Load Factor and Unserved Energy Webinar

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Agenda

1. Fundamentals, macroeconomics, primary drivers
2. Measures to influence peak and future trends
3. Unserved energy
4. International comparisons and general observations

   -Country case studies: India, Afghanistan, Sri Lanka, Bangladesh, Nepal, Denmark
5. Load Forecasting in Pakistan

Fundamentals

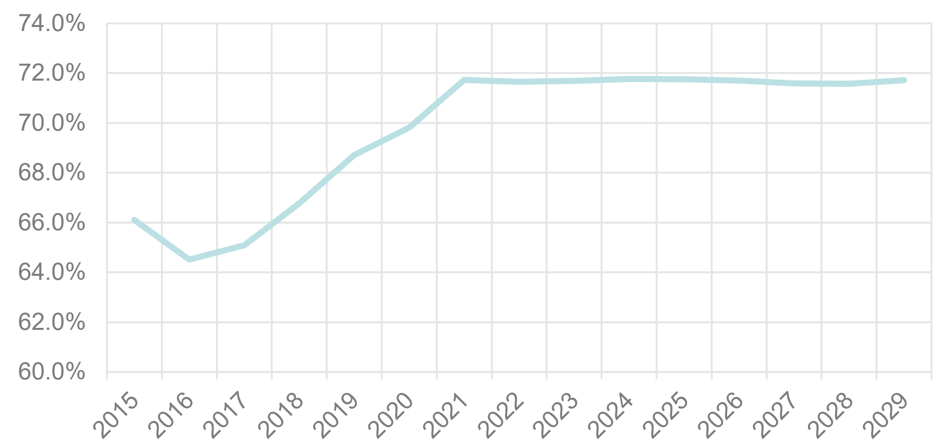
Definition of load factor:

$$L.F.(\%) = \frac{Energy\ (MWh)}{Peak\ (MW) x\ 8760\ hours}$$

2018 Example of Northwest Power Pool in USA
(parts of states Washington, Oregon, Idaho, Montana, Nevada, Utah, Wyoming)

$$66.8\ \% = \frac{288{,}002{,}000\ (MWh)}{49{,}235 (MW) x\ 8760\ hours}$$

Northwest Power Pool USA Load Factor
(actual 2015-2018, forecast 2019-2029)



Macro Trends Affecting Load Factor

Traditional variables used to predict electricity consumption

- Gross domestic product
- Weather factors (heating degree days, cooling degree days, seasonal differences)
- Tariffs, lagged
- Individual customer sector growth
- Population growth
- Employment or other labor statistic
- Household size

Macro Trends Affecting Load Factor

Historically electricity intensity (MWh/GDP) increased as an economy developed

Third world	→	Second world	→	First world
Agricultural economy	→	Industrial economy	→	Service economy

Factors that may dampen the traditional relationship

- Distributed generation (as inhabitants get wealthier, more likely to purchase rooftop solar and possibly storage)
- Energy efficient technologies are more ubiquitous
- Smart technology making customers more price responsive

Primary Drivers of Peak Load

Residential

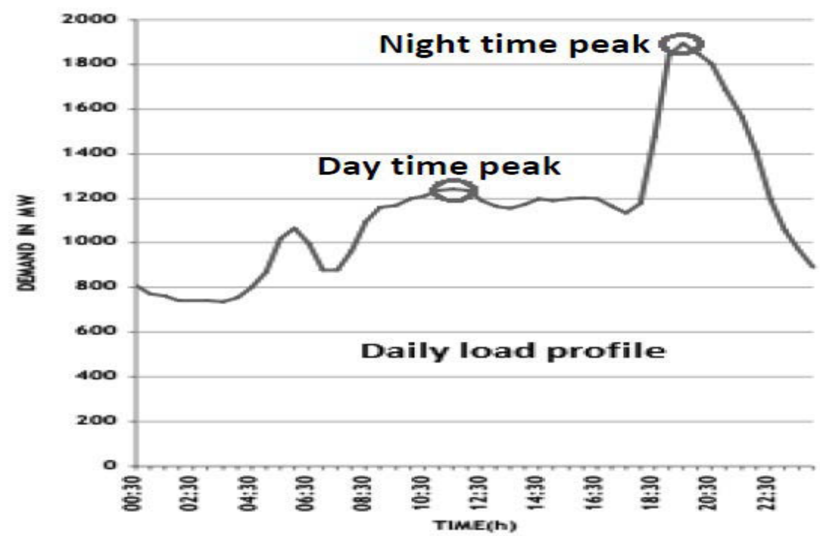
- Air conditioning, heating, television (Sri Lanka peaks during cricket matches)

Commercial

- Business hours

Industrial

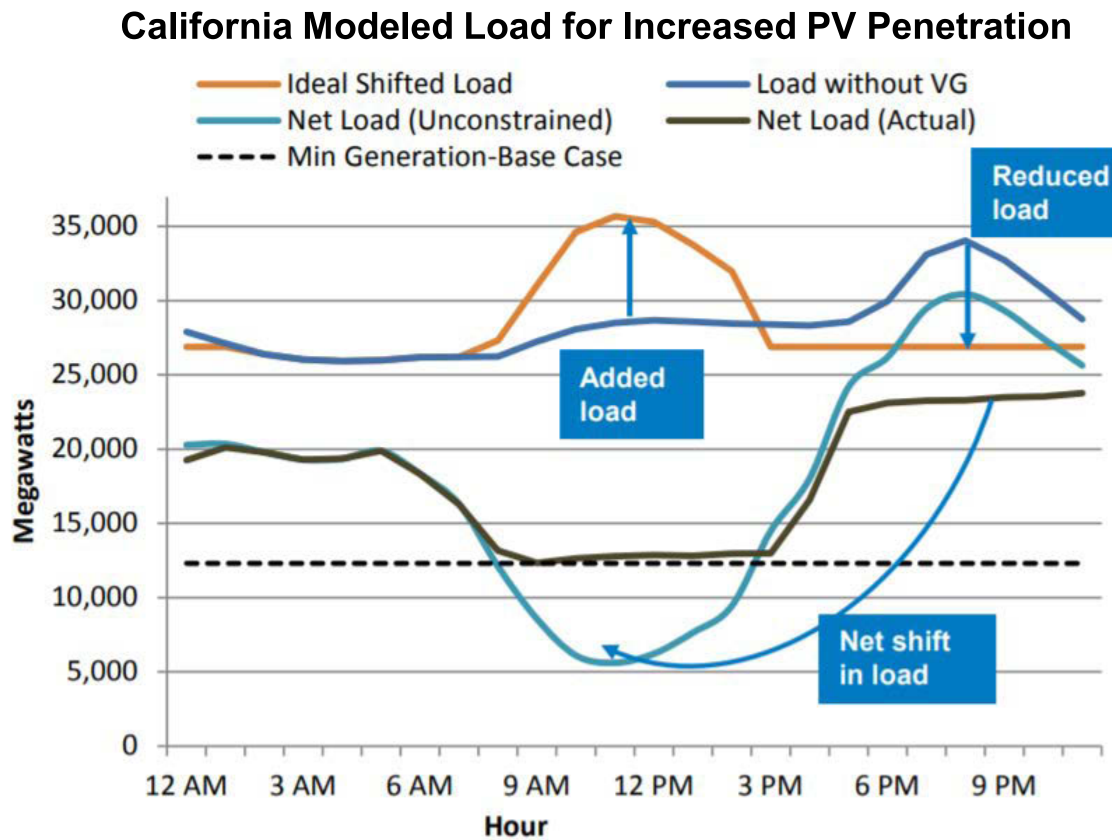
- Seasonal production
- Single, double, or triple shift work days



Source: *Peak Electricity Demand Prediction Model for Sri Lanka Power System (G.V.Buddhika et al. De Silva and Lalith A. Samaliarachchi)*

Measures to Influence Peak

- Industrial demand response
- Time Of Use pricing
- Smart meters
- Energy efficiency
- Electric vehicle policy



Source: Denholm, P., *Overgeneration from Solar Energy in California – A Field Guide to the Duck Chart*, https://www.nrel.gov/docs/fy16osti/65453.pdf

Future Trends

Electrification

- Transport sector, i.e., electric vehicles
- Hot water heaters (natural gas, electric, on-demand)
- Heating (natural gas furnace, electric baseboard heating, directed space heating)
- Increased plug load, yet more efficient appliances

(e.g., computers, phones, electronic devices)

Other considerations

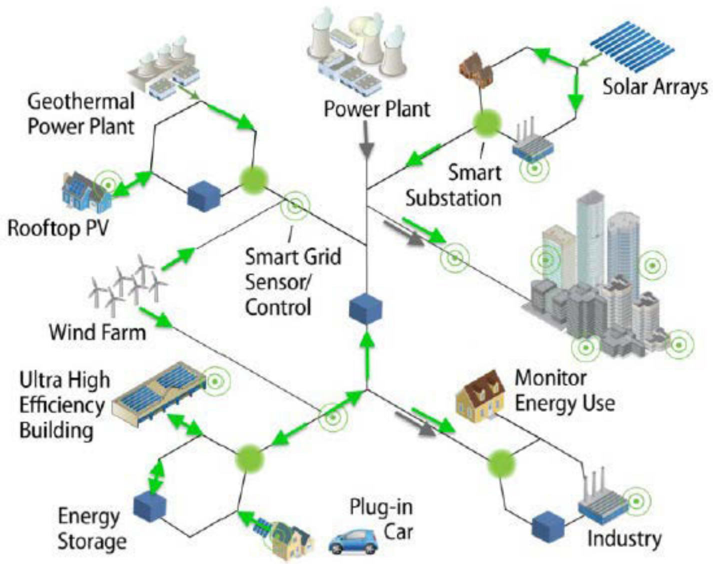
- Individual market players both generate and consume power (e.g., blockchain technology)
- Storage technology use increases
- Players intentionally maximize the economics of doing so
- Net load daily and seasonal peak that the utility sees will change.

Unserved Energy Categories

Not straightforward

$$L.F.(\%) = \frac{Energy\ (MWh)}{Peak\ (MW) x\ 8760\ hours}$$

1. Not connected to grid



Source: *Hodge, Bri-Mathias, Future Use of Big Data in the Smart Grid, https://www.nrel.gov/docs/fy16osti/66326.pdf*

Unserved Energy Categories

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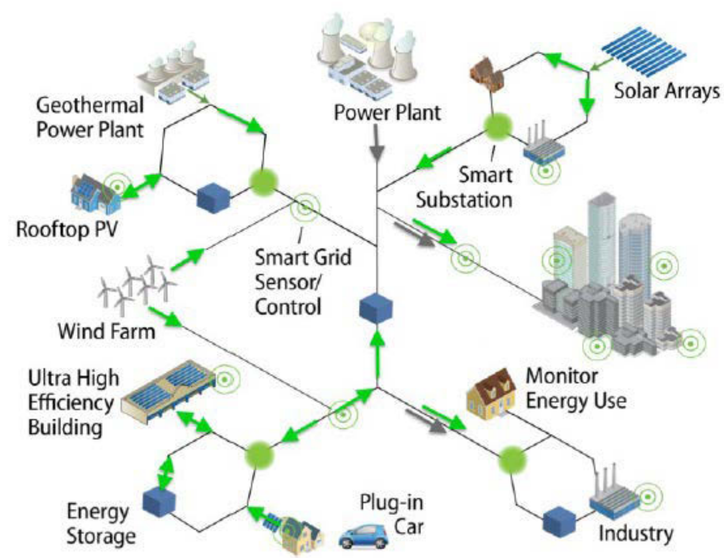
$$L.F.(\%) = \frac{Energy\ (MWh)}{Peak\ (MW) x\ 8760\ hours}$$

1. Not connected to grid
2. Self-generation (captive demand)



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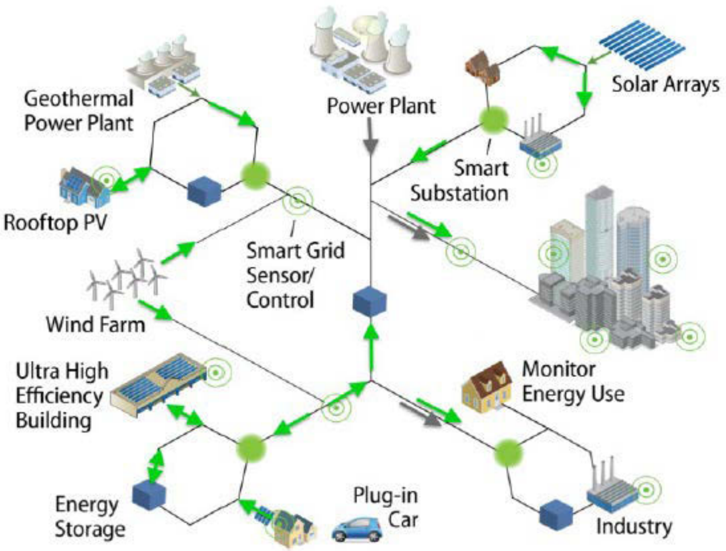
1. Not connected to grid
2. Self-generation (captive demand)
3. Load shed



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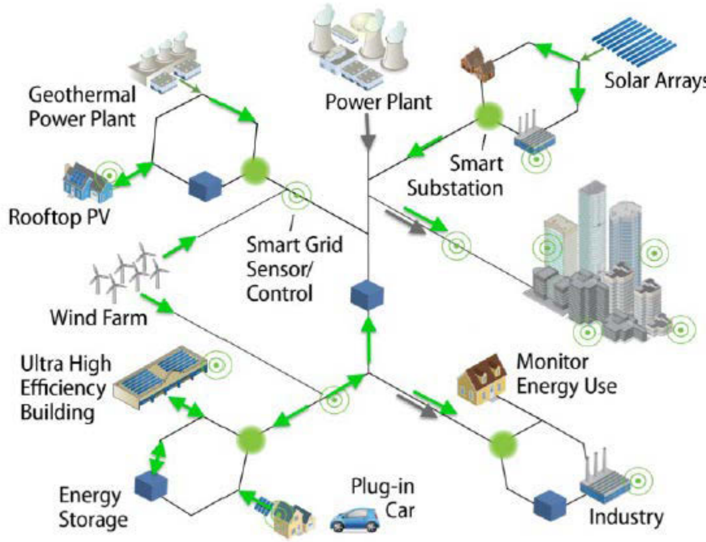
Unserved Energy Categories

Not straightforward

$$L.F.(\%) = \frac{Energy\ (MWh)}{Peak\ (MW) x\ 8760\ hours}$$

1. Not connected to grid
2. Self-generation (captive demand)
3. Load shed
4. Emergent demand: increased demand due to increased grid reliability/availability



Source: Hodge, Bri-Mathias, Future Use of Big Data in the Smart Grid, https://www.nrel.gov/docs/fy16osti/66326.pdf

Comparison against current load factors in other countries

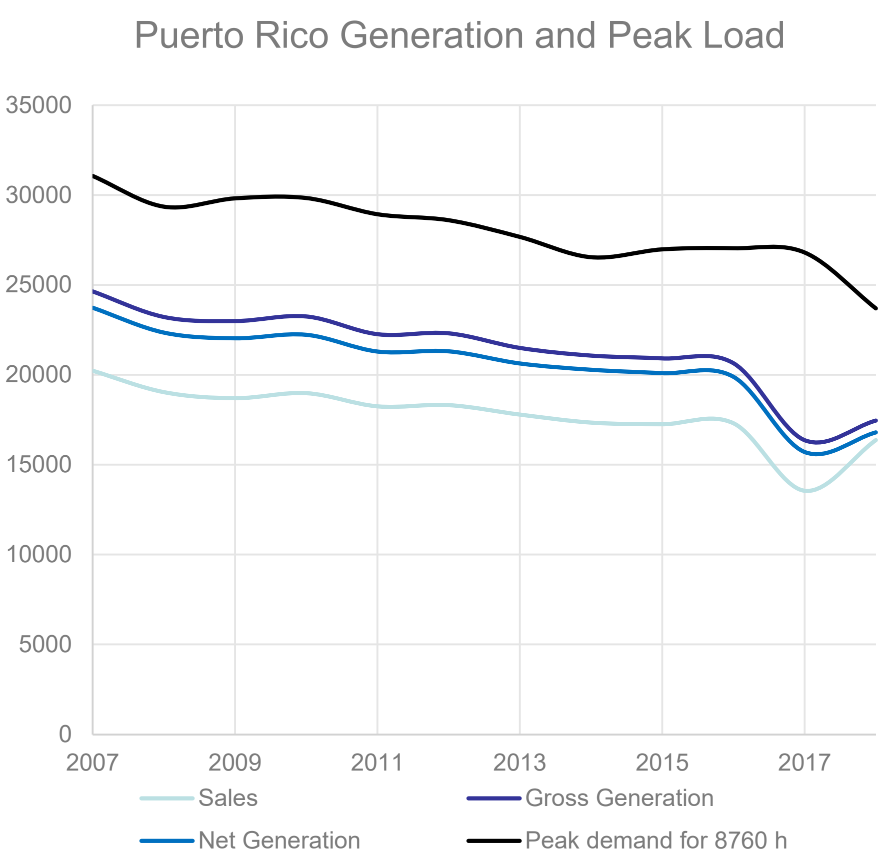
Country	Load Factor	Average Cold Season Temp (°C)	Average Hot Season Temp (°C)
Pakistan (Islamabad)	61.0%*	13	29
India (New Delhi)	71.5%	17	39
Afghanistan (Kabul)	60.0%	1	24
Nepal (Kathmandu)	56.9%	12	23
Sri Lanka (Colombo)	60.8%	26	28
Germany (Berlin)	86.2%	1	17
Turkey (Istanbul)	70.7%	7	22
France (Berlin)	62.2%	4	18
Denmark (Copenhagen)	61.4%	1	16
Italy (Rome)	62.1%	9	23

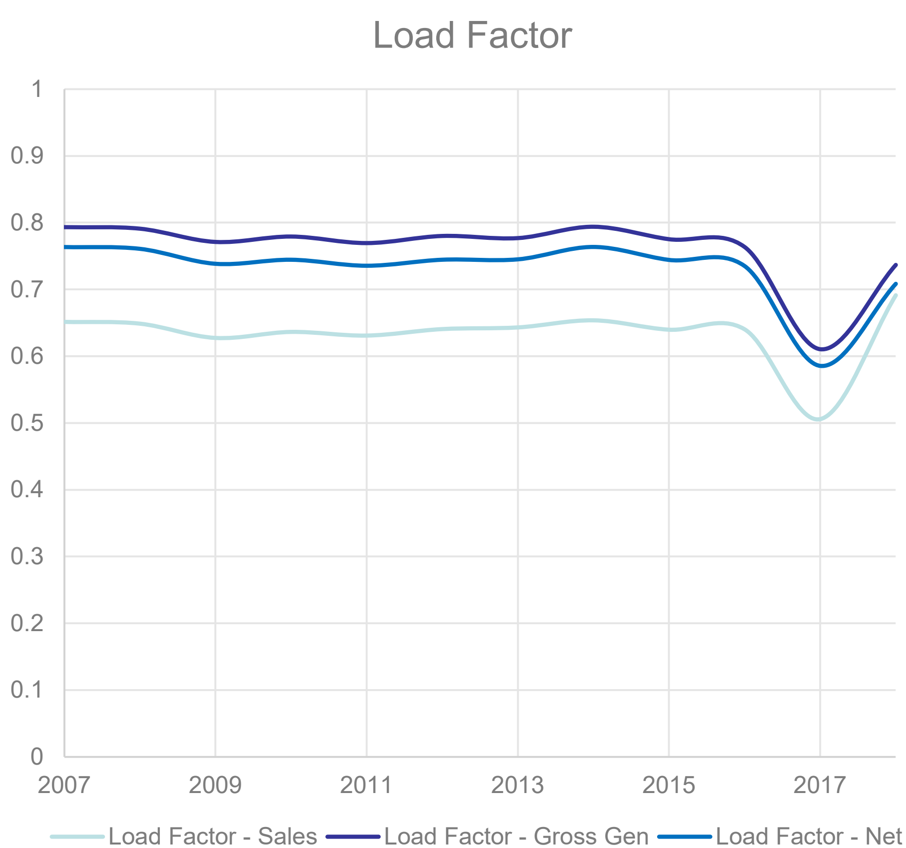
**2019 NTDC Regression modeling*
https://en.climate-data.org

Country Case Studies

- Difficult to compare load factors across countries
- Apples and oranges for energy parameter
  - A. gross generation
  - B. net generation after house power
  - C. net energy after imports and exports
  - D. energy sales after transmission and distribution losses
  - E. energy sales after non-technical losses

Example of Varying Energy Parameter





Source data from Puerto Rico Integrated Resource Plan 2018-19 by Siemens PTI for Puerto Rico Electric Power Authority

Country Case Studies

Load is forecast using two different methods

I. Load factor as a result
   A. Use regression (or other method) to forecast energy
   B. Use regression (or other method) to forecast peak
   C. Load factor time series is a calculated result

II. Load factor forecast as a driver
   A. Use regression (or other method) to forecast energy
   B. Explicitly forecast load factor
      i. Hold constant or
      ii. Show improvement, i.e., increase or higher capital use efficiency
   C. Peak is a calculated result

- However, in reality load factor usually changes over time depending on drivers discussed previously e.g., air conditioning use, tariff structure, economic development curve

Specific Country Examples

Case Study 1 of India

National Electricity Plan based on 2011, projected to 2037

- Used a Partial End Use Method (PEUM) for Energy & Demand
  - "bottom-up" approach focusing on end uses
- Based on past demand + projected policies, development, energy efficiency
- Done on a state-by-state basis
- Included stakeholders from across the power sector
- Considerations
  - Category-wise energy and load, T&D losses, population, # consumers, # irrigation pumps & capacity, electrification, railway expansion,
  - Policies – reduction of T&D losses, EE & DSM programs, Power for All Initiative, Dedicated freight corridor, make in India
    - Rooftop Solar Prog. – 100 GW solar by 2022, 40 GW rooftop
    - EVs – 6 mill by 2020, charging schedule won't increase demand

Source: National Electricity Plan (Volume 1), Generation, Government of India Ministry of Power, Central Electricity Authority

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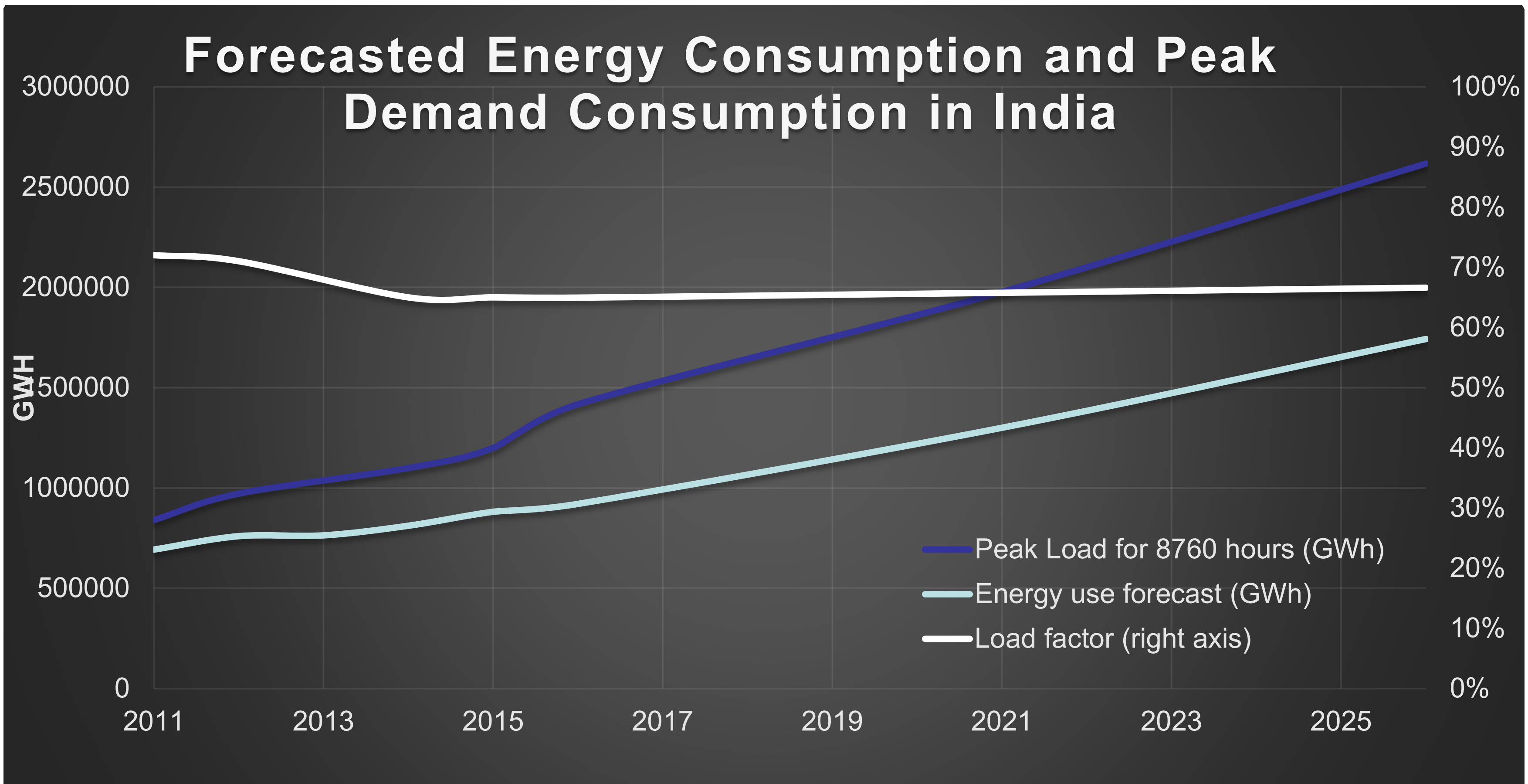
Case Study 1 of India



Sources: India CEA National Electricity Plan, https://community.data.gov.in/gross-electricity-generation-in-india-from-2010-11-to-2016-17/

Case Study 2 of Afghanistan

Power Sector Master Plan, analysis period 2011-2032

- 3 consumer types – residential, commercial/industrial, public sector
- 34 provinces each with a demand forecast (23 with no or low elect.)
- Base, Low, and High forecasts
- Simplified econometric approach, based on estimates and assessments from similar countries (economically) considers:
  - Income development – available income (res), GDP (comm/ind & public)
  - Electricity price development

  Can combine these to calculate elasticity of electricity demand
- Other considerations: reductions in T&D losses, no DSM or EE
- Future development of load calculated from load factor

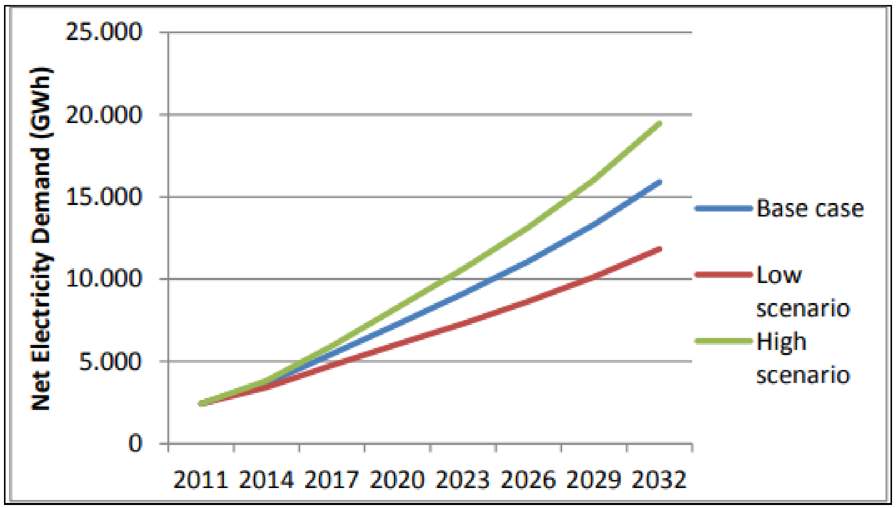
Source: Islamic Republic of Afghanistan: Power Sector Master Plan, https://www.adb.org/sites/default/files/project-document/76570/43497-012-afg-tacr.pdf

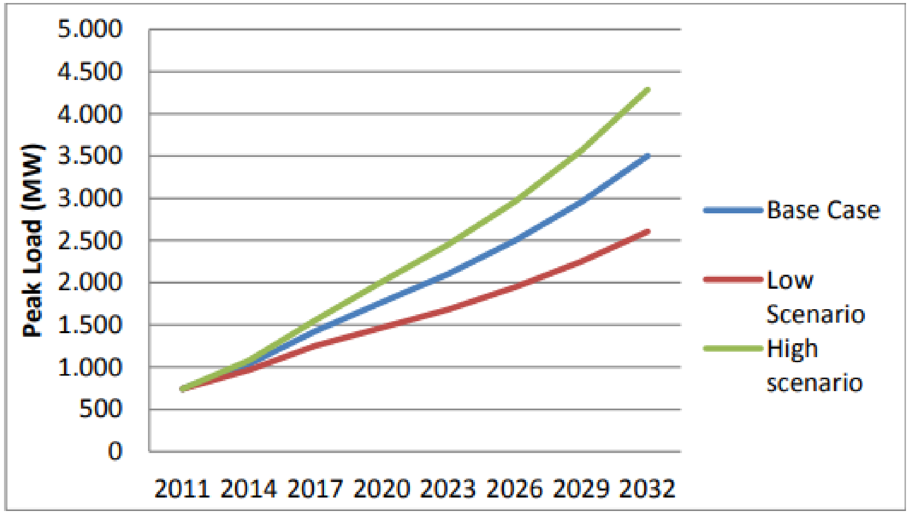
Case Study 2 of Afghanistan

- *Assumptions for load factor forecasting*

Parameter	Unit	2012	2015	2020	2025	2030
GDP growth rate	%	7.1%	6.2%	5.5%	4.0%	4.0%
Income elasticity, households	-	1.1	1.1	1.1	1.1	1.1
Income elasticity, industry	-	1.0	1.0	1.0	1.0	1.0
Income elasticity, public	-	0.9	0.9	0.9	0.9	0.9
Average power price, residential	US-cent/kWh	from 4.9 to 10.6	from 7.4 to 12.0	15.0	15.0	15.0
Price elasticity, residential	-	0.2	0.2	0.2	0.2	0.2
Price elasticity, industrial	-	0.3	0.3	0.3	0.3	0.3
Price elasticity, public	-	0.1	0.1	0.1	0.1	0.1
Technical losses	%	14.7%	13.8%	12.3%	10.8%	9.6%
Commercial losses	%	28.3%	23.2%	14.7%	10.6%	8.8%
Load factor (exc. Kabul/Herat)	-	0.553	0.562	0.577	0.592	0.60

Case Study 2 of Afghanistan





Load Factor

2012	2015	2020	2025	2030
55%	56%	58%	59%	60%

Source: Islamic Republic of Afghanistan: Power Sector Master Plan, https://www.adb.org/sites/default/files/project-document/76570/43497-012-afg-tacr.pdf

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Case Study 3 of Sri Lanka

Load forecast considerations

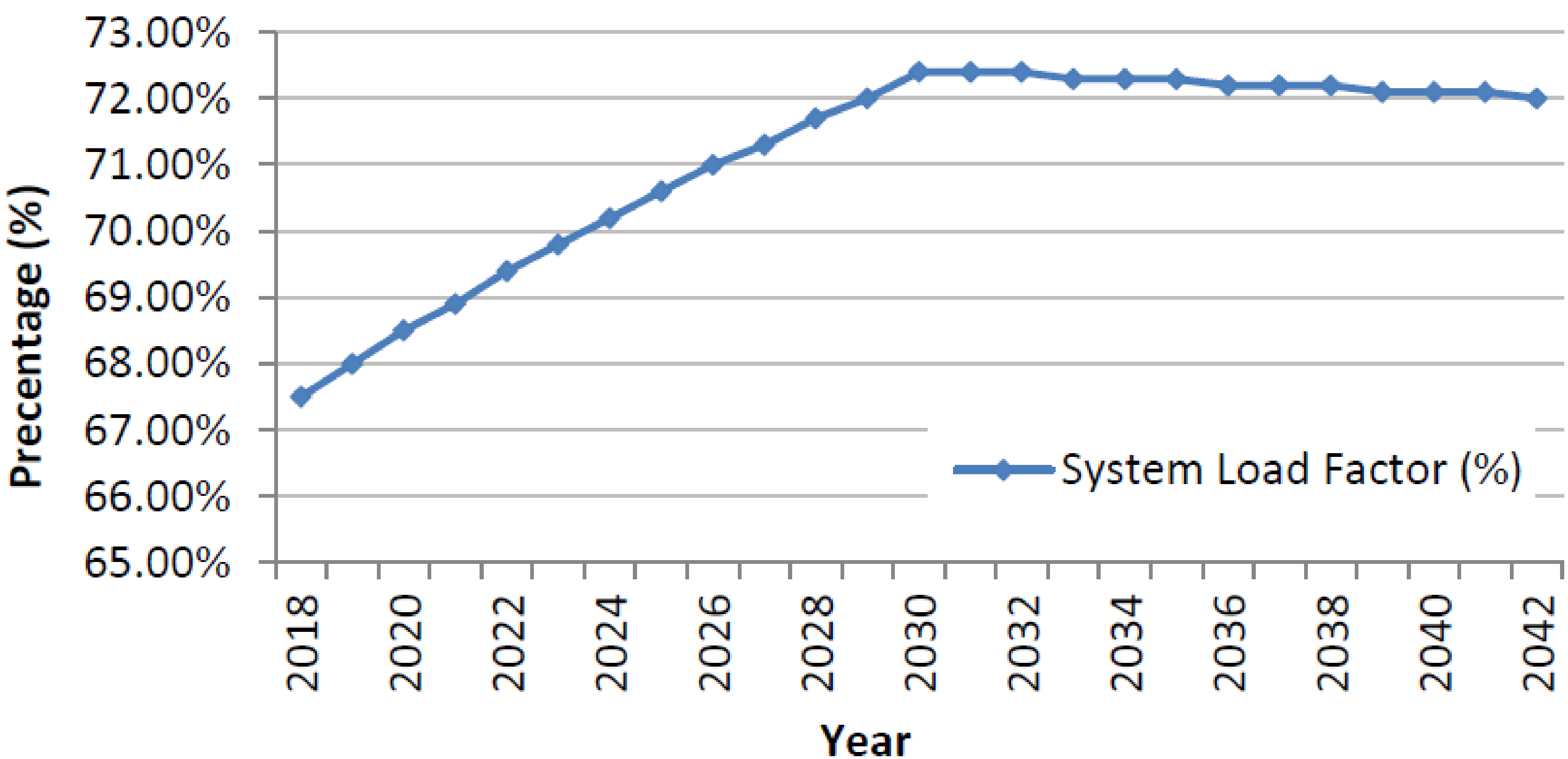
- Historical energy and peak consumption growth rates
- Historical load factor
- Decreasing trend in losses
- Future impact of national energy policies
- Future developments in transport, urban growth, tourism, industry, agriculture, manufacturing
- Excluded special days – holidays, etc.

Methodology

- Forecasted electricity consumption
- Forecasted load factor
- Calculated forecasted demand

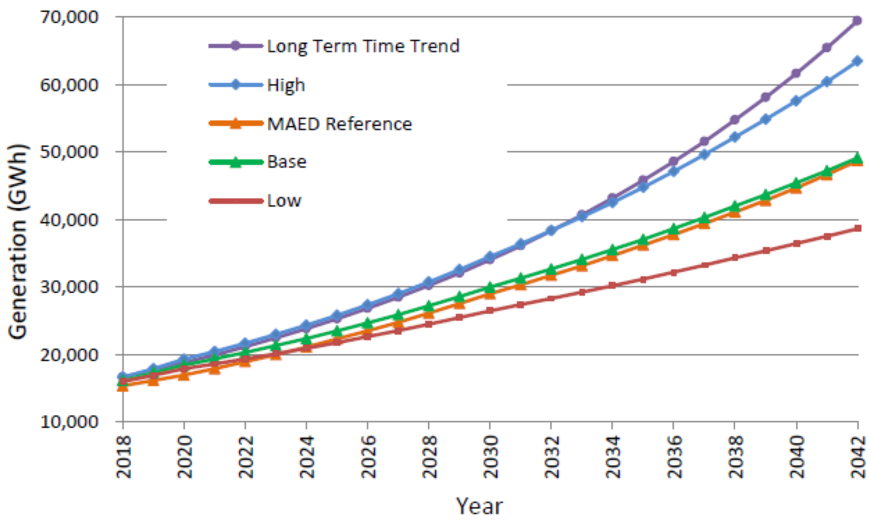
Source: Ceylon Electricity Board Long Term Generation Expansion Plan, 2018

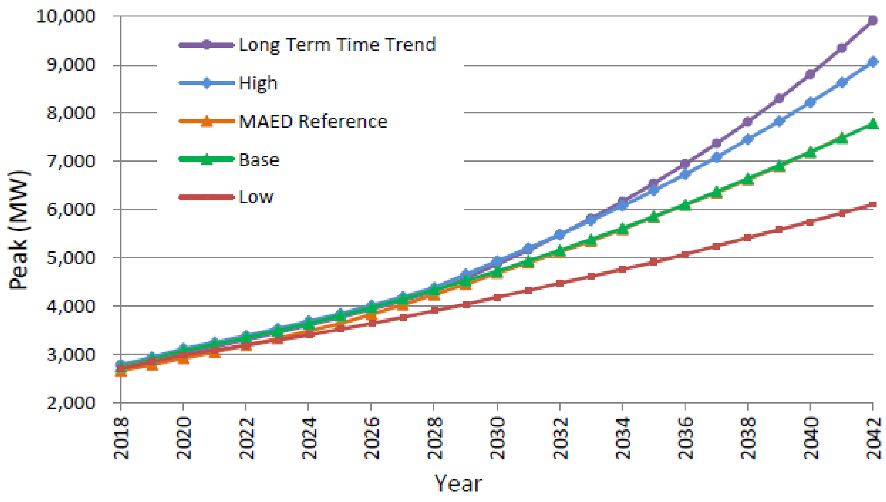
Sri Lanka System Load Factor



Source: *Ceylon Electricity Board Long Term Generation Expansion Plan, 2018*

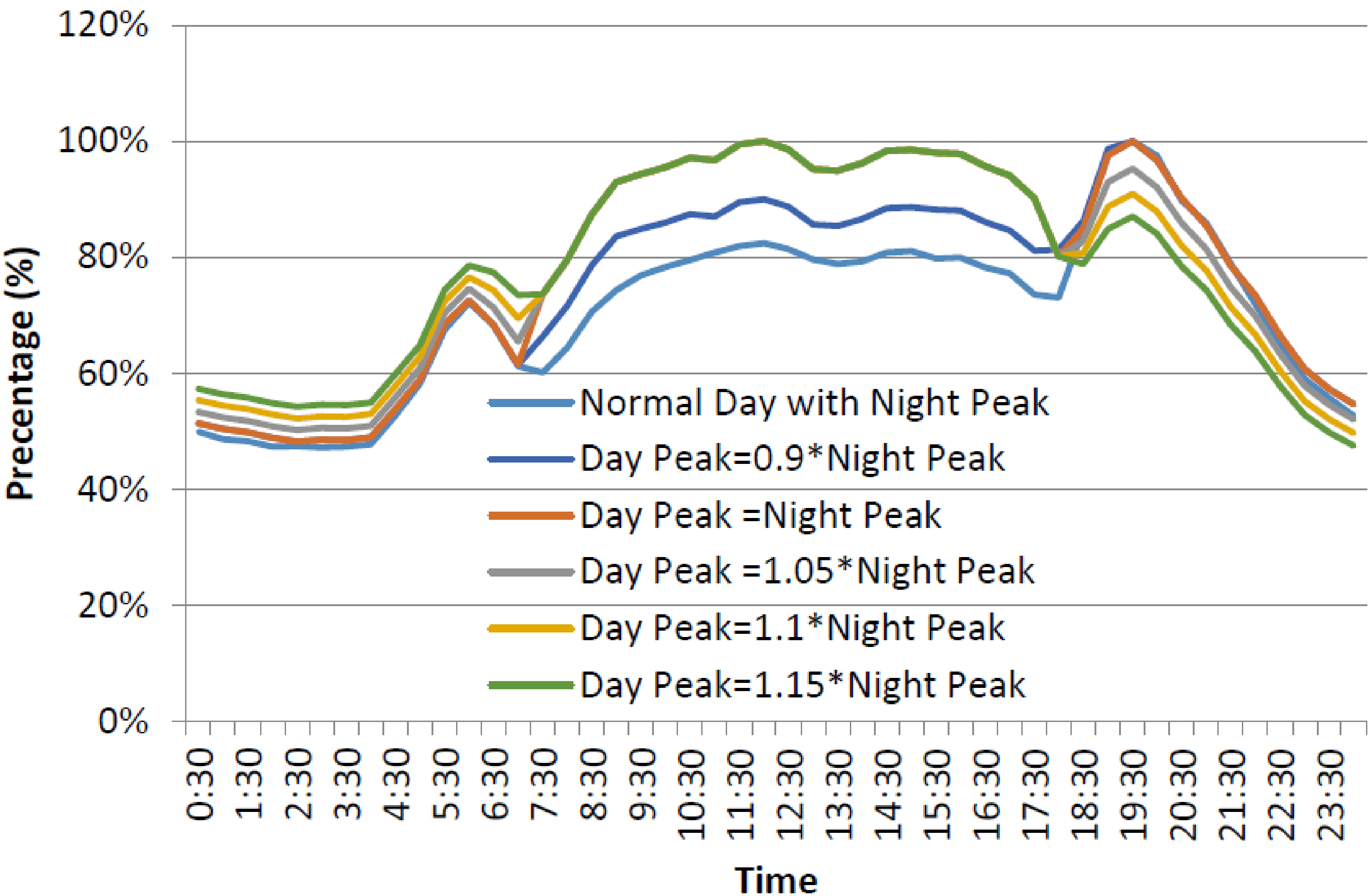
Sri Lanka Forecast Scenarios





Source: Ceylon Electricity Board Long Term Generation Expansion Plan, 2018

Sri Lanka Forecast of Flattening Daily Curve

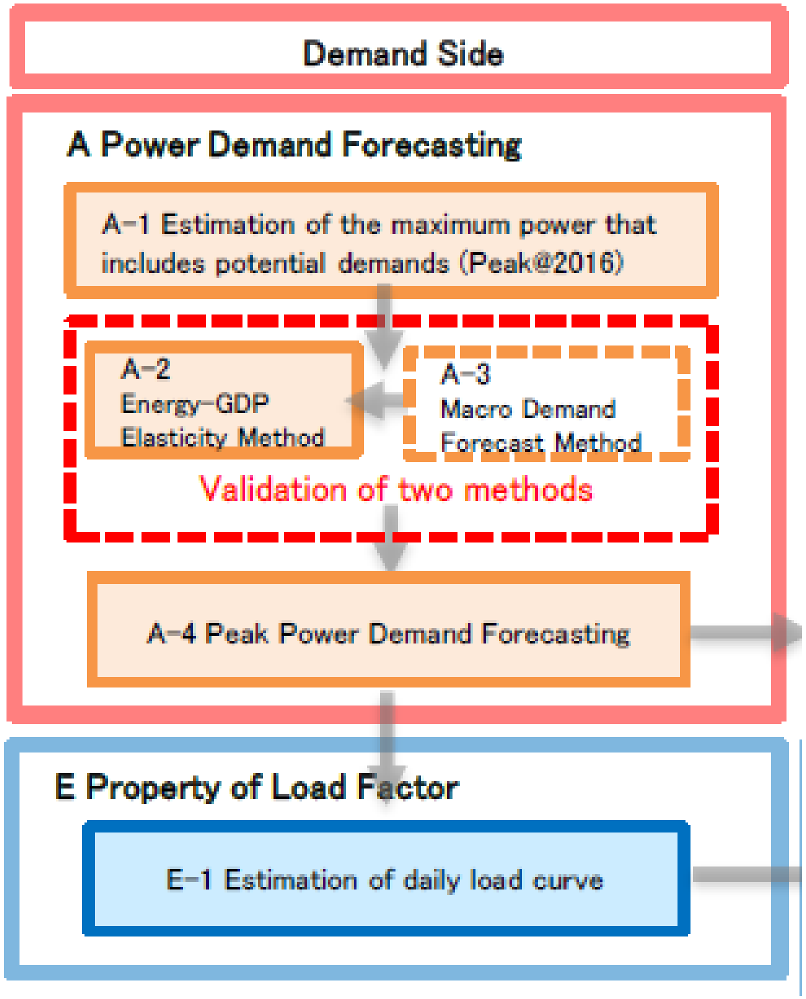


Source: Ceylon Electricity Board Long Term Generation Expansion Plan, 2018

Case Study 4 of Bangladesh

- Peak demand forecast using
  - GDP elasticity method
  - Sectorial analysis method
  - Consistency confirmed
  - Integrated both projections to hybrid approach
- Included theoretical estimation of load curves considering historic black-outs and energy not served
- Composite daily load curve estimated from summer and winter actual values
- Exogenous forecast of peak demand reduction relative to GDP
- Daily load curve estimated using assumed load factor

Source: Power Sector Master Plan 2016, supported by Japan International Cooperation Agency and Tokyo Electric Power Company for Power Division of Ministry of Power, Energy, and Natural Resources of the Government of the People's Republic of Bangladesh



Step 1 Sectoral energy consumption (A)
= Sectoral energy consumption intensity
× Sectoral GDP (Population for residential sector)

Step 2 Sectoral power demand (B)
= Sectoral total energy consumption (A) × Electrification ratio
× Power tariff elasticity × EE&C factor (Energy efficiency & conservation)

Step 3 Final electricity consumption (C)
= Sum of (B) for each sector, e.g. agriculture, industrial, commercial & public services and residential

Step 4 Electricity sent from the grid (net generation) (D)
= Final electricity consumption (C) + Transmission & distribution losses

Step 5 Peak demand (E)
= Electricity sent from the grid (D) / Load factor / 24 hours / 365 days

Case Study 6 of Nepal

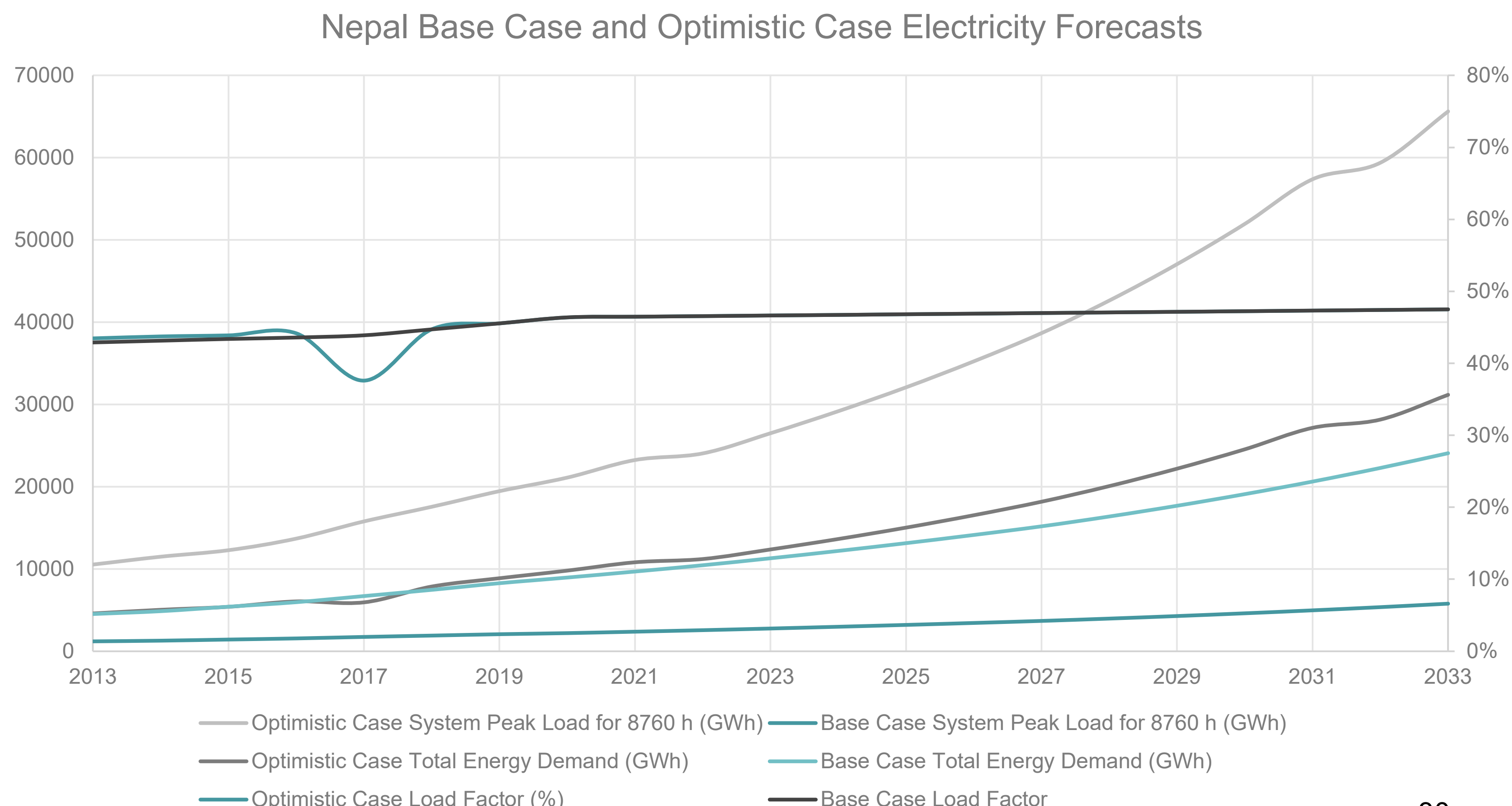
Energy Demand and Peak Load Forecasts (Base Case)

Appendix 1

Fiscal Years	Domestic Energy (GWh)	Industrial Energy (GWh)	Commercial Energy (GWh)	Irrigation Energy (GWh)	Other Loads (GWh)	Internal Consumption	Nepal Energy Demand	**Export Energy (GWh)	Total Sales (GWh)	Sales Growth (%)	Energy Demand (GWh)	System Losses (%)	Generation Requirement (GWh)	System Load Factor(%)	System Peak Load(MW)	Peak Load Growth
2013/14	2,138.90	1,618.65	369.09	50.92	334.88	3.5	4,515.91	3.4	4,515.84		4,519.32	24.5	5,988.98	56.9	1201.0	
2014/15	2,249.01	1,801.89	380.51	70.78	357.02	3.7	4,862.87	3.5	4,862.72	7.7	4,866.37	23.2	6,334.73	56.2	1286.1	7.1
2015/16	2,500.28	2,008.59	411.43	91.63	391.04	3.8	5,406.80	3.6	5,406.58	11.2	5,410.41	21.8	6,920.41	55.5	1422.8	10.6
2016/17	2,772.01	2,192.02	444.86	113.52	428.30	4.0	5,954.73	3.7	5,954.42	10.1	5,958.45	20.5	7,491.08	54.8	1559.7	9.6
2017/18	3,065.69	2,543.88	481.00	136.51	469.11	4.2	6,700.41	3.8	6,700.01	12.5	6,704.24	19.1	8,287.02	54.3	1742.2	11.7
2018/19	3,409.20	2,847.56	520.83	160.64	514.54	4.4	7,457.21	3.9	7,456.71	11.3	7,461.15	17.7	9,070.15	54.4	1903.3	9.2
2019/20	3,787.29	3,159.67	563.96	185.98	564.36	4.7	8,265.93	4.1	8,265.33	10.8	8,269.99	16.4	9,889.91	54.5	2071.5	8.8
2020/21	4,198.76	3,307.32	610.66	212.59	619.02	4.9	8,953.24	4.2	8,952.53	8.3	8,957.43	15.0	10,540.57	54.6	2203.8	6.4
2021/22	4,634.33	3,464.54	661.23	240.53	678.96	5.1	9,684.74	4.3	9,683.91	8.2	9,689.05	15.0	11,398.88	54.7	2378.9	7.9
2022/23	5,082.17	3,631.95	715.99	269.87	744.71	5.4	10,450.09	4.4	10,449.13	7.9	10,454.53	15.0	12,299.44	54.8	2562.1	7.7
2023/24	5,582.84	3,812.51	776.49	300.68	818.08	5.7	11,296.26	4.6	11,295.17	8.1	11,300.84	15.0	13,295.10	54.9	2764.5	7.9
2024/25	6,107.47	4,004.93	842.10	333.02	898.68	5.9	12,192.15	4.7	12,190.91	7.9	12,196.86	15.0	14,349.25	55.0	2978.3	7.7
2025/26	6,652.43	4,209.97	913.26	366.98	987.22	6.2	13,136.11	4.9	13,134.71	7.7	13,140.96	15.0	15,459.95	55.1	3203.0	7.5
2026/27	7,219.30	4,428.48	990.43	402.64	1,084.48	6.6	14,131.89	5.0	14,130.32	7.6	14,136.88	15.0	16,631.63	55.2	3439.5	7.4
2027/28	7,809.79	4,661.33	1,074.12	440.08	1,191.32	6.9	15,183.53	5.1	15,181.79	7.4	15,188.68	15.0	17,869.03	55.3	3688.7	7.2
2028/29	8,502.10	4,912.64	1,166.56	479.40	1,310.55	7.2	16,378.48	5.3	16,376.55	7.9	16,383.78	15.0	19,275.03	55.4	3971.7	7.7
2029/30	9,266.99	5,180.65	1,266.96	520.68	1,441.71	7.6	17,684.57	5.5	17,682.44	8.0	17,690.03	15.0	20,811.80	55.5	4280.7	7.8
2030/31	10,097.43	5,466.49	1,375.99	564.02	1,585.99	8.0	19,097.89	5.6	19,095.54	8.0	19,103.52	15.0	22,474.72	55.6	4614.4	7.8
2031/32	10,999.00	5,771.32	1,494.41	609.53	1,744.72	8.4	20,627.35	5.8	20,624.78	8.0	20,633.15	15.0	24,274.29	55.7	4974.9	7.8
2032/33	11,977.76	6,096.42	1,623.02	657.32	1,919.33	8.8	22,282.64	6.0	22,279.81	8.0	22,288.60	15.0	26,221.88	55.8	5364.5	7.8
2033/34	13,040.26	6,443.14	1,762.69	707.50	2,111.42	9.2	24,074.23	6.1	24,071.15	8.0	24,080.37	15.0	28,329.85	55.9	5785.3	7.8
A (%)	10.1	8.9	7.7	19.4	9.3		9.6	3.0	9.6				8.3		8.7	
B (%)	9.5	7.2	8.1	14.1	9.6		8.7	3.0	8.7				8.1		8.2	

A : Average Annual Growth of First Ten Years
B : Average Annual Growth over Forecast Period

Case Study 6 of Nepal



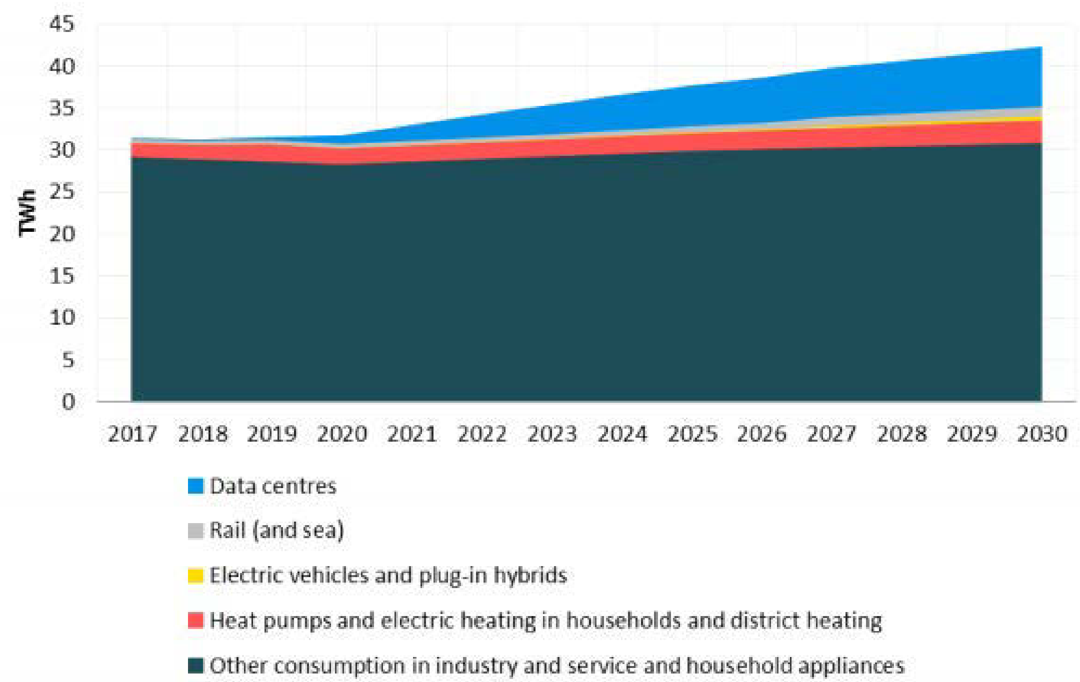
Source data: Nepal Electricity Authority Load Forecast Report

Case Study 7 of Denmark

Demand forecasting

- Biggest factor: increase in data center energy consumption (65% of demand increase, 16.7% of total energy by 2030)
- EVs and heat pumps are also significant

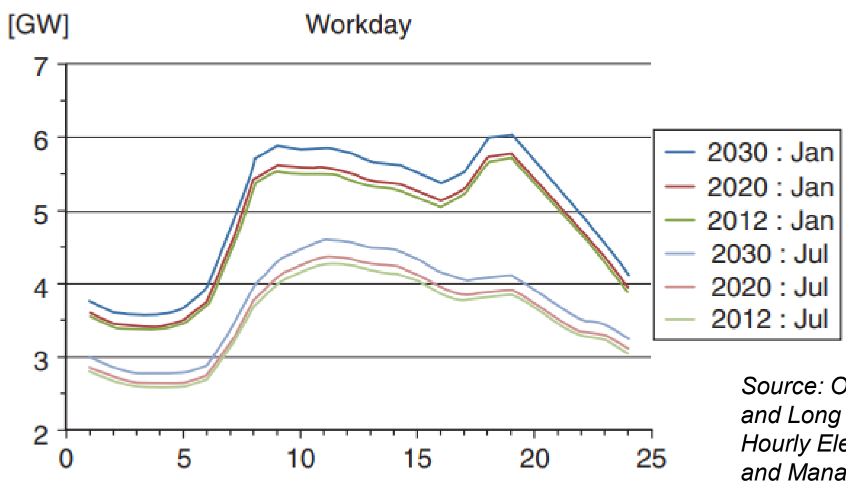
Figure 5: Electricity consumption (excluding grid losses) by use 2017-2030 (TWh).



Source: Ostergaard, Andersen, and Kwon, "Energy Systems Scenario Modelling and Long Term Forecasting of Hourly Electricity Demand". International Journal of Sustainable Energy Planning and Management, Vol. 07 2015 99-116

Case Study 7 of Denmark

	Projected electricity consumption [GWh]			Change [coefficient k_i^T] in Eq. (2)	
	2012	2020	2030	2012–2020	2012–2030
Households	9750	9774	10042	1.0025	1.0299'
Agriculture	1847	1818	1895	0.9841	1.0255
Industry	7309	7983	8419	1.0922	1.1520
Private service	9604	9937	10801	1.0346	1.1246
Public service	2412	2272	2355	0.9418	0.9763
	30922	31783	33512	1.0278	1.0837
Electrical vehicles	0	140	660		
Individual heat pumps	73	431	778		
Total	30995	32355	34949	1.0439	1.1276



	2012	2020	2030
Demand (GWh)	30922	31783	33512
Peak Load (GW)	5.72	5.8	6.04
Load Factor (%)	**62%**	**63%**	**63%**

Source: Ostergaard, Andersen, and Kwon, "Energy Systems Scenario Modelling and Long Term Forecasting of Hourly Electricity Demand". International Journal of Sustainable Energy Planning and Management, Vol. 07 2015 99-116

Load Forecasting in Pakistan

Load Forecasting in Pakistan

- NTDC provides the primary load forecast that is used within the Government of Pakistan
  - A full report outlining the regression methodology and results were published in 2014
  - This process was updated in 2019
  - Data from the 2019 analysis are utilized in NTDC's Indicative Generation Capacity Expansion Plan (IGCEP)
  - The methodology is briefly reviewed in the IGCEP

Indicative Generation Capacity Expansion Plan 2018-40, NTDC February 2019. https://www.ntdc.com.pk/ntdc/public/uploads/downloads/NTDC.PSP.IGCEP.pdf

NTDC 2019 Load Forecasting

- Ordinary Least Squares regression model based on historical data

Sectors

- Domestic
- Commercial
- Industrial
- Agriculture

Variable	Description
Y_T	Electricity Demand of current year (Sales GWh)
Y_{T-1}	Electricity Demand of previous year (Sales GWh)
GR	Growth Rate
G, R, L	Independent variable (GDP, Real Price, Lag)
b, c, d	Elasticities of independent variables (GDP, Real Price and Lag respectively)

Independent variables

- Annual GDP (by sector)
- Electricity tariff (by sector)
- Number of consumers
- Population trend
- Lag of dependent variables
- Consumer Price Index
- Dummy variables

$$Y_T = Y_{T-1} * (1+GR\ of\ G)_b * (1+GR\ of\ R)_c * (1+GR\ of\ L)_d$$

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NTDC 2019 Load Forecasting

- Regression accounts for historical load management
  - Projections are for ***actual*** demand
  - Regardless of whether or not that demand can be served by the power system
- The total annual electricity demand (GWh) is projected for each sector of the economy
  - Through regression analysis
- National generation requirements are then determined by considering projected T&D losses
  - Method for projecting future changes in T&D losses is not outlined in detail
- Peak demand (MW) is then obtained by applying a projected load factor
  - Method for forecasting load factor is not outlined in detail
  - Load factor depends on many system interactions and can be very challenging to forecast

NTDC 2014 Regression Study

- Assumed reduction in load factor from 69.1% to 68.1%
  - PEPCO only
- Assumed reduction in T&D losses
  - 265kV+: Decrease from 2.92% (2012) to 2.52% (2016 and beyond)
  - 132 kV: Decrease from 2.10% (2012) to 2.06% (2016 and beyond)
  - Distribution: Decrease from 14.52% (2012) to 10.0% (2021 and beyond)
- Considered 3 GDP growth scenarios
  - Low: 3.56% (IMF value for 2012-13)
  - Normal: 5% (based on last 30 years)
  - High: 6.5% (goal)
- Results are presented for six subsets of country demand
  1. Sectoral sales for PEPCO and KESC
  2. Load forecast for PEPCO excluding export to KESC
  3. Load forecast for KESC
  4. Load forecast for PEPCO + KESC + Self-generation
  5. Load forecast for PEPCO + KESC + Self-generation with Demand Side Management

"Electricity Demand Forecast Based on Multiple Regression Analysis: Period 2014 to 2037", NTDC, March 2014.

NTDC 2014 Regression Results

PEPCO excluding exports to KESC – Normal Growth Projection

Base Year	Energy Sale (GWh)	Energy Generated (GWh)	Load Factor (%)	Peak Demand (MW)
2012-13 (Recorded)	70,508	90,893	82.8	12,527
2012-13 (Computed)	89,535	116,611	69.1	19,265
2013-14	94,222	120,469	68.1	20,195
2014-15	99,537	126,296	68.1	21,171
2015-16	105,418	132,747	68.1	22,253
2016-17	111,741	139,655	68.1	23,411
2017-18	118,829	147,591	68.1	24,741
2018-19	126,651	156,335	68.1	26,207
2019-20	135,005	165,624	68.1	27,764
2020-21	144,283	175,928	68.1	29,492
2021-22	154,497	187,241	68.1	31,388
2022-23	165,568	200,658	68.1	33,637

Recorded Demand represents the load that was actually served in the base year

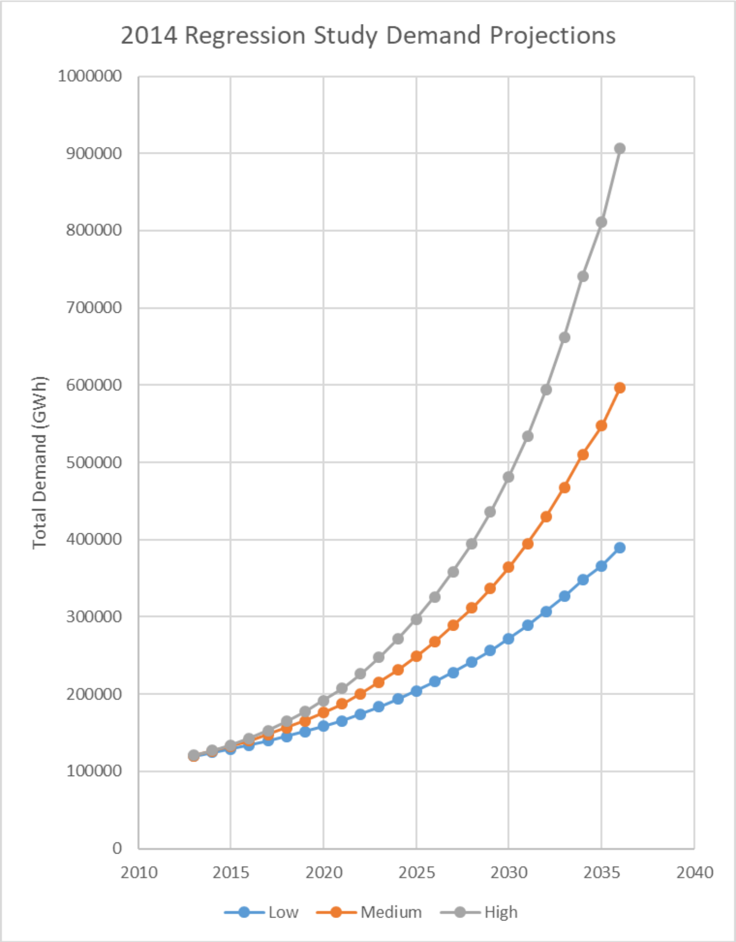
Computed Demand represents the load that would have been served without load shedding

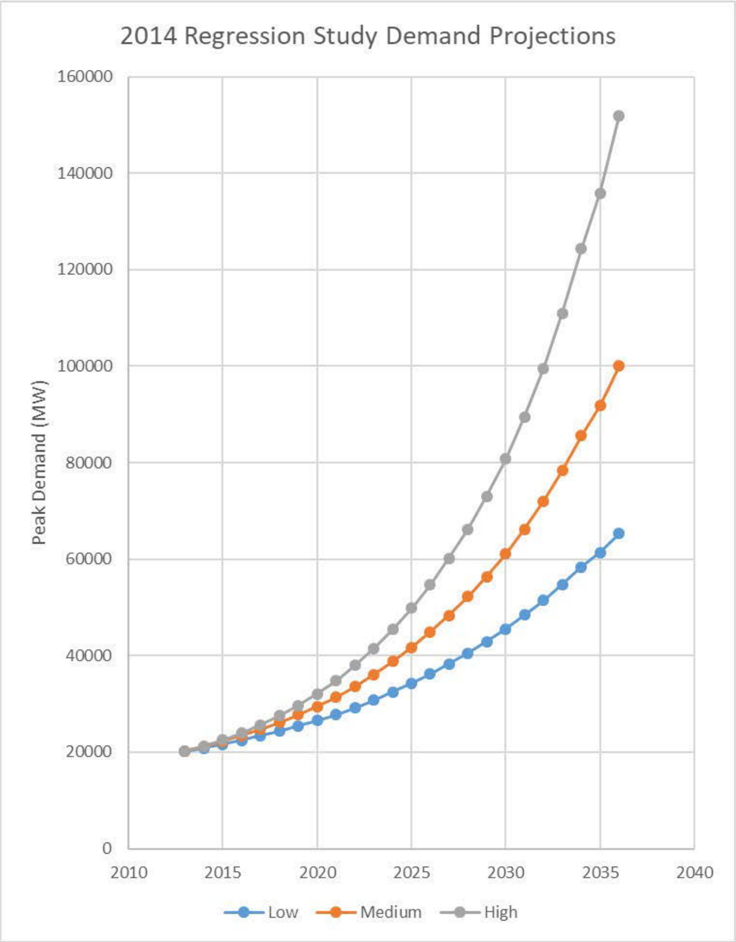
Auxiliary Consumption is electricity consumed by IPPs

- Electricity demand is projected to grow faster than GDP
- Increasing from 5% to 9% per year by 2036, vs. assumed constant 5% per year GDP growth
- Load factor projected to remain constant at 68.1%
- Projected load factor in KESC is greater (~80-90%)
- The peak generation shortfall (computed – recorded) in 2012-13 was roughly 6750 MW

Source: "Electricity Demand Forecast Based on Multiple Regression Analysis: Period 2014 to 2037", NTDC, March 2014.

NTDC 2014 Regression Study





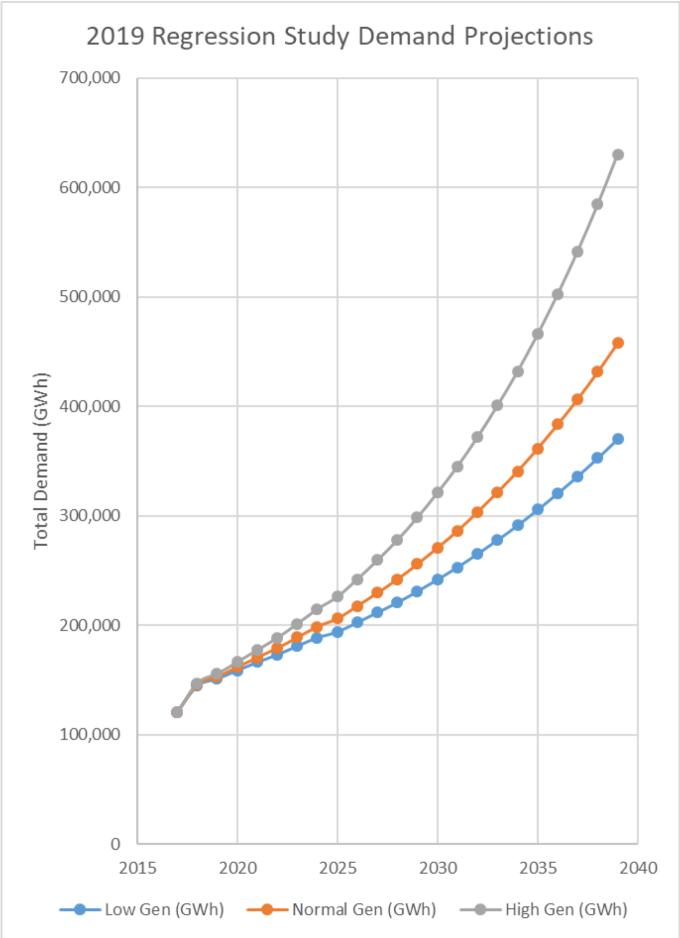
*PEPCO Only

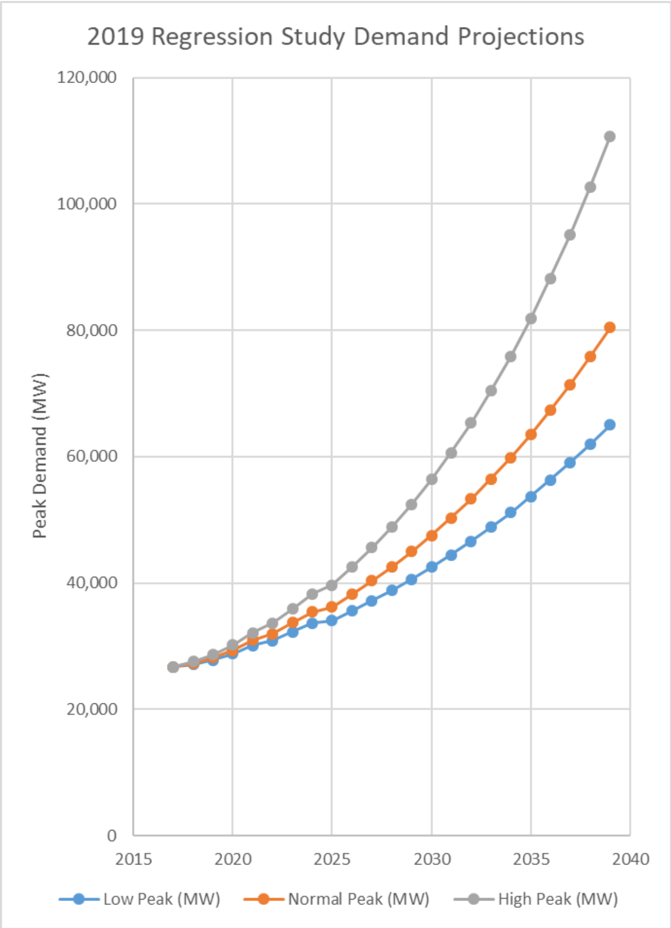
NTDC 2019 Regression Results

	Low		Normal		High		
Fiscal Year	Gen (GWh)	Peak (MW)	Gen (GWh)	Peak (MW)	Gen (GWh)	Peak (MW)	Load Factor
2017-18*	120,791	26,741	120,791	26,741	120,791	26,741	0.516
2018-19	144,665	27,072	145,674	27,261	147,188	27,545	0.610
2019-20	151,062	27,814	152,914	28,155	155,718	28,671	0.620
2020-21	158,842	28,782	161,841	29,325	166,429	30,157	0.630
2021-22	166,267	30,127	170,645	30,921	177,416	32,147	0.630
2022-23	173,178	30,889	179,142	31,953	188,476	33,618	0.640
2023-24	181,051	32,294	188,914	33,696	201,374	35,919	0.640
2024-25	188,749	33,640	198,744	35,422	214,788	38,281	0.641
2025-26	193,948	34,062	206,155	36,206	226,011	39,693	0.650
2026-27	202,763	35,610	217,664	38,227	242,228	42,541	0.650
2027-28	211,718	37,183	229,603	40,324	259,492	45,573	0.650
2028-29	220,940	38,802	242,104	42,519	277,960	48,816	0.650
2029-30	231,142	40,594	255,989	44,958	298,670	52,453	0.650
2030-31	241,889	42,481	270,792	47,557	321,130	56,398	0.650
2031-32	253,101	44,451	286,441	50,306	345,315	60,645	0.650
2032-33	265,289	46,591	303,554	53,311	372,070	65,344	0.650
2033-34	278,069	48,835	321,710	56,500	400,940	70,414	0.650
2034-35	291,403	51,177	340,888	59,868	431,973	75,865	0.650
2035-36	305,685	53,686	361,590	63,504	465,916	81,826	0.650
2036-37	320,652	56,314	383,529	67,357	502,479	88,247	0.650
2037-38	336,293	59,061	406,719	71,429	541,779	95,149	0.650
2038-39	352,917	61980	431,584	75,796	584,509	102,653	0.650
2039-40	370,348	65,042	457,939	80,425	630,529	110,736	0.650

- 2017-18 data are recorded, 2018-19 onward are computed
- Recorded load factor in 2017 was 51.6%
- Load factor projected to grow from 61% to 65%
- Data provided in the IGCEP Report Table 5-2

NTDC 2019 Regression Study





***Data provided in the IGCEP Report Table 5-2**

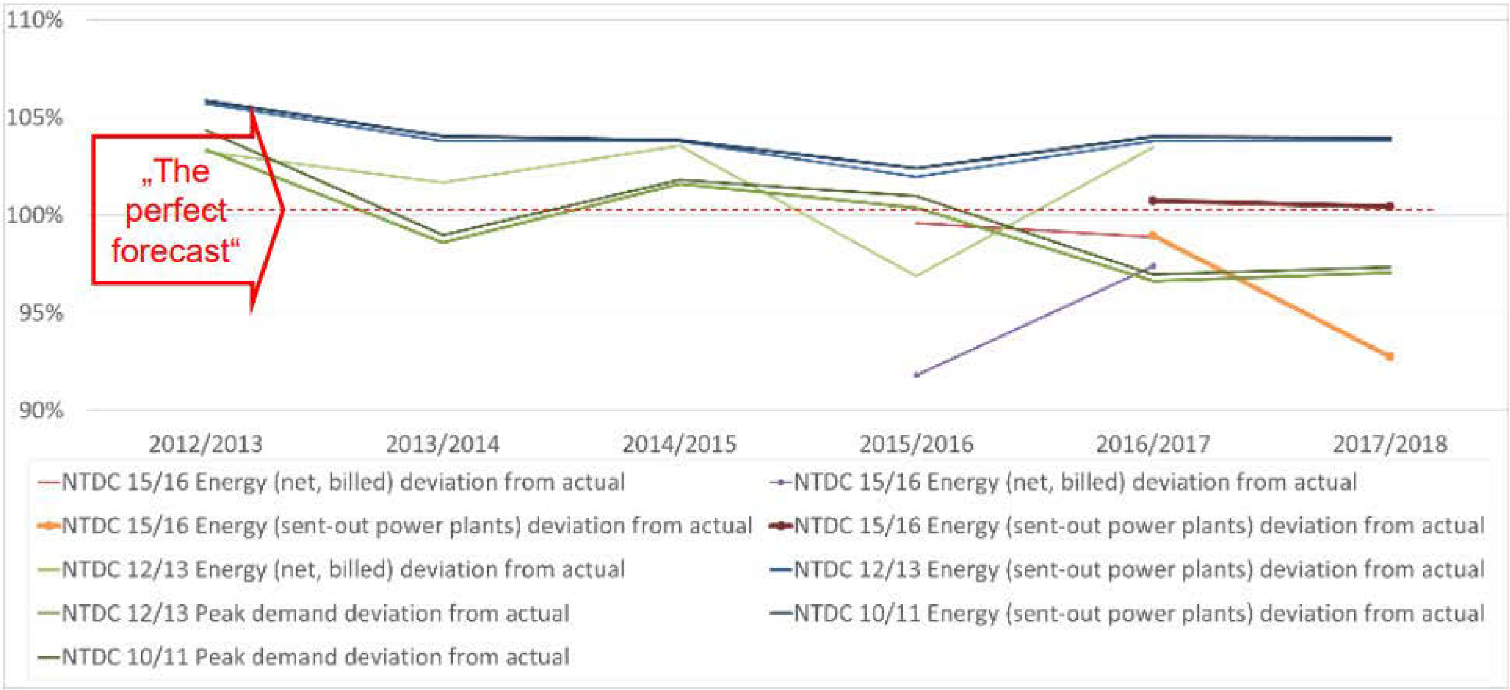
World Bank*: Review and Contributions

- World Bank reviewed a number of past internal NTDC forecasts
  - Compared forecasts to actual realized demand in future years
- Goal to determine if they are suitable and prioritize methodological improvements
- NTDC conducts regular load forecasting driven by regression analysis
  - Long Term (20+ years)
  - Top-down macroeconomic regression analysis
  - Base years: 10/11, 12/13, 15/16 and 16/17

*Funding provided by the Energy Sector Management Assistance Program (ESMAP)

Source: http://pubdocs.worldbank.org/en/871161554646154248/pdf/VRE-Study-Stakeholder-Workshop-Tasks-1-2-Slides-04Apr2019.pdf

Regression Analysis



- Overall very accurate, within +/- 5%

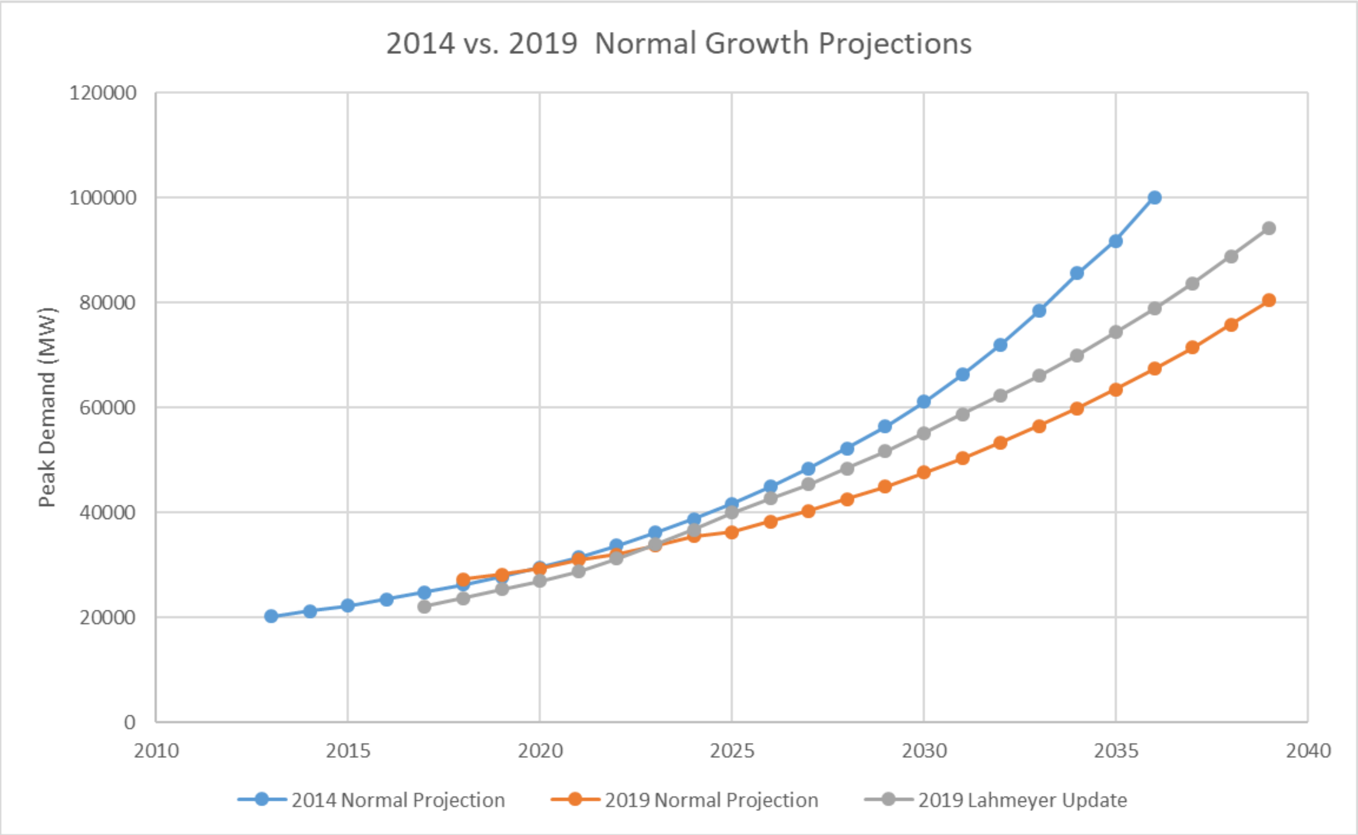
Source: http://pubdocs.worldbank.org/en/871161554646154248/pdf/VRE-Study-Stakeholder-Workshop-Tasks-1-2-Slides-04Apr2019.pdf

World Bank Findings and Recommendations

"The NTDC forecasts provide very accurate results to forecast future electricity demand for the NTDC system on a national level."

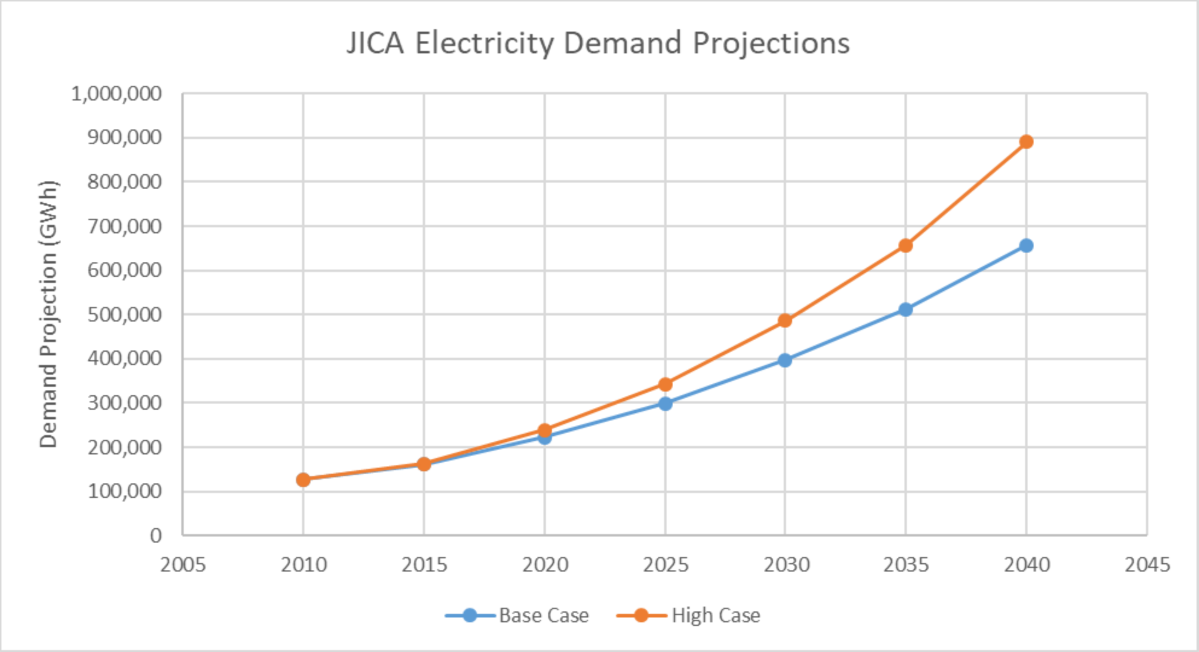
Source: http://pubdocs.worldbank.org/en/871161554646154248/pdf/VRE-Study-Stakeholder-Workshop-Tasks-1-2-Slides-04Apr2019.pdf

2014 vs 2019 Peak Demand Projections



- Projected demand growth declined between the 2014 and 2019 regression studies
- Lahmeyer revised the 2019 NTDC regression forecast moderately upwards

JICA: 2016 Least-cost Expansion Plan



- Energy intensities are estimated based on past sectoral consumption
  - Consumption per unit GDP (or per capita for residential)
- Base case: Assumes 5% GDP growth - 5.8% electricity demand growth rate
- High case: Assumes 6.5% GDP growth - 7.0% electricity demand growth
- Project constant future load factors for three regions
  - North (57.5%) South (61.0%) and Karachi (62.0%)

Source: "Project for Least Cost Power Generation and Transmission Expansion Plan", JICA and IIEP, 2016.

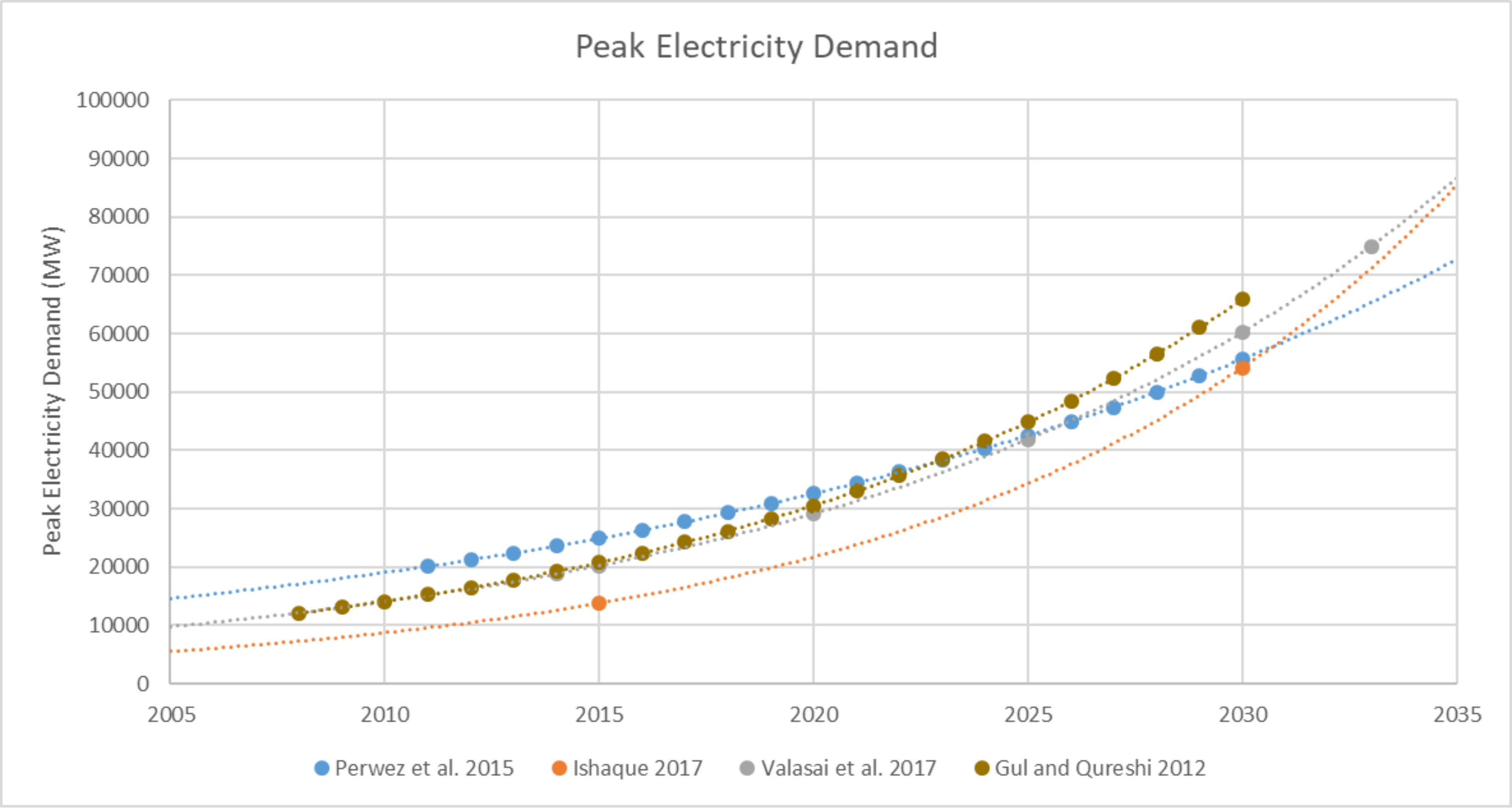
University Demand Projections

At least four academic studies have projected electricity demand in Pakistan, three using LEAP and one using TIMES

1. Gul and Qureshi 2012 (LEAP)
2. Perwez et al. 2015 (LEAP)
3. Ishaque 2017 (LEAP)
4. Valasai et al. 2017 (TIMES)

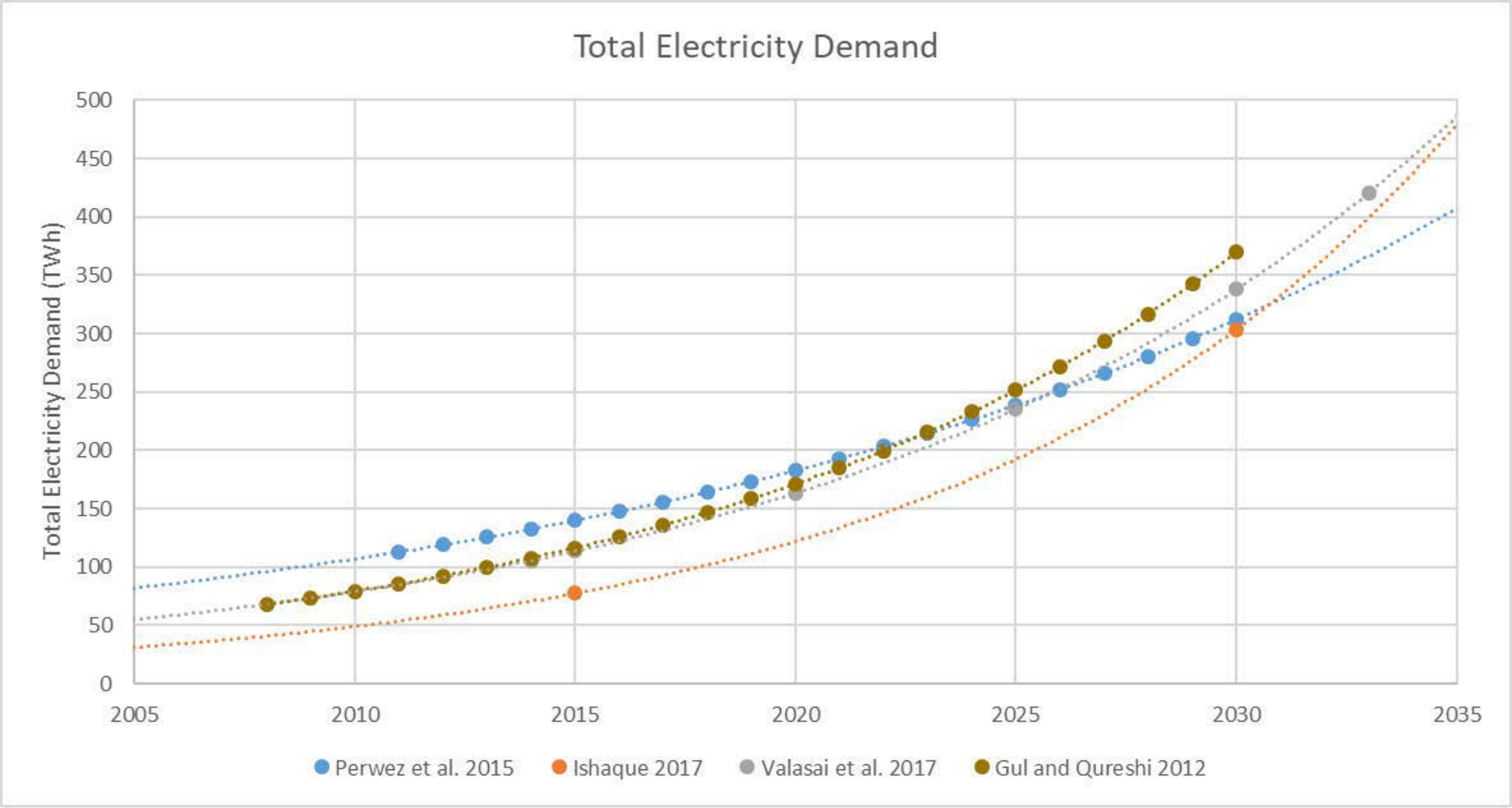
- Typically directly project total demand
- Calculate peak demand based on exogenous load factor

Comparison of University Peak Projections



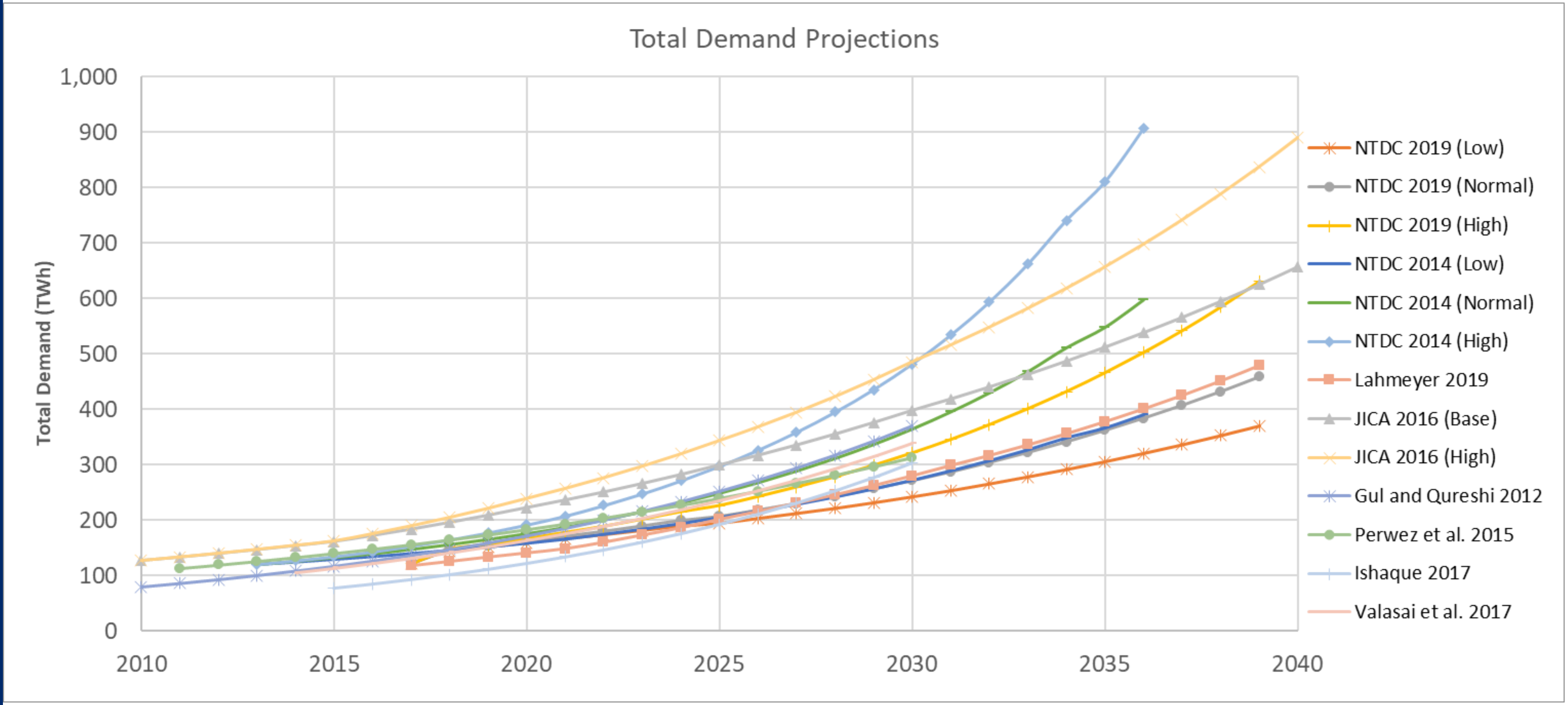
- Comparable to 2019 NTDC high projections

Comparison of University Energy Projections

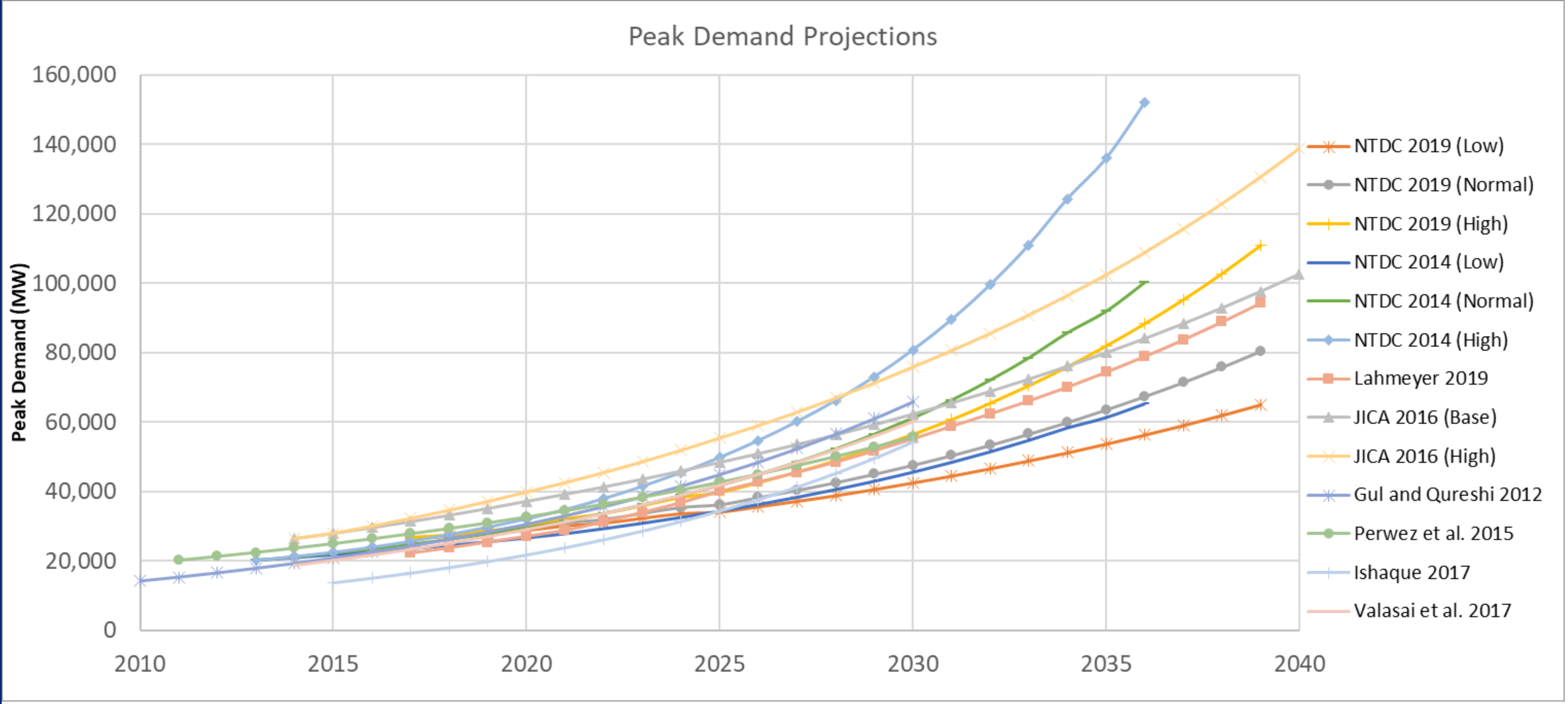


- Comparable to 2019 NTDC high projections

Comparison of all Projections



Comparison of all Projections



Conclusions

- Most projections are for total demand, based on macro-economic indicators
  - GDP growth
  - Population growth
  - Electricity tariffs
- Often converted to peak demand by applying a load factor
  - Load factor is hard to predict with a top-down economic model
- Need to be careful with definitions when making comparisons
  - Recorded demand vs. Computed Demand
  - Sales vs. Generation (T&D losses)
- NTDC methodologies have been externally validated
  - Demand projections are still always limited by macroeconomic projections
- No single demand projection is ever perfectly correct
  - All projections are based on assumptions
  - It is important to draw upon a number of studies
  - Help to understand how different factors may influence future demand

Questions?

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Photo by Dennis Schroeder / NREL

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