Chapter 3

Treatment of Missing and Inconsistent Energy Data

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The GDE and GDP-MME provided the country's 2000–2009 and 2019 primary energy data to update the energy statistics 2010–2018. Table 3.1 shows the primary energy data of coal, electricity (which includes petroleum consumption for power generation), and biomass as provided by the GDE-MME. On the other hand, Table 3.2 shows the import of petroleum products as supplied by the GDP-MME. Some of the data were missing and were estimated. The data were also checked for inconsistency.

The sections below explain the method applied to estimate the missing data and revise the inconsistent data of Cambodia's energy statistics from 2000 to 2019.

1.   Coal

1.1   Coal consumption

As described in chapter 2, coal is consumed for power generation and industrial production. Since coal power generation started in 2008, we assume that no coal was consumed to generate power before 2008. As for industrial production, the GDE provided coal consumption data only from 2010 onwards. Considering that the major industrial subsectors of Cambodia are garment and food and beverage, we assume that no coal was consumed for the industry before 2010.

1.2.   Coal supply

Coal import data was not available from the GDE before 2014. Since then, the GDE reported coal import data based on the Customs Office's data. However, since data on coal consumption for power generation and the cement industry are available, the coal imports for 2008–2013 were estimated as the sum of coal consumption in the power plants and the cement industry.

2.   Petroleum Products (Oil)

2.1.   Import data

The GDP-MME provided the data on petroleum products (oil) imports from 2000 to 2019, based on the Customs Office's data (Table 3.2). There were some differences compared to the previous import data of petroleum products in the MME EBT 2010–2018:

- ❖ Include import data 2000–2009
- ❖ Include kerosene import from 2000 to 2013, which is assumed to be consumed for lighting in the residential sector

Table 3.1. Total Final Energy Consumption by Fuel

	Description	Unit	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal Consumption	Generation	kt									25.51	30.62	35.04	40.09	58.13	91.89	563.32	1002.82	1394.08			2092.7
	Industry	kt											10.19	11.89	13.02	13.43	18.93	26.67	34.56			252.78
Heavy Fuel Oil (HFO)	Generation	kt	59.28	63.75	68.31	81.12	89.58	124.68	179.53	236.89	258.79	214.34	170.96	183.61	174.91	107.72	61.81	43.03	44.38			200
Diesel		kt	26.42	28.41	30.44	36.15	51.21	39.92	24.28	18.04	18.9	12.68	6.05	6.06	8.95	3.3	2.1	1.46	0.94			8.48
Power Generation	Hydro	GWh	30.42	33.28	36.24	40.51	28.42	43.54	50.61	49.71	46.28	47.43	31.73	51.52	517.37	1,015.54	1,851.60	2,000.38	2619.11			4025.34
	Coal	GWh									23.36	28.03	32.08	46.5	37.42	168.75	863.02	2,376.49	2551.17			3734.01
	Diesel/HFO	GWh	447.16	489.15	532.66	595.38	714.81	835.71	1,034.82	1,294.36	1,409.94	1,152.65	898.73	908.61	856.56	578.99	326.97	227.62	252.41			731.85
	Wood&Biomass	GWh				-	-	0.12	1.68	5.25	4.53	6.49	5.82	11.91	11.75	6.68	16.79	40.47	43.35			184.05
Electricity	Import	GWh	43.77	47.88	52.14	58.28	59.49	82.25	107.98	167.41	374.25	842.4	1,546.44	1,829.79	2,104.32	2,281.63	1,803.04	1,541.00	1582.85			3062.65
Electricity Consumption	Residential	GWh	237.1	252.61	268.45	292.17	325.19	365.84	388.83	458.25	575.4	682.03	869.08	854.16	1,079.28	1,186.58	1,323.08	1,527.15	2523.49			3399.57
	Commercial	GWh	185.81	204.27	223.49	229.86	270.74	348.03	449.22	548.91	694.41	778.15	892.89	1,082.45	1,275.90	1,539.47	1,639.29	2,530.31	2651.45			3408.23
	Industrial	GWh	26.45	34.73	43.45	76.46	105.93	143.76	215.98	338.61	389.62	388.59	489.88	629.87	900.32	820.04	1,054.35	1,136.84	1992.6			3383.29
	Other	GWh	0.55	0.55	0.55	0.55	0.46	0.72	3.13	3.35	4.96	4.72	2.19	6.26	10.31	6.5	6.84	7.18	7.51			26.5
Biomass Production	Firewood	ton	3,455,084	3,532,727	3,606,432	3,707,993	3,841,962	4,031,521	4,207,773	4,272,869	4,459,457	4,583,360	4,644,997	4,856,076	5,053,881	5,262,683	5,520,148	5,681,802	5,575,106	5,482,156	5,208,000	5,154,509
	Biogas	ton	251	286	325	370	421	480	546	621.57	1,265.29	1,413.93	2,023.60	2,608.41	2,270.61	602.65	881.54	1,661	1,745	1,957	2,195	2,461
Firewood Consumption	Electricity	ton						144	2,017	6,304	5,438	7,783	6,983	14,288	14,096	8,016	20,148	48,562	46,000	43,000	39,000	110,878
	Charcoal	ton	1,851,940	1,893,090	1,932,151	1,985,977	2,056,978	2,157,364	2,249,782	2,280,673	2,380,875	2,445,854	2,479,230	2,588,155	2,693,994	2,808,858	2,940,000	2,984,159	2991286	2,955,000	2,860,000	2,811,835
Charcoal Production		ton	211,650	216,353	220,817	226,968	235,083	246,556	257,118	260,648	272,100	279,526	283,341	295,789	307,885	321,012	336,000	341,047	341,861	343,000	332,000	321,353
Consumption of Firewood	Residential	ton	1,160,462	1,182,968	1,204,332	1,233,771	1,272,603	1,327,508	1,378,053	1,380,816	1,441,482	1,480,823	1,501,030	1,566,978	1,631,058	1,700,601	1,780,000	1,806,735	1,730,852	1,658,156	1,575,000	1,521,796
	Industrial	ton	442,682	456,670	469,948	488,245	512,381	546,505	577,921	605,077	631,661	648,900	657,755	686,653	714,733	745,207	780,000	842,347	806,968	826,000	734,000	710,000
Consumption of Charcoal	Residential	ton	211,650	216,353	220,817	226,968	235,083	246,556	257,118	260,648	272,100	279,526	283,341	295,789	307,885	321,012	336,000	341,047	341,861	343,000	332,000	321,353
Consumption of Biogas	Residential	ton	250.95	285.67	325.19	370.17	421.38	479.68	546.03	621.57	1,265.29	1,413.93	2,023.60	2,608.41	2,270.61	602.65	881.54	1,660.90	1,744.91	1,956.96	2,194.78	2,461.50

Note: Yellow = existing data, white = estimated data, red = revised data.
Source: GDR-MME in-house data (2021).

Table 3.2. Cambodia's Imported Petroleum Products (in tonnes)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Jet A-1	17,365	16,781	16,826	16,834	19,671	20,033	27,061	48,733	44,311	35,187	46,349	54,598	68,991	79,211	91,658	96,947	105,736	152,810	201,519	224,711
Gasoline	119,760	120,857	116,931	103,797	96,748	129,298	158,980	238,399	293,220	313,615	384,095	398,516	387,729	392,011	426,830	481,071	490,898	560,046	606,092	711,381
Diesel	387,832	465,648	389,202	400,577	409,624	346,579	449,810	492,527	456,100	677,059	762,077	814,544	897,641	918,437	1,005,484	1,073,248	1,240,184	1,247,632	1,343,339	1,661,325
Kerosene	29,550	28,265	50,406	83,687	47,824	30,336	24,408	32,621	30,785	28,948	30,593	12,072	6,256	3,034	0	0	0	0	0	0
Fuel oil	95,513	92,124	122,456	118,531	142,354	180,034	248,803	293,950	310,085	269,943	244,073	228,784	213,743	165,929	89,280	35,592	138,532	77,694	84,065	179,922
Lubricant	3,637	3,138	5,126	5,651	6,520	7,464	6,943	11,411	12,830	14,248	14,225	14,174	14,769	16,896	11,685	20,385	25,125	12,097	11,834	13,832
LPG	13,434	16,663	18,129	22,283	27,542	28,243	38,264	47,342	43,294	56,946	65,109	71,943	84,678	98,692	112,120	162,332	193,595	224,369	270,320	340,958
Naphtha	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18,094	13,504	0	0	0
MTBE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,096	9,361	1,998	0	14,273
Base Oils	-	-	-	-	-	-	-	-	-	3,292	2,517	3,463	3,251	1,949	-	0	0	0	0	0
Total	667,091	743,476	719,076	751,360	750,283	741,987	954,269	1,164,983	1,190,624	1,399,238	1,549,038	1,598,094	1,677,059	1,676,158	1,737,057	1,895,765	2,216,935	2,276,646	2,517,169	3,146,402

Note: Yellow-coloured cells indicate a revised number; gasoline includes naphtha and methyl tert-butyl ether (MTBE); lubricant includes base oils.
Source: GDE-MME in-house data (2021).

2.2. Breakdown of import data to sectoral demand

The sales structure of the current Cambodia energy statistics 2010–2018 is applied to estimate the international aviation bunkers, stock, and final consumption of motor gasoline, kerosene-type jet fuel, kerosene, diesel oil, fuel oil, LPG, and lubricants. As for additives and bitumen, the reported data from petroleum companies are adopted.

1) Jet fuel

Jet fuel import data is the total consumption of domestic aviation (DA) and international aviation bunker (IAB). However, the current MME energy statistics 2010–2018 already estimated the share of the total consumption for IAB and DA. IAB and DA consumption from 2000 to 2009 was estimated using the shares of IAB and DA in 2010 as follows:

$$IAB_t = IMJF_t * IAB_{2010} / (IAB_{2010}+DA_{2010})$$

$$DA_t = IMJF_t * DA_{2010} / (IAB_{2010}+DA_{2010})$$

Where,

IAB: International aviation bunker

IMJF: Import of jet fuel

DA: Domestic airways

t = year (2000 to 2009)

IAB and DA consumption for 2019 was estimated using a similar method, but with the 2018 shares of IAB and DA as follows:

$$IAB_{2019} = IMJF_{2019} * IAB_{2018} / (IAB_{2018}+DA_{2018})$$

$$DA_{2019} = IMJF_{2019} * DA_{2018} / (IAB_{2018}+DA_{2018})$$

2) LPG

LPG is consumed by the road transport, residential, and commercial sectors. Thus, it is necessary to break down LPG imports from 2000 to 2009 into those three sectors. According to the GDP-MME, LPG is widely used by the three-wheeled tuk-tuks in 2006. Based on this, LPG consumption for vehicles is assumed to have started in 2006. Therefore, the formula to calculate LPG consumption in the road transport, residential, and commercial sectors are as follows:

$$RDt = IMLPt * RD2010 / (RD2010+CM2010+RS2010)$$

$$CMt = IMLPt * CM2010 /(RD2010+CM2010+RS2010)$$

$$RSt = IMLPt * RS2010 / (RD2010+CM2010+RS2010)$$

Where,

IMLP: Import of LPG

RD: LPG consumption in the road transport sector

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CM: LPG consumption in the commercial sector

RS: LPG consumption in the residential sector

t = year (2000 to 2009)

3) Diesel

Similar to LPG, it is also necessary to break down diesel oil imports amongst the road transport, industry, commercial, and the other sector for 2000–2009. Diesel is also consumed as input for power generation. Therefore, the total import must first be deducted from the fuel input for power generation, then calculate the sectoral breakdown estimation using the following formula:

$$RD_t = (IMDO_t - PGDO_t) * RD2010 / (RD2010+IN2010+CM2010+AG2010+NS2010)$$

$$IN_t = (IMDO_t - PGDO_t) * IN2010 / (RD2010+IN2010+CM2010+AG2010+NS2010)$$

$$CM_t = (IMDO_t - PGDO_t) * CM2010 /(RD2010+IN2010+CM2010+AG2010+NS2010)$$

$$AG_t = (IMDO_t - PGDO_t) * AG2010 / (RD2010+IN2010+CM2010+AG2010+NS2010)$$

$$NS_t = (IMDO_t - PGDO_t) * NS2010 / (RD2010+IN2010+CM2010+AG2010+NS2010)$$

Where,

IMDO: Import of diesel oil

PGDO: Diesel consumption for power generation

RD: Diesel consumption in the road transport sector

IN: Diesel consumption in the industry sector

CM: Diesel consumption in the commercial sector

AG: Diesel consumption in the agriculture sector

NS: Diesel consumption in non-specific other sector

t = year (2000 to 2009)

4) Gasoline

Gasoline is consumed only in the road transport sector. The GDP-MME data includes naphtha imports (reformate) and methyl tert-butyl ether (MTBE). Naphtha (reformate) is primarily used as a high-octane blend stock for making gasoline. Another use is as a source of aromatics for the petrochemicals industry. MTBE, on the hand, is an additive for unleaded gasoline as it increases octane and oxygen levels in gasoline and helps achieve complete combustion in gasoline engines. Since both relate to gasoline, the total gasoline consumption of the road transport sector will be:

Gasoline road transport = import of (gasoline + naphtha (reformate) + MTBE)

5) Lubricant

Lubricant is usually used in vehicles and is thus assumed to be all consumed in the road transport sector. Imported base oils are also consumed in the road transport sector. Thus, these other petroleum products are calculated as:

Other Road transport sector = Import of lubricant + import of base oils

6) Kerosene

Previous energy statistics of Cambodia excludes kerosene imports (non-jet-fuel-kerosene type). The GDP-MME's current import data includes kerosene import data from 2000 to 2013. Afterwards, there was no more import of kerosene. The residential sector is assumed to be the user of kerosene. Thus,

Kerosene Residential sector = import of kerosene

3. Biomass

The biomass data maintained by the GDE-MME covers fuelwood, charcoal, and biogas. Charcoal and biogas are consumed only in the residential sector. Fuelwood is used to produce electricity and charcoal; it is also consumed in the industry and residential sectors. Fuelwood consumption for electricity generation is in the form of bagasse; it will be discussed in the following section on fuel input for power generation.

Before 2007, biomass demand and supply data were not available. These data were estimated as described below.

3.1. Fuelwood

In estimating fuelwood demand data before 2007–2016, the demand for fuelwood (firewood) in the residential and industrial sectors are assumed to be related to the gross domestic product (GDP). The demand function of firewood was estimated through the ordinary least squares regression method, using demand and GDP data (constant LCU) from 2007 to 2016. For the residential sector, the estimated regression formula is:

Y = 858,234 + 21.32 GDP (correlation 0.94)

Where,

Y: Firewood consumption in residential sector

GDP: Gross domestic product in constant LCU

For the industry sector, the estimated regression formula is:

Y = 301,259 + 11.77 GDP (correlation 0.97)

Where,

Y: Firewood consumption in the industry sector

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The charcoal factory's fuelwood consumption was estimated, assuming the furnace efficiency is 25%. Thus,

Fuelwood consumption = charcoal production/0.25

3.2. Charcoal consumption

Charcoal is assumed to be consumed only by the residential sector. Similar to firewood, charcoal consumption was estimated using the following regression formula:

Y = 148,496 + 4.45 GDP (correlation 0.98)

Where,

Y: charcoal consumption in the residential sector

3.3. Biogas consumption

Biogas is also consumed by the residential sector. Biogas consumption was also estimated using the regression formula. However, the GDP correlation is quite low (0.06). Therefore, the biogas consumption was re-estimated by calculating the average annual growth rate (AAGR) during 2007–2016, as follows:

AAGR = $(Y2016/Y2007)^{(1/9)}$ -1 = 0.12

Where, Y: Biogas consumption in the residential sector

4. Electricity

4.1. Fuel input for power generation

Cambodia's primary power generation sources are hydro, oil (fuel oil and diesel), coal, biomass, and solar. Hydro and oil were the only power generation sources from 2000 to 2004. In 2005, Cambodia started to use biomass in the form of bagasse to generate electricity. In 2008, coal was added to the power generation mix, while the solar-powered plant was first generated in 2017.

1) Bagasse

The GDE has provided generation data from bagasse power plants since 2005. However, bagasse consumption for power generation was available only from 2007. Thus, it was necessary to estimate the missing bagasse fuel input data for 2005 and 2006.

In principle, fuel input is estimated as follows:

INPUT = OUTPUT / EFFICIENCY

The output data unit, which is generated electricity from the bagasse power plant, is in GWh. The fuel input data, the amount of bagasse used for power generation, is in tonnes. Thus, it is necessary to provide the thermal value of bagasse and the thermal conversion factor of electricity.

The thermal efficiency for 2005 and 2006 is assumed to be the same as that of 2007. In this regard, the thermal efficiency for 2007 was calculated using the following formula:

$$EF2007 = (PG2007*TC1*1000)/(FC2007*1000*TC2/10000000)$$

Where,

EF2007: Thermal efficiency in 2007

PG2007: Power generation by bagasse in 2007 (GWh)

TC1: Thermal conversion factor of electricity (0.086 toe/MWh)

FC2007: Firewood consumption for power generation in 2007 (tonne)

TC2: Thermal value of firewood (3,820 kcal/kg)

Using EF2007, the bagasse input for power generation in 2005 and 2006 is then estimated as follows:

$$FCt = (PGt *TC1*1000/EF2007*10000000)/TC2/1000 \text{ (tonnes)}$$

Where,

FCt: Firewood consumption for year-t

PGt: Power generation by bagasse in year-t

EF2007: Thermal efficiency for 2007

TC1: Thermal conversion factor for electricity (0.086 toe/GWh)

TC2: Thermal value of bagasse (3,820 kcal/kg)

Based on the estimation, the fuel input of bagasse for power generation increased from 0.1 kilotonnes (Kt) in 2000 to almost 112 Kt in 2019 (Figure 3.1)

Figure 3.1. Bagasse Input for Power Generation
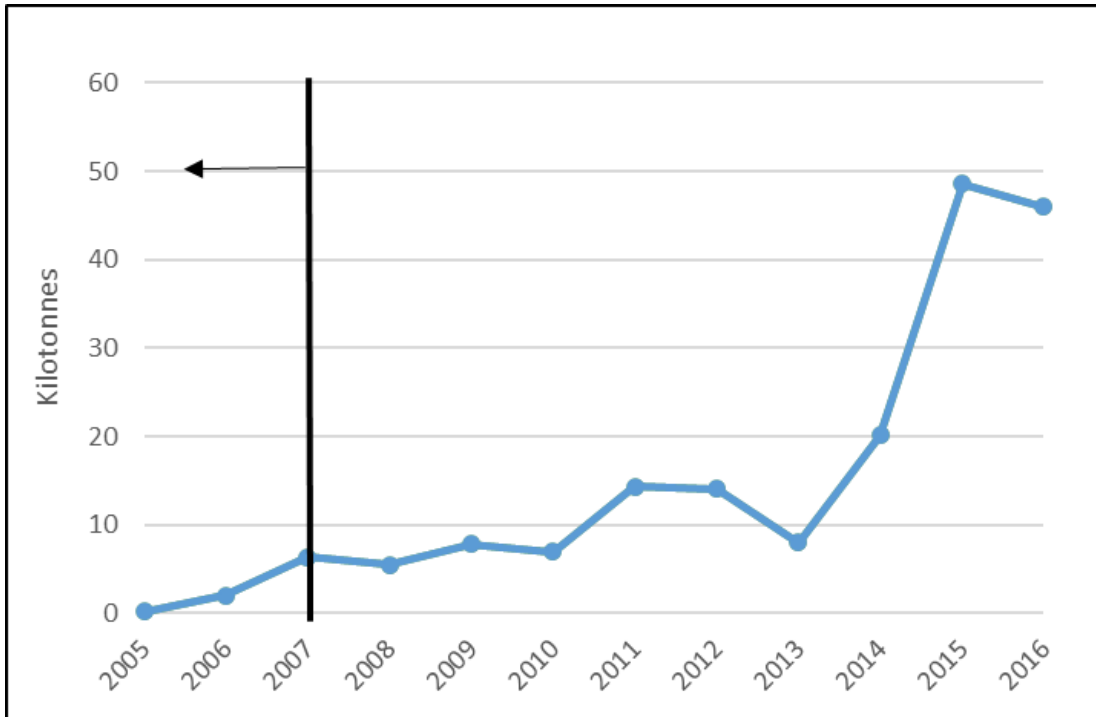
Source: GDE-MME in-house data (2021).

2)   HFO/diesel consumption

Thermal efficiency in 2003–2009 looks unusual (refer to Figure 3.2). Therefore, it was necessary to re-estimate the oil (HFO/diesel) consumption for power generation using the 2010 thermal efficiency. The thermal efficiency in 2010 (EF2010) is calculated as follows:

$$EF2010 = (PG2010*TC1*1000)/(HDC2010*1000000*TC2/10000000)$$

Where,

PG2010: Power generation by firewood in 2010 (GWh)

TC1: Thermal conversion factor of electricity (0.086 toe/MWh)

HDC2010: HFO/diesel consumption for power generation in 2010 (Kt)

TC2: Thermal value of HFO/diesel (10105 kcal/kg)

The approach to estimating the HFO/diesel input for power generation in 2000–2009 will be as follows:

$$HDCt = (PGt *TC1*1000/EF2010*10000000)/TC2/1000000 \text{ (Kt)}$$

$$HFCt = HDCt * (HFC2010/(HFC2010+DOC2010))$$

$$DOCt = HDCt * (DOC2010/(HFC2020+DOC2010))$$

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Where,

> HDCt: HFO/diesel input for power generation at year t
>
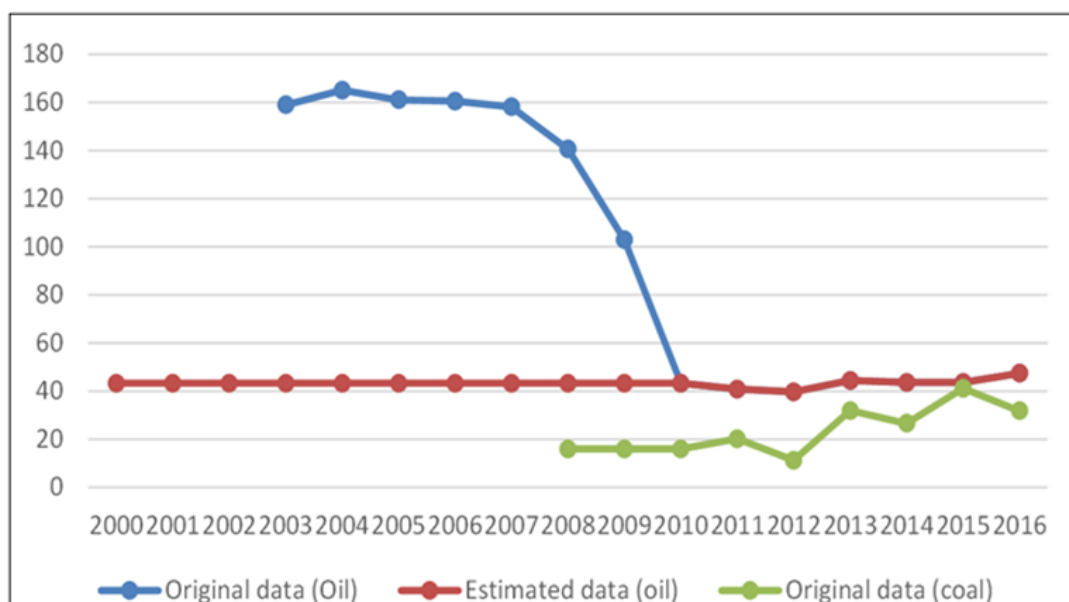> HFCt: HFO input for power generation at year t
>
> DOCt: Diesel input for power generation at year t
>
> HFC2010: HFO input for power generation at year 2010
>
> DOC2010: Diesel input for power generation at year 2010

The thermal efficiency for 2000–2016 is shown in Figure 3.2.

Figure 3.2. Historical Thermal Efficiency

Source: GDE-MME In-house data (2021).

4.2. Electricity consumption

The primary energy data from the GDE excludes electricity data before 2003. In this case, it is necessary to estimate the missing data on electricity consumption from 2000 to 2002. The method to estimate the missing data is as follows:

1) Residential sector

We estimate the regression formula using the GDP of 2003–2016.

> Y = 74.38 * 1.000074^GDP (correlation 0.93) + constant adjustment

Where,

> Y: Electricity consumption in the residential sector
>
> GDP: Constant LCU

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2) Commercial sector

We estimate the regression formula using the GDP of 2003–2016.

$$Y = 52.083 * 1.000089 \char`^ GDP \text{ (correlation 0.96)}$$

Where,

Y: Electricity consumption in the commercial sector

GDP: Constant LCU

3) Total final energy consumption (TFEC) sector

We estimate the regression formula using the GDP of 2003–2016.

$$Y = 134.77 * 1.000087\char`^GDP \text{ (correlation 0.93) + constant adjustment}$$

Where,

Y: Electricity consumption in the TFEC sector

GDP: Constant LCU

4) Other sector

Estimation is very difficult; therefore, we treat it as exogenous.

$$Y_t = Y_{2003} \text{ (t=2000-2002)}$$

Where,

Y: Electricity consumption in the other sector

5) Industry sector

Calculation as balance in 2000–2002

$$Y_t = TEC_t - RS_t - CM_t - Ot_t \text{ (t=2000-2002)}$$

Where,
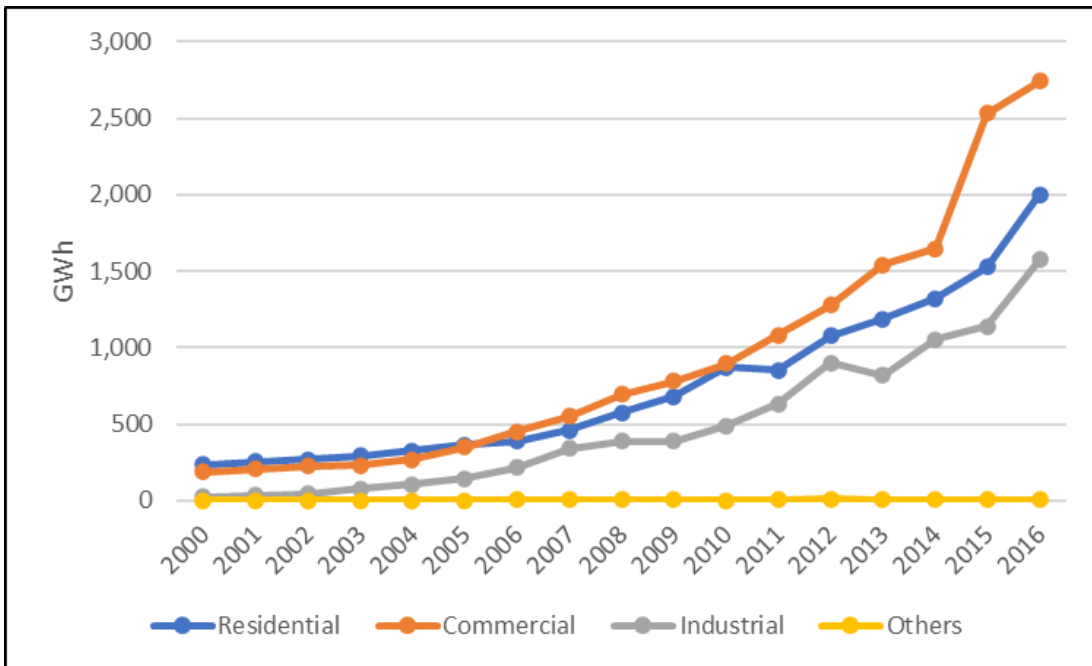
Y_t: Electricity consumption in the industry sector

TEC_t: Total electricity consumption in the final energy consumption sector

RS_t: Electricity consumption in the residential sector

CM_t: Electricity consumption in the commercial sector

Ot_t: Electricity consumption in the other sector

Figure 3.3. Electricity Consumption by Sector

Source: GDE-MME In-house data (2021).

4.3. Power balance

Electricity supply is the total amount of domestic and imported electricity. The power generation fuel input consists of coal, oil (fuel oil and diesel), hydropower, and biomass. The total electricity demand will be that of the industry, commercial, residential, and other sectors.

Own use and transmission and distribution (T&D) losses are the difference between electricity supply and demand. The ratio of own use and T&D losses for each year was estimated as follows:

❖ $B_t = ES_t - ED_t$

❖ $Ratio = B_t / ED_t$

Where,

Bt = Power balance of year-t

Est = Electricity supply in year-t

Edt = Electricity demand in year-t

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