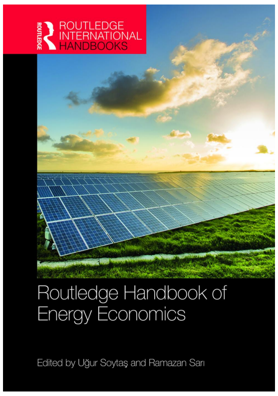

Routledge Handbook of Energy Economics

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Energy demand

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Energy demand

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1 Introduction

Energy is a vital input to economic development and human well-being (Goldstein et al. 1997; Csereklyei et al. 2016). In the absence of access to modern energy resources (electricity, petroleum), the economic development achieved today would not have occurred. Similarly, human life has become so dependent on energy – particularly electricity – that human survival would be extremely difficult if not impossible in the absence of energy, especially in developed countries. Being a basic need of the economic growth and social welfare, energy demand increases along with increasing economic growth and improved quality of life or living standards.

Energy demand has been ever increasing along with economic growth and its role in economic development has remained critical over the last two centuries (Goldstein et al. 1997; Stern and Kander 2012). Many economic historians believe that coal was one of the key drivers of industrial revolution in Britain (Church 1986). Since 1971, when the International Energy Agency (IEA), the energy wing of the Organisation of Economic Co-operation and Development (OECD), started to keep a systematic account of energy production, trade, and consumption, quantitative evidence suggests that energy demand is very closely following economic growth, measured in terms of gross domestic product (GDP). Based on a calculation later in this chapter using energy and economic data compiled by the OECD for more than 150 countries around the world, we have observed that each percentage change in GDP drives a 0.7% change in energy demand, on average, over the 45 years from 1971 to 2014.

Energy commodities are derived from various primary sources. Electricity is generated from hydro, nuclear, wind, and solar resources. Coal, crude oil, and natural gas are derived from energy mining or exploration/drilling. Biomass (e.g. fuelwood) is harvested from forest resources. Energy resources, thus derived directly from mother nature, are called 'primary energy' resources in the energy literature. Not all primary energy resources as such are useful to provide energy services; they require physical or chemical conversion from one form to another before being useful for energy services (e.g. heat, light). The conversion process is called 'energy transformation'. Generation of electricity from coal, refining of crude oil to produce various products (e.g. gasoline, diesel, kerosene, fuel oil), processing of raw natural gas, and conversion of wood to charcoal are some examples of energy transformation. The energy commodities derived through the transformation process are referred to as 'secondary energy' commodities. Electricity and heat could be both primary and secondary, depending on how they are derived. For example, electricity generated by using natural resources directly, such as from hydro, nuclear, solar, and wind, is primary electricity, whereas thermal electricity generated burning fossil fuels or biomass is secondary electricity.

Energy is used in various final demand sectors such as residential, industry, commercial/service, transport, and agriculture. The demand for energy for final consumption is referred to as 'final energy demand'. It does not account for energy consumption during the transformation process, such as consumption of coal for electricity generation. The difference between the primary energy consumption and final energy consumption is that the former accounts for all consumption of energy including at the transformation stage and at the final consumption stage, whereas the latter does not account for consumption for the transformation purpose. The definition of energy consuming sectors in the energy statistics are different from the economic statistics used in standard national accounts. For example, the household sector in the national accounts covers everything used by the households (e.g. fuel wood for cooking, gasoline for cars, electricity for televisions); the household or residential sector in the energy account does not include energy consumption for transportation. Energy consumption for transportation, no matter who uses the transportation services (household, governments, industry) is included in the transport sector. All energy consumption excluding those for transportation by commercial/service enterprises other than manufacturing, mining, and construction is included in the 'commercial/service' sector. Energy consumption in the mining, manufacturing, and construction activities is covered by the 'industrial sector'. Energy consumption in agricultural, forestry, and fishery activities is sometimes included in a separate 'agricultural' sector or in the industrial sector, depending on the convention practiced in a country.

Energy commodities are also used as raw materials in industry. For example, use of natural gas for fertilization production, or the use of petroleum products for production of chemicals and plastics. They are reported in energy statistics as 'non-energy' consumption. Energy consumed by international aviation and marine transportation is separately accounted as 'bunker fuels' and is excluded from transport sector energy consumption of a particular country.

Within a given sector, energy commodities are used for various purposes. For example, in the residential and commercial/service sectors, they are used for cooking, water heating, home heating, lighting, air conditioning and ventilation, refrigeration, and electrical/electronic devices such as television and computers. These energy services (heating, cooking, lighting, etc.) are referred to as 'end-use energy services'.

This chapter briefly discusses global energy demand from a historical perspective over the 45 years since 1971, when the IEA started a systematic reporting of energy statistics. This is followed by key drivers of energy demand, particularly in the long run. The chapter also discusses methodologies used and estimates made on future energy demand by well-known institutions, and finally it draws key conclusions.

2 Global energy demand – the historical trends

Global energy demand has increased at an average growth rate of 2% per year over the last 45 years (1970–2014). During this period, the highest annual average growth rate observed during the 1970s (3%) followed by the first decade of the 2000s (2.5%).

Figure 1.1 presents the fuel mix to supply global energy demand over the last 45 years. It is interesting to note that the mix of fuels to meet the primary energy demand has not changed significantly over the time period. In 1971, fossil fuels (coal, oil, and natural gas) accounted for 86% of the global energy demand; this has slightly decreased to 81% by 2014. The share of non-fossil fuels (i.e. biomass and waste, nuclear, hydro, and new and renewables such as solar, wind,

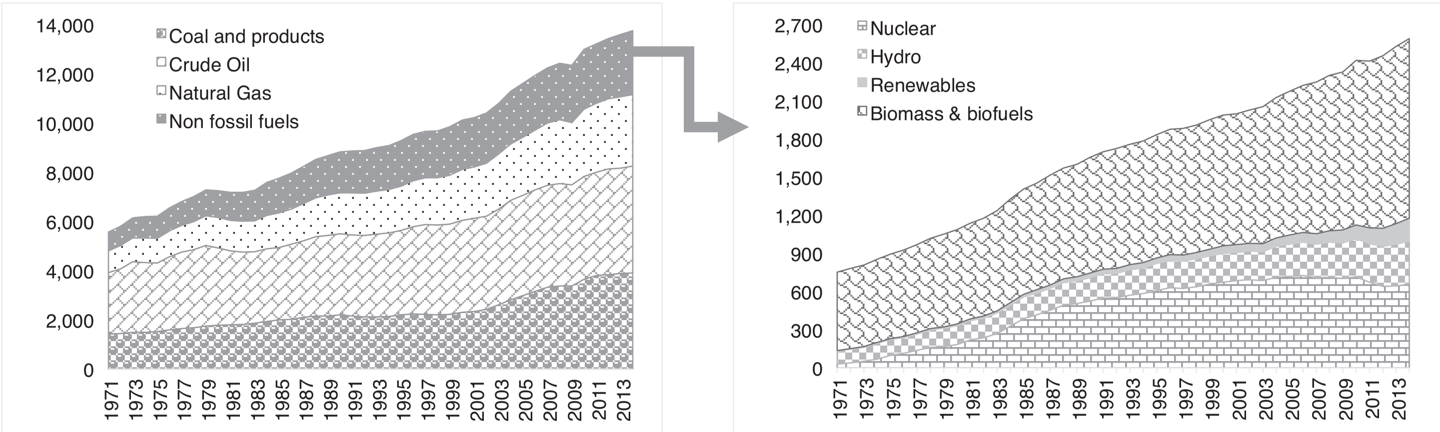

Figure 1.1 Global energy demand by fuel type (Mtoe)

Source: OECD (2017).

and geothermal) in the total primary energy demand has slightly increased from 14% in 1971 to 19% in 2014. It is worth noting that although the importance of new and renewable energy sources (i.e. solar, wind, and geothermal) has increased substantially to address global climate change, their contribution to the global energy supply is still insignificant, at 1% in 2014. This fact indicates the scale of the efforts that are needed to have significant substitution of fossil fuels with new and renewable energy sources.

Oil is one of the largest sources of energy supply, accounting for 32% of the global energy requirement. Its share was much bigger in the past. Until 1980, oil used to contribute more than 40% of the global primary energy demand. Despite the increasing pressure to cut coal use to address climate change, the share of coal in the total primary energy supply is increasing, from 24% in 1973 to 29% in 2014. The share of coal and oil would have been much higher in the absence of increased exploration and better economics of natural gas, whose share has continuously increased over the last 45 years, from 16% in 1971 to 21% in 2014. Natural gas has substituted for oil in industrial applications and coal for power generation.

Among the non-fossil fuel energy resources, the share of hydro and biomass and waste in total primary energy demand remained the same (2% and 10%, respectively) over the last 45 years. The share of nuclear peaked during the 1995–2002 period, with 7% of the global energy supply; however, it has decreased since then and stayed at 5% in 2014.

Figure 1.2 illustrates the evolution of energy demand growth of developed (OECD) and developing (non-OECD) countries. Until the year 2004, OECD countries used to consume more energy than non-OECD countries. However, their share of global energy consumption was continuously deceasing. It decreased from 61% in 1971 to 52% by 1990 and to 38% by 2014. On the other hand, the share of non-OECD countries continuously increased and surpassed the OECD countries in 2005, while non-OECD and OECD countries accounted for 36% and 61%, respectively, of the global energy demand in 1971. The situation has reversed by 2014, with non-OECD countries' share at 59% and OECD countries' share at 38%. Rapid economic growth in non-OECD countries driven by industrialization, along with urbanization and motorization, has played the role behind this. Among the non-OECD countries, China alone is responsible for almost 40% of the total non-OECD energy consumption. Other Asia (excluding China) is not far behind, with 22% of the total non-OECD energy consumption. On the other hand, the share of Africa in total non-OECD energy consumption remained almost the same over the last 45 years at around 10%. The same is true for non-OECD America (Latin America and the Caribbean, excluding Mexico which is an OECD member) with 8% to 10% share in the total non-OECD energy consumption during the last 45 years.

In the case of OECD countries, not a significant change in terms of energy consumption was observed over the last 45 years. The share of OECD America in total OECD energy consumption is almost the same (around 50%) over the time period. The share of OECD Europe in total OECD energy slightly decreased from 37% in 1971 to 32% in 2014. The share of other OECD increased due to inclusion of new countries (e.g. South Korea) in the group. It is, however, interesting to note that total energy consumption in OECD peaked in 2007 at 5,555 Mtoe and stabilized since then at a slightly lower level, at around 5,300 Mtoe.

Another interesting fact is that the sectoral mix of final energy demand has not changed over the last 45 years at the global level (see Figure 1.3). For example, the share of the residential sector in total final energy demand was 27% in 1971, whereas it slightly decreased to 25% in 2014. There does not exist any historical pattern (i.e. continuously increasing or decreasing over time) of final energy demand for a given sector; instead it increased in some years and decreased in others. The share of the industrial sector (which includes agriculture and forestry sectors) in the global final energy demand decreased from 39% in 1971 to 35% in 2014; on the other hand, the share of the

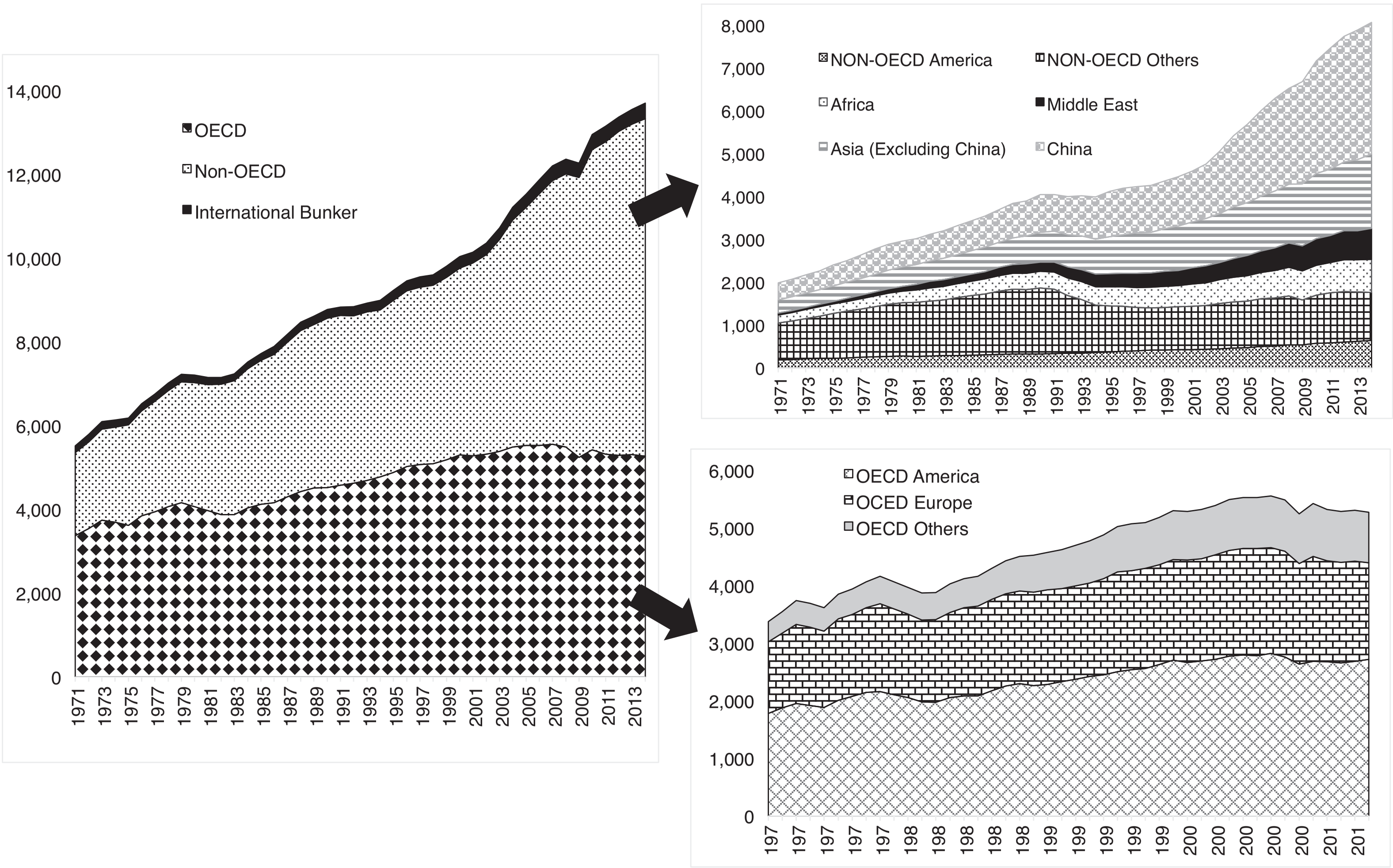

Figure 1.2 Global energy demand by economic blocks/geographical region or countries (Mtoe)

Source: OECD (2017).

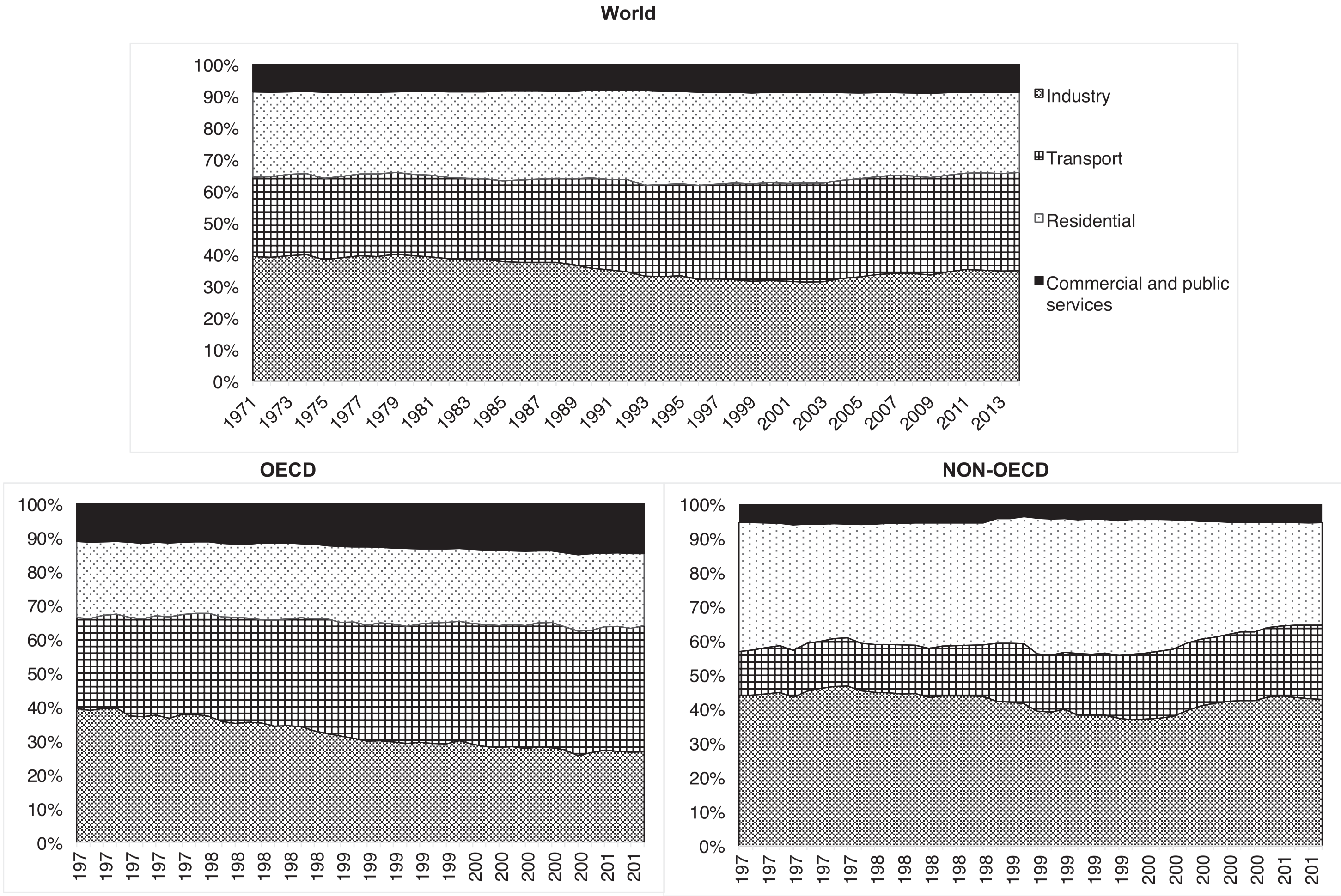

Figure 1.3 Sectoral energy mix (%)

Source: OECD (2017).

transport sector increased to 31% in 2014 from 25% in 1971. Note, however, that the transport sector share in the global final energy demand has remained flat at around 30% over the last 20 years.

In developed countries (i.e. OECD countries), significant changes have occurred in the sectoral energy mix. Increased motorization, especially during the 1975–1995 period, has substantially substituted energy consumption in the industrial sector with that in the transport sector. While the industry sector share in OECD countries' total final energy demand decreased from 40% in 1975 to 30% in 1995, the transport sector share increased from 29% in 1975 to 35% in 1995. The shares of residential and commercial sectors remained stagnant during the 1971–2014 period.

In the case of developing countries (non-OECD countries), the transport sector has played a greater role in driving total energy demand as its share has increased from 13% in 1971 to 22% in 2014. The increasing of the transport sector share started in the early 1990s. The shares of industrial sector went up and down, slightly increased during the 1970s, decreased during the 1980–2000 period and started to increase again. Interestingly, the share of the residential sector in developing countries total final energy demand has significantly decreased after 2000, from 40% in 2002 to 30% in 2014. This is contrary to several studies (e.g. Wolfram et al. 2012) which argued energy consumption in developing countries has increased due to rapid increase in use of energy, specifically electricity appliances caused by increased household income, thereby driving their total energy consumption and GHG emissions. However, as illustrated in Figure 1.3, this argument is untrue.

3 Drivers of energy demand

Energy demand is driven by different factors. In the long run, two factors (population growth and economic growth) are mainly responsible for changes in energy demand. The long-term factors are used to expand production capacity for energy generation, such as installed capacity of power generation and pipeline capacities for natural gas transportation. On the other hand, factors such as weather (e.g. heating or cooling degree days), energy prices, specific events (e.g. World Cup football matches) determine energy demand in the short run. Short-run factors basically affect the utilization of installed capacities to generate energy.

Figure 1.4 plots the indices of economic growth and population growth along with that of total primary energy demand at the global level over the last 45 years. The figure illustrates that

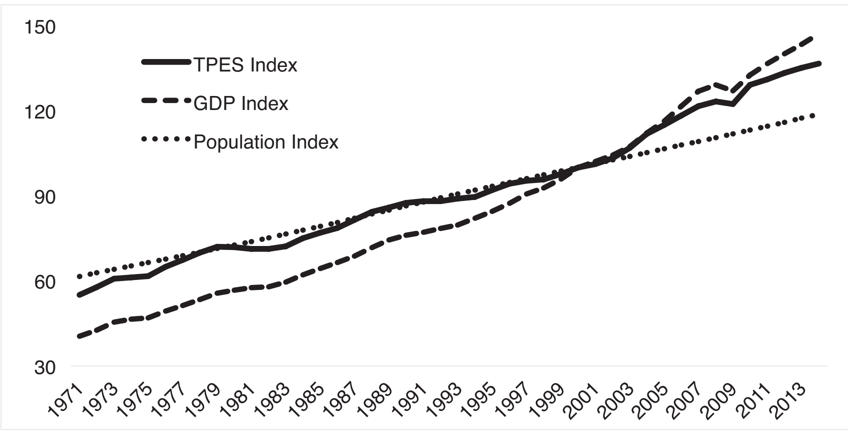

Figure 1.4 Key drivers for energy demand: economic growth and population growth

Note: Data to calculate these indices are from OECD online database. Indices for year 2000 are 100.

Figure 1.5 Energy demand growth vs. economic growth

Note: Data to calculate the energy-GDP elasticity are taken from OECD online database. Countries for which entire data series for the 1971–2014 period are not available (e.g. former Soviet republics, former Yugoslav republics, which exist as independent countries only after 1990) are not included.

growth of total energy demand follows economic growth and population growth. A closer look reveals that energy demand, in fact, follows GDP growth very closely. This fact is further illustrated in Figure 1.5 where average annual growth rates of energy demand in various countries over the last 45 years are plotted against corresponding economic growth (i.e. annual average growth rate of GDP over the last 45 years). The relationship is linear. At the global level, data for the last 45 years reveal that a 1% increase in economic growth has driven a 0.7% increase in energy demand. This energy-GDP elasticity (percentage change in energy demand with respect to the percentage change in GDP), varies between 0.3 and 2.0 for a majority of the countries for which data are available for all years during the 1971–2014 period.[1]

The power of economic growth to drive energy demand depends on the level of economic development. Figure 1.6 shows, based on data from more than 100 countries over 45 years, the inverse relationship between energy-GDP elasticity and level of economic development (proxied by per capita GDP). Similar observations were also made in some earlier studies (Gilland 1988). Developed or high-income (i.e. OECD) countries often have low economic growth in the long term. Energy demand also grows slowly in those countries because their basic energy needs have been already fulfilled. Therefore, their energy-GDP elasticity would be lower. On the other hand, developing (i.e. non-OECD) countries often have higher economic growth, which in turn drives energy demand faster to maintain economic growth as well as providing access to energy for an increasing population. Thus, their energy-GDP elasticity would be higher. During the last 45 years, the average annual growth rate of GDP of the OECD countries was 2.6%; their aggregated energy-GDP elasticity for the period (i.e. 1971–2014) was 0.41. On the other hand, non-OECD countries experienced annual economic growth rate of 4.3%, on average; consequently their energy-GDP elasticity for the period was 0.77 – almost double that of the OECD countries. Figure 1.6 also shows that a large cluster of countries which have GDP per capita less than USD

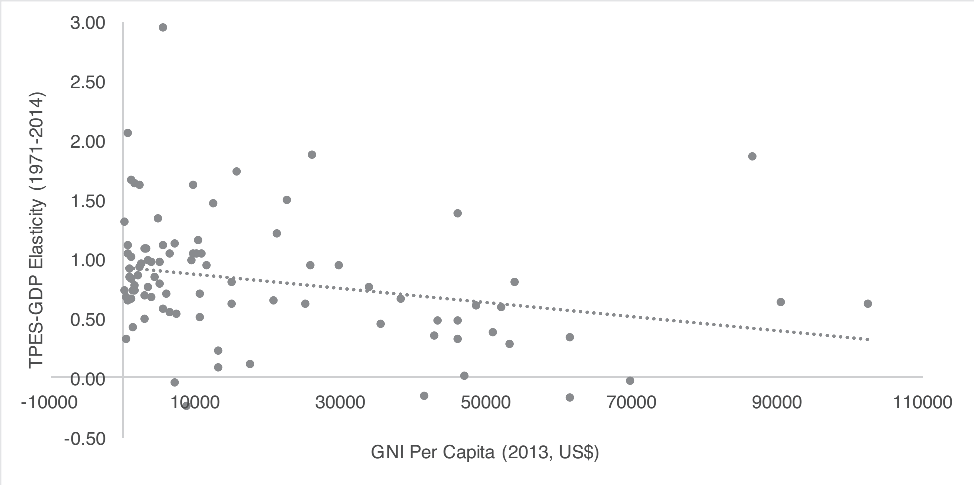

Figure 1.6 Inverse relationship of energy-GDP elasticity with the level of economic development

Note: Data to calculate the energy-GDP elasticity are taken from OECD online database and data for GNI per capita are from World Bank online database. Countries for which entire data series for the 1971–2014 period are not available (e.g. former Soviet republics, former Yugoslav republics, which exist as independent countries only after 1990) are not included. Middle Eastern countries, which are outliers due to very high energy-GDP elasticities, are also excluded.

10,000 have an energy-GDP elasticity around 1.0. Most countries with GDP per capita more than USD 30,000 have an energy-GDP elasticity less than 0.7.

4 Future energy demand

As discussed in Section 3, different approaches and techniques have been used for forecasting future energy demand.[2] The techniques are broadly divided into two categories: (1) econometric and (2) end-use accounting. Table 1.1 briefly illustrates the difference between the two approaches. The selection of techniques depends on a number of factors. For example, for forecasting of aggregate or total energy demand or demand for a particular fuel, the econometric approach would be preferable. For detailed demand forecasting, where forecasts of different energy commodities for different sectors and end-uses is needed, the econometric approach does not work because data for drivers for end-use or sectoral demand are often not available. Therefore, end-use accounting approaches, which are often based on scenario analysis and detailed data for a reference or base year, are preferred.

There exists a long list of literature utilizing both techniques. Examples of studies using econometric techniques are Gilland (1988 and 1995) for long-term global energy demand; Pindyck (1980) and Chan and Lee (1996) for residential energy demand; Limanond et al. (2011) for transport sector energy demand forecast in Thailand; and Semboja (1994) for industrial energy demand forecast in Kenya. Stinbuks (2017) compares various econometric models for forecasting electricity demand based on data from 106 countries around the world. The end-use accounting approach is being increasingly popular for energy demand forecasting because of its flexibility in incorporating scenarios and so-called expert judgments. Most commercially available energy models used by research institutions and consulting firms use this approach. Bhattacharyya and Timilsina (2010b) provides a comparison of these models. Organizations that regularly publish national and global energy demand projections mostly use the end-use accounting approach.

Table 1.1 End-use accounting vs. econometric approaches for energy demand forecasting

End-use Accounting Approach	*Econometric Approach*
Establish relationship between energy services and physical driving variables (e.g. hot water/person; lumens/sq. ft; no. of vehicles/persons; vehicle utilization rate; no. of refrigerators/household)	Establish relationship between final energy use and economic variables (e.g. gasoline consumption and household income or GDP; energy consumption and sectoral outputs)
Devices and process efficiency (MJ/liter of hot water; liter of gasoline per km of driving)	Project driving variables (e.g. GDP, household income, sectoral outputs)
Projection of driving variables (e.g. households, travel demand, commercial buildings, industrial output)	Project of energy demand based on above established relationship which is normally calibrated to historical observations
Project of energy demand based on above established relationship and efficiency, which are mostly static	Does not account technology specific features which are key determinants of fuel consumption
Does not account pricing effect on demand	Price is often the key driving variable for energy demand

Often, large and complex models are used that are capable to forecast future energy demand and generate supply plans to meet the demand; such models are referred to as energy system models.[3] These models use a hybrid approach combining econometric approach and end-use accounting (or algebraic) approaches. Econometric techniques are used to forecast demand for driving variables, such as stock of dwellings, stock of electrical appliances, manufacturing outputs, stock of vehicles, and passenger kilometers traveled, as these drivers are often closely linked with economic and demographic variables (GDP, household income, population). These drivers are then linked with energy commodities through technical coefficients such as unit energy consumption (e.g. kWh of electricity per square meter of floor space in a building; kilometer driven per liter of gasoline by a car) and utilization rate of energy consuming processes and devices to estimate energy demand for various activities (cooking, refrigeration, transportation, heating in a manufacturing plant, etc.) in different sectors (residential, commercial, industrial, transport).[4] The energy demand thus estimated across the end-uses and sectors is then aggregated to produce national and international energy demand forecasts. As discussed in Bhattacharyya and Timilsina (2010b), there exists a large number of energy system models to generate energy demand forecasts and to produce corresponding energy supply plans. In this chapter we present energy demand forecasts using three such complex energy system models to indicate how would global energy demand evolve over time in the next 20–25 years. These long-term global energy forecasts produced by three organizations: (1) the International Energy Agency (IEA), the energy wing of the OECD (OECD and IEA 2016); (2) the Energy Information Administration (EIA), the main organization responsible for official analysis of energy markets and policies including energy demand analysis and forecasting in the United States (EIA 2016); and (3) British Petroleum (BP), a major global energy company (BP 2017). These forecasts are selected for three reasons. First, these organizations have a long history of energy demand forecasting and they produce regular (annual) updates and publish their demand forecasts. Second, these forecasts are considered credible and are often used by most stakeholders including policy makers, researchers and the private sector. Third, these forecasts are free and publicly available, except for the World Energy Outlook of IEA (which contains the IEA energy forecast), which does come at a cost. These forecasts are generated by hybrid or integrated models discussed above, which use both econometric and end-use accounting approaches in their different modules.[5]

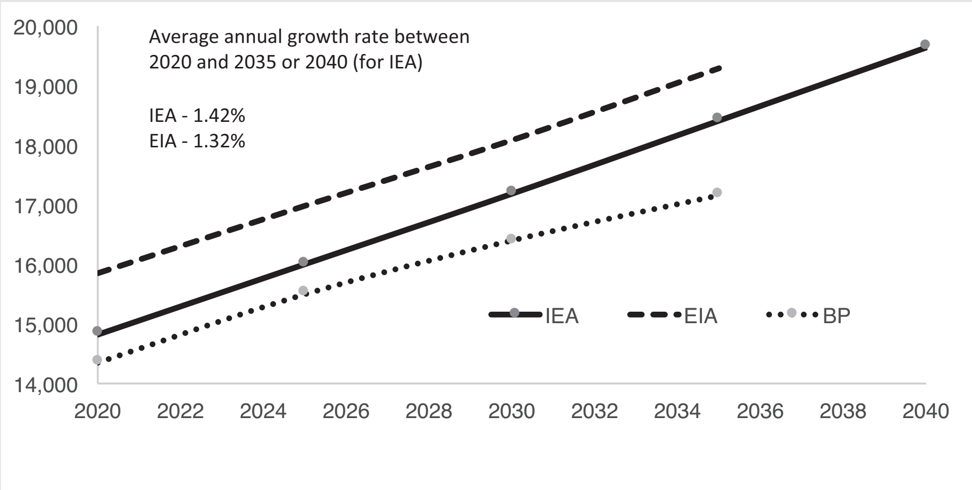

Figure 1.7 World energy demand forecasts by different organizations

Source: OCED and IEA (2016); EIA (2016) and BP (2017).

Figure 1.7 presents the latest forecasts of total energy demand for the next 20 to 25 years projected by IEA, EIA and BP. The trends are linear in all three forecasts, with small deviations in their average annual growth rate (1.42% IEA; 1.32% EIA and 1.2% BP). The difference in magnitude reflects the difference in assumptions and data used in the respective models utilized to generate these forecasts. The BP forecast has the smallest magnitude, as it already considers various policies including present and likely such energy efficiency standards, in its main forecasts. The baseline or reference case of other two forecasts (IEA and EIA), which we have considered here in this chapter, do not include future policies or scenarios; those are used in other scenarios, such as the 'New Policy' scenario and the 450 PPM scenario of the IEA forecast.

The breakdown of fuels (i.e. fuel mix) in these three forecasts are presented in Figure 1.8. There are two interesting observations here. First, there is no significant change in fuel mix over time; second, there is not much difference in the fuel mix between these three forecasts. For example, the share of coal is expected to remain between 24% and 27% in all years and in all three forecasts, implying that coal will continue to play a major role in meeting global energy demand unless there exists a significant policy shift due to global efforts on climate change mitigation.[6] The share of oil would vary between 28% and 32% during the next 20 years in the three forecasts. For natural gas, its share of the total energy supply will remain between 22% and 25% over the 2020–2035 period in all three forecasts. The share of renewable energy, including hydro and biomass, would remain between 12% and 16% throughout the forecast period in all three projections.[7]

Table 1.2 presents regional distribution of future energy consumption projected by IEA, EIA, and BP. All three projections concur that non-OECD countries' share in global energy demand would be more than 60% by 2020 and could reach almost 70% by 2040. China alone would account for one-quarter of global energy demand beyond 2020, whereas the US share would drop to 12%–14%. Non-OECD countries excluding China would account for more than 30% of the global energy demand after 2020. On the other hand, OECD countries' share in global energy demand is projected to drop significantly to around 30–35%. Note that their share was 61% in 1971, 52% in 1990, and 38% in 2014.

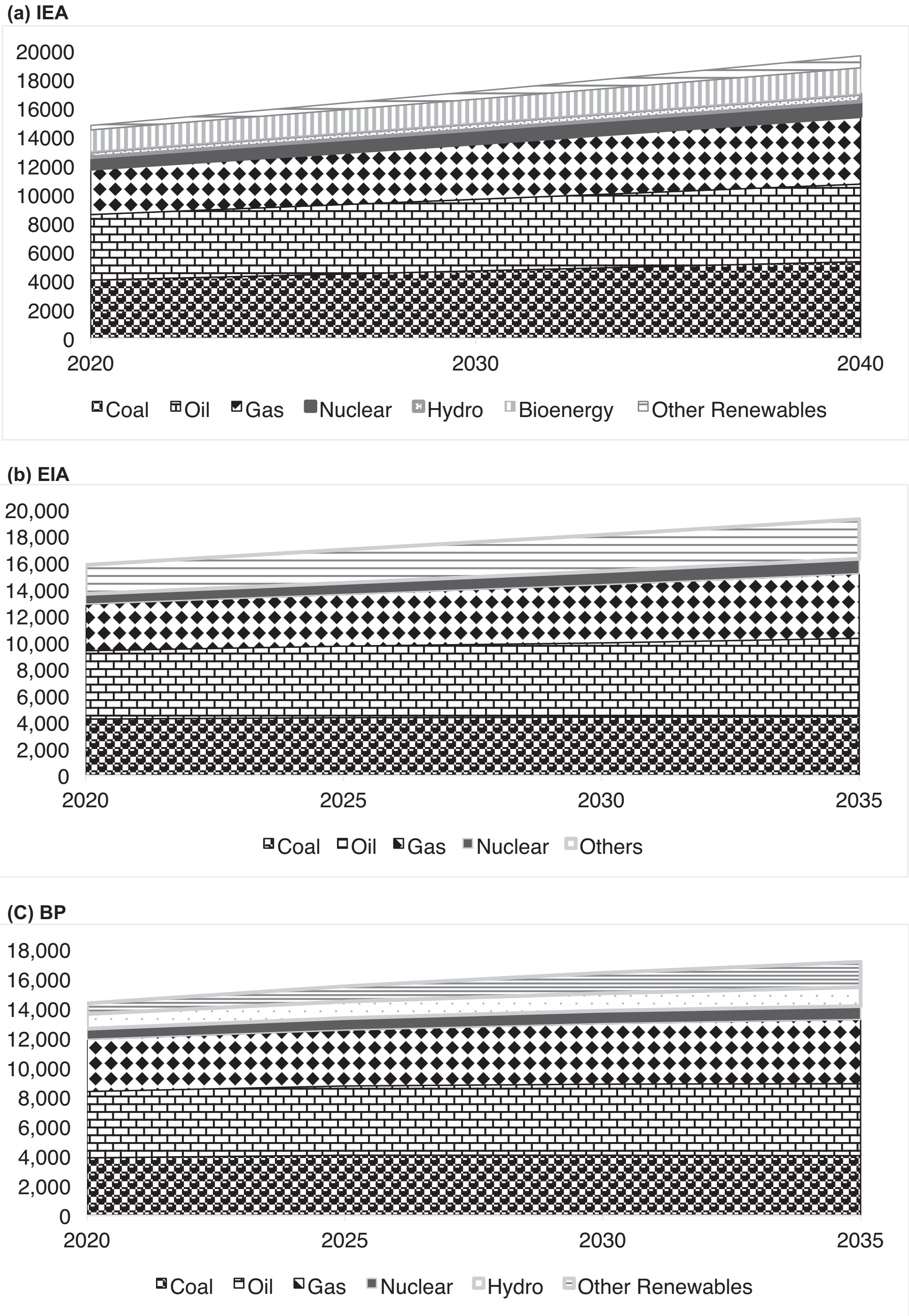

Figure 1.8 World energy demand forecasts by fuel type

Source: OCED and IEA (2016); EIA (2016) and BP (2017).

Table 1.2 Regional distribution of future energy consumption (%)

Forecasts	*OECD*				*Non-OECD*			
	2020	*2025*	*2030*	*2035*	*2020*	*2025*	*2030*	*2035*[a]
IEA	36%	n.a.	32%	28%	61%	n.a.	65%	68%
EIA	40%	39%	37%	36%	60%	61%	63%	64%
BP	40%	37%	34%	33%	60%	63%	66%	67%
	United States				China			
IEA	15%	n.a.	13%	12%	23%	n.a.	24%	23%
EIA	16%	15%	14%	14%	23%	24%	24%	24%
BP	17%	15%	14%	13%	24%	26%	26%	26%
	European Union				India			
IEA	11%	n.a.	9%	8%	7%	n.a.	9%	11%
EIA	13%	13%	13%	12%	5%	6%	6%	7%
BP	12%	10%	10%	9%	6%	7%	8%	9%
	Other OECD				Other Non-OECD			
IEA	10%	n.a.	10%	9%	31%	n.a.	32%	34%
EIA	11%	11%	10%	10%	31%	32%	33%	34%
BP	11%	11%	11%	10%	30%	31%	31%	32%

[a] IEA forecast is for year 2040.

Source: OECD and IEA (2016); EIA (2016) and BP (2017).

5 Conclusions

Being an essential input to economic growth and human well-being, energy demand increases along with population and per capita income, normally measured by GDP per person in a country. Historical data from more than 150 countries around the world reveals that energy demand has increased, on average, by 0.7% for each percent increase in GDP, on average, over the 45 years from 1971 to 2014. Historically, developed countries had a disproportionate share in global energy consumption. The trend has now reversed since 2005 due to rapid growth of energy demand in emerging economies along with their economic growth. Currently, China alone accounts for 40% of the total energy consumption of the non-OECD countries.

The current global climate change debate has put a strong pressure on the energy supply mix to meet the growing energy demand. This is important because the mix of fossil fuels and non-fossil fuels in meeting the global energy demand has not changed much over the last 45 years. In 1971, fossil fuels occupied 86% of the global energy demand; they still account for more than 80%. Despite the importance of new renewable energy sources (i.e. solar, wind, and geothermal) to combat global climate change, their current share in the global energy supply is negligible at around 1%, thereby indicating the scale of the efforts (e.g. public policies) needed to have significant substitution of fossil fuels with new renewable energy sources.

Although a large number of factors are identified in the literature that drive the energy demand, a careful look based on the historical data from more than 150 countries around the world suggests that economic (or GDP) growth is the primary driver of energy consumption in the long run, as income growth drives energy-consuming assets such as buildings, factories, and vehicles. In the short run, however, other factors such as energy prices, weather and special events affect the energy demand, as these factors influence utilization of energy consuming and producing facilities. Long-run energy projections made by reputed organizations, such as the International Energy Agency, the US Energy Information Administration, and a major oil company (British Petroleum) show that global energy demand would increase at an annual average rate of 1.2% to 1.4% over the next 20–25 years. Non-OECD countries will continue to occupy more than 60% of global energy consumption. Unless major policy shifts are made aiming to avoid global climate change, fossil fuels would still be predominant in the global energy supply mix, with a more than 75% share over the next two decades.

Notes

1 Ninety out of 110 countries for which data are available throughout the 1971–2014 period have energy demand elasticity with respect to GDP, in the range of 0.3 to 2.0. More than half of the countries (63) have energy-GDP elasticity between 0.6 and 1.5.

2 Please refer to existing studies such as Bhattacharya and Timilsina (2010a) for detailed discussions on energy demand modeling.

3 Bhattacharya and Timilsina (2010b) provides detailed comparisons of these models, their strengths and weaknesses, and their suitability.

4 Please see Malla and Timilsina (2016) for a simple account of energy demand estimations in different sectors for different end-uses.

5 The IEA uses its World Energy Model (WEM), which is an integrated model used by the IEA over the last 20 years to produce its world energy outlook each year. The energy outlook provides long-term energy demand forecasts by type of energy commodities and by major geographical regions or countries. The EIA uses its World Energy Projection System Plus (WEPS+) model. Like the WEM, it also has modular structure. Its end-use demand modules project demand for energy commodities in various sectors (i.e. residential, commercial, industrial, transport) and its transformation model produces energy mix to satisfy the demand (EIA 2016, Appendix L). It produces the energy demand and supplies for 16 regions/countries around the world. The BP energy demand forecasts are mainly based on secondary data on the key drivers of energy demand. It develops various scenarios based on current energy policies and uses experts' judgments over the evolution of various energy commodities in the future (BP 2017).

6 IEA projects that the share of coal in total primary energy supply falls to 13% by 2040 if policies are implemented to keep the global concentration of GHG emissions at 450 PPM level (IEA's 450 PPM scenario).

7 IEA projects that the share of renewable including hydro and biomass would increase from 16% in 2020 to 31% in 2040 under a scenario to keep the global GHG concentration at 450 PPM.

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