Attachment 7.3.3

Energy and Customer Numbers Forecast YE2016

Access Arrangement Information

2 October 2017

Access Arrangement Information (AAI) for the period
1 July 2017 to 30 June 2022

westernpower

Energy & Customer Numbers Forecast (Transmission & Distribution)

2016

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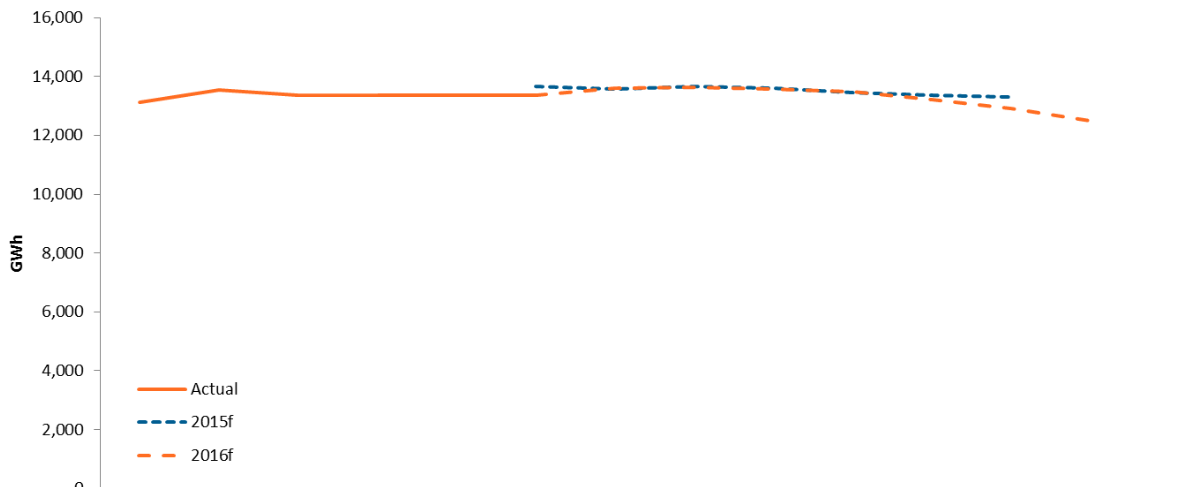
Contents

1 Executive summary

This report presents the Energy and Customer Numbers trend forecasts for the 2016-17 Annual Price Review as well as expenditure forecasts and network charges for Regulatory Control Period 1. The main points are as follows:

- The average actual annual customer numbers growth of the recent five-year period to June 2015 is approximately 21,800 per annum, representing a compound annual growth rate of 2.2%. This represents an additional 109,000 customers with total customers increasing from 957,159 in FYE 2010 to 1,065,958 in FYE 2015.
- The forecast for the five-year period including the gap year and RCP1 (i.e. FYE 2017-2022, inclusive) is on average 20,700 connections per annum (a 5% reduction on the average number of new connections per annum for the current five-year period) and a lower compound annual growth rate of 1.8% for FYE 2017-2022. The forecast includes the connection of approximately 103,700 residential and commercial customers over the period FYE 2017-2022 with a total connection forecast of 1.2M as at June 2022.
- Looking at sales volumes, Distribution Sales volumes (GWh) grew by a meagre 0.01% over 2014-15 while Transmission Sales (GWh) grew by 16% over the same period. Commercial tariff sales grew by 2.3% over 2014-15; however, this masks a 2% contraction for a subset of commercial tariffs (i.e. RT2 and RT4).
- The 2015 volume forecast over-estimated actual sales volume by 2.6% in FYE 2015. Several factors contributed to this outcome: a more severe cyclical downturn in economic activity than forecast; and faster than anticipated accumulation of solar photovoltaic electricity generation systems, which are increasingly eroding network delivered sales volumes.
- Distribution Transported Energy sales are forecast to contract by 1.0% per year to FYE 2022. This consists of a forecast contraction in Distribution Sales by 1.4% per year. Transmission Loads will likely contract by 0.3% per year.

Figure 1: Forecast comparison



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Actual	13,135	13,546	13,373	13,362	13,370	13,371							
2015f						13,654	13,575	13,654	13,606	13,459	13,351	13,309	
2016f						13,371	13,615	13,638	13,572	13,469	13,217	12,899	12,482

Table 1: Summary of forecast energy volume (GWh)

FYE	2016	2017	2018	2019	2020	2021	2022
Distribution Transported Energy	**14,434**	**14,454**	**14,382**	**14,271**	**14,002**	**13,667**	**13,227**
Distribution Generation	**255**	**252**	**252**	**251**	**249**	**248**	**246**
Distribution Generation	255	252	252	251	249	248	246
Distribution Generation	**255**	**252**	**252**	**251**	**249**	**248**	**246**
Distribution Losses	**564**	**563**	**557**	**550**	**536**	**520**	**498**
Distribution Sales	**13,615**	**13,638**	**13,572**	**13,469**	**13,217**	**12,899**	**12,482**
Distribution Metered Sales	13,445	13,465	13,396	13,290	13,035	12,715	12,295
Distribution Demand Tariff Sales	**5,788**	**5,799**	**5,817**	**5,843**	**5,867**	**5,904**	**5,945**
RT5	515	551	593	638	677	723	773
RT6	2,053	2,056	2,060	2,064	2,071	2,079	2,087
RT7	2,565	2,542	2,522	2,504	2,491	2,479	2,468
RT7Z	442	441	437	434	430	427	423
RT8	213	209	206	202	199	196	193
Distribution Energy Tariff Sales	**7,657**	**7,667**	**7,579**	**7,448**	**7,168**	**6,811**	**6,350**
RT1	5,026	5,033	4,992	4,882	4,640	4,329	3,919
RT1	4,190	4,175	4,094	3,929	3,621	3,212	2,686
RT13	837	858	898	953	1,019	1,117	1,234
RT2	1,097	1,115	1,097	1,087	1,080	1,060	1,034
RT14	14	13	13	13	13	13	12
RT2	1,083	1,101	1,084	1,074	1,068	1,048	1,021
RT3	140	151	142	154	150	156	162
RT15	56	62	61	73	80	97	117
RT3	85	89	80	81	70	59	45
RT4	1,394	1,369	1,349	1,324	1,297	1,266	1,236
RT16	57	54	51	49	46	44	41
RT4	1,337	1,315	1,298	1,276	1,251	1,222	1,194
Streetlights & Unmetered Supplies	169	173	176	179	182	185	187
Streetlights & Unmetered Supplies	**169**	**173**	**176**	**179**	**182**	**185**	**187**
RT10	32	33	33	33	33	33	33
RT9	137	140	143	146	149	152	155
PV Self Consumption	**223**	**325**	**409**	**498**	**585**	**671**	**754**
Transmission	**4,199**	**4,163**	**4,156**	**4,148**	**4,141**	**4,133**	**4,126**
Transmission Losses	**101**	**100**	**100**	**100**	**100**	**99**	**99**
Transmission Sales	**4,097**	**4,063**	**4,056**	**4,048**	**4,041**	**4,034**	**4,027**
Total	**18,855**	**18,942**	**18,947**	**18,916**	**18,729**	**18,471**	**18,107**

2 Introduction

Purpose

This document presents the 2016 forecasts required as input for the 2016-17 Annual Price Review. The Review requires forecasts of energy volumes measured in gigawatt-hours (GWh) and the number of customers by network tariff.

Definitions

Western Power assigns customers to a tariff according to various criteria as set out in the Price List Information. In order to measure the number of customers assigned to each tariff, it is necessary to have a clear, unambiguous definition of a customer. In this report, each National Meter Identifier (NMI) code represents a customer. For tariffs without NMIs (i.e. streetlights and unmetered supplies), network connection counts are used. Note that when referring to NMI counts and connection numbers, the term ‘connection numbers’ is used as a collective noun since every NMI also has a network connection.

In addition, a customer is restricted to those customers whose NMI status is active. This NMI status excludes extinct and inactive NMIs. Consequently, discrepancies arise when comparing the customer numbers reported here to customer numbers compiled according to alternative definitions. For example, some definitions also include inactive NMIs.

The energy volume assigned to a given tariff is simply the energy aggregated across all NMIs associated with the specific tariff.

Major change in tariff structure

Four new bidirectional tariffs introduced in FY 2015-16 are RT13; RT14; RT15; and RT16. These new tariffs apply to residential and commercial customers with small-scale[1] solar photovoltaic (PV) electricity generation systems.

The reallocation of energy volume and customer numbers to the new tariffs (based on retailer provided information on a monthly basis) impedes comparison of tariff based customer numbers and energy volumes in this report to previous forecast reports. An approximate reconstruction of the old tariff structures provides a basis to compare forecasts.

Note that this can only be approximate because:

- Some NMIs that were active last year are now either extinct or inactive
- Similarly, there are newly active NMIs that did not exist last year
- There has been a considerable amount of customer reallocation from commercial to residential tariffs.

Confounding issues associated with bidirectional tariffs

Many NMIs now assigned to the bidirectional tariffs capture the volume of supplied electricity before the customer’s solar PV system installation. The volume of supplied electricity after the installation of the customer’s solar PV system is materially less than the pre-installation history.

[1] In this report, a small-scale solar photovoltaic electricity generation system is one that does not require a Declared Sent-Out Connection.

Unfortunately, there is insufficient post-solar PV system installation history to establish the new demand profile using statistical methods.

Another important forecasting issue is the expected (i.e. forecast) growth rate of connection numbers for the bidirectional tariffs.

Because of these confounding issues, there may be deterioration in forecast accuracy compared to the forecast accuracy of previous forecast years.

Report organisation

The remainder of this report is organised as follows. Section 3 discusses the dependent variables in detail. Then section 4 describes the time series statistics methods used to develop forecast models. The presentation of the forecast results follows in section 5. Appendix A provides a list of source files and source details of data used in the forecasting process. For completeness, the SAS script used to prepare the forecasting data is in Appendix B. The Forecast Studio file names are listed in Appendix C.

3 Forecast variables

This section describes the forecast variables, viz., energy volume and connection numbers by tariff. The next subsection provides the descriptive names and tariff codes for each tariff. The remaining subsections provide basic summary statistics and an overview of the explanatory variables used to forecast each tariff.

3.1 Dependent variable definitions

The dependent variables are (1) the number of customers and (2) the amount of electricity exported to customers by tariff. See Table 2 for a list of the tariffs and a brief description.

Table 2: Tariff definitions

Tariff	Descriptive name
RT1	Anytime Energy (Residential) Exit Service
RT2	Anytime Energy (Business) Exit Service
RT3	Time of Use Energy (Residential) Exit Service
RT4	Time of Use Energy (Business) Exit Service
RT5	High Voltage Metered Demand Exit Service
RT6	Low Voltage Metered Demand Exit Service
RT7/RT7Z[2]	High Voltage Contract Maximum Demand Exit Service
RT8	Low Voltage Contract Maximum Demand Exit Service
RT9	Streetlighting Exit Service
RT10	Un-Metered Supplies Exit Service
RT13	Anytime Energy (Residential) Bi-directional Service
RT14	Anytime Energy (Business) Bi-directional Service
RT15	Time of Use (Residential) Bi-directional Service
RT16	Time of Use (Business) Bi-directional Service
TRT1	Transmission Exit Service

Source: Western Power, *2015/16 Price List Information*, Table 1, p. 4; http://www.westernpower.com.au/documents/PriceListInformation20152016.pdf

As indicated, the tariffs group customers by their basic type (i.e. residential, business), by demand type (i.e. volumetric, demand/capacity) and direction (entry, exit, bi-directional). Note that any change to these tariffs prior to the commencement of RCP1 will prompt a forecast update.

3.2 Summary statistics associated with variables in levels

This section describes the basic statistical properties of the dependent variables: energy volume; and connection numbers. Some noteworthy observations are:

- RT1 is still the largest tariff by volume, followed by TRT1.
- The large number of RT1 connections account for 74% of the total NMI count, which explains the relatively large scale of RT1 energy volumes.
- The bi-directional tariffs (RT13, RT14, RT15, RT16) collectively account for 6.5% of the mean energy volumes.

[2] RT7 indicates a metered connection to the network at a distribution connection point. RT7Z indicates a metered connection directly to a zone substation.

- 88 monthly observations (seven years and four months) were available to establish forecast trends.

Table 3: Summary statistics for energy volumes by tariff (GWh) (2008 – 2015)

Tariff	Mean	Std. Dev.	Min.	Max.	Obs.
RT1	351 GWh	33 GWh	290 GWh	418 GWh	88
RT13	77 GWh	10 GWh	53 GWh	101 GWh	88
RT14	1 GWh	GWh	1 GWh	1 GWh	88
RT15	5 GWh	1 GWh	4 GWh	7 GWh	88
RT16	4 GWh	GWh	4 GWh	6 GWh	88
RT2	92 GWh	7 GWh	80 GWh	113 GWh	88
RT3	7 GWh	1 GWh	6 GWh	9 GWh	88
RT4	113 GWh	11 GWh	95 GWh	138 GWh	88
RT5	33 GWh	5 GWh	24 GWh	43 GWh	88
RT6	160 GWh	13 GWh	133 GWh	188 GWh	88
RT7	205 GWh	11 GWh	180 GWh	232 GWh	88
RT7Z	24 GWh	8 GWh	10 GWh	42 GWh	88
RT8	19 GWh	1 GWh	16 GWh	22 GWh	88
TRT1	245 GWh	74 GWh	104 GWh	373 GWh	88

Table 4: Summary statistics for connection numbers by tariff (2008 – 2015)

Tariff	Mean	Std. Dev.	Min.	Max.	Obs.
RT1	736,753	34,921	669,177	804,344	88
RT13	153,101	8,202	137,022	165,682	88
RT14	960	77	814	1,050	88
RT15	9,601	166	9,082	9,874	88
RT16	237	14	214	276	88
RT2	67,063	2,158	63,156	73,027	88
RT3	10,387	232	9,753	10,922	88
RT4	10,955	473	10,027	12,014	88
RT5	156	16	123	184	88
RT6	3,512	188	3,129	4,114	88
RT7	255	16	228	318	88
RT7Z	12	5	4	27	88
RT8	60	2	57	76	88
TRT1	35	4	29	43	88

3.3 External variables

This section provides a description of the external (i.e. independent) variables included in the forecast training data set[3]. Selection of these variables is justified by economic or

[3] The training data set, also known as the estimating data set, is the data used to calculate forecast model parameters.

demonstrated statistical relevance. Note that other variables could also have been included but are either not available or are difficult to obtain reliable forecasts.

The following categories apply to the selected external variables:

- Economic Activity: variables that measure the level of activity in the economy
- Price: volumetric component of the electricity price
- Seasonal: temperature and other weather variables
- Substitution: capture any influence of alternatives to network delivery electricity

Table 5: External variable description

Category	Variable	Description
Economic activity	AccomFoodServices	Component of GRP
Economic activity	AdminSupportSrvcs	Component of GRP
Economic activity	AgricForFish	Component of GRP
Economic activity	ArtRecSrvcs	Component of GRP
Economic activity	Construction	Component of GRP
Economic activity	DetachedHouses	Number of detached houses ('000s)
Economic activity	Dwellings	Number of dwellings ('000s)
Economic activity	EdTraining	Component of GRP
Economic activity	ElecGasWater	Component of GRP
Economic activity	FinInsurance	Component of GRP
Economic activity	GovAdminSafety	Component of GRP
Economic activity	GRP	Gross Regional Product (GRP)
Economic activity	HealthSocialAss	Component of GRP
Economic activity	InfoMediaTelecom	Component of GRP
Economic activity	Manufacturing	Component of GRP
Economic activity	Mining	Component of GRP
Economic activity	MultiUnitDwellings	Component of GRP
Economic activity	NonFARM	Component of GRP
Economic activity	OtherSrvcs	Component of GRP
Economic activity	ProfScienTechSrvcs	Component of GRP
Economic activity	RentHiringRE	Component of GRP
Economic activity	RetailTrade	Component of GRP
Economic activity	Total	Total construction ('000s)
Economic activity	Total1	Total housing construction ('000s)
Economic activity	TransPostalWare	Component of GRP
Economic activity	WA_Pop_A	WA Tomorrow Population Forecast (Band A; WA)
Economic activity	WA_Pop_B	WA Tomorrow Population Forecast (Band B; WA)
Economic activity	WA_Pop_C	WA Tomorrow Population Forecast (Band C; WA)
Economic activity	WA_Pop_D	WA Tomorrow Population Forecast (Band D; WA)
Economic activity	WA_Pop_E	WA Tomorrow Population Forecast (Band E; WA)
Economic activity	WholesaleTrade	Component of GRP
Economic activity	WPN_Pop_A	WA Tomorrow Population Forecast (Band A; Western Power Network Area)
Economic activity	WPN_Pop_B	WA Tomorrow Population Forecast (Band B; Western Power Network Area)
Economic activity	WPN_Pop_C	WA Tomorrow Population Forecast (Band C; Western Power Network Area)
Economic activity	WPN_Pop_D	WA Tomorrow Population Forecast (Band D; Western Power Network Area)
Economic activity	WPN_Pop_E	WA Tomorrow Population Forecast (Band E; Western Power Network Area)
Price	Bus_Price	Business Electricity Price (Nominal)
Price	Bus_Price_Real	Business Electricity Price (Real)
Price	CPI	Consumer Price Index
Price	Res_Price	Residential Electricity Price (Nominal)
Price	Res_Price_Real	Residential Electricity Price (Real)
Seasonal control	CDDD	Cooling Degree Days per Day
Seasonal control	CDDD_Jandakot	Cooling Degree Days per Day (Jandakot)
Seasonal control	CDDD_Mandurah	Cooling Degree Days per Day (Mandurah)
Seasonal control	CDDD_PerthAirport	Cooling Degree Days per Day (Perth Airport)
Seasonal control	CDDD_PerthMetro	Cooling Degree Days per Day (Perth Metropolitan Area)
Seasonal control	CDDD_Rottnest	Cooling Degree Days per Day (Rottnest Island)
Seasonal control	HDDD	Heating Degree Days per Day
Seasonal control	HDDD_Jandakot	Heating Degree Days per Day (Jandakot)
Seasonal control	HDDD_Mandurah	Heating Degree Days per Day (Mandurah)
Seasonal control	HDDD_PerthAirport	Heating Degree Days per Day (Perth Airport)
Seasonal control	HDDD_PerthMetro	Heating Degree Days per Day (Perth Metropolitan Area)
Seasonal control	HDDD_Rottnest	Heating Degree Days per Day (Rottnest Island)
Substitutes	PV_CAPACITY	Solar PV Installed Capacity (MW)
Substitutes	PV_INSTALLS	Solar PV Numbers of Installations

Table 6: Summary statistics for exogenous variables

Variable	Mean	Std. Dev.	Min.	Max.	Obs.
AccomFoodServices	3.377	3.877	-5.822	14.056	169
AdminSupportSrvcs	3.739	5.071	-6.066	14.999	169
AgricForFish	2.677	20.478	-42.642	45.114	169
ArtRecSrvcs	3.567	2.969	-1.466	12.286	169
Construction	0.516	6.310	-11.491	17.511	169
DetachedHouses	4.556	0.702	3.266	6.276	169
Dwellings	2.712	0.546	1.698	4.210	169
EdTraining	2.570	0.894	0.710	4.737	169
ElecGasWater	3.665	3.144	-1.613	12.823	169
FinInsurance	4.486	4.300	-1.983	12.668	169
GovAdminSafety	3.769	2.353	0.322	9.835	169
GRP	.146 M	.014 M	.111 M	.175 M	169
HealthSocialAss	4.878	0.990	3.336	7.106	169
InfoMediaTelecom	4.791	4.134	-5.999	12.776	169
Manufacturing	2.785	3.904	-4.411	12.336	169
Mining	1.709	8.179	-18.561	22.652	169
MultiUnitDwellings	1.295	0.367	0.539	2.283	169
NonFARM	2.647	1.142	1.287	5.509	169
OtherSrvcs	3.407	4.722	-4.911	15.211	169
ProfScienTechSrvcs	3.381	6.998	-12.084	12.671	169
RentHiringRE	3.353	4.513	-5.797	10.428	169
RetailTrade	3.041	2.661	-0.764	8.926	169
Total	2.561	1.187	0.606	5.551	169
Total1	5.851	0.987	4.057	8.487	169
TransPostalWare	2.522	2.563	-3.068	5.937	169
WA_Pop_A	2.403 M	.186 M	2.064 M	2.697 M	169
WA_Pop_B	2.432 M	.202 M	2.065 M	2.75 M	169
WA_Pop_C	2.451 M	.213 M	2.065 M	2.788 M	169
WA_Pop_D	2.472 M	.225 M	2.066 M	2.828 M	169
WA_Pop_E	2.502 M	.243 M	2.066 M	2.888 M	169
WholesaleTrade	2.887	4.781	-4.264	14.528	169
WPN_Pop_A	2.259 M	.175 M	1.95 M	2.542 M	169
WPN_Pop_B	2.301 M	.195 M	1.951 M	2.613 M	169
WPN_Pop_C	2.326 M	.208 M	1.951 M	2.658 M	169
WPN_Pop_D	2.353 M	.222 M	1.952 M	2.705 M	169
WPN_Pop_E	2.391 M	.242 M	1.952 M	2.772 M	169
Bus_Price	26.175	6.430	17.470	36.951	169
Bus_Price_Real	26.996	4.256	20.055	33.475	169
CPI	101.947	9.858	83.200	119.763	169
Res_Price	22.587	6.075	13.940	32.274	169
Res_Price_Real	23.242	4.298	16.002	29.238	169
CDDD	2.633	2.861	0.000	9.870	169
CDDD_Jandakot	2.423	2.713	0.000	9.668	122
CDDD_Mandurah	2.516	2.657	0.000	9.220	122
CDDD_PerthAirport	2.787	2.979	0.000	9.866	122
CDDD_PerthMetro	2.763	2.937	0.000	9.559	122
CDDD_Rottnest	2.233	2.209	0.000	7.889	122
HDDD	1.744	1.815	0.000	5.930	169
HDDD_Jandakot	2.089	2.106	0.000	6.926	122
HDDD_Mandurah	1.249	1.437	0.000	5.137	122
HDDD_PerthAirport	1.652	1.785	0.000	5.903	122
HDDD_PerthMetro	1.590	1.818	0.000	5.942	122
HDDD_Rottnest	0.943	1.072	0.000	3.882	122
PV_CAPACITY	.314 000s	.294 000s	. 000s	.883 000s	169
PV_INSTALLS	118.057 000s	98.298 000s	. 000s	282.203 000s	169

As indicated in Table 5 and Table 6, there are 55 variables included in the estimating data set. Many of these variables are highly correlated, so most of Western Power's forecast models only include a small subset of these variables based on a balance of goodness of fit and forecasting accuracy criteria.

The variables and associated data are from published documents by Western Australian Government agencies, Bureau of Meteorology (BOM), Australian Bureau of Statistics (ABS), Clean Energy Regulator (CER), Housing Industry Association (HIA), and BIS Shrapnel.

4 Forecast model design

The 2015-16 forecasts were created using Forecast Studio by SAS, which employs three broad styles of time series forecast models:

- ARIMA
- Unobserved components models
- Multivariate regression

Forecast Studio embodies best forecasting practice automatically, diagnosing the data (i.e. testing for trends, seasonality, autocorrelation, functional form etc.), constructing trial forecast models according to diagnostic test results, and then selecting the best fitting models from the competing alternatives using holdout MAPE scores.

Forecasters can also add customised models and call standard models from a model repository.

Another useful feature of Forecast Studio is the ability to produce forecasts by the following four-level top-down model hierarchy:

1. Total energy sales by sector: Residential; Commercial; and Industrial
2. 2015 Tariffs (RT1, RT2, RT3,…,RT10, TRT1)
3. 2016 Tariffs, which features the redistribution of energy and customer numbers across the bidirectional tariffs
4. Zone substation

Producing forecasts in a hierarchy permits the use of both space and time dimensions to maximize model flexibility, resulting in improved precision in model coefficients. In addition, the forecasts are reconciled so that the forecast sub-groups add up to the total.

The inclusion of the 2015 tariffs permits:

- Easier reconciliation against previous forecast
- Ability to apply the forecast models employed in previous forecast rounds
- The opportunity to influence the distribution of forecast growth across the new bidirectional tariffs.

Fully capturing these benefits required adopting a middle-out reconciliation method so that the 2015 tariff forecast models drive the distribution of trend growth across each sub-group in the model hierarchy.

Note that while most of the forecasts are produced automatically, forecast models can (and have been) manually constructed and selected. Forecast Studio provides a wide array of diagnostic test results that are relatively easy to interpret, but do require a high degree of expertise to use effectively.

Another important benefit of Forecast Studio is its visual interface, which facilitates easier review by auditors, managers and stakeholders.

4.1 Econometric forecasts

The large number and wide variety of statistical models used to produce the forecasts means that it is not practical to describe each forecast model applicable to each tariff as was done in previous reports.[4] Instead, this report describes the models employed within broader stylistic structures and themes.

Benefits of employing reduced form models

In previous rounds of energy and customer numbers, forecasting, long run structural models provided direct estimates of economic effects such as responses to variation in electricity tariffs and income or economic activity.

While such models are highly desirable for long-term business planning, directly estimated structural models often perform poorly as forecast models due to an array of statistical issues such as mis-specified dynamics and insufficient variation in explanatory variables such as tariffs. Forecast Studio overcomes such problems by employing data-driven time series methods.

In describing these models, it is important to note that most of the models represent reduced-form models as opposed to structural models.[5] That means, for example, that the estimated coefficients are not economic parameters such as long-run price and income elasticities.

The benefit of employing reduced form models is that fast, data-driven methods capture the short-run dynamics contained in the data. For example, most of the monthly energy volume series exhibit a high degree of serial correlation. This means that ARIMA models, which exploit serial correlation, produce accurate short-term forecasts. Methods described in econometric textbooks provide a way to obtain meaningful structural parameters from these models.[6]

Underlying drivers of electricity demand

Table 7 lists the explanatory variables used in producing the forecasts.

Table 7: Source of external variable forecasts

Variable group	External variable	Source
Economic activity	HIA	Forecast of housing commencements
	POPN	WA Tomorrow 2012
	GRP	BIS Shrapnel
Price effect	RESPR	State Budget 2014-15
	BUSPR	State Budget 2014-15
Substitution effect	PVMW	Western Power model
Seasonal control	CDDD	Time series model developed by Western Power
	HDDD	Time series model developed by Western Power

Each variable belongs to a broad category to indicate the economic interpretation of each variable. Population growth is a fundamental driver of construction activity, resulting in high correlation with housing activity (HIA series). Housing construction has a relatively high

[4] Note that any forecast model can be easily inspected in Forecast Studio

[5] For discussion on the distinction between reduced form and structural models, see this article: Peter C. Reiss and Frank A. Wolak, “Structural Econometric Modeling: Rationales and examples from Industrial Organization”, Ch. 64 in *Handbook of Econometrics, Volume 6A*, Elsevier

[6] See chapter 19 of Bo Sjö (2011), *Lectures in Modern Economic Time Series Analysis*, 2nd edition; https://www.iei.liu.se/nek/730A16/filarkiv/1.299872/tsbook24.pdf [accessed July 2016]

economic multiplier, so it can often by a good predictor of non-housing expansion (e.g. growth in small business).

Gross Regional Product is a broad measure of economic activity that typically accounts for a small component of monthly variation in electricity demand. Nevertheless, it will have an influence on the long-run trend in electricity demand since electricity is one of the inputs for productive activity.

Note that other economic measures of overseas demand for Western Australia's exports (such as exchange rates, the terms of trade, commodity prices etc.) are also likely to be influential on electricity demand. However, the relatively short time series of electricity demand impedes precise estimation of the impact on electricity demand. Moreover, the high volatility of these series and the absence of credible long-term forecasts for these additional economic variables limit the suitability of their use.[7]

Electricity prices have an inverse relationship with electricity demand, or at least network delivered electricity demand. Assuming fixed customers' budgets in the short-term, a higher price (i.e. higher electricity tariffs) should have a persistent dampening effect on electricity demand. This is an important factor for long-term forecasting.

An issue limiting the usefulness of the tariff is limited variation in prices. Typically, consumer electricity prices update just once a year. With just nine years of time series data, it is difficult to estimate a statistically precise relationship between electricity prices and the demand for network delivered electricity.

The number of solar PV electricity generation systems is a marginal substitute for network delivered electricity. A price series for solar PV use would be better than the quantity for measuring cross-price elasticity, but is not available. In the absence of the price series, we use the quantity series as a control for the substitution effect.

In considering alternatives to network delivered electricity, a notably absent variable is the price of natural gas. Given the extensive reach of the gas distribution network, it is likely that electricity and gas services compete, particularly in heating and cooking services. However, gas prices have typically increased at a faster rate than electricity prices, suggesting a long-term consumer preference for electricity. In turn, this suggests a high market share for electricity in supplying energy services.

Nevertheless, the prospect of gas prices to consumers beginning a long-term relative trend decline suggests that the prospect of competition from gas is more likely in the future.

Finally, cooling and heating degree-days per day control for the annual seasonal cycle. Temperature extremes tend to increase electricity demand, primarily to satisfy refrigeration and space heating demand.

Forecasting solar PV installations

The absence of reliable long-term forecasts for the number of solar PV installations is a serious impediment to developing accurate forecasts for electricity demand. Although the mass introduction of solar PV installations is a relatively recent phenomenon, the rate of adoption has had a material demand-reducing impact.

Given its importance, Western Power has conducted several investigations into forecast methods. The primary focus has been the investigation of sigmoid functions (otherwise known

[7] Note that these variables could be forecast using the International Monetary Fund's global VAR models.

as diffusion curves) to forecast the expected duration of the exponential growth phase as well as the longer-term market saturation level.

The investigation has revealed that aside from large changes to government subsidy for solar PV systems, the rate of adoption has been approximately constant. This suggests an approximately linear relationship with the growth in the housing and commercial building stock. In addition, the rate of growth in solar PV installations is not sufficient to demonstrate the short-term superiority of a non-linear forecast.

At this point, the key assumptions are:

- There is a higher proportion of new solar PV systems on new buildings.
- Installations on commercial buildings are likely to be larger than on residential buildings. Hence, faster demand reduction will occur across commercial tariffs.

The difference in growth rates across the bidirectional tariffs is a matter of judgement with relatively little support from observable trends. Western Power will continue to closely monitor these growth rates and warn that there may be material inaccuracy in forecasting the bidirectional tariffs.

For example, a likely error would be the misallocation of the growth proportions over time. However, given that there are far fewer commercial premises, the rate of change in the proportion of solar PV systems should decelerate quickly.

Forecasting cooling and heating degree days

The seasonal component of the underlying temperature series is relatively easy to forecast. The difficult components are the trend and irregular components. In past forecast rounds, Western Power has maintained a strictly stationary forecast for temperature. In other words, there is an assumed no trend in temperature. This has the effect of transferring any trend component to the irregular component, which can be volatile.

The introduction of Forecast Studio to Western Power provides an opportunity to adopt a data driven approach. Consequently, whether a trend is included is a data-driven matter.

In addition, there may be a changing relationship between temperature variation and associated electricity demand, such as:

- Continuing increases in penetration of temperature-dependent loads like air-conditioners (larger systems, or more split systems per household), will continue to increase the electricity demand impacts of extreme temperatures.
- Changes in demographics and technology adoption; for example, with a higher proportion of retirees with air-conditioners and solar PV systems, own-use of solar PV generated electricity may be increasing. This would appear as a daytime reduction in temperature related network demand.
- Changes in appliance and building efficiency; this is likely to be a subtle but persistent effect over time. Various estimates produced for the Australian Electricity Market Operator suggest this influence could amount to 0.5% per year. This efficiency effect remains unidentified in Western Power’s demand models due to the difficulty in statistically separating the efficiency effect from other trends evident in the data.

Prospect of further substitution via new technology

Since the 2015 forecasting round, speculation about mass adoption of other network competing technologies has intensified. Widespread adoption of battery storage systems could have a negative impact on network delivered electricity demand.

Western Power is monitoring developments in battery related marketing such as the Tesla PowerWall® system. At present, these appear to be expensive appliances that maybe adopted by wealthy households.

Factors affecting mass adoption of battery systems are:

- The present value cost of a battery system against the present value of the cost of purchasing network delivered electricity. If the present value of battery systems offers a lower cost (i.e. a net saving), wider adoption will occur.
- Consumer preference bias; if consumers perceive a positive utility in owning a battery storage system, then there need not be a net saving before mass adoption occurs. Measuring the desirability of battery systems is within the domain of marketing experts. Consequently, Western Power has been exploring the possibility of using marketing based models, such as EYC3's Simulait model.

More generally, economic theory provides a useful framework for evaluating the likelihood of new technology adoption. Relative price trends between network delivered electricity and alternatives predicts that as network delivered electricity become relatively more expensive, there is likely to be substitution from network delivered electricity to the alternatives.

Further, if energy becomes relatively more expensive than the other factors of production (i.e. capital, labour, materials, and services), then economic theory predicts a long-term bias toward energy conservation. However, the converse is also true; namely, if energy becomes relatively less expensive than one or more of the other productive inputs then there will be an energy-using bias.

These two fundamental economic forces can be either mutually reinforcing or offsetting. Therefore, it is important to monitor both forces to better anticipate long-run trends.

At present, there are no explicit assumptions with respect to new, network competing technologies included in these forecasts. However, the data-driven forecast modelling strategy would adjust long-run trends once these substitution effects manifest in the data.

5 Forecasts

This section presents an assessment of the 2015-forecast performance and the 2016 forecasts of energy volumes and connection numbers by tariff.

5.1 Estimated models and past performance

Table 8 presents a summary table of volumes as measured by Metering Business System (MBS)[8] records against the volumes invoiced and reported in the monthly Business Performance Report (BPR). The table also presents the annual 12-month-ahead forecast error, reported in percentage form.

Table 8: Out-of-sample forecast performance for the 2015 forecast

Month	MBS	BPR	Percent difference
Jul-2014	1,135 GWh	1,098 GWh	-3.2%
Aug-2014	1,075 GWh	1,065 GWh	-0.9%
Sep-2014	996 GWh	991 GWh	-0.4%
Oct-2014	1,031 GWh	1,026 GWh	-0.5%
Nov-2014	1,019 GWh	1,014 GWh	-0.5%
Dec-2014	1,112 GWh	1,099 GWh	-1.1%
Jan-2015	1,223 GWh	1,187 GWh	-3.0%
Feb-2015	1,160 GWh	1,129 GWh	-2.7%
Mar-2015	1,178 GWh	1,217 GWh	3.3%
Apr-2015	1,038 GWh	1,045 GWh	0.6%
May-2015	1,091 GWh	1,080 GWh	-1.1%
Jun-2015	1,101 GWh	1,046 GWh	-5.0%
Total	13,159 GWh	12,996 GWh	-1.2%
Forecast	13,498 GWh	13,498 GWh	
Percent error	2.6%	3.9%	

Source: (1) MBS data obtained from forecasting training data set

(2) BPR data obtained from DM# 11758789v30C; worksheet: KPI Details; V10:AG24

(3) Forecast data obtained from DM# 12764026; Table 11

Notes: Totals are sum of RT1, RT2, RT3, RT4, RT5, RT6, RT7, RT7Z, RT8

The month-to-month variation between the final MBS records and as reported via the BPR can vary significantly. Over the full financial year, there is a 1.2% difference. The BPR estimate comes partly from accrued energy and partly from forecast models contained within the Revenue Accruals Model, maintained by Revenue (an area within the Finance, Treasury and

[8] Metering Business System is the official source of metering data. However, given the large number of manual meter readings and the associated time lag in collecting and reporting MBS readings, the estimates as reported in the Business Performance Report proxy for the actuals. Given the difference between estimate and finalised actuals, it is important to consider the accuracy of the estimates when evaluating forecast models.

Risk function). Note that the largest monthly discrepancies occur around the time of summer and winter peak demand. Unexpectedly extreme weather can materially affect the outcome over forecast years.

The discrepancy affects assessment of forecast performance. Forecast error using MBS as the correct source of actual electricity volume delivered to distribution-connected customers is 2.6%. Against the BPR, the forecast error is 3.9%. Both measures are within the target +/-5% range. Nevertheless, Western Power notes that the forecast proved to be too optimistic.

The source of the optimism is not entirely clear. Table 9 provides a comparison of forecast and actual (based on MBS data) by tariff. The largest tariff by volume (RT1) was actually under-forecast. There were spectacularly large errors by tariff across the commercial tariffs and RT3. Given that the under-forecasts and over-forecasts largely balance, it seems that customer reallocation (i.e. customer churn) is probably the cause of the significant errors.

Table 9: Out-of-sample forecast performance of energy volume (GWh) by tariff

Tariff	Forecast	Actual	Percent difference	Difference
RT1	4,847	4,943	-1.9%	-95.9
RT2	1,173	1,059	10.8%	113.9
RT3	159	135	18.1%	24.4
RT4	2,006	1,369	46.6%	637.4
RT5	367	452	-18.8%	-84.8
RT6	1,642	2,024	-18.9%	-381.5
RT7	2,628	2,510	4.7%	117.9
RT7Z	449	453	-1.0%	-4.4
RT8	227	215	5.8%	12.4
Total	13,498	13,159	2.6%	339.3

Calculating the aggregate forecast error across tariffs (i.e. RT2, RT3, RT4, RT5, RT6) reveals an over-forecast of 6%. It is possible that some customers transferred to tariffs outside this group. However, it also suggests that the commercial sector reduced its demand on the electricity network. Several avenues to achieve this are:

- Increased solar PV installations across commercial customers
- A stronger than anticipated economic downturn.

Overall, it seems that the largest source of forecast error is customer reallocation across tariffs. In future, it would be highly desirable to establish a feedback loop from prices to forecast energy by tariff.

5.2 Forecast assumptions

Using external variables for forecasting adds insight, but raises the problem of sourcing accurate forecasts for the external variables. In cases where external variables are easy to forecast and statistically relevant, there can be a gain in forecast accuracy by using them. In other cases, it can introduce complications and add to the complexity of forecasting.

Regression on past values of dependent energy and customer numbers variables usually produces reliable forecasts. A variant on this is the Vector Auto-Regression (VAR) method, which exploits the serial correlation across variables that are statistically related.

Forecasts have been included for the following variables:

- WA Tomorrow population projections
- Housing Institute of Australia housing forecasts
- BIS Shrapnel forecasts of Gross Regional Product
- Cooling and heating degree days per day
- Solar PV forecasts

Table 10 presents the key external variable forecast assumptions. As shown, Western Power expects nominal electricity price 6% annual price increases. Housing activity contracts while solar PV installations continue to grow in excess of 10% per year. There is a slight increase in heating degree-days. Finally, population growth trends at 1.7% per year.

Table 10: External variables forecasts

Variable	2019	CAGR
Bus_Price	29.4	5.9%
CDDD	0.0	0.0%
DetachedHouses	5.2	-4.9%
Dwellings	2.5	-1.5%
GRP	157,542.8	2.1%
HDDD	4.1	5.2%
PV_CAPACITY	478.7	15.0%
PV_INSTALLS	184,188.0	10.2%
Res_Price_Real	25.4	6.2%
WA_Pop_C	2,590,251.5	1.7%
WPN_Pop_C	2,461,799.4	1.7%

5.3 Forecast results

Table 11 and Table 12 show the connection numbers history and forecasts, respectively.

Table 11: Actual connection numbers

Actuals Tariff	FYE 2011	2012	2013	2014	2015
RT1	728,793	738,997	754,205	769,336	791,705
RT13	153,988	156,006	159,542	162,773	165,425
RT2	66,328	66,553	67,686	68,764	71,034
RT14	969	1,014	1,039	1,039	1,057
RT3	10,438	10,430	10,450	10,512	10,449
RT15	9,815	9,722	9,713	9,698	9,668
RT4	10,910	10,926	11,127	12,017	11,931
RT16	240	234	242	264	277
RT5	149	160	165	186	183
RT6	3,498	3,551	3,607	4,123	3,858
RT7	253	257	265	323	286
RT7Z	11	11	11	18	19
RT8	61	62	62	78	66
RT9	229,736	238,048	239,630	246,848	253,858
RT10	15,580	15,752	15,852	15,538	15,720
TRT1	35	35	37	43	38
Total	1,230,804	1,251,758	1,273,633	1,301,560	1,335,574

Table 12: Forecast connection numbers

Forecast Tariff	FYE 2016	2017	2018	2019	2020	2021	2022
RT1	806,493	821,915	837,420	852,633	867,839	883,175	898,390
RT13	167,662	171,809	175,873	179,970	184,301	188,435	192,587
RT2	72,503	73,440	74,377	75,314	76,251	77,188	78,125
RT14	1,066	1,087	1,107	1,128	1,149	1,171	1,192
RT3	10,404	10,369	10,333	10,430	10,410	10,424	10,490
RT15	9,639	9,658	9,677	9,820	9,853	9,918	10,033
RT4	11,966	12,184	12,401	12,618	12,835	13,052	13,269
RT16	271	271	271	271	271	271	271
RT5	189	198	207	215	224	233	242
RT6	3,759	3,759	3,759	3,759	3,759	3,759	3,759
RT7	280	280	280	280	280	280	280
RT7Z	19	19	19	19	19	19	19
RT8	63	63	63	63	63	63	63
RT9	260,771	267,109	273,236	279,199	285,036	290,774	296,436
RT10	16,686	17,421	18,138	18,850	19,561	20,272	20,982
TRT1	41	41	41	41	41	41	41

Total	1,361,812	1,389,622	1,417,201	1,444,611	1,471,892	1,499,075	1,526,180

Table 13 and Table 14 present the energy volume history and forecasts, respectively.

Table 13: Actual energy volumes (GWh) by tariff

Actuals	FYE				
Tariff	2011	2012	2013	2014	2015
RT1	4,329	4,182	4,220	4,248	4,126
RT13	1,012	920	889	880	828
RT2	1,154	1,135	1,114	1,082	1,046
RT14	15	14	14	14	15
RT3	91	85	84	84	81
RT15	69	60	58	57	54
RT4	1,353	1,352	1,323	1,321	1,309
RT16	54	53	55	55	55
RT5	379	393	434	450	459
RT6	1,935	1,959	1,988	2,023	2,030
RT7	2,493	2,566	2,525	2,450	2,535
RT7Z	271	266	270	320	453
RT8	237	230	228	224	218
RT9	119	122	126	127	130
RT10	35	35	34	33	32
TRT1	2,430	3,043	3,296	3,613	4,188
Total	15,976	16,416	16,658	16,983	17,558

Table 14: Forecast energy volumes (GWh) by tariff

Forecast	FYE							
Tariff	2015	2016	2017	2018	2019	2020	2021	2022
RT1	4,149	4,190	4,175	4,094	3,929	3,621	3,212	2,686
RT13	831	837	858	898	953	1,019	1,117	1,234
RT2	1,045	1,083	1,101	1,084	1,074	1,068	1,048	1,021
RT14	14	14	13	13	13	13	13	12
RT3	82	85	89	80	81	70	59	45
RT15	54	56	62	61	73	80	97	117
RT4	1,286	1,337	1,315	1,298	1,276	1,251	1,222	1,194
RT16	55	57	54	51	49	46	44	41
RT5	460	515	551	593	638	677	723	773
RT6	2,043	2,053	2,056	2,060	2,064	2,071	2,079	2,087
RT7	2,551	2,565	2,542	2,522	2,504	2,491	2,479	2,468
RT7Z	443	442	441	437	434	430	427	423
RT8	225	213	209	206	202	199	196	193
RT9	131	137	140	143	146	149	152	155
RT10	33	32	33	33	33	33	33	33
TRT1	4,162	4,097	4,063	4,056	4,048	4,041	4,034	4,027
Total	17,564	17,712	17,701	17,628	17,518	17,258	16,933	16,509

Appendix A. Data preparation notes

This appendix provides a list of source files and source details of data used in the forecasting process.

Source files for this project are as follows:

- MBS data: NDWU.NMI_DIM; INFOMGMT.ENERGY_CONSUMPTION;
- External variables data: SFENERGY.INPUT_DATA; SFVALID.HIA_LONG_TERM_HOUSING_2016_02_19; SFVALID.BIS_GVA

The script for transforming the source files into forecasting training data sets is in the SAS Enterprise Guide project: Energy & Customer Numbers Forecast 2016_03_14.egp.

The key sources of external variables data are:

- BIS Shrapnel for Gross Regional Product and Gross Value Added series by industry. Customized data set prepared for Western Power.
- Clean Energy Regulator, Postcode data for small-scale installations for solar PV installation and capacity data; http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations
- Housing Institute Australia State and National Forecast for new housing construction data, which includes five-year forecasts; https://hia.com.au/BusinessInfo/economicInfo/EcoPublications.aspx
- Department of Planning, WA Tomorrow household and population data; http://www.planning.wa.gov.au/publications/6194.asp

Appendix B. SAS script for preparing the training data

```
/*
Objective: create a macro to create the training data suitable
for creating the Energy & Customer Numbers forecast process

Dependencies: This script depends on: NDWU.NMI_DIM;
INFOMGMT.ENERGY_CONSUMPTION; SFENERGY.INPUT_DATA
Author:       Grant Coble-Neal
Date:         17 March 2016

/* Step 0: Define macro variables */
%let TariffGroup1 = %str ('RT1', 'RT3', 'RT13', 'RT15') ;
* Residential customers ;
%let TariffGroup2 = %str ('RT2', 'RT4', 'RT5', 'RT6', 'RT14',
'RT16') ;      * Commercial customers ;
%let TariffGroup3 = %str ('RT7', 'RT7Z', 'RT8', 'TRT1') ;
* Industrial customers ;
* %let TariffGroup4 = %str ('RT11') ;
* Distribution generation customers ;
* %let TariffGroup5 = %str('RT9' 'RT10') ;
* Miscellaneous customers ;

%let DateSubscript = 2016_03_17 ;   * Date subscript for the
external variables data set ;

%let tariffBloc = RES COM IND; * DX_GEN MISC;      * Tariff
group subscript ;

%macro createData() ;
              %let i=1 ;
              %let v= %scan (&tariffBloc, &i) ;
              %do %while (&v ne ) ;

              /* Step 1: get customer NMI list and attributes
for the target tariff group */
              PROC SQL;
                 CREATE TABLE WORK.CUST_ATTR_&v AS
                 SELECT DISTINCT
                                 t1.NMI,
                        t1.TAR_CDE,
                        t1.SUBSTN_CDE
                    FROM NDWU.NMI_DIM t1
                    WHERE t1.CURR_FLG = 'Y' AND
t1.NMI_STAT_CDE = 'A' AND t1.TAR_CDE IN
                         (
                         &&TariffGroup&i
                         )
                    ORDER BY t1.TAR_CDE,
                             t1.SUBSTN_CDE,
```

```
                      t1.NMI;
QUIT;

      %let i= %eval (&i+1) ;
%let v= %scan (&tariffBloc, &i) ;
%end ;

%mend ;
%createData

        /* Reconstruct last year's tariffs */
        PROC SQL;
            CREATE TABLE WORK.CUST_ATTRIB_RES AS
            SELECT DISTINCT t1.NMI,
                           /* TAR_PV_CLASS */
                       (CASE
                                     WHEN
t1.TAR_CDE='RT13' THEN 'BIDIRECTIONAL'
                                     WHEN
t1.TAR_CDE='RT15' THEN 'BIDIRECTIONAL'

                                               ELSE 'EXIT'

                              END) AS TAR_PV_CLASS,
                      /* Old_Tariffs */
                        (CASE
                                     WHEN
t1.TAR_CDE="RT1" |  t1.TAR_CDE="RT13" THEN "RT1"
                                     WHEN
t1.TAR_CDE="RT3" |  t1.TAR_CDE="RT15" THEN "RT3"
                                        ELSE t1.TAR_CDE

                         END) LABEL="The old RT1 & RT3
tariffs" AS Old_Tariffs,
                      t1.TAR_CDE,
                      t1.SUBSTN_CDE
                FROM WORK.CUST_ATTR_RES t1;
        QUIT;

        PROC SQL;
            CREATE TABLE WORK.CUST_ATTRIB_COM AS
            SELECT DISTINCT t1.NMI,
                           /* TAR_PV_CLASS */
                       (CASE
                                     WHEN
t1.TAR_CDE='RT14' THEN 'BIDIRECTIONAL'
                                     WHEN
t1.TAR_CDE='RT16' THEN 'BIDIRECTIONAL'

                                               ELSE 'EXIT'

                              END) AS TAR_PV_CLASS,

                      /* Old_Tariffs */
                        (CASE
```

```
                                                     WHEN
t1.TAR_CDE="RT2" |  t1.TAR_CDE="RT14" THEN "RT2"
                                                     WHEN
t1.TAR_CDE="RT4" |  t1.TAR_CDE="RT16" THEN "RT4"
                                                       ELSE t1.TAR_CDE
                                           END) LABEL="Old RT2 & RT4
tariffs" AS Old_Tariffs,
                                         t1.TAR_CDE,
                                         t1.SUBSTN_CDE
                                     FROM WORK.CUST_ATTR_COM t1;
                               QUIT;

                               PROC SQL;
                                  CREATE TABLE WORK.CUST_ATTRIB_IND AS
                                  SELECT DISTINCT t1.NMI,
                                            /* TAR_PV_CLASS */
                                            ('EXIT') AS TAR_PV_CLASS,
                                         /* Old_tariffs */
                                           (CASE
                                                     WHEN  t1.TAR_CDE=
t1.TAR_CDE THEN  t1.TAR_CDE
                                           END) LABEL="Old tariffs from
last year" AS Old_tariffs,
                                         t1.TAR_CDE,
                                         t1.SUBSTN_CDE
                                     FROM WORK.CUST_ATTR_IND t1;
                               QUIT;

                    /* Step 2: get the energy sales history for the
NMI list obtained in Step 1 */
%macro createData2() ;
              %let i=1 ;
              %let v= %scan (&tariffBloc, &i) ;
              %do %while (&v ne ) ;

              PROC SQL;
                 CREATE TABLE WORK.CUST_KWH_MTH_&v AS
                 SELECT DISTINCT t1.NMI,
                        /* Date */
                          (MDY(INPUT(substrn(t2.YR_MTH_NO, 5 ,
2 ), 2. ), 1 , INPUT(substrn(t2.YR_MTH_NO, 1 , 4 ), 4. )))
FORMAT= Date9. AS Date,
                                 t1.Old_Tariffs,
                                 t1.TAR_CDE,
                                 t1.TAR_PV_CLASS,
                        t1.SUBSTN_CDE,
                        t2.EXPORT_CONSUMPTION_AMT,
                        t2.IMPORT_CONSUMPTION_AMT
                    FROM WORK.CUST_ATTRIB_&v t1
                         INNER JOIN
INFOMGMT.ENERGY_CONSUMPTION t2 ON (t1.NMI = t2.NMI)
                    ORDER BY t1.NMI,
                             Date;
              QUIT;
```

```
                /* Step 3: Aggregate the energy history by
tariff code by SUBSTN_CDE and created exported and imported
energy series normalised by dividing by the NMI count */

                PROC SQL;
                   CREATE TABLE SFENERGY.CUST_KWH_SUBSTN_CDE_&v
AS
                   SELECT DISTINCT t1.Date FORMAT= Date9. ,
                                t1.TAR_PV_CLASS,
                                   t1.Old_Tariffs,
                          t1.TAR_CDE,
                          t1.SUBSTN_CDE,
                          /* EXPORT */
                            (SUM(t1.EXPORT_CONSUMPTION_AMT))
FORMAT= comma12.1 AS EXPORT,
                          /* IMPORT */
                            (SUM(t1.IMPORT_CONSUMPTION_AMT))
FORMAT= comma12.1 AS IMPORT,
                          /* NMI_COUNT */
                            (COUNT(t1.NMI)) FORMAT= comma12.
LABEL= "NMI Count" AS NMI_COUNT,
                          /* EXPORT_PER_NMI */

((SUM(t1.EXPORT_CONSUMPTION_AMT))/(COUNT(t1.NMI))) FORMAT=
comma12.1 LABEL= "Exported energy per NMI" AS
                            EXPORT_PER_NMI,
                          /* IMPORT_PER_NMI */

((SUM(t1.IMPORT_CONSUMPTION_AMT))/(COUNT(t1.NMI))) FORMAT=
comma12.1 LABEL= "Imported energy by NMI" AS
                            IMPORT_PER_NMI
                      FROM WORK.CUST_KWH_MTH_&v t1
                      WHERE t1.Date BETWEEN '1Jul2008'd AND
'1Oct2015'd
                      GROUP BY t1.Date,
                               t1.TAR_CDE,
                               t1.SUBSTN_CDE,
                                         t1.TAR_PV_CLASS
                      ORDER BY t1.TAR_PV_CLASS,
                                         t1.SUBSTN_CDE,
                               t1.TAR_CDE,
                               t1.Date;
                QUIT;

 /* Step 4: Add the external variables to the data table
created in Step 3, to create a data table ready for use in
Forecast Studio */
PROC SQL;
   CREATE TABLE SFENERGY.ECN_2016_0317_&v AS
   SELECT DISTINCT t2.Date,
            t1.Old_Tariffs,
         t1.TAR_CDE,
         t1.TAR_PV_CLASS,
         t1.SUBSTN_CDE,
         t1.EXPORT,
```

```
            t1.IMPORT,
            t1.NMI_COUNT,
            t1.EXPORT_PER_NMI,
            t1.IMPORT_PER_NMI,
            t2.DIM,
            t2.CDDD,
            t2.CDDD_Jandakot,
            t2.CDDD_Mandurah,
            t2.CDDD_PerthAirport,
            t2.CDDD_PerthMetro,
            t2.CDDD_Rottnest,
            t2.HDDD,
            t2.HDDD_Jandakot,
            t2.HDDD_Mandurah,
            t2.HDDD_PerthAirport,
            t2.HDDD_PerthMetro,
            t2.HDDD_Rottnest,
            t2.CPI,
            t2.Res_Price,
            t2.Bus_Price,
            t2.Res_Price_Real,
            t2.Bus_Price_Real,
            t2.GRP,
            t2.BandA_Houses,
            t2.BandB_Houses,
            t2.BandC_Houses,
            t2.BandD_Houses,
            t2.BandE_Houses,
            t2.DetachedHousingStarts,
            t2.MultiDwellingsStarts,
            t2.WA_Pop_A,
            t2.WA_Pop_B,
            t2.WA_Pop_C,
            t2.WA_Pop_D,
            t2.WA_Pop_E,
            t2.WPN_Pop_A,
            t2.WPN_Pop_B,
            t2.WPN_Pop_C,
            t2.WPN_Pop_D,
            t2.WPN_Pop_E,
            t2.PV_CAPACITY,
            t2.PV_INSTALLS
        FROM SFENERGY.CUST_KWH_SUBSTN_CDE_&v t1
             RIGHT JOIN SFENERGY.EX_VAR_EXPANDED2 t2 ON (t1.Date
= t2.Date);
QUIT;

%let i= %eval (&i+1) ;
              %let v= %scan (&tariffBloc, &i) ;
              %end ;
%mend ;
%createData2
```

```
/* Objective: Add the NMI count forecasts to the energy volume
estimating data set
   Author: Grant Coble-Neal
   Maintainer: Somebody else
   Date: 3 March 2016

*/
/* Step 0: Define macro variables */
%let Lib_name=SFENERGY ;
%let Input_files_1 = %str(ECN_2016_NMI_RES3,
ECN_2016_NMI_COM3, ECN_2016_NMI_IND3) ;
%let Input_files_2 = %str(ECN_2016_0317_RES,
ECN_2016_0317_COM, ECN_2016_0317_IND);
%let Output_files_1 = %str(ECN_2016_NMI_RES3A,
ECN_2016_NMI_COM3A, ECN_2016_NMI_IND3A) ;
%let Output_files_2 = %str(ECN_2016_NMI_RES3B,
ECN_2016_NMI_COM3B, ECN_2016_NMI_IND3B) ;



/* Construct tables */
%macro createDataSets() ;
              %let i=1 ;
              %let v=%scan(&Input_files_1, &i) ;
                  %let w=%scan(&Input_files_2, &i) ;
                  %let x=%scan(&Output_files_1, &i) ;
                  %let y=%scan(&Output_files_2, &i) ;
              %do %while(&v ne ) ;

           PROC SQL;
              CREATE TABLE &Lib_name..&x AS
              SELECT t1.Old_Tariffs,
                     t1.TAR_CDE,
                     t1.SUBSTN_CDE,
                     t1.Date,
                     t2.EXPORT,
                     t2.IMPORT,
                     t2.NMI_COUNT,
                     t1.PREDICT LABEL="Reconciled Predicted
Values of NMI count forecast" AS NMI_FRCST,
                     t2.EXPORT_PER_NMI,
                     t2.IMPORT_PER_NMI,
                     t2.DIM,
                     t2.CDDD,
                     t2.CDDD_Jandakot,
                     t2.CDDD_Mandurah,
                     t2.CDDD_PerthAirport,
                     t2.CDDD_PerthMetro,
                     t2.CDDD_Rottnest,
                     t2.HDDD,
                     t2.HDDD_Jandakot,
                     t2.HDDD_Mandurah,
                     t2.HDDD_PerthAirport,
                     t2.HDDD_PerthMetro,
                     t2.HDDD_Rottnest,
```

```
                       t2.CPI,
                       t2.Res_Price,
                       t2.Bus_Price,
                       t2.Res_Price_Real,
                       t2.Bus_Price_Real,
                       t2.GRP,
                       t2.WA_Pop_A,
                       t2.WA_Pop_B,
                       t2.WA_Pop_C,
                       t2.WA_Pop_D,
                       t2.WA_Pop_E,
                       t2.WPN_Pop_A,
                       t2.WPN_Pop_B,
                       t2.WPN_Pop_C,
                       t2.WPN_Pop_D,
                       t2.WPN_Pop_E,
                       t2.PV_CAPACITY,
                       t2.PV_INSTALLS,
                       t2.AgricForFish,
                       t2.Mining,
                       t2.Manufacturing,
                       t2.Construction,
                       t2.ElecGasWater,
                       t2.AccomFoodServices,
                       t2.WholesaleTrade,
                       t2.RetailTrade,
                       t2.TransPostalWare,
                       t2.InfoMediaTelecom,
                       t2.FinInsurance,
                       t2.RentHiringRE,
                       t2.ProfScienTechSrvcs,
                       t2.AdminSupportSrvcs,
                       t2.ArtRecSrvcs,
                       t2.OtherSrvcs,
                       t2.GovAdminSafety,
                       t2.EdTraining,
                       t2.HealthSocialAss,
                       t2.Dwellings,
                       t2.Total,
                       t2.NonFARM,
                       t2.DetachedHouses,
                       t2.MultiUnitDwellings,
                       t2.Total1
                 FROM &Lib_name..&v t1
                        LEFT JOIN &Lib_name..&w t2 ON (t1.Date =
t2.Date) AND (t1.SUBSTN_CDE = t2.SUBSTN_CDE) AND
                       (t1.TAR_CDE = t2.TAR_CDE) AND
(t1.Old_Tariffs = t2.Old_Tariffs)

                 ORDER BY t1.Old_Tariffs,
                          t1.TAR_CDE,
                          t1.SUBSTN_CDE,
                          t1.Date;
                  QUIT;
```

```
PROC SQL;
   CREATE TABLE &Lib_name..&y AS
   SELECT t1.Old_Tariffs,
          t1.TAR_CDE,
          t1.SUBSTN_CDE,
          t1.Date,
          t1.EXPORT,
          t1.IMPORT,
          t1.NMI_COUNT,
          t1.NMI_FRCST,
          t1.EXPORT_PER_NMI,
          t1.IMPORT_PER_NMI,
          t1.DIM,
          t1.CDDD,
          t1.CDDD_Jandakot,
          t1.CDDD_Mandurah,
          t1.CDDD_PerthAirport,
          t1.CDDD_PerthMetro,
          t1.CDDD_Rottnest,
          t1.HDDD,
          t1.HDDD_Jandakot,
          t1.HDDD_Mandurah,
          t1.HDDD_PerthAirport,
          t1.HDDD_PerthMetro,
          t1.HDDD_Rottnest,
          t1.CPI,
          t1.Res_Price,
          t1.Bus_Price,
          t1.Res_Price_Real,
          t1.Bus_Price_Real,
          t1.GRP,
          t1.WA_Pop_A,
          t1.WA_Pop_B,
          t1.WA_Pop_C,
          t1.WA_Pop_D,
          t1.WA_Pop_E,
          t1.WPN_Pop_A,
          t1.WPN_Pop_B,
          t1.WPN_Pop_C,
          t1.WPN_Pop_D,
          t1.WPN_Pop_E,
          t1.PV_CAPACITY,
          t1.PV_INSTALLS,
          t1.AgricForFish,
          t1.Mining,
          t1.Manufacturing,
          t1.Construction,
          t1.ElecGasWater,
          t1.AccomFoodServices,
          t1.WholesaleTrade,
          t1.RetailTrade,
          t1.TransPostalWare,
          t1.InfoMediaTelecom,
          t1.FinInsurance,
```

```
            t1.RentHiringRE,
            t1.ProfScienTechSrvcs,
            t1.AdminSupportSrvcs,
            t1.ArtRecSrvcs,
            t1.OtherSrvcs,
            t1.GovAdminSafety,
            t1.EdTraining,
            t1.HealthSocialAss,
            t1.Dwellings,
            t1.Total,
            t1.NonFARM,
            t1.DetachedHouses,
            t1.MultiUnitDwellings,
            t1.Total1
      FROM &Lib_name..&x t1
      WHERE t1.Old_Tariffs NOT = '+' AND t1.TAR_CDE NOT = '+'
AND t1.SUBSTN_CDE NOT = '+' AND t1.Old_Tariffs NOT IS
           MISSING;
QUIT;
                  %let i= %eval(&i+1) ;
              %let v= %scan(&Input_files_1, &i) ;
                  %let w= %scan(&Input_files_2, &i) ;
                  %let x= %scan(&Output_files_1, &i) ;
                  %let y= %scan(&Output_files_2, &i) ;

              %end ;

%mend ;
%createDataSets
```

Appendix C. Forecast Studio Files

The following SAS Forecast Studio files are relevant to this report:

1. Solar PV forecast:
    a. ECN_2016_PVSYS [source file: SFENERGY.PV_COUNT_TRAIN; forecast results file: SFENERGY.ECN_2016_FRCST_PVSYS]
2. Distribution Generation forecasts: EC_2016_DG_PV [source file: SFENERGY.DG_PV_TRAINING; results file: SFENERGY.ECN_2016_DG_PV_FRCST]
3. Customer numbers forecasts:
    a. ECN_2016_NMI3_RES [Source: SFENERGY.ECN_2016_TRAIN3_RES; results file: ECN_2016_NMI_RES3]
    b. ECN_2016_NMI3_COM [Source: SFENERGY.ECN_2016_TRAIN3_COM; results file: ECN_2016_NMI_COM3
    c. ECN_2016_NMI3_IND [Source: SFENERGY.ECN_2016_TRAIN3_IND; results file: ECN_2016_NMI_IND3]
4. Energy volumes per NMI (GWh) forecasts:
    a. ECN_2016_AV_EN_RES [Source: SFENERGY.ECN_2016_TRAIN3_RES; results file: SFENERGY.ECN_2016_AV_EN_FRCST_RES]
    b. ECN_2016_AV_EN_COM [Source file: SFENERGY.ECN_2016_TRAIN3_COM; results file: SFENERGY.ECN_2016_AV_EN_FRCST_COM]
    c. ECN_2016_AV_EN_IND [Source file: SFENERGY.ECN_2016_TRAIN3_IND; results file: SFENERGY.ECN_2016_AV_EN_FRCST_IND]
5. Streetlights and Unmetered Supplies energy volumes and connection numbers:
    a. ECN_2016_FRCST_NMI_RT9_10
    [Source file: SFENERGY.INPUT_DATA_2016_02_08;
    results file: SFENERGY.ECN_2016_FRCST_RT9_10]

Note that each Forecast Studio project name consists of a concatenation of abbreviations:

- AV: Average energy (i.e. GWh per NMI/connection)
- ECN: Energy & Customer Numbers
- RES: Residential customers
- COM: Commercial customers
- IND: Industrial customers
- NMI: Network Meter Identifier
- PV: Solar PV
- VOL: energy volume in GWh
- FRCST: Forecast