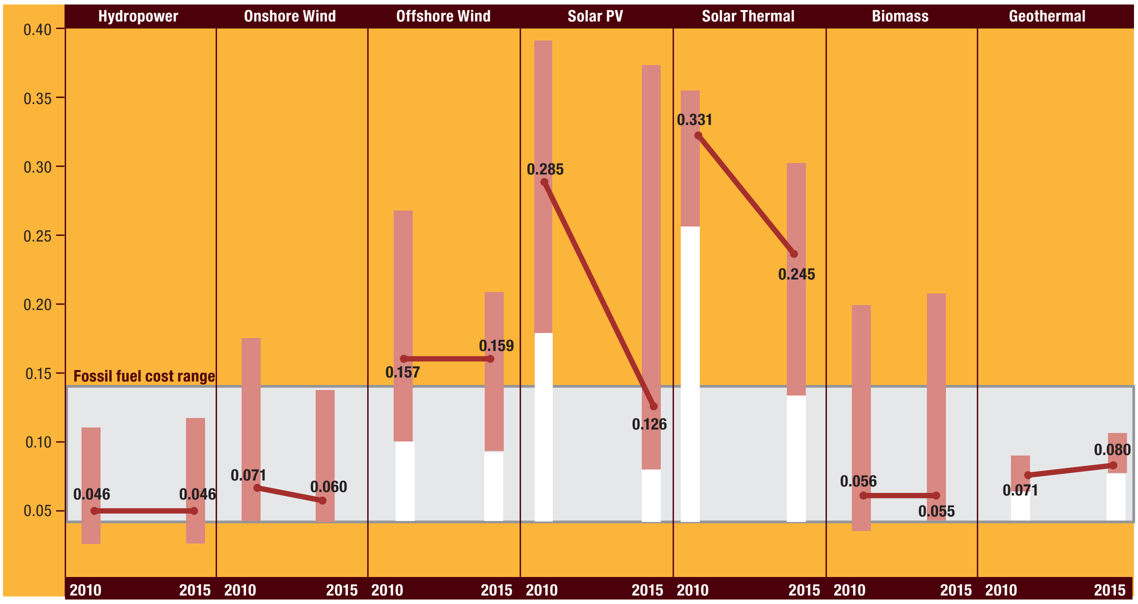
While the soundness of technical assumptions can be validated only on a case-by-case basis, the sensitivity of the LCOE to the three other sets of assumptions requires greater consideration by policymakers. First, since many LDCs depend on fossil-fuel imports for their power generation, uncertainties related to future fuel prices are compounded by those concerning exchange-rate fluctuations. Consequently, technology choices may also have broader macroeconomic implications, which are not reflected in the LCOE calculation. Second, the choice of interest rate – which is typically assumed to be higher in LDCs, to account for tighter financing conditions and greater risks – has profound implications for the LCOE of capital-intensive technologies, notably renewables. With a higher interest rate, a larger capital expenditure implies greater upfront financing costs, while the effect of fuel savings throughout a plant's life cycle tapers off quickly because of discounting. Third, accounting for both localized and global externalities is essential if the LCOE is to reflect sustainable development concerns fully (i.e. the social cost); but, as seen above, it is debatable whether environmental costs are appropriately internalized and evaluated.[24]

Generation mixes should reflect sustainability, inclusivity and structural transformation concerns as well as cost effectiveness

Indicative figures for the LCOE across main technologies are provided, by cost element, in box 3.3 (baseline), along with two examples of the sensitivity of the computation to the above considerations. This highlights the critical importance of sensitivity analysis in the interpretation of the LCOE.

Figure 3.13

Worldwide trends in levelized cost of electricity, 2010–2015 (Ranges and capacity-weighted average)



Source: IRENA Renewable Energy dashboard, http://resourceirena.irena.org/gateway/dashboard/?topic=3&subTopic=33.

Even aside from these considerations, "a static analysis of LCOEs of different power generation technologies alone cannot identify their optimal role… in a country's energy mix" (IRENA, 2016a: 24). While its exclusive focus on private costs is in line with private investment decisions, it neglects key policy issues, including (unpriced) environmental externalities, system-wide considerations (notably the time profile of generation) and energy security. Energy-security concerns underline the importance of attention to resource endowments and geographical factors as well as the relative climate resilience of different energy sources (highlighted by the slump in hydro-based electricity generation following the 2016 drought in Southern Africa).

Policy decisions related to the generation mix thus need to go beyond narrow cost-effectiveness criteria to encompass the full range of sustainable-development considerations, including sustainability, inclusivity and structural transformation.

2. System-wide considerations

While different generating technologies may be alternatives at a project level, a systemic perspective requires attention to their interactions and complementarities, given their different time profiles of generation, location, cost structures and resilience to shocks. Such considerations are essentially ignored in LCOE metrics (IEA, 2016c). Anticipating growing complexity as systems develop, and enhancing system flexibility from the planning and design phases for newly built electricity infrastructure, could offer significant leapfrogging opportunities to LDCs, by reducing the need to retrofit existing infrastructure (Welsch et al., 2013).

Electricity demand (load) needs to be continuously matched with supply in real time to avoid outages and load shedding. This requires sufficient generating capacity to serve peak demand, while leaving part of this capacity idle in off-peak periods. Some generating technologies, notably gas- and oil-based generators and hydro plants, are better able than others to vary output according to demand fluctuations. Under appropriate topological conditions, hydro plants can be combined with additional reservoirs for pumped hydro, thereby allowing energy from other sources to be stored.

The roles of different technologies in matching supply with demand can be illustrated by a typical daily electricity supply curve from the Bangladeshi grid operator (figure 3.14), which shows the use of oil-

Box 3.3. **An illustration of the levelized cost of electricity from a societal perspective**

This box presents an indicative illustration of the distinctive cost structures of the major power generation technologies from a societal perspective, and their implications for LCOE computation in the face of apparently "technology-neutral" changes in the underlying assumptions, using the Danish Energy Agency's Levelized Cost of Energy calculator (Danish Energy Agency, 2016).[a] In line with a societal approach, relevant cost elements encompass system costs, air pollution and climate externalities, in addition to the private cost elements included in the LCOE. The latter elements comprise other costs (i.e. decommissioning), fuel costs, operation and maintenance costs, and capital costs. The underlying data, based on typical values for generic international power production plants, allow LCOE computation for seven different technologies: coal (with and without flue gas desulphurization), combined cycle gas turbine, nuclear, solar PV, wind and biomass. Unless otherwise stated, the default settings are applied (box figure 3.2).

A comparison of the different technologies in the baseline scenario highlights three important considerations.[b] First, accounting for environmental externalities ("air pollution", mainly of SO2, NOx and PM2.5, "climate externalities" in the form of GHG emissions and "other costs", including radioactivity) significantly alters the cost comparison across different technologies, especially for coal-based generation. Second, solar- and wind-based generation (and to a lesser extent nuclear) are characterized by relatively high capital expenditure, with negligible marginal operating costs. Third, unlike fully controllable technologies, variable renewable technologies have positive system costs, reflecting the need to balance their variable temporal profile and enhance grid flexibility. These costs increase with the unpredictability of the energy source, so are higher for wind than for solar.

The second scenario features higher prices for fuels and CO2, consistent with a maximum global temperature increase of 2°C.[c] This has significant effects on combustible fuels technologies, increasing the LCOE for coal-based generation sharply, due to its high emission intensity, and to a lesser extent for natural gas and biomass. These results underscore the extreme sensitivity of the relative LCOEs of renewable and fossil-fuel technologies to accounting for fuel costs and environmental externalities.

The third scenario repeats the baseline scenario, but raising the weighted-average cost of capital of 10 per cent, to reflect LDCs' tighter financing conditions. While this increases the LCOE across all technologies, the rise is much greater for solar PV, wind, biomass and nuclear, reflecting their greater capital intensity.

[a] The LCOE Calculator modelling tool is available at no charge at: https://ens.dk/en/our-responsibilities/global-cooperation/levelized-cost-energy-calculator.

[b] The baseline scenario applies the default settings, including fuel prices consistent with the "2015 new policies scenario", and a 4-per-cent weighted-average cost of capital.

[c] This corresponds with the "450 ppm" fuel and CO2 price scenario, all other parameters remaining at their default values.

Box 3.3 (contd.)

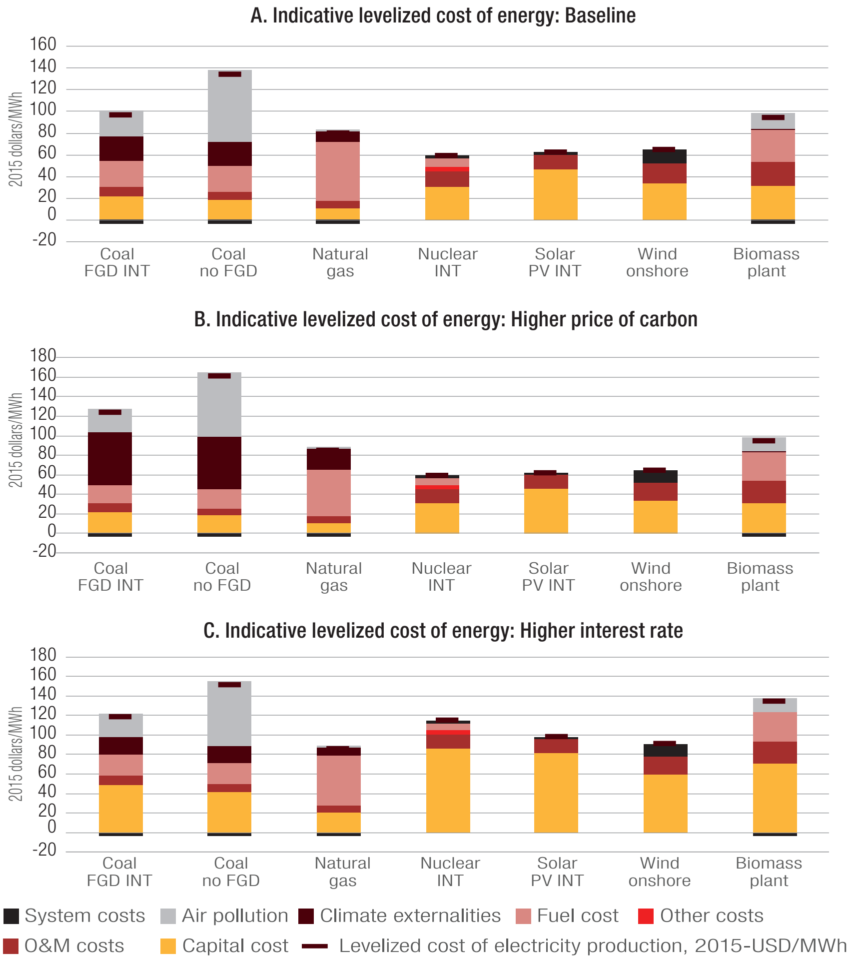
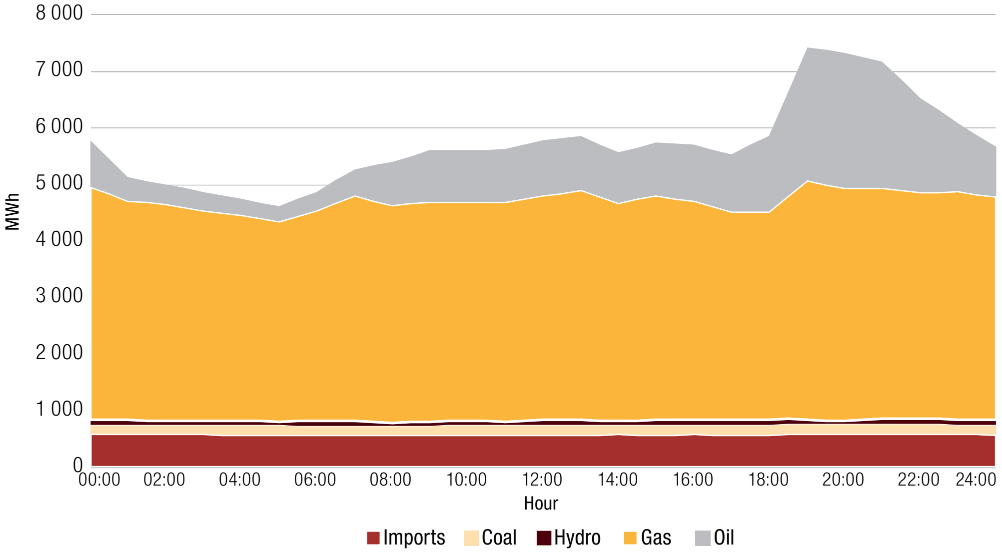


Figure 3.14

Typical daily electricity supply curve in Bangladesh, 13 March 2017



Source: UNCTAD secretariat estimates, based on the operational daily report by the Power Grid Company of Bangladesh Ltd., https://www.pgcb.org.bd/PGCB/?a=user/home.php (accessed May 2017).

based power generation for peak load, while other technologies complemented by imports provide the baseload.[25] While daily supply curves and power generation mixes vary widely across countries and seasons, this example highlights the crucial importance of rapidly dispatchable peak-load capacity and/or storage, in order to match the time-varying profile of electricity demand.[26] The need for such system flexibility is likely to become even more pronounced in the future, with an increasing penetration of variable renewables.

Furthermore, the distinct cost structures of the various technologies (illustrated in box 3.3) will gradually play a deeper role in LDCs' energy markets, as the integration of variable renewables – nowadays largely off-grid – will advance; and such a development could create additional challenges for LDC grid operators. The negligible marginal costs of solar and wind generators, once installed, means that they can outcompete centralized conventional plants, especially if they are located close to users (as in mini-grids operating in "islanding mode"). However, while this could help to reduce overall electricity prices and foster greater access, the partly unpredictable fluctuations of solar and wind generation may result in additional ramping costs and lower capacity factors for conventional backup generators (Boccard, 2010; IEA, 2016a). As the penetration of variable renewables increases, system flexibility thus plays a more and more fundamental role in supporting the decarbonization of the power sector, while limiting price fluctuations.

These issues may appear somewhat distant for LDCs, given the generally limited role of non-hydro renewables in grid generation; but anticipating such systemic challenges and fostering the emergence of a diversified and flexible electricity system is important to smooth and sustainable development of the sector. Past energy transitions highlight the critical importance of technological interrelatedness and infrastructure needs in supporting the widespread adoption of innovative technologies for energy supply (Grubler, 2012; Sovacool, 2016). Fully exploiting the potential of technological innovations in renewable energy and storage involves the co-evolution of the energy demand (end-use) and supply systems; and this requires a systemic approach to energy policy, geared towards transformational energy access.

From an LDC perspective, this suggests four priorities. First, once the initial phase of technological experimentation has been completed, LDCs could reap significant benefits from becoming "early followers", adopting advanced energy technologies to the extent possible.[27] As energy transitions typically take several decades, accelerating technology diffusion from the "core" (early adopters) to the "rim" (early followers) and "periphery" (late adopters) could minimize the risk of locking in less efficient technologies (Lund, 2010; Grubler, 2012).

Second, diversifying the power generation mix, while taking account of each country's resources and comparative advantages, is essential to system resilience. Progressive investment in appropriate renewable and hybrid technologies could thus help to redress LDCs' dependence on a narrow range of energy sources (figure 3.3), as well as exploiting complementarities across different technologies.[28] Geographical diversification may also help to smooth output variability in the case of wind, and to a lesser extent solar (IEA, 2016c).

Third, strengthening grid flexibility and upgrading monitoring and control capabilities, to ensure interoperability and manage the increasing complexity of power flows, could offer considerable opportunities for leapfrogging (Welsch et al., 2013; IEA, 2016a). However, it would also entail significant investment costs, and take considerable time, especially in light of the ICT-intensive nature of "smart grids". Interconnection of electricity network infrastructures internationally could further promote diversification (chapter 4), especially where resource potential and technological portfolios are complementary (Africa Progress Panel, 2015; IEA, 2016c).

Finally, systemic approaches to electricity markets in LDCs need to address the role of energy-efficiency practices and demand-side management (IPCC, 2014; Ouedraogo, 2017). The greater capital stock in downstream and end-use sectors than in generation highlights the need for a bottom-up, design-driven approach to end-use technologies (Grubler, 2012).

E. Scope and challenges for energy technology transfer

As recognized by the international community (e.g. in the 2030 Agenda and the Istanbul Programme of Action), access to technology is a fundamental enabler of LDC structural transformation; and facilitating the development and transfer of environmentally sound technologies is a key pillar of the global fight against climate change (under UNFCCC and its Technology Mechanism, Technology Transfer Framework and Poznan Strategic Programme on Technology Transfer). Thus, technology transfer is essential to the achievement of SDG 7.

Of the four main channels for technology and knowledge transfer (trade, foreign direct investment (FDI), licensing and labour mobility), trade is by far the most relevant to energy-related technologies. The expansion of LDC electricity generating capacity over the past 20 years has been reflected in a major increase in imports of generating machinery and equipment and of electrical end-use machinery and appliances (figure 3.15). Around half of LDCs' imports of power-generating machinery and 70 per cent of electrical end-use machinery and appliances are from ODCs, highlighting the growing importance of South-South trade as a vehicle for energy-related technology transfer. While China has been the main driver, increasing its market share spectacularly since the mid-2000s, several other ODCs are also involved, especially for end-use appliances.[29]

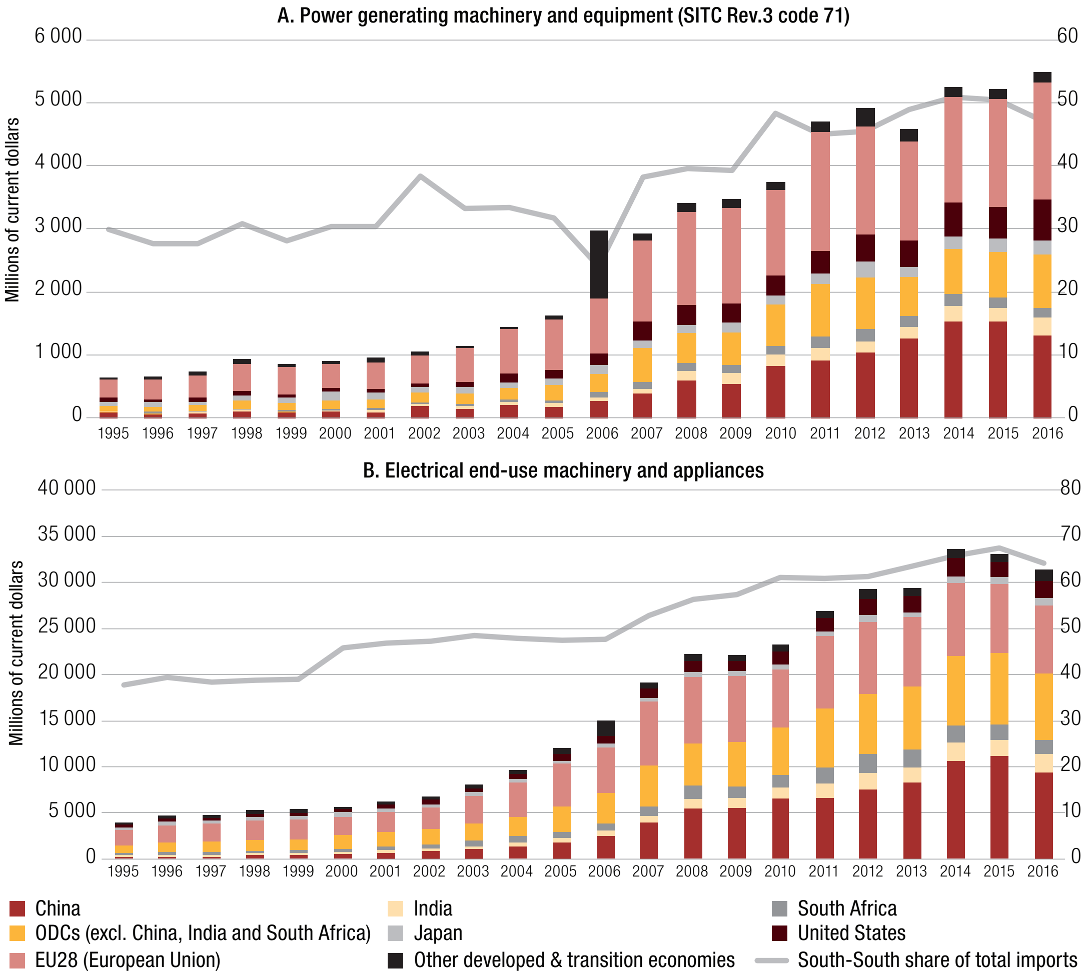
Burgeoning trade flows confirm the dynamism of investment in LDC energy sectors, but assessing the effectiveness of technology transfer is much more complex. The process of technology transfer encompasses not only the "discovery" of the technology, but also the acquisition of related knowledge and capabilities and viable economic application of the discovery in the recipient country's context (UNCTAD, 2011a, 2014b). From this perspective, technology-transfer measures in favour of LDCs have a rather inadequate track record, reflecting vague and non-binding formulation, lack of adequate funding, fragmentation and limited political will (UNCTAD, 2016b).

South-South trade is an important means of energy technology transfer to LDCs, but local absorptive capacities need to be strengthened

Local absorptive capacities and innovative capabilities are thus particularly critical in the energy sector, given its complexity and the importance of context-specific conditions to technology design, its integration in the broader electricity system and the viability of

Figure 3.15

LDC imports of electricity-related capital goods, by origin, 1995–2016



Source: UNCTAD secretariat estimates, based on data from UNCTAD, UNCTADstat database (accessed June 2017).

Notes: The SITC Rev. 3 items considered as a proxy for electrical end-use machinery and appliances include chapters 72 to 77, excluding those items which are non-electric or explicitly related to transport, namely 722, 723, 744, 745, 746, 747 and 748.

the underlying business model. However, LDCs have relatively weak local innovation systems, reflecting their structural vulnerabilities (UNCTAD, 2014b). Despite overall improvements in secondary and tertiary enrolment ratios, skilled workers with science, technology, engineering and mathematics backgrounds remain scarce, women being particularly underrepresented (UNCTAD, 2011b). Moreover, LDCs invest barely 0.3 per cent of GDP in research and development (R&D) activities, and only one tenth of this in engineering and technology.[30]

This highlights the need for:

- A strong emphasis on capacity development in the design, implementation and monitoring of energy-related projects;
- A robust science, technology and innovation (STI) policy framework, ranging from use and adaptation to technology production and innovation;
- Greater involvement of local universities and research institutions in energy-related activities;
- Concerted efforts to promote experience-sharing, mutual learning and regional collaboration in energy-related research.[31]

F. Conclusions

Achieving sustainable structural transformation and universal access to modern energy by 2030 will require a momentous increase in LDCs' power generation, faster than the expansion witnessed over the past 20-25 years. Relative to 2014, LDCs' combined electricity generation needs to be scaled up by a factor of between 3.4 and 6.8 to be adequate for productive use, and by a factor of 13.5 to meet modern energy needs.

Meeting this challenge will require harnessing all available energy resources and technologies, according to local circumstances, coupled with energy efficiency measures, especially to upgrade grids and reduce transmission losses. As well as reflecting local endowments and resource potential, the energy mix should evolve in such a way as to kick-start the structural transformation process, while maximizing the development opportunities within the energy value chain. If complementarities across technologies are effectively harnessed, the wider range of options for grid-connected generation offered by the increasing competitiveness and technological improvements in non-hydro renewables could foster more diversified, more reliable, and less import-dependent electricity systems, with additional benefits for the national economy and energy security. While fossil-fuel-based generation is likely to play a continuing role where substantial sunk costs have already been incurred and in countries with significant reserves, a progressive move towards renewable technologies could offer substantial development opportunities as well as environmental co-benefits.

In rural areas, while grid extension still has a role to play (especially in view of the higher demand resulting from structural transformation), the emergence of off-grid technologies has the potential to accelerate electrification. In this respect, the modularity of off-grid renewable technologies makes them particularly suitable to incremental deployment. Renewable and hybrid off-grid solutions can also contribute to diversification of LDCs' power generation mix, system reliability and energy security.

However, in contrast with the relatively smooth roll-out of small-scale off-grid systems in some LDCs, the deployment of mini-grids still faces a number of technical, economic and institutional challenges. Moreover, the ambiguity as to whether off-grid solutions represent an alternative to, or a stepping stone towards, grid extension gives rise to potential tensions and time inconsistencies between support for off-grid solutions and grid extension, which would be more conducive to more sophisticated productive uses of energy.

These circumstances highlight the need for a systemic approach to the energy sector, exploiting the synergies and complementarities between technologies and energy sources in support of structural transformation, while maintaining flexibility to respond to rapidly evolving technologies and cost structures and avoiding locking in technologies that may prove inappropriate as structural transformation proceeds. This includes a carefully planned and forward-looking approach to transformational energy access, including transparent plans for grid extension, with clear strategic guidelines to ensure the early adoption of mutually compatible standards to allow mini-grid interconnection as appropriate at a later stage; a proactive policy framework that supports and facilitates progressive technological upgrading; and conducive STI policies, fostering a greater involvement of local research institutions in efforts towards adaptation and innovation in energy technologies and their wider use.

Notes

1 United Nations Statistics Division (UNSD) data comprise under the label "combustible fuels" all fuels that can be ignited or burnt, hence fossil fuels (oil, coal and natural gas) but also bioenergy products such as biofuels, biogas, agricultural waste, wood, charcoal, etc. While a detailed breakdown of the electricity generated from each fuel is unavailable (partly due to the possibility of "cofiring", i.e., using different fuels in the same plant), this can be estimated on the basis of country-level data on fuel inputs and their corresponding efficiency. Box 3.1 provides some basic explanations of the main features of various combustible fuel technologies.

2 Data limitations are particularly acute in relation to non-hydro-renewable technologies due to their use in off-grid energy systems, which are more difficult to monitor.

3 Available at http://www.world-nuclear.org/information-library/country-profiles/others/emerging-nuclear-energy-countries.aspx (accessed September 2017).

4 Due to limitations in UNSD data coverage of renewable off-grid energy systems, this subsection uses data from the International Renewable Energy Agency (IRENA).

5 Afghanistan, Bangladesh, Bhutan, Burkina Faso, Cambodia, the Comoros, Democratic Republic of the Congo, Ethiopia, the Gambia, Haiti, Kiribati, Madagascar, Malawi, Nepal, the Niger, Rwanda, Senegal, South Sudan, the Sudan, Timor-Leste, Tuvalu, the United Republic of Tanzania, Vanuatu and Yemen.

6 Box 3.1 provides some basic explanations of the main features of different generating technologies.

7 Solar and wind technologies are often jointly referred to as variable renewables, because of the fluctuating nature of their output.

8 Equally, no LDC has yet sought to deploy marine power, suggesting that LDCs tend to prioritize commercially viable technologies over less mature alternatives whose success requires greater research and development.

9 Notwithstanding the lack of a universal definition of "utility scale", the expression typically refers to large-scale projects (often with a capacity of 10 MWe or larger), to be connected to the national grid.

10 Benin, Burkina Faso, Cameroon, Cape Verde, Kenya, Madagascar, Malawi, the Niger, Senegal, South Africa, Uganda and United Republic of Tanzania.

11 The Intergovernmental Panel on Climate Change (IPCC) finds "robust evidence" and "high agreement" that "Efficiency enhancements and behavioural changes, in order to reduce energy demand compared to baseline scenarios without compromising development, are a key mitigation strategy in scenarios reaching atmospheric CO2eq concentrations of about 450 to about 500 ppm by 2100" (IPCC, 2014: 20).

12 In the absence of an agreed definition and classification of off-grid systems, this Report uses the term to refer to a broad suite of technologies for local generation and distribution, which *typically* operate disconnected from the national grid (IEA, 2011; Kempener et al., 2015).

13 "Islanding" refers to the temporary isolation of a portion of the grid to enable it to operate independently.

14 In the case of solar PV, for example, small- and large-scale plants differ significantly, utility-scale applications having higher capital costs but also better performance (IEA, 2016b).

15 Another example of intervention aimed at building the market for SHSs is the World Bank's Lighting Global platform, which supports market development in 18 developing countries (including 13 LDCs) through market intelligence, quality assurance, business support services and consumer awareness-raising.

16 Cultural norms and age appear to be important determinants of gender differences in education effects: in Rwanda, for example, study time was not significantly affected for secondary school children, and increased only for boys in primary school, whereas girls of the same age just shifted their study time from the afternoon to the evening (Grimm et al., 2014).

17 Energy demand is generally contingent on the availability of appropriate end-use machinery and devices, indispensable to make use of related energy services, be it for residential or productive purposes (Grubler, 2012; Sovacool, 2016). A firm recently connected to the grid, for instance, needs also to invest in electrical machinery before being able to harness electricity for productive purposes.

18 Given their less sophisticated nature and potential backward linkages with the local economy, bioenergy-based mini-grids could potentially offer significant developmental benefits (UNCTAD, 2011a). However, their sustainable-development impact depends on a host of context-specific considerations, including changes in crop patterns, pressure on natural resources, local pollutants and land-based investment issues.

19 Unlike diesel, biofuels are often not readily available, making the viability of biofuel-based mini-grids dependent on the suitability and scalability of the local upstream supply chain for bioenergy products.

20 While long-term sustainability warrants some emphasis on cost recovery, this does not necessarily imply an unfettered emphasis on profit maximization on the part of mini-grid operators: subsidized tariffs and cross-subsidization measures are standard practice in community- and utility-based mini-grid business models.

21 These figures may be biased downwards by the lack of systematic geological prospecting in some regions.

22 More formally, the LCOE is defined as the ratio between expected lifetime expenses and total expected electricity generation, both in net present value terms. It thus represents the minimum average electricity price consumers would have to pay to recover all costs, including a rate of return equal to the discount rate.

23 The global average LCOE of concentrating solar power and offshore wind could witness similar trends, dropping

by 43 per cent and 35 per cent respectively by 2025 (IRENA, 2016a).

24 Accounting for CO_2 emissions in LCOE computations is seriously complicated by the absence of a global mechanism for carbon pricing and uncertainties about climate-change impacts.

25 Although Bangladesh is the leading LDC in the deployment of SHSs (figure 3.6), the absence of solar power in figure 3.14 reflects the fact that electricity generated from solar PV is not fed into the grid but rather used for off-grid systems.

26 Whether different technologies are substitutes or complements thus depends on their time profiles of generation as well as relative costs (Ambec and Crampes, 2012). Some practitioners anticipate that storage may become the next disruptive technology, if cost reductions and performance improvements continue, allowing still faster deployment of variable renewable technologies (Frankel and Wagner, 2017).

27 Examples include low-wind speed mills, solar modules allowing for orientation and tilt, or even solar towers with integrated storage components (IEA, 2016c).

28 For example, hybrid PV/wind plants may benefit from higher efficiency and partly complementary time profiles of generation (Ludwig, 2013).

29 According to Comtrade data, the one segment where China has emerged as the undisputed market leader is solar PV, scale economies and declining production costs allowing it to supply nearly three quarters of all LDC imports of photosensitive semiconductor devices and light-emitting diodes in 2015 (SITC Rev.3 basic heading 77637).

30 These figures are based on a simple average of the latest observations for the 12 LDCs for which data are available from the United Nations Educational, Scientific and Cultural Organization (UNESCO), UIS.STAT database.

31 India’s Barefoot College represents an insightful example of South-South collaboration for skills transfer. Barefoot College and Vocational Training Centres provide illiterate or semi-literate rural women from several LDCs with training and skills to install, maintain and repair solar home systems, as well as basic business, financial and digital literacy (Roy, 2016).

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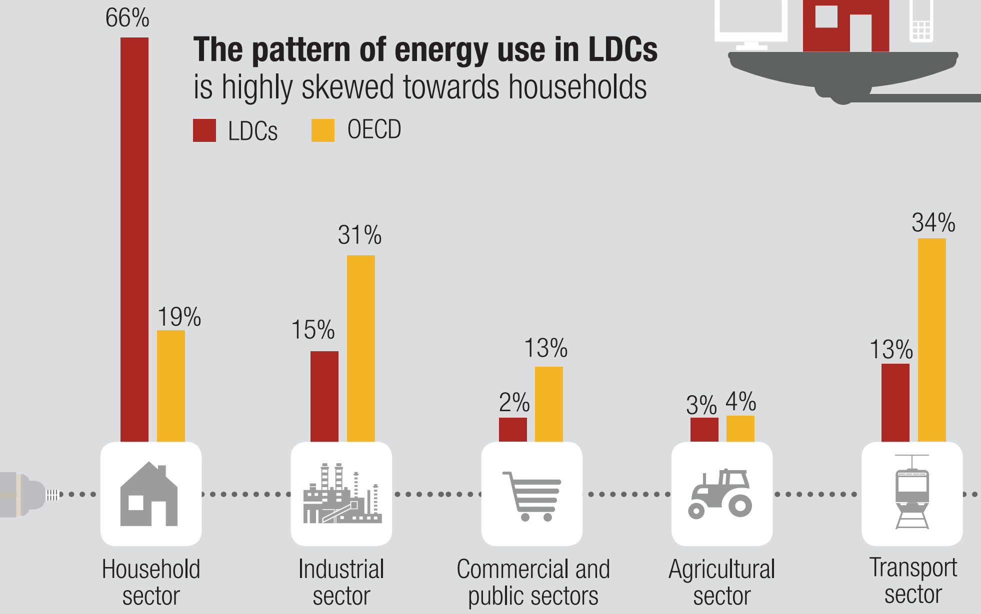
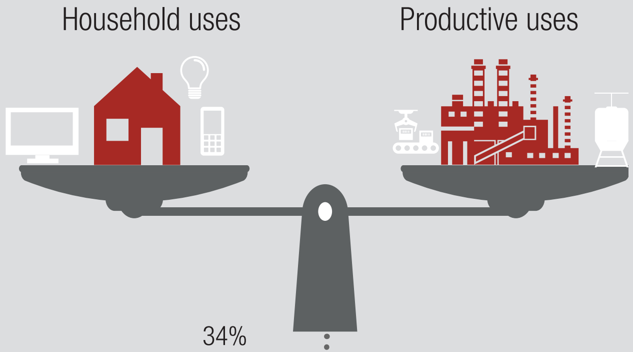


The pattern of energy use in LDCs
is highly skewed towards households



TRANSFORMATIONAL ENERGY ACCESS

= equal priority to productive and household uses of electricity

A HOLISTIC AND COORDINATED APPROACH

is essential to the delivery of transformational energy access

INTERLOCKING POLICY INFLUENCES

underpin electricity policy

CHAPTER 4

Governance and policy in electricity provision

CHAPTER 4

Governance and policy in electricity provision

A. Introduction

Governance structures — the set of institutions, policies and regulations that frame ownership structures and operations, and the rights and responsibilities of actors in the electricity sector — are generally recognized as important determinants of sectoral performance, the quality of electricity services and private-sector participation and finance in the sector. Governance and finance choices today thus have major implications both for the future coverage, capacity, sustainability and viability of electricity systems, and for the financing of the investments needed. Since the nature of electrification systems affects the types of productive activities that develop, and thus the future competitiveness of the economy, governance options need to be carefully evaluated in the light of structural-transformation goals.

The environment for such choices will be affected by the new challenges and opportunities associated with climate change and the advent of distributed electricity provision, and by the current context of technological disruption, which highlights the importance of maintaining flexibility in a sector where the time-horizon for planning is typically 30-40 years (Bharath Jairaj, 2016). This chapter assesses the governance challenges and opportunities in least developed countries (LDCs) brought about by the rapidly changing context of the electricity sector.

B. Electricity fundamentals: Implications for governance

A full appreciation of the fundamentals of electricity sector governance is aided by the recognition that the sector is subject to the interaction of a combination of market, political and technical forces. Governance frameworks thus evolve in line with the weightings that national contexts and choices assign across these interlocking and always-present influences. The key market, political and technical forces underlying governance frameworks are discussed here.

1. Natural monopoly and the role of the public sector

Until the late 20th century, electricity provision generally relied on conventional technologies in the form of turbine generators fired by fossil fuels or hydropower, which are characterized by considerable economies of scale (Martin, 2009). This favoured large-scale centralized generation, which in turn fostered the development of transmission systems to provide power to users away from where generation took place, giving rise to interconnected grids. Typically, each area was served by a single transmission and distribution (T&D) network, as duplicating such networks was economically unjustifiable, giving rise to geographical monopolies.

Electricity governance frameworks are shaped by a combination of market, political and technical forces

Like other network industries, such as transportation and telecommunications, the electricity sector is thus composed of complementary nodes and links that exhibit increasing returns to scale and scope in production or consumption. Consequently, it has traditionally been regarded as a natural monopoly. A natural monopoly arises where an entire market, by its nature, can be served at lower cost by a single supplier than by multiple suppliers (Corneli and Kihm, 2016), typically as a result of extreme economies of scale and scope, often associated with high fixed costs. The high fixed costs of centralized systems required a large and guaranteed market to generate reasonable returns on investment, which favoured population agglomeration; hence an apparent urban bias in developing-country contexts.

In the case of electricity supply in centralized systems, the natural monopoly is reinforced by significant barriers to entry by multiple providers (Besant-Jones, 2006). It is also reinforced by the need for a single-system operator to balance demand and supply continuously to keep up service quality and avoid costly blackouts in the absence of cost-effective technologies to maintain voltage, frequency and reliability automatically (UNCTAD, 2007).

This technical and economic evolution of electricity systems underlies both the active role the public sector has traditionally played in the electricity sector (Byrne and Mun, 2003) and the widespread organization of the sector as a vertically integrated industry, with a single entity responsible for generation, transmission and retail distribution within a given geographical area. In many developed and developing countries, electricity has been provided by public utilities with a legal monopoly, subject to price controls, as a means of capturing the cost advantages of economies of scale and scope while avoiding abuses of monopoly power, in order to ensure a high-access, low-cost service.

The natural-monopoly status of electricity transmission and distribution remains undisputed, and a well-regulated legal monopoly is widely recognized among economists as a more efficient response to natural monopoly than multiple competing firms. However, technological advances since the 1970s have conclusively challenged the natural-monopoly status of electricity generation. Together with poor performance of some regulated industries, changes in the political economy of regulation, and an ideological shift in favour of free markets, this has led to the transformation of Governments' participation in, and governance of, the electricity sector, as part of a wider restructuring of network industries in many jurisdictions.

2. Private goods and public goods

According to economic theory, electricity supplied for domestic or business consumption is a private good because individual homes and businesses can be excluded from receiving electricity services. Consequently, it can be traded as a commodity.

In contrast, the availability and reliability of the electricity supply are classifiable as public goods. However, electricity continues to be widely perceived by many as a public good (Byrne and Mun, 2003) because it is the means of producing other important public goods, such as street lighting. Moreover, Governments in many developing countries and smaller markets continue to play a central role in the development of electricity infrastructure, reflecting the scale of the investments required for centralized generation and distribution and the essential nature of electricity. Its exploitation of natural resources (such as water and natural gas); public financing of its large ongoing fuel costs; and the historical role of the public sector in its provision mean that it remains widely viewed as a public service (Corneli and Kihm, 2016) in spite of liberalization efforts.

Even before the adoption of the Sustainable Development Goals (SDGs), a majority of developing countries had adopted universal access to electricity as a development objective (Scott and Seth, 2013). Its public provision provided a means of promoting both inclusiveness and affordability through cross-subsidization (Heald 1994: 38). It also enabled Governments to circumvent coordination challenges through centralized planning and system design.

3. Energy security

Energy is essential to the fulfilment of many of the rights enshrined in the Universal Declaration of Human Rights and to the achievement of many of the SDGs, as well as being vital to structural transformation (chapter 2). Since the 1973 oil crisis, it has also been widely recognized as a strategic resource. Energy security — defined by the International Energy Agency (IEA) as "the uninterrupted availability of energy sources at an affordable price"[1] — is thus a major priority, whose absence threatens serious economic and social impacts.

A key part of this is reliable and affordable access to electricity, for which Governments are widely held responsible. Electricity access is commonly acknowledged as a basic need for human development (Scott and Seth, 2013), and has been described as a moral imperative, socially prudent and an economic necessity (GEA, 2016: 19). Aside from the public-good dimension of safe and reliable electricity supply, consumer protection and guaranteed access are important political-economy considerations (Bamber et al., 2014; Scott and Seth, 2013). Such energy-security concerns generally serve to reinforce State control and regulation of the electricity sector (Kuik et al., 2011).

Central concerns for electricity security are fuel security and adequacy and security of energy systems (IEA, 2016e). However, its interpretation is heavily influenced by national contexts, for example in terms of energy access, the energy mix and dependence on energy imports. For energy-importing countries (developed as well as developing), particular concerns are the resilience of energy systems to external supply shocks, the balance-of-payments effects of changes in international energy prices and diversification of energy suppliers (Yergin, 2006).

The challenge of electricity security in developing countries is inextricably linked with that of sustainable development, and the primary concerns remain meeting basic human needs at the household level and powering structural transformation and economic growth. However, the main focus has shifted from securing reliable low-cost supplies of fossil fuels for electricity generation and transport to identifying new and diversified sources of baseload power in the context of structural transformation and climate policy (Global Network on Energy for Sustainable Development, 2010).

4. Market power

The tendency towards natural monopoly in electricity provision and the significant barriers to entry by multiple providers give rise to a particular threat of abuse of monopoly power, even in liberalized electricity markets. While the nature of the industry lends itself to monopoly leveraging, predatory pricing and other anticompetitive uses of market power, the application of competition law and policy is far from straightforward (Kim and Kung, 2013; Pindyck, 2008). For instance, the complexity of electricity markets complicates the measurement of sunk costs under competition, precluding a simple test of the exercise of market power and giving rise to apparently similar behaviour among generators with and without market power (Hogan, 2002).

Consequently, electricity markets tend towards oligopoly rather than perfect competition (Murphy and Smeers, 2003). Even in the European Union in

2015, following decades of liberalization and regional regulations, the largest generator in at least 15 of the 28 member countries had a market share at or above the Organisation for Economic Co-operation and Development (OECD) dominance threshold of 40 per cent.[2] That share exceeded 50 per cent in 10 cases and 70 per cent in seven. This underlines both the key role of competition policy in liberalized and unbundled electricity markets and the complexity of liberalized electricity sectors relative to monopoly public utilities (UNCTAD, 2007). It also underlies the emphasis placed by experts on appropriate sequencing of electricity-sector reform and the importance of establishing strong regulatory institutions and comprehensive ancillary regulations ahead of liberalization (Besant-Jones, 2006; UNCTAD, 2009; Vagliasindi and Besant-Jones, 2013; Nepal and Jamasb, 2011; Jamasb and Pollitt, 2005; Kessides, 2012b; Joskow, 2008; Williams and Ghanadan, 2006; Heller et al., 2003; Wamukonya, 2003; Scott and Seth, 2013).

C. The evolution and status of market structures and governance in LDCs

1. Electricity-sector reform since the 1980s and 1990s

The electricity industry has experienced more than one cycle of reorganization since its inception. The predominant pattern of centralized provision by vertically integrated public monopolies (section B1) was itself the result of a deliberate shift away from mainly private and distributed provision of electricity services. This State-led model was encouraged both by the Cold War super-Powers and by multilateral development agencies, and was bolstered by economic growth, official development assistance (ODA) and expanding national budgets; and it proved largely successful (Kessides, 2012a; Williams and Ghanadan, 2006).

The 1980s and 1990s saw a new wave of reforms affecting market structures, private participation and regulatory regimes, reflecting a dramatic shift in attitudes towards ownership, organization and regulation in the electricity industry (box 4.1). This wave of reform largely bypassed the LDCs, although a few, such as Bangladesh (1996), Burkina Faso (1998), Chad (1999) Guinea-Bissau (1998), Nepal (1993) and Uganda (1997), implemented or experimented with various aspects of the reform model, with varying degrees of success. In Burkina Faso, for example, the sector was opened to private-sector participation in 1998 but had little success in attracting private-sector investment, while attempts at reform in Guinea-Bissau between 1998 and 2005 were frustrated by political instability.

Past energy reforms demonstrate the need for a pragmatic approach, based on local realities

Since 2000, many more LDCs have instituted reforms, partly driven by changes in the international development finance landscape. The Addis Ababa Action Agenda (adopted in 2015 at the third International Conference on Financing for Development) has reaffirmed the emphasis on the private sector's role in delivering developmental outcomes; lending policies of the World Bank and other multilateral donors combine investment lending with loans linked to institutional reform (Bacon and Besant-Jones, 2001); and electricity-sector reform has been included by multilateral development banks in financial rescue packages (Nakhooda, 2011; Woodhouse, 2006).

Private participation in electricity supply is also actively promoted by bilateral initiatives, such as the Power Africa Initiative led by the United States Agency for International Development[3] and the Energy Africa programme of the United Kingdom Department for International Development, both of which target increased off-grid access to electricity for households by private-sector providers. Power Africa implements a "reform-driven approach linking policy and regulatory reform to tangible power sector investment",[4] and compacts with national Governments include voluntary commitments to restructure electricity sectors (e.g. the Partnership Memorandum of Understanding between the Government of Liberia and Power Africa of 2014) and to implement cost-reflective tariffs (e.g. Malawi in 2016).

Further impetus to reform in LDCs has come from changes in the context of the electricity sector arising from technological advances and the challenge to the dominance of fossil fuel-based centralized generation associated with climate change and increasing emphasis on environmental sustainability. In LDCs that are heavily dependent on oil imports for generation, an additional factor has been pressure to diversify energy sources as a result of high and volatile oil prices, particularly in 2010–2014.

While the model of reform has evolved since 2000, the experience of the earlier reforms has important lessons for LDCs. In particular, it highlights the need for a pragmatic approach based on local realities rather than a particular school of economic thought, and the fundamental need for realism in terms of the complexity of reforms, countries' capacities for implementation and the time frame for delivery of their objectives. Of particular relevance to LDCs is recent empirical evidence that unbundling is unlikely to be worthwhile when electricity systems are below an optimum size and markets below an optimum per capita income level (Vagliasindi and Besant-Jones, 2013).

One response to the problems with the wider reform agenda has been the promotion of long-term purchasing contracts (power purchase agreements, or PPAs), often for 20 years or more, with independent power producers (IPPs). This is seen as a relatively quick and straightforward way to introduce competition without extensive restructuring, while protecting social equity (Sen et al., 2016; Besant-Jones, 2006; Heller et al., 2003). Such arrangements have played a significant role in expanding generation capacity in many developing countries. However, the success of this model depends on a coherent policy framework and effective regulatory governance and capacity (Nepal and Jamasb, 2011), and it has been a major avenue for corruption and other governance failures in electricity sectors (World Bank, 2010; Eberhard et al., 2016). It has also proved very costly in countries without the technical skills necessary to negotiate favourable terms, and costs are often increased by "take-or-pay" payment structures delinked from actual electricity use, and/or by denomination in foreign currency.

Box 4.1. **The 1980s/1990s electricity-sector reform model**

The electricity-sector reforms of the 1980s and 1990s centred on the concepts of electricity generation as producing a tradable commodity, for which cost discipline and risk management were needed, and of T&D as a service business reliant on network management (Besant-Jones, 2006). They broadly followed the experiences of early reformers, such as the United Kingdom, Norway, Chile and the United States (Sen et al., 2016; Nepal and Jamasb, 2011), and targeted efficient pricing, long-term transmission rights and addressing market power.

A core element of the reforms was unbundling — separation of the potentially contestable generation subsector from the monopoly transmission and distribution segments (see box table 4.1) — to create a market structure conducive to competition. This takes four main forms (Jamasb and Pollitt, 2005):

- Accounting unbundling — the least drastic form, achievable within a vertically integrated enterprise – entails separation of the accounts of network and generation activities, to prevent cross-subsidization.
- Functional (or management) unbundling combines accounting unbundling with separation of operational activities and management.
- Legal unbundling entails corporatization, to locate transmission and generation in separate legal entities (although they may be owned by the same parent company).
- Ownership unbundling, the strictest form of separation, requires generation and transmission activities to be owned by independent entities confined to operation in only one segment of the industry.

Developing countries were encouraged to unbundle their electricity utilities, vertically and horizontally, to create independent regulators and make space for private-sector participation — an approach actively promoted by the World Bank from 1990 until 1996 through a "no-lend" policy for the sector in the absence of substantial reforms aimed at commercialization and independent regulation (Woodhouse, 2006: 133).

Liberalization and unbundling fundamentally change the structure of the sector, necessitating changes in governance frameworks. In the electricity sector, competition leads, not to less regulation, but to different regulation (Hogan, 2001), as the much greater number of actors involved requires more elaborate governance frameworks that spell out the roles of all industry players and define the role of the State, with an independent regulator to establish and enforce regulations governing interactions amongst the various actors. The resulting shift to more complex systems dependent on specialist skills and regulation also gives rise to a greater legislative burden to create competitive electricity wholesale markets and trading arrangements, establish system operators and independent regulators, and prevent abuse of market power.

The nature, extent and final outcomes of the 1980s reforms differed widely between countries, particularly between developing and developed countries, largely reflecting differing initial conditions and motivations for reform (Wamukonya, 2003; Vagliasindi and Besant-Jones, 2013; Kessides, 2012b; UNCTAD, 2007), as shown in box table 4.1. While developed countries broadly followed the standard reform model, reform efforts were reversed or went awry in many developing countries, so that most have incomplete unbundling, and are expected to retain such intermediate structures for the foreseeable future. Many national electricity industries, reformed as well as unreformed, continued to perform poorly, financially and operationally, many years after reform (Williams and Ghanadan, 2006).

The shortcomings of the reforms of the 1980s and 1990s are now widely recognized, including the undue weight given to techno-economic considerations rather than implications for national energy sectors in the light of existing resources, institutions and capacities (Heller et al., 2003), and underestimation of the complexity of reforms and the time required to achieve lasting outcomes (Zhang et al., 2008). The limited implementation of reforms has been attributed to "differing views and a degree of theoretical ambiguity in the economic literature on the effectiveness of unbundling and competition", and "a large gap in understanding about power market structures" due to a focus on the extremes of vertical integration and complete unbundling to the neglect of intermediate options (Vagliasindi and Besant-Jones, 2013: 19, 26).

2. Electricity market structures in LDCs: A typology

While a typology of market structures in LDCs is complicated by the fluid nature of policies and current or prospective reforms and legislation, most can be divided into five broad categories of sector structures.

- **Vertically integrated:** the traditional centralized structure in which a single entity operates generation, transmission, distribution and supply (including public utilities co-existing as single buyers with IPPs, build-operate-transfer contracts or concessions and/or operating disconnected grid systems). This model exists in Burundi, Central African Republic, Chad, Democratic Republic of the Congo, Djibouti, Eritrea, Guinea, Guinea-Bissau, Haiti, Lao People's Democratic Republic, Nepal, the Niger, Sao Tome and Principe, Senegal, Timor-Leste and Zambia.
- **Partial vertical disaggregation:** functional or legal unbundling of the public utility, operating as a single buyer, with only generation opened to private participation. This is an increasingly common structure amongst LDCs, and exists in such countries as Bangladesh, Bhutan, Cambodia, Ethiopia, the Gambia and Rwanda.
- **Vertically disaggregated:** several companies active in all segments of the electricity supply chain. This model operates in Uganda, one of the few LDCs to undertake legal unbundling of the national utility, where nine IPPs feed into the grid, including a 20-year concession to operate the former public utility's generation assets, and the publicly owned West Nile Rural Electrification Company. However, the

Box 4.1 (contd.)

Box table 4.1

Motives and drivers of 1980s reform

Country group	Initial conditions	Motives for reform	Drivers of reform
Developed countries	**Sector** • Surplus generation capacity and low investment needs • Developed transmission networks • High construction and operating costs • High retail tariffs • Tolerable performance • Universal access **Institutional** • Established law, skills and experience • Institutions able to facilitate arm's-length regulation of natural monopolies and private-sector ownership	**Sector** • Promise of more economically efficient sector with advent of smaller, lower-cost and higher-efficiency electricity generation technologies • Quest for lower retail prices and enhanced consumer choice through retail competition **Institutional** • New institutional arrangements providing long-term benefits to society	• Ideology • European Union Electricity Directives of 1996 and 2003 required member States to move towards independent regulation and system operation, stronger network unbundling, regulated grid access and full consumer choice by 2007 (a third EU liberalization package to improve the functioning of the internal energy market and resolve structural problems followed in 2007)
Developing countries	**Sector** • Highly subsidized low retail tariffs alongside theft and chronic non-payment of utility bills in some countries • Insufficient generation capacity compounded by high distribution losses; frequent power outages • Underdeveloped transmission networks • High infrastructure investment needs for expansion, maintenance, upgrading or modernization • Pent-up and rising demand • Very low access and persistent urban/rural divide in electricity distribution **Institutional** • Inability to self-finance modernization, expansion and maintenance of infrastructure on account of lack of public finance; low customer base with constrained ability to pay; and uneconomical tariffs • Widespread mismanagement of public utilities • Low capacity to implement reform and regulate at arm's length, with few precedents to learn from	**Sector** • Desire for economic growth and development, and social equity • Expanding supply, quality and reliability to sustain productive activity • Broadening access to address energy poverty **Institutional** • Reducing fiscal stress/sovereign debt	• Financier conditionality exacting the substitution of self-regulating markets for political governance of electricity provision • Reform-targeted loans and blueprints from donors and multilateral agencies • Priority given to financial over social concerns (e.g. universal access, affordability, etc.) • Privatization often prioritized

Source: UNCTAD secretariat, based on Wamukonya (2003); Vagliasindi and Besant-Jones (2013); Kessides (2012b); UNCTAD (2007).

LDCs have a wide variety of electricity market structures

challenges of insufficient generation, limited access, high T&D costs and power outages remain, while subsidized domestic consumption coexists with tariffs above the regional average (Mawejje et al., 2013). Myanmar also has a vertically disaggregated model, with a number of Ministry of Electric Power companies operating in each segment of the supply chain; corporatized entities responsible for distribution in Yangon and Mandalay; and IPPs in generation and distribution.

- **Locally disaggregated:** generation, transmission and distribution are fragmented by locality. This is by no means a new phenomenon in developing countries, but a long-standing practice of national utilities to address rural electrification, notably in Africa (AfDB and SE4All Africa Hub, 2017) and Asia (chapter 3), and a necessity in many island States. This model is typical of island LDCs (e.g. Comoros, Kiribati, Solomon Islands, Tuvalu and Vanuatu), in some cases with vertically integrated local utilities on larger islands. In Afghanistan and Angola, vertically integrated public utilities operate regionally disconnected grids, in the latter case with a number of smaller vertically integrated municipal operations.
- **Hybrids:** a combination of the above structures. In Mozambique, the public utility owns the major national grid, while smaller regional grids exist under the control of district authorities. The sector is based on a concession system, the national utility holding 50-year hydro concessions, while 25-50-year concessions are awarded by tender. Electricity sales are governed by bilateral agreements, and tariffs are generally unregulated. In Liberia, the Government has historically engaged the private sector through concessions (USAID, 2015), and all segments can now be licensed to the private sector, although the national utility can also continue to operate (Government of Liberia, 2015). Micro-utilities below a size threshold, operated by entrepreneurs, are permitted to operate and distribute power without a licence.

It is important to maintain the distinction between ownership and structure, as publicly owned utilities can adopt commercial principles and practices. Some vertically integrated public utilities (e.g. in Afghanistan and Lesotho) have undergone accounting or legal unbundling; and some developing countries have used management contracts as an alternative to privatization of public utilities.

Benin and Togo are unique among LDCs in operating a binational system with partially disaggregated public utilities. Generation is mainly undertaken by a binational generation company that also functions as a single buyer of electricity from IPPs or imports, while a public T&D utility in each country also maintains some generation activity. Privatization of electricity distribution in Togo in 2001–2005 was reversed due to unsatisfactory performance.

Electricity-sector structures in many LDCs reflect historical factors, such as conflict or strong regional identities. Somalia, for example, has a number of mainly private vertically integrated local operations, reflecting its difficult political environment and extensive destruction of electricity infrastructure. In the Somaliland region, a consolidation of IPPs (reflecting the industry's tendency towards oligopoly) has led to some attaining the scale of medium-sized utilities. In most cases, the grid is owned by IPPs, and parallel distribution networks coexist in the same locality.

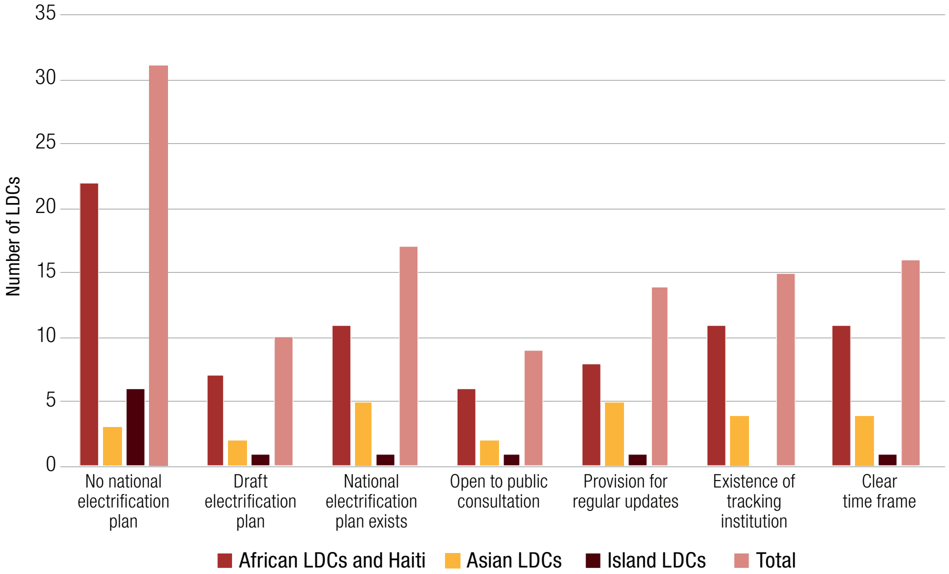
3. Current plans, policy frameworks and regulatory arrangements

While continued investment in infrastructure and capacity-building are firmly on the agendas of most LDCs, reflecting the inadequacy of capacity to meet current and future demand, their preparedness varies. Not all have detailed sector development plans, frameworks or strategies in place (figure 4.1); not all existing plans have been updated to reflect current realities; and not all national planning institutions have the skills required for such updating. The absence of such plans hinders the reconciliation of consumer, producer and market needs, the identification of least-cost alternatives, and estimation of financing needs. While some LDCs, such as Bhutan, Lao People's Democratic Republic and Senegal, have successfully expanded access without national electrification plans under their centralized systems, most LDCs are unlikely to be able to do so, given current global conditions in the electricity sector and low levels of access. Seventeen of the 47 LDCs have renewable-energy policy frameworks (figure 4.2).

Energy-efficiency targets and performance standards are needed to implement energy-efficiency programmes effectively, to prioritize funding and to devise scalable strategies. Twenty-one LDCs have energy-efficiency plans, although four do not include explicit targets, and in six LDCs the targets feature in their energy policies rather than in energy plans (figure 4.3). While technologies linked to smart grids are efficiency-enhancing and could in principle improve the economic viability of existing centralized systems, smart grids are not simply plug-in additions to existing networks, but require new approaches to electricity network design and operation.

Figure 4.1

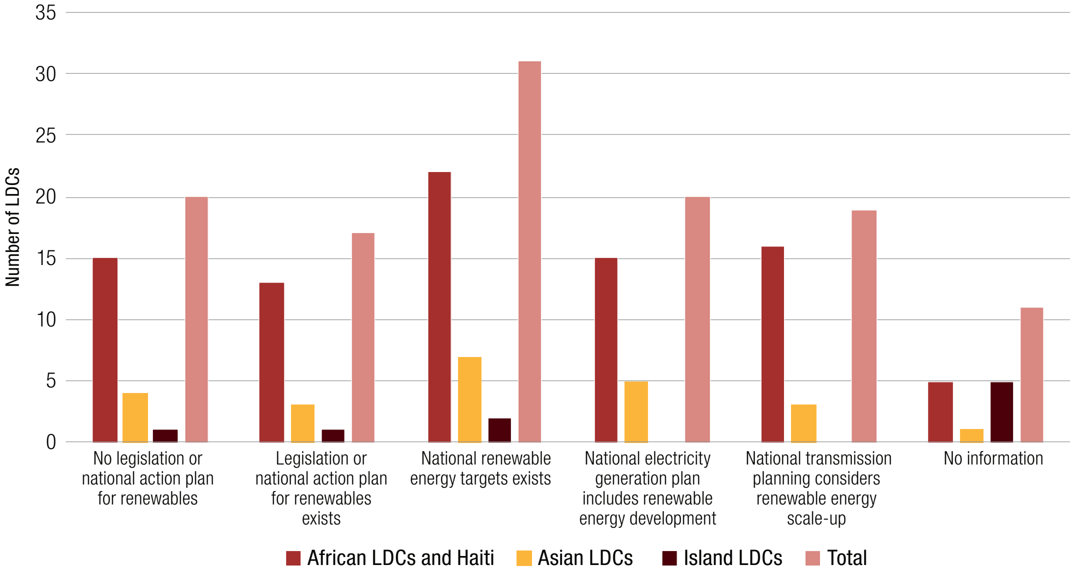
Prevalence of LDC electrification plans



Source: UNCTAD secretariat estimates, based on data from World Bank, Readiness for Investment in Sustainable Energy (RISE) database and Renewable Energy and Energy Efficiency Partnership (REEEP) Policy Database (accessed April 2017).

Figure 4.2

Prevalence of LDC renewable energy policy frameworks



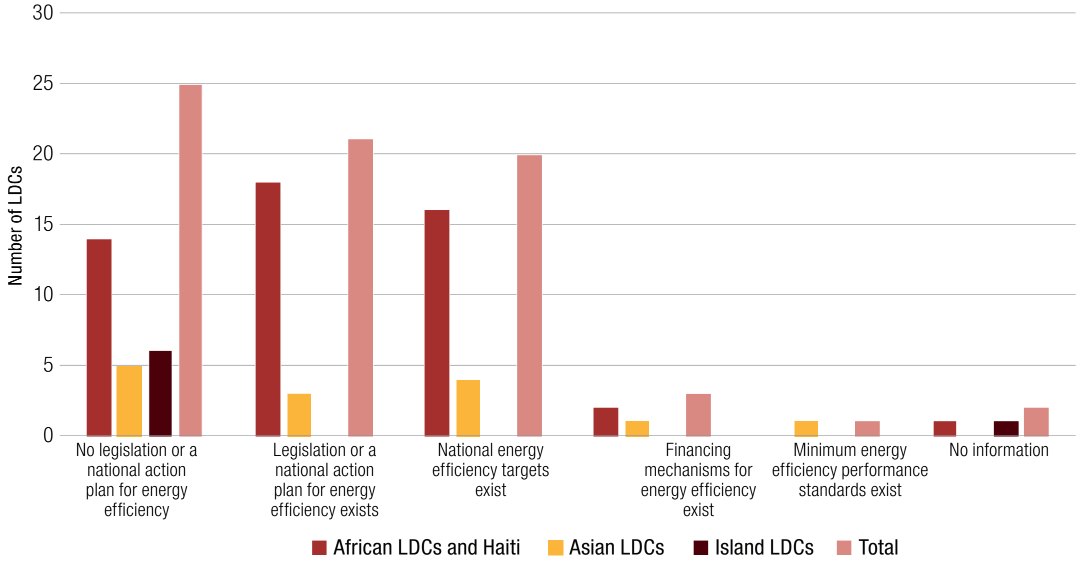
Source: UNCTAD secretariat estimates, based on data from World Bank RISE database (accessed April 2017).

Virtually all LDCs have a rural electrification agency or programme (figure 4.4). A significant number also have legal frameworks for mini-grids, although these are often inadequate or incomplete. In some cases, the private sector is permitted to own and operate mini-grids and receive some type of public support in the absence of a legal framework, and only a minority of LDCs specify technical standards for mini-grids. These limitations of legal and institutional frameworks have implications for the viability and profitability of private-sector investments in mini-grids, because the ability to recoup investment in a mini-grid depends on how long it operates before the area it serves is reached by the national grid and the conditions of its integration into the grid. Mini-grids capable of sustaining semi-industrial and industrial activity at a lower cost have high upfront costs, and uncertainties arising from inadequate policy frameworks are an important constraint to private investors' access to commercial finance (ESMAP, 2017; IRENA, 2016b; Berthélemy and Béguerie, 2016; Béguerie and Pallière, 2016; GMG MDP, 2017).

Less than two thirds of LDCs have separate sector regulators for the electricity sector, while in a few the public utility performs the regulatory and planning functions (figure 4.5). In a number of LDCs, electricity

Figure 4.3

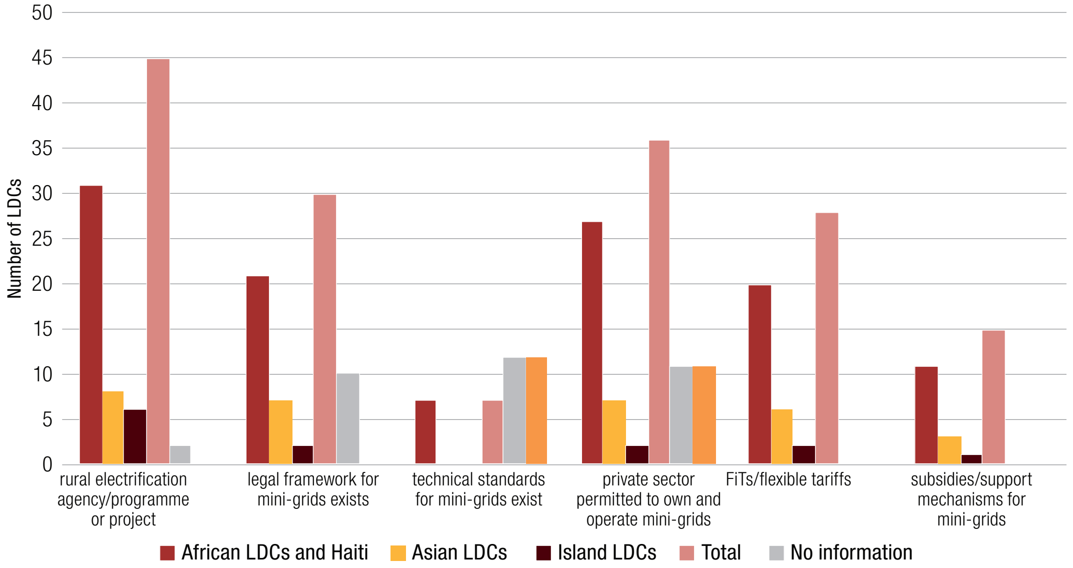
Prevalence of LDC energy efficiency policy frameworks



Source: UNCTAD secretariat estimates, based on data from World Bank RISE database and REEEP Policy Database (accessed April 2017).

Figure 4.4

Prevalence of mini-grid frameworks in LDCs



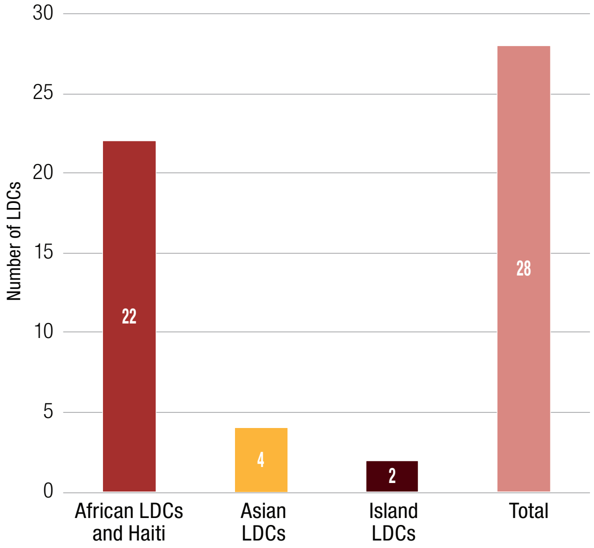
Source: UNCTAD secretariat estimates, based on data from World Bank RISE database and REEEP Policy Database (accessed July 2017); UN DESA (2014).

is regulated by a multisector regulator, in many cases combined with water supply and in one instance with telecommunications. The African LDCs and Haiti as a group have the highest proportion of countries with a dedicated sector regulator. Where there are regulatory bodies, their powers may be limited or shared with a supervisory ministry. It should also be noted that the existence of sectoral legislation does not indicate that it is effective: it is not uncommon for regulatory bodies established by law to be constrained by the absence of complementary rules and regulations necessary for their effective operation.

Approaches to electricity regulation in LDCs vary, ranging from regulation by a minister, alone or assisted by a board, through a regulatory commission chaired by a minister, to regulation by separate autonomous institutions. As the major role of some Governments in setting electricity tariffs demonstrates, some aspects of the regulatory function remain outside the domain of the sector regulator in some LDCs.

Figure 4.5

Electricity regulator prevalence in LDCs



Source: UNCTAD secretariat estimates, based on data from World Bank RISE database and REEEP Policy Database (accessed July 2017).

D. Key issues in electricity governance in LDCs

The global energy landscape has bifurcated between markets characterized by rapid demand growth and capacity constraints (including most LDCs and other developing countries (ODCs)), and markets with flat or decreasing demand and overcapacity (including most developed countries). These divergent trajectories strongly shape planning strategies and opportunities for power-system transformation (NREL, 2015), and require different tools and skills. Conditions of rapid demand growth represent a much more complex and challenging environment for assessing, planning and implementing investments.

These challenges are all the more important because of two fundamental changes faced by electricity industries worldwide: a shift from centralized fossil fuel-based generation towards more distributed generation with greater reliance on renewable energy (Lammers and Diestelmeier, 2017); and an increasing information and communication technology (ICT)-based sophistication of grid systems, which (inter alia) allows consumers to take a more active role, proactively controlling their electricity use and potentially feeding into the grid as “prosumers” (electricity consumers who also produce electricity). Such technological changes are occurring at a very rapid pace for an industry accustomed to planning on a 30-40-year time horizon, creating significant uncertainty (Bharath Jairaj, 2016). At the same time, the entry of actors new to the electricity sector, and the active engagement of consumers as a result of these new technologies, raises multiple technical, commercial and regulatory issues, requiring a “whole-system” approach and fresh thinking about electricity supply chains.

Rapid demand growth and capacity constraints are major challenges to assessment, planning and implementation of energy investments

Some observers have highlighted the opportunity for “less-gridded” countries to leapfrog carbon-intensive industrialization (e.g. The Economist, 2015; Harvey, 2015; Oh et al., 2016); and LDCs such as Bhutan, Nepal, Senegal and the United Republic of Tanzania have succeeded in stimulating rural electrification projects by mainstreaming renewables and implementing distributed generation as a central option in national energy strategies (UNEP, UNCTAD, UN-OHRLLS, 2011).

However, other observers advocate caution (e.g. Lee et al., 2016).[5] The transition towards non-hydro renewables remains at a relatively early stage in LDCs, partly reflecting technical, economic and institutional challenges (chapter 3) and the need for policy frameworks to foster their implementation. The cost of renewable technologies remains relatively high for LDCs even after recent dramatic reductions (chapter 3);

Box 4.2. **The Internet of Things**

One area where developing countries are considered by some to have a potential technological advantage is the application of the Internet of Things (IoT) in electricity provision. The IoT is defined by the International Telecommunications Union as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things, based on existing and evolving interoperable ICTs. An example of electricity-sector applications is the use of ICT to facilitate remote monitoring of the functioning and output of solar photovoltaic (PV) systems by the Kenyan solar energy company M-Kopa.

However, the growing digital divide between LDCs and ODCs in all indicators of ICT access and usage (except mobile-broadband prices) may be a constraint on their use of ICTs in the electricity sector, especially in rural areas where the relevance of such applications is greatest, but ICT penetration is weakest. While the development and success of mobile money indicates the possibility of IoT use in the absence of supporting infrastructure, optimism about its potential in LDCs is premature in the absence of LDC-specific research.

Source: ITU (2015, 2016a, 2016b).

> **A holistic sector and systems approach to energy planning and policy is needed in LDCs**

and renewables markets globally continue to be driven largely by government incentives or regulations (REN21, 2017). Adoption of new technologies is also often constrained by the absence of the capabilities required for technology access, transfer and deployment, due to the inadequacy of absorptive capacity and effective industry institutions and regulations. Some technologies with potential benefits for the electricity sector in LDCs, such as the "Internet of Things", remain out of reach for most of these countries (box 4.2).

Nonetheless, increased reliance on off-grid and non-hydro renewable energy in LDC electricity sectors in the coming years may foster a rethink of sectoral governance arrangements, particularly in conjunction with the increasing role of developed country-based private energy companies with a greater propensity to apply such new technologies. This rapidly evolving context has important implications for governance of the sector, potentially raising questions as to whether current sectoral governance arrangements remain fit for purpose (Scott, 2015).

1. Sector-wide policy and planning

The evolution of LDCs' electricity systems, as they seek to leverage new technologies and energy sources, will be shaped by the spectrum of electricity market structures and by national contexts. Beyond the standard model of reform (section C1), there is now a growing body of knowledge on the potential pathways for planning and policy (IEA, 2017a; NREL, 2015). The principal pathways are outlined in figure 4.6. Of these, the structural challenges and limited access characteristic of LDCs point towards three, based on vertical integration or partial unbundling:

- An adaptive pathway, with a vertically integrated utility prioritizing the delivery of value rather than minimizing cost;
- A reconstructive pathway, using new markets to facilitate the integration of clean energy sources and optimize systems, learning the lessons of past experiences of restructuring;
- A "bottom-of-the-pyramid" coordination pathway, focused on applying new technological options and business models to accelerate access.

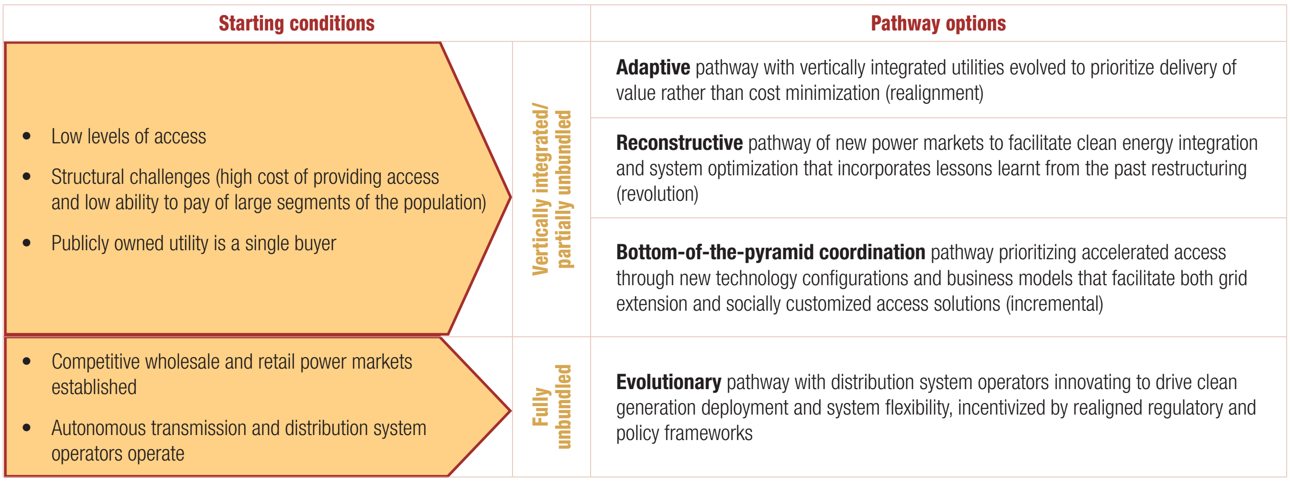
Such models imply a considered and coordinated approach to electricity system development from the outset, taking account of local contexts, sector-specific and other developmental goals and priorities, financing needs, and regulatory requirements and capacities.

Planning is particularly important for electricity systems because of the mismatch between the time required to build distribution networks and that required to build generation facilities, highlighting the need for coordination of planning processes for generation and transmission (Chattopadhyay et al., 2014; Bhattacharyya and Palit, 2016), as well as the complementarities among generation technologies (chapter 3). This is especially relevant in the context of efforts to expand access and integrate renewables in electricity systems through an optimal mix of centralized and distributed generation (Chattopadhyay et al., 2014).

Optimal reliability of electricity systems based on all available options and technologies for generation and distribution at the lowest cost requires planning on a

Figure 4.6

Electricity system transformation pathways



Starting conditions		Pathway options
- Low levels of access - Structural challenges (high cost of providing access and low ability to pay of large segments of the population) - Publicly owned utility is a single buyer	Vertically integrated/ partially unbundled	**Adaptive** pathway with vertically integrated utilities evolved to prioritize delivery of value rather than cost minimization (realignment) **Reconstructive** pathway of new power markets to facilitate clean energy integration and system optimization that incorporates lessons learnt from the past restructuring (revolution) **Bottom-of-the-pyramid coordination** pathway prioritizing accelerated access through new technology configurations and business models that facilitate both grid extension and socially customized access solutions (incremental)
- Competitive wholesale and retail power markets established - Autonomous transmission and distribution system operators operate	Fully unbundled	**Evolutionary** pathway with distribution system operators innovating to drive clean generation deployment and system flexibility, incentivized by realigned regulatory and policy frameworks

Source: UNCTAD secretariat compilation, based on NREL (2015); IEA (2017a).

timescale commensurate with the 30-40-year time horizon of investments in new facilities and the process of system development. Planning should encompass choices between private and public provision of electricity, and private and public financing. For example, public provision through centralized systems provides an opportunity for cross-subsidization to increase affordability, while distributed or stand-alone systems locally operated by the private sector usually aim to be financially self-sustaining with full recovery of operating and maintenance costs.

A holistic sector and systems approach is important to safeguard the economic viability and affordability of existing centralized systems as off-grid solutions develop. While LDC grids commonly serve urban and peri-urban areas, where the concentration of industrial activity is usually located, the low quality and unreliability of supply often motivates large clients, such as international hotels and medium-to-large firms, to rely on own-generation[6] as the main source rather than supplementary ones. This deprives the public utility of the most profitable parts of the customer base and sustains a vicious cycle whereby public utilities are unable either to cover operational costs or to finance necessary infrastructure investments.

The inability to expand access is thus both a cause and a consequence of the financial malaise of public utilities' struggling to attain financial viability. It can also contribute to larger consumer subsidies and fiscal distress where the majority of consumers have low capacity to pay, but there are limited possibilities for cross-subsidization, an issue of first-order importance in LDCs (Estache et al., 2015). In LDCs that use the single-buyer model of electricity supply, adverse effects on the public utility's financial position are compounded by higher premiums to IPPs for offtake risk under PPAs, and may even discourage IPP participation.

The ability or inability of centralized systems to provide low-cost electricity has potential knock-on effects on structural transformation and productivity. Should the transition towards renewables give rise to a high-cost environment for industrialization, this would be at odds with the basic principle of common but differentiated responsibility under the United Nations Framework Convention on Climate Change (UNFCCC), given the very limited contribution of LDCs to greenhouse gas (GHG) emissions (Bowen and Fankhauser, 2011).

2. Policy coordination

Effective planning and management of the transition to cleaner and more affordable electricity systems requires the involvement of multiple stakeholders under the clear leadership of a lead agency, to ensure that all the relevant development goals and priorities are taken into account, including investment promotion, access to technology, industrial development, gender equity, rural and urban development, poverty reduction and environmental sustainability.

Coordination among stakeholders, rural-urban linkages and gender considerations require due consideration

Policymaking structures in the electricity sector are not always conducive to clear and effective leadership. In many LDCs, ministries responsible for electricity governance may have limited or shared authority. In the Solomon Islands and Somalia, for example, energy policy is fragmented amongst several government bodies that have direct or indirect influence on the sector. In Myanmar, eight ministries are involved in the energy sector (Nam et al., 2015). In the absence of effective coordination, the involvement of multiple actors raises governance challenges and concerns around policy development, coherence, implementation and evaluation; and it inhibits holistic perspectives and approaches to national planning, policy formulation and sector governance.

The predominance of rural residents among those without access to electricity (chapter 1) has led a growing number of LDC Governments to place rural electrification (often excluding large hydro) under separate governance structures that prioritize distributed systems and renewables, in some cases under a different ministerial authority from that of long-established centralized systems. This may in part reflect a recognition of the different governance structures required for distributed systems and the need to avoid the delays associated with adapting existing governance frameworks. However, this approach may not always be indicative of a deliberate policy action backed by an adequate governance framework, effective institutions and coordinated planning.

Effective coordination can also enhance the contribution of the energy sector to other developmental goals. As well as facilitating access to a variety of services, including financial inclusion (particularly as utility bills are commonly accepted as proof of identity or address), grid extension can potentially contribute to domestic resource mobilization and combating tax evasion. In the presence of weak institutional capacities and high levels of informality, grid connections can help to broaden the tax base by identifying clandestine property development and facilitating the compilation of property registers and the collection of property taxes.[7]

By spreading the tax burden more widely, this can also help to nurture the wider State-citizen relationship (Carnahan, 2015; IMF, 2015). However, the availability of stand-alone home systems as an alternative to grid connection may limit the effectiveness of such measures.

3. Rural-urban dynamics

Electricity industries in LDCs are often dualistic, combining traditional centralized systems in cities, large provincial towns and industrial centres with poorly served rural areas, where grid extension is constrained by low incomes and/or logistical constraints. Energy-sector planning in LDCs therefore requires careful consideration of the relationship between rural-urban linkages and migration, rural electrification and structural transformation of rural economies, and the role of this relationship in inclusive development.

Developing countries are urbanizing at unprecedented rates, leaving little room for experimentation and adjustment (Henderson, 2002), and giving rise to risks of infrastructure failure and social instability. Many rapidly growing cities in LDCs are characterized by expanding or consolidating slums with increasing poverty and sometimes inequality, and around half of slum dwellers across developing countries as a whole access electricity through illegal connections (UN-Habitat, 2016). This leads to costly outages, increased reliance on own-generation, and revenue losses through electricity theft, jeopardizing the quality and stability of supply and the financial viability of public utilities. It is also incumbent on urban planners to understand the implications of inequitable access to infrastructure (UN-Habitat, 2016). Where a large proportion of urban households without access to electricity live in informal and unauthorized settlements, efforts to extend access may be constrained by lack of legal tenure, possibly requiring resettlement and complementary measures.

Rural-urban linkages also have important implications for rural electrification. Many countries in Asia and Africa have a pattern of temporary and circular rural-urban-rural migration whereby agricultural workers seek work in urban areas as domestic workers or seasonal staff in the hospitality sector during agricultural slack seasons (IOM, 2015; Srivastava and Kumar Pandey, 2017). This means that rural dwellers are by no means necessarily unfamiliar with modern electricity or electrical appliances. Expectations of rural electrification initiatives may thus be very high, and disappointment with initiatives limited to basic needs may give rise to social discontent, potentially fuelling pressure for unplanned and costly grid extensions (Acquah et al., 2017). While an incremental approach to rural transformation may be appropriate in some national contexts, rural transformation should not be assumed to be a linear process.

Internal, regional and international migration also contribute substantially to rural household income in LDCs through remittances, which are likely to be a significant factor underlying the observed "willingness to pay" for electricity among rural communities.[8] While some 75 per cent of remittance flows are estimated to be allocated to meeting immediate needs, and patterns of use vary widely between countries and sources of remittances, they can also contribute significantly to education, productive investment and entrepreneurship. Remittances from abroad are typically larger and more readily used for investment in physical capital (IFAD, 2017; Ratha et al., 2011).

Some rural electrification projects, for example in Bangladesh, recognize that lack of access and unreliability of electricity supply may disproportionately affect women's income-generating activities, and therefore seek to promote women's participation in decision-making and to identify entrepreneurial opportunities created for women. However, it is not always clear that such initiatives contribute to women's empowerment, particularly as they may be vulnerable to appropriation by men once a certain level of profitability is reached, and their impact is dependent on other cross-cutting issues (ENERGIA, 2016). Neither do they necessarily contribute to structural transformation if the income-generation opportunities they provide are no greater than traditional pursuits. A more active, concerted and comprehensive planning approach may therefore be needed to achieve meaningful contributions to gender equity and women's empowerment.

Gender considerations also reinforce the importance of ensuring adequate and appropriate levels of access. A real change in gender dynamics is likely to require a sufficient level of access to electricity to allow women to break out of the labour-intensive productive activities that dominate the agricultural sector, in which they are typically confined in certain countries.

An important issue in both rural and urban areas is the substantial impact of renewable-energy technologies on land use — the so-called "energy sprawl" (Moroni et al., 2016; Trainor et al., 2016). The management of land and natural resources is among the most critical challenges facing developing countries (United Nations Interagency Framework Team for Preventive Action, 2012). As well as being an important economic asset and source of livelihoods, land is closely linked to community identity, history and culture. Land issues thus readily lend themselves to conflict.

The land requirements of renewable energy projects are therefore a significant consideration in energy planning, requiring careful attention in the light of local land tenure systems, which vary widely both between LDCs and often within them. Targeted action by Governments may be necessary with respect to the siting of energy projects, social acceptance and societal factors, limiting competition in land use, and protection of biodiversity and landscape.

4. Private and community roles

Rural electrification is fast becoming established as a commercial opportunity. "Base-of-the-pyramid" customers are increasingly viewed as a major potential market for energy and novel business models for electricity supply, estimated at $37 billion per year globally (IFC, 2012); and such estimates are viewed as indicative of a high willingness to pay for energy services among poor households. This perception is putting pressure on LDC Governments to put in place frameworks and support measures to facilitate and increase the commercial viability of private for-profit provision of electricity to unserved rural populations.

In rural areas of LDCs, the private sector is active primarily in providing household-level devices and systems, such as solar lanterns, solar home systems and improved biomass cookstoves. It is also involved in community-level mini-utilities (often powered by hydro or diesel generators, but increasingly using biomass, solar and wind energy) (IFC, 2012). The latter range from those that supply sufficient electricity to power two light bulbs and one appliance per household (Power to the Poor initiative in Lao People's Democratic Republic), to utility-like interventions providing sufficient power for such activities as water pumping, milling, and grinding.

While entrepreneurial activities can support the growth of stand-alone home-energy systems, mini-grids with the potential for productive use require an institutional context for planning, operation, pricing and maintenance (PwC, 2016; Bhattacharyya and Palit, 2016; Tenenbaum et al., 2014; IFC, 2012). Consequently, the divide between purely private and public provision in this segment is often blurred.

Purely commercial models for grid electrification remain rare, reflecting high costs and limited consumption by low-income users (Bhattacharyya and Palit, 2016; Pueyo et al., 2013; Acquah et al., 2017; IFC, 2012). Rural electrification schemes with an emphasis on cost recovery and commercial viability have proved neither necessarily affordable for most poor households nor sustainable. Private-sector interest in poorer and more remote areas is by no means guaranteed, and the emphasis on productive uses has generally been limited (Bhattacharyya, 2012).

Cooperatives (either non-profit or for-profit) are potential drivers of sustainable development, and offer a successful model for rural electrification with local control. In India, household connection rates are four times higher in villages serviced by energy cooperatives than in villages served by the State electricity board (ILO, 2013). Energy cooperatives operate, for example, in Bangladesh, Cambodia, South Sudan and Uganda. Bangladesh's programme, inspired by the United States model (box 4.3), is considered one of the most successful in the developing world. Subsidies and grants play a significant role in setting up such cooperatives. However, initiatives may fail to gain traction where there is a history of failed projects (ILO, 2013), or where the tier of service is too low to sustain interest (Acquah et al., 2017); and complementary support to income-generating activities is important to sustainability.

5. Regulation and regulatory capacity

The adoption of renewables may diversify energy mixes and accelerate rural access to electricity; but, if it is to increase system resilience, it needs to be accompanied by appropriate policies, regulations and codes (Cox et al., 2016). However, most LDCs have limited capacity for electricity regulation, reflecting both a lack of staff with the requisite skills and experience and financial constraints.

Building regulatory capacity is a process that typically takes a number of years; and electricity regulatory institutions in most LDCs are quite young. Very few

Box 4.3. **Rural cooperatives in the United States**

In the 1930s, 90 per cent of rural homes in the United States lacked access to electricity, while 90 per cent of urban homes had access, leaving most rural economies critically dependent on agriculture. Since high development costs and low profit margins deterred investor-owned utilities from expansion into rural areas, as in LDCs today, most rural electrification occurred through consumer-owned, not-for-profit electric cooperatives. Created in 1935 as part of the New Deal, the Rural Electrification Administration (REA) spearheaded the Electric Cooperative Corporation Act passed by Congress in 1936. By 1953, funds made available by REA to cooperatives to build lines and provide service on a not-for-profit basis allowed electricity access to more than 90 per cent of United States farms. By 2009, cooperatives served 12 per cent of national consumers (42 million people) in 47 states.

REA is now the Rural Utilities Service (RUS), operating under the United States Department of Agriculture.

Source: Deller et al. (2009); https://www.electric.coop/our-organization/history/ (accessed July 2017).

Regulatory capacity is limited in most LDCs, reflecting human-resource and financial constraints

were established before 2000, a majority after 2005, and a significant number since 2010. In a highly complex and increasingly multidimensional sector, many of these institutions are thus unlikely to possess mature regulatory skills or the high level of expertise and access to resources and information required for effective use of regulatory tools.

Experience of structural reform in the electricity sector — learning by doing — is itself a key aspect of strengthening regulatory capacity. However, even LDCs that have undertaken extensive reforms and benefited from technical assistance on sectoral and regulatory policy over a prolonged period can still face challenges in terms of regulatory capacity. Mali, for example, has implemented a series of reforms and a host of legislative and statutory instruments in the electricity sector since 1998, notably the 2006 Politique Energétique Nationale (National Energy Policy) and the Stratégie Nationale pour le Développement des Energies Renouvelables (National Strategy for Renewable-Energy Development), opening the sector to private operators and redefining the role of the State. The Rural Electrification Fund (Fonds d'Electrification Rurale) was also established in 2005, and strategies have been developed on biofuels and climate-change adaptation. Even in 2011, however, neither the National Energy Directorate nor the regulator (Commission Nationale de l'Energie) was functional, and the role of the latter remained poorly defined. Cohesion among the various mechanisms and institutions created was weak, implementation of existing policies poor, and there was no effective mechanism to evaluate and update the National Energy Policy (AfDB, 2015).

Distributed and local electricity systems further increase regulatory needs and challenges, as they often imply local management and a high level of beneficiary participation; and rural citizens play a key role in the prevention, detection and solution of problems in rural renewable electricity provision. From a regulatory perspective, this implies a potential proliferation both of market players and of local institutions in national energy sectors. It also confers on Governments the primary responsibility for mapping out the roles of different actors; establishing rules of engagement and ensuring their enforcement; setting technical and safety standards; and planning for human development. Consumer protection, and protections against the abuse of market power, may also be a consideration where micro- or mini-grid owners attain effective monopoly status locally.

6. International trade and regional cooperation

Trade in electricity can help to lower prices, mitigate power shocks, relieve shortages and facilitate the transition to cleaner energy, while also increasing flexibility in the integration of variable renewables by fostering market integration (Pollitt and Mckenna, 2014; REN21, 2017). A transition to more environmentally sustainable systems can lead to shortages of generation capacity — as has been the case even in some European countries (Deloitte, 2015). The particular vulnerability of LDCs to extreme weather, climate-change impacts and electricity shortages reinforces the potential gains from trade in electricity, as well as from the potential

Table 4.1

Regional cooperation on electricity trade

Initiative	Date of cooperation	LDC members
Africa Clean Energy Corridor Initiative	2014	Angola, Burundi, Democratic Republic of the Congo, Djibouti, Ethiopia, Lesotho, Malawi, Mozambique, Namibia, Rwanda, Sudan, Uganda, United Republic of Tanzania, Zambia
ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025	2016	Cambodia, Lao People's Democratic Republic, Myanmar
Eastern Africa Power Pool (EAPP)	2005	Burundi, Democratic Republic of the Congo, Ethiopia, Rwanda, Sudan, Uganda, United Republic of Tanzania
Greater Mekong subregion	1992	Cambodia, Lao People's Democratic Republic, Myanmar
Southern African Power Pool (SAPP)	1995	Angola, Democratic Republic of the Congo, Lesotho, Malawi, Mozambique, United Republic of Tanzania, Zambia
West African Power Pool (WAPP)	2006	Benin, Burkina Faso, Gambia, Guinea, Guinea Bissau, Liberia, Mali, Niger, Senegal, Sierra Leone, Togo
South Asian Association for Regional Cooperation (SAARC) "framework agreement" for regional cooperation on electricity	2014	Afghanistan, Bangladesh, Bhutan, Nepal

Source: UNCTAD secretariat.

Box 4.4. **International trade in electricity**

Trade agreements (as evidenced by initiatives described in table 1) have tended to underpin international trade in electricity, either by providing a basis for power pools or through bilateral power trading contracts and memoranda of understanding or accords. Most regional generation projects are started by electricity utilities, although there are exceptions, such as the Manantali dam completed in 1987, a joint initiative of Mali, Senegal and Mauritania to develop the agricultural and hydropower potential of the Bafing River, which was initiated by their joint water organization (Organisation pour la Mise en Valeur du fleuve Sénégal).

Trade agreements or legal and regulatory frameworks compensate for the current inadequacy and fragmented framework of World Trade Organization (WTO) rules on trade in electricity. The latter arises partly because electricity provision and trade combines goods and services (see section B), and involves other policy objectives (Oseni and Pollitt, 2014: 23; Cossy, 2009; WTO, 2010). WTO law does not contain any specific provisions on electricity. Indeed, energy services were not included in the Uruguay Round negotiations. However, electricity is classified as a "good" in international trade statistics, and the WTO Customs Valuation Agreement (CVA) is among the relevant WTO rules under the General Agreement on Tariffs and Trade (GATT) for the trade of electricity. In addition, the General Agreement on Trade in Services (GATS) provides a framework for cross-border trade in services, inclusive of aspects of electricity trade that involve its transmission. However, neither the GATT nor the GATS enables an integrated, comprehensive or coherent regulation of electricity and energy trade. To date, few GATS commitments have been undertaken on energy transportation services under the Agreement.

Electricity trade may take the form of a single-buyer model, in which only one agent is allowed to import (export) electricity from (to) other interconnected control areas. This model is common in LDC and ODC markets dominated by a legislated monopoly provider (sections B1 and C2). Alternatively, all or several of the agents operating in one jurisdiction may be permitted to import and/or export energy from/to other interconnected control areas. This model is mandated in the European Union and many other liberalized jurisdictions in the United States, Canada and Latin America where multiple operators in different segments of the electricity supply chain are present and participate in international trade in electricity.

Electricity cooperation and trade can bring economies of scale in investments; strengthen electricity-sector financing capability; enhance competition and improve sector efficiency; increase load and fuel diversity; enable cost-effective renewable electricity penetration; address seasonal variability in generation; provide emergency support; provide a market for surplus generation; and generally increase the security and robustness of participating national electricity systems.

Trade in electricity demands considerable infrastructure to ensure the interconnection of different electricity transmission systems across national borders. In addition, complementary network codes for the cross-border transmission infrastructure and related arrangements should be selected, agreed and implemented to facilitate the interoperability of nationally designed systems. Moreover, efficient cross-border trade in electricity requires harmonization of rules across interconnected electricity markets. Interoperability and trade facilitation can be advanced through the creation of an umbrella regulatory body such as the Regional Electricity Regulators Association of Southern Africa (RERA), established in 2002. Among its duties is to facilitate harmonized industry policy, legislation and regulations for cross-border trade; elaborate the terms and conditions of access to transmission capacity; and set cross-border tariffs and make recommendations on issues that affect the economic efficiency of electricity interconnections and electricity trade among members. RERA issued regulatory guidelines in 2010.

Regional agreements for power-sector cooperation and trade and for the planning, development and implementation of related infrastructure can take time to achieve. For example, electricity-sector cooperation in the Greater Mekong subregion has a timeline spread over two decades, and continues to evolve. Similarly, it was not until 2015 that WAPP, created in 2006, took steps to design and develop the market models and rules for power exchanges between its member utilities.

Across all jurisdictions, whether developed or developing, slow progress in the operationalization of cross-border electricity trade can be attributed to technical, operational, political and commercial issues. While liberalized markets often rely on market-based procedures for electricity trade, developing countries have tended to rely on long-term supply contracts that lend somewhat greater stability in prices and supply and mitigate trading-partner political and commercial risk.

It should be noted that regional trade in electricity is not exempt from the exercise of market power. For example, there are concerns over possible predatory pricing behaviour within SAPP. While sophisticated market design and regulation is not a prerequisite for trade in electricity, eventual consideration of competition regulation may be desirable, especially in the developing-country context.

Source: Oseni and Pollitt (2014); European Parliament (2016); World Bank (2008); Singh et al. (2015); Marhold (2013); Cottier (2011).

for "islanding" (independent operation of local grids in the event of wider grid failure) afforded by distributed generation.

LDCs in several regions pursue bilateral, regional or multilateral approaches to coordinating and pooling efforts to create common infrastructures and facilities with the aim of reducing individual countries' capital investment requirements and lowering system operational costs (World Bank, 2008). While many LDCs are members of power pools or trade initiatives (table 4.1), some are constrained by lack of interconnection or by transmission congestion within transit countries. The Southern African Power Pool (SAPP) may represent a regional trade market capable of being leveraged to attract investment (ICA, 2011).

To the extent that national, subregional and regional electrification plans prioritize the extension of national grids and regional interconnections, coherence with rural electrification programmes is necessary, underlying the need for policy coordination and whole system approaches. Some rural areas close to generation facilities in neighbouring countries may most readily or cheaply be supplied by imports of electricity. Equally, renewable energy sources in such areas may provide opportunities for electricity exports to adjacent areas in neighbouring countries.

E. Conclusion

The context for electricity market structures and governance arrangements is once again in a state of flux. Current developments suggest an increased private-sector role in LDC electricity systems that were largely bypassed by earlier rounds of sector liberalization. LDCs have the opportunity to learn lessons from the shortcomings of reforms in the ODCs over the previous 20 years when seeking to leverage private-sector participation in their national systems. Electricity governance systems are often adapted or adaptable to national conditions or around national peculiarities. The fact that electricity is a service with monopolistic characteristics and of great social and economic importance is at the heart of many of its governance challenges in LDCs. Political considerations, reinforced by the sustainable development goals (SDGs) and affordability considerations, can be expected to retain their relative importance alongside technological and market fundamentals in shaping electricity-sector governance into the foreseeable future.

Equally, the environment for the electricity sector is evolving rapidly as a result of major shifts in technologies and their relative costs, coupled with climate change and increasing emphasis on environmental goals. Incorporating renewable sources of electricity generation has potentially significant impacts on the efficiency, expansion and upgrading of national electricity systems. However, the manner in which renewables are incorporated into existing systems will have an impact on the viability and cost of services delivered, and concurrent investments in ICT and regulatory capacity are a significant contingent factor in maximizing efficiencies and fully leveraging the potential of new technologies. Energy security concerns linked to achieving structural transformation will demand a great deal of LDCs in terms of foresight and technical knowledge. A wide range of legitimate societal interests and a diverse number of policy and user interests will need to be addressed in this respect. In a context of serious institutional capacity constraints, this is giving rise to numerous challenges to sectoral governance.

Strategic planning and regulatory capacity are expected to be critical factors for accelerating investment and coordinating investments by more, and likely non-public, investors. While best practice-sharing is desirable and useful, LDCs are subject to conditions significantly different from those in earlier transforming countries. Electricity sectors can be structured in different ways and electricity transformations can take different pathways depending on past legacy, as well as on previously achieved stages of transformation. Initial conditions will matter in this respect and will strengthen the case for adopting considered, joined-up and measured approaches to market and governance reforms, taking into account country specificities. In addition, it is unlikely that leapfrogging can take place by accident; LDCs will have to actively target leapfrogging as a specific policy goal.

Central to meeting these multiple challenges will be policy coordination, bringing together stakeholders across all relevant dimensions of development under the clear leadership of a single agency.

Notes

1 Available at https://www.iea.org/topics/energysecurity/.

2 Based on data from EUROSTAT electricity production, consumption and market overview (http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production,_consumption_and_market_overview, accessed April 2017).

3 Power Africa includes the collective resources of the Governments of Canada, France, Japan, Norway, Sweden, United States; institutions such as the World Bank Group, African Development Bank, European Union, Development Bank of Southern Africa, African Union's New Partnership for Africa's Development, United Nations Sustainable Energy for All initiative, International Renewable Energy Agency, Industrial Development Corporation of South Africa, United Kingdom Department for International Development; and over 100 private companies (https://www.usaid.gov/powerafrica/partners, accessed April 2017).

4 https://www.mcc.gov/initiatives/initiative/power-africa, accessed April 2017.

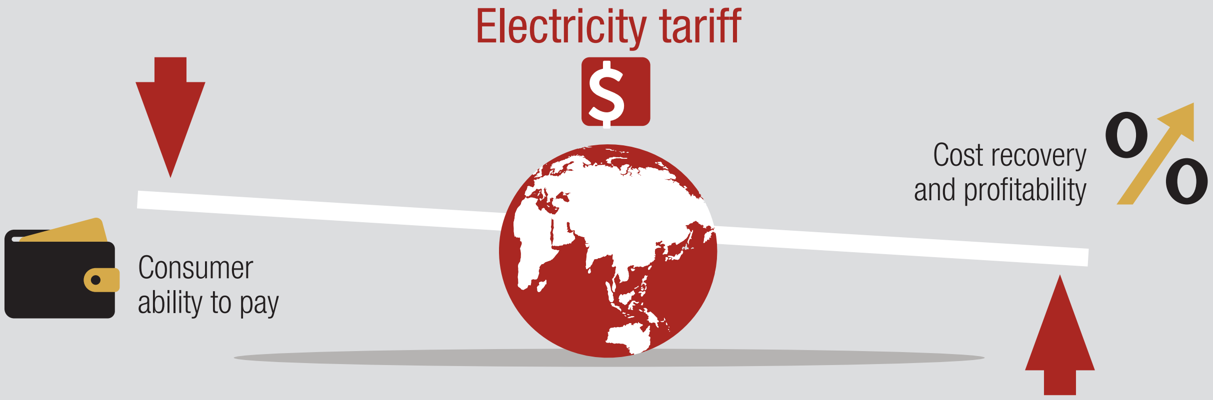
5 See also Ola (2016).

6 This is also a common practice with respect to large mining or tourism activities located away from urban and grid-serviced areas.

7 Country case studies in the context of research on measures being employed in African countries to combat illicit financial flows undertaken by the United Nations Economic Commission for Africa in 2016 revealed that grid extension had proved an effective tool in this respect.

8 Some of the new remittance transfer channels developing to exploit these markets allow electronic payment of relatives' bills, including for electricity, in countries of origin.

KEY CHALLENGE:
reconciling financial sustainability with affordability

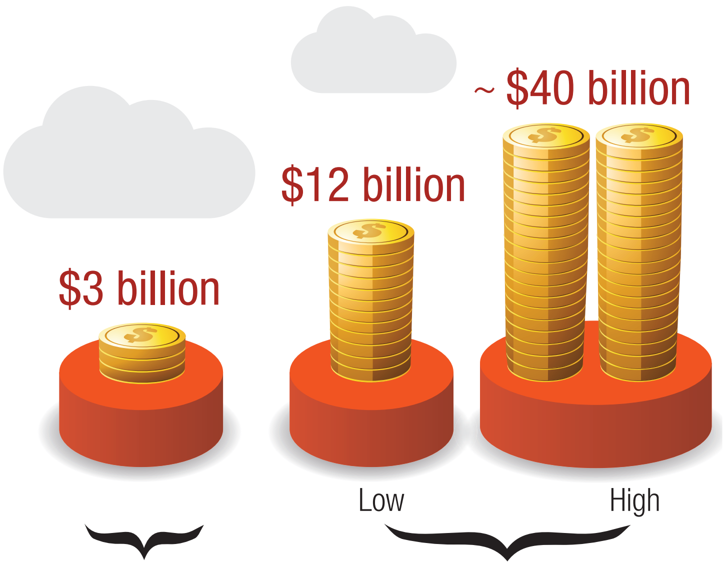


TRENDS IN DEVELOPMENT FINANCE

1.8% of total official development assistance to LDCs went to the **energy sector** in 2015

23% of this went to **renewables**

Increasing significance of sovereign borrowing and South–South financing



Official development assistance

Annual estimated cost for basic household needs in LDCs even without transformational energy access

24%–40% increase in **cost** of commercial finance due to risk and uncertainty

CHAPTER 5

Financing modern electricity provision

CHAPTER 5

Financing modern electricity provision

A. Introduction

Finance will be a major challenge for the massive expansion and upgrading of the electricity systems of least developed countries (LDCs) necessary to achieve universal access by 2030, and still more so for the greater investment implied by transformational energy access. However, just as the particularities of energy supply have implications for the market structures and governance arrangements appropriate to the sector, so, too, does the nature of investments in the sector give rise to particular issues and challenges in their financing.

This chapter reviews these issues, and the associated tension between the affordability of electricity supply and the financial sustainability of the investments it requires. It also provides indicative estimates of the investment costs of achieving universal access to electricity and transformational energy access in LDCs by 2030, and reviews recent trends in, and prospects for, potential sources of financing for these investments.

B. Electricity fundamentals: Finance

1. The economics of electricity: Intersections with private finance

Infrastructure investments are critically dependent on access to long-term finance. Long-term finance is scare in LDCs, and external public finance has not been at a sufficient scale to cover domestic shortfalls. Recourse to alternative sources of development finance, such as commercial and institutional investors (including pension funds, insurers and sovereign wealth funds), must be explored.

These alternative sources of long-term finance typically have different motives and risk appetites from those of traditional public investors. This presents a number of challenges, since the nature of infrastructure assets has implications for the structure and cost of financing.

Electricity is a special class of infrastructure assets with its own specific challenges. In common with other infrastructure projects it does not lend itself to direct private investment because it typically requires a large amount of financing. In addition, not all electricity projects are likely to generate a dedicated revenue stream for investors, especially in LDCs characterized by a large proportion of the population with constrained ability to pay. The majority of private sector-led, new-build infrastructure projects, including electricity projects, are financed through project finance that is usually syndicated.[1] Project development is subject to significant risks and unknowns while requiring an ongoing investment of time, financial and political resources (Springer, 2013; USAID, 2014).

Some characteristics of electricity investments complicate private financing...

The following characteristics of electricity tend to complicate private financing.

a. Fixed and sunk costs

As with other production processes, generating, transmitting and distributing electricity entails fixed and variable costs. In generation, fixed costs reflect the cost of the land and building the plant and do not change with the amount of electricity produced or used but differ across generation technologies.

The electricity industry faces a substantial front-loading of investments before cost recovery can take place. In particular, the transmission and distribution network is characterized by massive fixed costs and irreversible investments in idiosyncratic (unique) and illiquid assets. These characteristics oblige investors to engage in complex risk analysis and risk allocations. Moreover, any investment decision under these conditions involves the exercising of a call option — the option to invest productively at any time in the future (Kim and Kung, 2013; Pindyck, 2008). When investment is irreversible and the future economic environment is uncertain, market players employ strategies to mitigate the inability to disinvest in adverse economic conditions. This creates an ex ante incentive to delay investment when uncertainty about the future profitability of their investment is high.

Non-hydro renewable generation technologies, such as wind and solar, are also characterized by high fixed costs, although these costs are much lower than those of large-scale centralized fossil fuel-driven plants or other renewable sources, such as nuclear and hydro plants. In common with transmission and distribution in traditional electricity systems, their cost structure is dominated by the cost of land and start-up installation. Relatively low variable costs for operations and maintenance and fuel are their main advantage over traditional fossil fuel-based generation technologies (Borenstein, 2016; IDC, 2012).

Studies estimate that the cost and terms of debt can add between 24 and 40 per cent to the cost of utility-scale wind and solar photovoltaic (PV) projects in developing countries (Nelson and Shrimali, 2014; Waissbein et al., 2013).

… including large upfront costs, irreversible investments, high uncertainty and risks, and carbon lock-in

b. Longevity and risk

Private-sector investors look for safe, long-term investments that will generate a worthwhile return on capital. Infrastructure projects may not generate positive cash flows in the early phases. They tend to have high risks and costs due to lengthy pre-development and construction processes. It is uncommon for countries to maintain portfolios of "shovel-ready" projects already selected, planned and designed, and for which risk assessments have been completed. This poses a significant obstacle and cost impediment for developing countries in particular in securing private infrastructure financing (UNCTAD, 2014d; Sy and Copley, 2017). In addition, economic infrastructure typically has a useful life of 25 years or more. Long project and asset life is fraught with uncertainties and generates substantial financing requirements and the need for dedicated resources on the part of investors to understand and manage project-specific risks. LDCs are additionally disadvantaged in that a significant proportion of their electricity infrastructure needs are likely to require greenfield investments, which are more risky than brownfield projects (OECD, 2015a).

Country-related risks can be highly subjective and ad hoc, difficult to quantify, and therefore difficult to price (OECD, 2015b). Uncertainties and risks are perceived to be especially heightened by the weaker and less stable economic and financial conditions in LDCs. Country-specific risk is typically addressed through an upward adjustment to loan discount rates, which can lead to high costs of capital (Griffith-Jones and Kollatz, 2015; OECD, 2015b; Bekaert et al., 2015; Presbitero et al., 2015).

Commonly assessed risks in LDC electricity sectors are consumers' low ability to pay; absence of frameworks to guide private-sector participation; and perceived regulatory risk from monopoly public utilities subject to social mandates and political uncertainties. Table 5.1 provides a classification of infrastructure asset risks.

Guarantees are the main lever (60 per cent) for private investment in infrastructure but energy projects in middle-income countries benefit the most from such instruments (OECD, 2015b). Between 2012 and 2014, middle-income countries' share of finance mobilized through guarantees, syndicated loans and shares was 72.3 per cent. The LDC share was 8 per cent and other low-income countries' 2 per cent. Developing countries in Africa (29.1 per cent) benefited the most, followed by

Table 5.1

Classification of infrastructure asset risks

Risk categories	Development phase	Construction phase	Operation phase	Termination phase
Political and regulatory	Environmental review	Cancellation of permits	Change in tariff regulation	Contract duration
	Rise in pre-construction costs (longer permitting process)	Contract renegotiation		Decommission
				Asset transfer
			Currency convertibility	
	Change in taxation			
	Social acceptance			
	Change in regulatory or legal environment			
Macroeconomic and business	Prefunding		Default of counterparty	
	Financing availability		Refinancing risk	
			Liquidity	
			Volatility of demand/market risk	
	Inflation			
	Real interest rates			
	Exchange rate fluctuation			
Technical	Governance and management of the project			Termination value different from expected
	Environmental			
	Project feasibility	Construction delays and cost overruns	Qualitative deficit of the physical structure/service	
	Archaeological			
	Technology and obsolescence			
	Force majeure			

Source: OECD (2015b), table 1.

those in Asia (27.2 per cent) and the Americas (21.1 per cent) (OECD, 2016a). The current array of risk mitigation instruments used by international finance institutions to crowd in institutional investors has been found to be complex and non-standardized, and thus burdensome and costly for the private sector to use (WEF, 2016).

Measures aimed at improving the institutional environment (including through providing stable long-term infrastructure development plans, enhancing social acceptance for novel approaches to infrastructure development, preparing feasibility studies and bankable infrastructure pipeline projects, and increasing certainty on permits and tariff definition) are the standard prescription through which Governments can influence political and regulatory risk (OECD, 2015b).

c. Opacity

Infrastructure projects generally lack transparency. Commercial secrecy, diverse project structures and differences across a variety of generation technologies increases the financial opacity of projects. No two electricity projects are alike even for the same technology because local conditions influence the performance of the technology. Moreover, the information required by investors to assess project-related risk structures and the market is often non-existent in LDCs, a fact that serves to raise the level of risk.

d. Carbon lock-in

The concept of carbon lock-in or path dependence has been used extensively to explain the persistence of fossil fuel-based technological systems despite their negative environmental impacts (Erickson et al. 2015; Lehmann et al. 2012; SEI 2015; Economic Consulting Associates 2015; Klitkou et al. 2015). Although path dependence is itself judged to be neither good nor bad, the likelihood of policy decisions that serve to diminish or possibly exclude the adoption of alternative technologies is considered to be heightened by path dependence, especially under conditions of uncertainty (Lehmann et al. 2012). Accordingly, insofar as it may dampen private investors' investment appetite or heighten their perception of regulatory risks, carbon lock-in can be a factor in securing commercial credit. It may be particularly relevant in the case of renewables and in a global environment in which fund managers and industry players are increasingly concerned about their green credentials.

Increasing returns to scale and large fixed and sunk costs associated with legacy electricity systems may contribute to carbon lock-in, especially in the presence of abundant and cheap natural resources. For example, large centralized fossil fuel-based generation can be a relatively cheap and stable source of electricity supply and continue to be a favoured avenue for expanding and securing baseload generation capacity. Other contributory factors include the long lifespans of generation technologies and long-term fuel or electricity purchasing contracts common to legacy generation technologies and renewables.

There are tensions in LDCs between affordability and financial viability of electricity systems

In principle, the risk of carbon lock-in may be most limited in LDCs that have nascent, dilapidated and/or outdated electricity systems; those with import-dependent electricity systems that are a major source of macroeconomic instability; and those for which international trade in electricity does not offer a secure option for supplementing domestic generation capacity. Distributed systems may have a natural advantage in island LDCs, for example, as these economies typically lack the economies of scale and contiguous geography needed for centralized generation and transmission.

2. Financial sustainability and affordability

A financially sustainable electricity system is one that recovers operating costs, makes appropriate investments in infrastructure and delivers a secure and reliable service, as well as meeting environmental and social norms. This has long been recognized as a prerequisite for addressing growing electricity demand, particularly in the context of structural transformation, rapid urbanization and growing populations characteristic of LDCs. However, financial sustainability poses major challenges for most LDC electricity systems, as the high cost of expanding access to rural populations, coupled with persistently high levels of poverty and limited purchasing power, gives rise to serious tensions between financial sustainability and affordability.

a. Cost-reflective tariff-setting

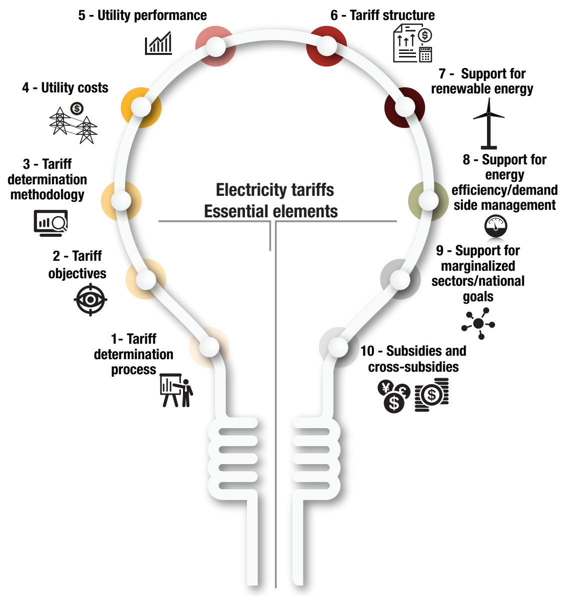
Since sector regulators and utilities in non-competitive markets have historically had an obligation to ensure the affordability of services and a standard national electricity tariff, below-cost regulated tariffs are a common feature of LDC electricity systems. This undermines both the financial viability of utilities and the quality of electricity supplied, and represents an important obstacle to national utilities financing investments to ensure universal electricity access. The result is a serious tension between the multiple

Box 5.1. Fundamental elements of tariff design

Globally, electricity tariffs can vary by total usage, consumer type (e.g. residential vs. industrial), time of day and generation source. The unit price per kilowatt-hour (kWh) may follow an increasing or decreasing step-function linked to sequentially defined blocks. It may also follow a linear format such that all units are charged at the same price. Tariff structures evolve over time and commonly reflect multiple national objectives that require a degree of balancing by regulators. For example, the European Union regulatory framework sets only some general standards with regard to the determination of network tariffs, with decisions on design left to member States. Best practice on tariff determination favours a process that is transparent, accountable and participatory. This best practice can sometimes delay or prevent tariff adjustments in developing countries, where utilities are obliged to apply for a tariff increase. Weak institutions and fierce opposition from policymakers and customers concerned about affordability of services can be a significant obstacle.

Box figure 5.1

Essential elements of electricity tariffs



Source: UNCTAD secretariat, based on Dixit et al. (2014).

Tariff design encompasses multiple policy elements in addition to the operational and maintenance costs of an electricity system. It is influenced by the structure of the industry and requires careful planning and effective management, especially in times of transition. Regulators require sufficient expertise and resources to assess, choose and implement appropriate tariff structures given the ramifications of pricing for the financial sustainability of the sector, economic activity and general affordability.

A review of the fundamental assumptions of tariff design may be called for under the new reality of variable renewables, and decentralized and own generation. For instance, in liberalized electricity systems changes are being necessitated by the blurring of the distinction between wholesale and retail electricity markets as consumers increasingly produce to sell to utilities, and with the need to reward consumers for their energy efficiency efforts through time-of-use tariffs. Energy efficiency measures, discounts to low-income customers, incentives for adopting renewable energy and research and development in renewables are costs that LDC utilities will likely confront as they transition to more renewables-based electricity systems. These additional costs will need to be recovered and factored in among the traditionally recognized essential elements and objectives of electricity tariffs.

Source: Bharath Jairaj (2016); Briceño-Garmendia and Shkaratan (2011); Lowry et al. (2015); Schweinsberg et al. (2011); Dixit et al. (2014).

objectives of increasing access, affordability, reliability of supply and the financial viability of investments.

Increased reliance on electricity supply by the private sector requires regulators to ensure commercial returns and protect providers' profitability. This means that cost-reflective tariffs should be set high enough to cover, at a minimum, the full cost of generation and transmission, plus operating and maintenance costs. Pressure on monopoly utilities to demonstrate financial sustainability is heightened when they are offtakers for independent power producers (IPPs), as financial fragility is reflected in higher risk premiums. The pressure for the adoption of cost-reflective tariffs has been further increased by the advent of renewables and distributed generation.[2]

To date, only one LDC (Uganda) has reported the successful adoption of cost-reflective tariffs (boxes 5.1 and 5.2).

Feed-in tariffs provide eligible renewable-power producers with a guaranteed above-market price for the power they generate, thereby reducing market risk to investors by offering an assured rate of return. They are widely used in developed markets, and are increasingly being adopted in developing countries. Almost 60 per cent of LDCs have feed-in tariffs or some other kind of flexible tariff arrangement[3] in place to accommodate private-sector provision (see chapter 4). Where these are indexed to foreign currency, this can give rise to risks of fiscal stress and unsustainability. Flexible pricing mechanisms can also expose customers to price volatility and uncertainty, because electricity prices may change in line with the variability of renewables generation.

Other common policy support instruments targeting power generation are feed-in premiums, and quota schemes (also known as renewable portfolio standards) for different technologies (KPMG International, 2015). Quota obligations are often combined with tradable renewable energy credits or renewable obligation certificates. Quota schemes oblige suppliers to

Box 5.2. **Uganda cost-reflective tariff case study**

In 1999, Uganda became the only LDC to fully restructure and embrace private-sector participation. Nevertheless, the generation mix remained highly concentrated and access very low (chapter 1). By 2011 electricity subsidies accounted for 1.1 per cent of gross domestic product (GDP) due to increasing fuel costs for expensive back-up thermal IPPs for hydro generation that was negatively affected by drought.

The acute fiscal distress brought on by the burden of the subsidies led the Government to default on thermal IPP payments, with resulting severe shortages in electricity and a slowdown in economic activity. With the realization that liberalization and private-sector participation were not sufficient conditions to guarantee favourable outcomes in terms of adequate investments in generation capacity and expansion of access, the Government assumed leadership in electricity infrastructure development and management. Subsidies were abandoned in favour of cost-reflective tariffs. Public funding was redirected to focus on lowering the costs of capital for private-sector investment to meet targets defined by policy, including the diversification of electricity generation sources; improving the quality of supply; and securing the customer base needed to guarantee affordability by rapidly widening and expanding access to unserved populations and areas of the country.

To that end, the Rural Electrification Agency was created, charged with establishing and maintaining a comprehensive database to facilitate informed decision-making on the subsector. A dedicated fund, the Uganda Energy Credit Capitalization Company, was also established with a view to supporting private investment and assuring pro-poor electrification.

The Government further undertook complementary actions to set operational targets that prioritized a systematic loss reduction trajectory and new investment and revenue collection targets as part of the scheduled review of the incumbent distributor concessionaire's licence in 2012. Uganda's main electricity distributor is Umeme Company Limited, wholly owned by Globeleq (initially a consortium formed with South Africa's national utility Eskom), which is a company majority-owned by the United Kingdom's private-equity group Actis.

The investment requirements of the concession agreement between the Government and Umeme were successful insofar as the distributor had exceeded investment targets set for its first five years of operation. Umeme had, in addition, successfully leveraged domestic capital markets by cross listing on the Uganda Stock Exchange to raise capital. However, the company struggled to expand access to rural areas, with the result that new customer numbers rapidly flattened out, thus contributing to a heavy reliance on public subsidies.

Following the withdrawal of subsidies to the sector, tariff determination has been governed by the automatic quarterly adjustment mechanism instituted by the Electricity Regulatory Authority since 2012. Adjustments respond to movements in inflation, exchange rates and the international price of fuel, with the result that current end-user tariffs recover 93 per cent of production costs. The remaining 7 per cent is accounted for by the government financing of standby thermal generation. End-user tariffs were increased immediately by 46 per cent. At the time of the tariff adjustment, government subsidies accounted for over 50 per cent of the end-user tariff.

Time-of-use tariffs and metering (except for residential customers) are now in place and have resulted in a shift of consumption to off-peak periods. The Authority also regulates and approves differentiated tariffs for off-grid distributors and implements a rigorous pre-qualification process for service providers.

Private project developers are contracted on standard 20-year power purchasing agreements (PPAs). They receive 50 per cent of the amortized feed-in tariff payments upfront. These generous capital recovery terms are extended to both domestic and foreign investors and are complemented by other fiscal incentives. The single-buyer model for private-sector participation guarantees a market for the private sector.

Lingering concerns remain with respect to high end-user tariffs that act as a constraint on economic activity and general well-being, even though the introduction of a lifeline tariff for vulnerable customers served to dampen opposition to cost-reflective tariffs. Uganda, together with Rwanda, has the highest end-user tariffs in East Africa.

Fiscal distress was the key motivator for decisive change and subsidy reform in Uganda. Problematic tariff structure, whereby the industrial sector that was responsible for 44 per cent of power consumption shouldered less than a quarter of electricity production, was also a contributory factor.

The Uganda case serves to underline that a change in governance and structure does not guarantee energy security; liberalization does not substitute for regulation and effective government oversight of electricity systems; resource constraints and affordability issues are likely to remain a primary challenge for LDCs into the foreseeable future; a systemic coordinated approach to planning and development of electricity systems is important; the comparative advantages of both public and private actors in the system should be leveraged; and there is a need for Government to balance often-conflicting goals and inherent trade-offs in achieving universal access and development goals.

Government leadership has proved to be a decisive factor in the successful implementation of rural electrification in other developing countries, particularly in the roll-out of renewable solutions to rural access.

Source: Bakkabulindi (2016); ERA (2016); Mawejje et al. (2012, 2013); MEMD (2012); Okoboi and Mawejje (2016); Tumwesigye et al. (2011); http://www.era.or.ug/index.php/statistics-tariffs/113-investment-in-renewable-energy, accessed July 2017.

generate and supply a predetermined percentage of their electricity from renewable sources. Generators or utilities that need certificates are able to comply with regulation by buying excess certificates from others. A key advantage of quota schemes is their potential to reduce the macroeconomic costs associated with expanding renewable energy capacity. Quota schemes can also be an important driver of private-sector investment for renewable energy (UNEP FI, 2012).

Tendering schemes (for example renewables auctions) have spread rapidly as a means of promoting renewable sources, growing faster than feed-in tariffs and quotas. The potential of auctions to achieve low prices has been a major motivation for their adoption worldwide (IRENA, 2017). For instance, South Africa abandoned costly feed-in tariffs in favour of auctions (Eberhard and Kåberger, 2016) and built local content requirements into the early auctions, which helped grow a local renewables industry (IRENA, 2017). However, while WTO rules give space for a range of renewable-energy incentives, domestic content requirements in the operation of a feed-in tariff are considered problematic (WTO, 2013). There are also concerns that renewables support measures, in general, may distort trade.

Auctions are an attractive approach for LDCs because of their potential for real price discovery. They can also be tailored to a country's economic situation; to the structure of the national energy sector; to the maturity of the national power market; and to the level of renewable-energy deployment (IRENA, 2017). In May 2016, Zambia became the first country to organize solar auctions under the International Finance Corporation (IFC) and World Bank Scaling Solar programme for sub-Saharan Africa. Zambia's auction set a new (low) price record[4] for utility-scale solar on the continent. However, auctions are generally associated with higher transaction costs for smaller providers and a greater degree of complexity for auction organizers than purely tariff-based or purely quota-based schemes. They also carry an attendant risk of underbidding, whereby developers bid too low so as to beat the competition. However, such low bids often cannot secure financing, and developers pressure Governments to raise prices retroactively so that they can actually realize the project (IRENA and CEM, 2015; IRENA, 2013).

Net metering or net billing policies, which allow consumers who generate their own electricity and are connected to the grid to offset their bills against electricity fed into the grid, represent other complementary options in renewable support systems (KPMG International, 2015).

b. Increasing ability to pay

Since rural electrification is rarely self-supporting financially, LDCs increasingly seek to promote microfinance and other forms of credit and offer training to facilitate the growth of micro and small businesses in conjunction with rural electrification schemes and projects. Such efforts are directed at increasing households' disposable income to enable them to meet the high upfront costs of electricity access, and to sustain and grow demand for electricity services. An example is the Nicaragua Off-grid Rural Electrification Project, launched in 2003, the first World Bank operation to link the development of infrastructure services explicitly with the development of micro and small businesses and microfinance institutions (Motta and Reiche, 2001). The project tackled the gap between willingness to pay and electricity access life-cycle costs through subsidies to consumers. It gave grants and short-term subsidies to providers of business development services[5] to innovate and provide adapted solutions for rural clients. Microfinance is also used to accelerate the market penetration of off-grid and sustainable energy products by providing credit to consumers with low purchasing power to cover initial upfront costs of access (Mary Robinson Foundation-Climate Justice, 2015).

In some cases, where the right conditions exist, strategies have evolved beyond mere market creation. For instance, the Electrified Activity Zone in south-east Mali (Béguerie and Pallière, 2016) takes into account the diversity of rural customers and the differences in needs between households and businesses, and between different types of business. These factors not only affect the financial viability of the provider but constitute a responsibility on the part of the provider to respond effectively to customer needs.

c. Redirecting subsidies

Lowering the costs of renewable energy is a major concern of climate policy. The financial return to renewables investments is driven by the costs and performance of different technologies, which vary widely according to local and site conditions, and according to the cost of competing non-renewable sources. In the absence of a systematic accounting of environmental impact in the price of fossil fuel-based generation, the promotion of sustainable electricity from renewables is generally underpinned by a variety of support measures, including subsidies to "level the playing field" for renewables and incentivize adoption.

In this context, the reduction or elimination of subsidies for fossil fuels has increasingly come under the spotlight, both as a means of reducing incentives for fossil-fuel use and as a potential source of funding for renewable energy. Global fossil-fuel subsidies have been estimated at $5.3 trillion (Coady et al., 2015). While sub-global estimates suggest a substantially lower level of subsidies (table 5.2), this at least partly reflects different definitions and methodologies, which

Table 5.2

Fossil-fuel subsidy estimates by country and regional group

Region	Size of subsidy	Year	Source of estimate
Global (projection)	$5.3 trillion	2015	Coady et al. (2015)
OECD, BRICS and Indonesia	$160-$200 billion	Annual (2010-2014)	OECD (2015)
EU	€39 billion	Annual (2010-2014)	OECD (2015)
40 developing countries	$325 billion	2015	IEA (2016b)
APEC	$70 billion	2015	IEA (2017b)
Sub-Saharan Africa	$26 billion	2015	Coady et al. (2015)

Source: UNCTAD secretariat compilation.

Note: BRICs comprise Brazil, China, India, Russian Federation and South Africa. Estimates from different sources are not comparable, due to major differences in definitions and methodologies and to the fact that subsidies may not always be readily identifiable and quantifiable in all jurisdictions.

makes comparison problematic. Subsidies in LDCs are considerably smaller. Even on the same basis as the global estimate, sub-Saharan Africa accounts for only $26 billion, or 0.5 per cent of total global subsidies. If (as an extreme approximation) subsidies are assumed to vary between countries in proportion to their gross national income (GNI), this would suggest total subsidies in African LDCs in the order of $8-$9 billion.[6]

A key strategy of climate policy globally is to reduce and ultimately eliminate direct and indirect subsidies for technologies not aligned with the long-term strategy of environmental sustainability. In this context, fossil-fuel subsidies are considered to favour consumption patterns incompatible with these aims by (i) disincentivizing consumers from actively seeking to adopt energy-saving habits and energy-efficient technologies; and (ii) hindering a proper comparison of fossil-fuel and renewable-energy costs by masking the true cost (including negative externalities) of fossil fuels and conventional electricity technologies. The conventional regime of fossil-fuel subsidies is thus seen as reinforcing carbon lock-in.

International cooperation is supporting national efforts to reform energy subsidies; and a number of developing countries (including a few LDCs), spurred by falling oil prices, have recently made significant progress in reforming subsidies for fossil fuels across a wide range of sectors. However, it is at best questionable whether LDCs could replicate the experience of developed countries, notably in Scandinavia (Merrill et al., 2017), in achieving a fiscally neutral substitution of renewable subsidies for fossil-fuel subsidies.[7] Assessing the potential for such a substitution would require studies adapted to the LDC context. A particular consideration is the limited share of renewable subsidies that is likely to accrue to the domestic private sector, in light of the considerable share of foreign private-sector actors in value added and participation in renewables. The political-economy implications of this approach could be a significant source of opposition.

Energy subsidies in developing countries are particularly criticized as being regressive in nature, so that the ultimate beneficiaries are effectively higher-income consumers rather than the poorest; as reducing the fiscal space available to pursue development goals; and as contributing to unacceptable levels of public debt (Vos and Alarcón, 2016; Vagliasindi, 2013; IMF, 2013). Equally, however, the application of this policy stance, based on the merits of competitive pricing mechanisms in resource allocation, may face challenges in developing countries, where market conditions are typically far from perfectly competitive (World Energy Council, 2001). In many LDCs, by no means all "higher-income" consumers have full access to modern energy, as evidenced by the reliance of many urban residents in LDCs on traditional biomass, and many remain vulnerable to electricity price increases. Since LDCs have particularly high (and in some cases increasing) levels of informality, these consumers, being the most visible, also make up the overwhelming majority of often very small national tax bases. Policies to remove subsidies and allow only targeted safety nets for the extreme poor may thus punish middle- and some low-income groups (Ortiz et al., 2017), and would need to be managed carefully.

Among the standard remedies advocated to address the negative impacts of eliminating subsidies are strengthening social protection, including cash transfers, and instituting targeting mechanisms to channel subsidies to deserving low-income consumers. However, many of these mechanisms are linked to employment and focus on formal social safety nets, and their effectiveness in LDCs is likely to be undermined by the considerable scale of informality, weak institutional capabilities and lack of resources, particularly in a context where the poor constitute a disproportionately high percentage of the population.

d. Demand-side management

Energy demand-side management is a complement to other measures needed to effectively address climate policy objectives while maintaining energy security and expanding access. Demand-side management programmes encourage all end-users (for example households and industry, including

Achieving universal access in LDCs by 2030 might require investment of $12-40 billion per year

electricity utilities) to be more energy-efficient. Specific measures include lighting retrofits; building automation upgrades; recommissioning; and heating, ventilation and air conditioning improvements. Demand-side management thus differs from demand reduction, which seeks to encourage end-users to make short-term reductions in energy demand.

The Least Developed Countries Group announced the launch of its Renewable Energy and Energy Efficiency Initiative (REEEI) to scale up the provision of renewable energy and promote energy efficiency during the 22nd Conference of the Parties (COP22) to the United Nations Framework Convention on Climate Change (UNFCCC) in November 2016. Its initial priorities for the period 2017–2020 include a stocktaking of existing activities and experiences, together with opportunities, and strengthening national policies and regulatory frameworks (Dhital, 2017).

Energy efficiency is a resource possessed by all countries in abundance (IEA, 2016d) and is the quickest and least costly way of addressing energy-security, environmental and economic challenges.[8] Globally, however, two thirds of the economic potential of demand-side management through energy-efficiency interventions remains untapped (IEA, 2014b). Since high prices alone cannot be relied upon to drive investments in energy efficiency, policy plays a central role (IEA, 2016d). Barriers to energy efficiency include lack of information and information asymmetries on energy-efficiency technologies and their benefits and risks to financial stakeholders; knowledge and technical capacity gaps that hinder the development and implementation of energy-efficiency projects; energy subsidies; shortage of affordable financing; and absence of clarity on roles and responsibilities for energy efficiency (IEA and ADB, 2014).

Effective demand-side management requires systematic efforts to reduce energy intensity by encouraging end-users to adopt technological improvements through an optimal mix of incentives. Policy measures include appropriate pricing; legislation, regulations, codes and standards; targeted financial incentives and quantitative energy targets; and knowledge-sharing. Actions typically have to be practical, scalable and replicable on a large scale, as well as having a significant impact. Accordingly, systems should be in place for measurement, reporting and verification of the effects of energy-saving activities (RAP, 2012).

Energy-efficiency obligations are the cornerstone of common schemes with quantitative energy-saving targets. These schemes may be administered by Governments or by independent bodies, or jointly by energy regulators and energy providers. Schemes can also be established principally by Governments, as integral components of government policies (RAP, 2012).

An important constraint to operationalizing meaningful demand-side management schemes in LDCs is the lack of institutional capacities and the knowledge and capability to design and implement such schemes on an economy-wide scale, as effective regulatory oversight, monitoring and evaluation, and verification systems are essential to their effectiveness.

C. Estimating the LDC electricity infrastructure finance gap

The financing needs for Sustainable Development Goal (SDG) 7 are considerable in those LDCs where electricity infrastructure is inadequate to ensure universal access targets. Infrastructure costs are generally high in LDCs, particularly in island LDCs, due to limited economies of scale and in some cases additional costs for climate-proofing. Distribution networks are the costliest segment of the electricity supply chain, and distributed generation and increased reliance on renewables are not expected to obviate the need for future investments in transmission and distribution.

The existing infrastructure is also often in disrepair: it is not uncommon for Governments (including those of developed countries and other developing countries (ODCs)) to prioritize investments in new infrastructure over maintenance of existing facilities, especially under conditions of rising demand and chronic public revenue weaknesses such as those typical of LDCs (WEF, 2014; Branchoux et al., 2017). The degraded state of existing infrastructure in many LDCs necessitates costly reconstruction and repair to allow increases in generation capacity and network efficiency, further increasing investment costs.

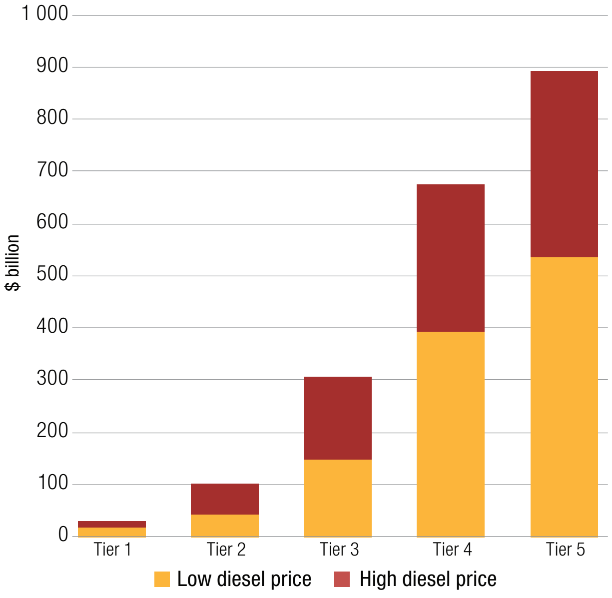
As part of the process of planning infrastructure investments, quantifying infrastructure financing needs helps to focus and direct efforts to mobilize development finance both in terms of the intensity of effort required and in identifying the most appropriate sources of finance. It is particularly important given that different sources of finance are distributed unequally across the segments of the electricity supply chain. For instance, a manifest private-sector bias in favour of generation leaves the transmission and distribution segments largely in the domain of public financing.

The likely order of magnitude of the costs of universal access to electricity in LDCs can be derived from estimates of the global cost of universal access to electricity. While there are important issues of comparability (due to variations in definitions, assumptions, levels of access, estimation methods and modelling approaches), recent global estimates mostly lie in a range of $35-$55 billion per year (Sustainable Energy for All, 2015: 66). Since 54 per cent of people without access to electricity globally live in LDCs (chapter 1), assuming equal average costs per person without access in LDCs and ODCs would indicate a range for LDCs in the order of $20-$30 billion per year. Allowing also for variation by a factor of 1.5 in either direction between LDCs and ODCs in average cost per person without access would widen this range to $12-$40 billion.

Country-by-country estimates are available for sub-Saharan Africa, though not for other regions (Mentis et al., 2017).[9] These indicate a cost for universal access in African LDCs of between $18 billion and $900 billion, depending on the tiers of access provided and variations in diesel prices (the latter also affecting the energy mix). The breadth of this range highlights the steep increase in investment costs associated with higher tiers of access: even moving from the minimalist tier 1 (0.1 kWh per household per day) to tier 2 (0.6 kWh) increases costs by a factor of 2.3-3.5, while tiers 3, 4 and 5 require increases in investment by factors in the order of 10, 20 and 30 respectively (figure 5.1).

Figure 5.1

Investment needs for universal access by 2030, African LDCs



Source: Mentis et al. (2017).
Notes: Tiers indicate tiers of access, defined in terms of average electricity use per capita. The range provided for each observation indicates estimates based on low and high prices for diesel fuel.

D. Financing investment in electricity infrastructure: Trends and prospects

1. Recent trends in resource mobilization

a. Domestic public resources

Domestic resource mobilization is a priority area for action in the Istanbul Programme of Action and is recognized by the 2030 Agenda for Sustainable Development as being critical to the ability of LDCs to finance their own development. However, LDC Governments have limited resources to meet financing needs from domestic sources. Many natural resource- and commodity-dependent LDCs, in particular, need to address long-standing and competing gaps in economic infrastructure under constrained revenue conditions while also seeking to maintain a reasonable degree of consumption in their economies.

Tax revenues are lowest in LDCs (IMF, 2016a); few manage levels above 15 per cent (compared with the OECD average of 34.4 per cent in 2014), as they typically have lower levels of tax collection and a narrower tax base. The relevance of the tax-to-GDP ratio as an indicator of domestic resources available to finance infrastructure investments in these countries is undermined by institutional weaknesses in tax collection and low compliance; the presence of large informal sectors; many small-scale firms; and a general dependence on a few natural resources, commodities or foreign aid.

Trends in net revenues (revenues excluding grants) may provide a clearer indication of the ability of LDCs to finance their own investments (figure 5.2). However, data coverage across all LDCs is generally patchy and incomplete. Nevertheless, for the few countries for which data are available for 2015, it is evident that for the majority, net revenues fall below 20 per cent of GDP. Thus, for most LDCs it remains unlikely that public revenues alone can meet electricity investment needs, and ODA will continue to be needed.

b. Public international development finance

In the absence of sufficient domestic resources, LDCs have traditionally relied on ODA[10] to supplement their infrastructure development financing deficits. However, while total ODA flows (figure 5.3) from members of the Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD) increased by 8.9 per cent in 2016, preliminary estimates show a reduction of 3.9 per cent in their ODA to LDCs (OECD, 2017c).

Public revenue constraints and limited private financing mean that ODA is needed for electricity investments

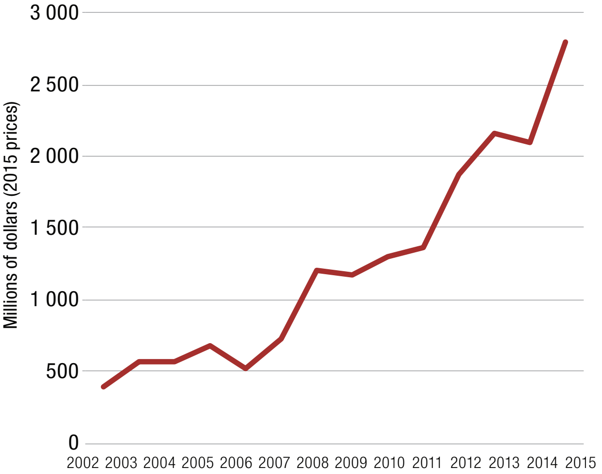
SDG target 17.2 reiterates developed countries' long-standing commitment to provide 0.7 per cent of their GNI in ODA to developing countries, and 0.15-to-0.20 per cent to LDCs, also urging donors "to consider setting a target to provide at least 0.20 per cent of ODA/GNI to least developed countries".

In 2015, only four members of OECD-DAC (Luxembourg, Norway, Sweden and the United Kingdom of Great Britain and Northern Ireland) provided 0.20 per cent of their GNI in ODA to LDCs, and three more (Denmark, Finland and Ireland) met the minimum target of 0.15 per cent. Compared with 2014, Belgium fell below the 0.15-per-cent threshold and Finland below the 0.20-per-cent threshold. In 2015, no DAC country allocated half of its total ODA to LDCs, and in only three did the share even reach 40 per cent (Ireland, Luxembourg and Iceland, at 48 per cent, 42 per cent and 41 per cent respectively).

Had all DAC donors met even the 0.15-per-cent target, their total ODA to LDCs would almost have doubled, from $37 billion to $70 billion, providing an additional $33 billion. Had all met the 0.20-per-cent target, this would have generated a further $20 billion. A target of 0.35 per cent would increase ODA to LDCs fourfold to $155 billion, providing additional resources of $118 billion per year (table 5.3).

Figure 5.3

Trends in ODA disbursements to LDC energy sectors, 2002–2015



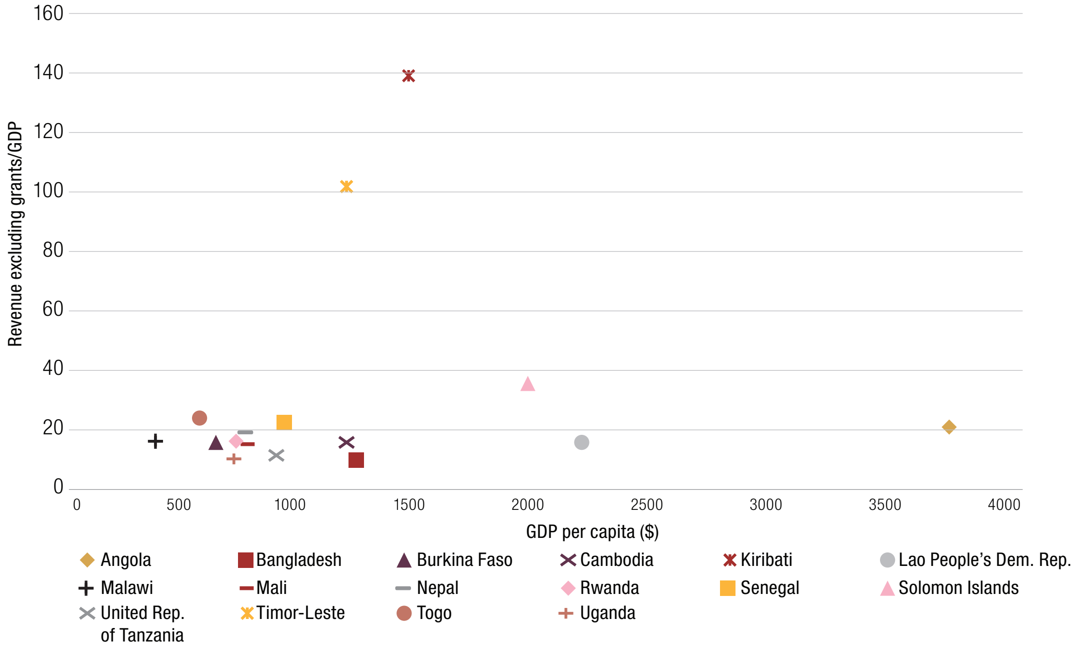
Source: UNCTAD secretariat estimates, based on data from World Bank, World Development Indicators database (accessed May 2017).

Gross ODA disbursements to the energy sector in LDCs have fared better, reflecting an increase in the proportion of disbursements going to the sector from 1.8 per cent in 2002 to 5.7 per cent in 2015 (figure 5.4). However, 43 per cent of funding went to five LDC recipients (figure 5.5). ODA in energy sectors in LDCs is concentrated in a small group of countries, in line with the overall pattern of ODA generally.

There has been an upward trend in disbursements to the energy sector in LDCs since 2006, continuing with a 25-per-cent increase to $2.8 billion in 2015. However, this remains less than half the level of ODA to ODCs ($6.4 billion), and total disbursements to LDCs were exceeded by those to the six largest ODC recipients (Pakistan, India, Viet Nam, Morocco, Indonesia and South Africa), each of which received more than $400 million.

Figure 5.2

Selected LDC revenue excluding grants, 2015 (per cent of GDP)



Source: UNCTAD secretariat estimates, based on World Bank, World Development Indicators database (accessed August 2017).

Table 5.3

ODA to LDCs and additional amounts generated by meeting targets, DAC member countries, 2015

(million dollars)

	Actual (2015)	Target amount			Increase from 2015		
Percentage of GNI:		0.15	0.20	0.35	0.15	0.20	0.35
Australia	931	1 976	2 635	4 611	1 045	1 704	3 680
Austria	222	562	750	1 312	340	528	1 090
Belgium	610	683	911	1 593	73	301	984
Canada	1 561	2 293	3 058	5 351	732	1 497	3 790
Czech Republic	41	259	346	605	218	305	564
Denmark	610	610	623	1 090	0	13	480
Finland	429	429	469	820	0	39	391
France	2 378	3 687	4 916	8 604	1 310	2 539	6 226
Germany	2 596	5 155	6 874	12 029	2 560	4 278	9 433
Greece	38	293	391	684	255	353	646
Iceland	16	25	33	58	9	17	42
Ireland	345	345	452	791	0	108	447
Italy	870	2 722	3 630	6 352	1 852	2 759	5 481
Japan	3 659	6 823	9 098	15 921	3 164	5 439	12 262
Rep. of Korea	728	2 080	2 773	4 853	1 351	2 045	4 125
Luxembourg	154	154	154	154	0	0	0
Netherlands	1 036	1 121	1 495	2 617	85	459	1 580
New Zealand	138	254	339	593	116	200	454
Norway	1 098	1 098	1 098	1 421	0	0	323
Poland	125	689	919	1 608	564	794	1 483
Portugal	90	290	387	677	200	296	587
Slovak Republic	19	129	172	300	110	153	282
Slovenia	10	63	84	146	53	74	137
Spain	314	1 788	2 384	4 172	1 474	2 070	3 858
Sweden	1 473	1 473	1 473	1 762	0	0	288
Switzerland	928	1 029	1 372	2 402	101	444	1 474
United Kingdom	6 117	6 117	6 117	9 876	0	0	3 759
United States	10 737	27 744	36 992	64 736	17 007	26 255	53 999
TOTAL DAC	**37 274**	**69 894**	**89 943**	**155 140**	**32 619**	**52 669**	**117 865**

Source: OECD, Statistics on resource flows to developing countries (http://www.oecd.org/dac/financing-sustainable-development/development-finance-data/statisticsonresourceflowstodevelopingcountries.htm), table 31, accessed July 2017, and UNCTAD secretariat estimates, based on GNI data from World Bank, World Development Indicators database (accessed July 2017).

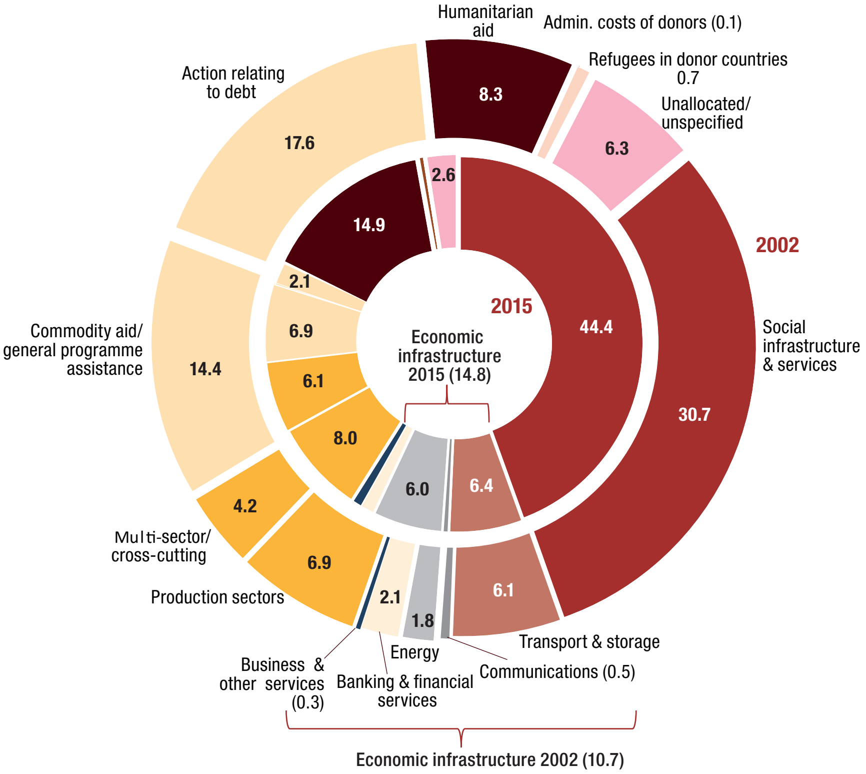
On average, 53 per cent of disbursements to LDCs between 2002 and 2015 were in the form of loans rather than grants (figure 5.6). Non-DAC donors, followed by the World Bank Group, disburse the highest shares of grant funding. OECD-DAC countries record the lowest share (figure 5.7).

A substantial part of the increase in ODA to LDC energy sectors since 2006 is accounted for by the entry of new non-DAC donors, such as the OPEC and Arab Funds, whose share in multilateral ODA in the LDC energy sector has increased rapidly (figure 5.8 and table 5.4), and by the growing role of regional development banks in LDC energy sectors. It is notable that the OPEC Fund shows a low level of concentration in terms of coverage of LDCs. The impact of multilateral funds linked to climate change, such as the Global Environmental Facility (GEF) and the Climate Investment Funds (CIFs), remains very small at present, partly because expanding electricity infrastructure is not a central part of their roles, and partly because both have been more active in ODCs than in LDCs.

Figure 5.4

ODA disbursements to LDCs by sector, 2002 and 2015

(2015 dollar prices)

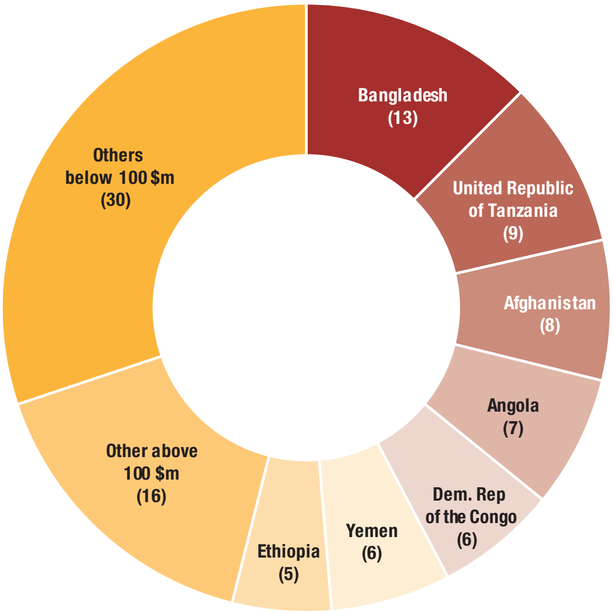


Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed May 2017).

Figure 5.5

Top LDC recipients of energy ODA, 2015

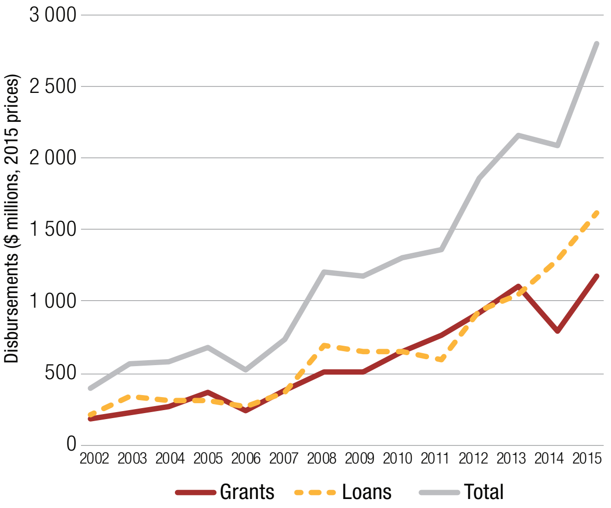
(per cent of total disbursements)



Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed July 2017).

Figure 5.6

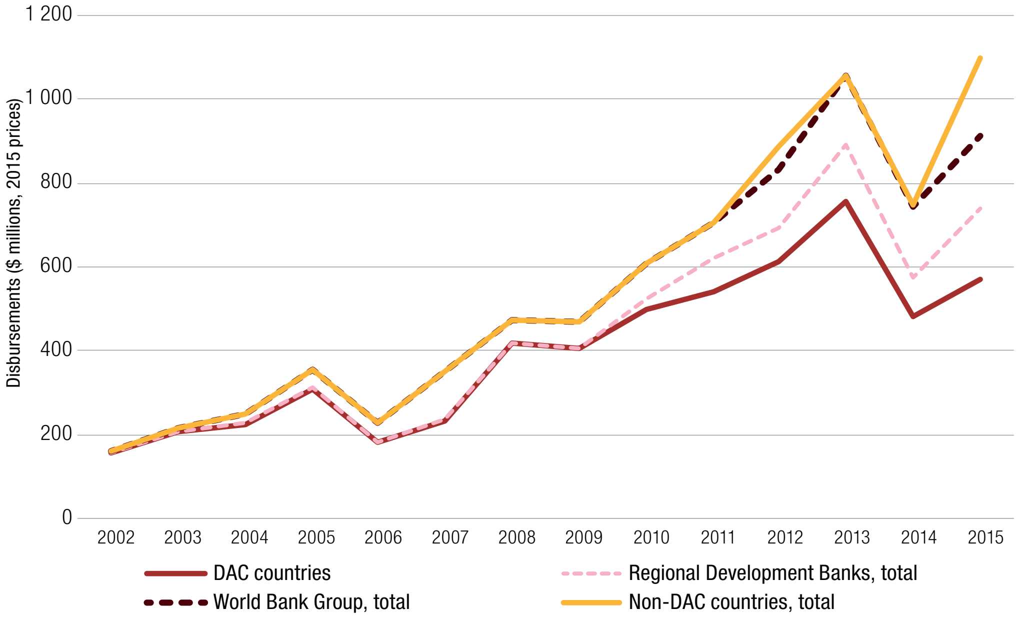
ODA disbursements to LDC energy sectors by type, 2002–2015



Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed May 2017).

Figure 5.7

ODA grants to LDC energy sectors by donor, 2002–2015

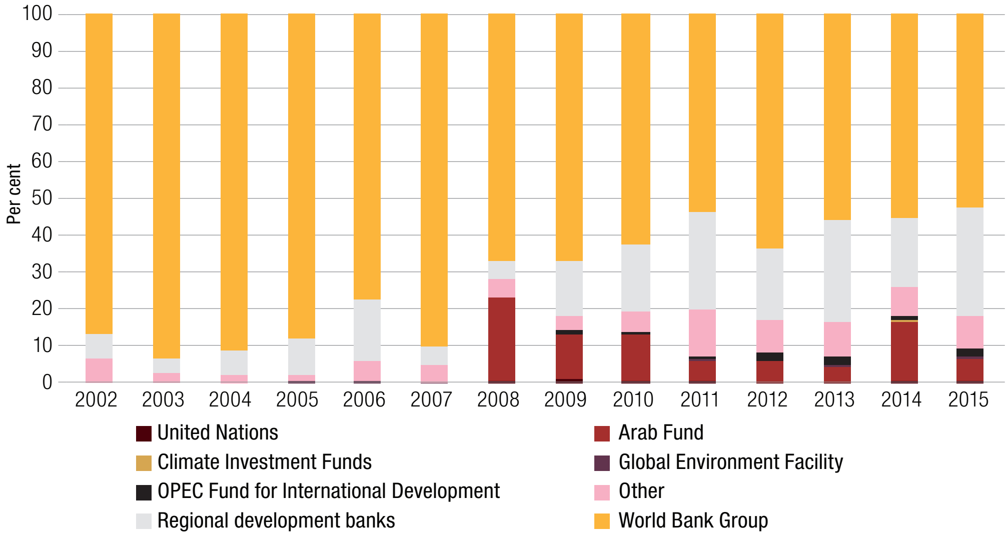


Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed May 2017).

Figure 5.8

Evolution of energy ODA disbursements by multilateral bodies to LDCs, 2002–2015

(2015 prices)



Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed May 2017).

Table 5.4

Non-DAC and regional banks' shares in multilateral ODA

(2015 prices)

Fund	First year	Average share in multilateral ODA 2008–2015 (%)
Arab Fund	2008	8.8
CIF	2013	0.01
GEF	2005	1.4
OPEC Fund	2009	5.5
Regional development banks	2002	25.4

Source: UNCTAD secretariat, based on OECD, OECD.Stat Creditor Reporting System database (accessed May 2017).

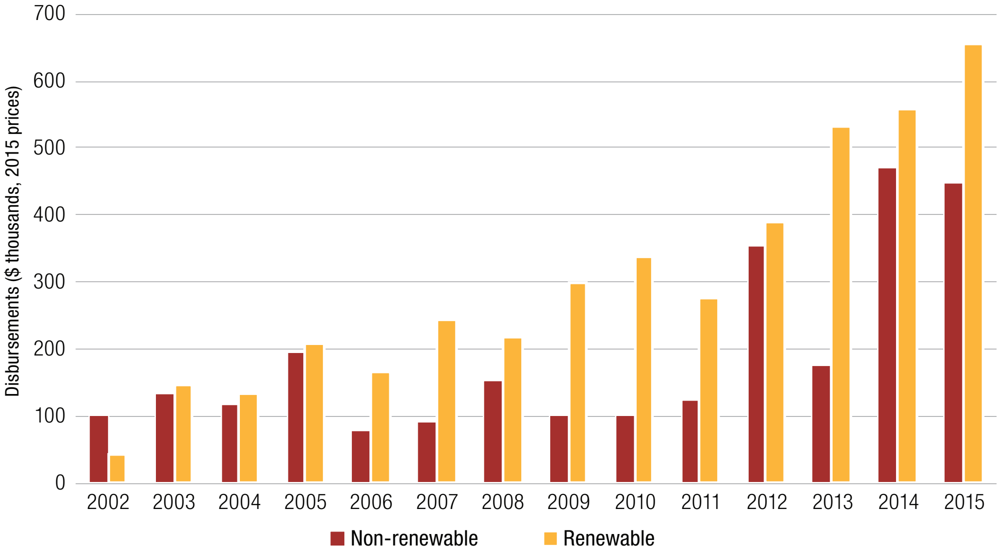
Notes: Regional development banks comprise the African Development Bank and the Asian Development Bank.

Since 2003, disbursements directed at renewable sources of electricity generation have surpassed those destined for the non-renewables subsector (figure 5.9). OECD-DAC countries and various multilateral donors have all been equally active in this category. The trends in the distribution of ODA disbursements between generation and network segments of the electricity industry are less clearcut, however (figure 5.10).

An important issue in ODA allocations is the lack of support to energy-sector planning, administration and regulation, which are recorded as having received zero disbursements between 2002 and 2015.[11]

Figure 5.9

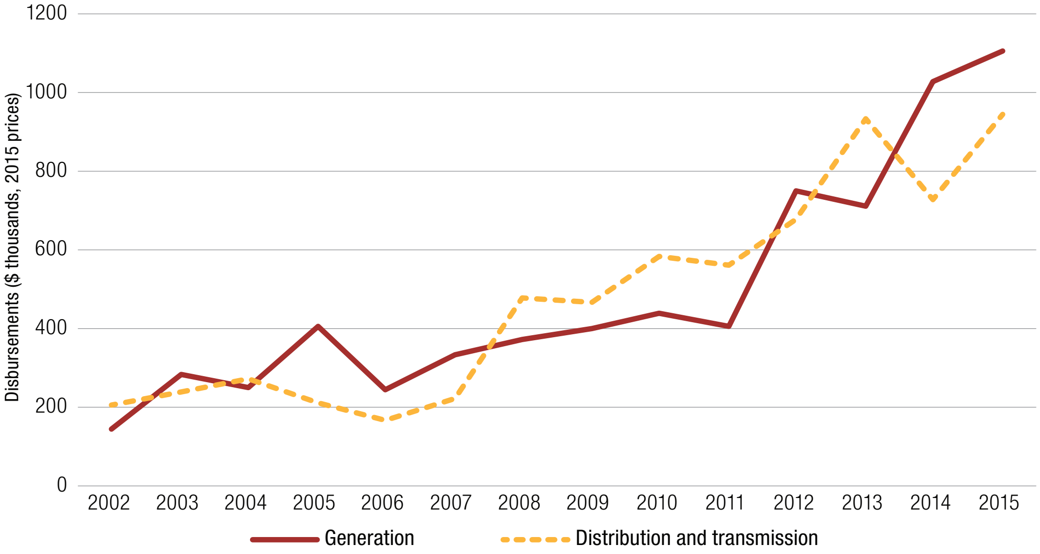
Distribution of ODA between renewable and non-renewable sources of energy, 2002–2015



Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed June 2017).

Figure 5.10

Distribution in ODA between network and generation segments, 2002–2015



Source: UNCTAD secretariat estimates, based on data from OECD, OECD.Stat Creditor Reporting System database (accessed June 2017).

Other official flows (public financing flows that do not meet the concessionality criteria for classification as ODA)[12] into LDC energy sectors averaged $173 million annually over the period 2005–2015 (figure 5.11). The majority of these funds were allocated to energy policy and administrative management (mainly funds from regional development banks) and electricity transmission and distribution (figure 5.12). Similar to ODA, zero disbursements were reported for the energy regulation subcategory.

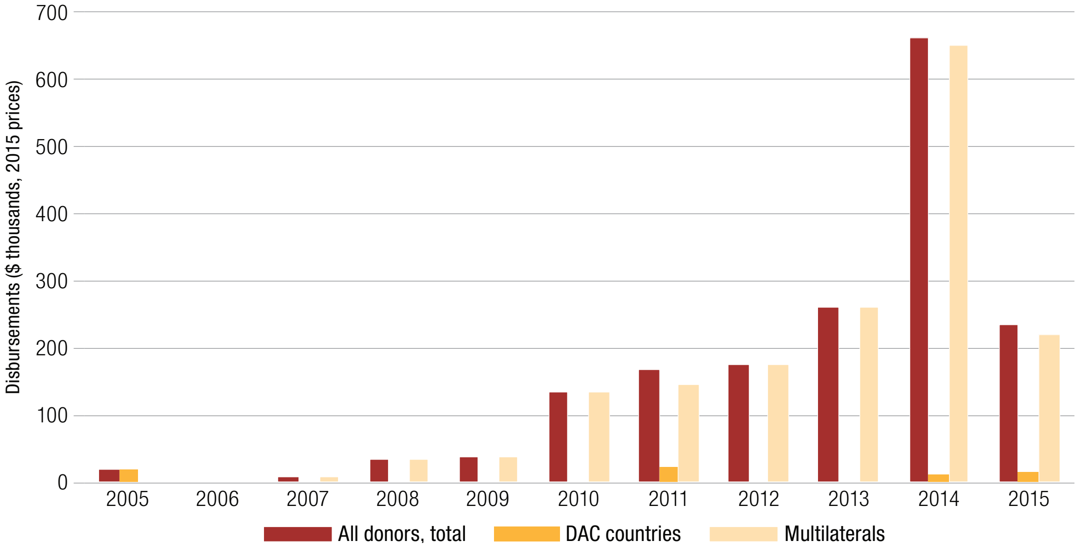
c. Public-private finance

Public-private partnerships (PPPs)[13] typically make up only about 5-10 per cent of overall investment in economic infrastructure (Mckinsey Global Institute, 2016); and the proportion of ODA disbursed through PPPs or equity in LDC energy sectors is minimal.

Financing for PPPs comes from a combination of private and public sources, including development finance institutions and other multilateral agencies. While only 5 per cent of global private infrastructure investment goes to lower-middle-income and low-income countries, some developing countries rely on PPPs for up to a quarter of their total financing. Regionally, across developing countries as a whole, the East Asia and Pacific region had the highest financing for PPPs from the private sector (83 per cent) in 2015, while Latin America and the Caribbean had the highest public share (39 per cent) (IFC, 2017a; World Bank, 2017a).

Figure 5.11

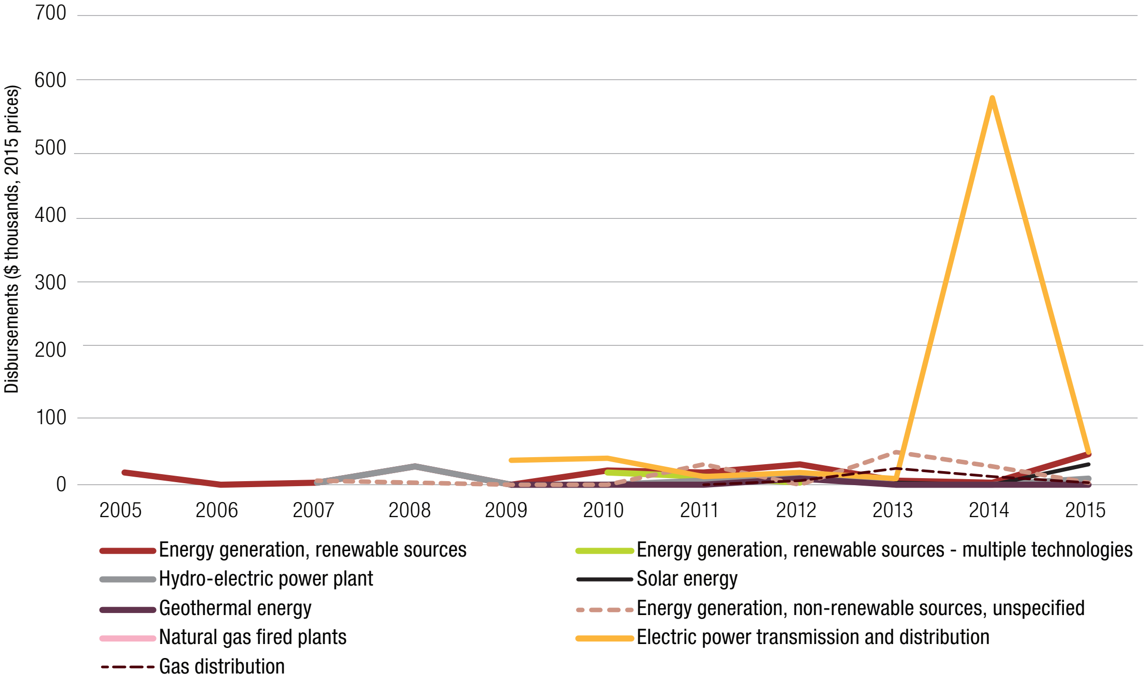
Trends in other official flows, 2005–2015



Source: UNCTAD secretariat estimates, based on data from OECD, Stat Creditor Reporting System (CRS) database (accessed June 2017).

Figure 5.12

Distribution of other official flows by generation source, 2005–2015



Source: UNCTAD secretariat estimates, based on data from OECD, Stat Creditor Reporting System (CRS) database (accessed June 2017).
Note: The spike in 2014 is explained by other official flows from the African Development Bank (AfDB) to Angola.

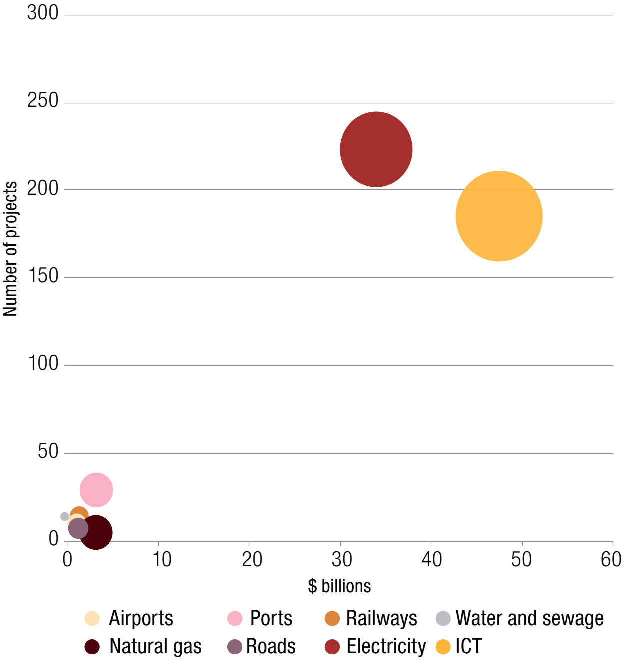
It should be noted, however, that PPPs do not necessarily liberate public funds, and that national Governments can generally raise finance at a lower cost than developers via concessional debt and aid (Nelson and Shrimali, 2014).

Since 1990, there have been 488 recorded PPP project investments in LDCs, amounting to $91.3 billion. More than half of these projects by value ($47.5 billion) were in the information, communications and telecommunications (ICT) sector; but a greater number of projects (223 projects totalling $34 billion) have been in the electricity sector (figure 5.13). This compares with $2.23 billion (5,971 projects) over the same period in ODCs, of which the electricity sector accounted for $748 billion (2,726 projects).

The total value of PPP energy projects in LDCs has increased rapidly since 2004, peaking at $14.1 billion (179 projects) in 2012, but has fallen dramatically since, to $6.9 billion (148 projects) in 2013, and a low of six projects ($0.8 billion) in 2016. Among the LDCs, the

Figure 5.13

Private participation in infrastructure in LDCs, 1990–2016



Source: UNCTAD calculations based on World Bank Private Participation in Infrastructure database accessed May 2017

Note: No information is available for Equatorial Guinea, Solomon Islands and Tuvalu.

country with the highest value of investments over the period was Lao People's Democratic Republic, with investments of almost $16 billion in electricity (table 5.5).

Chinese investments in LDC energy projects are estimated to be in excess of $9.4 billion, and its construction contracts (not involving ownership of infrastructure) in excess of $55.3 billion between 2005 and 2016 (table 5.6).[14] However, LDC energy markets accounted for only 0.2 per cent of Chinese investments worldwide between 2005 and 2016.

d. Sovereign borrowing

Rising commodity prices, high economic growth rates, and low interest rates in developed markets have encouraged some LDCs, particularly in Africa, to increase their issuance of international bonds to finance infrastructure development (UNCTAD, 2016a; WEF, 2016). Between 2006 and 2015, at least seven African LDCs have tapped Eurobond markets (Angola, Ethiopia, Mozambique, Rwanda, Senegal and Zambia). Demand for such bonds appears to remain strong, despite Mozambique's default on a coupon payment in January 2017: Senegal's fourth Eurobond, issued in May 2017, was eight times oversubscribed (Bloomberg 2017).

Table 5.5

Top four recipient countries of private participation in electricity and ICT

Country	Electricity		Country	ICT	
	Investment ($ billion)	No. of projects		Investment ($ billion)	No. of projects
Lao People's Democratic Republic	15.9	25	Bangladesh	8.2	12
Bangladesh	4.4	49	Sudan	4.2	5
Uganda	1.4	22	United Rep. of Tanzania	4.0	12
Nepal	1.9	29	Senegal	3.1	3

Source: World Bank Private Participation in Infrastructure database (accessed May 2017).

Table 5.6

Investment by Chinese companies in LDC energy

Year	Investor	Amount ($ millions)	Investor share (%)	Subsector	Country	Type
2008	Huadian	580		Hydro	Cambodia	
2010	Sinohydro	1 030		Hydro	Lao PDR	Greenfield
2011	Sinohydro	140	90	Hydro	Nepal	
2013	China Energy Engineering	130		Hydro	Nepal	Greenfield
2013	CNPC	4 210	29	Gas	Mozambique	
2013	Power Construction Corp	120	90	Hydro	Nepal	Greenfield
2013	Norinco	180	85	Hydro	Lao PDR	Greenfield
2013	Huaneng	410		Hydro	Cambodia	Greenfield
2015	Three Gorges	1 200	75	Hydro	Nepal	Greenfield
2016	Power Construction Corp	1 360		Hydro	Laos	Greenfield

Source: World Bank Private Participation in Infrastructure database (accessed May 2017).

Some LDCs use their natural resources as collateral to overcome barriers to accessing conventional bank lending and capital markets. Natural resource- or commodity-backed finance is a form of lending used by banks from a number of jurisdictions, including China (table 5.7), Brazil, France, Germany and Republic of Korea (Halland and Canuto, 2013).

2. Prospects for external financing

The need for massive injections of capital into LDC energy sectors comes at a time when the international development finance landscape is undergoing its own disruptions, and these countries may be facing a less supportive environment in which to raise additional funding. Shifts in that landscape have created new opportunities and options to access external finance, but also significant new challenges (box 5.3).

Changes in the international development finance landscape are creating new opportunities and new challenges

a. Public international development finance: A shrinking space?

New uncertainties have arisen around future levels of ODA that may serve to narrow LDCs' financing options. Political developments and continued economic stress in major donor economies are prompting some donors to rethink their ODA commitments, including possibly abandoning the commitment to provide 0.7 per cent of GNI in ODA and reducing contributions to multilateral bodies such as the World Bank.

Table 5.7

China energy finance to selected LDCs 2000–2016

Country	Borrower	Lender	Energy source	Energy subsector	($ billions)
Zambia	Government	Ex-Im Bank	Hydropower	Power generation	2.00
Cambodia	Government	Ex-Im Bank	Hydropower	Power generation	1.50
Democratic Republic of Congo	Government	Ex-Im Bank	Hydropower	Power generation	1.00
Sudan	Government	Ex-Im Bank	Hydropower	Multipurpose	0.61
Benin	Government	Ex-Im Bank	Hydropower	Power generation	0.55
Lao People's Democratic Republic	Government	Ex-Im Bank	Hydropower	Transmission and distribution	0.55
Uganda	Government	Ex-Im Bank	Hydropower	Power generation	0.50
Mali	Government	Ex-Im Bank	Hydropower	Power generation	0.44
Ethiopia	Government	Ex-Im Bank	Hydropower	Power generation	0.44
Guinea	Government	Ex-Im Bank	Hydropower	Power generation	0.34
Equatorial Guinea	Government	Ex-Im Bank	Hydropower	Power generation	0.26
Nepal	Government	Ex-Im Bank	Hydropower	Power generation	0.20
Myanmar	Government	Ex-Im Bank	Hydropower	Power generation	0.20

Source: China Global Investment Tracker, data compiled by the American Enterprise Institute and the Heritage Foundation.

Box 5.3. **New vocabulary in development finance explained**

Innovative finance encompasses a range of new or non-traditional funding mechanisms that seek to achieve specific results, such as raising additional funds, improving the efficiency of funding or linking finance to specific developmental impacts. The same or similar mechanisms may be labelled differently in different regions or sectors. The lack of common definitions and policy frameworks, including for monitoring and evaluating their efficacy and impact, constrains the sound assessment of these new forms of development finance, even as they gain prominence.

Blended finance/capital occurs when public development finance is used to attract or leverage commercial finance into developing countries. It is thus a means to mobilize additional development finance from the private sector. The World Bank Group incorporates this strategy as part of its cascade approach to assessing how best to fund development projects in order to improve the efficiency of Bank funding. OECD has also adopted blended finance as a means to bring together public and private investors to achieve the SDGs.

Impact investing is undertaken by companies, organizations or funds seeking to generate social and/or environmental impact alongside financial returns. Investors may target market-rate returns or seek only to recoup capital. Impact investors are not necessarily the same as social investors.

Social investment or socially responsible/green/ethical investing encompasses investment strategies that seek to bring about social change. However, unlike impact investors, social investors consciously avoid investments that do not meet their ethical standard, over and above an investment's potential social impact.

Source: Mohieldin (2017); OECD (2017a, 2017b); Saldinger (2017).

The Addis Ababa Action Agenda (adopted in 2015 at the Third International Conference on Financing for Development) presents catalysing resources from other public and private sources as an important use of ODA and other international public finance. This may be an opportunity for LDCs, if it effectively broadens their options for development finance. However, the current array of risk mitigation instruments used by international finance institutions to crowd in institutional investors has been found to be complex and non-standardized, and thus burdensome and costly for the private sector to use (WEF, 2016). Guarantees are[15] the main lever by which international official financing is used to leverage private investment in infrastructure, accounting for 60 per cent of the total amount; but guarantees for energy projects benefit mostly ODCs (OECD, 2015b). Between 2012 and 2014, LDCs received only 8 per cent of finance mobilized through guarantees, syndicated loans and shares. Overall, developing countries in Africa (29.1 per cent) benefited the most, followed by Asia (27.2 per cent) and the Americas (21.1 per cent) (OECD, 2016a).

Changes are also under consideration in multilateral development financing institutions. Specifically, the World Bank Group is considering the adoption of a cascade approach to financing infrastructure projects (Mohieldin, 2017). This approach would prescribe that support for public-sector solutions to development financing, including concessional lending, could only be considered if private-sector solutions (first priority) and public-private partnerships (second priority) were deemed not to be feasible. If adopted, this approach is expected to apply equally to the International Development Association (IDA) fund for the poorest countries, which was replenished by $75 billion (50 per cent) in December 2016. The "blended finance" approach of OECD and the Addis Ababa Agenda follows a similar logic.

b. New global financial sector rules

Stricter liquidity and capital adequacy requirements under Basel III[16] implementation are expected to increase the price of long-term debt and reduce its supply.[17] Basel III is also expected to induce changes in the way that project financing is structured and documented (OECD, 2015a; IRSG, 2015). As a consequence, banks in developed countries have become more reluctant to take on the risks associated with infrastructure project finance. This emerging gap in long-term bank financing contributes to a widening frontier of vulnerability in the development finance landscape for LDCs and developing countries generally.

The volume of private participation in financing infrastructure projects in lower-income countries remains modest (OECD, 2015b). There is evidence that institutional investors, estimated to account for assets in the trillions of dollars, may be gradually increasing their exposure to infrastructure and other real assets. However, the vast majority of their investments are still concentrated in their home OECD economies and in traditional financial instruments (Inderst and Stewart, 2014). For instance, pension funds continued to invest mainly (75 per cent) in equities and bonds in 2016 (OECD, 2017d).

The challenge is to channel institutional investment towards developmental purposes. The infrastructure push associated with the 2030 Agenda is widely expected to encourage institutional investors to further diversify their portfolios and turn their attention to developing countries. However, in the Basel III environment, these investors are showing signs of being increasingly wary of large investments that require the bespoke due diligence which typically characterizes infrastructure projects (Kharas, 2015). First-mover risks linked to ongoing technological disruption in energy markets could also be viewed as a potential source of systemic risk by investors (Ma, 2016).

A further challenge is that changes in institutional investors' own rules may be necessary to allow them to invest in development-oriented projects (UNCTAD, 2012). Developments in climate policy have so far not stimulated any discernible change in this context. For instance, sovereign wealth fund mandates do not typically include green finance (OECD, 2016b), and related actions in this area have been taken with a view to reducing the portfolio exposure to fossil fuels (Halland, 2017) in the debt and equity of listed corporations. Willingness to invest in any given country is also heavily influenced by perceptions in areas in which LDCs tend to be at a disadvantage, such as sovereign risk, investment climate, policy settings and institutional quality (OECD, 2016b; Inderst and Stewart, 2014).

c. The rise of infrastructure and energy-related funds

Notwithstanding an uncertain future for development finance generally, infrastructure, including the electricity sector, has increasingly been the focus of considerable interest from donors, the private sector and multilateral development finance institutions. There has been a proliferation of infrastructure- and energy-specific development finance and impact investment funds (box 5.4), and of climate and green financing facilities, at the bilateral, regional and multilateral levels. Such initiatives are often linked to climate-change policy or sustainable development and may or may not target energy infrastructure and/or access. Many are led by regional development banks or fall under the rubric of South-South or bilateral cooperation, often with a regional or country focus, but a specific LDC focus is rare. In the new development finance paradigm, the blending of public and private finance is transforming the profile of fund investors to include development finance institutions, private equity managers, impact investors and institutional investors. This contributes to an interlaced web of interests, motivations and flow of development finance.

These initiatives are important because they are increasingly successful in marshalling large financing commitments that have the potential to contribute to development alongside public spending and ODA.

The European Sustainable Development Fund, proposed in September 2016, is expected to raise up to €44 billion for investment in Africa and in countries neighbouring the European Union. A minimum of 28 per cent of that fund will be earmarked for investments in climate action, renewable energy and resource efficiency. The proposed fund aims primarily at creating jobs and addressing root causes of migration (European Council, 2017). At the multilateral level, the Green Climate Fund had mobilized $10.3 billion in pledges as at July 2017, and 13 of its 43 active projects, amounting to only $2.2 million in commitments, are in LDCs. The Africa Hub of the Sustainable Development Investment Partnership (SDIP) for infrastructure investment was launched in 2016, and a hub for ASEAN is planned. The partnership is a collaborative initiative comprising public, private and philanthropic institutions from around the world, coordinated by the World Economic Forum with support from OECD, and aims to mobilize $100 billion using blended finance by 2020.

The explosive growth of such initiatives is illustrated by the mapping of (a conservative list of) 58 multi-country energy-related initiatives and programmes targeting Africa, shown in table 5.8. Multilateral donors are involved in 77 per cent and bilateral donors in 65 per cent of the Africa initiatives and programmes. Almost all of them focus on the promotion of renewable energy and the vast majority address the electricity sector, 74 per cent supporting grid-connected electricity generation (AEEP, 2016).

However, this proliferation of energy initiatives could exacerbate the already skewed nature of development finance flows amongst LDCs as a group and between regions. It also highlights the persistent challenges around tracking, measuring and understanding the motivations and nature of non-traditional sources of development finance. The large volume of often non-comparable and opaque data associated in particular with initiatives involving the private sector, South-South cooperation and impact investment makes it increasingly difficult to assess fully how much funding is available, its coverage, additionality and impact. Furthermore, official estimates of the activities of private entities (e.g. philanthropic foundations, corporate philanthropy) that aim primarily to support national or international development rather than making a profit and that involve a transfer of resources to developing countries are generally lacking or provide insufficient sectoral and country detail (United Nations, 2016). Changes in the global development finance landscape have thus created an information scarcity problem while also contributing to an increasingly complex and fragmented development finance architecture for LDCs and other developing countries to navigate (UNCTAD, 2016b).

Impact investors are also seen as potential sources of financing, in particular for medium-scale renewable and hybrid projects on larger grids capable of supporting

Box 5.4. **The impact investment industry**

Impact investments are considered to have complementary and significant potential for the realization of the SDGs alongside public spending and ODA, and were initially driven in large part by bilateral donors and philanthropic communities. Impact investors invest in private-sector companies, organizations and funds, primarily in developing countries. Their key selling point is a perceived ability to drive inclusive and green business through catalytic investment in small and medium-sized enterprises and reach bottom-of-the-pyramid populations using innovative new business models.

By September 2016, the Global Impact Investing Network's database included more than 400 impact investment funds, 60 per cent of which had been in existence for less than three years, with committed capital amounting to $31.2 billion. Major emphases are rural and urban areas; bottom-of-the-pyramid; community/local investing; women; minorities/previously excluded populations; fair trade; human rights; and faith-based themes. Access to finance and access to basic services were by far the two most important focus areas, followed by employment generation and green technology. Private equity and venture capital account for more than 50 per cent of funds' investment vehicles, especially in emerging markets. Funds predominantly (79 per cent) pursue risk-adjusted market returns.

Challenges faced by fund investors include the limited number of sustainable social enterprises or impact investees that meet their criteria for investment in their target markets; a lack of innovative fund and deal structures that match investor risk and return profiles; a lack of visibility; an unclear regulatory environment in target markets; and limited possibilities to dispose of investments profitably. The development of standard social-impact measurement systems remains a significant challenge for the industry.

Source: GIIN (2015); UNDP (2015); Wilson (2016).

Alternative sources of development finance include South-South finance, diaspora investment and domestic capital markets

semi-industrial and industrial productive activities (box 5.4). Securing commercial financing for larger decentralized grids is problematic in many developing countries because of their intermediate size, greater complexity and need for formal institutional and legal frameworks. In most instances public financing, which can be as high as 80 per cent, comes in the form of a capital subsidy (IFC, 2012). Larger decentralized systems designed with business rather than household customers in mind are able to exploit economies of scope to provide more reliable and differentiated services, such as peak and off-peak services, and to cater for different loads. Inadequate policy frameworks, periodic adjustment costs necessitated by rising demand, long-term management and maintenance, and lack of funding at the intermediate scale have contributed to the concentration of private-sector interventions in household and off-grid solutions.

d. South-South financing

Chinese policy banks have emerged as global leaders in finance for energy projects in developing countries (table 5.7), and it is estimated that China's banks and funds have doubled the availability of global development finance and hold more assets than the

Table 5.8

Overview of major energy initiatives and programmes targeting Africa

High-level initiatives	
Africa Clean Energy Corridor	Africa Renewable Energy Initiative (AREI)
Africa Energy Leaders Group (AELG)	Presidential Infrastructure Champion Initiative (PICI)
Africa-EU Energy Partnership (AEEP)	Program for Infrastructure Development in Africa (PIDA)
Africa Power Vision	SE4ALL (Africa Hub)
High-level initiatives with an operative programme	
Africa 50	New Deal on Energy for Africa
Africa Renewable Energy Access Program (AFREA I & II) – ESMAP	Power Africa
ElectriFi	Public Private Infrastructure Advisory Facility (PPIAF)
Energies pour l'Afrique	World Bank Guarantee Program
Global Alliance for Clean Cookstoves	
Operative programmes and delivery mechanisms	
ACP-EU Energy Facility	GET FiT Uganda
AFREA Gender and Energy Program	Global Energy Efficiency and Renewable Energy Fund (GEEREF)
Africa Clean Cooking Energy Solutions Initiative (ACCES)	Green Mini-Grids Africa Regional Facility
Africa Energy Guarantee Facility (AEGF)	IRENA/ADFD Project Facility
Africa Enterprise Challenge Fund (AECF)	Lighting Africa
Africa-EU Renewable Energy Cooperation Program (RECP)	Mediterranean Solar Plan (MSP)
African Development Bank Partial Risk Guarantee (PRG)	NEPAD Bioenergy Programme for Africa
Africa Renewable Energy Fund (AREF)	NEPAD Continental Business Network (CBN)
Biofuels Programme for Household and Transport Energy Use	NEPAD Infrastructure Project Preparation Facility (NEPAD-IPPF)
Carbon Initiative for Development (Ci-Dev)	PIDA Service Delivery Mechanism (SDM)
Clean Technology Fund (CTF)	Private Infrastructure Development Group
EEP Africa – Energy and Environment Partnership	Regional Energy Project for Poverty Reduction
Energising Development (EnDev)	Regional Technical Assistance Program (RTAP)
Energy Access Ventures	Renewable Energy Performance Platform (REPP)
Energy Africa Campaign	Renewable for Poverty Reduction Program (REPoR)
EREF ECOWAS Renewable Energy Facility	Renewable Energy Solutions for Africa (RES4Africa)
EU-Africa Infrastructure Trust Fund (ITF) / Africa Investment Facility (AfIF)	Scaling Solar
EU Development Finance Institutions (EDFIs) Private Sector Development Facility	Strategic Climate Fund – Scaling Renewable Energy Program (SREP)
EU Energy Partnership Dialogue Facility (EUEI PDF)	Sustainable Development Investment Partnership (SDIP)
European Union's Technical Assistance Facility (TAF)	Sustainable Energy Fund for Africa (SEFA)
Geothermal Risk Mitigation Facility	

Source: AEEP (2016), table 1.

major multilateral development banks operating in developing countries. In Africa, China has become the major bilateral source of infrastructure financing (Sy and Copley, 2017). Between 2007 and 2014, Chinese banks added $117.5 billion in energy finance, which doubled globally available energy financing (Gallagher et al., 2016). Loans extended by China have sometimes been found to meet the OECD-DAC and World Bank concessionality criteria, but even when they do not, their disbursement processes and lack of conditionality are key selling points (Bhattacharya and Rashmin, 2016). The diversity of LDCs receiving credit from China is significantly greater than that of recipients of direct investment.

China's dominance in infrastructure finance is expected to continue. It played a major role in capitalizing the New Development Bank[18] and the Asian Infrastructure Investment Bank.[19] Among the latter's list of projects approved in 2016 is a $20-million electricity generation project in Myanmar and a $165-million project in electricity distribution in Bangladesh. The Asian Infrastructure Investment Bank, which became operational in January 2016, is projected to provide $10 billion to $15 billion in loans annually over the next 15 years. It is estimated that the New Development Bank has the ability to reach an annual lending capacity of $3.4 billion by 2024 and almost $9 billion by 2034 (United Nations, 2016).

China's Belt and Road Initiative, which calls for massive investments in infrastructure, is also expected to boost Chinese lending, including in the electricity sector in Asia. The establishment of the China South-South Climate Cooperation Fund, announced in 2015, is also relevant to the electricity sector.

Other South-South finance is also set to increase. For instance, India announced in 2015 a $10-billion concessional credit to African countries over five years, along with $600 million in grant assistance, augmenting existing lines of credit to the continent.

e. Domestic financing

LDC Governments and international donors are now focused — albeit from different perspectives — on alternative investment sources that can help bridge funding gaps as pressures mount in some traditional donor countries to reduce public sources of international development finance. Increasing attention is directed to three potential financing sources that are seen as exceeding ODA and as being relatively stable and resilient during periods of economic downturn: illicit financial outflows (in particular from Africa but also from other jurisdictions); resources that could be liberated through the reform or elimination of inefficient support for the consumption or production of fossil fuels; and personal remittances. The last of these is not a source of development finance or of long-term capital, but rather a flow of private money between households, largely for consumption expenditure. However, there may be some potential for direct investment in development-related activities by diaspora members.

A prerequisite for tapping alternative sources of development finance in LDCs is the development of domestic instruments for infrastructure-related debt. Underdeveloped capital markets in LDCs result in an unavailability of typical infrastructure debt instruments, such as corporate bonds and project bonds, including municipal bonds, that can be rated and traded and are normally allowed in institutional-investor portfolios (Inderst and Stewart, 2014; IFC, 2016). The generally insufficient level or outright unavailability of such instruments hampers investors' ability to diversify risk. It also constrains the development of a local investor base. For example, the importance of pension funds relative to the size of the economy in some LDCs (e.g. Lesotho) is significant (OECD, 2014) and could be better exploited if the domestic capital market were more developed.

Notable developments are signs that national development banks are assuming a more prominent role in financing regional and subregional infrastructure (United Nations, 2016), and the growing number of initiatives aimed at assisting developing countries to develop nascent domestic capital markets and tap new breeds of investors.

Some international initiatives are under way to support domestic resource mobilization. At the multilateral level, IFC promotes local currency bonds (IFC, 2017b). At the regional and continental levels, a "Big Bond for Africa" has been mooted;[20] and a number of initiatives already exist in Asia, such as the Asian Bond Fund initiative of the Executives' Meeting of East Asia Pacific Central Banks (EMEAP), launched in 2003,[21] and the Credit Guarantee and Investment Facility (CGIF), which provides bond guarantees in the Association of Southeast Asian Nations (ASEAN)+3 region.[22] Examples at the bilateral level include the African Local Currency Bond Fund established by Germany's KfW Development Bank in 2012.[23] National examples include Ethiopia's diaspora bond and Bangladesh's migrants' bonds (Guichard, 2016).

However, the LDC coverage of these initiatives is variable. For instance, IFC bonds have largely benefited ODCs — including the BRICS countries — perhaps underlining the acute difficulties in LDC contexts, while only Zambia and Rwanda have so far benefited from the IFC initiative and LDC members of the EMEAP initiative have not yet participated. Impacts may also be constrained where listing is confined to national markets, as is the case for Bangladesh's migrants' bonds.

E. Conclusion

The costs of achieving universal access to electricity in LDCs, and still more of transformational access, are very considerable, and much greater than existing financial flows to the sector. Estimates presented in this chapter suggest the total investment cost for basic universal access by 2030 to be in the order of $12-$40 billion per year across LDCs as a whole; and increasing supply to fulfil the needs of transformational access would increase these costs significantly. However, the prospects for an increase on the scale required are clouded by a number of current and impending challenges.

Current trends in development finance, notably as expressed in the Addis Ababa Action Agenda, highlight the potential role of private financing for development-oriented infrastructure investment and of official flows in catalysing such financing. However, the role of private infrastructure financing remains limited in LDCs, and there are substantial obstacles to its deployment to achieve universal access. This approach also presents the challenge of balancing the drivers of private finance with the very different motivations of public finance. Together with the high cost of private finance, these considerations strongly indicate a continuing central role for public investment and ODA. An increase in ODA to LDCs is critical in the context of the internationally recognized principle of common but differentiated responsibility with respect to climate-change mitigation.

The particular circumstances of LDCs, with high costs of electrification and very limited purchasing power, give rise to potentially serious tensions between the multiple objectives of increasing access, affordability, reliability of supply and financial sustainability. These tensions may be further heightened to the extent that LDCs seek to increase the share of renewables in their electricity generation mix significantly through private-sector participation, as this is likely to require consideration of renewable energy support schemes that involve above-market prices. Further constraints arise from the limited availability of planning and regulatory capacities, which need to be taken into account in the design and choice of support mechanisms, and also highlight the need for proactive efforts to build the requisite capacities to broaden policy options in the future.

Notes

1 A syndicated loan is financed by a group of lenders rather than a single borrower.

2 Whereas for developed countries the pressures revolve around the inequities among residential customers created by the emergence of distributed generation, for LDCs (and other developing countries) the drivers are linked to structural weaknesses exposed by increased private-sector participation in the sector.

3 For example, tariffs differentiated by technology and site location, or tariffs exempt from regulation and set by operators in consultation with communities, as in the United Republic of Tanzania (IRENA, 2016b).

4 Bearing in mind that renewables' costs differ by locality, auction prices are not comparable within or across countries.

5 Business development services often mean the difference between the success and failure of entrepreneur credit schemes and the successful uptake of credit, as the availability of credit does not in and of itself lead to an increase in entrepreneurs or borrowing (Molenaar, 2006; Naidoo and Hilton, 2006).

6 While LDCs represent 60 per cent of the population of sub-Saharan Africa, they account for only one third of the region's GDP, reflecting their lower GDP per capita and the substantial shares attributable to South Africa and Nigeria.

7 During 2010–2015, 22 climate-related official development assistance-funded projects were aimed directly at fossil-fuel subsidy reform (Merrill et al., 2017).

8 https://www.iea.org/topics/energyefficiency/.

9 An online repository of supplementary materials to this study, including the modelling tool used (developed by the United Nations Department of Economic and Social Affairs), is available at https://github.com/UN-DESA-Modelling/electrification-paths-supplementary.

10 Official development assistance (ODA) remains a unique and important driver of development cooperation and is the only form of international public finance that is explicitly targeted at promoting the development and welfare of developing countries (United Nations, 2016).

11 The OECD-DAC database subdivides ODA for energy data into six thematic areas: energy policy and administrative management; energy sector policy, planning and administration; energy regulation; energy education/training; energy research; and energy conservation. Disbursements to LDCs in the first two categories are recorded as zero between 2002 and 2015.

12 Other official flows include bilateral financing for commercial purposes, such as direct export credits; subsidies to the private sector to soften its credits to developing countries; and funds in support of private investment. The data reported here exclude export credits.

13 Public-private partnership (PPP) contracts have emerged as a major legal structure to define project finance investment. They have few standardized structures and are often project-specific (OECD, 2015a).

14 China Global Investment Tracker database (http://www.aei.org/china-global-investment-tracker/). The database excludes deals with a value of less than $100 million.

15 At least up until the cascade/blending arrangements are fully effective.

16 The introduction of Basel III is to be completed in 2019 and is expected to be in operation worldwide.

17 The European Commission and European Investment Bank have established the Europe 2020 Project Bond Initiative as a means to attract alternative financing for individual infrastructure projects (http://www.eib.org/products/blending/project-bonds/).

18 The New Development Bank was founded by the BRICS countries (Brazil, Russian Federation, India, China and South Africa) in 2015 with a particular focus on lending for sustainable development and sustainable infrastructure (it targets 60 per cent of lending to renewable energy) in the BRICS, other emerging-market economies and developing countries (http://www.ndb.int/about-us/essence/history/).

19 The China-led Asian Infrastructure Investment Bank is a multilateral development bank that came into existence at the end of 2015 with the aim of addressing infrastructure needs across Asia. As of May 2017, five Asian LDCs (Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar and Nepal) and one African LDC (Ethiopia) were members. Prospective LDC members listed on the Bank's website in May 2017 include Afghanistan and Timor-Leste.

20 Proposed by Ngozi Okonjo-Iweala, former Finance Minister of Nigeria and Managing Director of the World Bank, and Nancy Birdsall, President Emeritus and senior fellow at the Center for Global Development (Birdsall and Okonjo-Iweala, 2017).

21 https://aric.adb.org.

22 http://www.cgif-abmi.org/. ASEAN and EMEAP LDC members comprise Cambodia, Lao People's Democratic Republic and Myanmar.

23 http://www.alcbfund.com/.

CHAPTER 6

Policies for transformational energy access

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Policies for transformational energy acces

A. Introduction

Universal access to modern energy could have a transformative effect on the economies of least developed countries (LDCs); but realizing this potential is critically dependent on the expansion of productive uses of modern energy, to increase productivity in existing activities and diversify output into new sectors and products. Equally, the expansion of productive energy use can play an important role in strengthening the electricity sector, by providing the demand needed to make investments viable, and possibly supporting the diversification of LDC energy sources.

Harnessing this synergetic relationship that lies at the heart of the energy-transformation nexus requires going beyond the social and environmental lenses that have tended to dominate discussions of energy access, and paying due attention also to the economic dimension. It requires proactive efforts to ensure “transformational energy access” and to promote the use of electricity in productive processes.

Energy requirements for productive uses differ widely across sectors/activities, but typically go far beyond the minimalist view of universal access as the physical connection of households to sources of electricity. Unless producers’ energy needs are met — including in terms of adequate peak power, reliability, quality of supply and affordability — the unprecedented development opportunities offered by recent technological advances in electricity generation (and to a lesser extent storage) will be largely missed.

Serious efforts to achieve transformational energy access by 2030 will entail massive investments in physical infrastructure, and parallel improvements of the energy sector’s institutional architecture. Such investments are very long-term in nature, and may give rise to an important element of path dependency. Pursuing an approach to universal access that fails to address adequately the current and prospective energy needs in a context of structural transformation thus risks locking LDCs into a suboptimal development path for decades to come. This has major implications for energy policy, for development strategies, and for the articulation between the two.

This chapter provides policy conclusions based on the earlier chapters, within the electricity sector, in the articulation of energy-sector policies with broader development strategies, and in relation to the international economic system.

Not integrating transformational energy access into universal access strategies risks locking LDCs into suboptimal development paths

B. Strengthening LDC electricity systems

1. System-wide energy planning and policy coordination

Transformational energy access requires the development of an electricity provision system that meets the needs of expanding productive sectors. This means ensuring, in addition to increasing physical access, an adequate, affordable and reliable supply of electricity in a context of accelerating energy demand to power the process of structural transformation.

The scale of this challenge is enormous in most LDCs. It is also immensely complex, requiring careful consideration of the particular circumstances of each locality, and weighing them against multiple rapidly evolving technological options and a changing business landscape. Some of the decisions required, notably regarding technology choices and business models, may arguably be decentralized to economic actors, such as independent power producers or household themselves; but some degree of central planning is needed to anticipate and address the system-wide implications of their investment choices and to fully exploit the potential synergies and complementarities across different technologies in integrating each country’s power generation mix. The multifaceted challenges of strengthening LDC energy systems thus call for a combination of system-wide long-term planning and flexibility.

The effectiveness of system-wide energy planning hinges on policy consistency, realism and a sound information base. Grid extension inevitably leads to increased electricity demand. If generation capacity fails to keep pace with this increase, this will be reflected in reduced reliability of supply, impairing the developmental benefits of grid extension, and leaving producers and households to resort to higher-cost (and possibly more polluting) options. Thus, consistency

Strengthening LDC energy systems requires a combination of long-term system-wide planning and flexibility

between the pace of grid extension and the rate of increase in generation capacity is vital. The planned pace of increase in access and electricity production also needs to be realistic, taking into account not only the availability of finance and construction times, but also logistical and human-resource constraints, as well as likely delays in decision-making, access to finance and project implementation.

The foundations of any planning process lie in a sound information base. In this respect, the generalized lack of systematic, reliable and comparable statistics on LDC energy issues calls for a major strengthening of the relevant statistical capabilities, including through international initiatives to “mobilize the data revolution”. The need for improved statistics is all the more pertinent in the context of increasing energy access (and redefining it along the lines proposed by the Sustainable Energy for All (SE4All) initiative, notably because related data requirements touch on a range of dimensions, from the site-specific resource potential to geospatial data, and from market prospects to demographic variables.

In this context, strengthening existing international initiatives to map energy-resource potential in LDCs (for instance, the Global Atlas for Renewable Energy of the International Renewable Energy Agency (IRENA), or the Renewable Energy Resource Mapping Initiative of the Energy Sector Management Assistance Program (ESMAP), as discussed in chapter 3) could go a long way towards enabling a sound evidence-based planning process, as well as helping to enable viable investment in renewables. Moreover, since much of the underlying data will also be needed for planning processes in other sectors (e.g. water, sanitation, health, education and transport), there are likely to be substantial economies of scale in developing a national intersectoral process for data collection, to coordinate information needs from geographical information systems, household and enterprise surveys, etc.

While predictability and transparency in the broad directions of long-term planning are needed from an investor perspective, the planning process must also have the flexibility to respond to changing circumstances, as the electricity sector continues to be subject to rapid technological changes, especially in the area of renewable technologies. Some degree of flexibility is hence needed to adjust to the evolving feasibility and relative costs of alternative technologies, which may be affected in the coming years by shifting incentives associated with efforts to promote universal access, and by changes in the climate and energy finance landscape.

The domestic context for grid extension and rural electrification is also subject to a particularly high level of uncertainty. Concerted efforts to achieve the Sustainable Development Goals (SDGs) can be expected to bring major changes in demand patterns for electricity, both by increasing domestic demand and through the establishment of new community facilities, such as schools and clinics. Electricity needs will further be affected by the consequences of energy-related policies, which may not be readily anticipated. This gives rise to a significant degree of endogeneity, in that policies need to respond to changes in demand which themselves arise in part from policies themselves. For example, policies to promote productive use will affect demand, while progress towards rural electrification may affect the rate of urbanization and rural settlement patterns. Changes in institutions, market structures, regulation, pricing systems and subsidies could also have important effects that may not be fully anticipated.

In light of the above, it is important to review long-term energy planning frameworks on a regular basis, to monitor progress, with a view to improving and coordinating implementation, and to reassess the appropriateness of the plan to the changing context.

The application of gender mainstreaming tools in national and local energy utility plans should be bolstered, as should building capacities for incorporating gendered approaches into energy programmes and projects at all levels of governance (ENERGIA, 2017). Greater integration of gender considerations into energy planning can also play a key role in harnessing the potential synergies between transformational energy access and enhancing women’s economic participation and structural transformation (chapter 2). Examples of initiatives to promote gender mainstreaming include the Programme on Gender Mainstreaming in Energy Access (ECOW-GEN) of the Economic Community of Western African States (ECOWAS) and the integration of gender equity and social inclusion objectives, indicators and targets into Nepal’s National Rural Renewable Energy Programme (ECREEE and NREL, 2015; ADB et al., 2015). However, effective design of gender-sensitive energy policies requires improving the availability of gender-disaggregated data on energy access and uses.

Despite the growing recognition of the importance of system-wide energy planning, especially in the context of greater penetration of renewable energy systems, this remains inadequately reflected in development assistance allocations. In addition to greater financial support for energy planning, LDCs and other developing countries (ODCs) could also benefit from the development of planning tools appropriate for their national contexts.

2. Scaling up supply and strategically diversifying the generation mix

The development of the electricity sector does not start with a blank slate, but builds on the existing (albeit inadequate) energy system. In light of the considerable increase in generation capacity that will be needed to achieve transformational energy access in LDCs, it would make little sense to decommission existing capacity or forgo related investment plans where these remain viable, irrespective of the technology used. It may, however, be desirable to improve or upgrade existing capacity to increase its efficiency and reduce greenhouse gas (GHG) emissions intensity (IPCC, 2014).

An evolutionary approach to the power sector is thus warranted, whereby planned capacity additions are integrated into existing assets, progressively expanding and upgrading supply while simultaneously affecting the power generation mix. As discussed in chapter 5, investments in electricity infrastructure have very long life cycles, which makes an appropriate and forward-looking choice of technologies for new capacity critical. From a system-wide perspective, the overarching objective is thus to strategically steer the portfolio of technologies, to attain a generation mix suited to the country's resources and future needs.

A simple comparison of levelized cost of electricity (LCOE) (chapter 3), while providing useful information on the relative costs across different technologies, is not appropriate — on its own — to identify the optimal role each technology can play in a country's power generation mix. Besides the benefits of diversification for risk-spreading and energy security purposes, different technologies can provide a distinct system value reflecting, inter alia, the scope, flexibility and time profile of their generation as well as its relative cost.[1] Moreover, the sensitivity of the LCOE estimates to assumptions related to future prices, financing conditions and environmental externalities deserves careful scrutiny from a policymaking standpoint, because of the specificities of the LDC context (chapter 3). An additional consideration may be the balance between capital and recurrent costs: to the extent that capital costs are funded by official development assistance (ODA) grants or other (non-debt-creating) official flows, these are not borne by the country itself, so that the main consideration is relative recurrent costs of alternative technologies. This is likely to shift the balance of advantage decisively towards renewable technologies, where recurrent costs are a much smaller part of the total. However, while the availability of external financing is thus relevant to technology choices, it is important that such choices be driven by local circumstances, and not simply by the availability of financing.

LDCs need to diversify their generation mixes, selecting technologies according to local conditions…

Since LCOE computations focus on private cost elements, they neglect environmental and social impacts of distinct technological choices. From a societal point of view, these impacts are a critical aspect of integrated energy planning. Gradually internalizing environmental externalities, stemming from both local pollutants (notably particulates) and GHG emissions, is desirable in the long term. However, this should not preclude developmental opportunities linked to the use of fossil-fuel technologies, where these are otherwise the best option. In such cases, the international community should ideally provide the finance, technology transfer and technical support needed for pursuing further decarbonization of LDC power sectors. Similarly, environmental sustainability considerations call for an adequate assessment of the options for the safe disposal or recycling of generation apparatus containing potentially hazardous materials (notably solar panels), or — in the case of large-scale hydroelectricity projects — of their potential social and environmental impact on river-based ecosystems and related communities.

Particularly in the case of variable renewable technologies (wind and solar), adequate consideration should be paid to their intermittent nature and ensuing needs for complementary storage systems. While the costs of storage technologies have declined rapidly over the last few years and may make battery storage a feasible option in due course, this is not yet the case in all LDCs (at least not at mini-grid or utility scale). In the near term, continuity of supply may therefore entail the use of hybrid systems, combining variable renewables either with pumped hydro or with diesel or biofuel generation. Solar thermal energy may also become a viable option in the future, combining renewable generation with storage of thermal energy to allow greater flexibility in the time profile of supply; but this would depend on substantial cost reductions.

…and to combine grid extension and upgrading with appropriate deployment of off-grid solutions

On the other hand, the scalability of renewable energy sources (i.e. the potential to gradually increase electricity supply over time as demand rises) might facilitate their deployment by somewhat smoothing investment costs over time. Especially with reference to mini-grids, exploiting the modularity of solar photovoltaic (PV) and to a lesser extent wind generators could help facilitate a relatively fast initial deployment, while leaving room for gradual capacity increases as demand rises.

Overall, while the identification of the desired power generation mix is necessarily country-specific, and must reflect local endowments and resource potential, it is clear that the underlying evolution should ideally be oriented towards kick-starting structural transformation and should seek to maximize the development opportunities within the energy value chain. As discussed in chapter 3, this implies a continued and possibly increasing role for fossil fuel-based generation, especially in countries with significant fossil-fuel reserves and where sunk costs have already been incurred to expand fuel-based generation capacity. Nonetheless, increasing renewable generation could make a substantial contribution to transformational energy access as well as providing environmental co-benefits; and harnessing complementarities across technologies could widen options for grid-connected generation and foster more diversified, more reliable and less import-dependent electricity systems.

3. Extending and upgrading the grid

Achieving universal access to modern energy will require a combination of grid upgrading and extension in urban and peri-urban areas, with the deployment of mini-grids, and stand-alone solutions for dispersed rural populations (chapter 3). As productive use of energy often requires higher-power devices (typically consistent with grid or mini-grid connection), the realistic scope and rate of grid extension is a priority consideration from the perspective of integrated energy planning for structural transformation. This will be determined by a combination of logistical and economic considerations — particularly the relative costs of grid extension and mini-grids for rural communities — and the resources available for investment.

Beyond the potential scope of grid extension, priority areas for mini-grid and stand-alone home system deployment should be identified, taking account (among other factors) of community size, dispersion, energy demand and potential for productive use. Such assessments should also be informed by forward-looking consideration of the prospects for structural transformation and productive energy uses in each area, as greater energy demand tilts the optimal technology split towards mini-grids or, where possible, grid extension. Mini-grids may also play a role in peri-urban areas (and potentially in unserved urban areas, such as informal settlements) as a stepping stone to grid connection. Particularly where transmission capacity is a constraint, they can provide a means of establishing a local distribution network that can be connected to the wider grid later.

Sound planning, transparency and policy coordination are essential to this process, in order to ensure appropriate prioritization of investments, to avoid deterring potential investors and to allow mini-grids to be interconnected and/or integrated into an overall grid as appropriate at a later stage. Grid connection requires the adoption of technical standards compatible with the overall grid to ensure interoperability. Equally, investors in mini-grids need clarity about the likelihood and time frame for grid connection, and its financial implications for their investments.

As well as the extension of the distribution network, universal access will require a significant upgrading of the existing network in most LDCs, in order both to enable the flow of greater load and to tackle disproportionately high transmission and distribution losses, thereby enhancing energy efficiency. Moreover, the ongoing emergence of off-grid system and distributed generation is likely to affect the requirements for a supportive infrastructure, increasing the need for system flexibility and for effective management of bidirectional electricity flows. An upgraded grid, with adequate high voltage cables and interconnections, is also a precondition for more effectively integrating LDC energy systems at an international level, thereby allowing cross-border trade of electricity.

While the technical requirements of “smart grids” (and the need for interoperating end-use devices) mean that they are unlikely to be suitable for most LDC markets in the near future, the upgrading of distribution systems may still offer the opportunity to leapfrog to progressively more sophisticated grids within LDCs’ technological constraints. This underscores the need for a proactive policy framework that supports and facilitates technological upgrading, by:

- Leveraging the regulatory framework to promote the adoption of appropriate technological standards;
- Emphasizing capacity development, both for grid developers and operators and for end-users, whose behaviour can strengthen the energy system value;

- Harnessing the scope for both North-South and South-South cooperation and technology transfer, and favouring experimentation and diversification across energy sources;
- Preserving a system-wide approach to energy planning.

4. Closer integration of regional energy markets

Cross-border trade in electricity can be conducive to achieving universal access and upgrading the power sector, with positive effects on development strategies more broadly. For some LDCs, particularly those with substantial hydroelectricity potential and large and relatively prosperous neighbours, electricity may offer significant potential for boosting export revenues. In some instances, however, this may give rise to trade-offs, where electricity exports are an important source of hard currency and macroeconomic stability but also contribute to domestic shortages that constrain demand and economic activity, or cannot be readily diverted for domestic supply.

For other LDCs, importing electricity may be a viable and lower-cost alternative to increasing domestic generation, depending on resource potentials and relative comparative advantages. However, any potential savings need to be weighed against the implications for energy security and dependence on supplying countries (and on the cross-border transmission infrastructure).

In particular circumstances, cross-border trade may also offer a means of energy storage. By exporting electricity at times of peak production and importing it at times of peak demand, a country can effectively import pumped hydro storage services. This can allow greater reliance on variable renewable technologies than would otherwise be possible without sacrificing continuity and reliability of supply.

In all these contexts, regional power pools can play a substantial role, offering stable and durable frameworks for commercial energy exchanges. They facilitate joint systems planning and organization, and the equitable sharing of the cost of interconnecting transmission networks. Most importantly, they leverage differences in the mix of the generation capacities and sources of their members. In so doing they enable countries to achieve significant reductions in emissions by substituting electricity generated using renewable technologies in neighbouring countries. They also enable pool members to leverage the complementarity between their different generation technologies to mitigate the variability of renewable sources of energy.

Cross-border trade and cooperation in electricity can support universal access and power-sector upgrading

The possibility of crafting flexible purchasing agreements and leveraging solidarity amongst pool members can contribute significantly to energy security. For example, in line with the statutes of the Southern African Power Pool, South Africa was able to supply Zambia and Zimbabwe with emergency power in 2016, with voluntary and complementary action also taken by Swaziland and Lesotho to reduce consumption.

Regional power pools often comprise a mix of countries that are at different levels of development but face common challenges. In such circumstances, they can be a significant source of technical cooperation and technology transfer, given the potential benefits of joining forces in complex research and development (R&D) projects with positive but uncertain spillovers for pool members. Similarly, given their requirements for interoperability, policy harmonization, and maintenance of appropriate technical hardware and software, they offer substantial possibilities for skills pooling and exchange, and capacity-building at the planning, technical and regulatory levels.

Membership of regional power pools can thus offer the possibility of pursuing reliable and efficient access to energy while simultaneously obtaining a greater share of energy trade, and technical cooperation. However, the pursuit of these goals needs to be underpinned by measures to ensure adequate, efficient and affordable access to energy by all population segments to foster the growth and diversification of high-productivity economic activities.

Regional electricity trade often takes place among countries with varied generation capacities. Power pools need to be structured carefully to avoid the abuse of market power. In this context, the existence of regulatory institutions with regional scope, as in the European Union, constitutes a distinct advantage.

C. Electricity system governance and finance

1. Building effective governance frameworks for the electricity sector

Governance frameworks are critical to ensuring efficient electricity systems. Government's ability to visualize the electricity system a country wants and

Key goals of electricity governance include robust regulatory systems, diversification of energy sources, affordability and financial sustainability

needs, and to articulate and lead the implementation of that vision, is an indispensable factor that underpins all other processes and facilitates the setting of related benchmarks and system development targets. In this context, and as part of their governance frameworks, LDCs should buttress measures to accelerate universal access with clear benchmarks on the levels of access and quality of services required to meet transformational energy access goals.

While there is a discernible divide between developed and less developed electricity systems, there is no one-size-fits-all model for market structure. The design and governance of electricity systems is highly dependent on country-specific factors, technological innovation and disruptions, and the evolution of economic theory; and countries face different challenges in the evolution of their electricity systems when they seek to change their generation mix and market structure.

Electricity systems evolve, and market structures reflect this evolution. In developed economies, characterized by high generation capacity and falling demand, liberalized energy systems have emerged as the dominant (although not universal) model. In most LDCs and ODCs, however, electricity systems are neither served by a monopoly provider nor fully liberalized, but are situated between these extremes; and their domestic markets are characterized by insufficient generation capacity and rising demand. Virtually all developing countries have sought to allow private-sector participation either through concessions or power purchasing contracts, or through liberalization of the generation segment of electricity supply.

In seeking to transform their electricity sectors to take advantage of current technological innovations and sustainability requirements, it is important that LDCs avoid market structures that are overly demanding in terms of administrative and regulatory capacity. However, this does not rule out an eventual transition to fully liberalized systems. Gradual transition is a common feature of most successful cases of liberalization. Failure to take into account institutional, financial and human-resource capacity constraints could lead to negative outcomes and substantial economic costs in LDCs, given the complexity implied by liberalized systems both nationally and for regional power-pool arrangements.

It is also important that Governments maintain a clear vision of the roles of the public and private sectors in the electricity system, based on their national contexts, and put in place the institutions, supports or safeguards needed to achieve national developmental goals. Governance frameworks also play a central role in building regulatory trust and thus influence investments within and into national electricity sectors. Experience shows that electricity systems need to be steered, and that improvements in industry performance and consumption habits (energy efficiency) are incentivized by policy and regulation.

The focus of electricity sector governance is now primarily on what electricity systems should deliver, and on how to achieve energy security, rather than on ownership and structure. While energy-security issues vary widely across national contexts, the primary goal of adequate supply with maximum reliability and quality is universal. LDC governance frameworks for transformational energy access should therefore ensure:

- Sufficiently robust regulatory and governance systems, including clarity on regulatory processes;
- Universal access at the lowest long-term generation cost;
- A diverse and flexible mix of electricity sources and technologies underpinning electricity supply;
- Reasonable affordability for users in all segments of society, and the competitiveness of economic actors;
- Financial sustainability of operators;
- Appropriate conditions to leverage public and private finance to ramp up generation capacity and investments in network infrastructure.

Also important is a systemic and coordinated approach to electricity system development that takes into account multiple national development goals, a gendered perspective, energy efficiency goals, and complementary policies and investments in other sectors to sustain energy security.

While LDCs have made significant strides in all areas of their governance frameworks, policy and regulatory gaps or inconsistencies are evident with respect to many aspects of national electricity frameworks (chapter 4). The approach to the development of national electricity frameworks appears in some cases to be ad hoc, or in response to donor initiatives, rather than systemic. Rural electrification and efforts to meet climate change-related commitments may be particularly vulnerable to less coherent approaches to electricity systems development. Lack of coherence in electricity governance frameworks can weaken LDCs' ability to manage the trade-offs inherent in developing-country contexts effectively and pragmatically.

Trade-offs can arise in a variety of contexts in LDCs, and choices are often not clearcut, particularly in rural electrification. The concerted push to reach universal access in the context of renewables by the year 2030 embodies an opportunity for LDCs to further leverage the private sector in the provision of sustainable sources of electricity and innovative business models to serve diverse rural and urban settings. LDCs should thus continue their efforts to increase supply capacity in collaboration with the private sector. However, in rural areas characterized by dispersed populations or hostile terrain, trade-offs often exist between the achievement of economies of scale and scope in the provision of a differentiated service that supports transformational energy access on the one hand, and providing only for basic needs as the most profitable option on the other. Similarly, there may be tensions between the roll-out of stand-alone solutions and grid extension in areas where the latter could be a viable longer-term option.

In all these contexts, policymaking, planning, coordination and regulation within the energy sector all assume a primary focus. This further underlines the need for a system-wide approach to electricity system design and transition. The variety of delivery options and potential increase in the number of sector participants implied by distributed systems reinforces the need for enhanced regulatory oversight. For instance, it is essential that the quality and reliability of electricity installations is safeguarded not only for the benefit of electricity users, but also for the reliability of the grid. In this regard, the sector regulator will need to put in place the necessary rules to govern product, safety, and system interoperability. Similarly, the importance of affordability to achieving universal access in LDCs highlights the need to regulate and incentivize private providers to meet this goal. Since a reliable service is the result of cooperation and communication among all industry stakeholders, it will also be necessary to put in place effective mechanisms and rules governing the interaction of industry actors. This includes regulating to prevent the abuse of market power, which is a particular risk in the case of independent mini-grids that may have effective monopoly status in a particular locality. In electricity systems, liberalization is not a substitute for regulation.

Equally, there is no one-size-fits-all model for transition to low-carbon electricity systems. All countries encourage renewable energy generation to varying degrees, including LDCs. Accordingly, based on the national context, countries may seek to fit renewables to the grid or fit the grid to renewables (Matek and Gawell, 2015). A diverse mix of renewable energy sources is equally important for managing volatility and ensuring grid stability and security. In order to be effective, governance frameworks must clarify policy direction to guide investments and attract and develop the right market actors.

The challenges inherent in incorporating larger shares of renewables into electricity systems reinforce the need for a managed and regulated transition. Accordingly, LDCs should plan and implement the necessary investments in human and institutional capacity to enable effective governance. Donors should also give more priority to supporting electricity regulation, which is currently not funded by ODA, in their development assistance.

2. Balancing affordability and cost-reflectiveness

Financial sustainability through cost-reflective tariffs is a critical factor in electricity systems, underpinning service quality, innovation and adequate investments in infrastructure, maintenance and upgrading. It also has a bearing on whether, and how rapidly, electricity systems grow. LDC Governments have traditionally succumbed to popular pressure to maintain uniform national below-cost electricity tariffs, but often at the expense of fiscal distress, compounding chronic underinvestment by public utilities and poor quality of power supply. Under these conditions, vicious circles of low access, small customer bases and customer shedding due to poor quality service exacerbated financial deterioration and became entrenched.

Momentum is growing for transitioning to cost-reflective tariffs, driven largely by fiscal distress, universal access commitments in the context of the global development agenda and associated incentives for private-sector participation.

The right tariff structure determines the efficiency and effectiveness of the utility's cost recovery effort. In addition to increasing tariffs, modifying tariff design can offer a route to matching the structure of the tariff to the structure of electricity supply costs. This is important because the bulk of electricity infrastructure investment is directed at meeting peak demand. Tariff structures vary in regulatory complexity in terms of design and implementation. While they have evolved in line with successive tariff theories ever since electricity was discovered, distributed generation has exposed failings in existing rate designs in unbundled and liberalized electricity systems. The roll-out of new technologies, such as smart and pay-as-you-go meters, has in turn facilitated the implementation of such new tariff structures as time-of-use tariffs, which address demand-side management goals and possible inequities in cost allocation that might arise between low-demand and high-demand customers under traditional tariff structures.

LDCs should consider moving towards cost-reflective tariffs, cushioning distributive impacts with social policies and job creation

LDCs should study, and where possible exploit, the opportunity presented by technological changes to boost the financial sustainability of their utilities. However, some tariff structures may imply a level of regulatory sophistication that is beyond the reach of some of these countries. In addition, the deployment of digitized technologies like smart meters is reliant on LDCs making the necessary complementary investments in information and communication technologies (ICTs); new or upgraded grid infrastructure; and relevant human-resource capacities. LDCs should also be aware that digitized technologies heighten security risks. Unlike developed countries, LDCs have not invested as much in ICT or digital security, and both the public and private sectors are likely to lack sufficiently skilled data managers.

LDCs can also tackle the issue of financial sustainability by accelerating the number of electricity customers connected to the grid. A significant proportion of urban and peri-urban populations in these countries are close to a grid but remain unconnected, often because of connection charges. Easing the conditions for connection is a priority for growing the customer base and stimulating demand, particularly as demand may be limited until customers acquire electrical appliances.

A change in tariff structure may also contribute to the reduction of subsidies and the incidence of cross-subsidization. Very large, explicit and hidden subsidies for energy, including electricity, are a prevalent feature in both developed and developing countries. In LDCs, such subsidies can have a crippling effect on public budgets. The entry of the private sector into LDC energy sectors can sometimes result in tariff and subsidy increases (section G2). Subsidies can increase because Governments with weak negotiating capacity enter into disadvantageous power purchasing agreements with independent power producers or high capital costs for investment (chapter 4). While initial tariff increases may be necessary to attain cost recovery levels, later tariff increases may rather reflect the private sector's fundamental need to seek profits.

As with general electricity system transition, tariff transitions benefit from strategic foresight. Experience shows that the gradual phasing-in of tariff increases contributes to their acceptability by end-users. The chances of sustaining such increases are also significantly improved when implemented under favourable economic conditions. For instance, a number of developing countries took the opportunity to scale back on energy subsidies during the period of sustained low international oil prices (IMF, 2013). That said, tariff hikes and changes are generally underpinned by strong political will. A commitment to transparency and effective communication campaigns to engage end-users to explain the reasons, nature and impacts of the programmed changes is an additional success factor. In LDC contexts, the need to make adequate provision for safety nets and lifeline tariffs is a critical consideration that should help maintain and extend gains in universal access, while also supporting the financial viability of infrastructure investments.

However, social policies to cushion the impact of a move to cost-reflective tariffs may not be sustainable unless underpinned by concerted measures to facilitate structural transformation and meaningful job creation. LDCs should thus aim to strengthen their capabilities to implement renewables auctions, as these have proved to be a lower-cost option that delivers cheaper services which are less burdensome for public budgets. Auctions may prove to be a pragmatic approach, given the need to structure feed-in tariffs to a specific generation technology and a specific locality's cost structure. In the rural context, end-users can often face differentiated tariffs by locality and technologies, which can raise equity issues and present challenges in terms of the type of productive activities that can be fostered in a given location. Unforeseen impacts on internal migration and social discontent might therefore arise. The international development community should also prioritize the development of LDC capacity in the area of renewables auctions for development assistance.

The sustainability of electricity provision and access could be in doubt in LDCs where it relies on feed-in tariffs largely financed by donor funding. Sustainability could also be jeopardized by reliance on microcredit to facilitate private-sector provision, especially with respect to rural electrification. Over-indebtedness is increasingly a concern among microcredit clients in developing countries. It also affects the viability of microcredit institutions (Schicks and Rosenberg, 2011). For these reasons, excessive reliance on microcredit should be avoided and LDCs should maintain their vigilance over the sector.

3. Greater mobilization of domestic sources of finance

LDCs need increasingly to seek cheap sources of development finance. Developments on international markets are raising concerns about the availability of long-term finance in the form of ODA and private finance (section G2). The advantages of domestic credit markets include lower exposure to currency risk; lower vulnerability to capital flow reversals; the possibility of using countercyclical monetary policy to mitigate external shocks; the strengthening of local financial markets development; contributing to a lessening of aid dependence; and increasing the availability of long-term finance for network investments, which typically attract less private-sector interest. Expanding and deepening domestic financial markets should also have positive effects on the growth of local industry, including in the electricity sector.

There is thus a strong case for prioritizing public funding and the development of domestic capital markets to drive needed investment in national electricity sectors. LDC Governments need to assume policy leadership in the development and diversification of domestic debt instruments that will be attractive to various domestic and external institutional investors. Efforts should focus on increasing the availability of de-risking instruments, including insurance and guarantee products to protect investors, although limited institutional and human capacities are an important constraint. LDCs that have significant diasporas with the necessary financial means should also seek to attract diaspora direct investment.

The development community, including impact and infrastructure fund investors, may wish to consider giving enhanced priority to LDC efforts to nurture domestic debt markets. While the number of international and regional initiatives to stimulate domestic debt instruments and capital markets is on the increase, LDCs may require special attention and complementary assistance.

The energy-transformation nexus is critical to policy frameworks for structural transformation

D. Harnessing the energy-transformation nexus

1. Integration of energy policies and structural transformation strategies

The central role of the energy-transformation nexus in sustainable development highlights the importance of integrating electrification and access to modern energy fully into development strategies. A development process based on sustainable and inclusive structural transformation implies an increased supply of modern energy to producers in agriculture, industry and services as well as to the residential sector and community facilities. In turn, the resulting demand growth can make investments in energy production and distribution systems more viable, helping to reap the benefits of scale economies and higher overall efficiency. Equally, however, if this demand remains unsatisfied then the process of structural transformation may itself be slowed down or disrupted.

Increasing access to modern energy can only be fully effective in promoting structural transformation within an overall development strategy oriented towards this objective. Broad policy recommendations to foster

Box 6.1. **Development strategies for structural transformation**

Previous editions of the Least Developed Countries Report have identified the following key policy priorities to foster structural transformation in LDCs:

- Pursuing a development-oriented macroeconomic policy, preserving macroeconomic stability while fostering investment and employment creation;
- Harnessing public investment to relieve key bottlenecks for productive sectors (especially in labour-intensive infrastructure projects), so as to crowd in private investment;
- Enhancing the mobilization of resources (public revenues, foreign direct investment (FDI), ODA and new sources of development finance) and their strategic allocation towards key sectors/activities;
- Pursuing proactive agricultural and industrial policies to strengthen backward and forward linkages (especially in relation to FDI) and spur the emergence of more sophisticated, higher value added activities;
- Promoting financial inclusion, broadening access to credit for SMEs and smallholder farmers, and supporting the emergence of effective financial systems;
- Building capabilities in science, technology and innovation (STI), particularly for the absorption, adaptation and application of new technologies;
- Preserving existing policy space and exploiting it strategically to foster structural transformation.

Source: UNCTAD (2006, 2014, 2015a, 2016b).

structural transformation, drawn from previous editions of the Least Developed Countries Report, are outlined in box 6.1; the main text focuses instead on articulating the links between those recommendations and energy policies.

Many of the policies outlined in box 6.1 are intimately linked with energy access and supply. As discussed in chapter 2, poor and unreliable access to modern energy triggers additional costs for firms, creating a competitiveness wedge that penalizes LDC producers vis-à-vis their competitors. In light of this, the natural-monopoly tendencies of the electricity sector (chapter 4) mean that electricity infrastructure is arguably a form of social overhead capital, which allows public investment to crowd in private investment by relieving bottlenecks in productive sectors.

Widening access to modern energy and improving the quality of modern energy provision enable the shifting of LDCs' comparative advantage towards progressively more sophisticated activities, creating new opportunities for dynamic "entrepreneurs by choice" (as opposed to survivalist "entrepreneurs by necessity"). The nature of these opportunities (and their location within the geographical pattern and time frame of widening access) needs to be factored into the design of rural development and industrial policies.

There are also a number of more indirect synergies between wider access to electricity and the broader needs of structural transformation. As noted in chapter 4, information on grid connections can help identify taxpayers and businesses for tax collection purposes, while the availability of electricity for productive use could reinforce the incentives for microenterprises to join the formal sector. Wider access to electricity can also help unlock the development potential of ICTs, which play a growing role in financial inclusion through "mobile money" systems like Kenya's M-PESA and in disseminating market information and knowledge of productive technologies.

The energy-transformation nexus highlights the critical importance of the feedback relationship between demand and supply, to policy frameworks for structural transformation. The economic viability of investments in electricity generation, transmission and distribution is highly dependent on an adequate level of demand. In this context, productive use is not merely additional to domestic use, but often complementary, as it helps smooth the time profile of electricity consumption: while the peak period for domestic use is the evening (for lighting and entertainment), productive use occurs primarily during the day. Accordingly, the expansion of productive uses of energy may also be conducive to supporting the penetration of variable renewable technologies, especially in the case of solar energy.

Demand for modern energy is affected not only by households' and producers' incomes, but also by the overall level of economic activity. In line with box 6.1, tackling supply-side constraints within a context of strong demand growth and investment dynamism is thus a key factor in successful development strategies. As for other infrastructure projects, the multiplier effects of energy investments in LDCs are expected to be particularly pronounced, at least during the initial phase, owing to the labour requirements for the construction of power plants (especially large hydroelectric dams), and transmission and distribution networks. Energy-related infrastructure could thus play a prominent role in a "big push" strategy for LDCs.

2. Leveraging technological options towards rural electrification and development

The structural transformation of rural economies is critical to development in LDCs, and its importance is further reinforced by the goal of poverty eradication and the principle of "leaving no one behind". In the average LDC, less than 11 per cent of people in rural areas have access to electricity, compared with 59 per cent in urban areas. Since populations in most LDCs are predominantly rural, this means that 82 per cent of those currently without access to electricity in LDCs live in rural areas (chapter 1).

Thus, in most LDCs, the potential impact of broadening electricity access is much greater in rural areas than in urban ones, where reliability of supply is likely to be of greater importance. The ongoing emergence of scalable renewable-energy technologies and mini-grids provides an unprecedented opportunity to realize this ambition, if the technical, economic and institutional constraints identified in chapters 3-5 can be overcome.

Fostering a coordinated process of agricultural upgrading and diversification into non-agricultural activities is key to rural structural transformation and to harnessing intersectoral linkages between farming and non-farming activities. Extending access to modern energy could thus relax an important supply-side constraint (mainly on non-farming activities), while the labour-intensive nature of the underlying infrastructure investments could sustain local demand. This is an early priority in a sequenced approach to rural economic transformation. However, complementary measures are also necessary, notably in agriculture, finance, and training and human-resource development (UNCTAD, 2015a).

It is important to acknowledge, though, that rural electrification will not necessarily lead to an immediate and rapid expansion of its use for productive purposes. As discussed in chapter 3, it is more likely to trigger a slow and disruptive process of creative destruction, whereby traditional activities are shaken up by the gradual introduction of electrical equipment into production processes. Leveraging electrification for LDC rural transformation is thus likely to require proactive support to facilitate this transition, supporting the adoption of previously unavailable technologies and production methods and fostering the establishment of new dynamic enterprises. This could be promoted, for instance, through in-kind microgrants of electrical equipment for use in economic activities for which there is local demand (UNCTAD, 2015a). Proactive support of rural firms and cooperatives embarking on the processing of agricultural crops could, for example, enhance local value addition, while simultaneously creating that “anchor load” which generates substantial electricity demand, increasing the viability of mini-grids.

Given realistic time frames for achieving universal energy access in LDCs, it is also in rural areas that the issue of energy options prior to electrification is most pertinent, with a view to avoiding undue delays in rural economic transformation for the most remote communities. While electricity is the most versatile form of energy, most of the energy services it provides can also be furnished — albeit in some cases imperfectly — by alternative energy sources: mechanical power by wind or flowing water, lighting by kerosene, product and space heating by biomass, and even product cooling by evaporation fridges. Such intermediate-technology options (and others, such as improved stoves) can play an essential role in initiating structural transformation prior to electrification, increasing agricultural productivity and facilitating the development of non-farm enterprises. These technologies offer major opportunities for local production, as they are not particularly sophisticated, and often need to be tailored to context-specific needs and preferences.

Many such interim energy solutions have the additional advantage of possessing greater potential for local production and uptake than relatively more sophisticated generation equipment, and they also provide the scope for below-the-radar innovation. Fostering the emergence of a viable supply chain for the production of such equipment, including by providing access to the technologies involved (many of which are not subject to intellectual property protection), training in their production and adaptation to local needs, and facilitating access to the necessary inputs and finance, can thus be an important component of a wider strategy for pre-electrification rural transformation.

Pre-electrification technologies can help to initiate rural structural transformation ahead of rural electrification

3. Complementary policies for structural transformation and productive energy use

Electricity access stimulates structural transformation in part through a process of creative destruction. Those enterprises better able to access electricity and to exploit its potential through complementary investment in electrical equipment may gain considerably, but partly at the expense of those less able to do so. Equally, greater penetration of fuel-efficient stoves and increased access to modern fuels may result in a reduction of employment and economic opportunities in the production and supply of woodfuel for the charcoal supply chain, which is often an important source of income, particularly in peri-urban areas.

Unattended, these effects will at least partly undermine structural transformation and poverty-eradication efforts, by increasing underemployment and reducing the incomes of those so displaced. Reaping the full benefits of the energy-transformation nexus thus requires complementary policies to foster economic diversification and promote alternative employment.

A first key policy priority in this respect is fostering the emergence of a domestic supply chain in modern energy and fuel-efficiency business. The precise strategies to attain such an objective are contingent on each country’s power generation mix, and other structural features. In general, though, the overarching objective should be to enhance intersectoral linkages and create the conditions for scaling up modern energy provision without exacerbating import dependence (for instance by establishing adequate refining capacities in fuel-producing LDCs, or promoting the sustainable production of bioenergy from local agricultural inputs).

Similarly, the processing and distribution of modern fuels for cooking (e.g. gas canisters) can provide major opportunities in this area. LDCs may also be able to benefit, to varying degrees, from increased employment in electricity production and supply, notably renewable-energy technologies. While few of them are likely to be able to compete with established suppliers in the manufacture of sophisticated equipment, such as solar panels or wind turbines, there is potential for job creation in certain segments of the renewable-

Policies for transformational energy access include building modern-energy supply chains and fostering linkages with other sectors

energy sector value chain (e.g. installation, operation and maintenance of solar equipment and pico-solar devices) and in locally appropriate applications (IRENA, 2012).

The promotion of backward linkages calls for targeted efforts to tackle the main bottlenecks to the emergence of a viable domestic supply chain, strengthening policy coordination across all actors involved, and promoting the development of viable business models. Relevant energy-related activities thus represent important targets in such areas as industrial policy, enterprise development, access to finance, training and vocational education, and STI policy.

A second policy priority lies in promoting forward linkages between modern energy provision and downstream activities, capitalizing on electrification to enhance productivity in existing businesses and above all to spur the emergence of new higher value added activities. Vocational training and skills upgrading programmes — in financial literacy and general business skills, and in the use of electrical equipment — can play a major role in facilitating the process of labour reallocation associated with structural transformation. Broadening access to credit and financial services is also a crucial priority to enable technological upgrading and adoption of (mainly electrical) productive equipment, especially on the part of SMEs. Importantly, however, the ability of firms to reap the benefits of electrification is inevitably contingent on the provision of a broader range of social overhead capital and each sector's specific conditions and dynamics. This underscores the importance of close coordination between energy policies and other macroeconomic and sectoral policies for structural transformation.

While the objective of universal access to modern energy is often assumed to be gender-neutral, its welfare impacts are inevitably mediated by the socioeconomic context and cultural norms. As highlighted in chapter 1, though, the discussion on these issues is often simplistic and overgeneralized. If men are better able than women to harness the potential economic benefits of access to electricity, increasing access to electricity could even exacerbate gender inequality in some contexts. Sound and context-specific research is thus needed to shed more light on intra-household and broader socioeconomic factors that hamper women's access to (and productive use of) modern energy, thereby supporting evidence-based policymaking.

An important aspect of the benefits of access to modern energy is the prospect of reducing the time spent by women in collecting fuelwood and in other domestic tasks. However, translating this into an improvement in women's economic empowerment depends critically on the creation of income-earning opportunities for them. Proactive interventions to address the constraints they face in accessing income, inputs, technology, credit and markets can both contribute to their empowerment and simultaneously enhance the overall viability of the energy system, by raising the prospects for energy demand and productive use.

Access to modern energy can greatly reduce the time required for some economic activities in which women traditionally play a substantial role in many cultures, potentially allowing them to benefit considerably. Food processing is particularly important in this regard, not only because of its potential scale, but also because of its key role in rural structural transformation, as a critical part of the non-farm economy and a facilitator of agricultural development (UNCTAD, 2015a). Some energy-related activities may also be highly conducive to women's entrepreneurship and employment, especially in the conception and design of end-use equipment, such as cook stoves and other electrical appliances (Puzzola et al., 2013). This may also provide an entry point into a much wider range of other (often male-dominated) small- and medium-scale manufacturing activities.

4. Science, technology and innovation policies for transformational energy access

The successful scaling-up of modern energy provision in LDCs hinges on a successful process of technology transfer, whereby these countries strengthen their national capacities to acquire modern energy technologies, adapt them to local contexts, and integrate them effectively into national energy systems. Technological capability acquisition is all the more critical in the context of the ongoing penetration of renewable-energy technologies, which have witnessed rapid technological advances and whose performance is often determined by site-specific conditions.

This process will require a wide range of skills with varying degrees of specialization, ranging from the installation and maintenance of modern energy equipment to more complex sets of skills for system regulation, or standard-setting and testing. Boosting investments in education and training programmes

— particularly in science, technology, engineering and mathematics — is hence of primary importance both to support modern energy access and to fully exploit the development potential of the energy value chain itself.

As the experience of India's Barefoot College in several LDCs demonstrates (chapter 3), formal education is not necessarily a precondition for all skilled occupations, even in high-technology sectors. Vocational training and apprenticeship schemes can also serve an important role, as may other, less conventional, approaches promoting circular rural-urban-rural migration to enhance urban-rural skills transfer (UNCTAD, 2015a).

More broadly, the fundamental importance of technological upgrading to the energy-transformation nexus calls for proactive STI policies aimed at strengthening the local innovation systems, by improving both domestic absorptive capacities and innovation capabilities to engage in R&D activities. The latter can be expected to play a prominent role not only in the pursuit of radical innovation, but also to engineer incremental technical improvements in existing devices, facilitating their adaptation and use in productive sectors. This also warrants proactive efforts to support the emergence of sustainable business models in the energy sector, to enable the deployment of modern energy technologies in ways consistent with the goal of leaving no one behind.

An STI policy framework paying adequate attention to modern energy technologies, especially renewable-based ones, can thus help LDCs to harness their transformative potential (UNCTAD, 2011a).

Such a framework should perform the following functions:

- Define STI policy strategies, goals and targets;
- Enact policy incentives for strengthening technology-absorptive capacity and related R&D activities;
- Promote domestic resource mobilization for modern energy technology adaptation/adoption, including through closer collaboration among research institutions, utilities and relevant private actors;
- Explore alternative ways to improve innovation capacity in modern energy technology, including through South-South collaboration and shared regional research and testing facilities.

A promising area that might be covered by STI policy frameworks is the establishment of research institutions oriented towards the development, adaptation and dissemination of pre-electrification intermediate technologies for mechanical energy. Close consultation with prospective users of such technologies would be a crucial aspect, as their adoption and use is critically dependent on their ability to meet locally and culturally specific needs and preferences. The scope for greater involvement by women in the conception and design of efficient stoves and other end-use appliances deserves specific attention here.

The participation of foreign direct investors in the energy sector must not crowd out domestic actors

E. International dimensions

1. Enhancing the impact of foreign direct investment

Private-sector participation has played a pivotal role in the rapid increase in generation capacity recorded by LDCs since 2006. However, LDCs continue to be less attractive to private-sector investment than ODCs because of their particular logistical challenges with electrification. Depending on the various national contexts in LDCs, private-sector participation in their electricity sectors has expanded from the commercial management of national utilities and the operation of concessions by transnational corporations to the ownership of distributed electricity systems in rural settings (such as mini-grids) and the provision of various stand-alone electricity products and solutions. LDCs stand to benefit from the advent of distributed generation technologies, whose modular application is particularly relevant to accelerating universal access in diverse contexts. However, the potential of distributed modes of electricity using renewable energy is constrained by high upfront capital costs. Beyond basic needs services and stand-alone systems and products, renewable energy tends to rely on public funding to sustain profitability.

The crowding-out of domestic companies continues to be a significant concern in LDCs. There is typically a dearth of companies with advanced technologies in legacy or renewable generation in developing countries. Foreign transnational corporations, including utility companies, have traditionally been the most active in developing-country electricity sectors (UNCTAD, 2008, 2010); and the combination of low demand in their home markets with rising demand in LDCs suggests this trend will persist. The situation is no different for distributed generation, including in the rural setting. Moreover, foreign utilities have the added advantage of an established track record in the electricity business when it comes to raising capital in international financial markets. Utility companies based in ODCs are also beginning to play a role in LDC electricity sectors. Chinese investors, for example, are active in greenfield

Sovereign borrowing to finance energy infrastructure investments may be constrained by debt sustainability

investments, and Chinese firms have become the most significant players in electricity-sector construction contracts, the value of which dwarfs that of their investments in the sector.

LDC Governments are looking to tap new growth options from green growth, and to leverage low-carbon FDI to grow local private-sector providers. In order to do so, however, they require the necessary policy space. In the renewables sector many countries use local content rules as a policy measure for green industrial development. While some countries have successfully linked local content rules to their renewables auctions, as noted in chapter 5, LDCs have a limited capacity to put in place fiscal and regulatory measures. They can, however, ensure that fiscal and regulatory support measures in the electricity sector afford the same support to domestic as to foreign providers in the local market. LDC Governments and firms should also seek to make use of existing preferential measures (for example, flexibilities under the World Trade Organization (WTO) Agreement on Trade-related Investment Measures (TRIMs) or the WTO Agreement on Subsidies and Countervailing Measures) to support their legitimate industrial policy goals. However, effective use of such measures also depends on institutional capacities, financial resources and productive capacities (UNCTAD, 2016a). Similarly, the various energy infrastructure initiatives and funds that have been initiated by a variety of global actors can ensure that funding equally targets the development of local industries.

2. Leveraging debt without compromising sustainability

As discussed in chapter 5, investors perceive the attendant risks of investing in LDC electricity sectors as very high. This has the detrimental effect of raising the costs of capital because perceived high risks are reflected in high interest-rate premiums and the need for government-backed credit guarantees for borrowing in international markets. As a consequence, costs remain unsustainably high for both centralized and distributed systems. Even renewable technologies, whose costs have fallen dramatically and continue to fall, can in many instances remain a high-cost proposition for LDCs. The risk associated with these technologies is generally higher because they are relatively new, and renewables projects have not yet established a track record in LDC contexts. There is correspondingly insufficient availability of risk management resources, including risk expertise, industry data and insurance cover.

High credit costs translate into high end-user tariffs and, crucially, low competitiveness in international trade for LDCs. To lower capital costs they should intensify their efforts to reduce risk factors that fall within their scope of direct action, including sovereign, political and regulatory risk factors.

The perceived high risk associated with LDCs is compounded by current and emerging developments in global financial markets. These developments include stringent liquidity requirements in the financial sector associated with Basel III implementation, which mandate banks to hold a buffer of liquid assets and skew incentives away from higher-risk investments (Bertholon-Lampiris, 2015; BIS, 2016; UNCTAD, 2015c). Infrastructure is considered to be an illiquid asset. Basel III is thus likely to significantly constrain the availability of commercial long-term finance, and loans in particular. Private-sector participation in infrastructure projects in developing countries is often linked to commercial capital in the form of syndicated loans, which constitute the main alternative to bilateral and multilateral loans for such projects. Under Basel III, these loans are likely to be more costly to administer and manage (LMA, 2015). In a climate where institutional investors continue to favour liquid over illiquid assets, a shortage of long-term finance is potentially on the horizon. At the very least, long-term finance could become a lot more costly than it is already. In this context, private interest in LDCs' infrastructure development, which is already lower than in other developing countries (UNCTAD, 2008), may dwindle.

The high cost of private finance raises the economic value of public finance. There is a strong case for the development finance community, including donors and multilateral finance institutions, to prioritize traditional public development finance channels for electricity, and the infrastructure sector generally. The current trend in development finance is to prioritize the use of public resources to leverage private-sector financing. In view of the projected shortages in long-term finance in the financial sector globally, this may not be a least-cost strategy for developmental finance.

The high cost of private finance likely also skews private-sector participation towards the household sector, with a particular focus on services that meet basic needs, whereas structural transformation goals favour a differentiated service that takes into account the growth of different types of businesses with varying load requirements. The latter level of service typically requires higher levels of investment and is more onerous in terms of project development – as well as carrying higher risk. It will be important for LDCs and their development partners, including impact and other infrastructure fund asset investors, not to neglect assistance to this transformational aspect of universal access.

Sovereign borrowing may assume a prominent role as a consequence of current developments in global financial markets and policies to prioritize private finance in development funding that lead to further declines in ODA (section G3). LDCs, especially in Africa, are increasingly turning to international bond markets to raise development finance, particularly to address infrastructure deficits. International investor interest is high. Crucially, this represents a significant change in creditor compositions. This change may have implications should debt restructuring be required. Bond restructuring tends to be more complex because of the number of different creditors involved.

LDC sovereign borrowing abroad to finance infrastructure investments can make economic sense (chapter 5). More so than in other developing countries, LDC domestic banks tend to be risk-averse; banking-sector imperfections can raise costs; and credit markets are largely underdeveloped. However, external borrowing is not without its risks, including sudden and drastic currency-related cost escalations that dramatically worsen debt sustainability. The present combination of persistent low-growth, low-interest rates, and low commodity prices in the global economy raises parallels with the conditions that precipitated the 1980s debt crisis. Eleven of the 36 LDCs for which assessments have been undertaken are at high risk of debt distress (Afghanistan, Burundi, Central African Republic, Chad, Djibouti, Haiti, Kiribati, Lao People's Democratic Republic, Mauritania, Sao Tome and Principe, and Tuvalu), while three (the Gambia, South Sudan and the Sudan) are already in debt distress (IMF, 2017b).

LDC Governments should therefore continue to exercise caution in external borrowing to finance investments in electricity, particularly as the projected impacts of Basel III, if realized, will increase the severity of reputational spillovers from debt defaults. Moreover, an increased tendency to borrow on international markets increases LDCs' exposure to global financial shocks while also heightening risks that offshore markets will draw liquidity away from domestic markets (Black and Munro, 2010).

There is a strong case for scaling up ODA to finance energy investments in LDCs, and for adequate technology transfer

3. Official development assistance and climate finance

The cost of the infrastructure investment needed to ensure universal access to electricity in ways consistent with structural transformation is far beyond the means of LDCs' domestic public finances. Estimates presented in this report suggest the total investment cost for basic universal access by 2030 to be in the order of \$12-\$40 billion per year across LDCs as a whole; and increasing supply to fulfil the needs of transformational access would raise these costs considerably. While there is some potential for greater mobilization of domestic and external sources of financing towards energy-sector investments, this is very limited relative to the resulting gap. In practice, therefore, achieving universal access — and still more transformational access — will be critically dependent on ODA and other official external financing, mainly in the form of grants, given most LDCs' debt sustainability constraints. Securing this financing will require a very considerable increase in such financing for the power sector (chapter 5).

Official grant financing is particularly appropriate to investment in renewable electricity generation. While there are some local environmental benefits from such technologies in terms of reduced ambient air pollution, the primary reason for preferring renewable technologies to fossil-fuel generation is the reduction in GHG emissions. Grant financing from developed countries, whose historical emissions give rise to the need to reduce emissions in the future, provides a means of internalizing these externalities in accordance with the "polluter pays" principle (Principle 16 of the Rio Declaration on Environment and Development) and the principle of common but differentiated responsibilities established in the United Nations Framework Convention on Climate Change (UNFCCC).[2] The cost structure of renewable generation also lends itself particularly well to grant financing, as the recurrent costs are limited to equipment operation and maintenance.

This makes a strong case for the use of official financing on grant terms for the development of renewable energy sources in LDCs. By allowing these countries to avoid the capital costs of increasing capacity, grant financing of the purchase and installation of equipment for renewable generation can also allow a lower level of cost-reflective tariffs than in the case of fossil-fuel generation, given the more limited recurrent costs of the former. This can provide an important means of reconciling the tension between affordability and financial sustainability.

While the capital costs of universal access are considerable, fulfilment of donors' existing financial commitments with respect to ODA (to provide 0.15-0.20 per cent of their gross national income (GNI) in ODA to LDCs) would go a long way towards meeting that goal. As discussed in chapter 5, this would provide an additional $34-$54 billion of ODA per year. Substantial further resources could be generated if developed countries honoured their commitments with respect to climate finance.

Moreover, a strong case can be made for increasing the ODA target for LDCs, particularly in the context of the 0.7-per-cent overall target. If donors provided 0.7 per cent of their GNI in total and allocated 0.15-0.20 per cent of this to LDCs, given their relative populations, per-capita ODA to LDCs would be 1.8-2.6 times that allocated to ODCs. This falls far short of reflecting the major differences in their development needs and domestic capacity to meet those needs.

This discrepancy is further underlined by the 2030 Agenda for Sustainable Development. The overall and LDC targets for ODA imply that 21-29 per cent of total ODA should be allocated to LDCs. However, their share in global shortfalls from the standards set by the SDGs, together with their more limited financial capacity, suggests that a proportion in the order of 50 per cent would be more appropriate (UNCTAD, 2015a). As noted in chapter 1, 54 per cent of people without access to electricity globally lived in LDCs in 2014, a proportion that has almost doubled since 1991. LDCs also accounted for 45 per cent of those without access to an improved source of water in 2014, and for 40-50 per cent of those in extreme poverty globally in 2013. The former figure has more than doubled, and the latter almost tripled, since 1990.[3]

In conjunction with the 0.7-per-cent commitment for total ODA, a target that at least half of total ODA should be allocated to LDCs would imply approximately doubling the target ODA for LDCs to 0.35 per cent of donor GNI. As noted in chapter 5, this would provide additional resources of $118 billion per year.

Of particular relevance to renewable energy are the developed countries' additional commitments on climate financing, as well as those on aid effectiveness under the 2005 Paris Declaration on Aid Effectiveness, the 2008 Accra Agenda for Action and the 2011 Busan Partnership for Effective Development Co-operation (OECD, 2005, 2008, 2011). Particularly important are donors' commitments to "Respect partner country leadership and help strengthen their capacity to exercise it" and to "Base their overall support — country strategies, policy dialogues and development co-operation programmes — on partners' national development strategies" (OECD, 2005: paras. 15, 16).

Donors have also committed themselves to "ensure that existing channels for aid delivery are used and, if necessary, strengthened before creating separate new channels that risk further fragmentation and complicate co-ordination at country level" (OECD, 2008: para.19(c)). However, the opposite has been the case in the context of climate finance, giving rise to an extraordinarily complex financial architecture that represents a significant obstacle to LDCs' access to finance, as well as unnecessary costs, loss of economies of scale and administrative burdens. This proliferation of funding channels should be reversed by consolidating the multiplicity of institutions and financing windows. Until this is done, there is a case for establishing a finance facilitation mechanism to match the particular funding requirements of each LDC's own development programme with the available sources, and to limit the administrative and technical burdens associated with the identification of sources, application processes and multiple inconsistent monitoring and reporting processes (UNCTAD, 2016b).

4. Access to technologies

The UNFCCC and its Kyoto Protocol create clear obligations for developed countries to transfer to developing countries such technologies as may be needed to reduce GHG emissions in all relevant sectors (explicitly including energy) where these are publicly owned or in the public domain; to create an enabling environment for the transfer of such technologies where they are not in the public domain; and to provide financing to meet the full incremental cost of their transfer. Developing countries' emissions reduction commitments under the Convention are explicitly conditional on developed countries' fulfilment of these obligations.

Outcomes of recent global conferences have contained much weaker language. The Addis Ababa Action Agenda (adopted in 2015 at the Third International Conference on Financing for Development), for example, contains much weaker commitments, and falls far short of recognizing the obligations to promote, cooperate in, facilitate and finance technology transfer, stating only (in paragraph 120):

> We will encourage the development, dissemination and diffusion and transfer of environmentally sound

> technologies to developing countries on favourable terms, including on concessional and preferential terms, as mutually agreed.

However, this does not in any way modify or dilute the legal obligations of signatories under the Convention, which should therefore be implemented in full.

A more specific obligation on developed countries arises under Article 66.2 of the WTO Agreement on Trade-related Intellectual Property Rights (TRIPs), which states that:

> Developed country Members shall provide incentives to enterprises and institutions in their territories for the purpose of promoting and encouraging technology transfer to least-developed country Members in order to enable them to create a sound and viable technological base.

Nevertheless, fulfilment of this obligation has been very limited, as has the extent of the resulting technology transfer to LDCs (Moon, 2008, 2011). A more rigorous implementation of this provision of the TRIPS Agreement in respect of energy-related technologies (including end-use technologies) could provide a means of operationalizing the technology-transfer provisions of the UNFCCC. This could usefully be supported by a more systematic approach to monitoring WTO Members' compliance with their obligations under this Article 66.2 (UNCTAD, 2016b).

International support measures for technology transfer and absorption could include an international innovation network for LDCs, to facilitate knowledge accumulation and innovation on energy technologies; global and regional research funds for the deployment and demonstration of such technologies, focused on adaptation and incremental innovations oriented towards local contexts; an international fund to facilitate private-private and private-public technology transfer; and an international energy-technology training platform to promote capacity-building and skill accumulation. South-South and triangular cooperation mechanisms can also help to facilitate the sharing of technological learning and knowledge. South-South technology cooperation might include training LDC nationals abroad in the use and maintenance of energy technologies and supporting research to adapt existing technologies to local needs, as well as grants of energy-related intellectual property rights (IPRs) or licensing on concessional terms (UNCTAD, 2011a).

In this context, the Technology Bank for LDCs, foreseen in the Istanbul Programme of Action for the LDCs and formally established on 23 December 2016 (through General Assembly Resolution A/RES/71/251), could potentially play an important role in supporting LDC access to energy-related technologies. Acting in close cooperation with relevant United Nations institutions — such as the United Nations Conference on Trade and Development (UNCTAD), UNFCCC or the United Nations Environment Programme (UNEP), as well as with other entities with sector-specific knowledge, such as ESMAP, IRENA and the International Energy Agency (IEA) – the Technology Bank could be perfectly placed to assist LDCs in the identification of the key bottlenecks to effective technology transfer in the energy area, and in tackling these barriers. UNCTAD's involvement could be particularly beneficial, with a view to fostering not only the attainment of SDG 7 as an end in itself, but more fundamentally the sustainable provision of modern energy for productive uses, thereby enhancing the synergies between energy policies and structural transformation. The involvement of the Technology Bank in energy-related Technology Need Assessments and similar support initiatives would fall squarely within its mandate and its three-year Strategic Plan, and could turn the Bank into a key hub to facilitate and coordinate international support in this area.

Notes

1 System value is defined as “the net benefit arising from the addition of a given power generation technology” (IEA, 2016c).

2 Principle 16 of the Rio Declaration states that “National authorities should endeavour to promote the internalization of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution, with due regard to the public interest and without distorting international trade and investment”. Paragraph 1 of Article 3 of the UNFCCC, which establishes the principles on which the Convention is based, states: “The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities. Accordingly, the developed country Parties should take the lead in combating climate change and the adverse effects thereof.” The 16th Conference of the Parties to the UNFCCC explicitly acknowledges in paragraph 35 of its decision 1/CP.16 “that the largest share of historical global emissions of greenhouse gases originated in developed countries and that, owing to this historical responsibility, developed country Parties must take the lead in combating climate change and the adverse effects thereof”.

3 Data on access to water are from the World Bank’s World Development Indicators database. Poverty figures are UNCTAD secretariat estimates using data from the World Bank’s PovcalNet database. No poverty data are available for Afghanistan, Equatorial Guinea, Eritrea, Myanmar, Somalia or Yemen. The estimate of 20-50 per cent allows for average headcount ratios across these countries of between 17 per cent and 77 per cent in 2013 (compared with an average of 36.3 per cent in those LDCs for which data are available). The equivalent range for 1990 is 15-18 per cent, allowing for a range of 24-97 per cent across countries for which data are unavailable (compared with 59.3 per cent for countries with available data).

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The international community has adopted the goal of achieving universal access to modern energy globally by 2030, as part of the Sustainable Development Goals. Together with the potential for renewable energy technologies to provide electricity access to even the remotest communities, this has reinforced the already considerable attention being paid to the issue.

However, this attention has so far focused mainly on households having access to electricity for their basic needs, and on the environmental benefits of limiting greenhouse gas emissions. Equally important is the economic dimension of modern energy access, which remains relatively neglected.

The 2017 edition of *The Least Developed Countries Report* highlights the potential contribution that access to modern energy can make to lasting development and sustainable poverty eradication in the least developed countries (LDCs). These countries require structural transformation of their economies, to increase their productivity and develop new economic activities that generate higher incomes. Access to modern energy, and particularly electricity, is essential to this transformation.

Fully harnessing the economic potential of energy calls for a different approach to universal access. It means going beyond basic domestic needs to what the *Report* calls **transformational energy access**, to meet the needs of enterprises for adequate, reliable, affordable and sustainable supplies of the energy they require for productive uses. Renewable energy technologies, such as solar and wind power, can play an important role in achieving transformational energy access in LDCs – but only if important financial, technical, economic and institutional obstacles can be overcome.

A holistic approach is critical. This means both a system-wide approach to the electricity sector itself, and effective integration of energy-access programmes into overall development strategies. Achieving universal access by 2030 – and still more transformational energy access – will also necessitate a major increase in both funding and the transfer of energy-related technologies.

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