

A Hybrid Model for Forecasting Electricity Sales

A Case Study of Peninsular Malaysia

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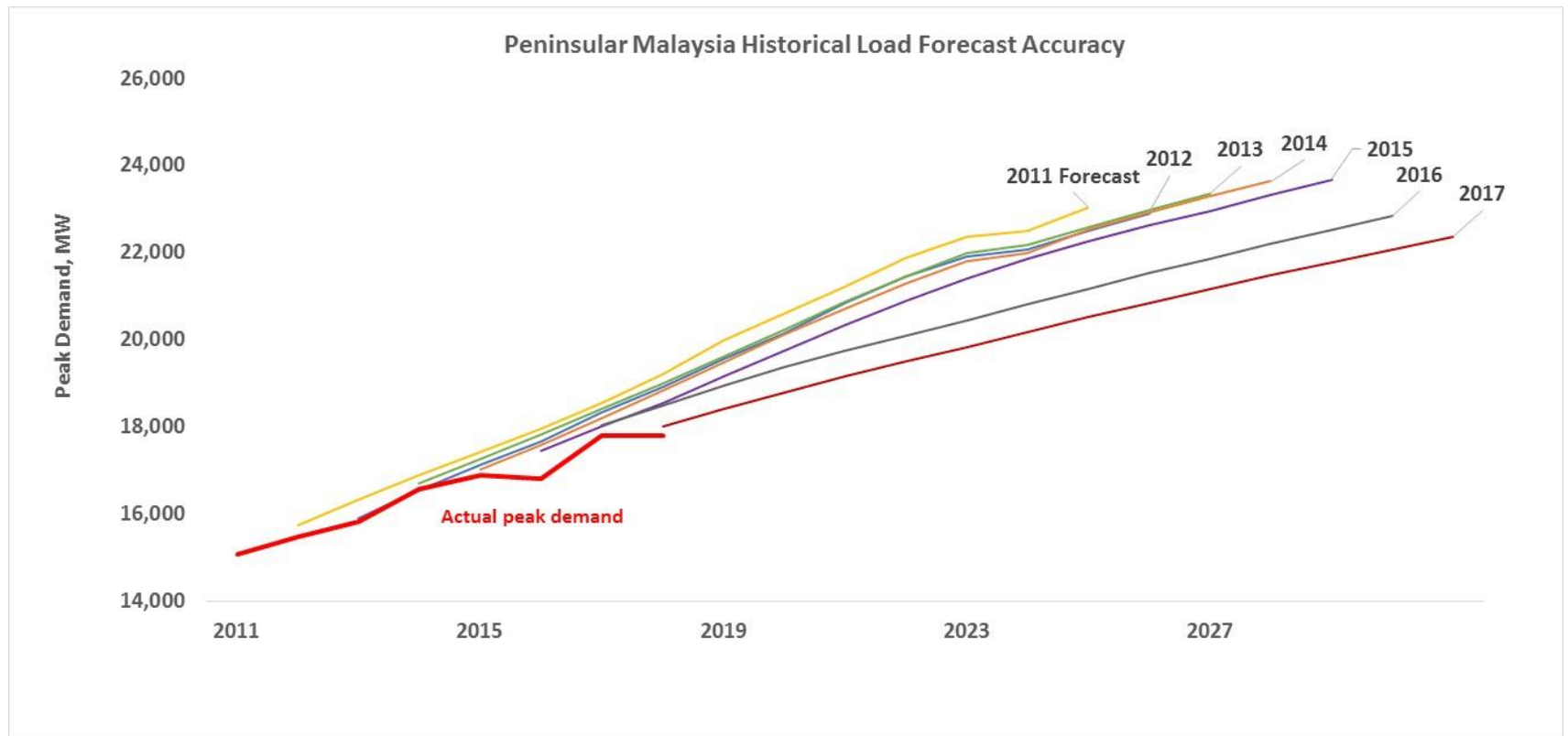
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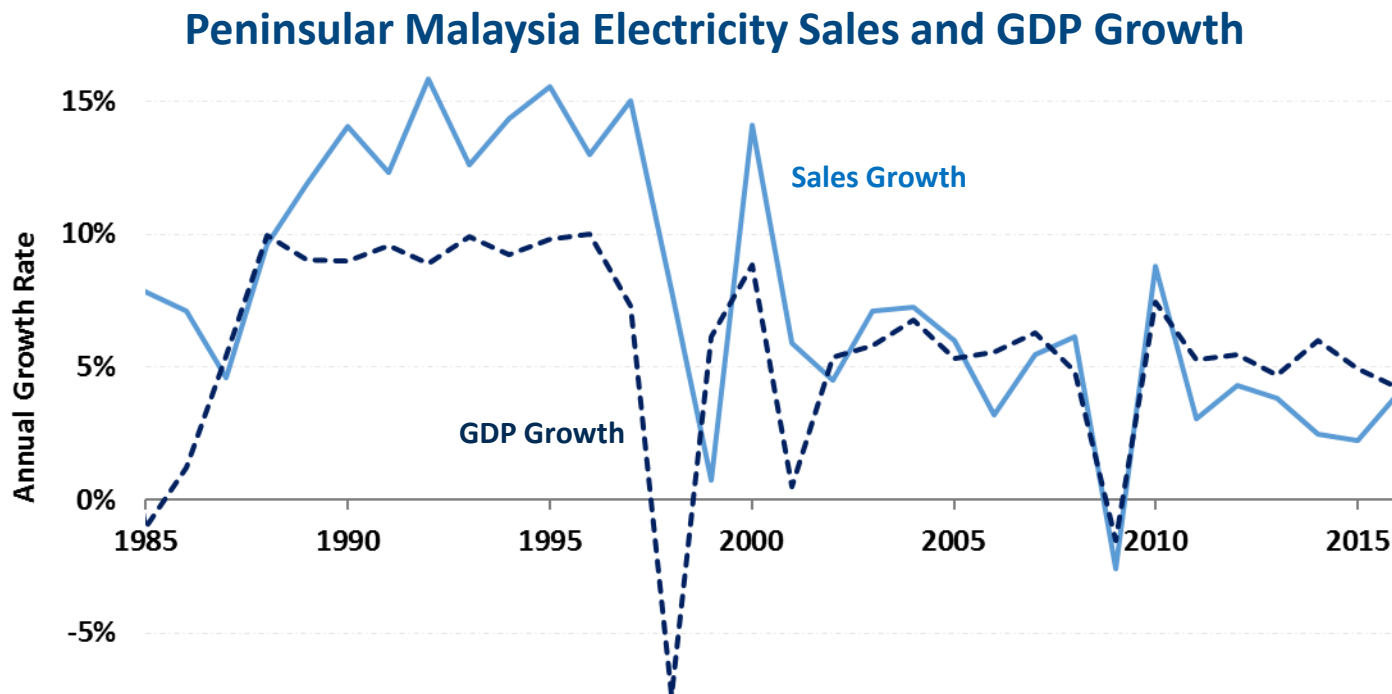
Motivation

Traditional econometric techniques are having a difficult time delivering accurate load forecasts in **Peninsular Malaysia**, due to economic changes, energy efficiency, and distributed generation

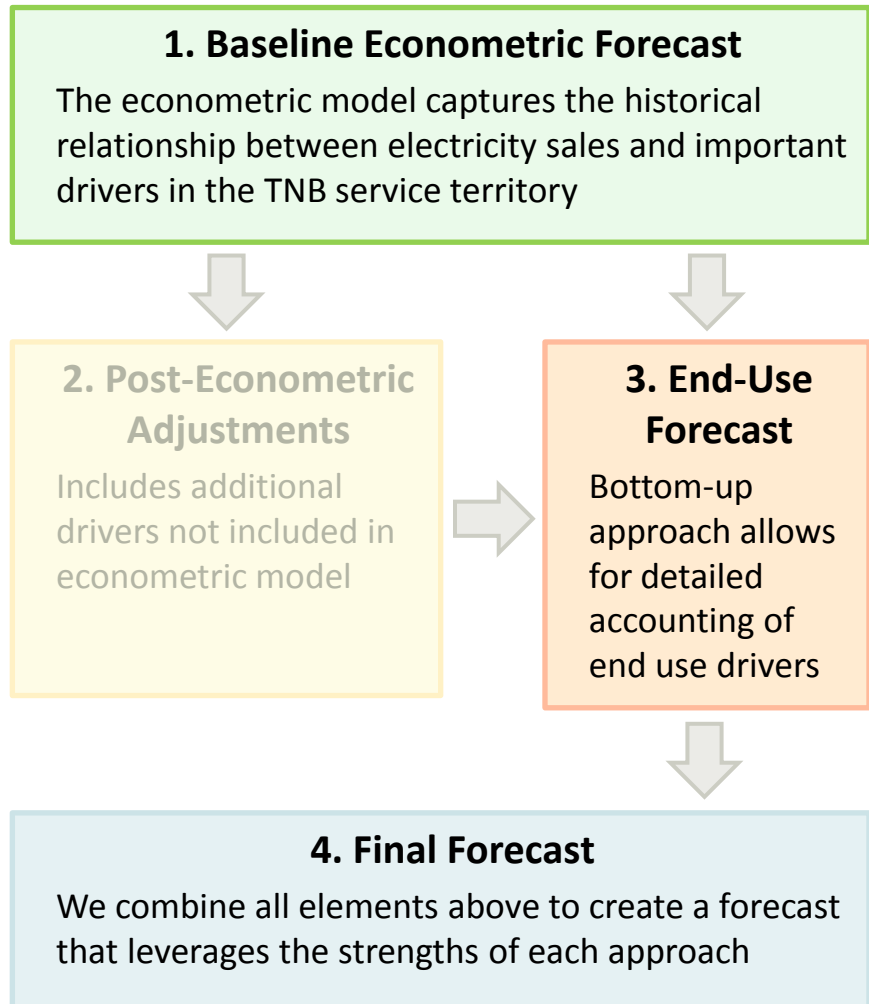


Setting and Context

In Peninsular Malaysia, this issue is particularly acute following the country's industrialization and economic boom in the 1990s. Both GDP and electric sales growth rates have been trending downwards.



Project Overview



We combined a number of elements to develop a new forecast of electricity sales and peak demand using a hybrid approach

- Econometric Forecast
- Post-Estimation Adjustments
- End-Use Forecast

The end-use forecast is calibrated to the econometric forecast, to incorporate information on **macro trends**, and additionally incorporates several **post-estimation adjustments** and detailed information on **customer end-use trends**

- Post-estimation and end-use adjustments account for energy efficiency estimates

Baseline Econometric Forecast

Our Approach to Econometric Forecasting

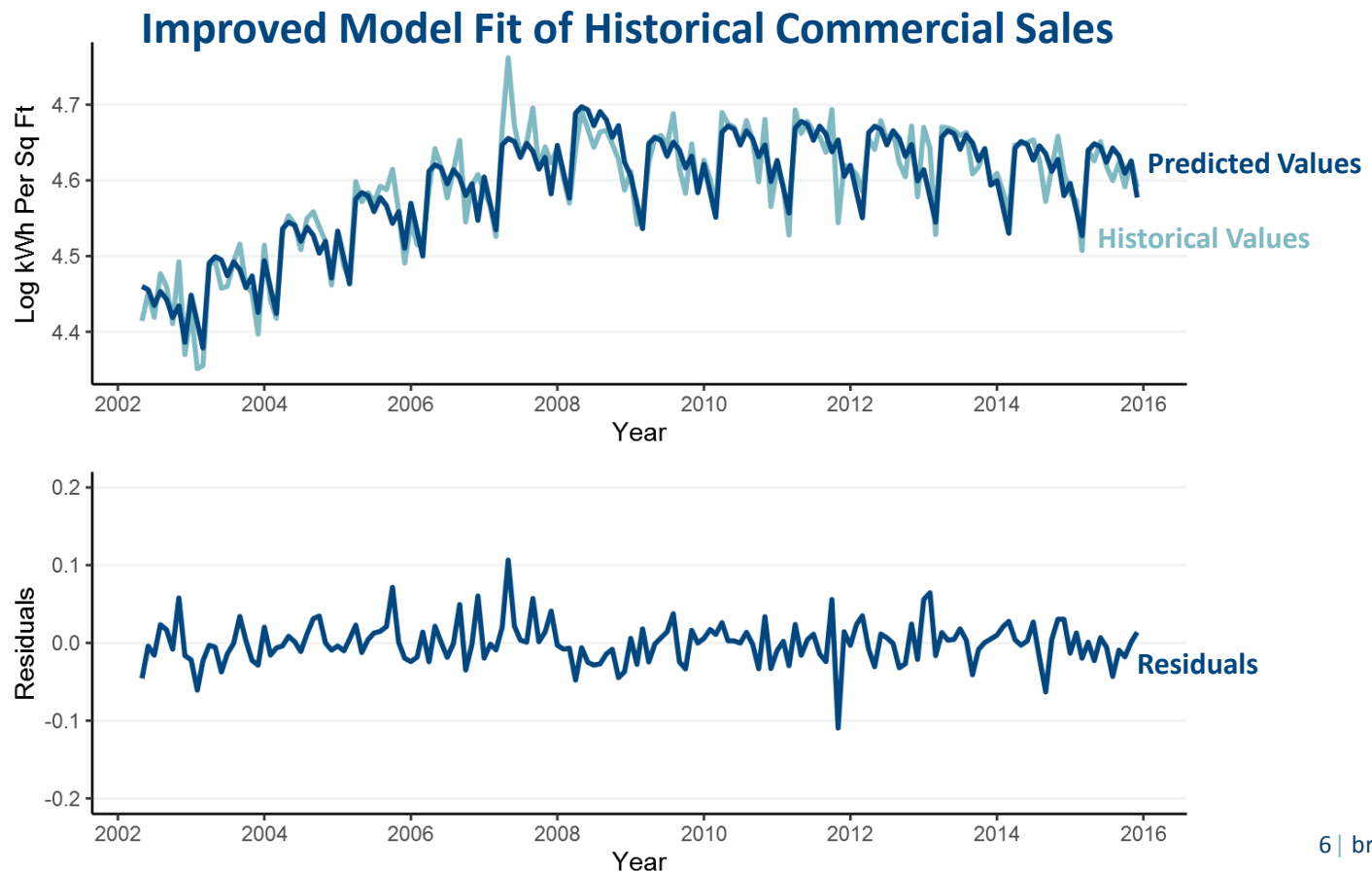
We used econometric methods to create a baseline forecast for sales, comprised of separate sectoral forecasts (commercial, industrial, domestic, and minor sectors) as well as a baseline forecast for annual peak demand

Our goal was to improve SB's sectoral models to the point that they could be used as the basis for the total sales forecast, helping to improve precision and granularity. Changes from SB's sectoral models include:

- Used variables to **allow for trends** not explained by the main drivers, and a trend break in 2009, when the historical relationship between drivers shifted in a way that we anticipate continuing into the future.
- **Use additional drivers in all sectors**, and removed some variables that we identified were not strong drivers.
- Changed from a simple linear model for all sectors to **modeling some sectors as intensities**
- Changed from a simple linear model for all sectors to **modeling some sectors as logs** to account for percentage/compounding/exponential growth (for commercial and industrial sectors)
- Used monthly dummies to **allow for seasonality** in electricity sales and improve model precision.
- Changed from annual to **monthly frequency of all drivers**, the dependent variable, and forecast

Example: Commercial Sales Model Fit

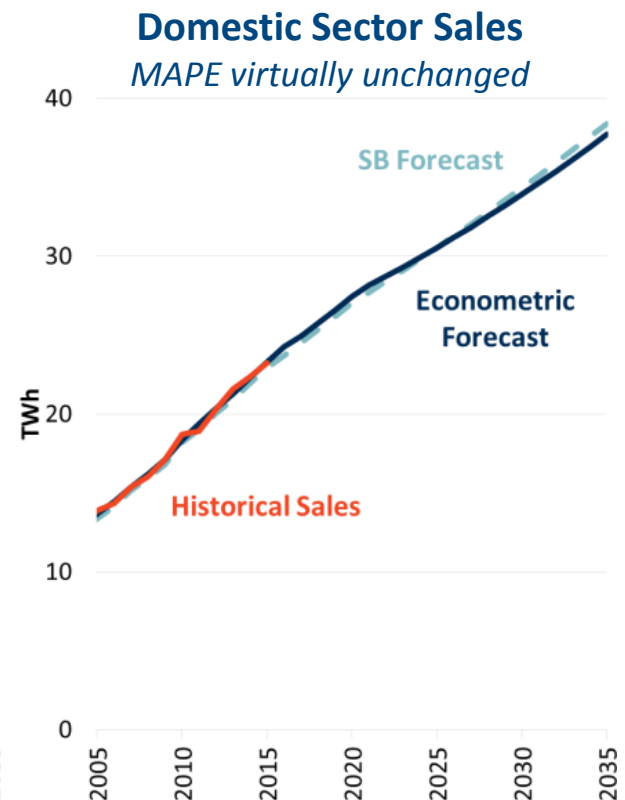
The improved econometric model allow us to capture seasonal trends and significant trend breaks



Econometric Forecast Performance

The in-sample and out-of-sample forecast performance of the revised econometric models was greatly improved.

- One important indicator of performance is in-sample Mean Absolute Prediction Error (MAPE)



Why We Need an End-Use Forecast

What the econometric model can do

The enhanced econometric model captures the historical relationship between electricity sales and important drivers in the TNB service territory

What the econometric model does not do

The model does not capture changes in how those drivers interact over time, or incorporate information about how changing appliance standards and other energy efficiency trends will affect future sales growth

Why we need an end-use forecast

End-use forecasting builds a model of customer demand from the bottom-up, and is thus detailed enough to incorporate additional drivers of sales. The two models are calibrated and combined to yield the final forecast

End-Use Model

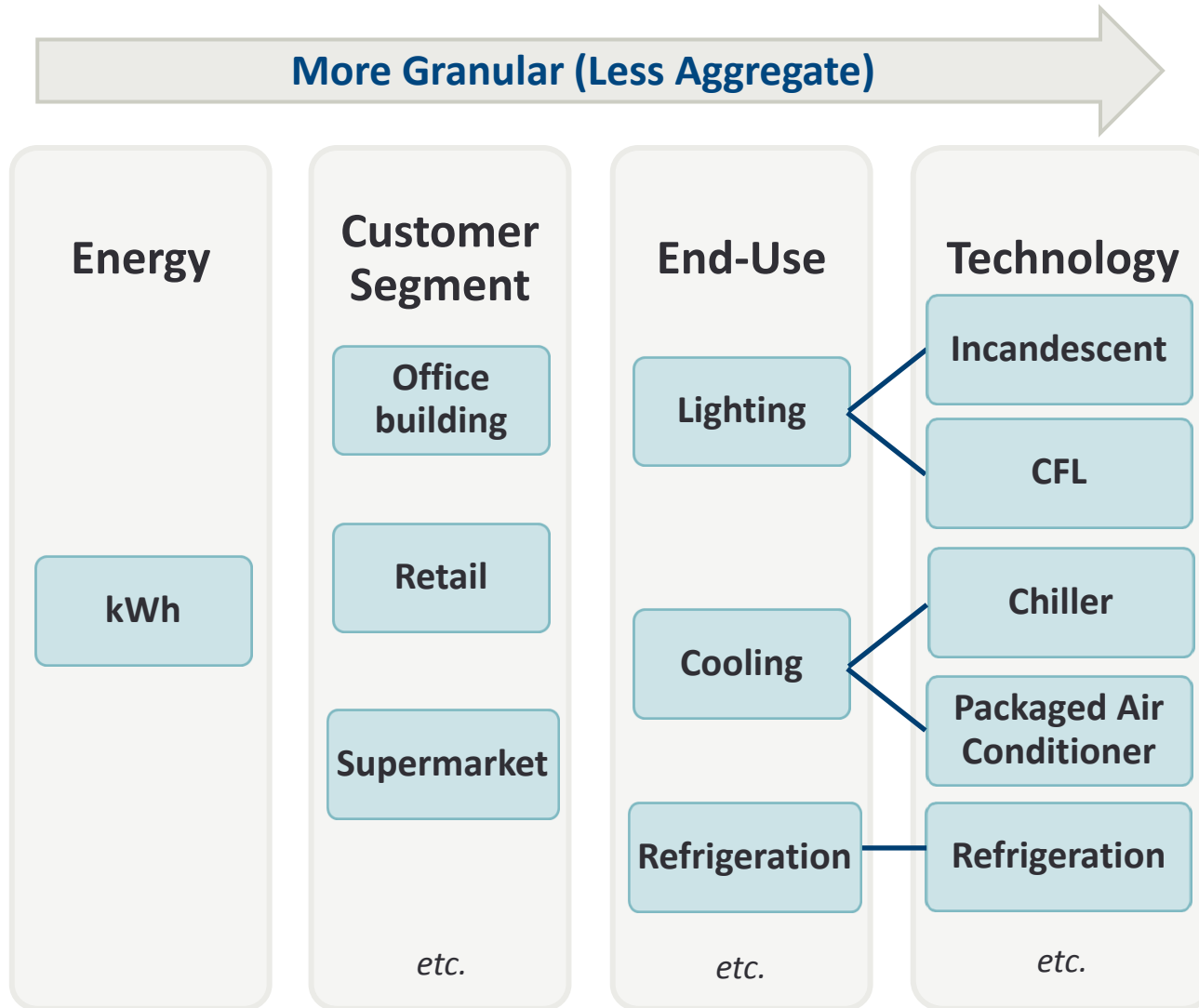
Overview of End-Use Forecasting

End-use forecasting uses a deterministic approach, rather than a probabilistic approach

- It builds a forecast from the bottom up for each customer segment, end use and technology identified for analysis
- It allows us to “tell a story” about what is happening in the market place
- Ideally, it would capture all the drivers that affect future use

	Econometric (“Top-Down”)	End-Use (“Bottom-Up”)
Advantages	Model can easily adapt to available data. Forecast uncertainty is more easily determined.	By construction, model allows analyst to decompose energy usage. Model can easily incorporate new changes into its forecast.
Limitations	Forecast is based on historical trends and will not capture new interventions or changes.	Model development is data intensive. Quantifying uncertainty of the forecast is difficult.

Multiple Layers in an End-Use Model



Survey of Commercial and Industrial (C&I) Customers

Many of the data required to construct an end-use forecast for TNB's commercial and industrial sectors were not available, so we surveyed these customers

The survey responses allowed us to estimate the most important base-year data needed for the model

- Market size per segment
- Annual energy intensity
- Appliance saturations
- Information to estimate energy use intensities (EUIs) for commercial and industrial customers and unit energy consumption (UEC) values for residential customers
- Base-year mix of efficiencies for lighting

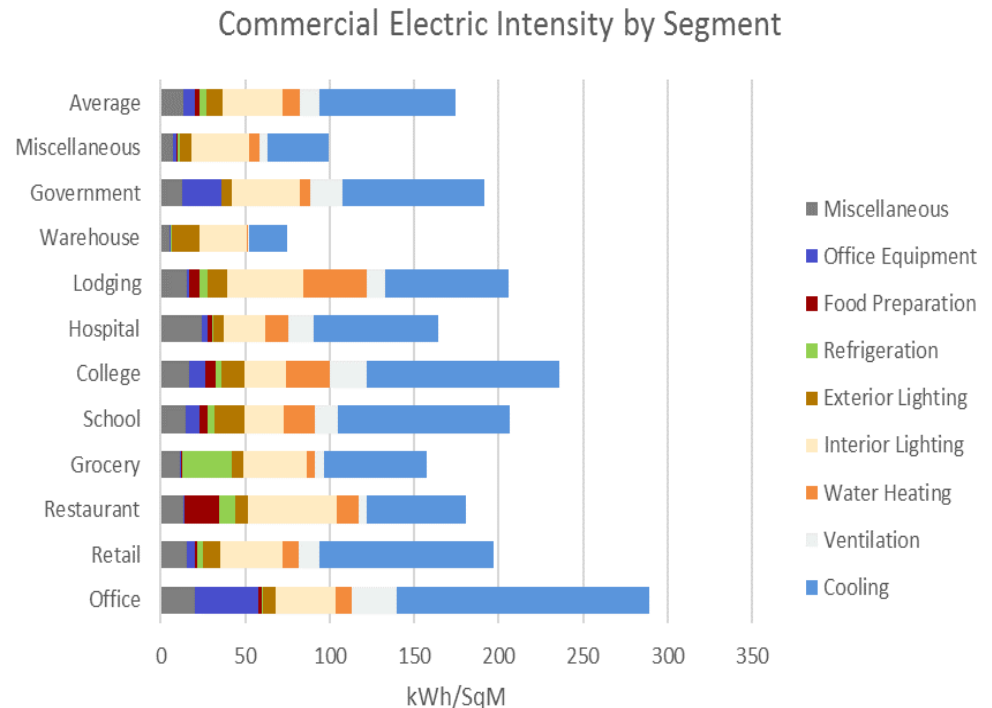
The survey also captured additional information about customers that will be useful for future marketing endeavors

Example: Commercial End-Use Disaggregation

The end-use model allows for disaggregation of each major sector along multiple dimensions. For the commercial sector, the disaggregation is done by building type and end use.

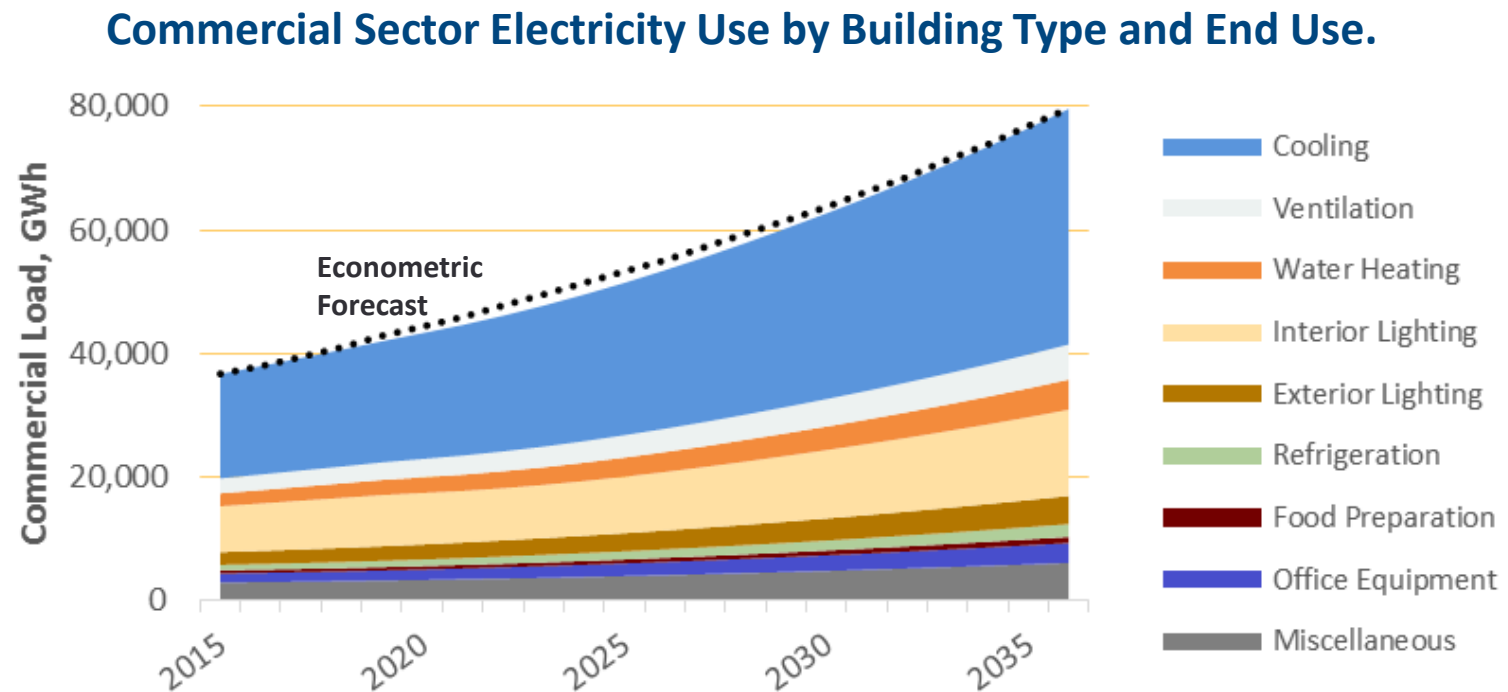
Commercial Sector Electricity Use by Building Type and End Use.

Segment	Electricity Use (GWh)	Intensity (kWh/SqM)	Floor space (Million M ²)
Office	2,680	289.0	9.3
Retail	15,687	197.2	79.5
Restaurant	1,125	180.5	6.2
Grocery	2,545	157.7	16.1
Hospital	1,479	282.2	5.2
College	1,789	235.6	7.6
School	1,083	120.1	9.0
Lodging	1,893	206.0	9.2
Warehouse	1,284	74.5	17.2
Government	4,230	191.2	22.1
Miscellaneous	2,851	99.6	28.6
Total	36,645	174.3	210.2



Example: Commercial End-Use Forecast

After disaggregating current load by end use, we use the model to forecast future sales in each sector, based on survey data, some modeling assumptions, and the econometric baseline results



Scenario Analysis

We used the end-use model to analyze scenarios incorporating alternative assumptions about the economy, electricity price, appliance standards, and energy efficiency programs

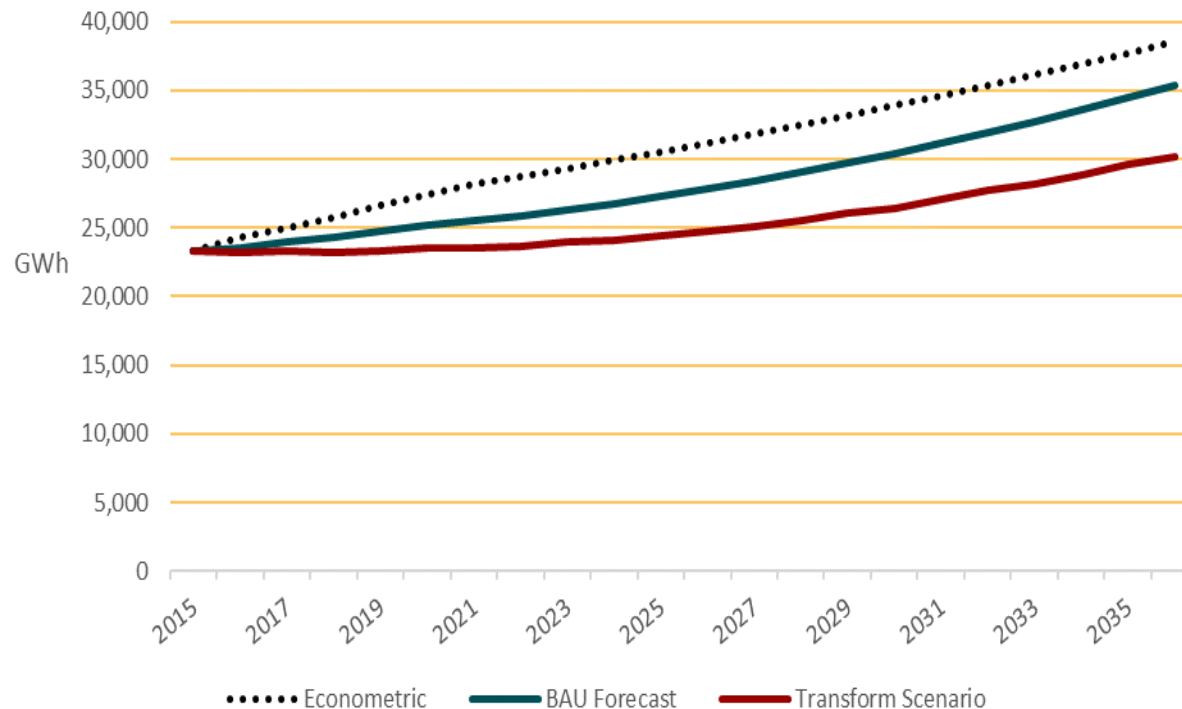
Summary of Drivers and Assumptions for Alternate Scenarios

Scenario Attributes	Econometric	“Business as Usual”	“Transform” Scenario
Economy - GDP Growth Rates (Com. & Ind.)	Econometric GDP Forecast	Econometric GDP Forecast	High GDP Scenario
Tariff - Price of Energy (All Sectors)	Flat Tariff	Flat Tariff	5% increase every 3 years
NEEAP Appliance Standards (Domestic)	No incorporation of standards	Penetration rate for 2-5 Star = 50%	Penetration rate for 2-5 Star = 100%
Energy Efficiency Programs - Building Audits (Com. and Ind.)	No programs	Lower penetration rate for energy audits (50%)	Higher penetration rate for energy audits (100%)

Example: Domestic Sector Alternate Scenarios

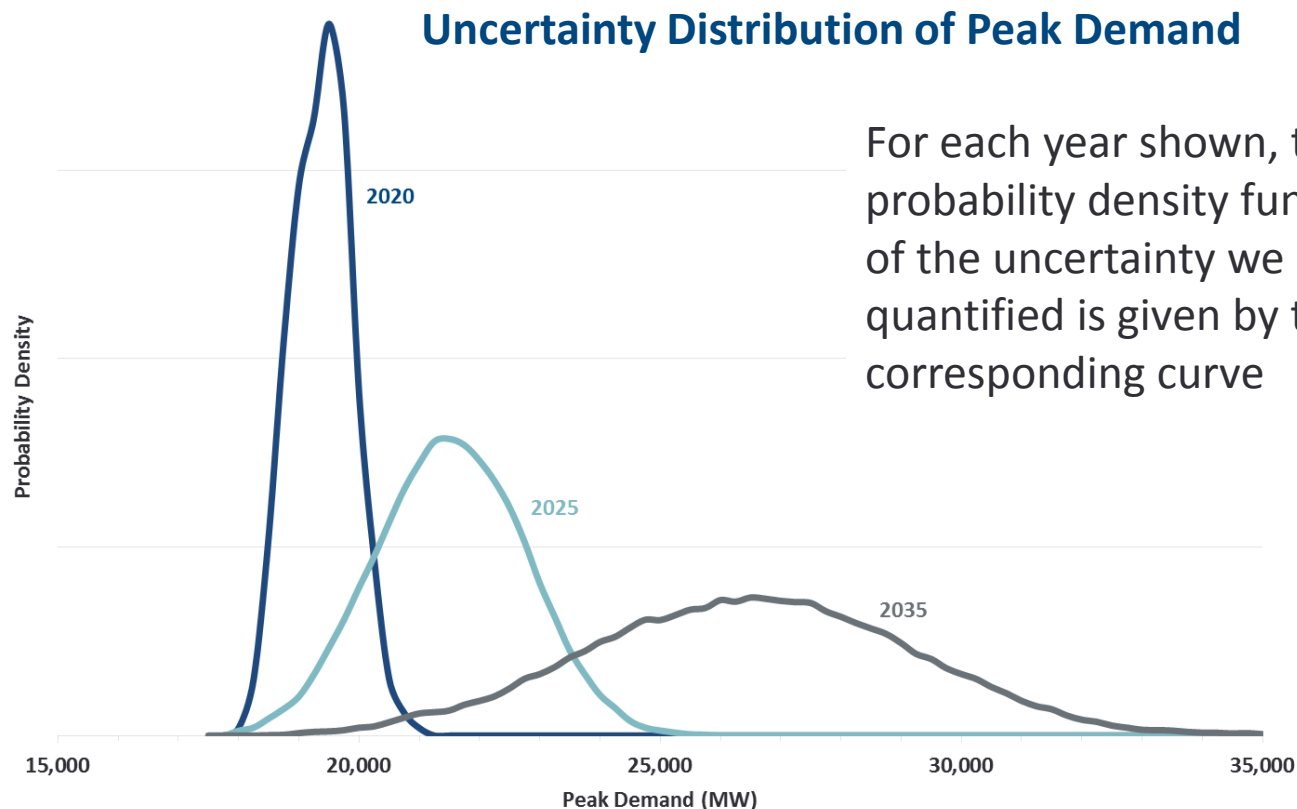
The end-use model allows comparison of alternate forecasts that depend on assumptions of future policy choices and economic growth

Comparison of Domestic Sector Forecasts across Alternate Scenarios



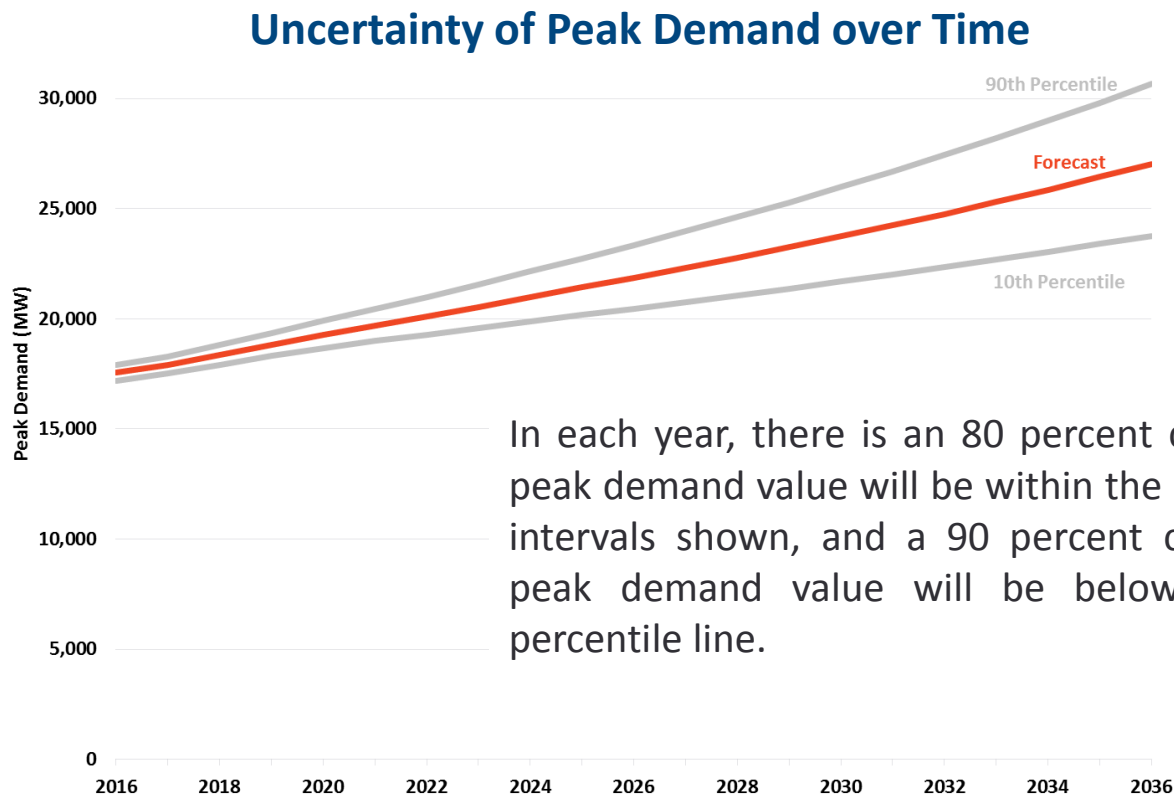
Modeling Uncertainty in Peak Demand

In addition to electric sales, we also model the peak demand on the system and use statistical techniques to characterize the uncertainty of those forecasts, yielding the “Probability of Exceedance”



Peak Demand Forecast Uncertainty over Time

Our model allows us to calculate the confidence intervals around the peak demand forecast over time and determine the probabilities of exceeding different percentiles of that distribution



Summary of Forecasting Process

Summary of Hybrid Approach to Forecasting

Econometric Forecast

The econometric model captures the historical relationship between electricity sales and drivers.

Compared to TNB's original forecast, we have made the following enhancements:

- Incorporated **additional drivers** into the model, including commercial square footage, GDP per capita, manufacturing GDP, and **weather data**
- Enhanced model to **forecast intensity** of commercial and industrial sales, following industry best practices
- Enhanced model of commercial and industrial sales to correctly **capture percentage growth in sales**, by using a log model
- Improved the temporal resolution of the model, moving from **yearly to monthly** data for all drivers
- **Directly model peak demand**, instead of as a multiplier on top of system sale
- Conducted **sensitivity analysis** for all forecasts and calculated the **probability of exceedance** of peak demand forecast

Post-Estimation Adjustments

Data on additional drivers from other jurisdictions

- Energy efficiency trends
- Distributed energy generation
- Electric vehicles

End-Use Forecast

Bottom-up approach allows for detailed accounting of customer trends

The end-use model enabled the following forecast enhancements:

- **Incorporate data from surveys** of commercial, industrial, and domestic customers on appliance and equipment saturation and energy use patterns
- **Disaggregate end uses** to see how each end-use contributes to aggregate forecast
- Incorporate information on **energy efficiency trends** based on data from other jurisdictions

Presenter Information



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Over the course of his consulting career, Dr. Ahmad Faruqui has advised dozens of clients on demand forecasting issues in the US, Canada, the Middle East, and Asia-Pacific. He has led the development of a wide range of forecasting models, including econometric models, end-use models, and hourly load shape models.

Recently, he has helped utilities and system operators diagnose why energy sales and peak demands are below forecasts even after adjusting for the effects of the economy. He has also assisted a regulated provider of steam analyze the decision by large commercial buildings to switch from purchasing steam to self-generating of steam and also to analyze the response of steam usage to rising steam prices.

Dr. Faruqui is the author, co-author or editor of four books and more than 150 articles, papers, and reports on efficient energy use, some of which are featured on the websites of the Harvard Electricity Policy Group and the Social Science Research Network. He has taught economics at San Jose State University, the University of California at Davis and the University of Karachi. He holds an M.A. in agricultural economics and a Ph. D. in economics from The University of California at Davis, where he was a Regents Fellow, and B.A. and M.A. degrees in economics from The University of Karachi, where he was awarded the Gold Medal in economics.

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Ms. Syazwani Aman is a Senior Manager with Single Buyer Malaysia, a ring-fenced entity authorized by the Malaysian Energy Commission for the management and procurement of electricity and related services. Ms. Aman currently leads the Long Term Load Forecasting Unit in Single Buyer Malaysia. In this role, she is responsible for producing long-term load forecasts at the aggregate, sectoral and regional level for Peninsular Malaysia.

Ms. Aman is an engineer with more than 10 years of experience in load forecasting. She began her career with Tenaga Nasional Berhad in 2004 as an engineer in Grid Systems Operation, before joining the System Planning Department in 2005 as part of the Capacity Planning Unit. She later joined the Load Forecast Unit in 2006 and has been involved in long term load forecasting ever since. The Load Forecast Unit was later absorbed into Single Buyer when the entity was formed in 2012.

Ms. Aman holds a B. Eng. degree in Computer Systems Engineering from the University of Warwick, United Kingdom and an MSc. Engineering from the University of Malaya, Kuala Lumpur.