ALTERNATIVES FOR POWER GENERATION IN THE GREATER MEKONG SUB-REGION

Volume 7:

GMS Power Sector Vision Modelling Assumptions Summary

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Acronyms

ASES	Advanced Sustainable Energy Sector
BAU	Business As Usual
BNEF	Bloomberg New Energy Finance
BTU / Btu	British Thermal Unit
CAGR	Compound Annual Growth Rate
CCS	Carbon Capture and Storage
CSP	Concentrated Solar Panel
EIA	Energy Information Administration
EPPO	Energy Policy and Planning Office (Thailand)
FO	Fuel Oil
GDP	Gross Domestic Product
GMS	Greater Mekong Subregion
IEA	International Energy Agency
IES	Intelligent Energy Systems Pty Ltd
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
JCC	Japan Crude Cocktail
LCOE	Overall Levelised Cost of Electricity
LNG	Liquefied Natural Gas
MKE	Mekong Economics
NYMEX	New York Mercantile Exchange
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
PDP	Power Development Plan
PDR	People's Democratic Republic (of Laos)
PV	Photovoltaic
SES	Sustainable Energy Sector
UN	United Nations
USD	United States Dollar
WEO	World Energy Outlook
WWF	World Wide Fund for Nature
WWF-GMPO	WWF – Greater Mekong Programme Office

Table of Contents

1   Introduction

This document provides a brief summary of a number of key assumptions that will be made in the modelling for this project. Most of the content of this report will be included as an appendix to projections of the electricity sectors of each GMS country.

This document is structured in the following way:

- Section 2 describes the main features of each of the three Power Sector Vision scenarios;
- Section 3 summarises demand trends in each GMS country;
- Section 4 sets out the BAU scenario demand forecasts for each GMS country;
- Section 5 sets out the SES scenario demand forecasts for each GMS country;
- Section 6 sets out the ASES scenario demand forecasts for each GMS country;
- Section 7 provides the fuel pricing assumptions;
- Section 8 provides the technology cost assumptions;
- Section 9 summarises the methodology for taken for estimating jobs created; and
- Appendix A provides some technical notes on the demand forecast modelling methodology.

2   Modelling Scenarios

The modelling will develop the following three scenarios for the electricity industries of the GMS countries considered in this study:

- Business as Usual (BAU);
- Sustainability Energy Sector (SES); and
- Advanced SES (ASES).

These are illustrated conceptually in Figure 1.

Figure 1   GMS Power Sector Scenarios
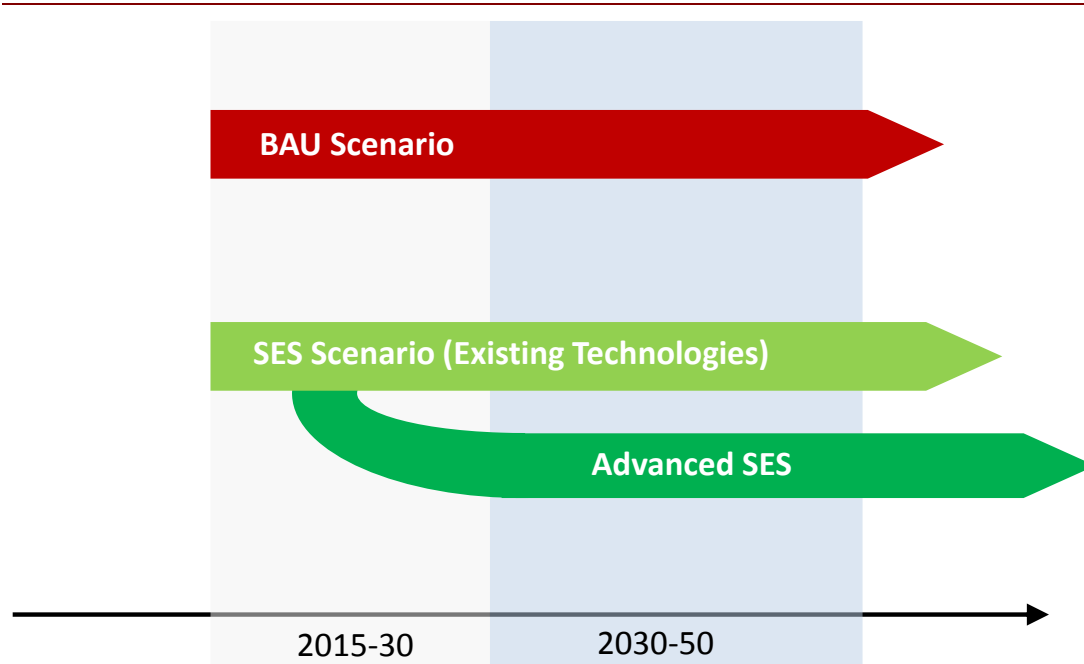
The BAU scenario is characterised by electricity industry developments consistent with the current state of planning within the GMS countries and reflective of growth rates in electricity demand consistent with an IES view of base development, existing renewable energy targets, where relevant, aspirational targets for electrification rates, and energy efficiency gains that are largely consistent with the policies seen in the region.

In contrast, the SES seeks to transition electricity demand towards the best practice benchmarks of other developed countries in terms of energy efficiency, maximise the renewable energy development, cease the development of fossil fuel resources, and make sustainable and prudent use of undeveloped conventional hydro resources. Where relevant, it leverages advances in off-grid technologies to provide access to electricity to remote communities. The SES takes advantage of existing, technically proven and commercially viable renewable energy technologies.

Finally the ASES assumes that the power sector is able to more rapidly transit towards a 100% renewable energy technology mix under an assumption that renewable energy is deployed

more than in the SES scenario with renewable energy technology costs declining more rapidly compared to BAU and SES scenarios. A brief summary of the main differences between the three scenarios is presented in Table 1.

Under all three scenarios, the electricity access rate (either via grid or off-grid technologies) reaches close to 100% by 2030. The BAU is based on full grid electrification, whereas the ASES is based on off-grid technologies in meeting 100% electricity access[1].

Table 1   Brief Summary of Differences between BAU, SES and ASES

Scenario	Demand	Supply
BAU	Demand is forecast to grow in line with historical electricity consumption trends and projected GDP growth rates in a way similar to what is often done in government plans. Electric vehicle uptake is assumed to reach 15% across all cars and motorcycles by 2050.	Generator new entry follows that of power development plans for the country including limited levels of renewable energy.
SES	• Assumes a transition towards energy efficiency benchmark for the industrial sector of Hong Kong[2] and of Singapore for the commercial sector by year 2050. • For the residential sector, it was assumed that residential demand per electrified capita grows to 750 kWh pa by 2050, 38% less than in the BAU. • Demand-response measures assumed to be phased in from 2021 with some 15% of demand being flexible[3] by 2050. • Slower electrification rates for the national grids in Myanmar compared to the BAU, but deployment of off-grid solutions	• Assumes no further coal and gas new entry beyond what is already understood to be committed. • A modest amount of large scale hydro (between 4,000 to 5,000 MW in total) is deployed in Lao and Myanmar above and beyond what is understood to be committed hydro developments[4]. • Supply is then developed by a least cost combination of renewable generation sources limited by estimates of potential rates of deployment and judgments on when technologies would be feasible for implementation to deliver a power system with the same level of reliability as the BAU. • Technologies used include: solar photovoltaics, biomass, biogas and municipal waste plants, CSP with

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[1] Cambodia and Myanmar off-grid potential demand is entirely met via solar PV and battery storage technologies once the levelised cost of generation falls below the levelised cost of grid generation.

[2] Based on our analysis of comparators in Asia, Hong Kong had the lowest energy to GDP intensity for industrial sector while Singapore had the lowest for the commercial sector.

[3] Flexible demand is demand that can be rescheduled at short notice and would be implemented by a variety of smart grid and demand response technologies.

[4] This is important to all countries because the GMS is modelled as an interconnected region with significant conventional baseload capacity retiring around 2030.

Scenario	Demand	Supply
	that achieve similar levels of electricity access. • Mini-grids (off-grid networks) are assumed to connect to the national system in the longer-term. • Electric vehicle uptake as per the BAU.	storage, onshore and offshore wind, utility scale batteries, geothermal and ocean energy. • Transmission limits between regions are upgraded as required to support the GMS as a whole, and a different (approximate) transmission plan to the BAU is allowed to develop.
ASES	The ASES demand assumptions are done as a sensitivity to the SES: • An additional 10% energy efficiency applied to the SES demands (excluding transport). • Flexible demand assumed to reach 25% by 2050. • Uptake of electric vehicles doubled by 2050. • Electrification rates in Myanmar remain constant after solar PV and battery storage reach parity with grid costs.	ASES supply assumptions are also implemented as a sensitivity to the SES, with the following main differences: • Allow rates of renewable energy deployment to be more rapid as compared to the BAU. • Technology cost reductions are accelerated for renewable energy technologies. • Implement a more rapid programme of retirements for fossil fuel based power stations. • Energy policy targets of 70% renewable generation by 2030, 90% by 2040 and 100% by 2050 across the region are in place.

3 Electricity Demand Trends in the GMS

3.1 Summary of Electricity Demand Trends in the GMS

Historical electricity demand in the GMS has grown from 189 TWh in 2005 to 337 TWh as of 2014 at an annual average rate of 6.6% pa. A significant share of this growth is attributable to Vietnam's high demand growth driven by high levels of economic growth in the country. Vietnam has grown its share of total electricity consumption from 27% in 2005 to around 40% as of 2014. Thailand's share of electricity consumption in the region has decreased from 69% to 54% over this period. Vietnam and Thailand make up the majority of the GMS's demand owing to their economies having experienced high growth, and having high electrification rates. Figure 2 and Figure 3 show electricity demand shares for each GMS country in 2005 and 2014. 2014 figures are IES estimates.

Figure 2   GMS Electricity Demand by Country (GWh, 2005)
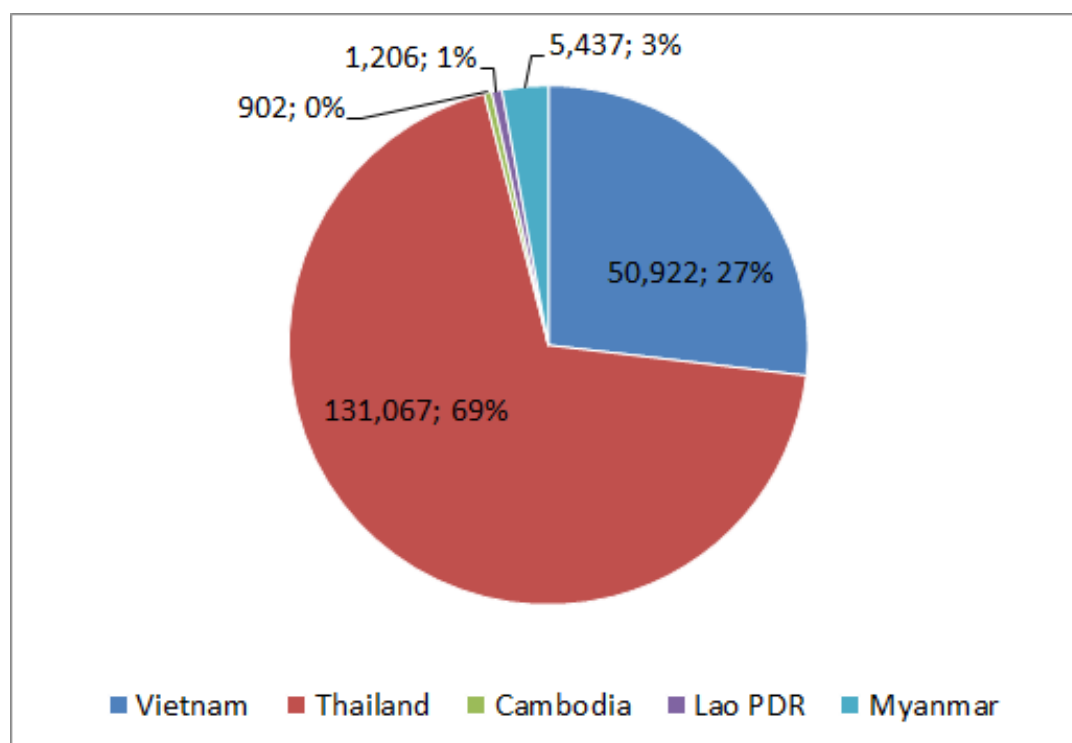
* Demands include transmission and distribution losses

Figure 3   GMS Electricity Demand by Country (GWh, 2014)
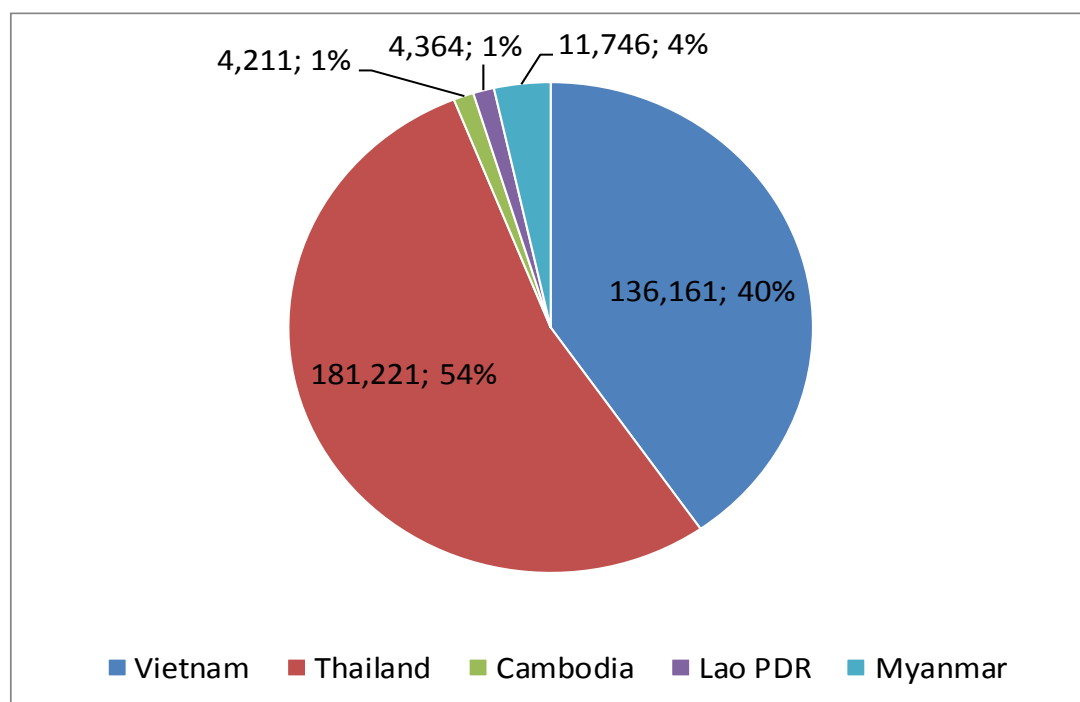
* Demands include transmission and distribution losses

Figure 4   GMS Historical Energy Demand (TWh) by Sector: 2005-14

* Demands include transmission and distribution losses

Figure 4 presents the GMS breakdown of consumption by the sectors. Industry almost accounts for half of electricity use in the region at 48%, followed by the residential and commercial sectors at 29% and 23% respectively. The composition of 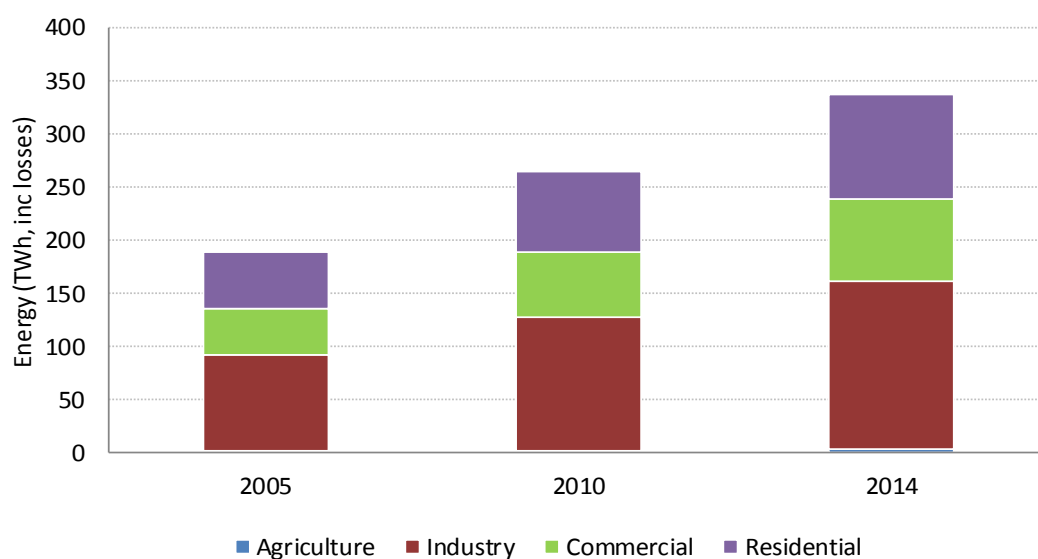sector consumption across the region has remained relatively stable with residential energy increasing 2% displacing the industrial sector, the result of increasing electrification rates and rising per capita consumption in the region.

3.2   Demand Trend in Cambodia

Electricity consumption in Cambodia has grown from 902 GWh in 2005 to 4,211 GWh by 2014 driven by significant increases in the industry, commercial and residential sectors. Each of these sectors grew on average 20% each year over this period with an increasing focus on industrialisation and household electrification. Over time, the composition of electricity demand has shifted away from agriculture and more towards the industrial, commercial and residential sectors. Transmission and distribution losses have also declined from 12.3% in 2005 to 6.6% by 2014. Peak demands in Cambodia have increased 19% each year from 2005 to 2014 in line with energy consumption levels.

Figure 5 and Table 2 contains the sector consumption breakdowns from 2005 to 2014.

Table 2   Cambodia Power Consumption Statistics: 2005-14

Power Consumption (GWh)	2005	2010	2011	2012	2013	2014
Industrial	116	384	430	552	601	883
Commercial	244	622	750	948	1,031	1,228
Residential	384	1,029	1,192	1,524	1,657	1,993
Agricultural	54	83	91	94	95	107
Losses (T&D)	112	223	261	276	262	295
Composition (%)	2005	2010	2011	2012	2013	2014
Industrial	12.8%	16.4%	15.8%	16.3%	16.5%	19.6%
Commercial	26.8%	26.6%	27.5%	27.9%	28.3%	27.2%
Residential	42.2%	44.0%	43.8%	44.9%	45.5%	44.2%
Agricultural	5.9%	3.5%	3.3%	2.8%	2.6%	2.4%
Losses (T&D)	12.3%	9.5%	9.6%	8.1%	7.2%	6.6%

Figure 5   **Cambodia Historical Energy Demand (TWh) by Sector: 2005-14**
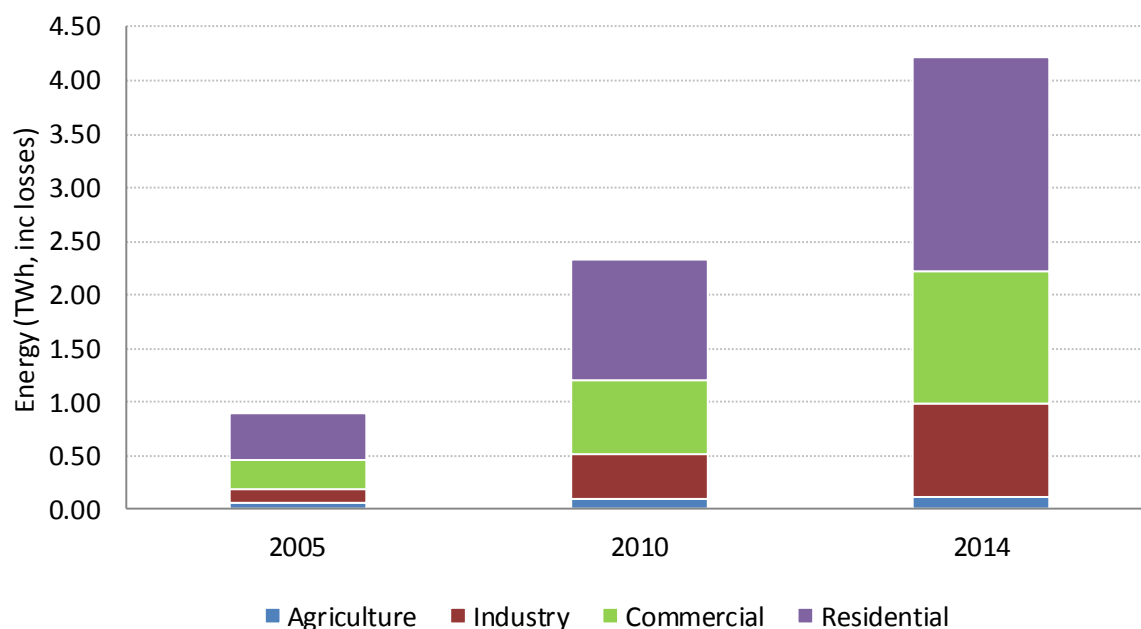
* Demand includes transmission and distribution losses

Table 3   **Cambodia Electricity Key Statistics**

Cambodia Year	Peak MW	Energy GWh	Annual Growth (%) Peak	Annual Growth (%) Energy
2005	147	902		
2010	380	2,328	14.2%	14.2%
2011	442	2,713	16.5%	16.5%
2012	551	3,381	24.6%	24.6%
2013	593	3,634	7.5%	7.5%
2014	687	4,211	15.9%	15.9%
CAGR (%)	18.7%	18.7%		
Average Increase per year	60	368		

3.3   Demand Trend in Lao PDR

Electricity consumption in Lao PDR has increased from 1,206 GWh in 2005 to 4,878 GWh in 2014 representing 17.6% annual average growth. Out of the four sectors, industry has grown the quickest at 22.1% per annum as a result of aluminium and bauxite mining activities from 2013. The commercial and residential sector grew at 21.9% and 12.9% per annum respectively. Agriculture has stayed relatively flat over this period and losses have come down from 16.2% in 2005 to 10.5% in 2014. Over the 2005 to 2014 period, energy growth has outpaced peak demand. Table 4 and Figure 6 contains the breakdown of consumption by sector.

Figure 6   **Lao PDR Historical Energy Demand (TWh) by Sector: 2005-14**
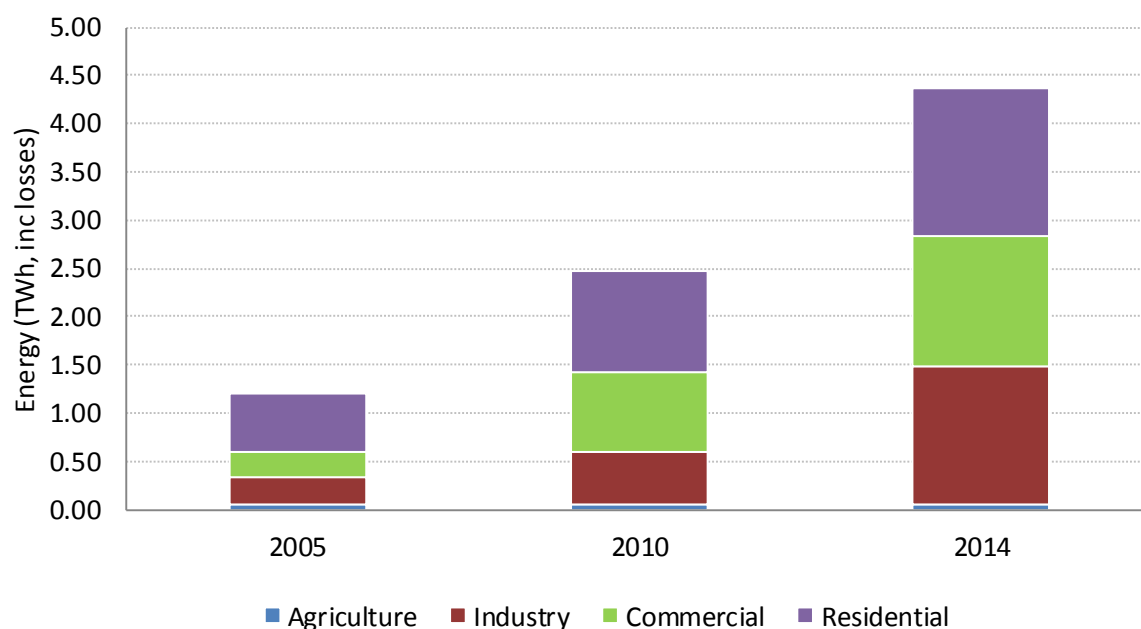
* Demand includes transmission and distribution losses

Table 4   **Lao PDR Power Consumption Statistics: 2005-14**

Power Consumption (GWh)	2005	2010	2011	2012	2013	2014
Industrial	237	495	584	681	1,118	1,430
Commercial	229	748	765	993	949	1,367
Residential	511	943	1,004	1,161	1,278	1,520
Agricultural	35	43	46	39	35	47
Losses (T&D)	195	240	243	297	406	514
Composition (%)	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Industrial	19.6%	20.0%	22.1%	21.5%	29.5%	29.3%
Commercial	18.9%	30.3%	28.9%	31.3%	25.1%	28.0%
Residential	42.3%	38.2%	38.0%	36.6%	33.8%	31.2%
Agricultural	2.9%	1.7%	1.7%	1.2%	0.9%	1.0%
Losses (T&D)	16.2%	9.7%	9.2%	9.4%	10.7%	10.5%

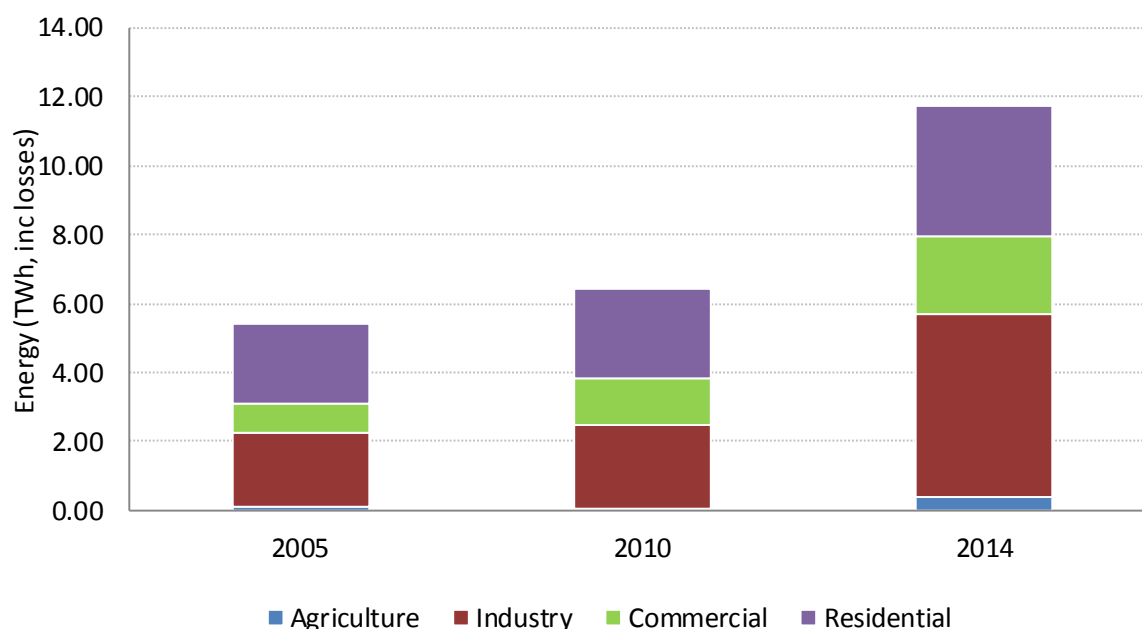**Table 5   Lao PDR Electricity Key Statistics**

Lao PDR Year	Peak MW	Energy GWh	Annual Growth (%) Peak	Annual Growth (%) Energy
2005	313	1,206		
2010	475	2,468	17.3%	15.9%
2011	527	2,643	10.9%	7.1%
2012	613	3,171	16.3%	20.0%
2013	649	3,787	5.9%	19.4%
2014	748	4,364	15.2%	15.2%
CAAGR (%)	10.16%	15.36%		
Average Increase per year	48	351		

3.4   Demand Trend in Myanmar

Agriculture electricity in Myanmar grew the fastest from 85 GWh in 2005 to 364 GWh in 2014 respectively at 17.5% per annum. However, in energy terms, Myanmar's industrial sector consumption increased 2,106 GWh to 3,768 GWh by 2014 corresponding to a 3.2% pa real increase in its industry GDP. Losses improved from 28.5% to 20.6%, however, they remain high due to the state of the electricity infrastructure. Total electricity consumption increased from 3,909 GWh to 11,746 GWh from 2005 to 2014, a growth rate of 13% per annum. Table 6 shows Myanmar's power consumption statistics. Figure 7 contains the breakdown of consumption by sector.

Table 6   Myanmar Power Consumption Statistics: 2005-14

Power Consumption (GWh)	2005	2010	2011	2012	2013	2014
Industrial	1,549	1,850	2,287	2,727	3,650	5,322
Commercial	613	1,071	1,306	1,532	1,643	2,292
Residential	1,662	2,015	2,653	3,381	2,681	3,768
Agricultural	85	57	66	77	281	364
Losses (T&D)	1,560	1,481	1,830	2,188	2,297	3,057
Composition (%)	2005	2010	2011	2012	2013	2014
Industrial	28.3%	28.6%	28.1%	27.5%	34.6%	35.9%
Commercial	11.2%	16.5%	16.0%	15.5%	15.6%	15.5%
Residential	30.4%	31.1%	32.6%	34.1%	25.4%	25.5%
Agricultural	1.6%	0.9%	0.8%	0.8%	2.7%	2.5%
Losses (T&D)	28.5%	22.9%	22.5%	22.1%	21.8%	20.6%

Figure 7   **Myanmar Historical Energy Demand (TWh) by Sector: 2005-14**

* Demand includes transmission and distribution losses

Table 7   **Myanmar Electricity Key Statistics**

Myanmar Year	Peak MW	Energy GWh	Annual Growth (%) Peak	Annual Growth (%) Energy
2005	1,034	5,437		
2010	1,226	6,441	4.9%	4.9%
2011	1,541	8,098	25.7%	25.7%
2012	1,875	9,857	21.7%	21.7%
2013	1,998	10,499	6.5%	6.5%
2014	2,235	11,746	11.9%	11.9%
CAGR (%)	8.94%	8.94%		
Average Increase per year	133	701		

3.5   Demand Trend in Thailand

Electricity consumption across all the sectors in Thailand has grown at relatively slower rates with the commercial and agricultural sectors growing the fastest at 4.9% and 5.8% from 2005 to 2014 respectively. Total electricity consumption in the country was 180 TWh in 2014 with the agricultural sector accounting for the smallest share at 414 GWh, less than 0.5%. Over the period from 2005 to 2014, the industrial share of consumption has decreased from 45.5% in 2005 to 41.1% in 2014, displaced by increasing consumption by the commercial and residential sectors. Peak demands have increased 3% per annum since 2005 compared to

energy at 3.7%. Losses have slowly improved, coming down from 7.5% to 6.1% in 2014. Figure 8, Table 8, and Table 9 contain the key statistics and trends for Thailand.

Table 8   Thailand Power Consumption Statistics: 2005-14

Power Consumption (GWh)	2005	2010	2011	2012	2013	2014
Industrial	59,669	68,039	67,942	72,336	72,536	73,782
Commercial	35,839	47,711	47,817	52,618	53,794	55,430
Residential	25,482	33,216	32,799	36,447	37,657	38,993
Agricultural	249	335	297	377	354	414
Losses (T&D)	9,827	9,473	10,338	11,011	10,961	11,022
Composition (%)	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Industrial	45.5%	42.9%	42.7%	41.9%	41.4%	41.1%
Commercial	27.3%	30.0%	30.0%	30.5%	30.7%	30.9%
Residential	19.4%	20.9%	20.6%	21.1%	21.5%	21.7%
Agricultural	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Losses (T&D)	7.5%	6.0%	6.5%	6.4%	6.3%	6.1%

Figure 8   Thailand Historical Energy Demand (TWh) by Sector: 2005-14
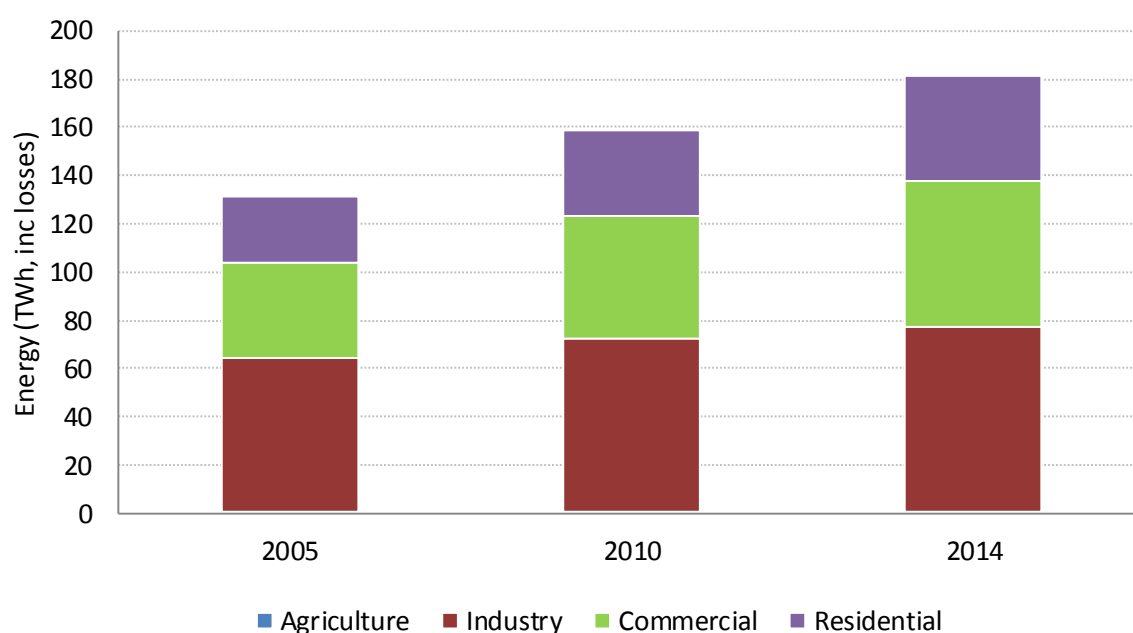
* Demand includes transmission and distribution losses

Table 9   Thailand Electricity Key Statistics

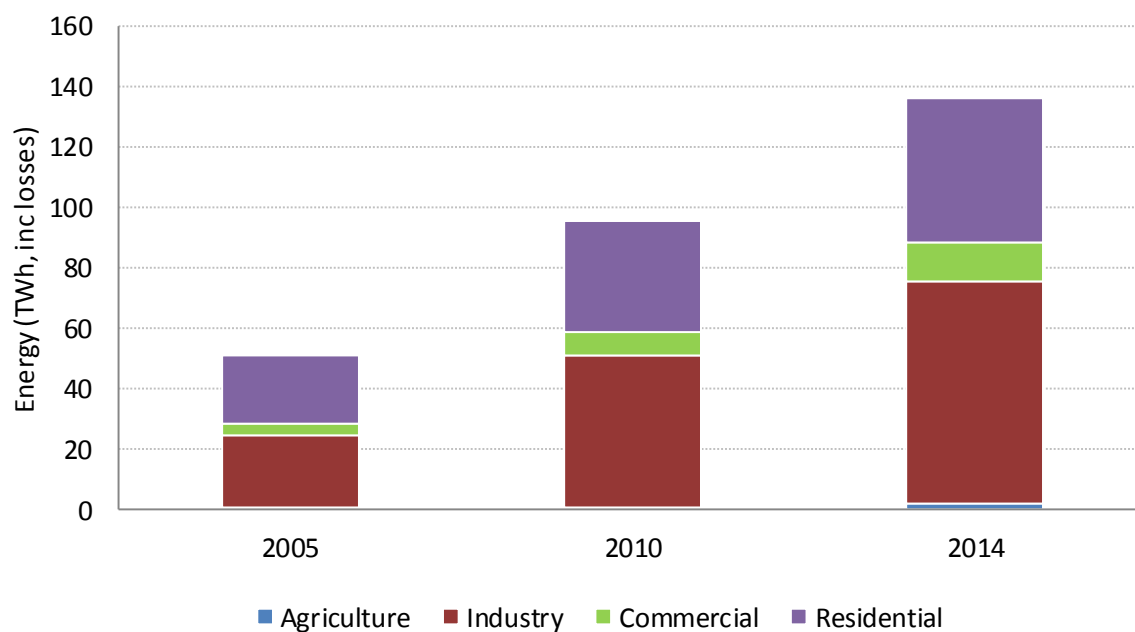| Thailand Year	Peak MW	Energy GWh	Annual Growth (%) Peak	Annual Growth (%) Energy
2005	20,538	131,067		
2010	24,010	158,774	8.9%	10.9%
2011	23,900	159,193	-0.5%	0.3%
2012	26,121	172,790	9.3%	8.5%
2013	26,598	175,302	1.8%	1.5%
2014	26,942	181,221	1.3%	3.4%
CAGR (%)	3.06%	3.67%		
Average Increase per year	712	5,573		

3.6   Demand Trend in Vietnam

Vietnam has experienced considerable electricity demand growth over the past 8 years growing 12.9% per annum over the period from 2005 to 2014. Peak demand has similarly grown at 10.1% from 9,255 MW in 2005 to 22,100 MW by 2014. During this period, the industrial, commercial and agricultural electricity consumption has grown between 13-15% per annum with the residential sector growing the slowest at 10.2%. Table 10, Table 11 and Figure 9 contains Vietnam's key power statistics.

Table 10   Vietnam Power Consumption Statistics: 2005-13

Power Consumption (GWh)	2005	2010	2011	2012	2013	2014
Industrial	21,302	45,568	50,085	55,300	60,337	73,723
Commercial	3,896	7,106	9,038	10,218	11,023	13,122
Residential	19,831	33,139	34,456	38,691	42,177	47,564
Agricultural	574	944	1,079	1,265	1,532	1,752
Losses (T&D)	5,319	8,773	9,601	10,485	11,210	12,999
Composition (%)	**2005**	**2010**	**2011**	**2012**	**2013**	**2014**
Industrial	41.8%	47.7%	48.0%	47.7%	47.8%	49.4%
Commercial	7.7%	7.4%	8.7%	8.8%	8.7%	8.8%
Residential	38.9%	34.7%	33.0%	33.4%	33.4%	31.9%
Agricultural	1.1%	1.0%	1.0%	1.1%	1.2%	1.2%
Losses (T&D)	10.4%	9.2%	9.2%	9.0%	8.9%	8.7%

Figure 9   **Vietnam Historical Energy Demand (TWh) by Sector: 2005-14**

* Demand includes transmission and distribution losses

Table 11   **Vietnam Electricity Key Statistics**

Vietnam	Peak	Energy	Annual Growth (%)	Annual Growth (%)
Year	MW	GWh	Peak	Energy
2005	9,255	50,922		
2010	15,416	95,529	11.2%	11.0%
2011	16,490	104,259	7.0%	9.1%
2012	18,603	115,959	12.8%	11.2%
2013	20,010	126,279	7.6%	8.9%
2014	22,100	136,161	10.4%	7.8%
CAGR (%)	10.15%	11.55%		
Average Increase per year	1,427	9,471		

# 4 Business as Usual (BAU) Electricity Demand Forecasts

4.1 Demand Key Drivers

This section summarises the main key driver demand assumptions that apply to both the BAU and SES projections.   Note that these key driver assumptions are key inputs for the long-term energy forecasts based on the regression relationships.

4.1.1 Real GDP Growth Scenario

Real gross domestic product (GDP) growth is assumed to stay relatively high around current GDP growth rates due to the focus on industrialisation in the GMS economies. Over time, GDP growth is assumed to decline towards 1.96%[5] pa by 2050 as seen in Figure 10. The trend down is assumed to reflect the economic development cycle of a developing country. This assumption is held consistent across all 3 scenarios.

Figure 10   IES Forecast GDP Growth
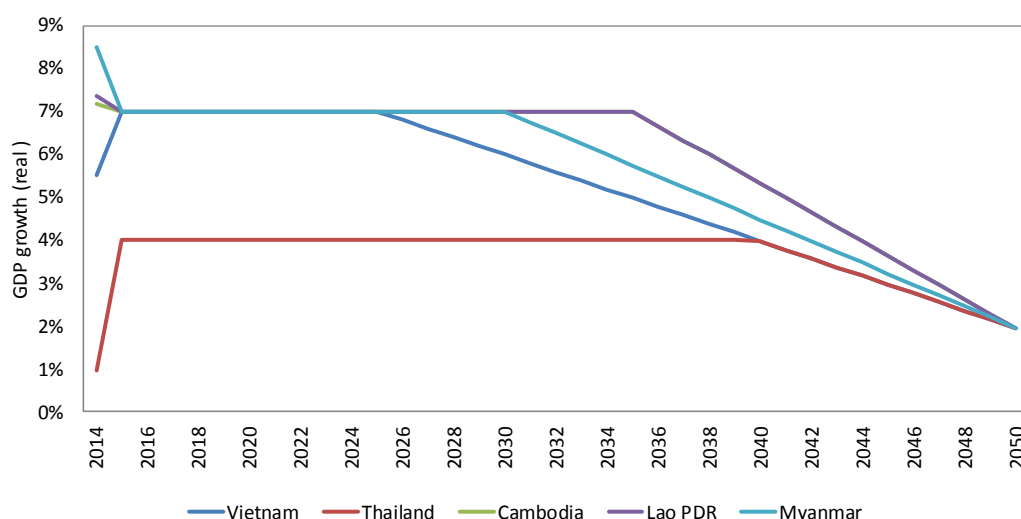
4.1.2 Composition of Real GDP

The GDP composition across all countries is weighted towards industry as each GMS country undergoes industrialisation, in line with the strategic aspirations of each country. The industry share of GDP in Vietnam and Myanmar is assumed to increase from 38% and 35% in 2013 to 55% and 70% in 2035 then decline to 46% and 60% in 2050 as the economies shift towards a service-based economy. Thailand, Cambodia, and Lao PDR areassumed to also increase their industry GDP percentage by 2035 and maintain those levels to 2050 (45%, 60%

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[5] 1.96% reflects the previous 5-year GDP growth of the top 10 GDP countries in the world excluding Brazil, China and Russia.

and 60% respectively). The GDP composition of each of the GMS countries is plotted in Figure 11 below. Note that this assumption is held constant across all scenarios.

Figure 11   IES Assumed GDP Compositions
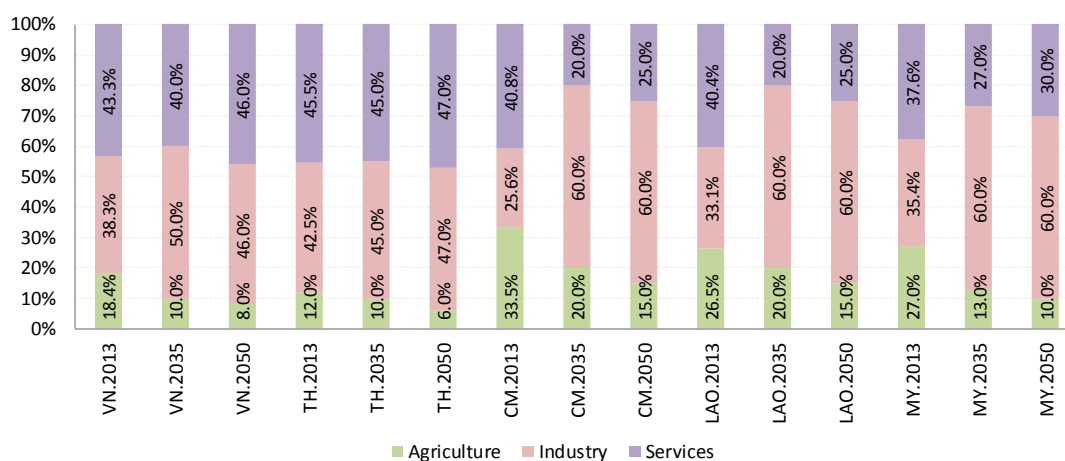
4.1.3   Population Projections

Population is assumed to grow in line with the growth estimates of the UN Medium Fertility scenario 6 . This scenario represents growth over the short-term reflecting historical population growth rates declining to 0% by 2039 for Myanmar, Thailand and Vietnam. Cambodia and Lao PDR growth rates trends towards 0.5% by 2050. Figure 12 plots the population growth rates. Note that this assumption is held constant in both the BAU,SES, and ASES.

Figure 12   Population Growth Rates

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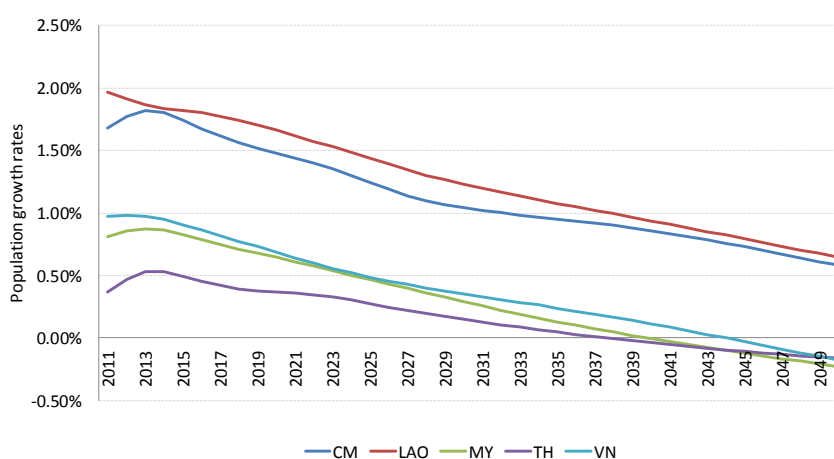
[6] Thailand was based on the High fertility scenario to remove negative population growth impacts before 2025. Thailand population growth rates follow similar developed countries with below replacement fertility rates.

4.1.4 Special Economic Zones and Industrial Developments

The baseline methodology is to forecast individual sector electricity demand based on GDP forecasts which depend on historical data. Given several of the GMS countries (Lao PDR, Cambodia, and Myanmar) are expected to undergo structural economic changes with the planning of special economic zones to foster industrial growth, IES has reviewed and estimated the developments and reviewed experiences in other countries to include some increases in the industrial component of electricity demand to reflect promotion of industry as part of a strategy to industrialise. This assumption has been applied to all three scenarios.

4.1.5 Urban and Rural Populations

Population splits between rural and urban over time have been assumed to remain constant in both the BAU and SES over the 50-year period although there is a slight historical trend of an increasing urban share in the poorer GMS countries. The impact of this is minimal as we have assumed a convergence of per capita consumption levels between the two populations in Cambodia, Myanmar and Lao PDR.

4.1.6 Electrification Rates

Electrification rates have been assumed in the BAU to increase to electrification targets as announced by the respective governments. The current and assumed population electrification targets are summarised in Table 12 below. Thailand and Vietnam are already close to 100% electrification and the other countries are assumed to reach close to 100% by 2030. Note that in the SES and ASES we adopt different electrification rates due to different electricity access strategies.

Table 12   Urban and Rural Electrification Rate Targets

	Cambodia			Lao PDR			Myanmar		
	2013	**2030**	**2050**	**2013**	**2020**	**2050**	**2013**	**2030**	**2050**
Urban	89.6%	97.0%	99.5%	98.2%	99.0%	99.5%	36.1%	97.0%	99.5%
Rural	20.1%	94.5%	98.5%	81.1%	95.0%	99.0%	15.6%	94.0%	98.5%

### 4.1.7 Per Capita Electricity Consumption (Residential)

The urban population electricity use per electrified capita is plotted Figure 13 below. Per electrified capita use takes into account the urban and rural population composition and assumes a factor of 50% (i.e. rural per capita use is half the levels in urban regions) in 2015 increasing to 70% by 2050 reflecting the increased electrification and adoption of electricity in rural regions over time.

Viet Nam and Thailand are assumed to increase to 1,661 kWh and 1,780 kWh respectively by 2050[7]. Lao PDR trends towards Singapore's residential per capita use of 1,268 kWh per capita, whereas Cambodia and Myanmar also trend towards this level albeit at a slower

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[7] 1,780 kWh is the 2014 average for Japan, Singapore, Hong Kong and Taiwan. Calculated as residential energy consumption divided by total population.

pace due to their lower electrification rates. The SES and ASES assume different consumption levels because of energy efficiency assumptions.

Figure 13   Projected Electricity Use Per Electrified Capita (Urban)
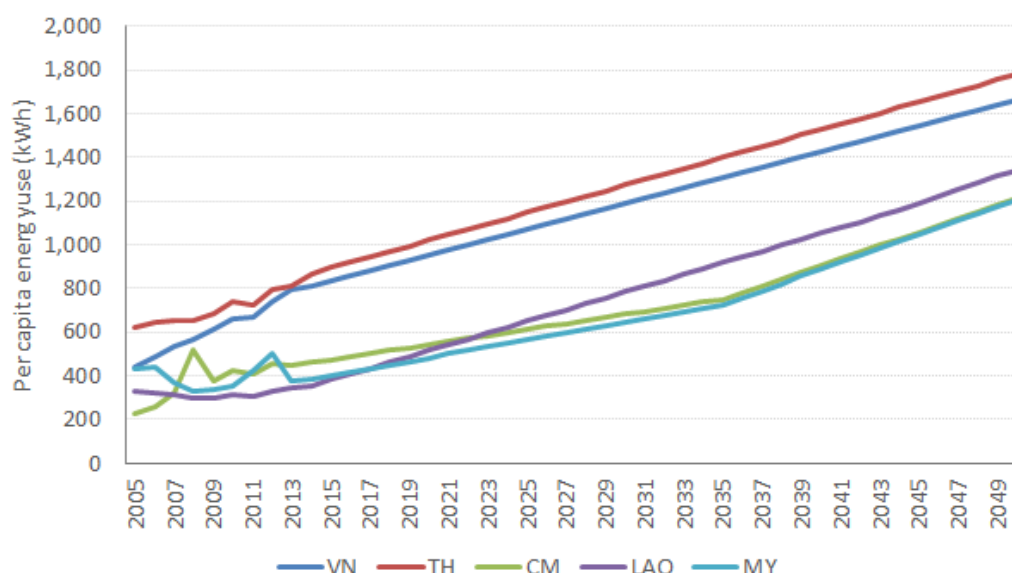
4.1.8 Transmission and Distribution Losses

Transmission and distribution Losses across all of the GMS regions are assumed to decline from their current rates by 2% per annum. A snapshot of the transmission and distribution losses for all three scenarios is presented in Table 13 below.

Table 13   Transmission and Distribution Losses

Losses	2015	2030	2050
Cambodia	7.1%	5.2%	3.5%
Lao PDR	11.5%	8.5%	5.7%
Myanmar	26.1%	19.3%	12.9%
Thailand	6.4%	4.7%	3.2%
Vietnam	9.4%	6.9%	4.6%

4.1.9 Energy Efficiency in BAU

Energy efficiency measures and targets have been announced in the GMS countries; in some cases, they have been legislated into policy in others they have been announced but not officially legislated. For the BAU electricity demand forecasts, we have made the assumption of a 7% efficiency gain (energy savings against a counterfactual 0% efficiency electricity demand trajectory) by 2035 and 9% by 2050. This only applies to the BAU and represents the view that without concentrated action plans to enhance energy efficiency, only modest gains. In the SES and ASES we have provisioned for higher efficiency gains that have been

based on an intensity metric benchmarked against energy intensity levels of other countries – see section 5.

4.1.10 Electric Cars and Electric Motorbike Electricity Demand

Electric cars and motorbikes are expected to displace traditional fuel-based transport due to lower running and maintenance costs and the expectation of lower battery costs as global production increases. Potential electricity demand from the transport sector (passenger cars, taxis and motorbikes and scooters) has been included in the overall demand forecasts. Modelled electric vehicle and motorbike electricity demand assumes the following:

- The cars per capita ratio is assumed to increase uniformly over time. The per capita ratio is assumed to stay below ratios of developed nations and adjusted by IES based on economic growth assumptions. Thailand, which has the highest ratio currently amongst the GMS countries, is assumed to reach 450 cars per 1000 people by 2050 compared to United Kingdom, France, Norway, and Japan which ranges from 500-600 cars per 1000 people. The number of motorbikes per 1000 people is assumed to remain constant in all countries. Figure 14 and Figure 15 plots the historical (to 2013) and forecast ratio for vehicles and motorcycles.

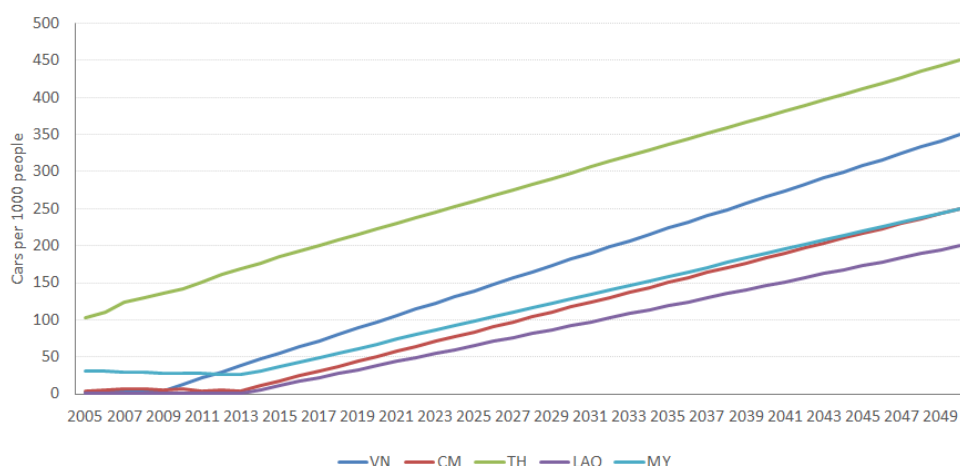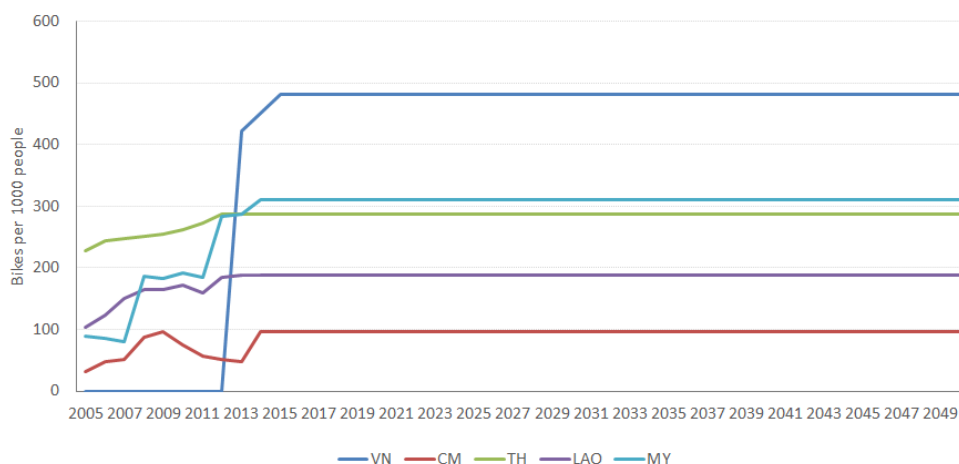**Figure 14   Number of Cars per 1000 People**

Figure 15   Number of Bikes per 1000 People

* Data was not available for Vietnam from 2005 to 2011

▪ Uptake of electric transport options from 2025 (Vietnam and Thailand), and 2030 (Cambodia, Lao PDR, Myanmar) increasing by 10% to 25% by 2050. These uptake rates are IES estimates based on internal work on electric vehicle uptake rates in the New South Wales (Australia) market which are expected to reach 60% by 2050. Figure 16 plots the assumed uptake rates.

Figure 16   Electric Vehicle and Motorbike Penetration
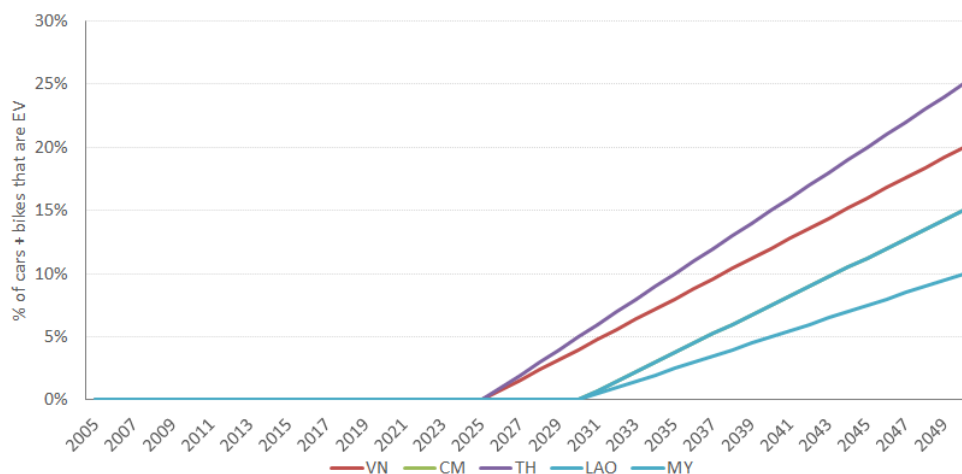

▪ Average electric vehicle demand of 3 MWh per car per annum and 0.6 MWh per bike per annum. The average electric vehicle demand is based on IES work on electric vehicle demand potential in the Australian market. Electric motorbike electricity demand is based on the equivalent installed battery size in motorbikes (Zero S motorcycle with 16 kWh vs Tesla Model S with 85 kWh).

The additional transport demand accounts for roughly 2-9% of total country demand across the various countries.

4.1.11 Load Factor Assumption in the BAU

Load factors for Viet Nam and all other GMS countries are assumed to trend from historical levels towards 80% and 75% respectively by 2050. The increasing trends were assumed to reflect the increased industrial loads (higher load factors) over time, with Thailand as an example of an economy having gone through industrialisation. The load factor assumption is plotted in Figure 17. The SES and ASES assume the load factor increases to 80% by 2030 due to demand-side management measures.

**Figure 17   Load Factors by Region**
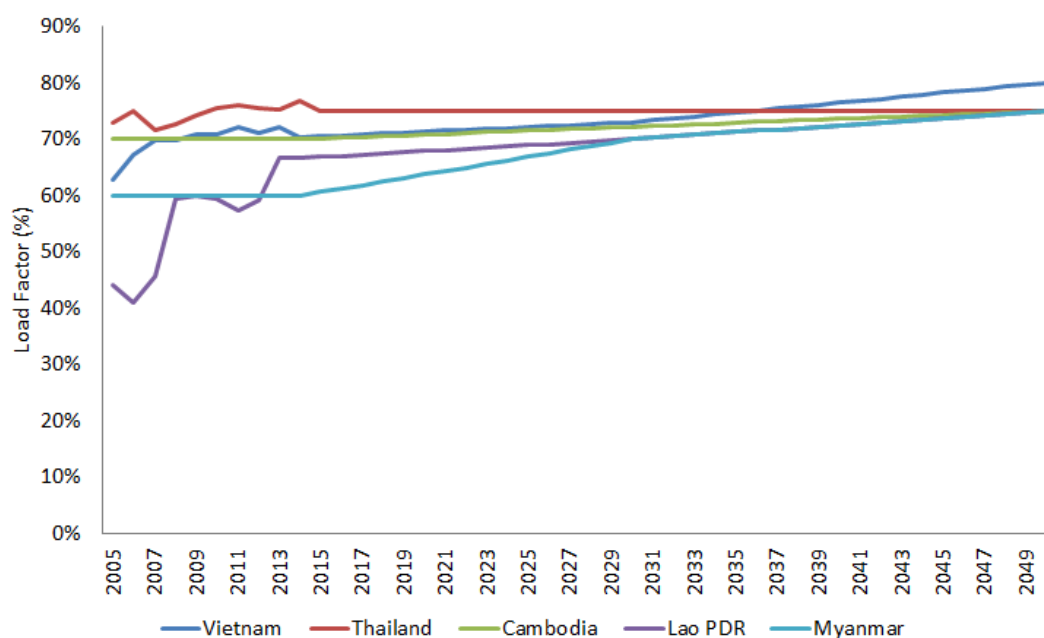
4.1.12 Peak Demand Projections by GMS Country for the BAU

The historical load factors and the forecast regional energy demands were used to forecast peak energy demands for each of the countries. This is plotted in below. It should be noted that within the SES and ASES scenario a number of additional demand-side management measures will be taken.

Figure 18   Peak Demand by Region (including losses)
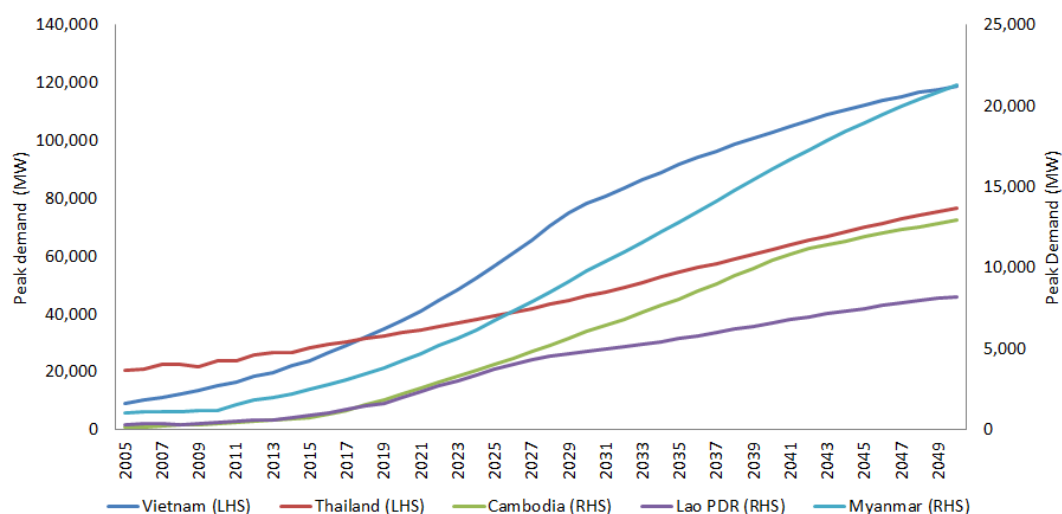
4.2   Overall GMS BAU Demand Forecast

We project the GMS region's total electricity consumption to grow by 4.8% per annum from a baseline of 319 TWh in 2013 to 1,142 TWh in 2035 and to 1,685 TWh by 2050. We have projected Viet Nam to account for 51.1% of the total with Thailand at 31.6% and the share of the smaller 3 GMS countries increasing from 5.6% in 2013 to 17.3% by 2050. Figure 19 plots the historical energy use up to 2013 and energy forecasts thereafter[8].

Figure 19   GMS Projected Electricity Demand (2005-2050, Base Case)

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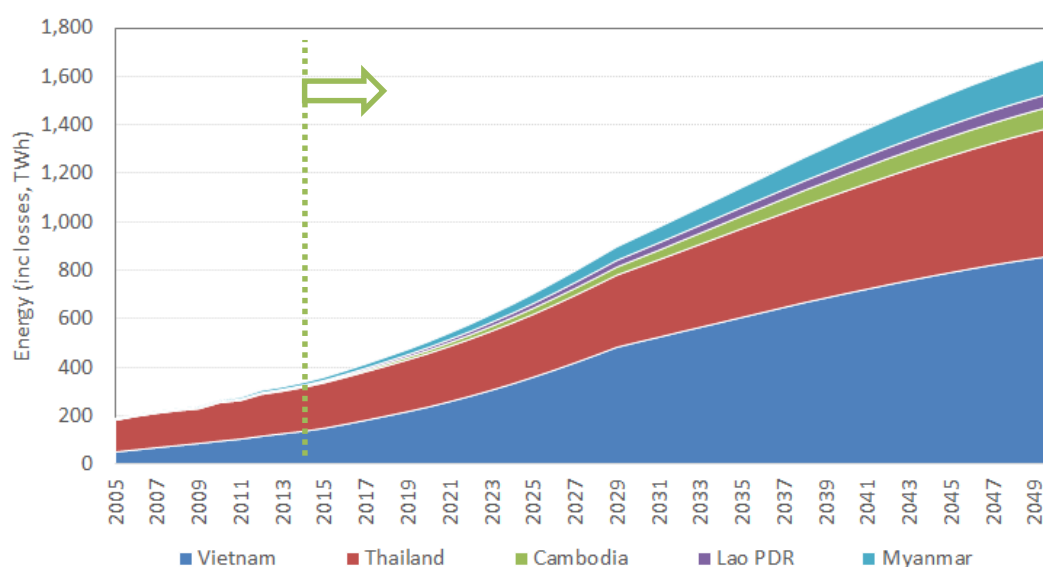
[8] Due to data availability most countries only have historical data published up to the year 2013 only.

Table 14 below summarises the compound annual growth rates for electricity consumption for each country and by the sectors over the period 2005 to 2050. The following subsections provide country-specific demand projections and commentaries. The slowdown in electricity consumption towards 2050 is driven by GDP trending back down towards the global[9] real GDP growth average of 1.96% by 2050.

**Table 14   Compound Annual Growth Rates by Sector (BAU)**

Sector	Country	2013-50	2013-35	2035-50
Agriculture	Vietnam	3.3%	4.5%	1.8%
	Thailand	1.2%	2.2%	-0.2%
	Cambodia	3.2%	4.1%	2.0%
	Lao PDR	0.7%	0.8%	0.6%
	Myanmar	1.0%	1.2%	0.7%
Industry	Vietnam	5.2%	8.3%	1.2%
	Thailand	3.2%	3.6%	2.7%
	Cambodia	11.9%	19.5%	2.6%
	Lao PDR	8.5%	13.5%	2.1%
	Myanmar	6.5%	9.4%	2.6%
Commercial and Services	Vietnam	7.8%	9.5%	5.7%
	Thailand	2.6%	3.1%	2.0%
	Cambodia	5.6%	5.4%	5.9%
	Lao PDR	5.1%	4.7%	5.6%
	Myanmar	7.7%	8.9%	6.1%
Residential	Vietnam	2.9%	3.4%	2.2%
	Thailand	2.5%	2.9%	1.9%
	Cambodia	6.5%	7.8%	4.8%
	Lao	5.6%	6.9%	4.0%
	Myanmar	7.3%	9.8%	4.0%
Transport	Vietnam	0.0%	0.0%	8.6%
	Thailand	0.0%	0.0%	8.0%
	Cambodia	0.0%	0.0%	14.0%
	Lao	0.0%	0.0%	13.6%
	Myanmar	0.0%	0.0%	12.0%
Total	Vietnam	5.1%	7.3%	2.4%
	Thailand	3.0%	3.4%	2.5%
	Cambodia	8.7%	12.8%	3.5%
	Lao PDR	7.0%	10.1%	2.9%
	Myanmar	7.1%	9.5%	4.1%

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[9] Based on top 10 GDP countries excluding Brazil, China and Russia.

4.3   BAU Demand Forecast for Cambodia

Agriculture energy growth slows down from 6.7% up to 2013 to 4.1% to 2035 then to 2.0% by 2050 as the economy gears towards higher productivity activities in industry and the commercial sectors. The industrial sector has experienced significant growth over the past few years and is forecast to continue growing at 19.5% during the 2015 to 2035 period, then slowing to 2.6% as total GDP slows down to the world average of 2.0% real growth per annum. The residential sector experiences consumption growth of 7.8% in the first half of the forecasts as the government continues to purse electrification rates of 97% and 94% of the rural and urban population by 2030 combined with increasing per capita consumption, slowing down to 4.8% growth thereafter. Cambodia is forecast to grow at 8.7% pa over the forecast period to 88 TWh in 2050. Cambodia's electricity demand is plotted in Figure 20.

Figure 20   Cambodia Projected Electricity Demand (2014-2050, BAU)
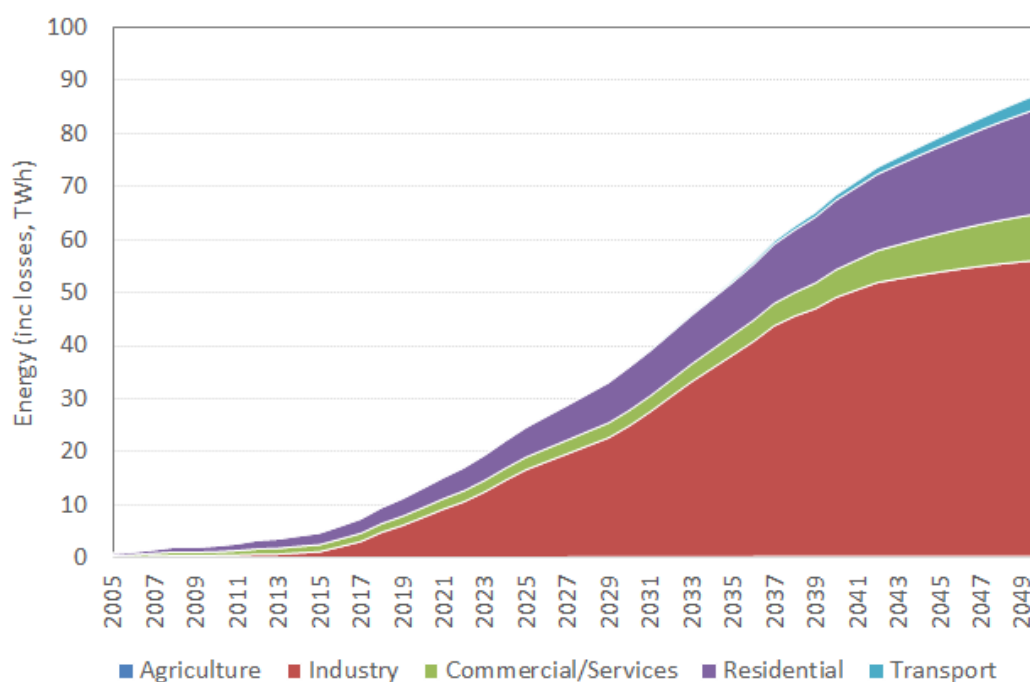

Agriculture electricity consumption remains relatively flat across the entire period as the economy, similar to Cambodia, shifts towards industrialisation. The Industry electricity consumption maintains high growth rates of 13.5% to 2035 as the sector is assumed to contribute 60% of the total GDP (up from 33% in 2013) and remains at this level by 2050[10]. The commercial sector is assumed to increase its share in the GDP from 2030 onwards to 25% by 2050, increasing consumption over this period by 5.1% pa to 2050. Residential energy growth is high in the earlier years (6.9% pa) due to electrification efforts and the

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[10] The rapid demand increase in the earlier years of the forecast is related to the aluminium bauxite smelter that is due to be online by 2015.

increasing consumption and population rates before declining towards 4.0% by 2050. Overall Lao PDR is forecast to grow at 7.0% pa to 55 TWh by 2050. Lao PDR's electricity demand is plotted in Figure 21.

Figure 21   Lao PDR Projected Electricity Demand (2014-2050, BAU)
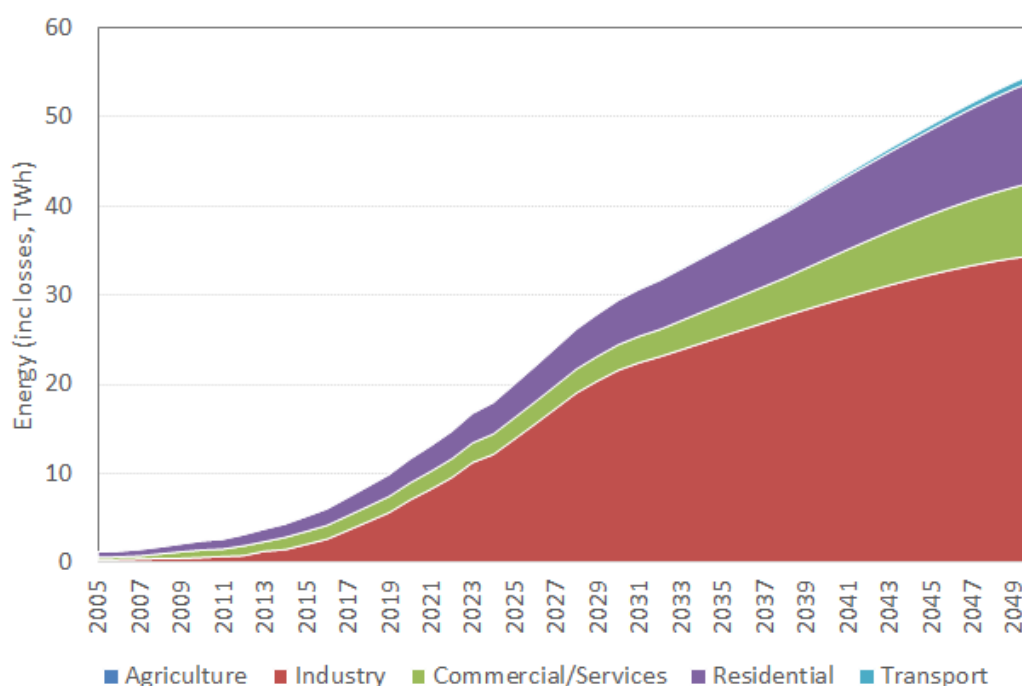
4.4   BAU Demand Forecast for Myanmar

The agriculture sector in Myanmar is assumed to contribute a smaller share towards total GDP declining from 27% in 2013 to 13% in 2030, and 10% by 2050. Like the other smaller GMS countries, the industrial sector dominates the GDP composition increasing from 35.4% in 2013 to 60% in 2030. The residential sector experiences growth to 9.8% in the first 20 years as a result of increasing electrification rates and higher per capita usage then drops back to levels around 4.0% post-2035. Myanmar energy demand grows at a rate of 7.1% pa over the period to 2050. Myanmar's electricity demand is plotted in Figure 22.

Figure 22   Myanmar Projected Electricity Demand (2014-2050, BAU)
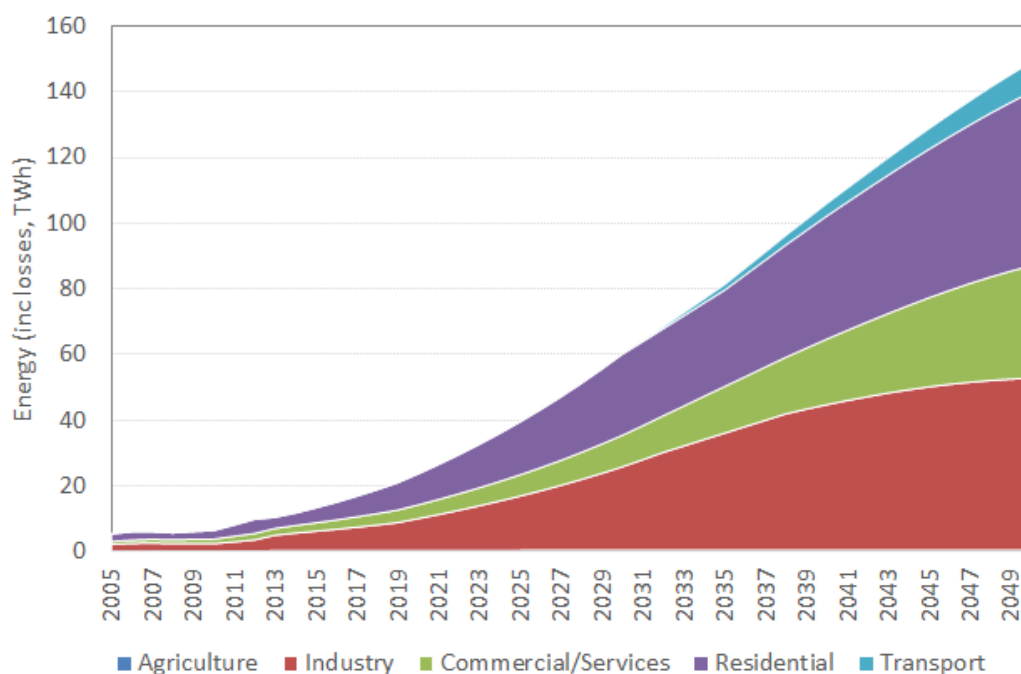
4.5   Thailand BAU Demand Forecast

Thailand's industry electricity demand growth picks up due to a recovering GDP then maintains growth at an average rate of 2.7% post-2035 as a result of a slight shift of the economy towards the industrial sector (42.5% in 2013 increasing uniformly to 47% by 2050). The commercial sector is assumed to increase its share of GDP by a similar share displacing agriculture as a share of total GDP. Residential energy grows at 2.9% pa to 2035 and then grows at 1.9% pa with increasing per capita usage offset by a declining population after 2035. Thailand's population growth starts to slow down from 2015 trending towards 0% by 2037 as fertility rates fall below population replacement levels. Thailand's electricity demand is plotted in Figure 23 below.

Figure 23   Thailand Projected Electricity Demand (2014-2050, BAU)
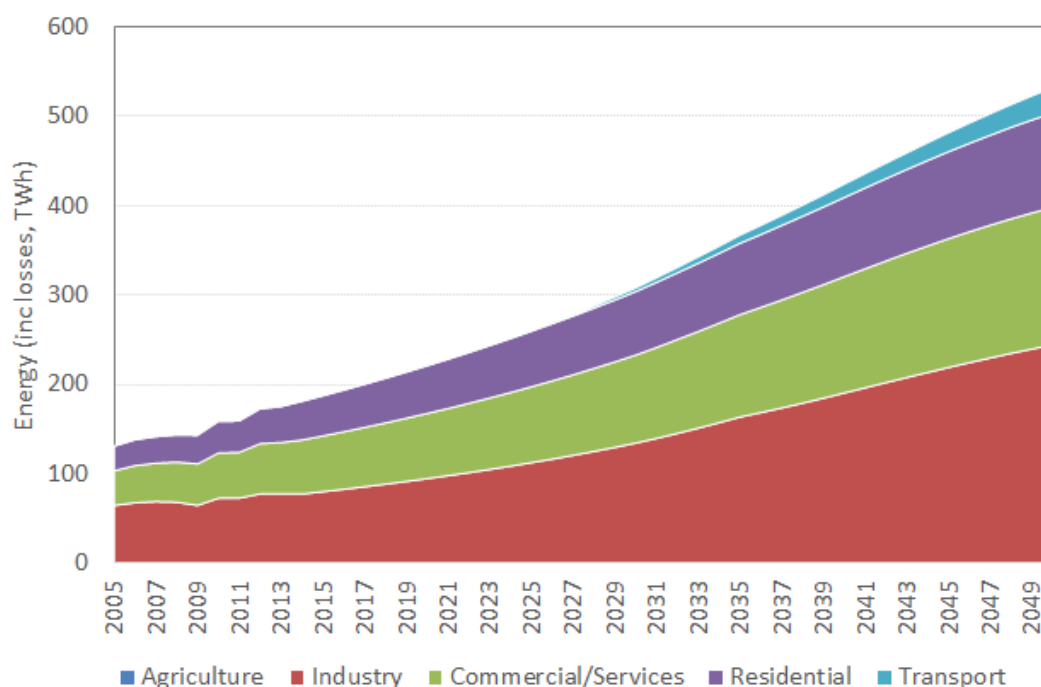
4.6   Vietnam BAU Demand Forecast

BAU electricity demand growth in the agriculture sector decreases over time as the country industrialises in line with Viet Nam's strategic vision; it decreases from 18.4% in 2013 to 10% in 2030 and 8% by 2050. The industrial sector growth declines from 8.3% pa in the initial 20-year period (2015-2035) to 1.2% pa (2035-2050) as the economy is assumed to shift from being heavily industrialised (accounting for 50% of GDP in 2035) towards services and commerce. The residential sector growth slows corresponding to lower population growth rates towards 2050 in line with the UN Medium Fertility scenario. Across all sectors, Viet Nam is forecast to grow at 5.1% pa over the forecast period (2015 to 2050). Viet Nam's electricity demand is plotted in Figure 24.

Figure 24   Viet Nam Projected Electricity Demand (2005-2050, BAU)
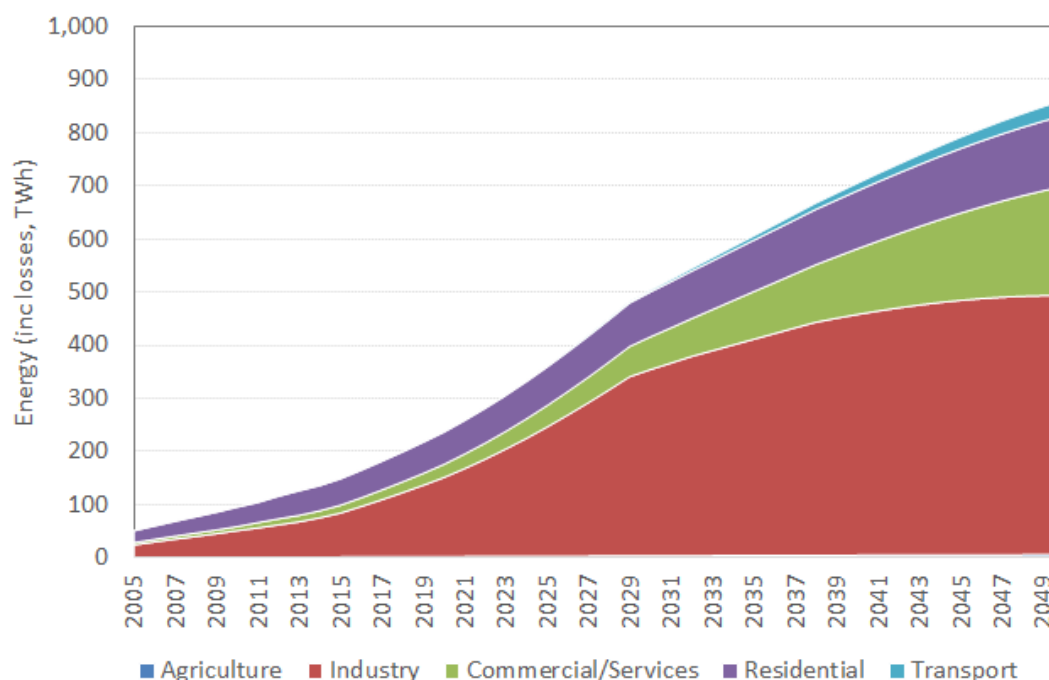
4.7   Comparison of IES BAU Demand Forecasts with Published Government Demand Forecasts

Comparisons against various official projections, generally as part of each country's national power development plan, found the following differences as presented in Table 15 below. Differences can be attributed to out of model adjustments for some of the smaller economies, and optimistic forecasts for Vietnam and Myanmar [11] . The government projections were taken from:

- Cambodia: Power Development Plan 2008, Ministry of Mines and Energy;
- Lao PDR: Summary Report on Power Development Plan in Lao PDR, MEM, 2011;
- Myanmar: Ministry of Electric Power Presentation 2015;
- Vietnam: Power Development Plan 7 (2011); and
- Thailand: Power Development Plan 2010 Revision 3 (2012).

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[11] Cambodia and Myanmar forecasts include out of model adjustments to reflect additional industrial load not captured by the regression forecast methodology, see BAU assumptions.

Table 15   Comparisons to Government Projections (BAU)

Viet Nam	2030 (PDP)	2030 (IES)	Difference
Energy (GWh)	615,205	503,947	-18.1%
Peak (MW)	110,215	78,806	-28.5%

Cambodia	2020 (PDP)	2020 (IES)	Difference
Energy (GWh)	8,019	13,177	64.3%
Peak (MW)	1,452	2,124	46.3%

Lao PDR	2020 (PDP)	2020 (IES)	Difference
Energy (GWh)	20,330	11,646	-42.7%
Peak (MW)	2,905	1,958	-32.6%

Myanmar	2030 (PDP)	2030 (IES)	Difference
Energy (GWh)	111,100	60,124	-45.9%
Peak (MW)	19,216	9,805	-49.0%

Thailand	2030 (PDP)	2030 (IES)	Difference
Energy (GWh)	346,767	307,819	-11.2%
Peak (MW)	52,256	46,852	-10.3%

4.8   Comparison of IES BAU Demand Forecasts to Other Countries

Figure 25 below plots the total electricity consumption per capita on an annual basis[12]. The dotted lines represent 2014 consumption levels in Japan, Hong Kong, Singapore and Taiwan with Taiwan at 10,000 kWh and Hong Kong around the 6,000 kWh level. The forecast shows Viet Nam exceeding Singapore and Thailand reaching Singapore by 2050. All the other smaller economies trend towards Hong Kong but do not reach 6,000 kWh by 2050. Lao PDR is higher than Myanmar and Cambodia due to its high electrification rates, and Myanmar lags behind Cambodia due to its larger population.

[12] Based on total population, and energy demand including transmission and distribution losses. GMS countries are based on the electrified population.

Figure 25   **Total Electricity Consumption per Electrified Capita (kWh per annum)**
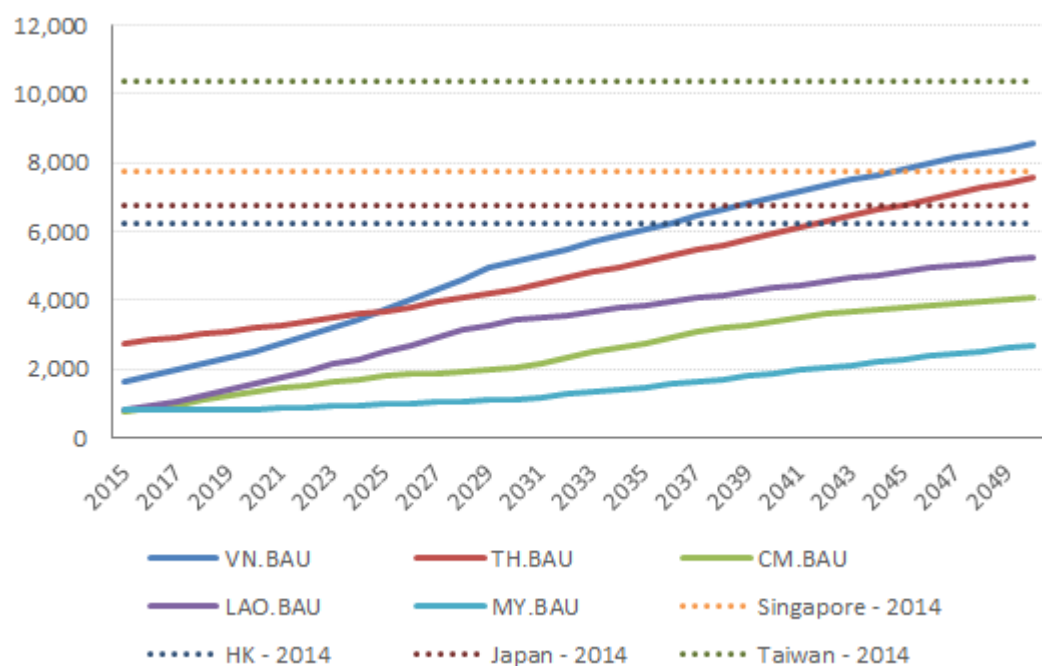
5 Sustainable Energy Scenario (SES) Demand Forecasts

The SES seeks to transition electricity demand towards the best practice benchmarks of other developed countries in terms of energy efficiency, maximise the renewable energy development, cease the development of fossil fuel resources, and make sustainable and prudent use of undeveloped conventional hydro resources. Where relevant, it leverages advances in off-grid technologies to provide access to electricity to remote communities. The SES takes advantage of existing, technically proven and commercially viable renewable energy technologies.

5.1 SES Key Driver Assumptions

Most of the key driver assumptions for the demand forecast of the BAU are the same in the SES, in particular the following remain the same:

- GDP growth rate scenarios;
- GDP composition;
- Population;
- Special economic zone developments;
- Urban and rural populations;
- Per capita electricity consumption;
- Transmission and distribution losses; and
- Load factor (although note that within the SES, there will be greater use of demand side management).

The details of these assumptions were presented in sections 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.7, 4.1.8 and 4.1.11.

The major differences for the SES demand forecasts are the assumptions made in terms of energy efficiency and the central grid electrification rates. These differences are described in detail in section 5.2 and 5.2.4.

5.2 Energy Efficiency Benchmarks for SES Demand Forecast

The SES electrical energy demand forecast uses benchmarks from demand intensities of selected countries for different demand sectors. The energy efficiency metric was based on the required energy input per dollar of GDP (kWh per real 2005 USD). These levels allowed IES to derive a reference energy efficiency level that was used to calculate the incremental energy consumption. We have assumed the current energy consumption follows the Base Case efficiency assumption, and that incremental year on year demands from the Base Caseare subject to further efficiency gains.

5.2.1 Industrial Demand

Figure 26 plots the industrial sector benchmarks for selected countries. The approach taken is explained as follows: Vietnam has a very high kWh/USD and was assumed to trend back towards Korea's 0.6 level by 2035 citing similar heavy industry based economies. Viet Nam

then continues on the trajectory to 2050. The other countries trend back towards the 0.2 level experienced by Hong Kong and France. Figure 26 and Figure 27 plots the benchmark and the GMS trajectory.

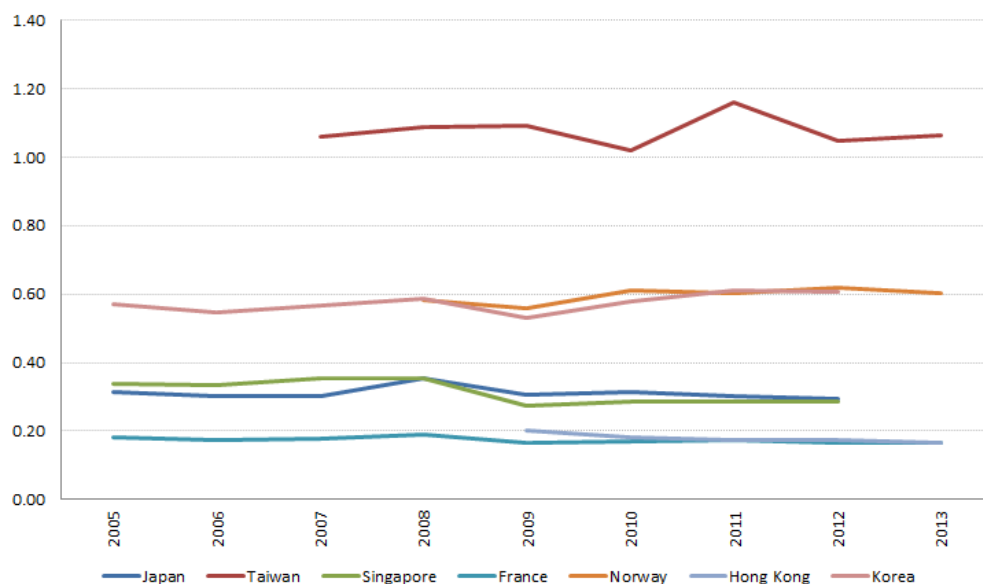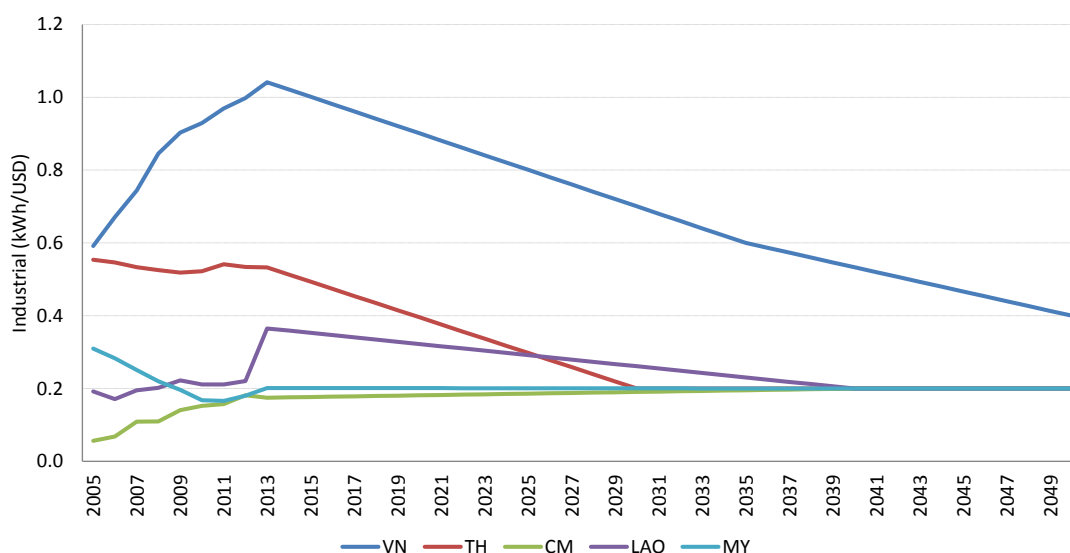**Figure 26** **Industrial Energy Intensity Benchmark (kWh per USD, real 2005)**

Figure 27 **Industrial Energy Intensity – GMS (kWh per USD, real 2005)**

5.2.2 Commercial Demand

Commercial: All GMS countries, with the exception of Myanmar[13], are assumed to trend towards levels around Singapore, Japan and Hong Kong. Figure 28 and Figure 29 plots the commercial sector benchmark and the GMS trajectory

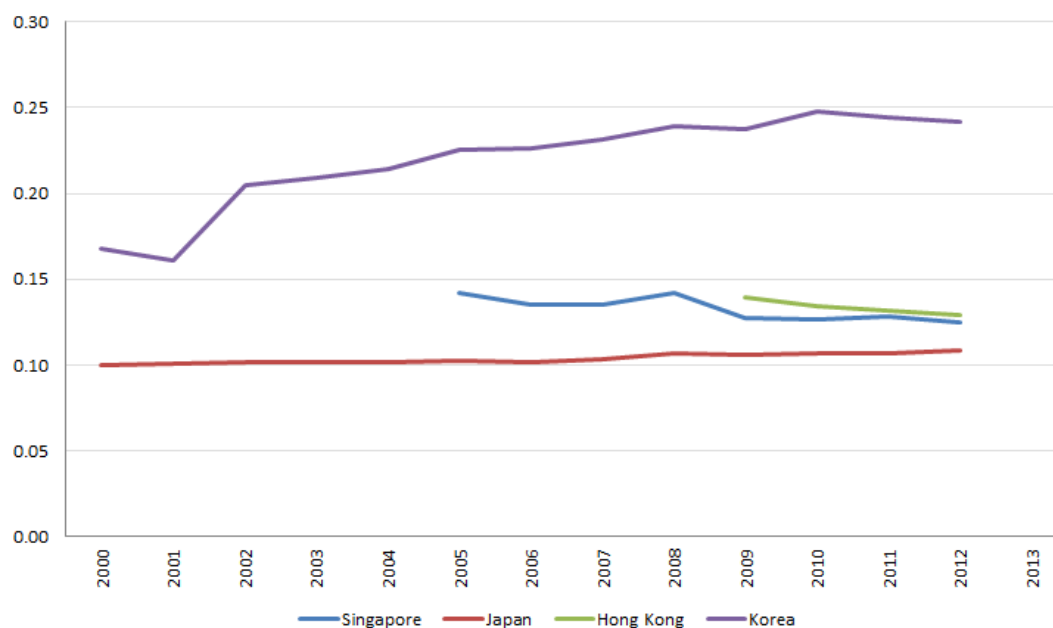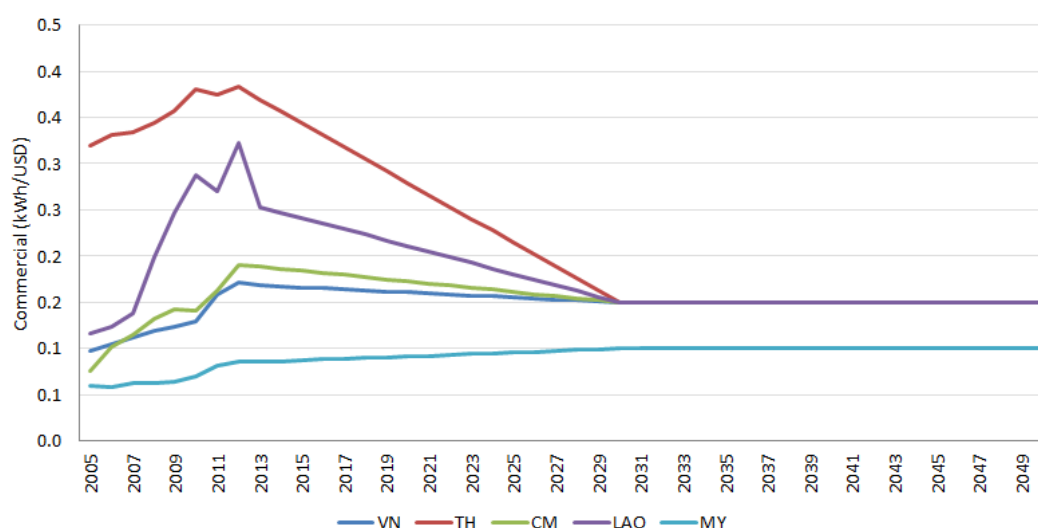**Figure 28   Commercial Energy Intensity Benchmark (kWh per USD, real 2005)**

Figure 29   Commercial Energy Intensity – GMS (kWh per USD, real 2005)

[13] Myanmar's actual levels remained below the chosen benchmark.

5.2.3   Agricultural Demand

Agriculture energy demand constitutes a very small amount of total energy demand. IES has assumed that all GMS countries revert to the Thailand long-term level by 2025. Agriculture makes up a very small percentage of total consumption of the GMS countries

5.2.4   Residential Demand

Urban per electrified capita residential electricity consumption is based on current levels trending towards Singapore's current level of approximately 1,200 kWh per annum then declines back towards 1,000 kWh by 2050 in Viet Nam and Thailand. The other GMS countries trends upwards then back down from 2045. Figure 30 plots the assumed urban residential per capita electricity consumption. Rural consumption increases to 70% of urban consumption by 2050.

**Figure 30   Urban Per Capita Consumption (kWh, per annum)**
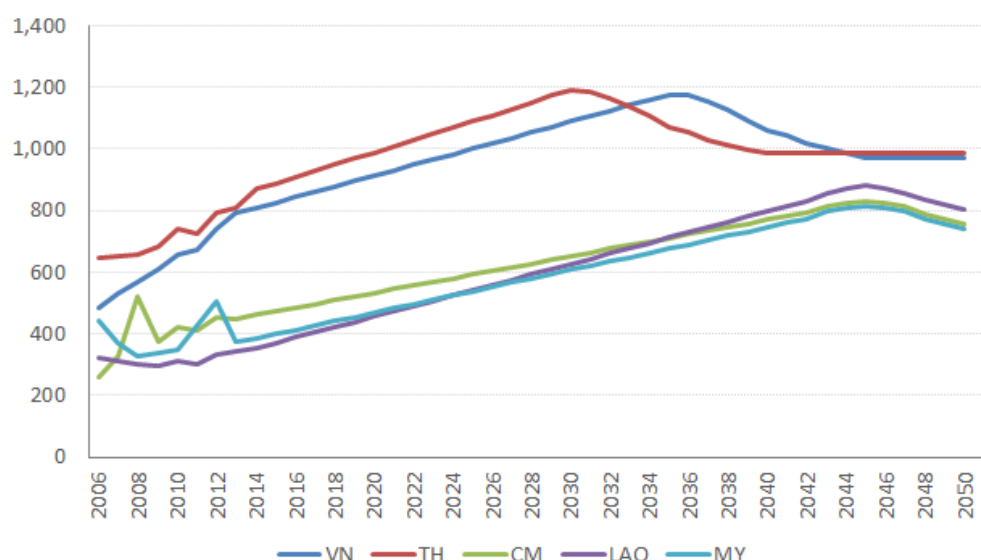
5.2.5   Energy Efficiency Costs

Energy Efficiency costs were based on the ranges quoted in the US market-based reports 'Unlocking Energy Efficiency in the US Economy' (McKinsey & Company, 2009) and 'The Total Cost of Saving Electricity through Utility Customer-Funded Energy Efficiency Programs' (Berkeley Labs, 2015). IES assumes relatively low cost energy efficiency savings in the GMS region from the outset, with costs slowly increasing at 2.5% pa (real)[14]. By 2050, IES assumed that energy efficiency costs would reach around 60% of that quoted in the

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[14] It was assumed a starting value that is 25% of the level quoted in the Berkeley lands report, or between $8-$13/MWh. This is commensurate with the range of costs quoted in the McKinsey and Company report for a range of end-use functions.

Berkeley Labs report based on judgments around the composition and efficiency of the USA demands today as compared to evolution of demand in the GMS.

Figure 31   Energy Efficiency Costs ($/MWh)
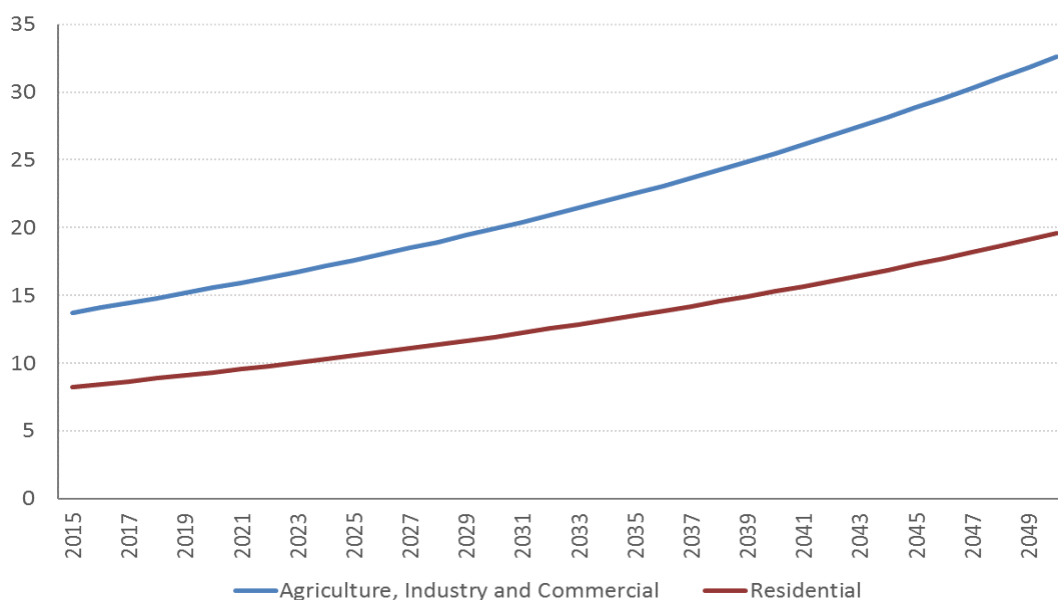
5.3   Grid Electrification and Off-grid Supply

Myanmar and Cambodia were modelled to achieve 70% central grid electrification by 2030 and 85% by 2040 in the SES. In the SES, distributed off-grid solutions to enhance provide electricity access were assumed, including mini-grids and meso-grids. These are deployed initially to provide access to remote areas of the grid however, over time the isolated mini-grids and meso-grids were assumed to become central grid connected based on economics. The ASES assumes grid electrification ceases from 2025 onwards as off-grid generation costs reaches parity with the grid. Because there are lower costs assumed in the ASES, the incentive for isolated mini-grids and meso-grids becoming central grid connected is not present. In all three scenarios electricity access, i.e. grid electrification and off-grid supply, are very similar, with levels reaching around 100% by 2030.

5.3.1   Potential Off-Grid Supply

Potential off-grid demand assumes the following and 4.5 persons per household. An additional 5% is added to reflect non-household energy requirements. Projected potential off-grid demand is assumed to increase at 3.5% pa in Myanmar and Cambodia reflecting the increase in standard of living and economic development.

Table 16   Breakdown of off-grid Household Consumption (2015)

Type	Household Size	kWh per HH	%
Urban	ALL	600	100%
Rural	Low	150	25%

Rural	Med	300	50%
Rural	High	600	25%

5.3.2 Grid Electrification and Off-grid Supply Costs

The cost of grid electrification is based on cost estimates of 100% electrification in Myanmar which is forecast to cover 7.2 million households by 2030 and forecast to cost $5.8 billion[15]. The pro-rated electrification cost per capita is applied to our electrification rate and population assumptions for Myanmar and Cambodia.

Off-grid supply costs are based on solar PV and battery storage systems with an efficiency of 85% around 2025 when we forecast significant uptake of off-grid technologies in the SES and ASES[16]. We have also assumed that the sizing of the battery is based on the mismatch of generated power from the solar PV systems and residential consumption, estimated at 25% of the total daily load.

Grid electrification costs only includes the building of the central transmission network and needs to also include grid cost of generation when comparing to off-grid supply costs.

5.4 Flexible Demand

Flexible demand represents changes in consumption behaviour or load shifting throughout the day. By 2050, we have assumed up to 15% of electricity demand is capable of being shifted. One third of the 15% (5%) is enabled through storage technologies such as pump and battery storage[17], with the balance directly attributable to end-user demand shifting. Note this is on top of the significant energy efficiency savings as discussed above.

5.5 Fossil Fuels

No additional coal, gas and large-scale hydro projects are to be developed from 2019 onwards representing a shift towards more sustainable energy types[18].

5.6 Transmission Planning

Transmission planning is optimised across the region to maximise the utilisation of renewable resources in an efficient manner compared to the BAU where generation and transmission planning was based on each individual country's needs.

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[15] Myanmar National Electrification Program Roadmap and Investment Prospectus, Castalia Strategic Advisors, 2014.

[16] SES: battery storage is assumed to cost $600/kWh decreasing to $300/kWh by 2050.

[17] Battery and pump storage is also scheduled in accordance with system generation requirements on top of this.

[18] Lao PDR and Myanmar have been allowed up to 2,500 MW of large-scale hydro on top of committed new entry to support the roll out of renewable projects.

5.7 Overall GMS SES Demand Forecast

The following section and results are compared to the Base case. Table 17 shows the percentage savings as a result of the assumed efficiency gains. Efficiency gains are based on current intensity benchmarks of the GMS countries trending towards levels experienced by other developed countries. See methodology for further details. Figure 32 plots the entire GMS region results for the BAU and SES case.

Table 17   BAU and SES Case Differences (GWh)

Country / Region	2030 BAU	2030 SES	2030 Difference	2050 BAU	2050 SES	2050 Difference
VN	503,947	396,400	-21%	861,417	582,401	-32%
TH	307,819	276,176	-10%	531,991	389,005	-27%
CM	36,034	28,566	-21%	87,811	62,512	-29%
LAO	29,459	25,813	-12%	54,924	43,414	-21%
MY	60,124	47,746	-21%	148,990	105,593	-29%
GMS	937,383	774,701	-17%	1,685,133	1,182,925	-30%

**Figure 32   GMS Electricity Demand (2005-2050) for the BAU and SES**
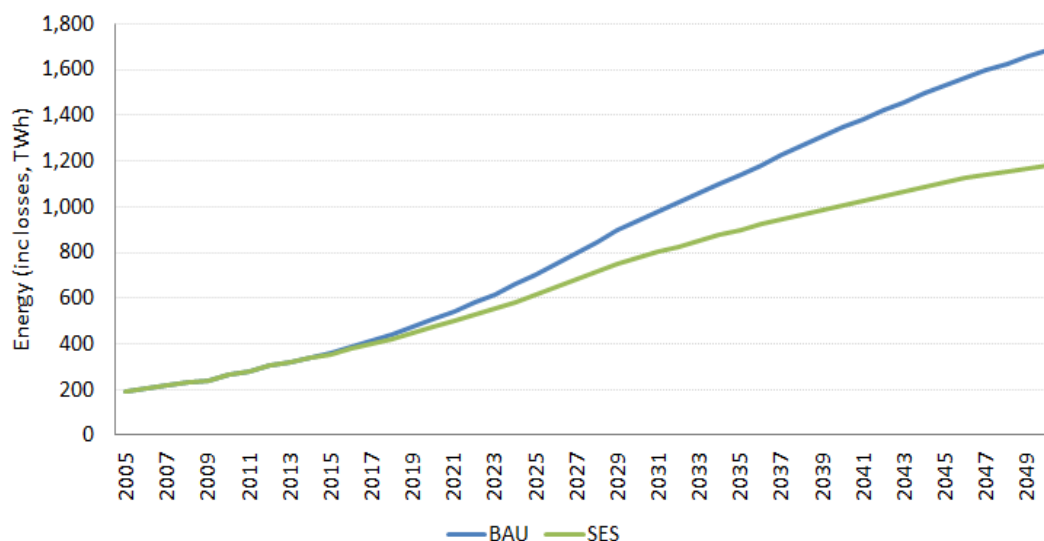
5.8 Cambodia SES Demand Forecast

Figure 33 shows the SES demand forecast and the BAU demand forecast.

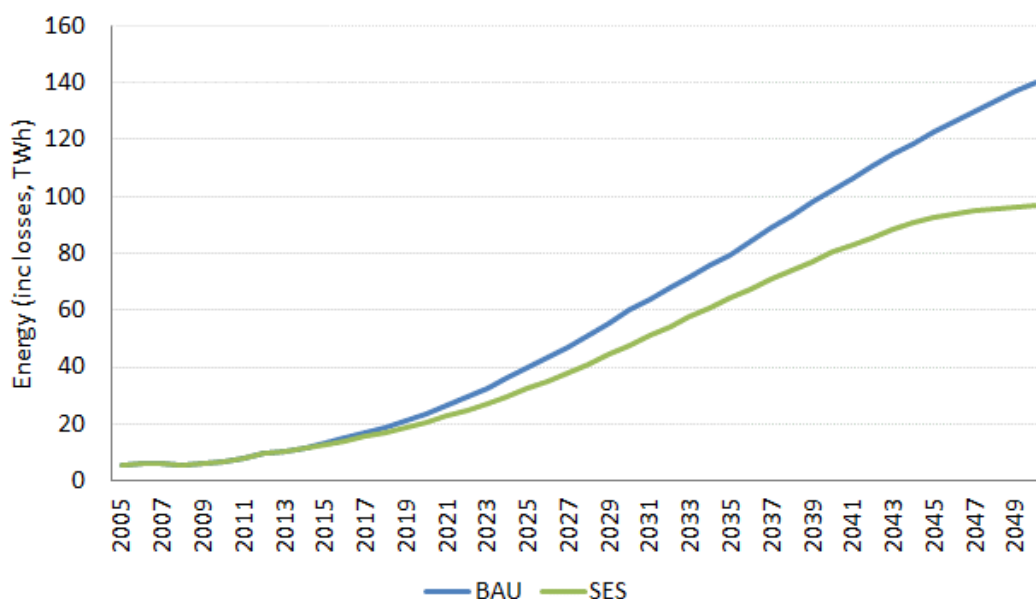**Figure 33**   **Cambodia Electricity Demand Forecast – BAU and SES**
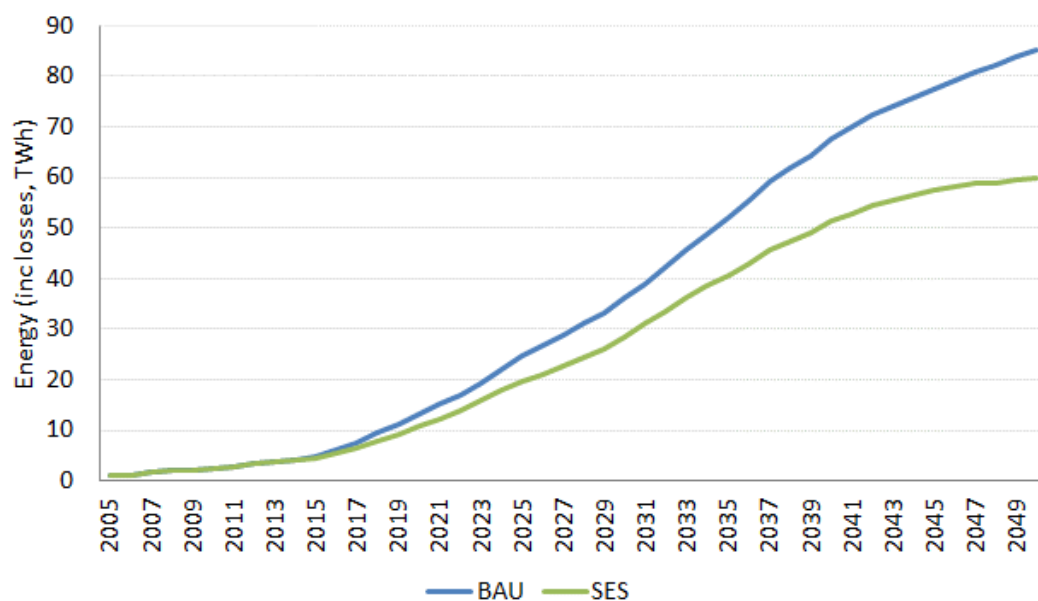
5.9   Lao PDR SES Demand Forecast

Figure 34 compares Lao PDR's SES demand forecast to the BAU demand forecast.

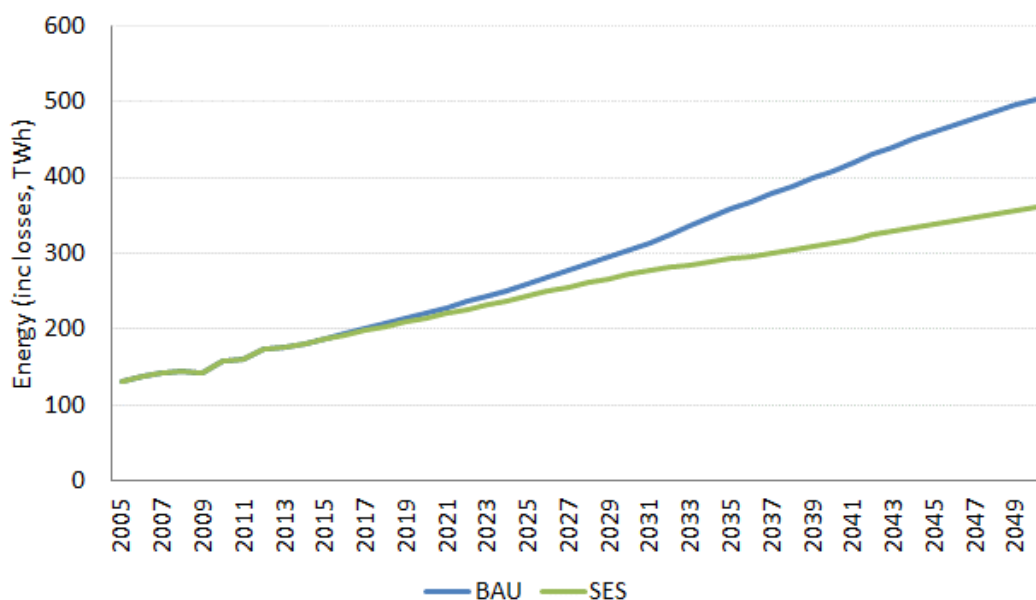**Figure 34**   **Lao PDR Electricity Demand by Case**
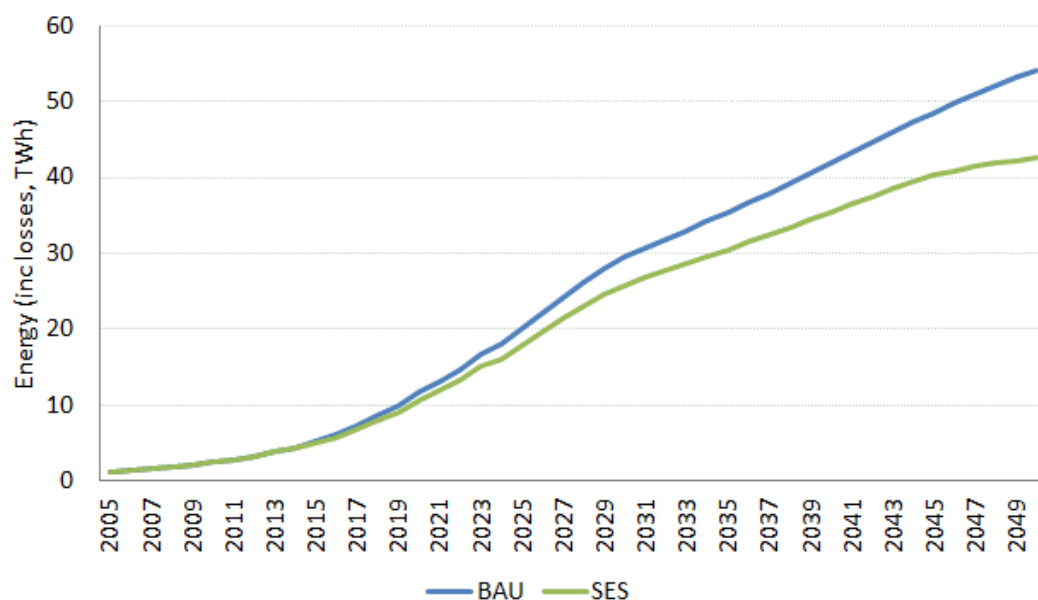
5.10 Myanmar SES Demand Forecast

Figure 35 compares Myanmar's SES demand forecast to the BAU demand forecast.

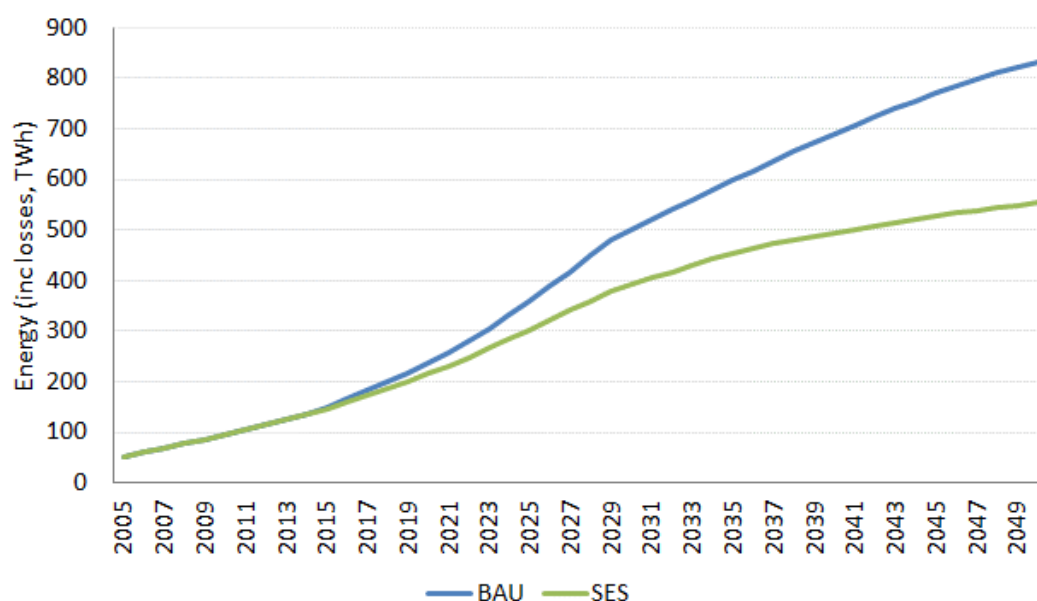**Figure 35   Myanmar Electricity Demand by Case**

5.11 Thailand SES Demand Forecast

Figure 36 compares Myanmar's SES demand forecast to the BAU demand forecast.

Figure 36   Thailand Electricity Demand by Case

5.12 Vietnam SES Demand Forecast

Figure 37 compares Vietnam's SES demand forecast to the BAU demand forecast.

**Figure 37   Vietnam Electricity Demand by Case**

5.13 Off-Grid Electricity Demand in the SES

The SES case assumes lower electrification targets in Myanmar and Cambodia relative to the BAU. Myanmar and Cambodia achieve 70% grid electrification by 2030 and 85% by 2040 in the SES case. Figure 38 provides the forecast potential off-grid demand in Myanmar and Cambodia. The energy levels are a function of electrification rates (rural and urban), and population sizes. Myanmar has the highest off-grid energy demand due to its current low rural electrification rate (15% in 2013) and high population size. This demand in the SES is expected to be met by off-grid renewable technologies and smart grids in the interim before the national electricity networks are expanded into rural areas.

Off-grid demand assumes 4.5 persons per household. An additional 5% is added to reflect non-household energy requirements. Additional assumptions relating to household size and usage are shown in Table 18 below.

Table 18   Off-grid Demand Assumptions

Type	Household Size	kWh per HH	%
Urban	ALL	600	100%
Rural	Low	150	25%
Rural	Med	300	50%
Rural	High	600	25%

Figure 38   **Off-grid Demand (SES, GWh)**
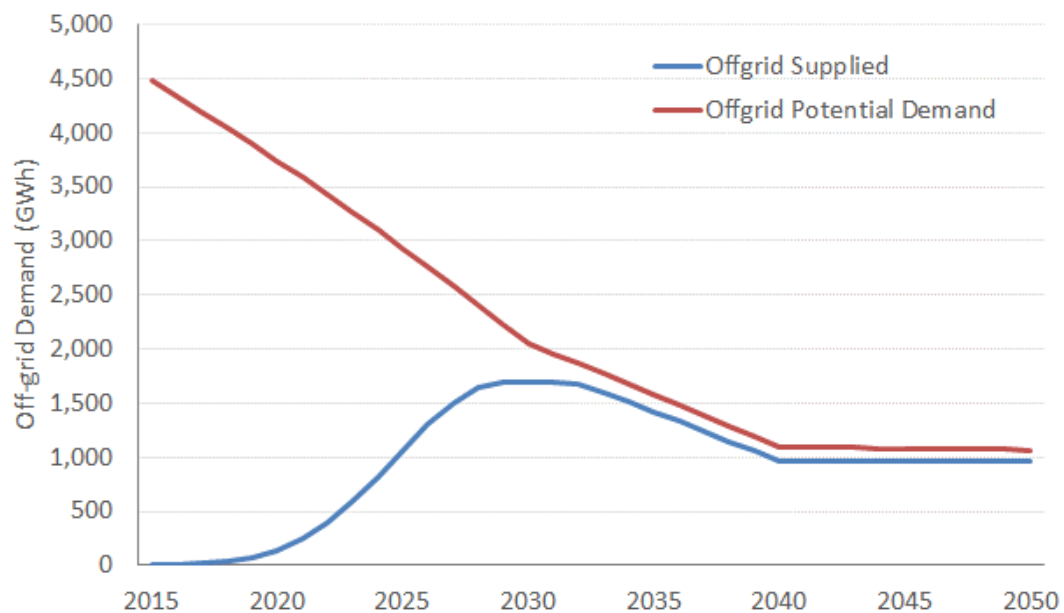
6 Advanced Sustainability Energy Scenario (ASES)

The ASES assumes that the power sector is able to more rapidly transition towards a 100% renewable energy technology mix under an assumption that renewable energy is deployed more than in the SES scenario with renewable energy technology costs declining more rapidly compared to BAU and SES scenarios.

A brief summary of the main differences between the ASES and SES is detailed below:

▪ **Demand**: Uptake of electric vehicles and motorcycles is doubled by 2050. An additional 20% in energy efficiency savings is applied to the incremental SES demand. Electrification rates in Myanmar and Cambodia stop increasing after solar and battery storage costs reach parity with the system LCOE and all potential off-grid demand is instead met by mini and micro grids – this is expected to occur after 2025.

▪ **Flexible Demand**: Flexible demand is assumed to increase from 15% in 2050 (SES) to 25% in 2050 under the ASES reflecting a faster change in policy, infrastructure and attitudes affecting consumption behaviour.

▪ **Technology costs**: The SES technology cost changes are accelerated by 10 years in the ASES. The trajectory from 2040 to 2050 assumes the same rate of change from 2030-2040.

▪ **Renewable Targets and Retirements**: The ASES assumes renewable policy targets are implemented across the region targeting 95% and 100% of renewable generation by 2045 and 2050. As such, coal and gas plants are assumed to retire earlier than in the SES.

6.1 Overall GMS SES Demand Forecast

The following section and results are compared to the Base case. Table 19 shows the percentage savings as a result of the assumed efficiency gains. Efficiency gains are based on current intensity benchmarks of the GMS countries trending towards levels experienced by other developed countries. See country modelling reports for further details. Figure 39 plots the entire GMS region results for the BAU, SES, and ASES cases.

Table 19   BAU and SES Case Differences (GWh)

Country / Region	2030 BAU	2030 SES	2030 Difference	2050 BAU	2050 SES	2050 Difference
Viet Nam	507,526	370,786	-27%	890,284	564,259	-37%
Thailand	311,872	271,312	-13%	560,269	397,371	-29%
Cambodia	36,034	24,573	-32%	90,584	55,636	-39%
Lao PDR	29,459	23,083	-22%	55,733	39,608	-29%
Myanmar	60,124	41,893	-30%	157,997	99,300	-37%
GMS	945,016	731,647	-23%	1,754,867	1,156,175	-34%

Figure 39 **GMS Electricity Demand (2005-2050) All Scenarios**
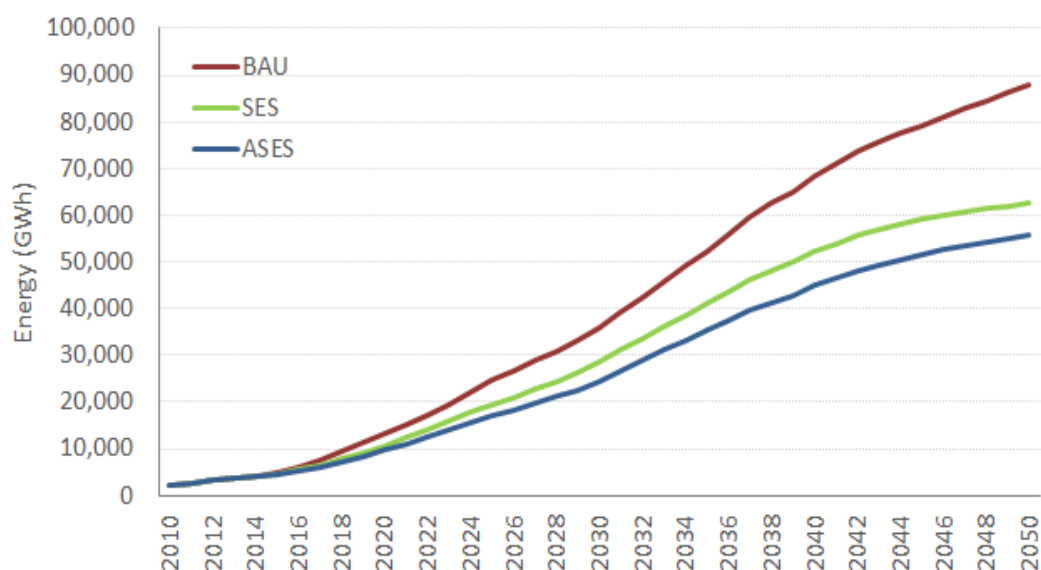
6.2 Cambodia SES Demand Forecast

Figure 40 compares Cambodia's ASES demand forecast against the BAU and SES demand forecast.

Figure 40 **Cambodia Electricity Demand – All Scenarios**
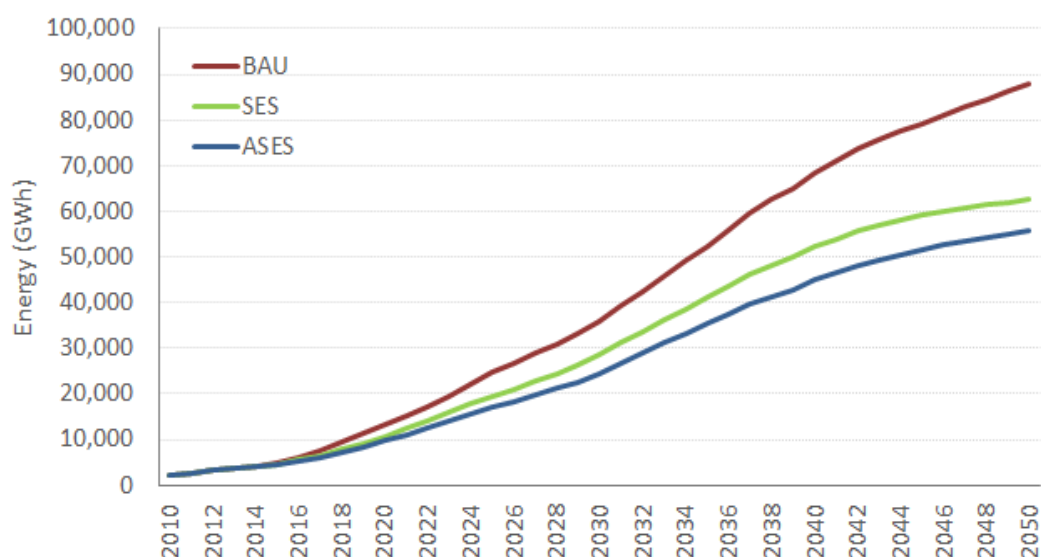
6.3 Lao PDR SES Demand Forecast

Figure 41 compares Lao PDR's ASES demand forecast against the BAU and SES demand forecast.

Figure 41   Lao PDR Electricity Demand - All Scenarios

6.4 Myanmar SES Demand Forecast

Figure 42 compares Myanmar's ASES demand forecast against the BAU and SES demand forecast.

Figure 42   Myanmar Electricity Demand - All Scenarios

6.5 Thailand SES Demand Forecast
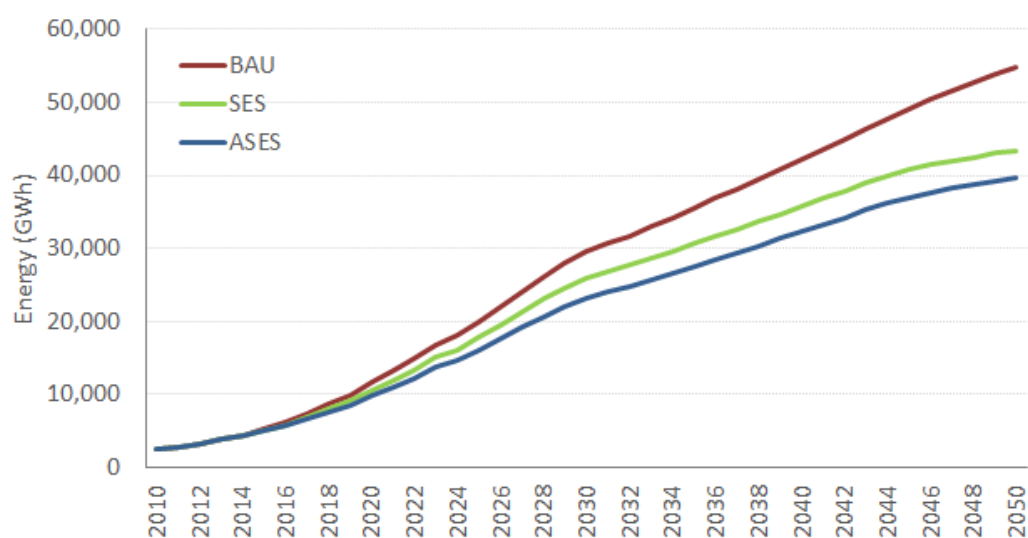
Figure 43 compares Thailand's ASES demand forecast against the BAU and SES demand forecast.

Figure 43   Thailand Electricity Demand - All Scenarios

6.6 Vietnam SES Demand Forecast

Figure 44 compares Vietnam's ASES demand forecast against the BAU and SES demand forecast.
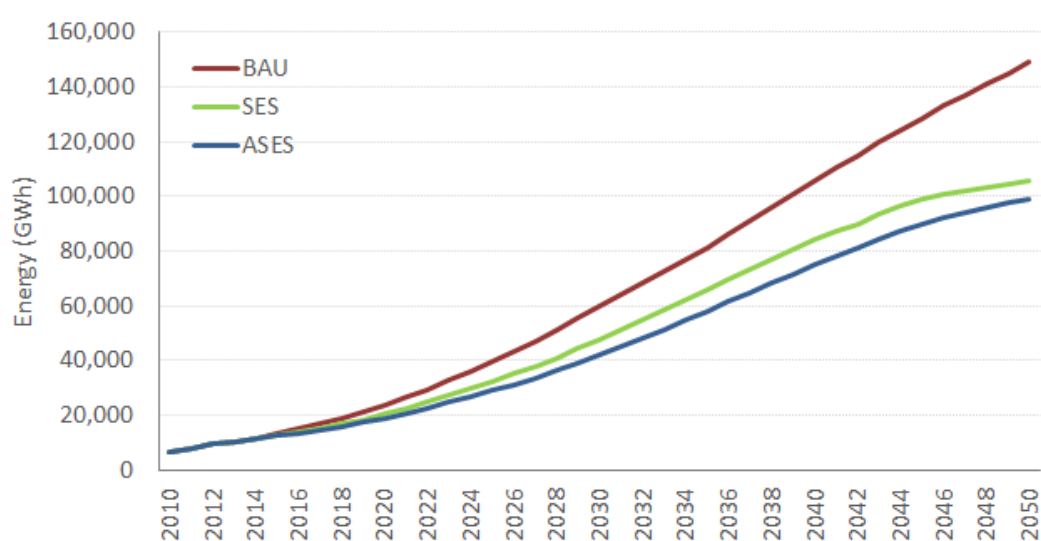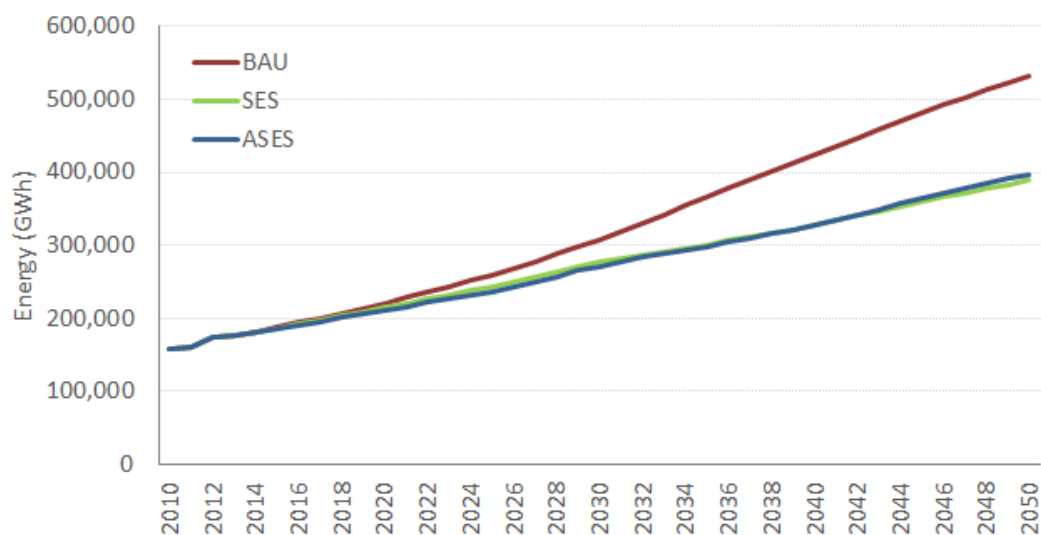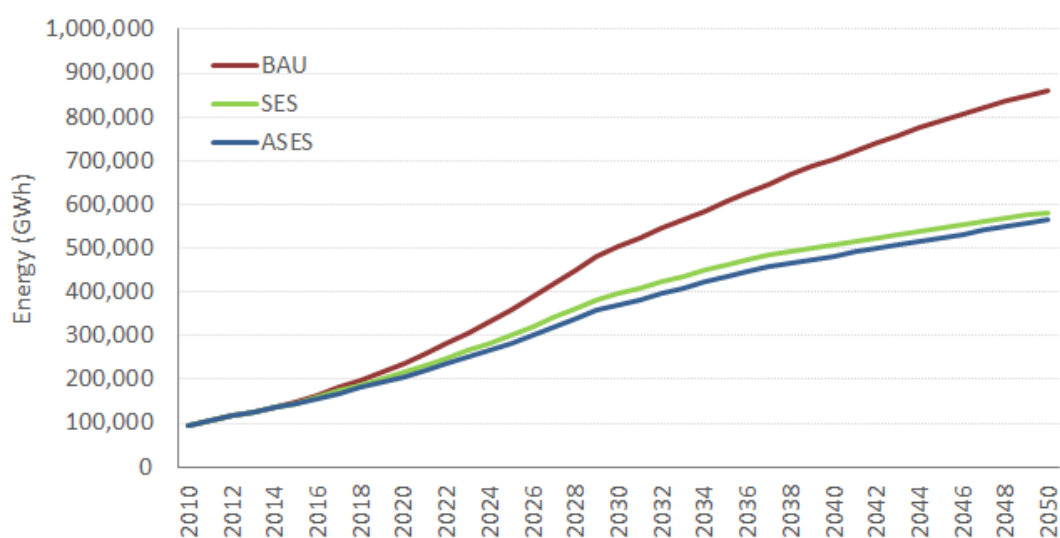
Figure 44   Vietnam Electricity Demand - All Scenarios

6.7 Off-Grid Electricity Demand in the ASES

The ASES case assumes lower grid-electrification targets in Myanmar and Cambodia relative to the SES as potential off-grid demand is met by off-grid renewable technologies and smart grids permanently. Figure 45 plots the forecast off-grid demand. The off-grid demand in Myanmar and Cambodia decline initially due to initial efforts towards grid electrification. From 2025, the demand that is supplied by off-grid technologies increases as solar PV and battery storage reaches parity with system generation costs. The trajectory upwards from 2030 reflects increasing population and higher per capita consumption levels as the GMS economy grows.

See section 5.13 for the common grid electrification and off-grid assumptions.

Figure 45   Off-grid Demand (ASES, GWh)
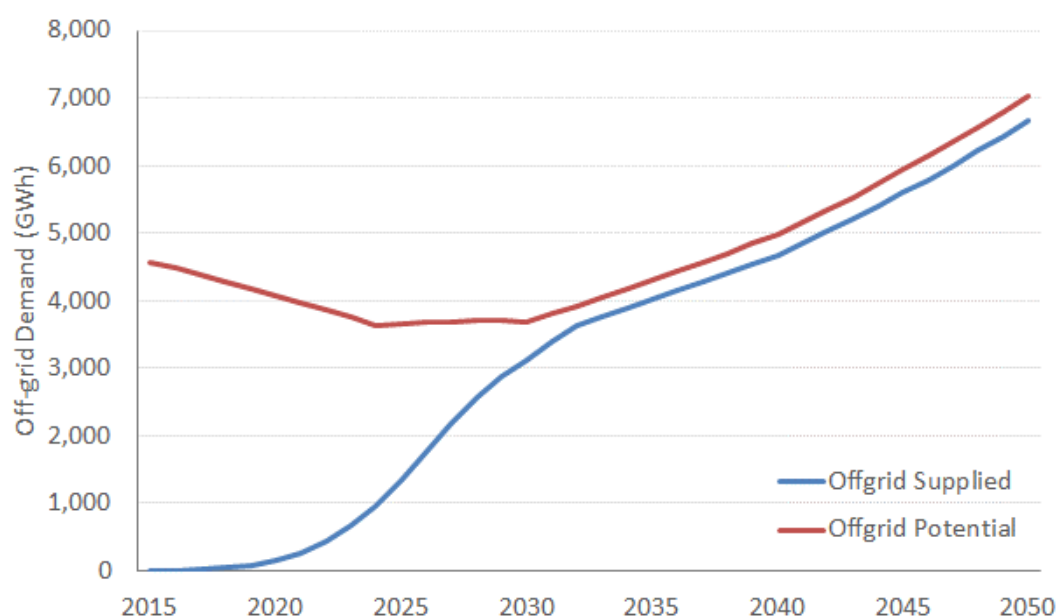
7   Fuel Pricing Assumptions

IES has developed a global fuel price outlook which is based in the shorter-term on the contracts traded in global commodity exchanges for fuels before reverting towards long-term price forecasts and relationships provided in energy agency reports. A summary of the fuel prices expressed on an energy basis ($US/MMBtu HHV) is presented in Figure 46 below. Fuel prices in this section are quoted on a FOB basis.

The 30% dip from 2014 to 2015 for the various fuels was the result of a continued weakening of global energy demand combined with increased stockpiling of reserves. Brent crude prices fell from $155/bbl in mid-2014 to $50/bbl in early 2015. The Organisation of the Petroleum Exporting Countries (OPEC) at the November 2014 meeting did not reduce production causing oil prices to slump. Fuel prices are assumed to return to long-term expectations by 2025.

Figure 46   IES Base Case Fuel Price Projections to 2050
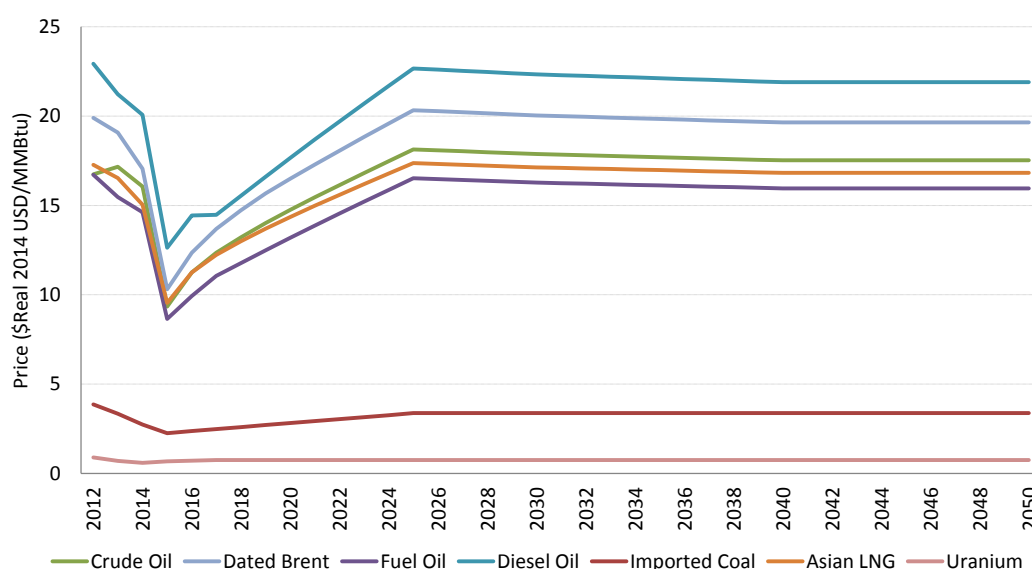
Key comments on the trends and relationships assumed in the fuel price scenarios are discussed below.

7.1   Crude Oil Prices

The crude oil price trajectory is made up of:

- Our base case crude projection is based on recent settlement prices of the New York Mercantile Exchange (NYMEX) monthly crude oil contract in the short term reverting to long-term pricing by 2025.

- The long-term outlook is derived from the IEA World Energy Outlook 2014 report. The IEA report contains three scenarios, current policy, new policy and a 450 scenario representing a global carbon intensity target of 450 ppm. Our long-term prices are

based on the 450 scenario, which are projected to decline over the longer period from $102.35/bbl in 2015 to $96.56/bbl by 2040, representing a more conservative view of long-run oil prices. Crude prices after 2040 are assumed to remain constant from 2040 to 2050.

• Given the significant price disparity between currently traded exchange contracts and the IEA long-term outlook trajectory, the projection of crude prices is based on a high weighting towards NYMEX contract prices in the short-term trending towards a 100% weighting towards the IEA 450 scenario projection by 2025.

The projection is shown in Figure 47.

Figure 47   IES Crude Oil Projection to 2050
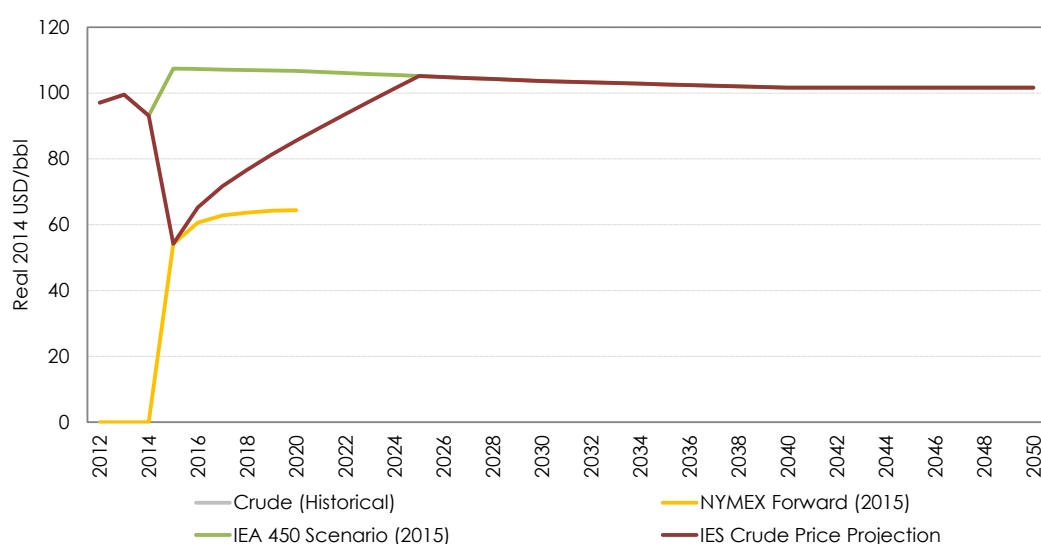

7.2   Dated Brent, Fuel Oil, and Diesel Oil

Dated Brent, Fuel Oil, and Diesel Oil are linked to the long-term forecast price movements of crude:

• Dated Brent in the short term, similar to our methodology with crude, is based on the NYMEX monthly exchange traded contracts to 2020. Longer-term prices are based on the historical relationship with crude oil applied to the IEA 450 scenario crude oil forecasts. Weightings, as per the methodology for crude oil, are applied to the short and long-term prices to derive the Dated Brent price trajectory.

• Short-term Fuel Oil and Diesel Oil prices (to 2017) are based on calendar swap futures listed on the Chicago Mercantile Exchange. The long-term prices are based on the IEA 450 scenario crude price growth rates applied to the historical Fuel Oil and Diesel Oil prices respectively. Weightings, as per the methodology for crude oil, are applied to the short and long-term prices to derive the Fuel Oil and Diesel Oil price trajectories.

Figure 48 plots the Dated Brent, Fuel Oil, and Diesel Oil price projections.

Figure 48   IES Dated Brent, Fuel Oil and Diesel Oil Price Projections to 2050
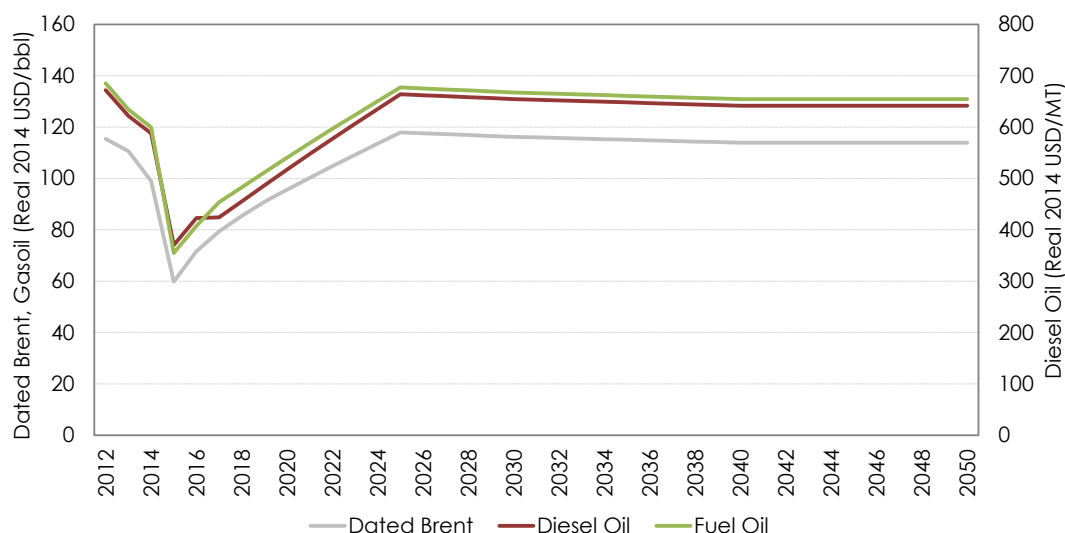
7.3   Coal Prices

Imported coal in the GMS is mostly sourced from Indonesia and Australia. Forecasts of imported coal prices are based on:

- Newcastle coal prices over the short-term are based on the monthly Newcastle coal futures listed on the Intercontinental Exchange. The long-term Newcastle prices are assumed to recover to 2013 levels by 2025 and held constant thereafter.

- Forecasted Indonesian coal prices are based on the relationship between historical Newcastle and Indonesian coal prices on a per equivalent energy basis. The historical ratio from 2010-2014 has been stable around 0.85, and we have estimated it to increase to 0.90 over the longer term.

- Average imported coal prices are assumed to reflect a 70/30 weighting of Newcastle and Indonesian coal respectively.

Figure 49 shows the coal price projections.

Figure 49   IES Coal Price Projection to 2050
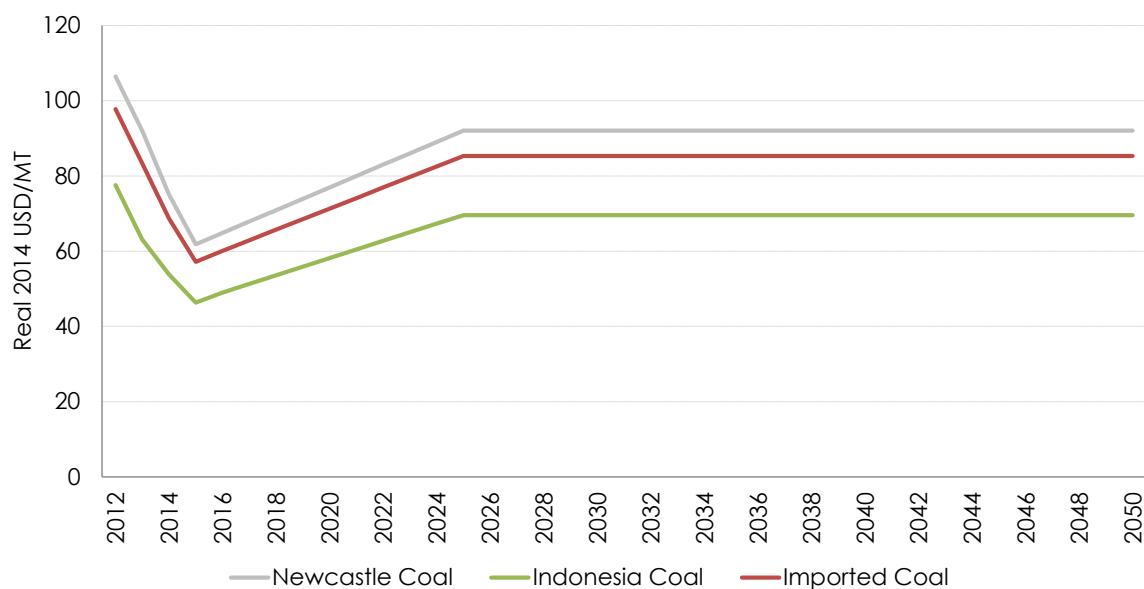
7.4   Asian LNG Prices

International Asian Liquefied Natural Gas (LNG) prices are based on the LNG price dynamic against Japan Crude Cocktail (JCC) prices:

- The JCC curve is based on the historical relationship with crude oil prices. These crude oil prices follow the IEA 450 scenario crude oil price projections out to 2040 which are then held constant.

- LNG prices are assumed to be a function of JCC prices, with a slope of 0.12 and an intercept of 1.05 ($US/MMBtu HHV).

Figure 50 plots the international Asian LNG prices.

Figure 50   IES LNG Asian LNG Price Projection to 2050
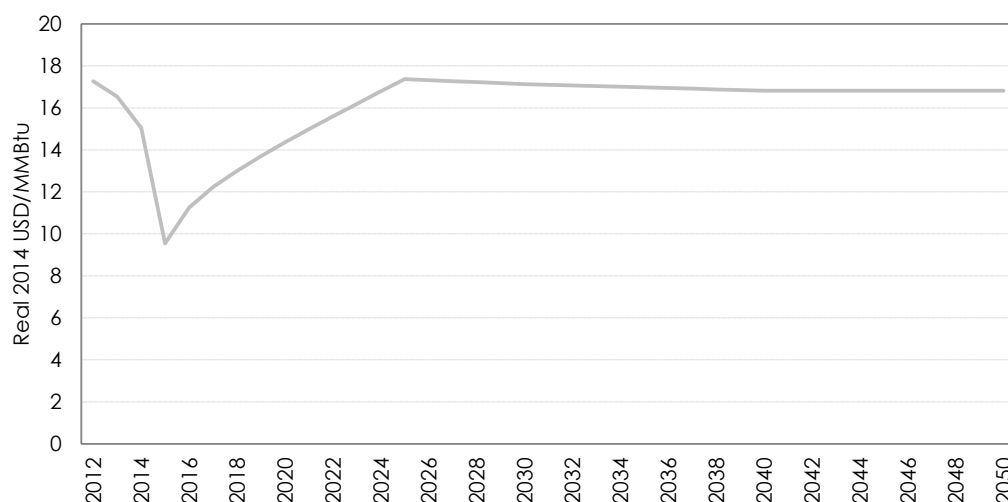
7.5   Summary of Key Fuel Price Assumptions

In this modelling we have assumed a single trajectory of prices and have not developed any alternative cases. Table 20 summarises the approach to IES fuel price projections. The short-term forward curve and long-term projections are weighted to smooth out the trajectory with higher weightings given to forward prices in the short-term which trend towards long-term projections.

Table 20   Fuel Price Assumptions

Fuel Source	Short-term price assumption	Long-term price assumption
Crude	Based on the NYMEX forward prices.	IEA World Energy Outlook 2014 450 scenario crude price projections from 2025 to 2040 then held constant to 2050.
Dated Brent	Based on the NYMEX monthly exchange traded contract	Follows growth rate of 450 scenario crude price trajectory
Fuel Oil	Singapore FO 180cst Futures (CME)	Follows growth rate of 450 scenario crude price trajectory
Diesel Oil	Singapore Gasoil 180cst Futures (CME)	Follows growth rate of 450 scenario crude price trajectory
Imported Coal	Newcastle Coal Futures (ICE) + Indonesian coal prices based on 90% parity of Newcastle coal	IES expectations of coal prices (approx. USD $92/tonne by 2025, real 2014) and held constant thereafter
Asian LNG	Based on constant relationship against JCC (which fluctuates according to crude)	Based on constant relationship against JCC (which fluctuates according to crude) and held constant after 2040
Nuclear	UxC Uranium U3O8 Futures Settlements (CME) to 2017	Short-term levels held constant to 2050

7.6 Fuel Prices

Table 21 sets out the Free on Board (FOB) fuel price assumptions that were used in the modelling presented in this report. This fuel price set was common to all three scenarios.

**Table 21   Fuel Price Assumptions (FOB) (Real 2014 USD/GJ)**

Year	Coal	Gas	Diesel	Uranium	Fuel Oil	Biomass*	Biogas*
2015	2.39	10.08	13.34	0.72	9.13	2.57	1.00
2016	2.51	11.88	15.24	0.76	10.49	2.62	1.00
2017	2.63	12.91	15.28	0.80	11.68	2.67	1.00
2018	2.74	13.72	16.41	0.80	12.43	2.72	1.00
2019	2.86	14.47	17.53	0.80	13.18	2.78	1.00
2020	2.98	15.16	18.64	0.80	13.93	2.83	1.00
2021	3.10	15.81	19.73	0.80	14.65	2.89	1.00
2022	3.21	16.46	20.80	0.80	15.36	2.95	1.00
2023	3.33	17.10	21.86	0.80	16.06	3.01	1.00
2024	3.45	17.72	22.90	0.80	16.76	3.07	1.00
2025	3.56	18.34	23.93	0.80	17.44	3.13	1.00
2026	3.56	18.29	23.86	0.80	17.39	3.19	1.00
2027	3.56	18.24	23.79	0.80	17.34	3.25	1.00
2028	3.56	18.19	23.72	0.80	17.29	3.32	1.00
2029	3.56	18.14	23.65	0.80	17.24	3.39	1.00
2030	3.56	18.09	23.58	0.80	17.19	3.45	1.00
2031	3.56	18.06	23.53	0.80	17.15	3.52	1.00
2032	3.56	18.02	23.49	0.80	17.12	3.59	1.00
2033	3.56	17.99	23.44	0.80	17.08	3.67	1.00
2034	3.56	17.96	23.40	0.80	17.05	3.74	1.00
2035	3.56	17.92	23.35	0.80	17.02	3.81	1.00
2036	3.56	17.89	23.30	0.80	16.98	3.89	1.00
2037	3.56	17.86	23.26	0.80	16.95	3.97	1.00
2038	3.56	17.83	23.21	0.80	16.92	4.05	1.00
2039	3.56	17.79	23.16	0.80	16.88	4.13	1.00
2040	3.56	17.76	23.12	0.80	16.85	4.21	1.00
2041	3.56	17.76	23.12	0.80	16.85	4.29	1.00
2042	3.56	17.76	23.12	0.80	16.85	4.38	1.00
2043	3.56	17.76	23.12	0.80	16.85	4.47	1.00
2044	3.56	17.76	23.12	0.80	16.85	4.56	1.00
2045	3.56	17.76	23.12	0.80	16.85	4.65	1.00
2046	3.56	17.76	23.12	0.80	16.85	4.74	1.00
2047	3.56	17.76	23.12	0.80	16.85	4.84	1.00
2048	3.56	17.76	23.12	0.80	16.85	4.93	1.00
2049	3.56	17.76	23.12	0.80	16.85	5.03	1.00
2050	3.56	17.76	23.12	0.80	16.85	5.13	1.00

Biomass energy content and prices can vary widely based on feedstock and a variety of other factors. We have assumed an energy content of 15MJ/kg and around $40/t feedstock cost increasing at 2% per annum. Biogas costs are based on IES estimates.

8   Technology Costs

Current and historical technology costs for the various conventional energy types have been obtained from a wide range of industry sources and public reports[19]. The costs outlined in this section are based on global estimates where GMS specific data was not available. The figure below shows the current cost trends between the various regions in the world according to the International Renewable Energy Agency (IRENA)[20]. Capital costs in China and India, which provide a proxy for the technology costs in the Greater Mekong Region are observed to be generally lower compared to other regions. Figure 51 presents a snapshot of the various renewable technology installed costs.

Figure 51   Current Cost Trends
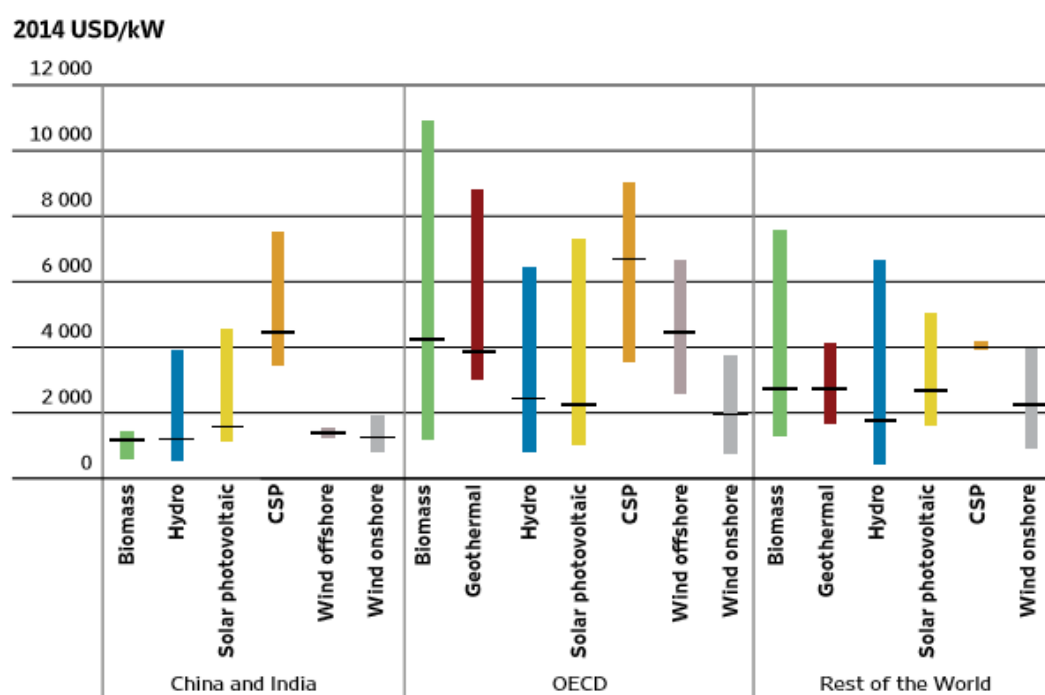
Source: Power Generation Costs 2014, IRENA (2015)

8.1   Review of Historical Technology Cost Trends

Technology costs over time tend to decrease as a function of the capacity produced or attaining greater economies of scale. Solar PV and Wind have grown at a rapid rate over the

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[19] Renewable Power Generation Costs in 2014 from IRENA (2015), The Model for Electricity Technology Assessment (META) from the World Bank's Energy Sector Management Assistance Program, World Energy Perspective: Cost of Energy Technologies by the World Energy Council and Bloomberg New Energy Finance (2013), Fuel and Technology Cost Review (2014) by ACIL Allen Consulting for the Australian energy markets, Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants (2013) by the US Energy Information Administration.

[20] Power Generation Costs 2014, IRENA (2015)

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past 10 years as installed capacity around the world increased from 4 and 48 GW to 177,000 and 370,000 GWh respectively, with significant cost decreases over the same period.

8.1.1   Onshore and Offshore Wind Turbine Costs

Figure 52 tables the growth in onshore and offshore wind farm capacity globally, which has increased 169% and 81% from 2010 to 2014. Over this period, the weighted average cost has dropped between 4% and 27%.

**Figure 52   Cumulative Wind Capacity and Cost Trends (World)**

	2010		2013		2014		2010-2014 (% CHANGE)	
	OFFSHORE	ONSHORE	OFFSHORE	ONSHORE	OFFSHORE	ONSHORE	OFFSHORE	ONSHORE
NEW CAPACITY ADDITIONS (GW)	1.0	37	2.0	33	1.2	40+	N.A.	N.A.
CUMULATIVE INSTALLED CAPACITY (GW)	3.2	193	7.4	310	8.6	350+	169%	81%
WEIGHTED AVERAGE INSTALLED COST RANGES (2014 USD/kW)	3 700 – 5 600	1 330 – 3 060	2700 – 6 530	1 340 – 2 330	2 700 – 5 070	1 280 – 2 290	-9% TO -27%	-4% TO -25%

Source: Power Generation Costs 2014, IRENA (2015)

Figure 53 plots historical wind turbine prices, which can account for up to 75% of the total project cost; those have declined significantly over the past 7 years. Chinese turbine prices are significantly lower than the other regions. Figure 54 shows the cost differences between various regions with wind farms installed in China and India being the cheapest at around $1,500/kW. Installed costs in China show a slight decline in prices from 2010 to 2014.
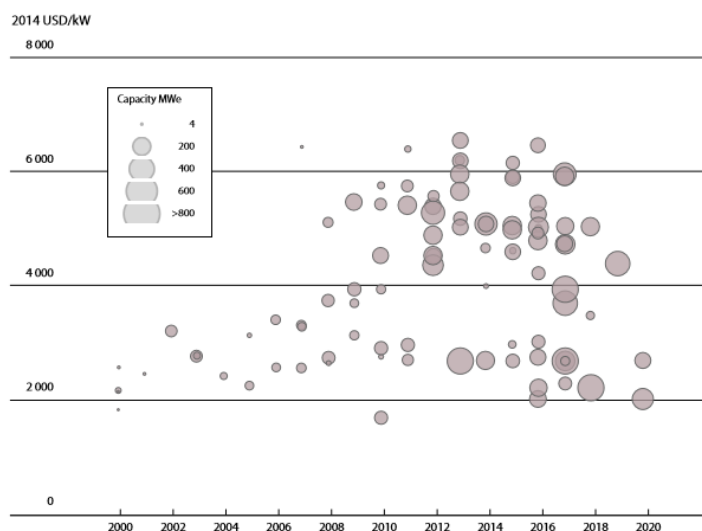
Figure 53   Historical Wind Turbine Prices
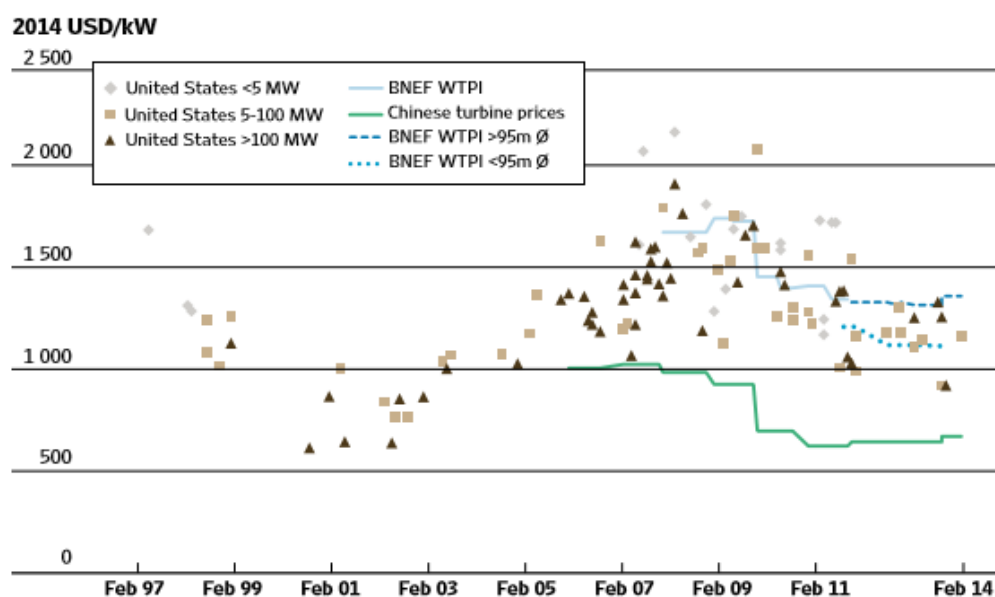
Source: Power Generation Costs 2014, IRENA (2015)

Figure 54   Historical Installed Cost by Region
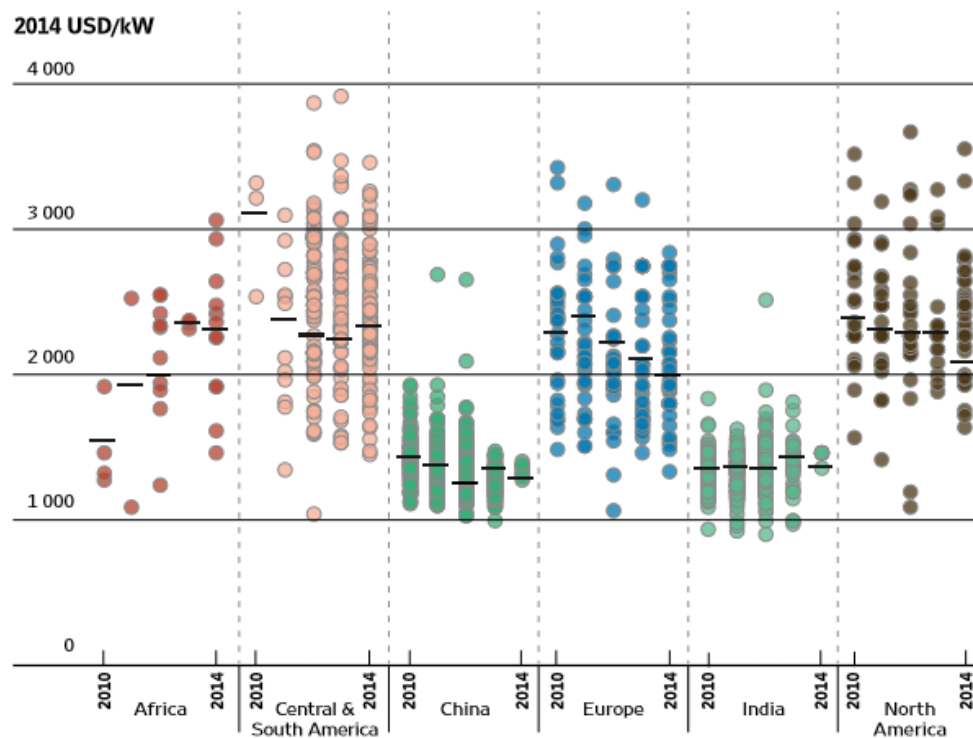
Source: Power Generation Costs 2014, IRENA (2015)

Figure 55 plots offshore windfarm costs around the world, and on average cost twice that of onshore wind farms.

**Figure 55   Commissioned and Proposed Offshore Wind Farm Costs**

Source: Power Generation Costs 2014, IRENA (2015)

8.1.2 Solar Photovoltaic (PV)

Figure 56 shows the historical utility-scale solar PV installed costs. The weighted average utility cost curve has decreased from around $4,000/kW to less than $2,000/kW by 2014. The average includes the various technologies including crystalline silicon, and thin film, with and without tracking.
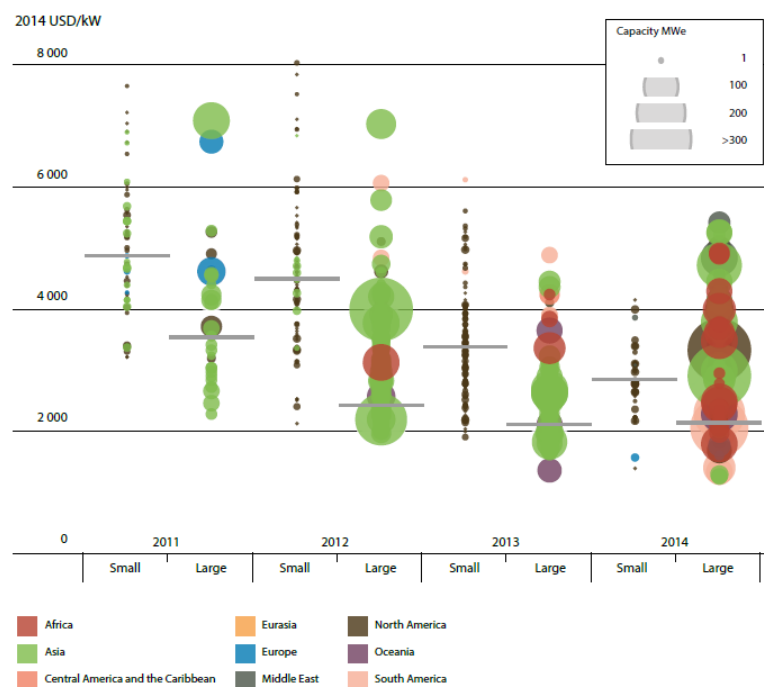
Figure 56   Estimated Historical Utility-Scale PV Costs
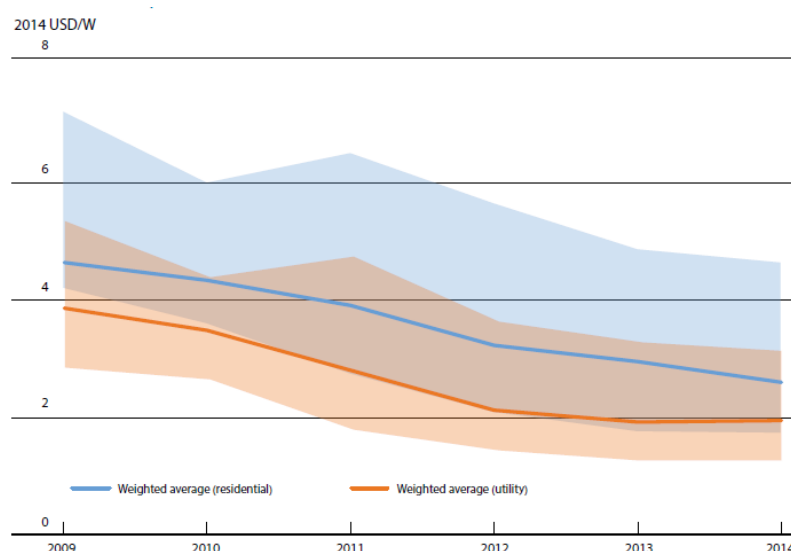
Source: Power Generation Costs 2014, IRENA (2015)

Figure 57 shows the historical cost trends across various regions.

Figure 57   Installed Prices by Year and Region

Source: Power Generation Costs 2014, IRENA (2015)

8.1.3   Concentrating Solar Power (CSP)

Figure 58 plots CSP installed costs by capacity factor and storage capability. There is a significant cost difference between having a storage capability (ranging from $6,000/kW to $12,000/kW) to CSP without storage ($3,000/kW to $9,000/kW) with an incremental capacity factor of between 10-15%.

Figure 58   Installed CSP Costs by Technology and Storage Capability
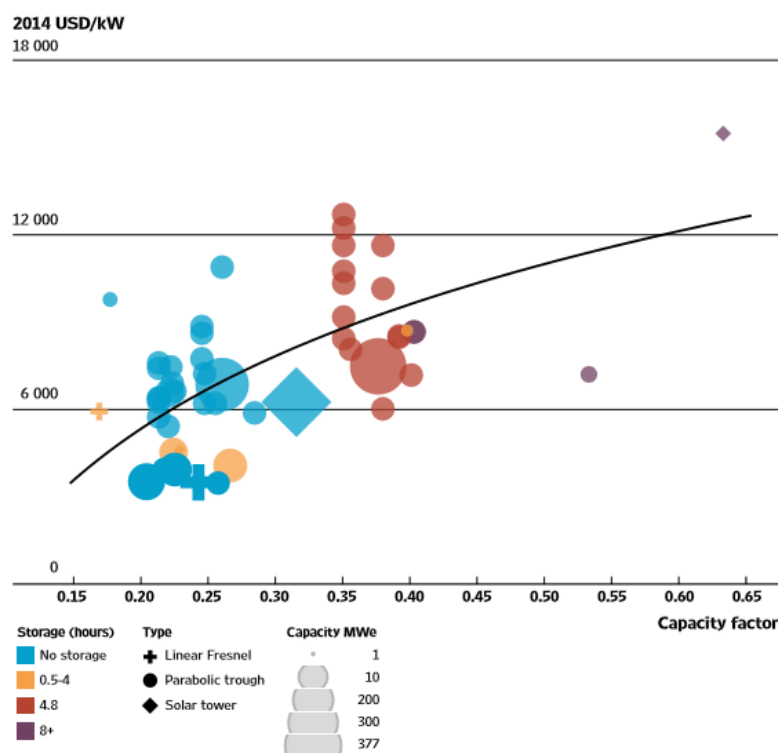
Source: Power Generation Costs 2014, IRENA (2015)

Figure 59 shows the costs of CSP which have not decreased as much as solar PV prices (utility-scale) to date.

Figure 59   Installed CSP Prices
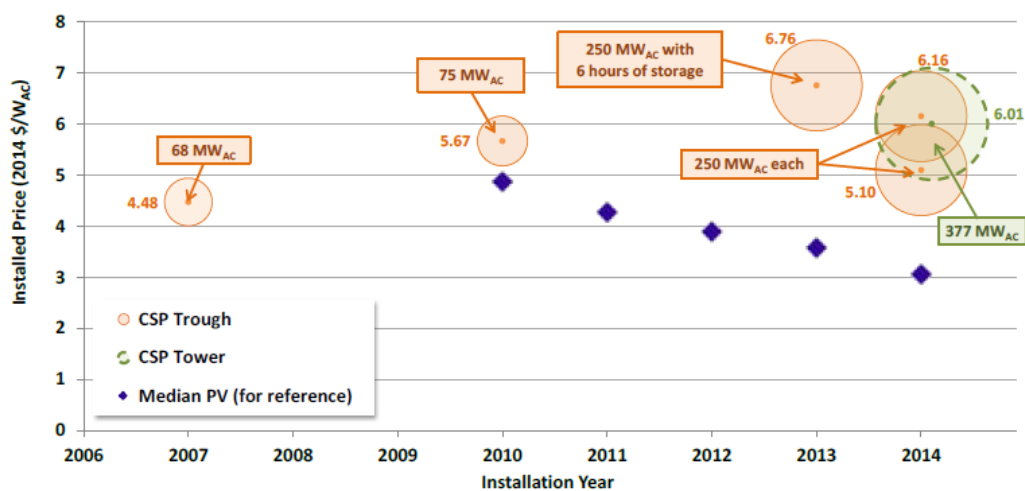
Source: Utility-scale Solar, US DOE, Sep 2015

8.1.4 Biomass

Figure 60 plots the biomass technology installed cost by region and shows projects in Asia are significantly cheaper than all other regions, ranging from as low as $500/kW to $2,000/kW depending on technology. Figure 60 also shows no evidence of economies of scale between 0 to 50 MW.

Figure 60   Installed Cost by Region and Capacity
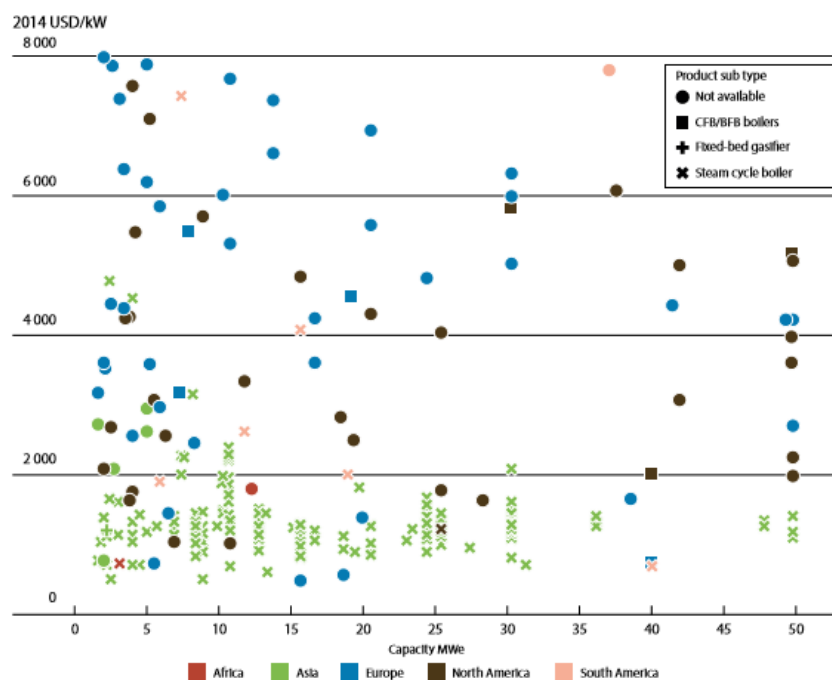
Source: Power Generation Costs 2014, IRENA (2015)

Figure 61 charts the installed cost of the various technologies across the OECD countries.

Figure 61   Installed Capital Cost by Technology (OECD, $2014/kW)

Source: Power Generation Costs 2014, IRENA (2015)

8.1.5 Hydro

Figure 62 plots the installed cost of small and large-scale hydro across the various regions. India and China show the lowest project costs between $1,000/kW and $2,000/kW installed.
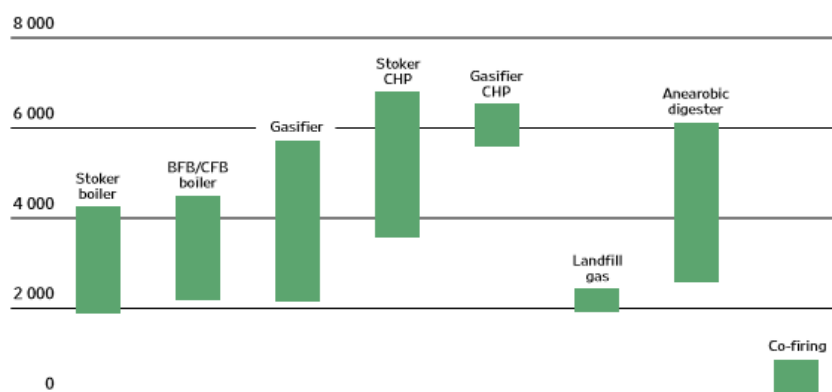
Figure 62   Installed Cost by Region
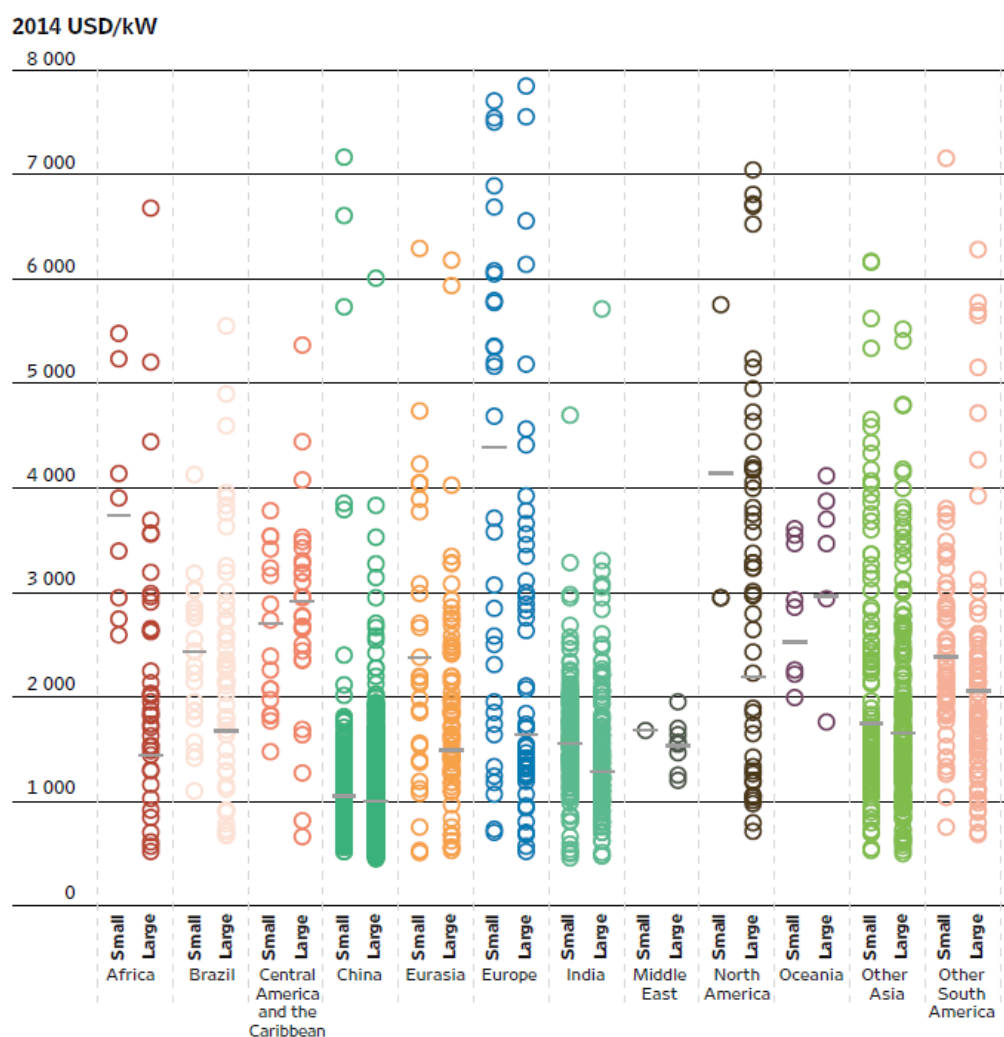
8.2   Projected Installed Cost Assumptions

Technology capital cost estimates from a variety of sources were collected and normalised to be on a consistent and uniform basis[21]. Mid-points were taken for each technology that is relevant to the GMS region. The data points collated reflect overnight, turnkey engineering procurement construction capital costs and are exclusive of fixed operating and maintenance costs, variable operating and maintenance costs and fuel costs. The capital costs by

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[21] We standardised on Real 2014 USD with all technologies costs normalised to reflect turnkey capital costs.

technology assumed in the study are presented in Figure 63 for the BAU and SES scenarios. For the ASES scenario, we assumed that the technology costs of renewable technologies declines more rapidly. These technology cost assumptions are listed in Figure 64. Note that the technology capital costs presented here do not include land costs, transmission equipment costs, nor decommissioning costs and are quoted on a Real USD 2014 basis.

Comments on the various technologies are discussed below in relation to the BAU and SES technology costs:

- Conventional thermal technology costs are assumed to decrease at a rate of 0.05% pa citing maturation of the technologies with no significant scope for cost improvement. Coal CCS costs are based on Supercritical Pulverised black coal technology with decreases over time based on the Australian Energy Technology Assessment 2013 Model Update report.

- Onshore wind costs were based on the current installed prices seen in China and India with future costs decreasing at a rate of 0.6% pa. Future offshore wind costs are also assumed to decrease at a rate of 0.6% pa starting at $2,900/kW.

- Large and small-scale hydro costs are assumed to increase over time reflecting easy and more cost-efficient hydro opportunities being developed in the first instance. IRENA reported no cost improvements for hydro over the period from 2010 to 2014. Adjustments are made in the case of Lao PDR and Myanmar where significant hydro resources are developed in the BAU case[22].

- Solar PV costs are based on the more mature crystalline silicon technology which accounts for up to 90% of solar PV installations (IRENA, 2015), and forecast to continue to drop (2.3% pa) albeit at a slower pace than in previous years.

- Utility scale battery costs are quoted on a $/kWh basis, and cost projections based on a report by Deutsche Bank (2015) which took into account several forecasts from BNEF, EIA and Navigant.

- Solar thermal (CSP) capital costs are projected to fall at 2.8% pa on the basis of the IRENA 2015 CSP LCOE projections. While globally there are many CSP installations in place, the technology has not taken off and the cost of CSP technology over the past 5 years has not been observed to have fallen as rapidly as solar PV.

- Biomass capital costs are based on costs observed in the Asia region, which are significantly less than those observed in OECD countries. Capital costs were assumed to fall at 0.1% pa. Biogas capital costs were based on anaerobic digestion and assumed to decline at the same rate as biomass.

- Ocean energy (wave and tidal) technologies were based on learning rates in the 'Ocean Energy: Cost of Energy and Cost Reduction Opportunities' (SI Ocean, 2013) report assuming global installation capacities increase to 20 GW by 2050[23].

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[22] Capital costs for large-scale hydro projects are assumed to increase to $3,000/kW by 2050 consistent with having the most economically feasible hydro resources developed ahead of less economically feasible resources.

[23] Wave and tidal costs are averaged.

- Capital costs are all discounted at 8% pa across all technologies over the project lifetimes. Decommissioning costs were not factored into the study.

- For technologies that run on imported coal and natural gas, we have factored in the additional capital cost of developing import / fuel management infrastructure in the modelling.

Figure 63   Projected Capital Costs by Technology for BAU and SES
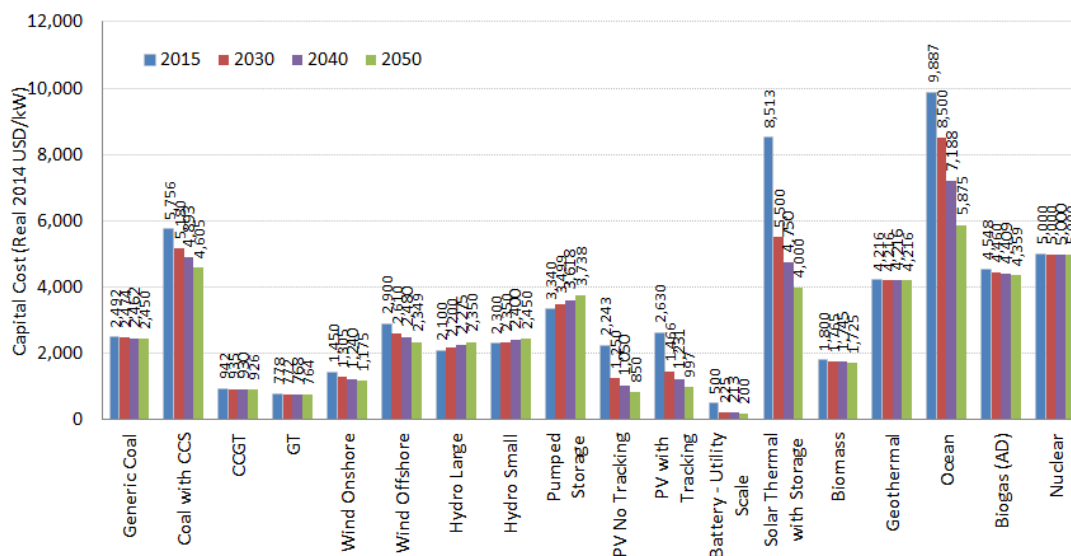
* Battery costs are quoted on a Real 2014 USD $/kWh basis.

Figure 64   Projected Capital Costs by Technology for ASES
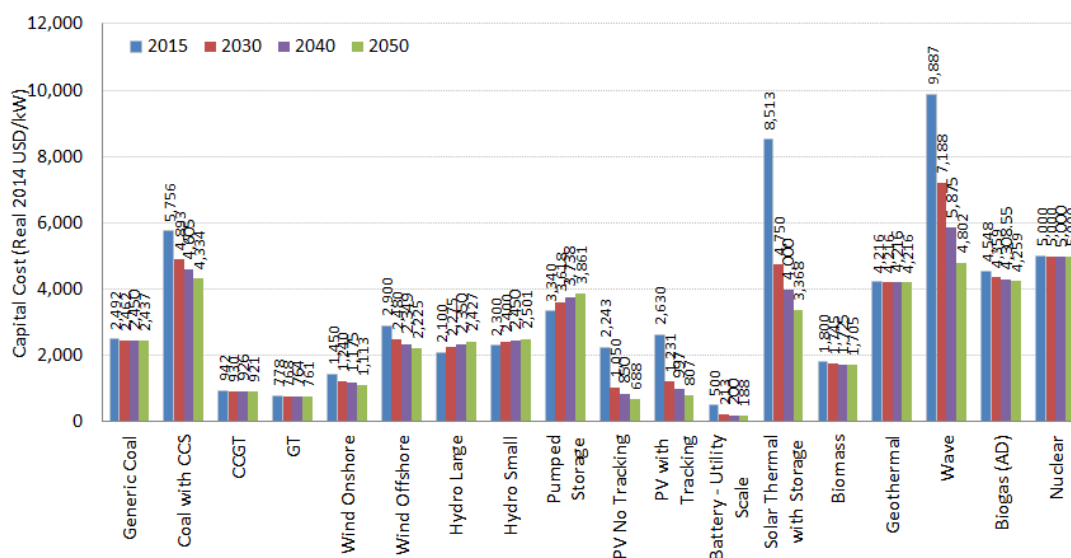
* Battery costs are quoted on a Real 2014 USD $/kWh basis.

8.3 Summary of Technology Costs

Table 22 sets out the technology cost assumptions that were used in the modelling presented in this report for the BAU and SES scenarios. Table 23 sets out the technology costs used in the ASES. The technology costs of coal and gas do not include overheads associated with infrastructure to develop facilities for storing / managing fuel supplies. These costs were however accounted for in the modelling.

Figure 65 and Figure 66 presents the levelised cost of new entry generation based on assumed capacity factors. LCOE levels presented in Section 9 are based on weighted average LCOE's and modelled output and will differ from the LCOE's presented here. The LCOE for battery storage is combined with solar PV technology assuming 75% of generation is stored for off-peak generation.

Table 22   Technology Costs Assumptions for BAU and SES Scenarios

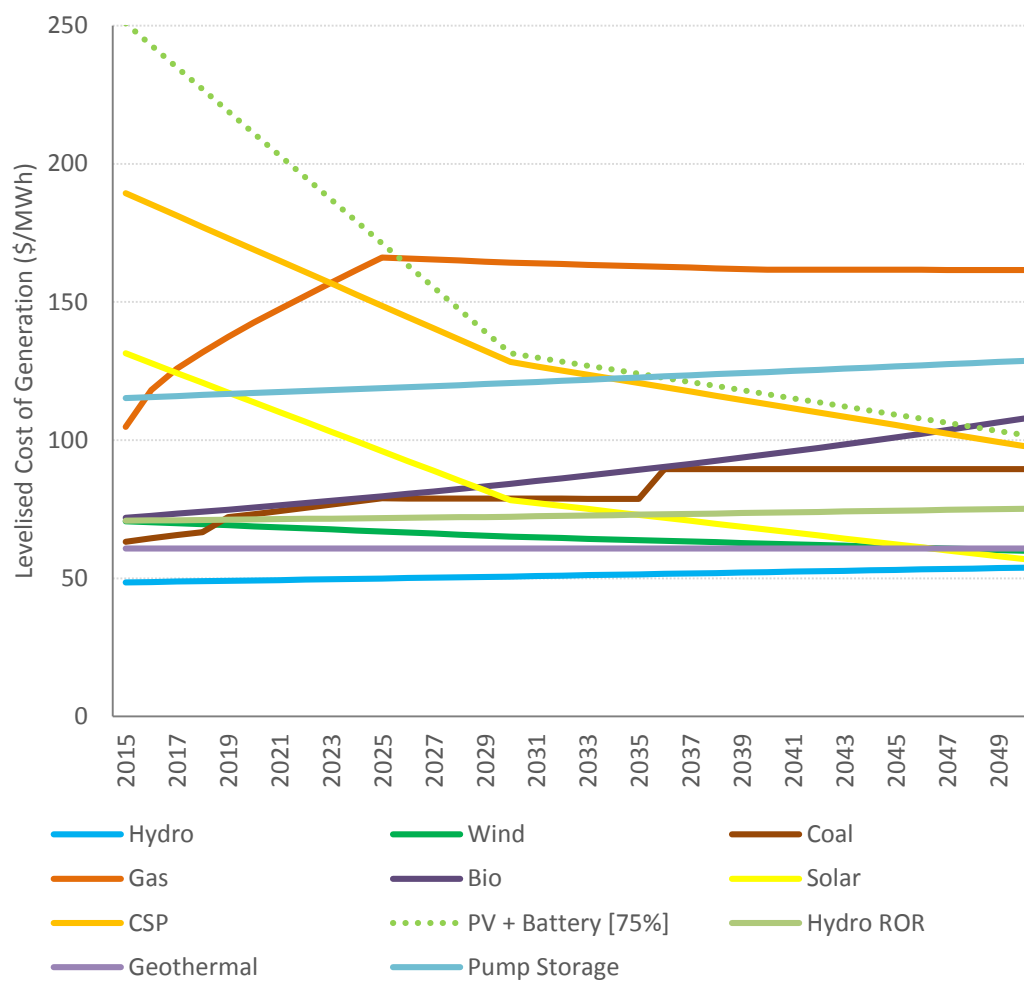| Technology	Technology Capital Cost (Unit: Real 2014 USD/kW)			
	2015	**2030**	**2040**	**2050**
Generic Coal	2,492	2,474	2,462	2,450
Coal with CCS	5,756	5,180	4,893	4,605
CCGT	942	935	930	926
GT	778	772	768	764
Wind Onshore	1,450	1,305	1,240	1,175
Wind Offshore	2,900	2,610	2,480	2,349
Hydro Large	2,100	2,200	2,275	2,350
Hydro Small	2,300	2,350	2,400	2,450
Pumped Storage	3,340	3,499	3,618	3,738
PV No Tracking	2,243	1,250	1,050	850
PV with Tracking	2,630	1,466	1,231	997
PV Thin Film	1,523	1,175	1,131	1,086
Battery Storage - Small	600	375	338	300
Battery - Utility Scale	500	225	213	200
Solar Thermal with Storage	8,513	5,500	4,750	4,000
Solar Thermal No Storage	5,226	4,170	3,937	3,703
Biomass	1,800	1,765	1,745	1,725
Geothermal	4,216	4,216	4,216	4,216
Ocean	9,887	8,500	7,188	5,875
Biogas (AD)	4,548	4,460	4,409	4,359

Battery technology quoted on a $/kWh basis

Figure 65   Levelised Cost of New Entry (BAU & SES, $/MWh)

FINAL

Table 23   Technology Costs Assumptions for ASES Scenarios

Technology	Technology Capital Cost (Unit: Real 2014 USD/kW)			
	2015	2030	2040	2050
Generic Coal	2,492	2,462	2,450	2,437
Coal with CCS	5,756	4,893	4,605	4,334
CCGT	942	930	926	921
GT	778	768	764	761
Wind Onshore	1,450	1,240	1,175	1,113
Wind Offshore	2,900	2,480	2,349	2,225
Hydro Large	2,100	2,275	2,350	2,427
Hydro Small	2,300	2,400	2,450	2,501
Pumped Storage	3,340	3,618	3,738	3,861
PV No Tracking	2,243	1,050	850	688
PV with Tracking	2,630	1,231	997	807
PV Thin Film	1,523	1,131	1,086	1,043
Battery Storage - Small	600	338	300	267
Battery - Utility Scale	500	213	200	188
Solar Thermal with Storage	8,513	4,750	4,000	3,368
Solar Thermal No Storage	5,226	3,937	3,703	3,483
Biomass	1,800	1,745	1,725	1,705
Geothermal	4,215	4,215	4,216	4,215
Wave	9,886	7,187	5,875	4,802
Biogas (AD)	4,548	4,358	4,308	4,259

Battery technology quoted on a $/kWh basis

Figure 66   Levelised Cost of New Entry (ASES, $/MWh)
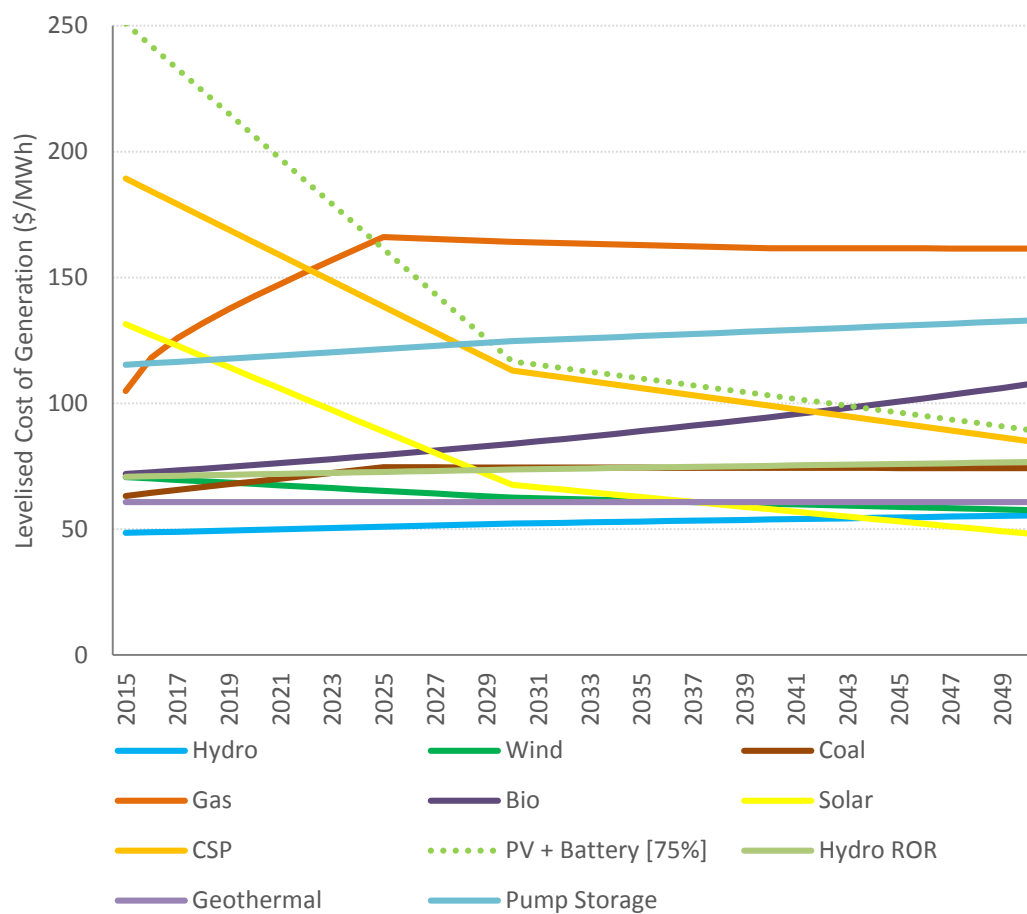
9   Jobs Creation Methodology

This section briefly summarises the methodology that we adopted for jobs creation. The methodology that we have adopted has been based on an approach developed by the Institute for Sustainable Futures at the University of Technology, Sydney and used by the Climate Institute of Australia[24]. In essence the jobs created in different economic sectors (manufacturing, construction, operations & maintenance and fuel sourcing and management) can be determined by the following with the information based on the numbers provided in Table 24.

Jobs = manufacturing + construction + operations and maintenance (O&M) + fuel, where:

Manufacturing	=	MW installed per year	x	Manufacturing employment multiplier	x	Annual decline factor (years)	x	% local manufacturing
Construction	=	MW installed per year	x	Construction employment multiplier	x	Annual decline factor years		
O&M	=	Cumulative capacity	x	O&M employment multiplier	x	Annual decline factor years		
Fuel supply (coal)	=	Electricity generation	x	Fuel employment multiplier	x	Annual decline factor years		
Fuel supply (gas)	=	Electricity generation	x	Fuel employment multiplier	x	Annual decline factor years	x	% local fuel supply

We have applied this methodology to the results in each scenario discussed in this report in order to make estimates of the jobs creation impacts and allow comparisons to be made.

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[24] A description of the methodology can be found in the following reference: The Climate Institute, "Clean Energy Jobs in Regional Australia Methodology", 2011, available:
http://www.climateinstitute.org.au/verve/_resources/cleanenergyjobs_methodology.pdf.

Table 24   **Employment Factors for Different Technologies**

Technology	Annual decline applied to employment multiplier 2010- 20	2020-30	Construction time years	Construction per MW	Manufacturing per MW	Operations & maintenance per MW	Fuel per GWh
Black coal	0.5%	0.5%	5	6.2	1.5	0.2	0.04
Brown coal	0.5%	0.5%	5	6.2	1.5	0.4	(include in O&M)
Gas	0.5%	0.5%	2	1.4	0.1	0.1	0.04
Hydro	0.2%	0.2%	5	3.0	3.5	0.2	
Wind	0.5%	0.5%	2	2.5	12.5	0.2	
Bioenergy	0.5%	0.5%	2	2.0	0.1	1.0	
Geothermal	1.5%	0.5%	5	3.1	3.3	0.7	
Solar thermal generation	1.5%	1.0%	5	6.0	4.0	0.3	
SWH	1.0%	1.0%	1	10.9	3.0	0.0	
PV	1.0%	1.0%	1	29.0	9.0	0.4	

Appendix A   Notes Demand Forecast Modelling Methodology

The IES GMS electricity demand forecasts are based on linear regression models linked to various macroeconomic indicators by sector types. The sector types were broken down into industrial, agriculture, commercial and services, and residential sectors across all GMS countries. Several independent variables were tested against historical energy demand with model selection based on achieving a high correlation factor (R-square) and significant F-test and t-test results indicating statistical significance. Model selections for the sector based models were based on achieving a suitable fit across all regions for model consistency. The data sources covering 2005 to 2013 are presented in Table 25.

Testing of various independent variables expected to drive energy demand found sector-based GDP to be the most relevant for industry, agriculture and commercial and services sectors across all of the GMS countries. These single variables were found to contain the most explanatory power i.e. multiple independent variables were not required.

For residential energy, population was found to be the most relevant for Thailand and Vietnam where electrification rates have been historically high, whereas a separate model was used to forecast residential energy demand in Cambodia, Lao PDR and Myanmar[25].

T-statistics for each of the individual independent variables were found to be statistically significant with the exception of agriculture GDP used in determining the Lao PDR agriculture energy demand, however, we chose to retain the model for consistency across the regions. A summary of the models used is summarised below:

- Agriculture Energy – determined using agriculture GDP;
- Industrial Energy – determined using industry GDP;
- Commercial Energy – determined using commercial GDP;
- Residential Energy – was split into 2 models representing the subset of countries with similar electrification rates;
    - Vietnam/Thailand – population was used to determine residential energy levels.
    - Cambodia/Lao PDR/ Myanmar – based on a separate model to model the changes in electrification rates and shifts in rural and urban populations over time.

Table 25 and Table 26 and summarises the statistical test results. All results indicate the selected variables help explain most of the variations in the sector-based energy volumes from year to year. Exceptions include agriculture energy in Lao PDR, and relatively low R-square values for Myanmar. The low R-square values for Myanmar is due to fluctuating energy volumes not explaining by the movements in annual sector-based GDP's.

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[25] The residential models for Myanmar, Lao PDR and Cambodia, are based on electrification rates, population and the average per capita consumption.

Table 25 **Historical Data Sources**

Historical Data	Vietnam	Thailand	Cambodia	Lao PDR	Myanmar
Total GDP (Real 2014 USD)	IMF WEO October 2014	IMF WEO October 2014	IMF WEO October 2014	IMF WEO October 2014	IMF WEO October 2014
Agriculture GDP share	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank
Industry GDP share	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank
Commercial GDP share	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank
Sector Demand	Power Development Plan 7	EPPO Energy Statistics	International Energy Agency	Annual Statistics Report, EDL	IES Analysis
Grid Losses	World Bank Databank	World Bank Databank	Report on Power Sector for the Year 2013, EAC	Annual Statistics Report, EDL	World Bank Databank
Population Data	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank	World Bank Databank
Household Data			Various Sources Compiled by IES	Various Sources Compiled by IES	Various Sources Compiled by IES
Electrification Rates			Various Sources Compiled by IES	Various Sources Compiled by IES	Various Sources Compiled by IES
Electrified Households - Urban			Various Sources Compiled by IES	Various Sources Compiled by IES	Various Sources Compiled by IES
Electrified Households - Rural			Various Sources Compiled by IES	Various Sources Compiled by IES	Various Sources Compiled by IES

Table 26 **Regression R-square Results**

R Squared	Vietnam	Thailand	Cambodia	Lao PDR	Myanmar
Agriculture Energy	0.84	0.68	1.0	0.85	0.27
Industry Energy	0.98	0.93	0.85	0.77	0.97
Commercial Energy	0.95	0.92	0.98	0.84	0.95
Residential Energy	0.99	0.95	n/a	n/a	n/a
Per Capita Consumption	n/a	n/a	0.95	0.98	0.1

Table 27 **Regression t-stat Results**

t-Stat	Vietnam	Thailand	Cambodia	Lao PDR	Myanmar
Agriculture Energy	6.07	3.86	17.8	0.342	-1.6
Industry Energy	23.5	10	6.32	4.92	8.3
Commercial Energy	12.3	8.77	18.4	6.1	11
Residential Energy	34.4	11.1	n/a	n/a	n/a
Per Capita Consumption	n/a	n/a	12	33.6	0.88