ACIL ALLEN CONSULTING

REPORT TO
QUEENSLAND COMPETITION AUTHORITY

2 JUNE 2017

WHOLESALE ELECTRICITY SPOT PRICES

ESTIMATION OF QUEENSLAND WHOLESALE ELECTRICITY SPOT PRICES FOR 2017-18

FOR USE BY THE QUEENSLAND COMPETITION AUTHORITY IN ITS ADVICE ON TIME VARYING FEED-IN TARIFFS

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ESTIMATED WHOLESALE ELECTRICITY SPOT PRICES FOR 2017-18 TIME VARYING FEED-IN TARIFFS, ACIL ALLEN, MAY 2017

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1 INTRODUCTION

ACIL Allen Consulting Pty Ltd (ACIL Allen) has been engaged by the Queensland Competition Authority (QCA) to provide expert advice on estimating the Queensland spot wholesale electricity price values to inform a time varying feed-in tariff (t-FiT) for regional Queensland for 2017-18.

Our engagement is in response to the Terms of Reference (ToR) ACIL Allen received from the QCA. The QCA has been directed by the Minister for Energy and Water Supply (the Minister) to provide advice (the advice) on a number of matters to inform the development of a t-FiT to apply in regional Queensland for 2017-18.

Under the ToR, ACIL Allen is required to provide expert advice to the QCA on the Queensland wholesale electricity spot price values for 2017-18 - with a time-varying component to reflect the value of exported solar PV during peak periods.

This report contains the following sections:

— Section **2** provides ACIL Allen's understanding of the scope and deliverables of the assignment as described in the QCA's ToR
— Section **3** describes our approach
— Section **4** provides a summary of the estimated prices for use by the QCA.

2 SCOPE AND DELIVERABLES

The engagement comprises two tasks:

— Task 1: ACIL Allen is required to provide expert advice to the QCA on Queensland spot wholesale electricity pool price values for each of the peak period definitions below and a corresponding off-peak period covering the remaining hours of a day. These values must be relevant for the 2017-18 tariff year. The peak time periods to be calculated are:
  - a peak period not less than two hours which provides the highest wholesale energy value when solar PV is generating
  - a period not less than two hours which reflects the highest electricity demand on the Ergon Energy network
  - a peak period from 5pm–7pm
  - a peak period from 4pm–7pm
  - a peak period from 3pm–7pm.

  This in effect provides five peak period definitions (and consequently, five off-peak period definitions).

— Task 2: ACIL Allen is also required to calculate a build-up (in dollars per megawatt hour) of peak and off-peak values (for each time period referred to in relation to Task 1) which includes:
  - the wholesale values calculated for Task 1 above
  - energy losses for Ergon Energy's east pricing zone
  - National Electricity Market and ancillary services fees.

  ACIL Allen has not been asked to provide any other advice to matters related to this assignment.

3 OVERVIEW OF APPROACH

In providing its advice to the QCA, ACIL Allen has made use of the energy purchase cost modelling and analysis it undertook for the QCA for the determination of regulated retail electricity tariffs in regional Queensland for 2017-18 (the determination). This retains an appropriate degree of internal consistency with the determination and the advice the QCA provides the Minister by using a consistent approach which has been well tested by the QCA's stakeholders over the past five years or so.

There are five steps to the work we have done:

1. produce projections of the hourly wholesale spot electricity price in Queensland in 2017-18
2. determine the appropriate method for aggregating the projected hourly spot prices to annual figures for each period type definition
3. apply the various definitions of peak and off-peak times set out in the ToR
4. select the best estimate of the annual peak and off-peak price for each period type definition
5. adjust the annual figures for network losses, and NEM and other fees.

The first four of these steps satisfy Task 1 of the ToR, and step five satisfies Task 2 of the ToR. Each of these five steps is discussed in turn in the following sections.

3.1 Step 1 – Produce projections of wholesale electricity spot prices

ACIL Allen has previously provided advice to the QCA regarding 2017-18 wholesale electricity spot prices in Queensland as an input to the QCA's determination of regulated retail electricity tariffs. In doing that, ACIL Allen utilised its:

1. stochastic demand model to develop 46 multiple weather influenced simulations of hourly demand traces for each region of the NEM
2. stochastic outage model to develop 11 power station availability simulations
3. energy market models to run multiple simulations of hourly spot pool prices of the NEM for 2017-18 using the stochastic demand traces and power station availabilities as inputs to produce 506 (46 x 11) simulations
4. analysis of contract data to estimate contract prices
5. hedge model taking the above analyses as inputs to estimate a distribution of hedged prices for each tariff class.

For the analysis presented in this report, we have made use of the results produced by the first three models described above.

However, our interpretation of the ToR is that the values we estimate should *not* include an adjustment for the cost of hedging to manage price risk.

Hence, it is not necessary to utilise our hedge model or to consider the load shape of the Net System Load Profile (NSLP) in this instance. Rather, the analysis is based on the projected wholesale electricity spot prices for Queensland for 2017-18.

Therefore, the projected wholesale electricity spot prices used in this analysis are consistent with the inputs to the regulated retail tariff process. They comprise 506 simulations for 2017-18, with each simulation consisting of 8,760 hourly wholesale electricity spot prices in chronological order (from the hour beginning at midnight 1 July 2017 to the hour beginning at 11 pm on 30 June 2018).

This distinguishes the work summarised in this report from the QCA's previous estimates of FiTs in Queensland which were based on the notion of avoided cost, and hence were related to the wholesale energy cost (WEC) that a retailer avoids (adjusted for losses and other avoided fees) when that retailer procures exported energy from a customer's rooftop PV system.

3.2 Step 2 – Aggregation of simulated spot price values

The second step is to determine the appropriate way to aggregate the projected hourly spot prices from each of the 506 simulations into the specified peak/off-peak periods. Specifically, whether to use simple or weighted averages and, if the latter, what weights to use.

We interpret the ToR, given it includes estimating the spot wholesale prices into various pre-defined peak periods and off-peak periods, such that the peak and off-peak periods cover all 24 hours in a day, as not requiring the use of weights when calculating the price within each peak period and off-peak period definition.

In effect, the various pre-defined peak/off-peak period definitions are substitutes for weighting, albeit at a broad level. Or put another way, within each peak and off-peak period definition it is not a requirement for ACIL Allen to calculate a solar PV export volume weighted price, but a simple time weighted price where each hour within a given period type definition is treated with the same weighting (regardless of PV exports). For example, in the off-peak period definitions, price outcomes during non-daylight hours contribute equally to the estimated price - even though there is no PV output (or exports) during those particular hours - as price outcomes during daylight hours.

3.3 Step 3 – Apply the definitions of period types

The ToR require that we compute wholesale electricity price values in peak and off peak periods. There are five different definitions of peak (with corresponding definitions of off peak).

Three of the five definitions are straightforward references to time. However the first two definitions are more complex and require interpretation. These definitions are:

- a peak period not less than two hours which provides the highest wholesale energy value when solar PV is generating
- a period not less than two hours which reflects the highest electricity demand on the Ergon Energy network.

Our interpretation of these two definitions is discussed below:

3.3.1 Definition 1 – a period not less than two hours which provides the highest wholesale energy value when solar is generating

Our interpretation of this definition is that it refers to a period of two or more continuous, daylight hours and that these must be the same hours every day, all year. The period should be selected so that the peak period price is the highest average possible value.

Therefore, we must take account of sunrise and sunset times in regional Queensland, as well as use estimates of PV generation by time of day to verify the times when PV is generating.

Sunrise and sunset times

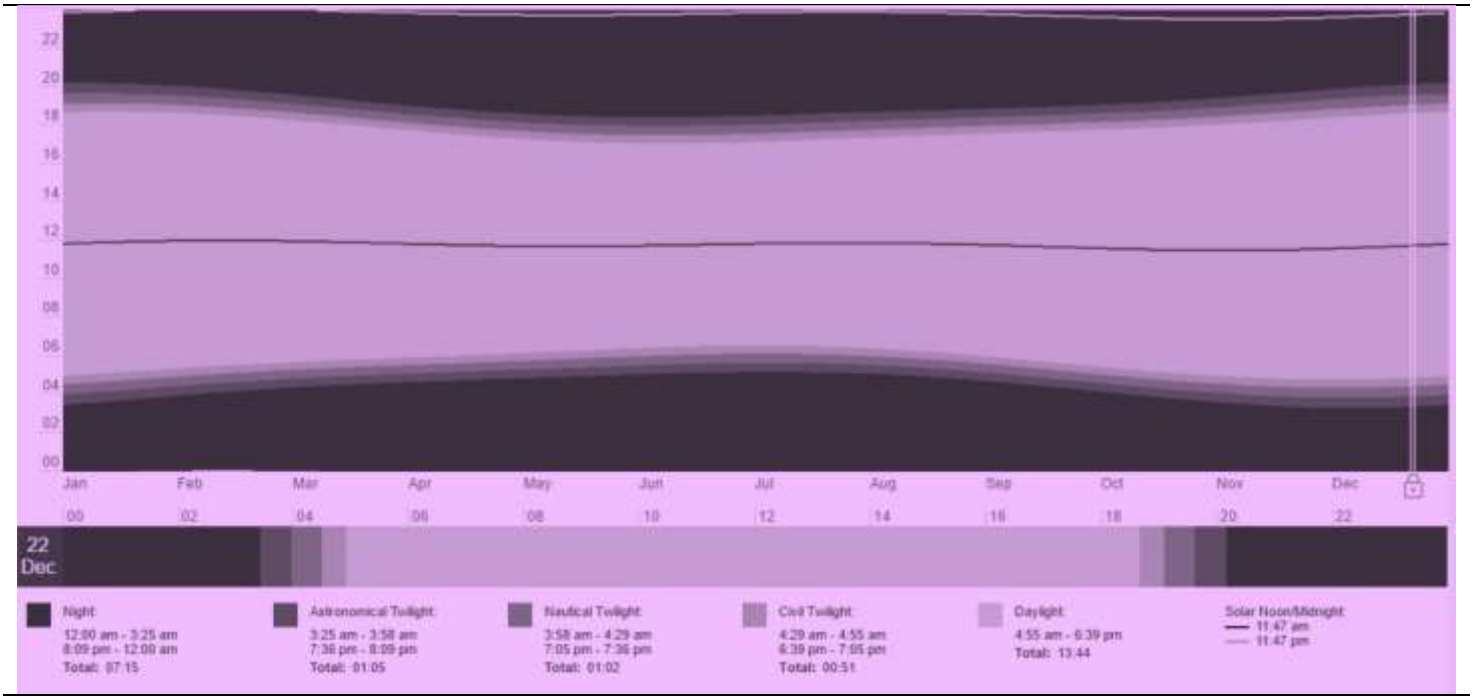
Identification of the times *when solar PV is generating* can be constructed in a number of different ways. Given that the analysis requires a single annual price, we think it is consistent to consider the time *when solar PV is generating* as the period spanned by:

- the earliest time in the day, across the entire year, that solar commences generating
- the latest time in the day, across the entire year, that solar ceases generating.

ACIL Allen accessed Bureau of Meteorology (BOM) data and found that:

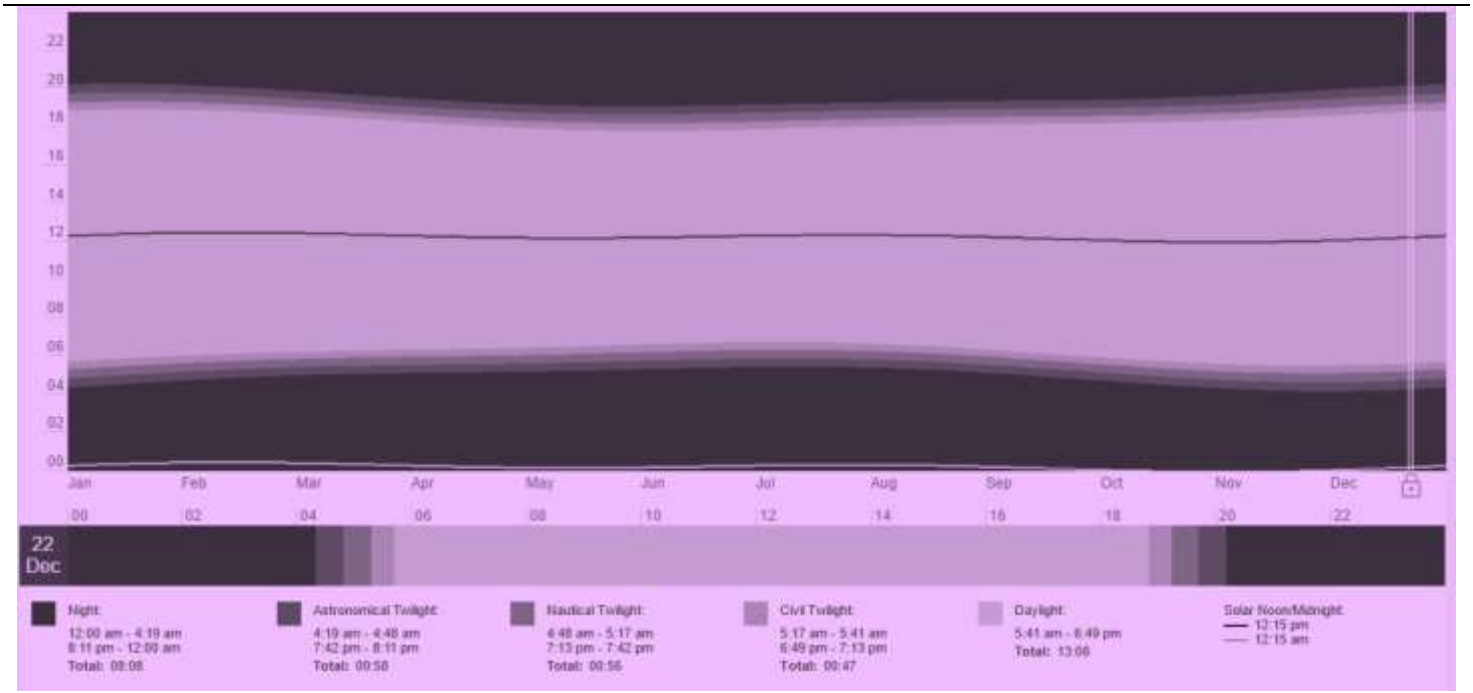
- in Maryborough the earliest sunrise is about 4:50 am in late November / early December, and the latest sunset is about 6:45 pm in mid-January
- in Cairns the earliest sunrise is about 5:34 am in late November / early December, and the latest sunset is about 6:57 pm in late-January.

FIGURE 3.1 SUNRISE, SUNSET, AND DAY LENGTH – MARYBOROUGH



SOURCE: HTTPS://WWW.TIMEANDDATE.COM/SUN/AUSTRALIA/HERVEYBAY

FIGURE 3.2 SUNRISE, SUNSET, AND DAY LENGTH - CAIRNS



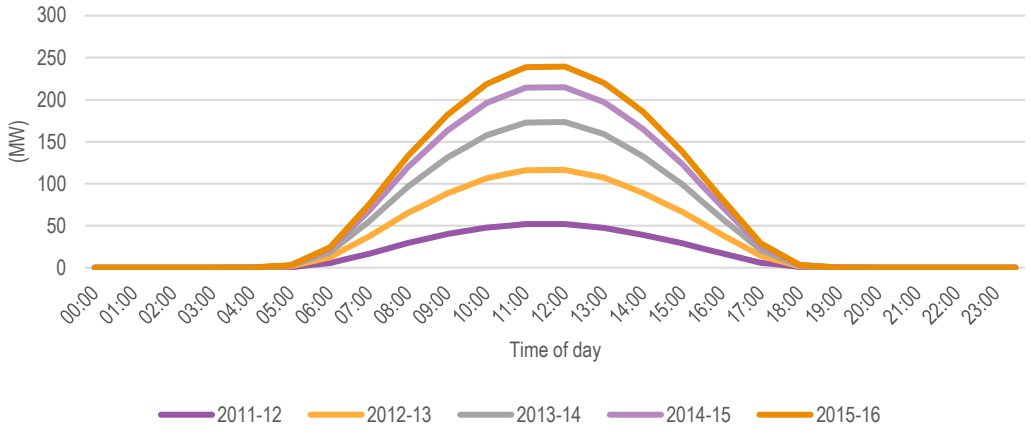
SOURCE: HTTPS://WWW.TIMEANDDATE.COM/SUN/AUSTRALIA/CAIRNS

Estimates of PV generation by time of day

The QCA provided ACIL Allen access to Ergon's estimated[1] half hourly generation from rooftop PV systems installed on customer premises (residential and commercial) on the Ergon network. ACIL Allen aggregated the data to estimate the total annual average time of day generation from PV systems installed on the Ergon network as shown in Figure 3.3. The graph suggests that on average, and in aggregate across a year, PV systems are generating from 5 am to 7 pm – which aligns with the sunrise and sunset data presented above.

[1] The generation is modelled using irradiation data and hence is an estimate only. However, ACIL Allen is of the opinion that the estimates are fit for the purposes for the analysis undertaken in this report.

FIGURE 3.3 ANNUAL AVERAGE TIME OF DAY SOLAR PV OUTPUT ON THE ERGON NETWORK (MW)



Note: The time of day value represents the hour beginning

SOURCE: ACIL ALLEN ANALYSIS OF DATA PROVIDED BY ERGON

On this basis, and given the other period type definitions are described to the nearest hour, and our market modelling is undertaken at the hourly resolution level, we have concluded that the period beginning at 5 am and ending at 7 pm provides the bounds for times when solar PV is generating.

3.3.2 Definition 2 - a period not less than two hours which reflects the highest electricity demand on the Ergon Energy network

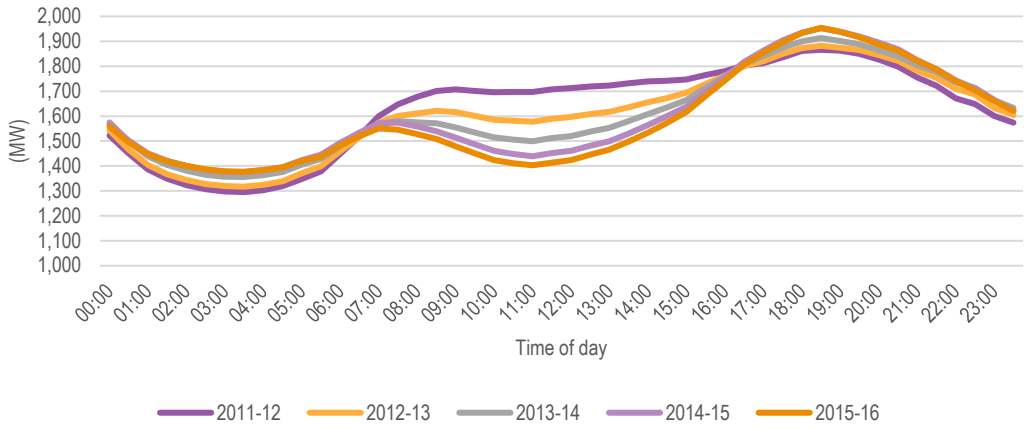
The second peak period definition provided in the ToR refers to a period of not less than two hours which reflects the *highest wholesale electricity demand on the Ergon Energy network*. Consistent with the first definition, we have calculated the annual average time of day demand across the entire year for the Ergon Energy network, which will identify the period of two consecutive hours of highest average demand. To be clear, we are not using the two highest of the 17,520 demands for the year.

The QCA provided ACIL Allen access to the half-hourly demand data from July 2011 to June 2016 based on the current configuration of the Ergon network. ACIL Allen calculated the annual average time of day demand which is presented in Figure 3.4.

We initially considered making use of our stochastic demand model to develop 46 multiple weather influenced simulations of the demand traces for the Ergon system (using the same process as that used when calculating the WEC). However, Figure 3.4 shows the profile has been so consistent on an annual average basis that we concluded it is not necessary to undertake this additional step.

Our analysis of the data in the graph below concludes that the period between 6 pm to 8 pm consistently results in the highest 2-hour average demand block each year for the past six years. Given each of these years has had its own set of peculiar events in regional Queensland – such as cyclones, floods, mild summers, hot summers etc – we see no reason why the 6 pm to 8 pm block will not be similarly representative of the highest demand period during 2017-18. Certainly, the continued penetration of rooftop solar PV will not play a role in influencing the timing of the 2-hour period that gives the highest annual average demands.

FIGURE 3.4 ANNUAL AVERAGE TIME OF DAY DEMAND ON THE ERGON NETWORK (MW)



Note: The time of day value represents the hour beginning

SOURCE: ACIL ALLEN ANALYSIS OF DATA PROVIDED BY ERGON

3.4 Step 4 – Selecting an annual peak and off-peak price from the distribution of 506 annual prices

When the above three steps are completed there is a distribution of 506 values in each of the period types. These values represent our estimate of the likely range of prices. The range is attributable to uncertainty in weather and plant outages.

The final step is to choose one value from within these ranges to put forward as the final estimate.

ACIL Allen has discussed this matter with QCA and has reached the conclusion that unlike the analysis for the regulated retail tariffs, and unlike advice we have provided in other jurisdictions in which there is full retail competition, the ToR require we are to provide our best estimate of the value of the spot wholesale electricity price for the given period type definitions, rather than a floor value (or cap value) and rather than considering the specific solar export profiles of rooftop PV systems installed by households in the Ergon distribution network .

In ACIL Allen's opinion, the best estimate is the risk weighted average spot price as this takes into account an unbiased view of the influence of short term stochastic influences on the market outcomes – such as weather driven demand and renewable generation coupled with power station availability.

ACIL Allen has calculated the risk weighted average spot wholesale electricity price for each period type definition by:

- for each simulation, calculating the simple annual average (or time weighted average) of the hourly simulated prices – which gives 506 estimates of the annual average price
- calculating the simple average of the 506 annual average prices which gives the risk weighted average price across all simulations (with each simulation equally likely to occur).

3.5 Step 5 - Other energy costs

ACIL Allen is required to add to the prices from Task 1 the estimated NEM and ancillary service fees. ACIL Allen has already calculated these fees as part of the regulated retail price engagement.

The prices estimated in Task 1 coupled with the NEM and ancillary service fees will be referenced at the Queensland regional reference node (RRN) and hence need to be adjusted for transmission and distribution losses to end-users. Distribution Loss Factors (DLF) for the Ergon Energy east zone and average Marginal Loss Factors (MLF) for transmission losses from the node to major supply points in the distribution networks are applied. ACIL Allen has already calculated these losses as part of the regulated retail price engagement.

4 ESTIMATION OF WHOLESALE ELECTRICITY SPOT PRICES

4.1 Introduction

In this chapter we apply the methodology described in Chapter **3** and summarise the estimates of the wholesale electricity spot prices for each period type definition for 2017-18.

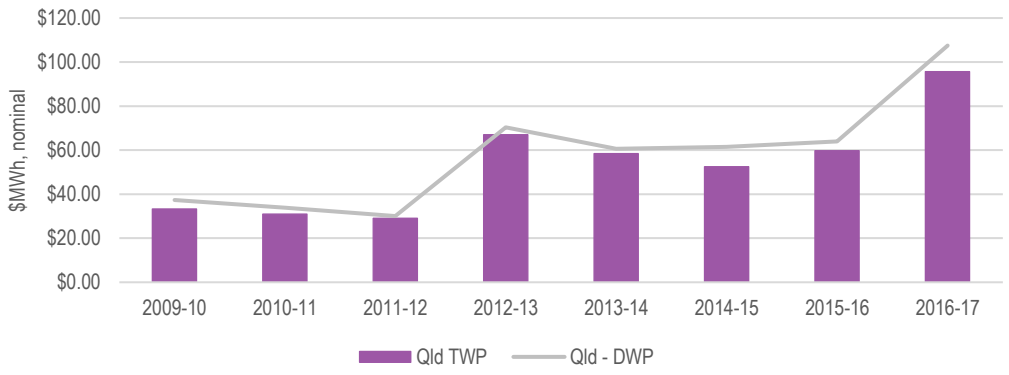
4.2 Historic energy cost levels

Figure 4.1 shows the actual annual time weighted average spot price (TWP) and demand weighted spot price (DWP) for Queensland over the past seven years.

The increase in spot price outcomes to date in 2016-17 is quite apparent, with prices on an average time weighted basis of about $95/MWh – compared with $60/MWh in 2015-16 (representing an increase of just under 60 per cent).

This is a result of an increase in the underlying demand in Queensland due to the ramping up of production associated with the LNG export facilities in Gladstone, as well as an increase in gas prices into gas fired generators, and the recent closure of Hazelwood power station in Victoria.

FIGURE 4.1 ACTUAL ANNUAL AVERAGE TIME WEIGHTED PRICE AND DEMAND WEIGHTED AVERAGE PRICE ($/MWH, NOMINAL) – 2009-10 TO 2015-16, QUEENSLAND



Note: Values reported are spot prices. Values for 2016-17 based on data up to 18 April 2017

SOURCE: ACIL ALLEN ANALYSIS OF AEMO DATA

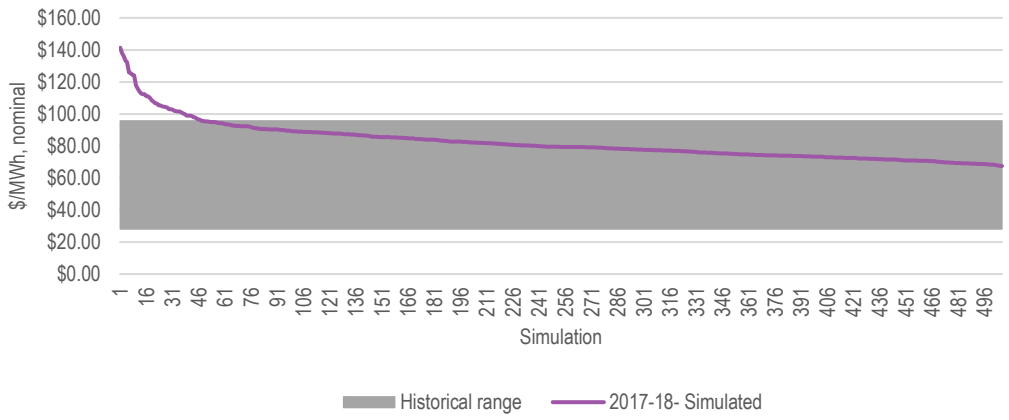
4.3 Simulation of the spot wholesale electricity prices

ACIL Allen's proprietary electricity model, *PowerMark* was run to estimate the hourly pool prices for 2017-18 for the 506 simulations (46 demand and 11 outage sets).

The modelled annual time weighted pool prices (TWP) for Queensland in 2017-18 from the 506 simulations range from a low of $67.47/MWh to a high of $141.39/MWh. This compares with the lowest recorded Queensland TWP in the last 15 years of $28.12/MWh in 2005-06 to the highest of $95.69/MWh to date in 2016-17.

Figure 4.2 compares the modelled Queensland TWP for the 506 simulations for 2017-18 with the Queensland TWPs from the past 16 years. Although there have been changes to both the supply and demand side of the market, the graph clearly shows that the simulations cover a wide range in potential prices for 2017-18 when compared with the past 16 years of history. The lower part of the distribution of simulated outcomes sits above a number of the actual outcomes (particularly for the earlier years of the market), but by 2017-18 gas prices are projected to be around $11/GJ, compared with $3 - $4/GJ in recent years, and the operating costs of coal plant have increased since the market's inception, and these, coupled with the assumed substantial demand growth due to the LNG terminals, have the effect of influencing an increase in the lower bound of annual price outcomes. ACIL Allen is satisfied that in an aggregate sense the distribution of the 506 simulations for 2017-18 cover an adequately wide range of possible annual pool price outcomes.

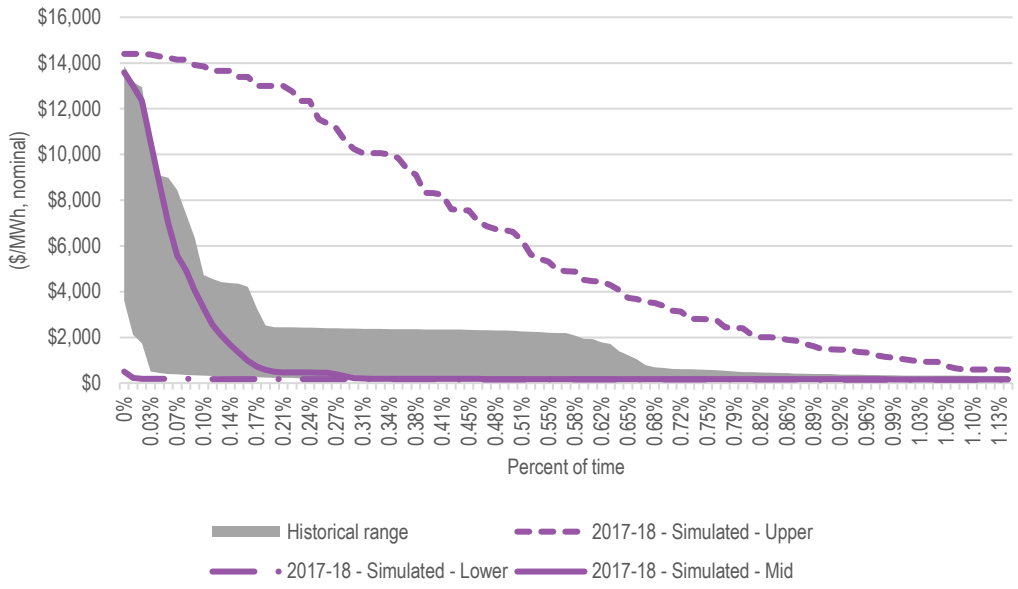
FIGURE 4.2 ANNUAL TWP FOR QUEENSLAND FOR 506 SIMULATIONS FOR 2017-18 COMPARED WITH ACTUAL ANNUAL OUTCOMES IN PAST YEARS



SOURCE: AEMO HISTORIC POOL PRICE DATA AND ACIL ALLEN RESULTS FROM POWERMARK MODELLING

Comparing the upper one percent of hourly prices in the simulations with historical spot prices shows the spread of the hourly prices from the simulations also more than adequately covers the historical spread of spot prices, as shown in Figure 4.3. It is also notable, that as would be expected, the distribution of simulated price outcomes demonstrates a strong positive skewness.

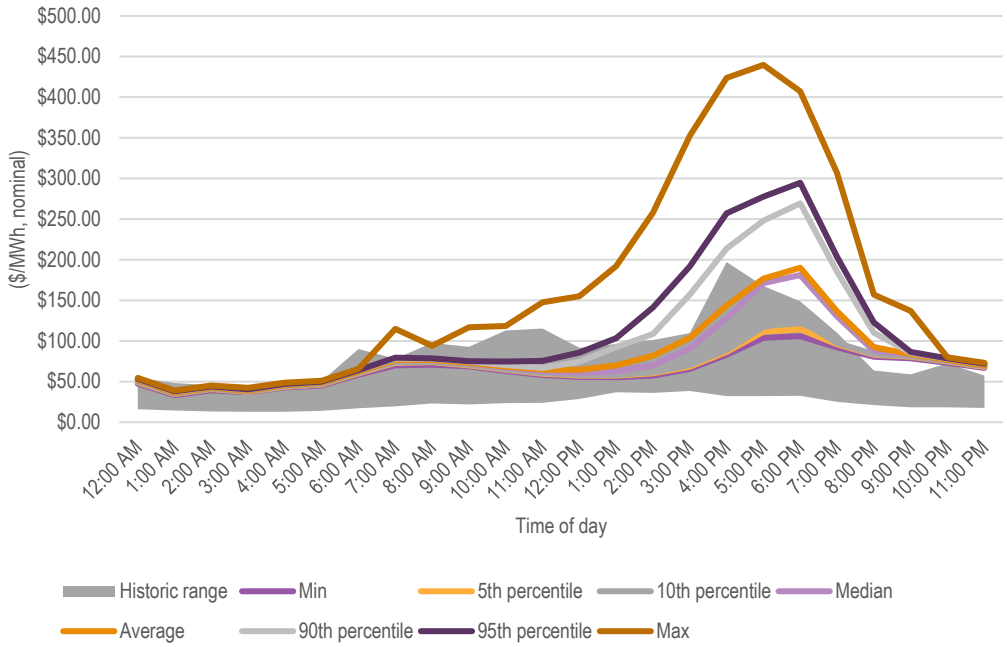
FIGURE 4.3 COMPARISON OF UPPER 1 PERCENT TAIL OF SIMULATED HOURLY PRICE DURATION CURVES FOR QUEENSLAND AND HISTORICAL OUTCOMES



SOURCE: AEMO HISTORIC POOL PRICE DATA AND ACIL ALLEN RESULTS FROM POWERMARK MODELLING

Figure 4.4 compares the modelled Queensland TWP by time of day for the 506 simulations for 2017-18 with the Queensland TWPs by time of day from the past 16 years. The simulated prices display a similar shape to the historical outcomes. However, Figure 4.5 shows that with the continued penetration of rooftop PV, and the gradual carving out of Queensland's demand during daylight hours, it is not surprising that price outcomes around midday have become relatively less volatile compared with prices in the evening, and this is projected to continue in 2017-18 as shown in Figure 4.6. ACIL Allen's modelling projects that price outcomes will be at their highest on average during the period between 5 pm and 7 pm in 2017-18.

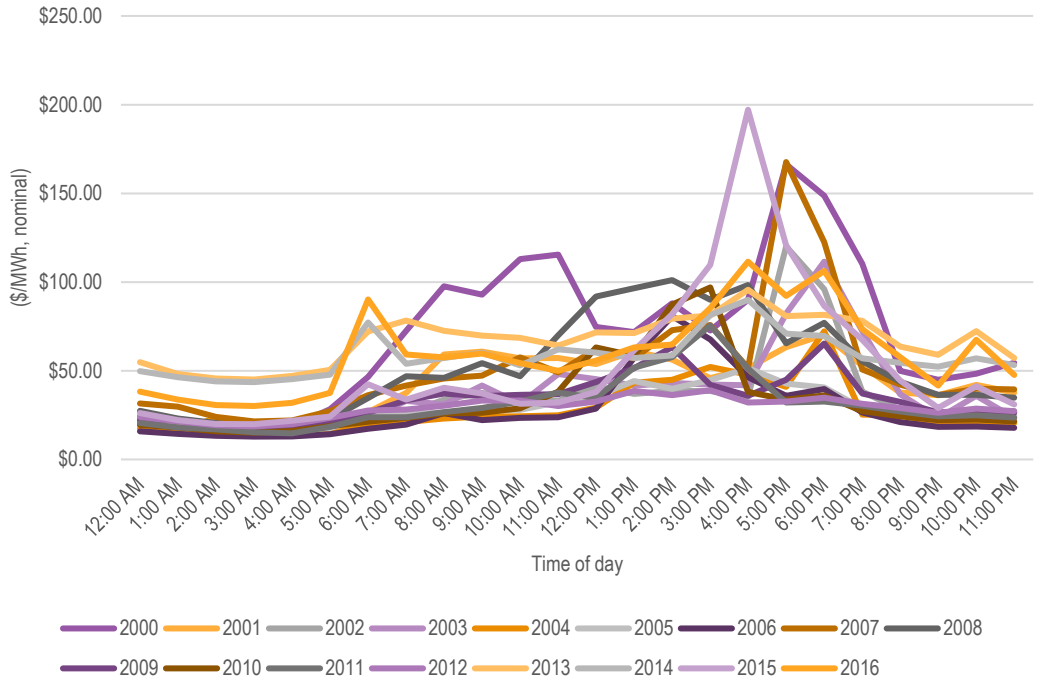
FIGURE 4.4 ANNUAL TIME OF DAY TWP FOR QUEENSLAND FOR 506 SIMULATIONS FOR 2017-18 COMPARED WITH ACTUAL ANNUAL OUTCOMES IN PAST YEARS



Note: The time of day value represents the hour beginning.

SOURCE: AEMO HISTORIC POOL PRICE DATA AND ACIL ALLEN RESULTS FROM POWERMARK MODELLING

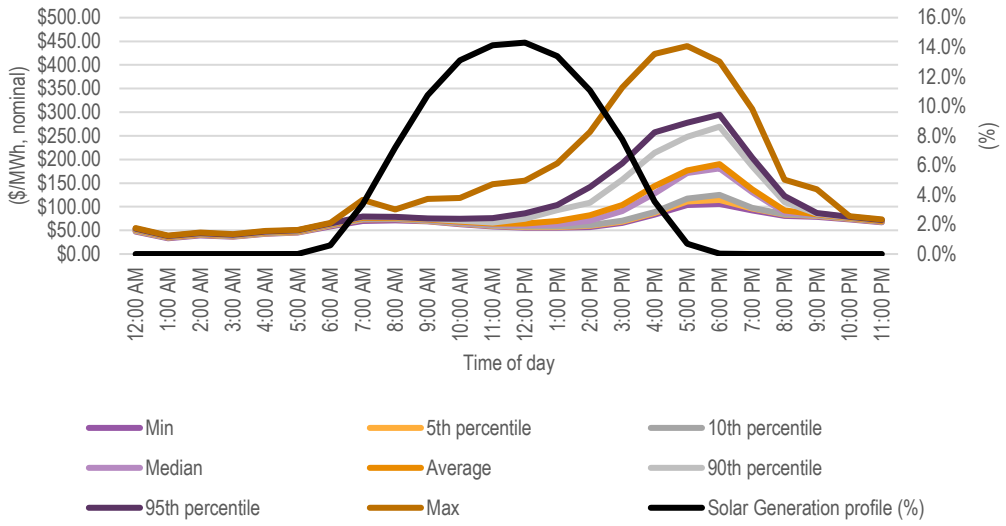
FIGURE 4.5 ANNUAL TIME OF DAY TWP FOR QUEENSLAND – 1999-2000 TO 2016-17



Note: Years in the legend refer to year ending June. The time of day value represents the hour beginning.

SOURCE: AEMO HISTORIC POOL PRICE DATA

FIGURE 4.6 ANNUAL TIME OF DAY TWP FOR QUEENSLAND FOR 506 SIMULATIONS FOR 2017-18 COMPARED WITH ANNUAL TIME OF DAY SOLAR PV OUTPUT



SOURCE: ACIL ALLEN RESULTS FROM POWERMARK MODELLING

4.4 Estimation of the spot wholesale electricity price by period type

ACIL Allen has taken the results of the 506 market simulations and calculated the distribution of annual price outcomes for each of the period type definitions which are presented in Table 4.1 and Figure 4.7.

Our analysis of the simulations concludes that defining the peak period as 5 pm to 7 pm provides the highest spot market value for a period of not less than two continuous hours when solar PV is generating (i.e. the first period definition in the ToR). This of course, is the same as the third period type definition.

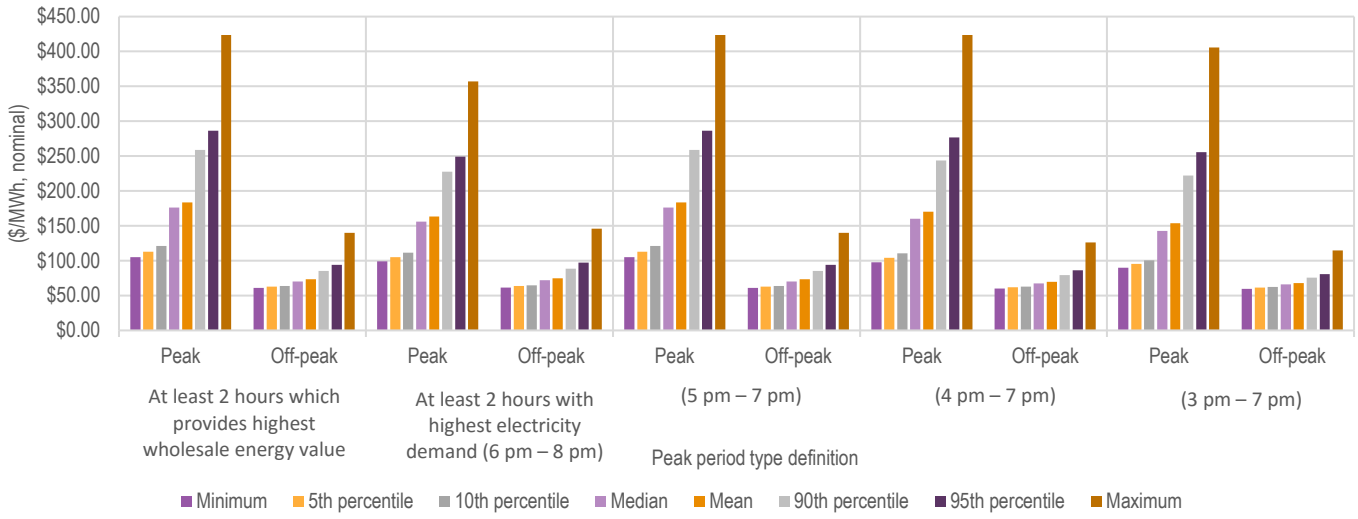
The table and graph show there is quite a spread in the values across the different percentiles within each period type definition. ACIL Allen concludes that using either the 5th or 95th percentile would run the risk of the resulting price values undervaluing or overvaluing the market outcomes quite considerably, particularly given the prices are spot values rather than hedged values. Therefore the choice in value can be shortlisted to the median and mean. Using the median effectively means there is a 50 per cent chance that the resulting price undervalues or overvalues the market. However, the mean value takes into account the skewed nature of spot wholesale electricity price outcomes which is a fundamental feature of the NEM (as demonstrated in Figure 4.2). ACIL Allen is of the opinion that, in the context of the Ergon distribution network, the mean value is appropriate for the purpose of estimating a single price per period type.

TABLE 4.1 PROJECTED ANNUAL WHOLESALE ELECTRICITY PRICE VALUE IN QUEENSLAND IN 2017-18 BY PERIOD TYPE DEFINITION ($/MWH, NOMINAL) – AT THE QUEENSLAND RRN

Peak period definition	Period	Minimum	5th percentile	10th percentile	Median	Mean	90th percentile	95th percentile	Maximum
Not less than 2 hours which provides highest wholesale energy value (5 pm – 7 pm)	Peak	$104.95	$112.83	$121.09	$176.23	$183.44	$258.77	$286.23	$423.62
	Off-peak	$61.06	$62.99	$63.80	$70.13	$73.13	$85.48	$93.86	$139.71
Not less than 2 hours which reflects highest electricity demand on Ergon energy network (6 pm – 8 pm)	Peak	$98.96	$105.19	$111.38	$155.79	$163.48	$227.44	$249.18	$357.04
	Off-peak	$61.61	$63.68	$64.68	$71.99	$74.95	$88.32	$97.23	$145.76
5 pm – 7 pm	Peak	$104.95	$112.83	$121.09	$176.23	$183.44	$258.77	$286.23	$423.62
	Off-peak	$61.06	$62.99	$63.80	$70.13	$73.13	$85.48	$93.86	$139.71
4 pm – 7 pm	Peak	$97.68	$104.09	$110.35	$160.17	$170.20	$243.84	$276.55	$423.61
	Off-peak	$60.01	$61.86	$62.60	$67.37	$69.77	$79.36	$86.08	$126.19
3 pm – 7 pm	Peak	$89.71	$95.22	$100.39	$142.84	$153.62	$222.11	$255.38	$405.85
	Off-peak	$59.72	$61.52	$62.21	$66.20	$68.07	$75.48	$80.79	$114.87

SOURCE: ACIL ALLEN ANALYSIS

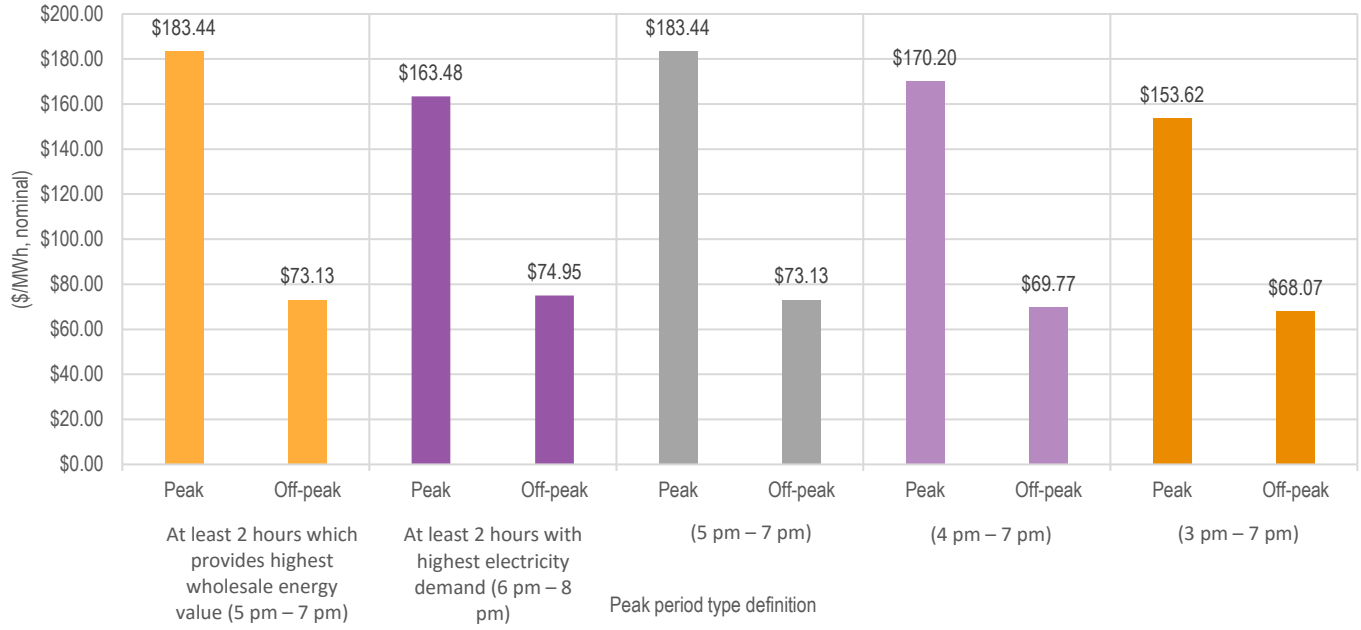
FIGURE 4.7 PROJECTED ANNUAL WHOLESALE ELECTRICITY PRICE VALUE IN QUEENSLAND IN 2017-18 BY PERIOD TYPE DEFINITION ($/MWH, NOMINAL)



SOURCE: ACIL ALLEN ANALYSIS

Figure 4.8 compares the projected annual price for the different period type definitions. The graph shows that the 5 pm to 7 pm definition provides the highest peak price, and that by extending this definition to include 4 pm and 3 pm progressively decreases the peak price.

FIGURE 4.8 PROJECTED ANNUAL AVERAGE WHOLESALE ELECTRICITY PRICE VALUE IN QUEENSLAND IN 2017-18 BY PERIOD TYPE DEFINITION ($/MWH, NOMINAL)



SOURCE: ACIL ALLEN ANALYSIS

4.5 Estimation of other energy costs

ACIL Allen's estimates of the NEM and ancillary services fees from our engagement for the final determination of the 2017-18 regulated retail prices[2] are:

- NEM fees: $0.53/MWh
- Ancillary Service fees: $0.34/MWh.

ACIL Allen's estimate of the total loss factor for the Ergon Energy east zone from our engagement for the final determination of the 2017-18 regulated retail prices is:

- 1.079.

4.6 Summary of the final estimated values for the Ergon Energy east zone

Taking account of the projected mean spot wholesale price values together with our estimates of NEM and ancillary services fees, as well as the total losses for the Ergon Energy east zone, we estimate the final values as shown in Table 4.2.

[2] http://www.qca.org.au/getattachment/f86e85e9-6969-49e3-a888-3a91889af9c3/ACIL-Allen-cost-of-energy-report-final-determinati.aspx

TABLE 4.2 BUILD UP OF PROJECTED ANNUAL WHOLESALE ELECTRICITY PRICE VALUE IN QUEENSLAND IN 2017-18 BY PERIOD TYPE DEFINITION ($/MWH, NOMINAL) – FOR ERGON ENERGY EAST ZONE

Peak period definition	Period	Wholesale spot value at RRN	Wholesale spot value plus NEM and Ancillary Service fees – at RRN	Value of Total losses	Final estimate
Not less than 2 hours which provides highest wholesale energy value (5 pm – 7 pm)	Peak	$183.44	$184.31	$14.56	$198.87
	Off-peak	$73.13	$74.00	$5.85	$79.85
Not less than 2 hours which reflects highest electricity demand on Ergon energy network (6 pm – 8 pm)	Peak	$163.48	$164.35	$12.98	$177.33
	Off-peak	$74.95	$75.82	$5.99	$81.81
5 pm – 7 pm	Peak	$183.44	$184.31	$14.56	$198.87
	Off-peak	$73.13	$74.00	$5.85	$79.85
4 pm – 7 pm	Peak	$170.20	$171.07	$13.51	$184.58
	Off-peak	$69.77	$70.64	$5.58	$76.22
3 pm – 7 pm	Peak	$153.62	$154.49	$12.20	$166.69
	Off-peak	$68.07	$68.94	$5.45	$74.38

SOURCE: ACIL ALLEN ANALYSIS