Chapter 3

Analysis of Energy Demand Supply Station

October 2016

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Chapter 3

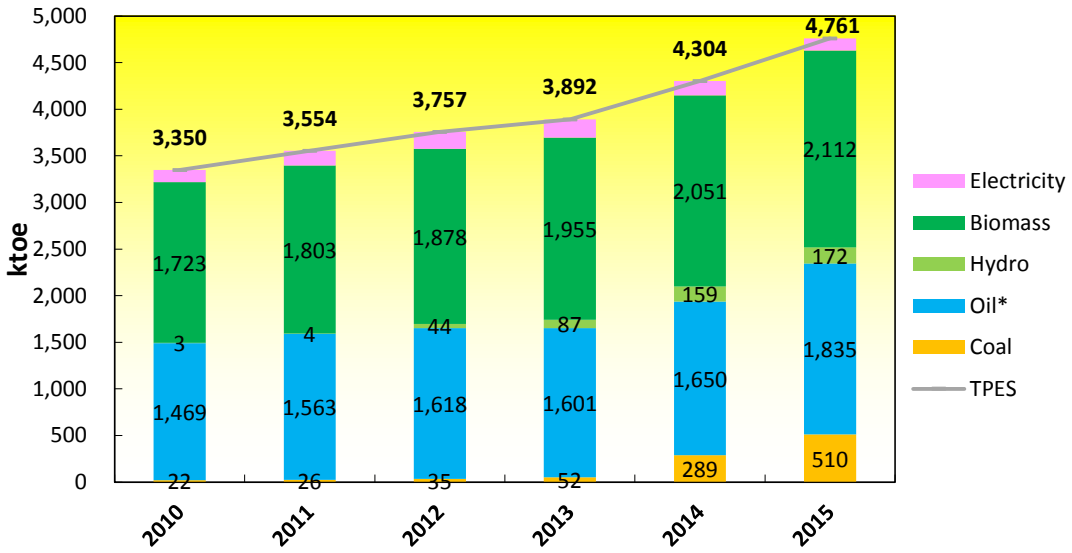
Analysis of Energy Demand Supply Situation

3.1 Primary Energy Supply

The total primary energy supply (TPES) of Cambodia increased from 3,350 kilotons of oil equivalent (ktoe) in 2010 to 4,761 ktoe in 2015 at an average annual growth of 7.3 percent (Figure 3.1). Coal and hydro have the highest increase over the 2010–2015 period because electricity demand has been increasing rapidly during that time. To meet this demand, the Government of Cambodia has commissioned new hydropower and coal power plants.

Electricity supply in Cambodia's TPES is through electricity imports. Electricity imports increased from 133 to 192 ktoe in 2010–2013. After 2013, its electricity imports declined to about 133 ktoe in 2015 due to the increase of domestic power generation.

Figure 3.1. Total Primary Energy Supply



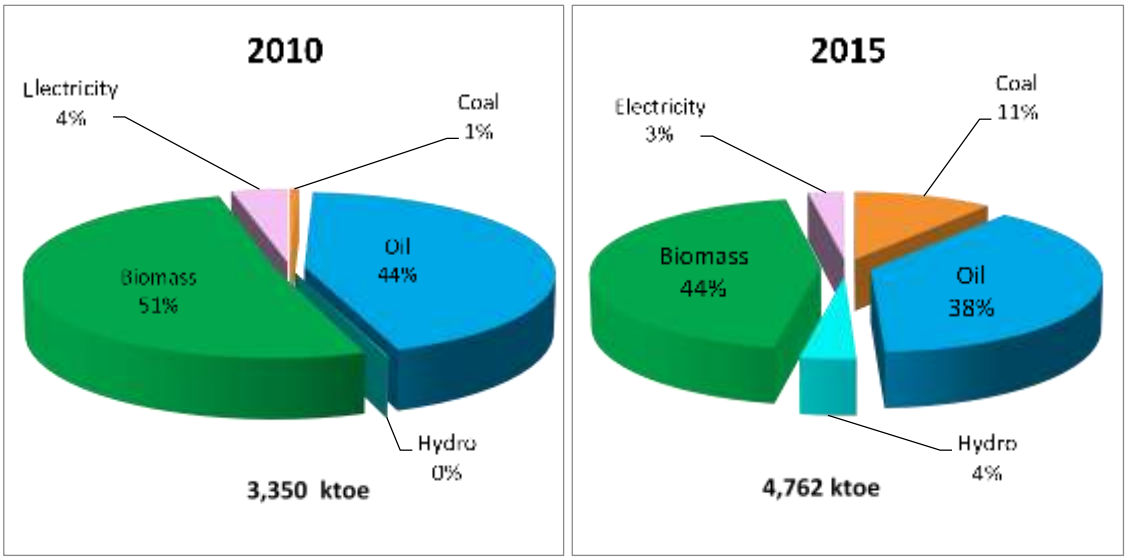
Note: *Oil includes additives for motor gasoline (MTBE) and petroleum products.
ktoe = kiloton of oil equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

The share of biomass in TPES was the largest in 2010 (51.4 percent), followed by petroleum (43.8 percent). By 2015, these two energy types remain the highest in the TPES mix but with decreasing shares.

The share of biomass decreased to 44.4 percent, whereas that of petroleum products is 38.5 percent (Figure 3.2). Both shares were relatively declining due to the high increase of coal and hydro demand in the power sector. Nonetheless, petroleum is still an important energy source, especially for the transport sector. Biomass, on the other hand, will be phased out gradually.

The share of coal in TPES increased to 10.7 percent in 2015 from 0.7 percent in 2010. The coal supply has increased significantly since 2014 since the Sihanoukville coal power plant came into full operation and the first unit of the CIIDG Erdos Hongjun Electric Power Co. Ltd coal power plant became operational. Hydro's share in TPES increased from 0.1 percent in 2010 to 3.6 percent in 2015 as more hydropower plants are being commissioned.

Figure 3.2. Energy Mix of the Total Primary Energy Supply



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Cambodia imports all of its coal and oil requirements. The import of oil increased on average by 4.1 percent per year from 2010 to 2015. Coal imports grew very fast during the same period to meet the power sector's requirement (Table 3.1). In total, the energy imports of Cambodia increased from 1,713 ktoe to 2,549 ktoe over 2010–2015 at an average rate of 8.3 percent per year.

Compared to energy imports, indigenous production of energy (hydro and biomass) grew at a slower rate of 5.8 percent per year. The majority of the biomass production is firewood. In the international context, the consumption of biomass equals its production.

Biomass production increased on average 4.1 percent per year from 1,723 ktoe in 2010 to 2,112 ktoe in 2015. Indigenous production of hydro was only 3 ktoe in 2010. By 2015, the production of hydro increased to 172 ktoe as hydropower plants are being commissioned to meet the increasing demand of electricity.

Table 3.1. Indigenous Production and Imports of Energy

Unit: ktoe

Year	Indigenous	Hydro	Biomass	Imports	Coal	Oil*	Electricity	Dependence on Imported Energy
2010	1,726	3	1,723	1,713	22	1,558	133	49.8
2011	1,807	4	1,803	1,791	26	1,608	157	49.8
2012	1,922	44	1,878	1,897	35	1,681	181	49.7
2013	2,043	87	1,955	1,925	52	1,676	196	48.5
2014	2,211	159	2,051	2,193	303	1,735	155	49.8
2015	2,284	172	2,112	2,549	510	1,906	133	52.7
AAGR	**5.8%**	**129.0%**	**4.1%**	**8.3%**	**86.8%**	**4.1%**	**–0.1%**	**-**

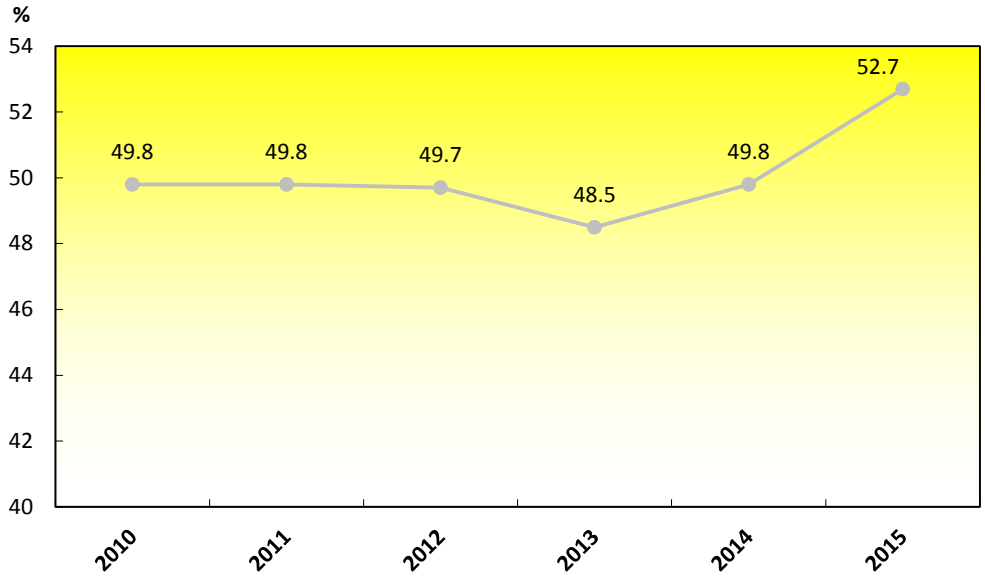
Note: *Oil includes additives for motor gasoline (MTBE) and petroleum products.
AAGR = average annual growth rate, ktoe = kiloton of energy equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Comparing the import of energy and indigenous production with the total, the share of indigenous production (51.2 percent) was slightly higher than that of imports (49.8 percent) in 2010. In 2015, the share of indigenous production decreased to 47.3 percent, whereas the import share increased to 52.8 percent. This is a consequence of the slowdown of biomass consumption due to the shift from traditional biomass to conventional energy.

The increasing share of imported energy compared with indigenous production implies that Cambodia is becoming more dependent on energy imports. Figure 3.3 shows the energy import dependency of Cambodia. As shown in the figure, the import dependency declined from 2010 to 2013 indicating that growth in imported energy is slower than indigenous production. The tenfold increase of hydropower production in 2012 and the twofold increase in 2013 contributed to this faster growth of indigenous production.

From 2013 to 2015, the energy imports increased faster than indigenous production as the coal requirement for power generation increased almost tenfold during this period. Consequently, the import dependency has increased and is expected to continue increasing as the demand for oil in the transport, industry, and residential sectors increases and more coal power plants under construction become operational.

Figure 3.3. Dependence on Imported Energy



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

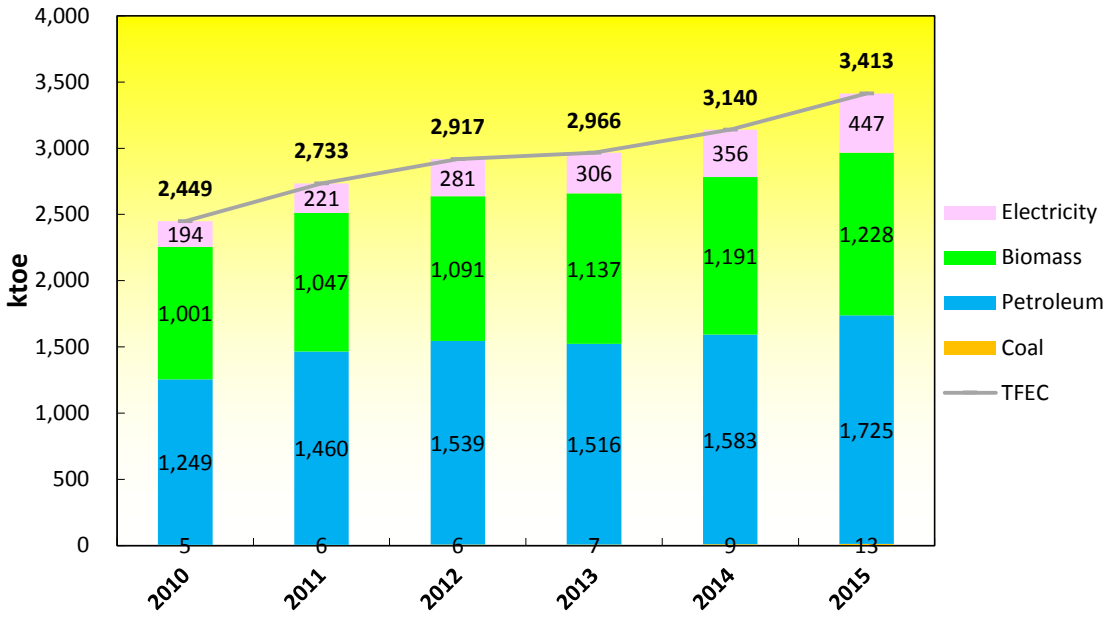
3.2 Total Final Energy Consumption

The total final energy consumption (TFEC) of Cambodia increased at an average annual growth rate of 6.9 percent – from 2,449 ktoe in 2010 to 3,413 ktoe in 2015 (Figure 3.4). By type of fuel, coal grew the fastest at 21.2 percent per year followed by electricity at 18.2 percent per year. Consumption of petroleum products and biomass, the major fuel consumed in Cambodia, grew at an annual average rate of 6.7 percent and 4.2 percent, respectively.

Although it increased the fastest over 2010–2015, especially for cement production, coal constitutes less than 0.5 percent of total consumption. On the other hand, petroleum products and biomass have a total share of more than 90 percent over the 2010–2015 period (Figure 3.5).

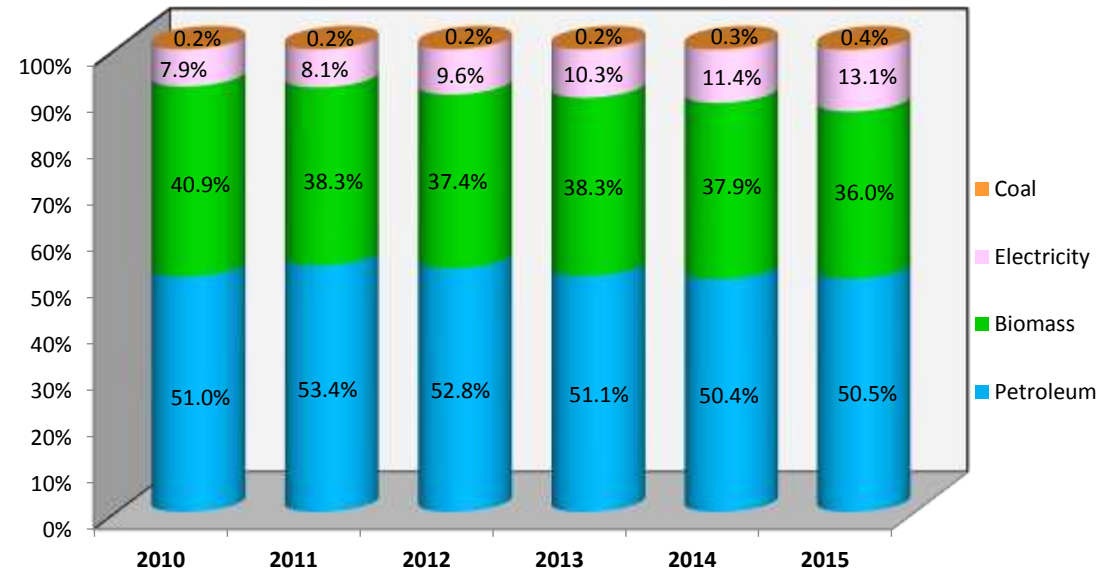
The transport sector consumed majority of the petroleum products. The average growth of the sector's consumption was 10.2 percent per year, from 950 ktoe in 2010 to 1,549 ktoe in 2015 (Table 3.2). The 'other' sector consumption covers the service (commercial and public), the residential, the agriculture, and other sectors. This sector's consumption increased from 1,014 ktoe in 2010 to 1,329 ktoe in 2015, at an average rate of 5.6 percent. The industry sector has the lowest energy consumption and experienced the slowest growth over 2010–2015. In the future, Cambodia shall promote economic zones and industrial zones; consequently, the industry sector has a large potential to increase energy demand, especially for electricity.

Figure 3.4. Total Final Energy Consumption (TFEC) by Fuel



ktoe = kiloton of oil equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Figure 3.5. Fuel Mix in Total Final Energy Consumption



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

The transport sector's consumption accounted for 39 percent of the TFEC in 2010 and reached almost 46 percent in 2015 (Figure 3.6). The industry sector's consumption accounted for around 20 percent of the TFEC in 2010 and declined to 16 percent in 2015.

Table 3.2. Total Final Energy Consumption by Sector

Unit: ktoe

Year	Total								Of Which Non-energy Use
		Industry	Transport	Other	Service	Residential	Agriculture	Others	
2010	2,449	483	952	1,014	133	849	32	0.2	14
2011	2,733	518	1,090	1,131	154	933	38	0.5	19
2012	2,917	546	1,250	1,126	153	923	43	0.9	17
2013	2,966	530	1,259	1,182	166	969	42	0.6	19
2014	3,140	543	1,354	1,245	161	1,020	50	11.1	14
2015	3,413	535	1,549	1,341	238	1,052	38	0.6	47
AAGR	**6.9%**	**2.1%**	**10.2%**	**5.6%**	**12.4%**	**4.4%**	**3.4%**	**26.8%**	**27.7%**

AAGR = average annual growth rate, ktoe = kiloton of energy equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

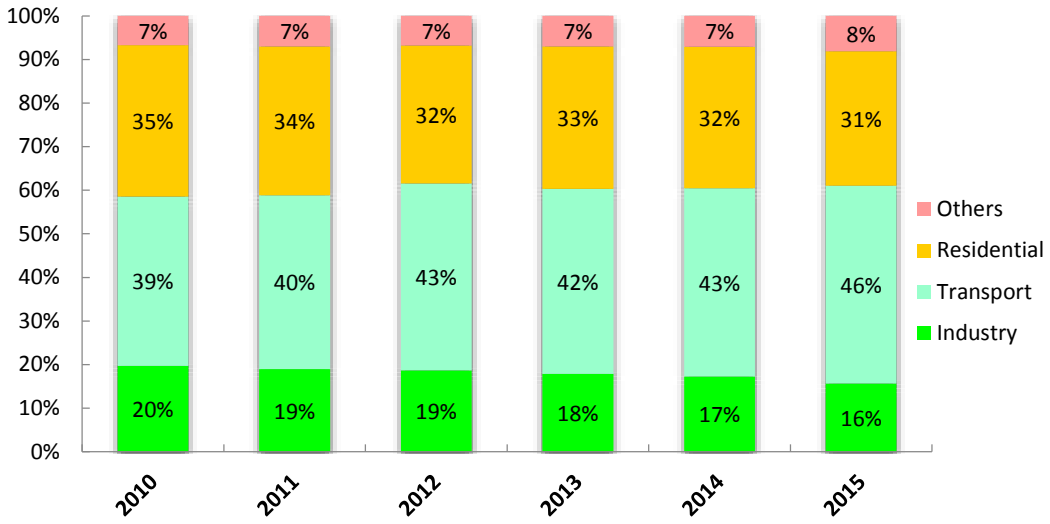
Table 3.3 Coal Supply and Consumption

Unit: ktoe

Year	Supply	Consumption		
			Electricity Generation	Industry
2010	22	22	17	5
2011	26	26	20	6
2012	35	35	29	6
2013	52	52	46	7
2014	303	289	279	9
2015	510	510	497	13
AAGR	**86.8%**	**86.8%**	**95.6%**	**21.2%**

AAGR = average annual growth rate, ktoe = kiloton of energy equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Figure 3.6. Total Final Energy Consumption by Sector



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Biomass has the largest share in the total consumption of the sector, followed by petroleum products. The share of these fuels in the industry sector's total consumption declined as the supply of electricity from EDC became more stable.

The 'other' sector has the second highest share in the TFEC: 35 percent in 2010 and 31 percent in 2015. Around 84 percent of the 'other' sector's consumption in 2010 is that of the residential sector (or 34.7 percent of the TFEC) with fuelwood being the main fuel consumed by this sector. By 2015, the share of the residential sector in the TFEC decreased 31 percent.

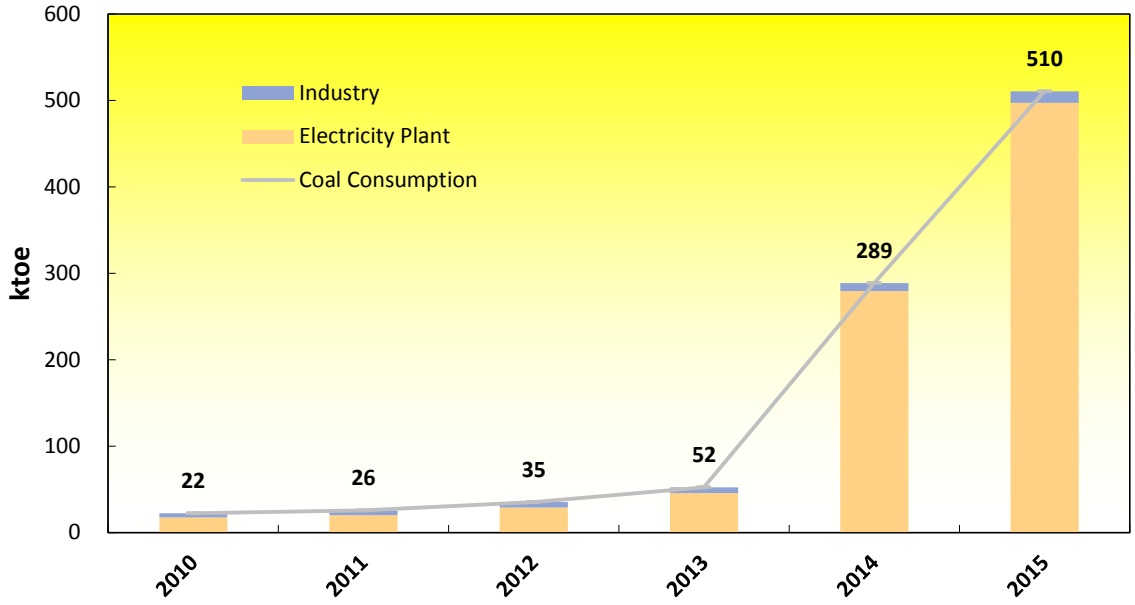
The remaining sectors (service, agriculture, and others) have the smallest share in the TFEC but experienced the fastest growth over the 2010–2015 period. The service sector's consumption grew at an average rate of 12.4 percent per year, increasing its share in the TFEC from 5.4 percent in 2010 to 7.0 percent in 2015 mainly as a result of the rapid increase in electricity consumption.

3.3 Supply and Consumption by Energy Products

The coal supply and consumption of Cambodia is shown in Table 3.3. Cambodia imports coal to meet the demand of the power and industry sectors. Over the 2010–2015 period, coal increased by 86.8 percent per year due to the rapid increase of consumption in the power sector. The sector's consumption increased from 17 ktoe in 2010 to 497 ktoe in 2015. The increase in coal use for power generation is in line with the government plan to reduce oil-based power generation in the country. Consumption of coal in power generation increased significantly since the plant in the Stung Hav district, Preah Sihanouk province started operation in early February 2014.

Coal consumption for power generation accounted for 77 percent in 2010, whereas the share for industry was 23 percent. In 2015, coal consumption of industry grew slower than power generation, resulting in a higher share of coal use for generating electricity. The share of coal for power generation reached 97 percent in 2015, whereas the share of coal consumption in industry declined relatively to around 3 percent (Figure 3.7).

Figure 3.7. Coal Consumption



ktoe = kiloton of energy equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Cambodia imported all of its oil requirements (petroleum products and additives for motor gasoline, MTBE). Total imports amounted to 1,558 ktoe in 2010 increasing to 1,896 ktoe in 2015 (Table 3.4). Some of the imported petroleum products were used to supply the need of international aviation and were thus deducted to derive TPES. Similarly, the increasing stock of petroleum products will also be deducted from imports while the reduction of stock implies an increase for domestic supply. In Table 3.4, supply refers to the imported petroleum products and thus will have a higher figure than consumption.

Table 3.4. Petroleum Products, Supply and Consumption

Unit: ktoe

Year	Supply	Consumption	Electricity Generation	Own Use	Total Final Energy Consumption							Of Which Non-energy Use
					Industry	Transport	Other	Service	Residential	Agriculture	Others	
2010	1,558	1,429	178	2	192	952	105	56	17	32	2	14
2011	1,608	1,653	191	2	204	1,090	166	61	67	38	5	19
2012	1,681	1,727	185	2	197	1,250	92	44	4	44	5	17
2013	1,676	1,645	112	17	177	1,259	81	34	5	42	5	19
2014	1,735	1,664	64	16	154	1,354	75	20	4	50	3	14
2015	1,896	1,786	45	16	112	1,549	64	21	5	38	0	47
AAGR	**4.0%**	**4.6%**	**−24.1%**	**52.4%**	**−10.2%**	**10.2%**	**−9.5%**	**−18.0%**	**−21.4%**	**3.4%**	**37.4%**	**27.7%**

Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Table 3.5. Consumption of Petroleum Products by Product

Unit: ktoe

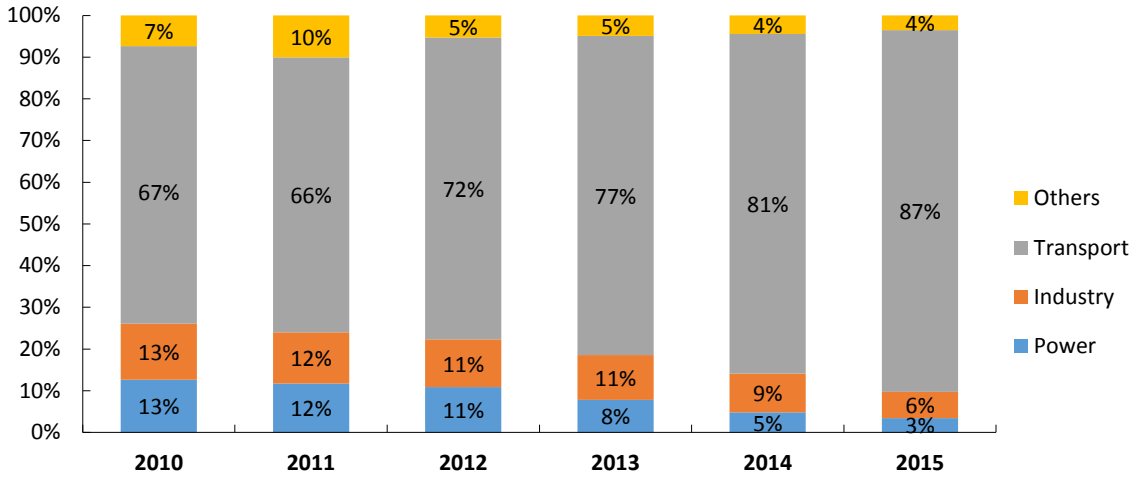
Year	Total	Motor Gasoline	Jet Fuel	Kerosene	Gas/ Diesel Oil	Fuel Oil	LPG	Other Petroleum Products
2010	1,429	392	3	24	649	306	42	14
2011	1,653	391	4	67	785	338	49	19
2012	1,727	421	4	5	910	316	54	17
2013	1,645	419	3	3	916	222	64	19
2014	1,664	455	5	0	979	136	75	14
2015	1,786	516	6	0	1,013	76	110	66
AAGR	**4.6%**	**5.6%**	**15.2%**	**−100.0%**	**9.3%**	**−24.4%**	**21.1%**	**37.0%**

AAGR = average annual growth rate, LPG = liquid petroleum gas.

Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Petroleum products are consumed by the final sectors (industry, transport, service, residential, and others) and for power generation and own use. The transport sector is the major consumer of petroleum products, growing on average 9.7 percent per year, with shares almost 67 percent of the total petroleum products' consumption in 2010 and 87 percent in 2015 (Figure 3.8).

Figure 3.8. Consumption of Petroleum Products by Sector



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

In industry, the consumption of petroleum products decreased at an average rate of 10.2 percent per year, reducing the share in the total consumption from 13 percent in 2010 to 6 percent in 2015. The industry sector is equipped with a self-generating system using diesel in case of a blackout. However, since the current public electricity supply is very stable, petroleum consumption in the industry sector shows a downward trend. Similarly, the power sector's consumption of petroleum products also declined rapidly at an average rate of 24.1 percent per year. This reduction corresponds to the government programme of increasing the share of hydro and coal as substitutes to oil products.

The overall consumption of the 'other' sectors – comprising service, residential, agriculture, and other sectors – also declined at an average rate of 9.5 percent per year. The service sector consumed the most, and reduced consumption in this sector implies that a substitution has occurred in this sector as in the industry sector.

By type of petroleum product, diesel is the main fuel consumed by the sectors. Total diesel consumption increased at an average rate of 9.3 percent per year, from 649 ktoe in 2010 to 1,013 ktoe in 2015 (Table 3.5). The share of diesel among all the petroleum products reached around 57 percent in 2015, increasing from 45 percent in 2010. Motor gasoline accounted for about 29 percent of the total consumption in 2015, higher than it was in 2010 (27 percent). This implies that

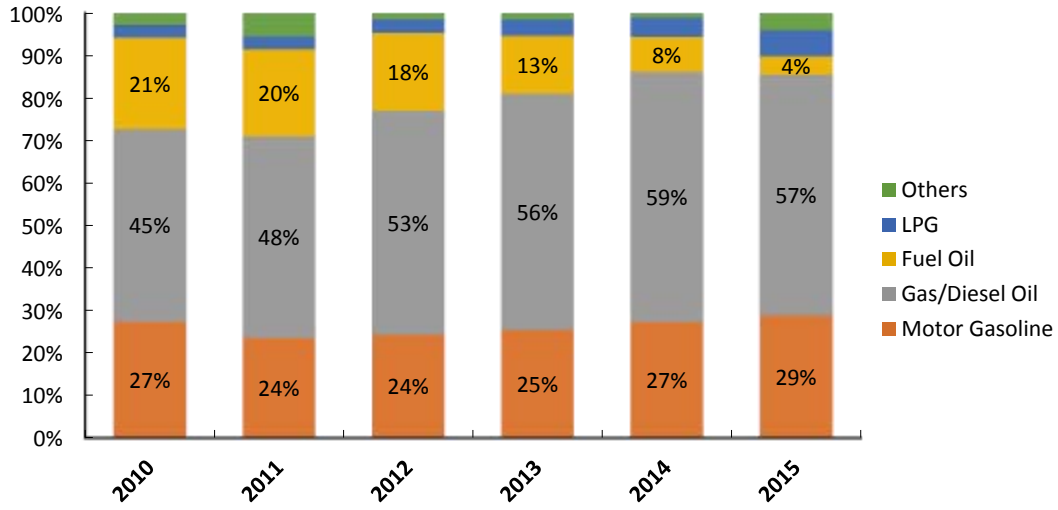
motor gasoline consumption also increased over the 2010–2015 period, but at a slower rate than diesel which is widely used across the sectors. The average growth rate for motor gasoline was 5.6 percent per year.Fuel oil had the third largest share of petroleum products consumed in 2010 (21 percent). Its consumption decreased significantly from 306 ktoe to 76 ktoe over the 2010–2015 period. The share of fuel oil in the total consumption of petroleum products was 4 percent in 2015 (Figure 3.9). Since the majority of fuel oil is consumed by the power sector, the significant decline in consumption is a sign of the shift to non-oil power generation system.

The share of liquid petroleum gas (LPG) in the total consumption of petroleum products was around 3 percent in 2010 and increased to 6 percent in 2015. Although the share of LPG is small, its consumption has increased significantly over the 2010–2015 period, at an average rate of 21.1 percent per year. The increasing consumption of LPG substituted the consumption of kerosene in the residential sector. Kerosene is no longer consumed since 2014.

Domestic jet fuel consumption was only 3 ktoe in 2010 and has increased to 6 ktoe in 2015. The significant increase of jet fuel consumption over this period, which on average was 15.2 percent per year, indicates the increase of air travel between cities in Cambodia.

The consumption of other petroleum products covers mainly lubricants. The consumption of lubricants increased almost threefold from 12 ktoe in 2010 to 47 ktoe in 2015 at an average rate of 28 percent per year due to the increase in the number of vehicles.

Figure 3.9. Petroleum Products Consumption by Products



LPG = liquid petroleum gas.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

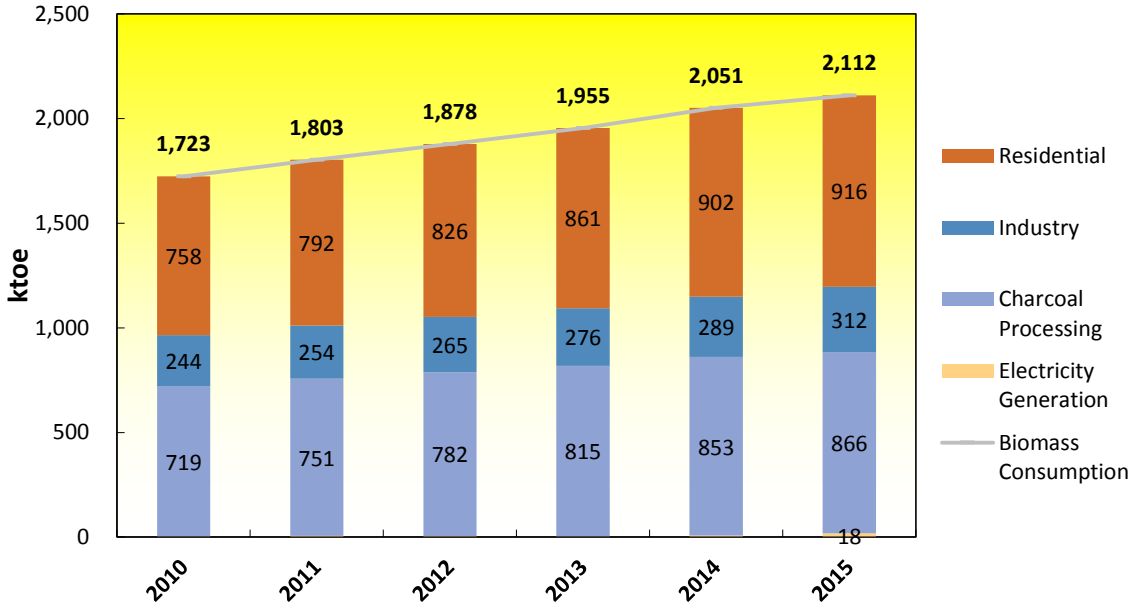
Biomass is the other major energy product consumed in the electricity generation, charcoal processing, industry, and residential sectors. Total biomass

consumption increased from 1,723 ktoe in 2010 to 2,112 ktoe in 2015 at an average rate of 4.2 percent per year. The residential sector is the largest consumer of biomass followed by charcoal processing, industry, and electricity generation (Figure 3.10).

Biomass consumption in the residential sector accounted for 43.4 percent of the total biomass consumption in 2015 whereas the share in industry was almost 15 percent. Compared with 2010, the share of biomass in the residential sector was smaller where it was higher in the industry sector. This indicates that the consumption of biomass in industry grew faster than that of the residential sector. On average, the annual growth rate of biomass consumption in the industry sector was 5.1 percent while in the residential sector it was 3.9 percent. Biomass will fade due to substitution to convenient energy forms such as LPG.

Biomass, particularly fuelwood, is used to produce charcoal. The amount of wood needed to produce charcoal was 719 ktoe in 2010 and had increased to 866 ktoe in 2015. Charcoal is consumed by the residential sector. An increase in the production of charcoal indicates an increase in the residential sector's consumption.

Figure 3.10. Biomass Consumption



ktoe = kiloton of oil equivalent.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Biomass consumption for generating electricity was 3 ktoe in 2010, only around 0.2 percent of the total biomass consumption. The consumption increased to 18 ktoe in 2015 resulting in an average increase of 47.4 percent per year. Biomass use is expected to increase in the future in compliance with government plans to increase the use of renewables in electricity production to support rural

electrification.

3.4 Power Generation

Cambodia's electricity supply increased on average by 19.7 percent per year from 2,515 GWh in 2010 to 6,186 GWh in 2015 (Table 3.6). Electricity imports from neighbouring countries (Viet Nam, Thailand, and the Lao PDR) accounted for 61 percent of total supply in 2010 and 25 percent in 2015. The amount decreased slightly, from 1,546 GWh in 2010 to 1,541 GWh in 2015. Considering that import amount is more or less the same, the significant reduction in the import shares indicates a significant increase in the domestic production. Electricity production increased almost fourfold during 2010–2015, from 968 GWh to 4,645 GWh.

Table 3.6. Electricity Generation

Unit: GWh

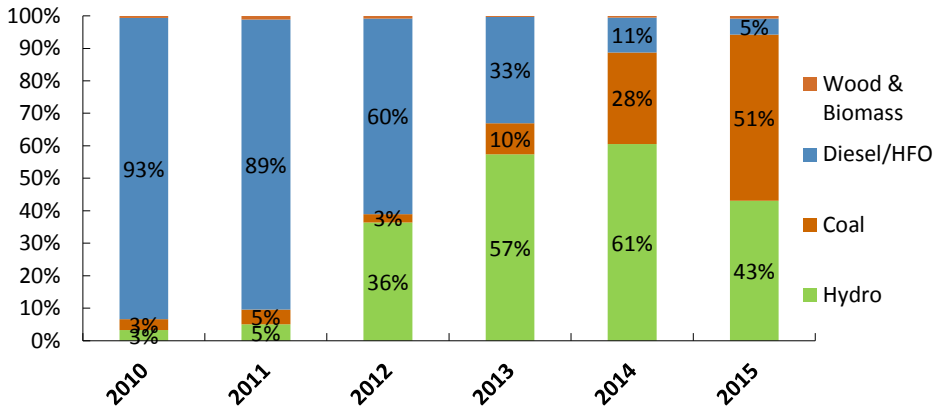
Year	Total	Hydro	Coal	Diesel/HFO	Biomass	Import
2010	2,515	32	32	899	6	1,546
2011	2,848	52	47	909	12	1,830
2012	3,527	517	37	857	12	2,104
2013	4,052	1,016	169	579	7	2,282
2014	4,861	1,852	863	327	17	1,803
2015	6,186	2,000	2,376	228	40	1,541
AAGR	**19.7%**	**129.0%**	**136.6%**	**– 24.0%**	**47.4%**	**– 0.1%**

AAGR = average annual growth rate, GWh = gigawatt-hour, HFO = heavy fuel oil.
Source: Electricity Authority of Cambodia.

Hydropower plants contributed 43 percent of the domestic generation in 2015, while the share was only 3 percent in 2010. Coal also had the same share as hydro in 2010, but the share increased to 51 percent in 2015, indicating a faster growth than that of hydro.

Increased generation from both hydropower and coal power plants is in accordance with the plan to reduce generation from oil-based power plants. Generation from oil-based power plants was dominant in 2010, accounting for 93 percent of total generation. In 2015, the share of oil-based power generation was reduced to 5 percent. The generation of oil-based power plants declined at an average rate of 24 percent per year.

Figure 3.11. Domestic Electricity Generation



HFO = heavy fuel oil.
Source: Electricity Authority of Cambodia.

Total electricity consumption was 2,283 ktoe in 2010, increasing to 5,398 ktoe in 2015 at an average rate of 19 percent per year (Table 3.7). Of the total consumption in 2010, around 29 ktoe (1.3 percent) is own use, while the remainder is for the final sectors (industry, residential, service, and others). Own use increased almost sevenfold in 2015, reaching 197 ktoe and indicating more new plants in operation.

Table 3.7. Electricity Consumption

Unit: GWh

Year	Total	Own Use	Final Sectors					Distribution Loss
				Industry	Service	Residential	Other	
2010	2,283	29	2,254	490	893	869	2	231
2011	2,605	32	2,572	630	1,082	854	6	244
2012	3,314	48	3,265	900	1,276	1,079	10	214
2013	3,620	68	3,552	820	1,539	1,187	6	431
2014	4,244	100	4,144	1,054	1,639	1,323	127	618
2015	5,398	197	5,201	1,137	2,530	1,527	7	788
AAGR	**18.8%**	**46.3%**	**18.2%**	**18.3%**	**23.2%**	**11.9%**	**26.8%**	**27.8%**

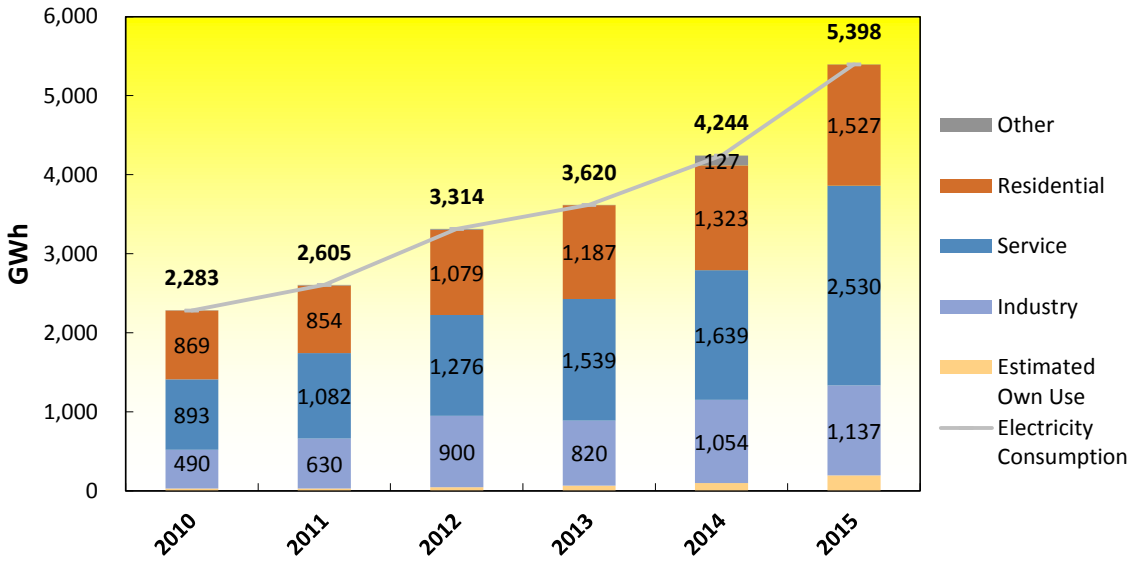
AAGR = average annual growth rate, GWh = gigawatt-hour.
Source: Electricity Authority of Cambodia.

Electricity consumption of the final sectors was 2,254 GWh in 2010. Of this total, the service sector's consumption accounted for 40 percent whereas the residential sector's share was 39 percent. The remaining 22 percent was the share of the industry and other sectors.

By 2015, the electricity consumption of the final sectors increased to 5,201 GWh at an average rate of 18.2 percent per year. The service sector's consumption increased at a faster rate of 23.2 percent per year as more hotels, hospitals, schools, and other commercial buildings were being constructed. The industry sector's electricity consumption increased at an annual average rate 18.3 percent per year while that of the residential and other sectors increased at 11.9 percent per year.

The consumption share of the final sectors to total consumption of electricity decreased to 96 percent in 2015 because the own use share increased to 4 percent (Figure 3.12). Since consumption in the service sector increased faster than in the industry and residential sectors, the share of the service sector to total electricity consumption increased to 49 percent, respectively, while the industry sector's share declined to 22 percent and the residential and other sectors' share, to 29 percent.

Figure 3.12. Electricity Consumption



GWh = gigawatt-hour.
Source: Electricity Authority of Cambodia.

The distribution losses compared to total consumption was projected to increase during 2010–2015. The losses in term of percentage would increase from around 10 percent to almost 14 percent.

3.5 Energy Indicators

Energy consumption is the result of human activities. Therefore, analysing the links between such human activities and energy consumption makes sense. These activities are (i) producing primary and secondary products, (ii) transporting persons

or cargo from point A to point B, (iii) service activities, (iv) household activities, and (v) agriculture, forestry, and fishery.

This chapter, however, focuses on overall activities, such as population and GDP, and analyses the relationship between macro indicators and energy consumption as follows: (i) TPES/GDP, (ii) factor analysis of TPES/GDP, and (iii) CO_2/GDP and CO_2/TPES.

These are called energy indicators and describe the link between energy consumption and human activity. They usually refer to a ratio between an energy consumption indicator and 'human activities', such as energy consumption per capita or energy consumption per unit of GDP (Trudeau, 2012).

Energy intensity (in TPES/GDP) is a measure of the amount of energy it takes to produce a dollar's worth of economic output, or conversely the amount of economic output that can be generated by one standardised unit of energy. The value varies widely between countries, depending on the country's level of industrialisation, the mix of services and manufacturing in the economies, and the efforts provided towards energy efficiency.

GDP is a popular index reflecting a country's economy. It is easily found in national accounts and statistics. GDP may be expressed in a national currency, US dollars, international dollars (using PPP conversions), or another common currency. The PPP conversion factor for GDP is the number of units of a country's currency required to buy the same amount of goods and services in the domestic market as US dollars would buy in the US.

3.5.1 Energy and economics

The real GDP of Cambodia increased at an average rate of 7.2 percent per year from 2010 to 2015. GDP, measured in purchasing power parity (PPP) at constant 2011 international dollars, increased from around $36 billion (at constant 2011 PPP) in 2010 to $51 billion (at constant 2011 PPP) in 2015. Garments, construction, agriculture, and tourism have driven Cambodia's growth. The garment industry accounts for about 70 percent of Cambodia's total exports and has been one of the key pillars of the economy.

The population has grown on average by 1.6 percent per year, from 14.4 million to 15.5 million over the same period. The TPES/capita indicator increased at an average annual growth of 5.6 percent from 0.23 tons of oil equivalent (toe) per person to 0.36 toe/person, while the TPES/GDP indicator remained around 0.09 toe per $1,000 (at constant 2011 PPP) over the 2010–2015 period (Table 3.8).

Figure 3.13 shows the relative changes of GDP, population, TPES, and energy indicators (TPES/GDP and TPES/capita) with 2010 as the baseline (2010 = 100). As

shown, the energy consumption per capita indicator changes in the same way as TPES but at a slower rate of growth. The increase in the energy consumption per capita is common for emerging economies in line with the growth in GDP per capita, electrification, and similar development programmes.

Table 3.8. Energy and Economic Indicators

Year	TPES	GDP	Population	TPES/GDP	TPES/Capita
	ktoe	$ million (constant 2011 PPP)	thousand persons	toe/$ '000 (constant 2011 PPP)	toe per capita
2010	3,350	36,100	14,365	0.093	0.233
2011	3,554	38,652	14,605	0.092	0.243
2012	3,757	41,459	14,864	0.091	0.253
2013	3,892	44,560	15,087	0.087	0.258
2014	4,304	47,711	15,313	0.090	0.281
2015	4,761	51,068	15,543	0.093	0.306
AAGR	**7.3%**	**8.9%**	**1.6%**	**0.1%**	**5.6%**

AAGR = average annual growth rate, GDP = gross domestic product, ktoe = kiloton of oil equivalent, PPP = purchasing power parity, toe = ton of oil equivalent, TPES = total primary energy supply.
Sources: National Statistics Office; IMF (2016), World Economic Outlook Database.

There is relatively small improvement in energy intensity (TPES/GDP) from 2010 to 2015. Energy intensity slightly declined from 2010 to 2013 and then increased to the 2010 level from 2013 to 2015, indicating a faster growth of TPES compared to GDP as a result of the rapid increase of coal consumption.

The energy intensity and GDP growth have separate effects on the change in energy consumption. As shown in Table 3.9 and Figure 3.14, an improvement in the energy intensity (intensity effect) decreased TPES in 2010–2015. GDP growth (production effect), on the other hand, increased TPES.

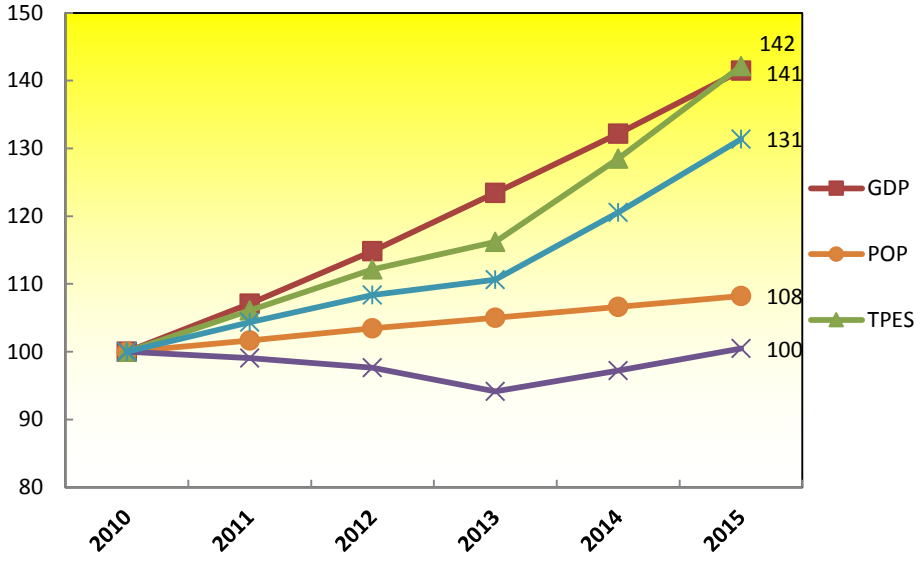
Table 3.9. Factor Analysis of Energy Consumption

Unit: ktoe

Year	Change in TPES	Intensity Effect	Production Effect	Cross Term
2011	203.874	−106.957	301.750	9.082
2012	203.143	−127.016	319.362	10.797
2013	135.115	−209.682	327.171	17.627
2014	412.453	68.742	349.289	−5.578
2015	456.655	112.598	352.391	−8.334
2010–2015	**1,411.2**	**−372.6**	**1,654.4**	**129.5**

ktoe = kiloton of oil equivalent, TPES = total primary energy supply.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Figure 3.13. Total Primary Energy Supply and Energy Intensity



GDP = gross domestic product, POP = population.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

TPES is measured as the energy intensity multiplied by GDP:

$$\text{TPES} = \text{TPES/GDP} \times \text{GDP}$$

The intensity effect is estimated as:

$$\triangle(\text{TPES/GDP}) \times \text{GDP}$$

The production effect is estimated as:

$$(\text{TPES/GDP}) \times \triangle\text{GDP}$$

Thus, the impact of the effects to TPES can be estimated as:

$$\triangle\text{TPES} = \triangle(\text{TPES/GDP}) \times \text{GDP} + \text{Intensity Effect}$$
$$(\text{TPES/GDP}) \times \triangle\text{GDP} + \text{Production Effect}$$
$$\text{Crossover Term}$$

Crossover term is just a term for the difference between the impacts of both effects with the changes in TPES.

3.5.2 Energy and CO_2 emissions

CO_2 emissions from fuel combustion can be calculated using the reference and the sectoral approaches as suggested in the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories. The reference approach provides simple estimates for CO_2 emissions from all fuel combustion and some fugitive emissions.

The sectoral approach provides estimates of CO_2 emissions from the main

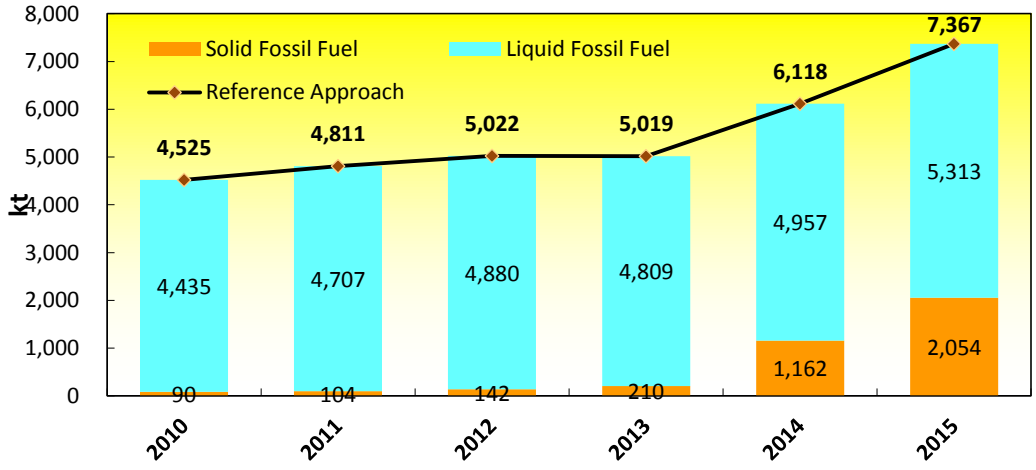
groups of fuel-using activities; as such, information is essential for monitoring and abatement of emissions.

The reference approach is often applied to countries with insufficient data for the sectoral approach. National fuel supply statistics are used to calculate the carbon flows. The sectoral approach uses the delivery or consumption of fuels to each of the main source categories, together with their carbon content, to estimate CO_2 emissions (Simmons, n.d.).

The reference approach was used to estimate the CO_2 emissions of Cambodia based on the Cambodia Energy Balance Table 2010–2015. The calculation showed that CO_2 emissions increased from 2010 to 2015 at an average rate of 10.2 percent per year. The major sources of CO_2 emissions from fuel combustion are solid fossil fuel (coal) and liquid fossil fuel (oil). CO_2 emissions from coal combustion contributed only 2 percent in 2010 because the use of coal constituted only 1 percent of the total primary energy consumption. Oil consumption, on the other hand, already accounted for 43 percent of the country's total fuel use. Therefore, the majority of CO_2 emissions came from burning oil in 2010 (Figure 3.14).

Since the transport sector consumed most of the oil, the burning of gasoline and diesel fuel contributed most to the emission, particularly from the use of motor vehicles in Phnom Penh. Total CO_2 emissions from oil combustion were 4,435 kilotons (kt) in 2010. By 2015, CO_2 emissions from oil has increased to 5,313 kt as the number of vehicles continues to increase and as the shift from biomass continues to occur in the industry and residential sectors. Emissions of CO_2 from coal combustion are also increasing, but at a faster rate than from oil combustion. The commissioning of new coal power plants contributed to this increase as coal consumption increased 23 times compared with 2010.

Figure 3.14. CO_2 Emissions from Fuel Combustion by Sector



kt = kiloton.
Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

Table 3.10 shows the energy and CO_2 emissions indicators. CO_2 intensity measures the impact of an increase in GDP or TPES on the absolute emissions of CO_2. The intensities (CO_2/GDP and CO_2/TPES) increased from 2010 to 2015 but at different average annual growth rates. For the CO_2/GDP intensity, the increase was 1.4 percent per year, from 0.12 to 0.13 tons of CO_2 per thousand dollars in PPP. The CO_2/TPES intensity increased at a faster rate of 2.9 percent per year, from 1.29 tons of CO_2 per ton of oil equivalent in 2010 to 1.49 tons of CO_2 per ton of oil equivalent in 2015.

Table 3.10. Energy and CO_2 Emissions Indicators

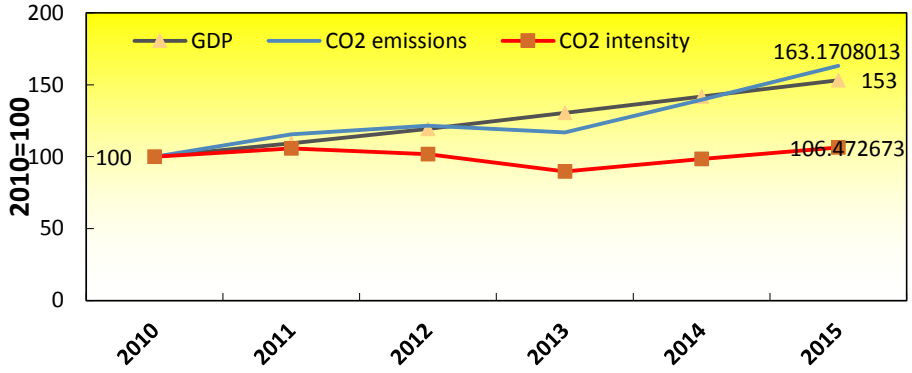
Year	Total Primary Energy Supply	GDP	CO_2 Emissions	CO_2/GDP	CO_2/TPES
	ktoe	10^6 USD in PPP	kt CO_2	ton CO_2/ $'000 PPP	ton CO_2/toe
2010	3,349.8	35,370	4,324	0.122	1.291
2011	3,553.7	38,652	4,992	0.129	1.405
2012	3,756.8	42,243	5,244	0.124	1.396
2013	3,892.0	46,120	5,042	0.109	1.295
2014	4,304.4	50,193	6,016	0.120	1.398
2015	4,761.1	54,205	7,100	0.131	1.491
AAGR	**7.3%**	**8.9%**	**10.4%**	**1.4%**	**2.9%**

AAGR = average annual growth rate, CO_2 = carbon dioxide, GDP = gross domestic product, kt = kiloton, ktoe = kiloton of oil equivalent, PPP = purchasing power parity, toe = ton of oil equivalent, TPES = total primary energy supply.
Sources: National Statistics Office; International Monetary Fund, 2016. World Economic Outlook Database.

Emissions intensities from fuel combustion are influenced primarily by shifts in energy intensity, economic structure, and fuel mix. They are not directly correlated with changes in activity levels (GDP and population). Absolute emissions levels, on the other hand, are most strongly influenced by GDP shifts. When GDP rises, emissions also tend to rise correspondingly (Figure 3.15) (Baumert, Herzog, and Pershing, 2005).

As explained previously, garments, construction, agriculture, and tourism have driven Cambodia's growth, resulting in GDP growth of almost 9 percent per year between 2010 and 2015. Oil and coal play an increasing role in achieving the growth in GDP, consequently resulting in high CO_2 emissions. Figure 3.16 shows the relative changes of GDP, CO_2 emissions, and CO_2 intensity with 2010 as a baseline (2010 = 100).

Figure 3.15. Relationship between CO_2 Emissions and Gross Domestic Product

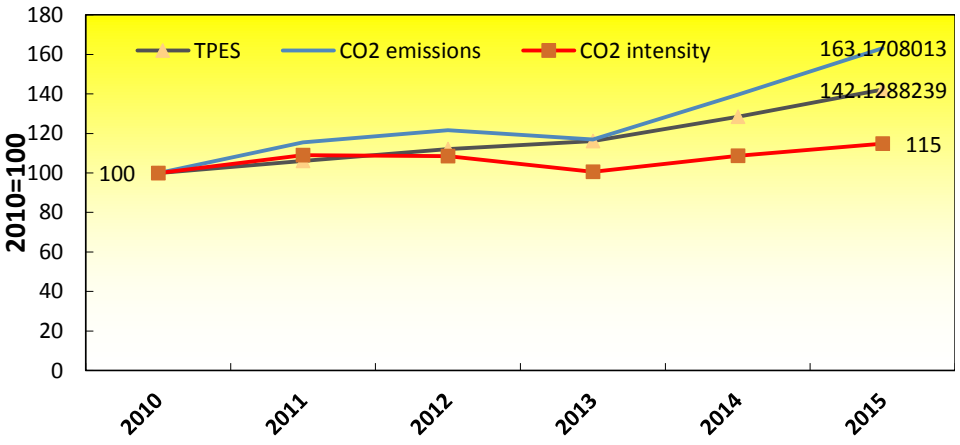


Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.

As shown, GDP and CO_2 emissions moved in tandem, while the CO_2/GDP intensity was less affected. By 2015, GDP and absolute CO_2 emissions increased 53 and 63 percent, respectively. The intensity, on the other hand, increased only 6 percent in 2015.

Similarly, TPES also moved in the same way as GDP, but slower. By 2015, TPES and absolute CO_2 emissions increased 42 and 63 percent, respectively. The changes in absolute emissions come from the increment of petroleum products. After 2013, coal use increased and resulted in higher CO_2 emissions. The CO_2/TPES intensity is affected more than the CO_2/GDP intensity. By 2015, the CO_2/TPES intensity increased 15 percent.

Figure 3.16. Total Primary Energy Supply, CO_2 Emissions, and CO_2 Intensity



Source: ERIA, calculated from the Cambodia Energy Balance Table 2010–2015.