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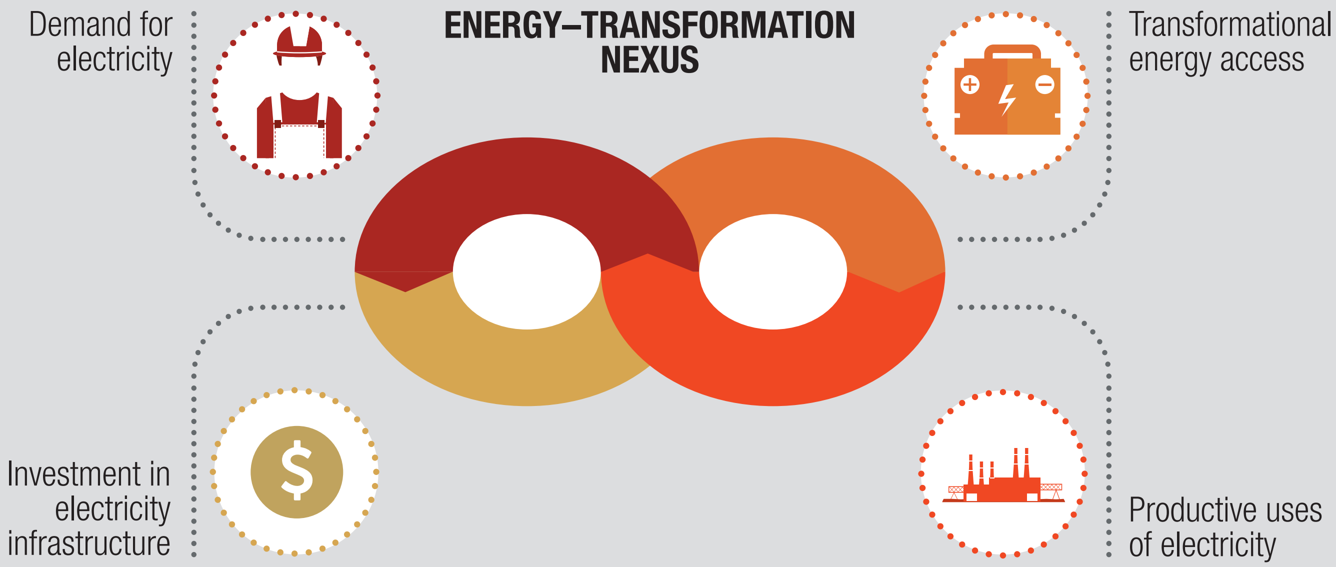
THE LEAST DEVELOPED COUNTRIES REPORT 2017

Transformational energy access

CHAPTER 2

Energy and inclusive economic structural transformation

ENERGY–TRANSFORMATION NEXUS



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

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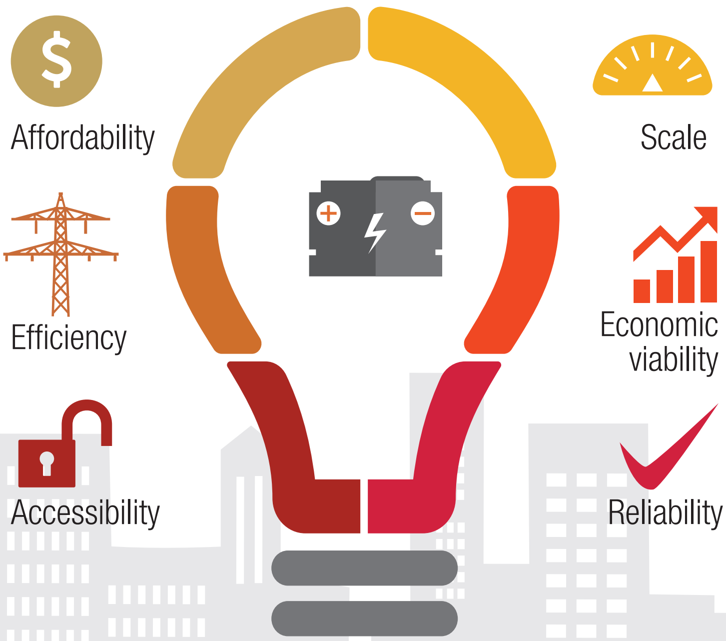
sufficient, reliable and affordable energy for all types of productive use



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

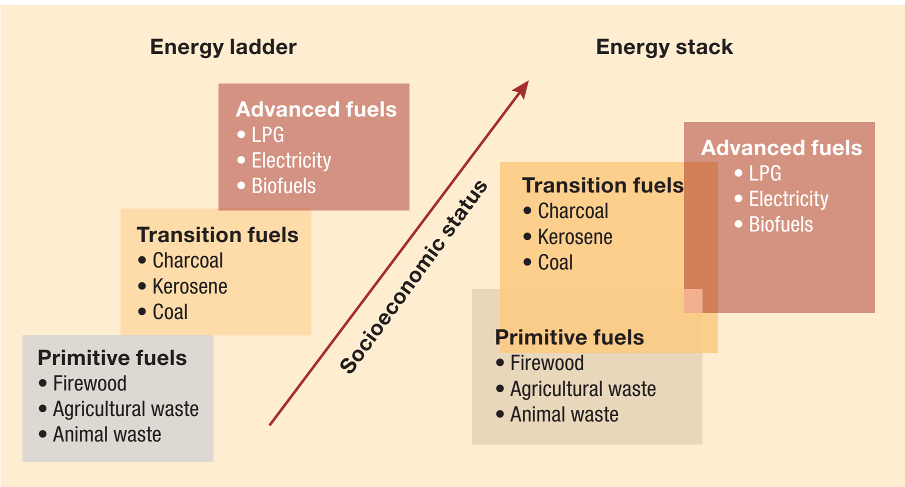
The relationship between energy and economic development is complex. It is often described as an "energy ladder" (as shown in figure 2.1) that characterizes changes in energy sources as development progresses and incomes rise.

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.

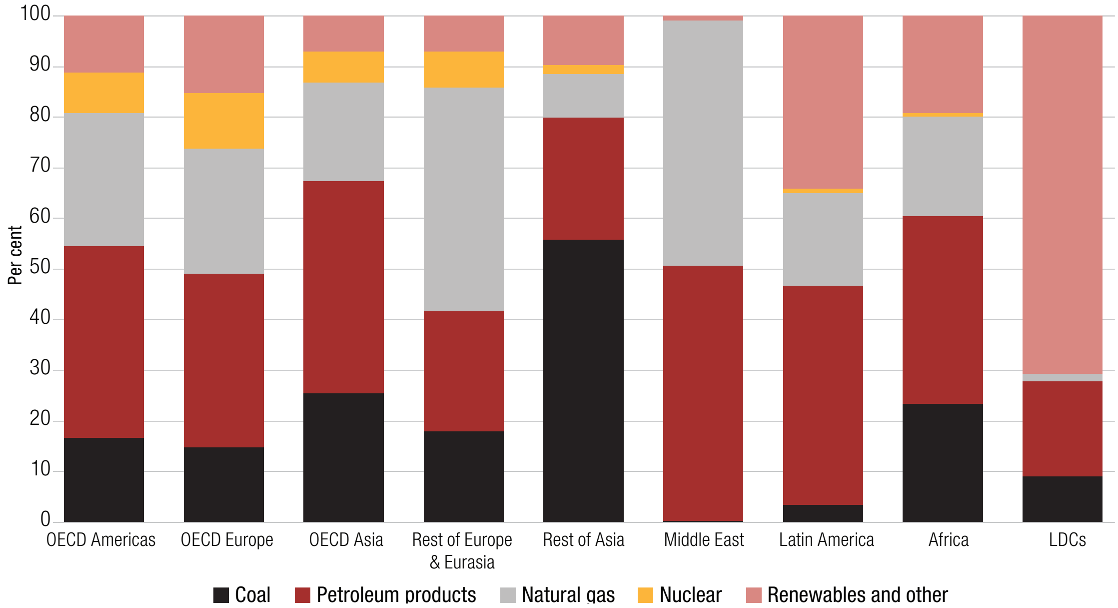
The different features of energy sourcing according to development level are illustrated by the composition of total primary energy supply (TPES) of different country groups. TPES is a measure of the energy inputs to an economy. It equals production of energy products plus imports minus exports minus 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



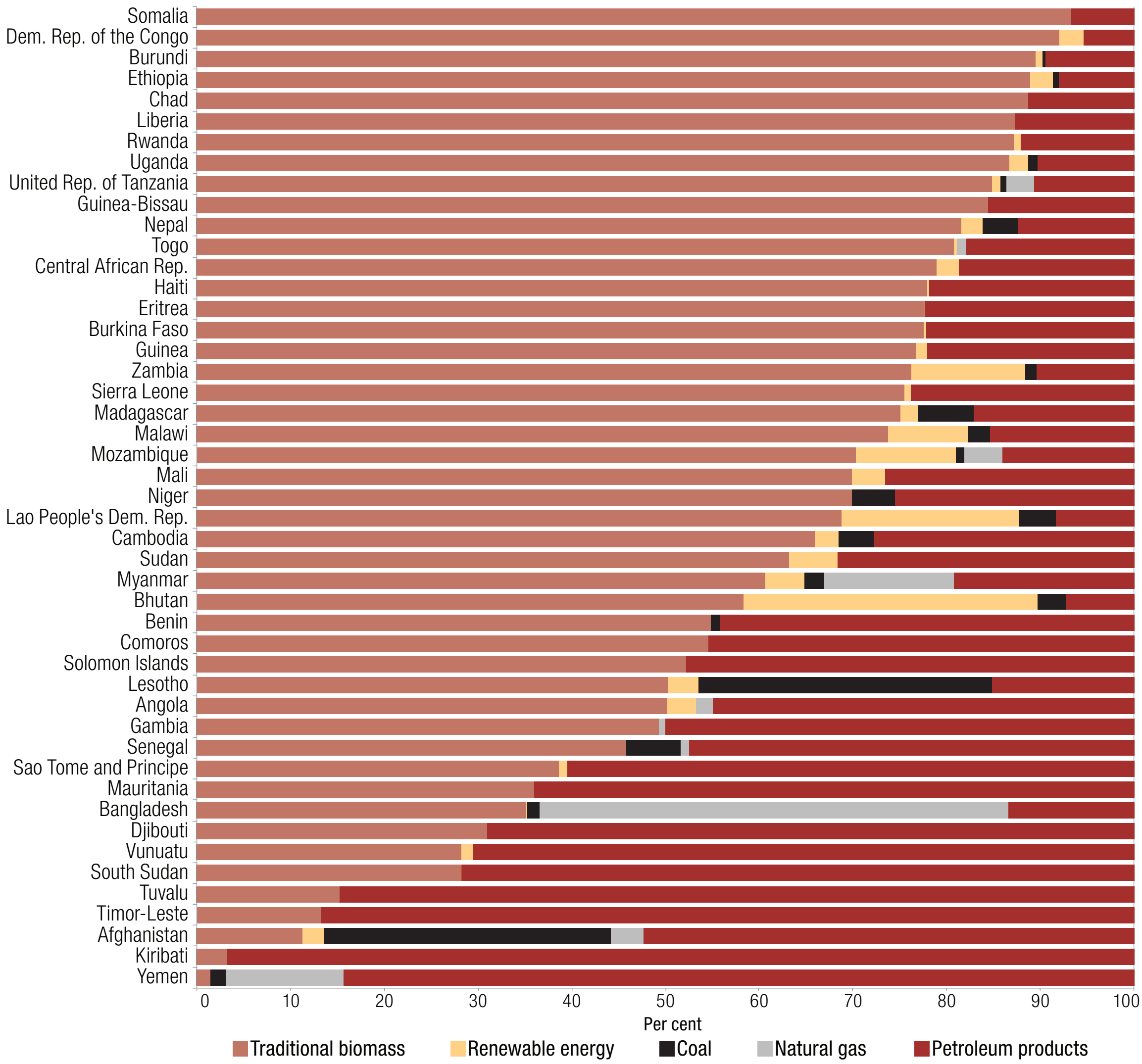
Source: IEA (2016b); UN DESA (2016b).

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).

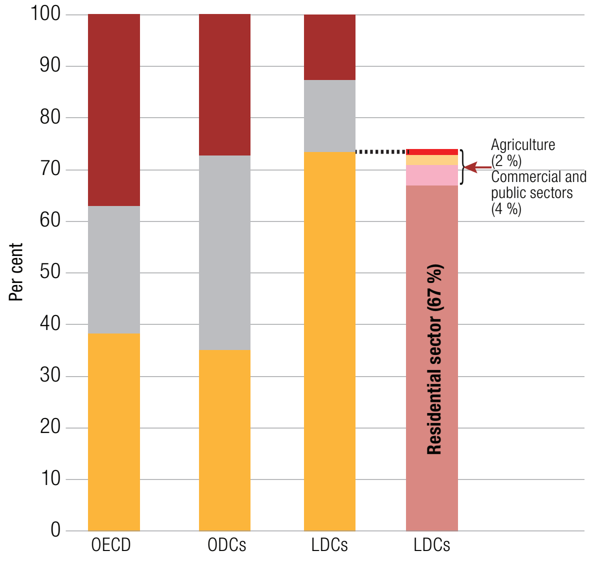
2. Patterns of energy use in LDCs

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

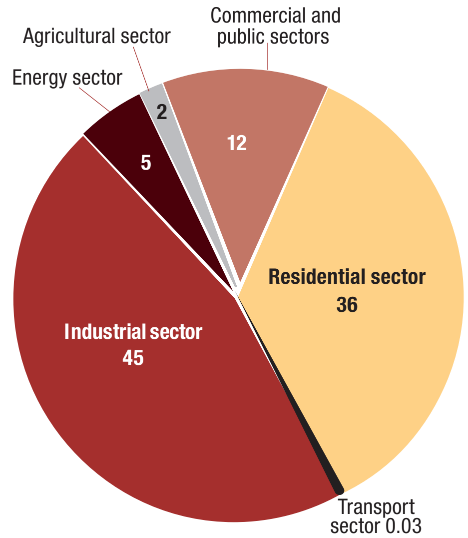
Total final energy consumption by sector, LDCs, ODCs and OECD countries, 2014



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.

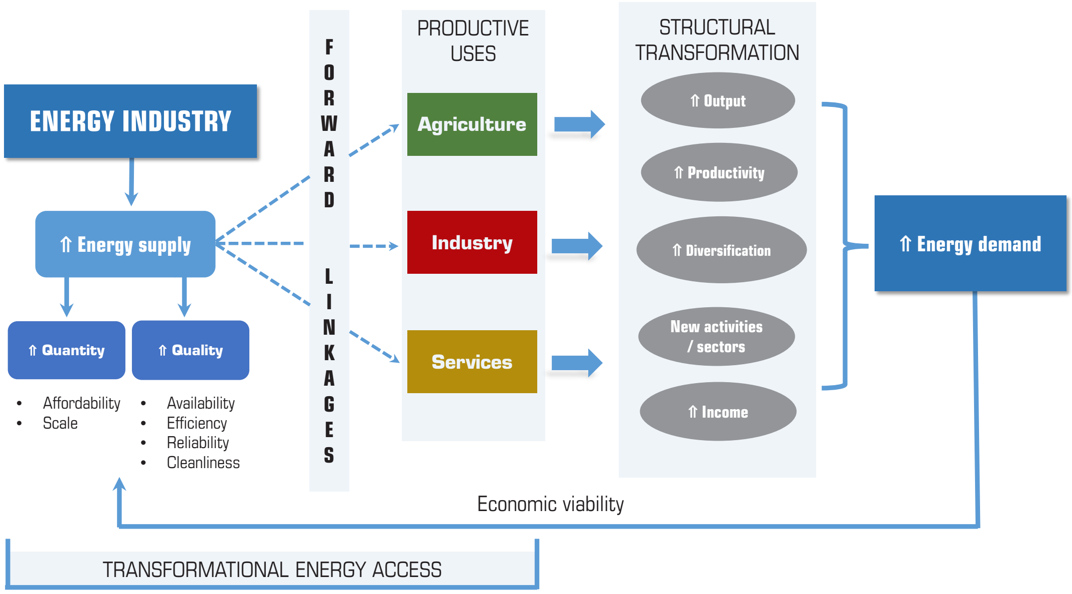
A similar two-way relationship arises in the case of economic structural transformation. This process entails the expansion and diversification of production – through the production of new goods and services and the establishment of new sectors and industries – the adoption of new technologies, and 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.

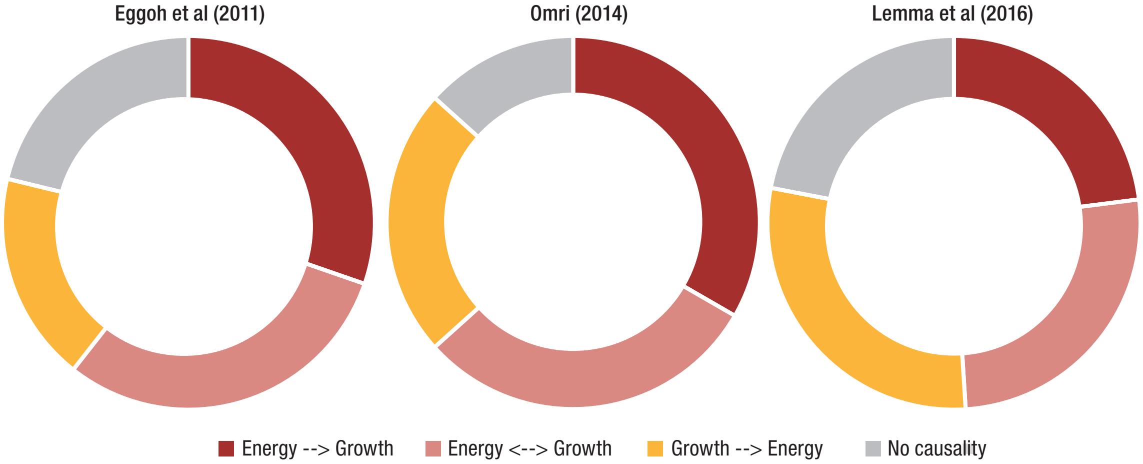
Pueyo et al. (2013) and Omri (2014) perform a similar exercise for electricity and growth. The former concentrates on developing countries, and this report presents the results of the latter solely for these countries. The findings are summarized in figure 2.8.

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)

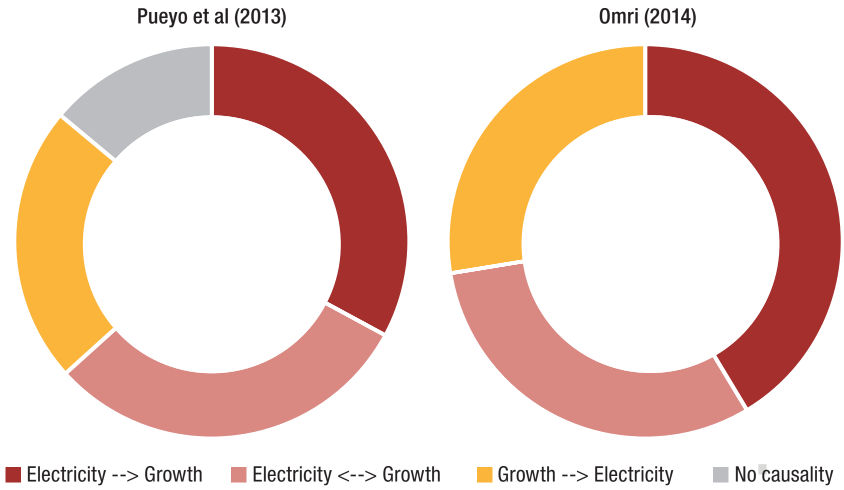


Source: UNCTAD secretariat elaboration, based on the cited references.

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

Causality between different forms of energy and:	Form of energy					
	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)

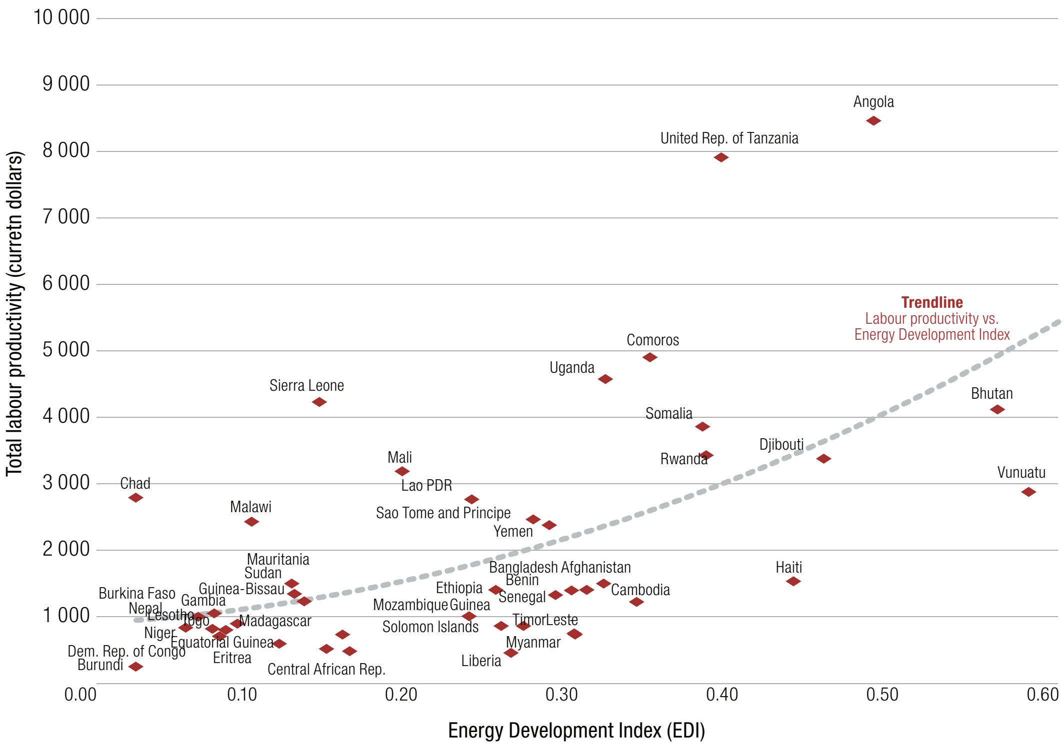
Electrification and the increased use of electrically operated equipment and machinery can enable a reallocation of resources towards higher-productivity sectors and activities (in a process of structural change), while enhancing the productivity of existing economic inputs, thus contributing to aggregate 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.

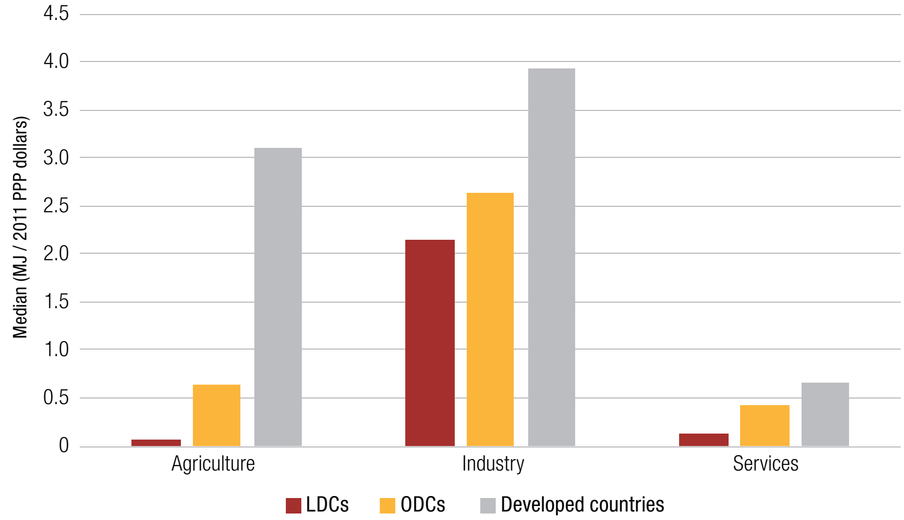
2. Energy as an essential input to production

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.

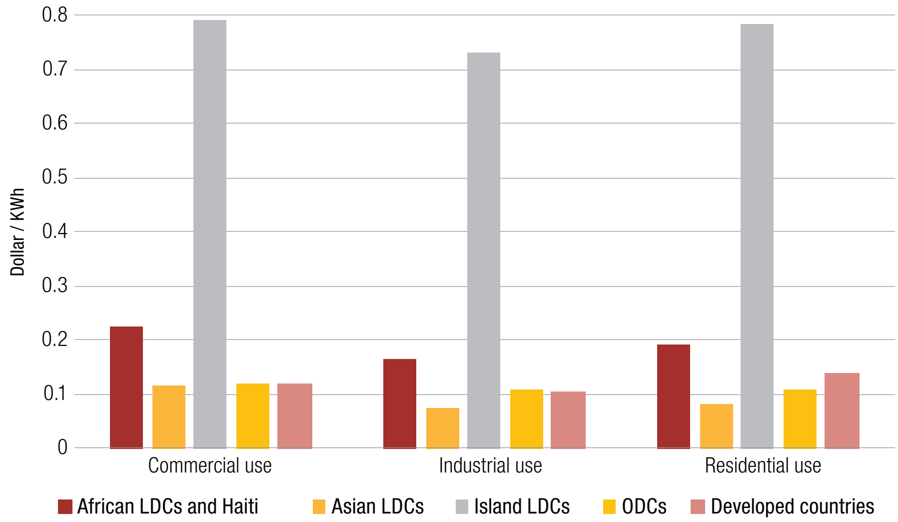
enterprise surveys tend to focus on larger enterprises, these figures may understate the challenges to micro and small enterprises, which tend to face higher costs in purchasing generators (Bhatia and Angelou, 2015).

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

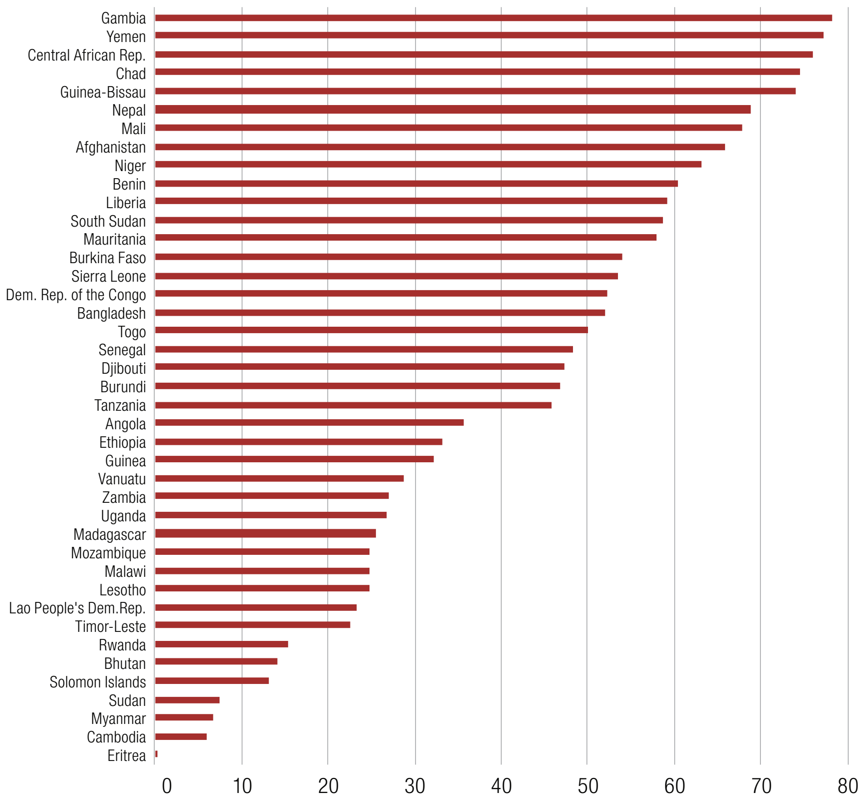
Average retail electricity tariff by end-use, latest available data



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.

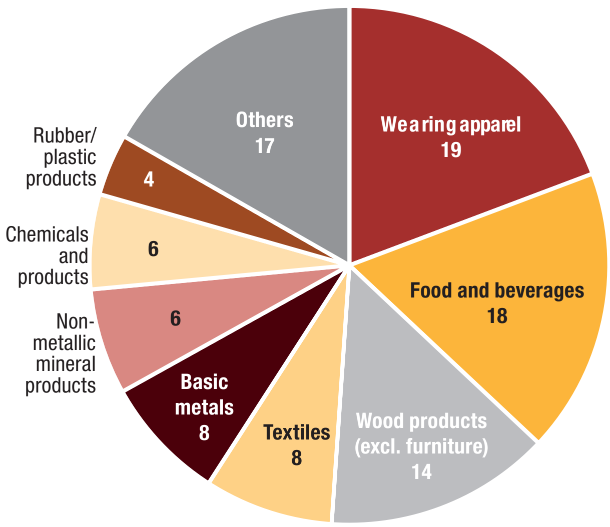
The relative contribution of factors (capital, labour, natural resources, energy and productivity) to manufacturing growth varies according to the technological intensity of sectors and the economy's stage of development. The decomposition of the long-term growth of the manufacturing sector in both developing 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

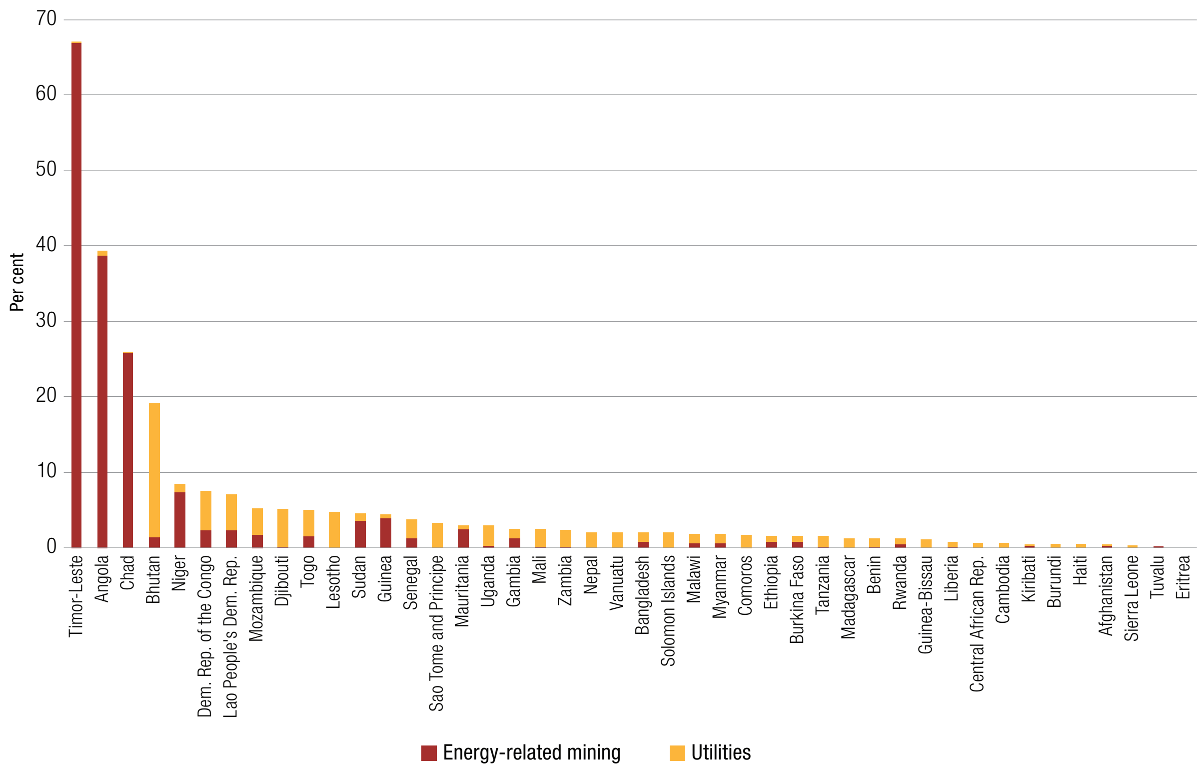
The energy industry (or sector) comprises the extraction of energy commodities and carriers; their processing, transformation, refining, manufacturing and distribution; and the production, transmission and distribution of electricity. As well as its enabling role in relation to other sectors examined 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

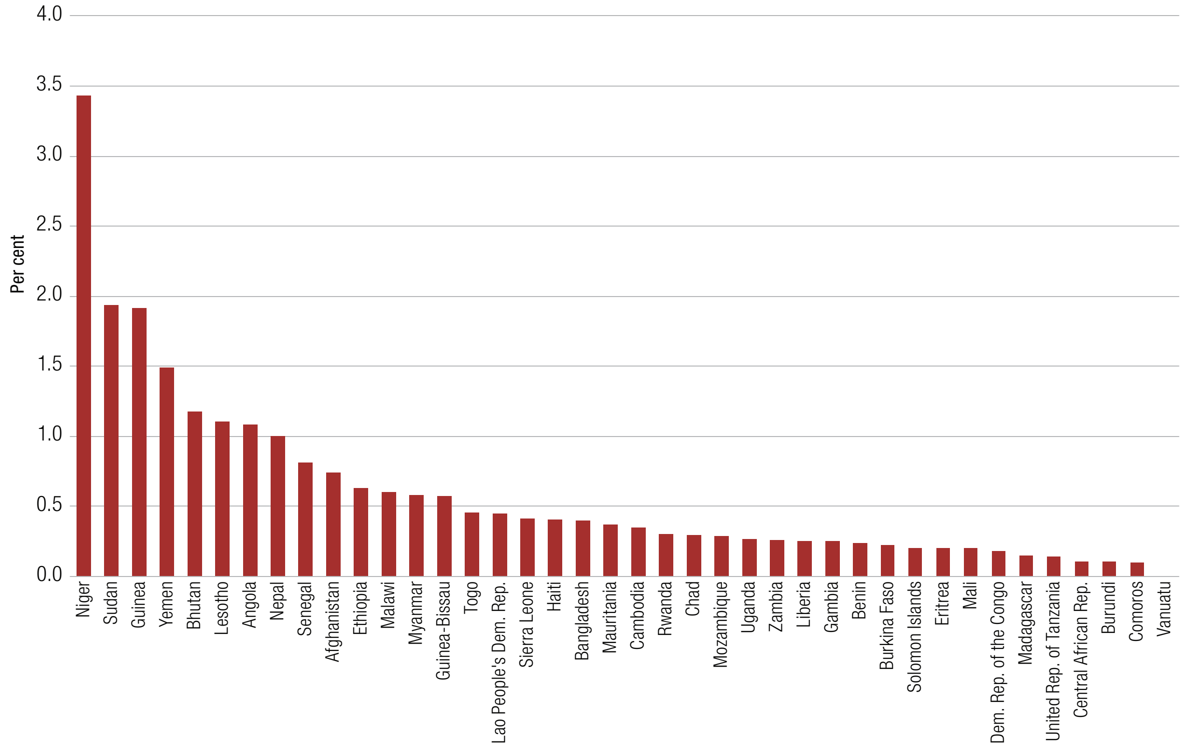
Overall, the contribution of the energy industry to employment is much smaller than its share of value added, implying a much higher level of labour productivity than other industries and sectors, reflecting its greater capital intensity. In Senegal and Zambia, for instance, utilities — including electricity, 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)

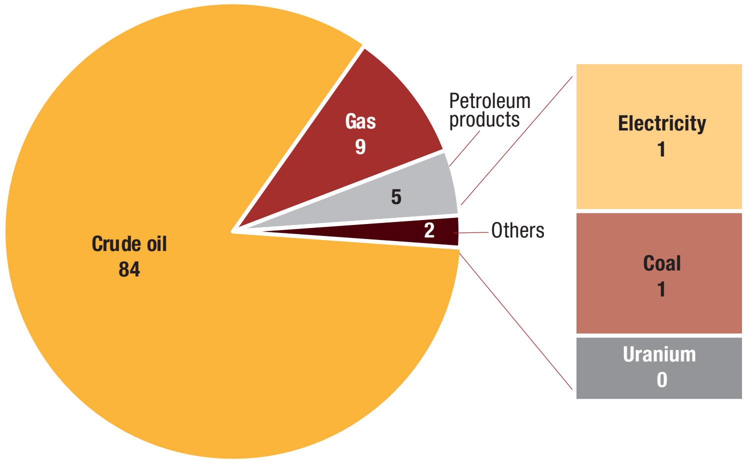
	Petroleum and products			Gas	Coal	Uranium	Electricity	Total
	Total	*of which:*						
		Crude oil	Petroleum products					
Value ($ million)								
Least developed countries	60 565	57 351	3 214	6 446	572	299	684	68 566
of which:								
African LDCs and Haiti	59 041	56 046	2 995	2 224	476	299	359	62 399
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.

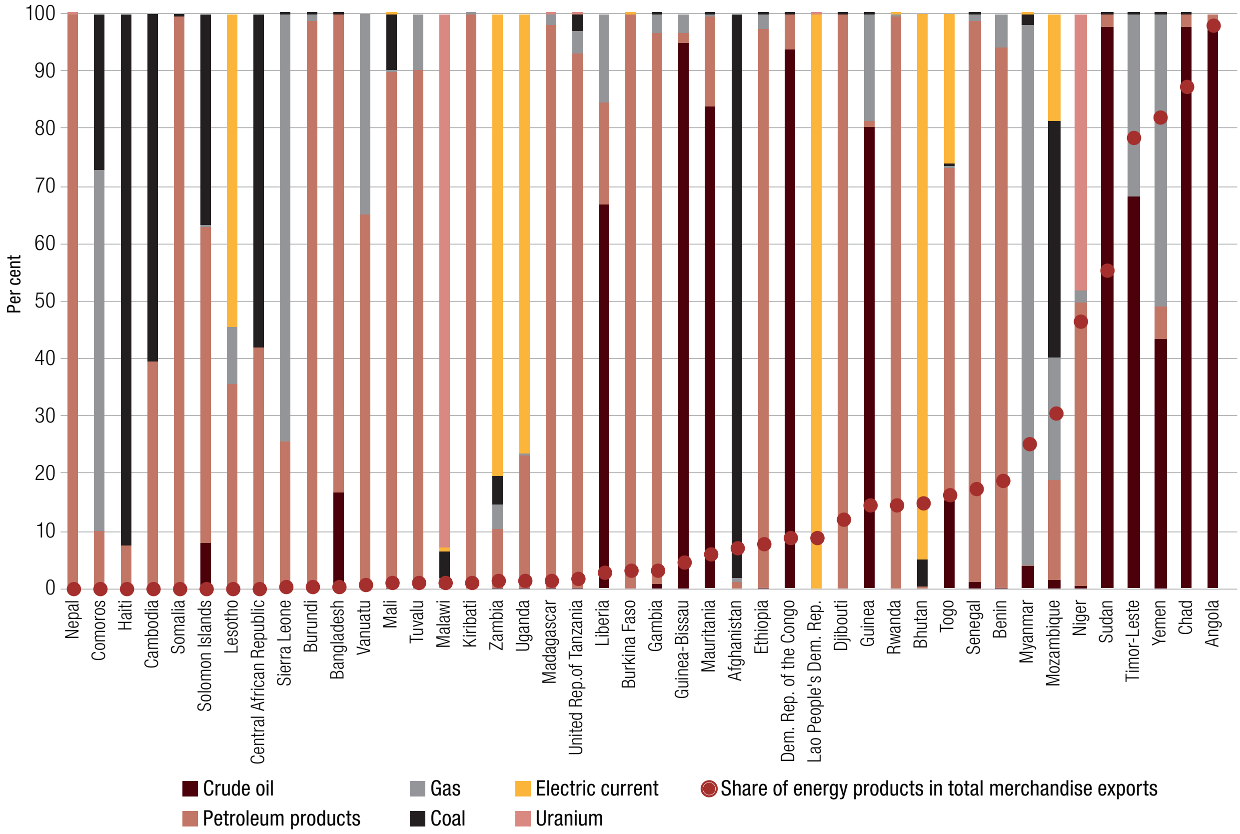
b. Imports

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

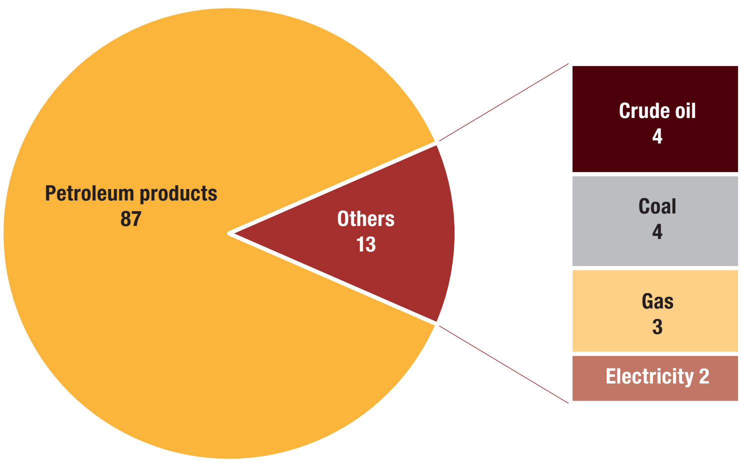
The vast majority of LDCs (38 of 46 for which data are available) are net importers of energy products (figure 2.19), reflecting the asymmetry between concentration of energy exports in a few LDCs while all are energy importers. For those which import primary energy sources for electricity generation, 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)

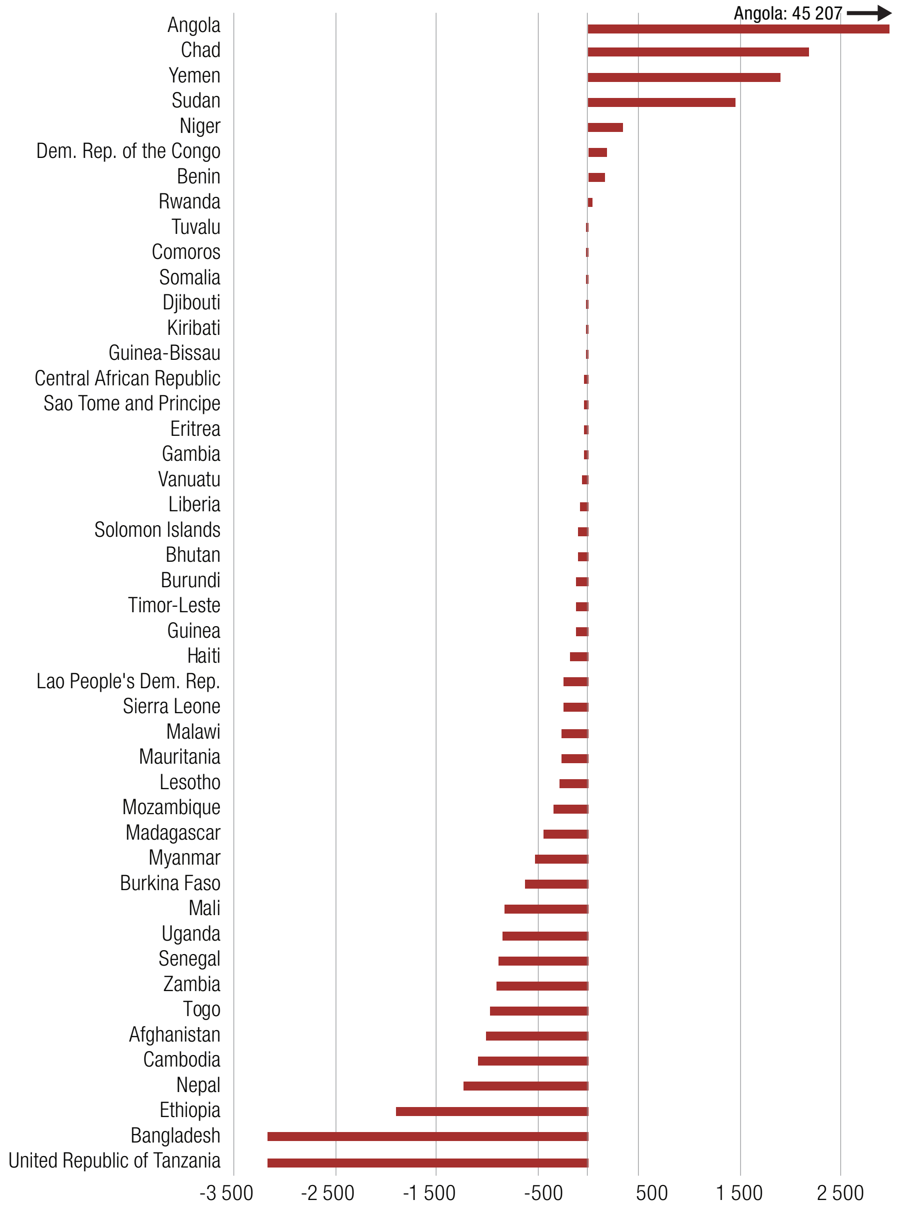


Source: UNCTAD secretariat calculations, based on data from UNCTAD, UNCTADStat database (accessed July 2017).

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.