Office of Energy and Climate Change

Sample study

PIAM&V Method Application Requirements for Non-Routine Events and Adjustments

October 2022

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Title Sample study on PIAM&V Method Application Requirements for Non-Routine Events and Adjustments

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Summary

This case study illustrates how to use the PIAM&V method to determine Energy Savings for an Implementation when a Non-Routine Event (NRE) has occurred within the Measurement Boundary. The process in this case study follows the PIAM&V Method Application Requirements for Non-Routine Events and Adjustments (referred to as the “NRE-A Requirements”).

A hotel in Sydney has its chiller replaced. The replacement occurs shortly before the COVID-19 pandemic had significant impacts on the hotel operation. To determine Energy Savings using the PIAM&V method, the NRE-A Requirements must be followed.

The introduction section of this document provides background information about the site and describes the impact of the COVID-19 pandemic. The proceeding sections will then describe the available site data and how the NRE was identified. The document will then go through the provisions of the NRE-A Requirements step by step to undertake the appropriate Non-Routine Adjustment (NRA).

Introduction

The Recognised Energy Saving Activity (RESA) was an upgrade involving the replacement of an existing chiller within the heating, ventilation, and air conditioning (HVAC) system at the hotel.

The Implementation Date was 3 December 2019.

Due to the COVID-19 pandemic and the relevant public health orders the hotel was turned into a quarantine hotel starting from the end of March 2020.

Due to these changes, significant operational impacts across the entire building were identified, including:

- A drop in the number of registered occupants
- Occupants being required to remain in their rooms at all times
- Meals were prepared offsite and supplied frozen to those in hotel quarantine
- Conferences and other social events were suspended

The impact of the energy efficiency upgrade and the COVID-19 pandemic on the chiller's electricity consumption can be seen in **Figure 1** below.

Missing sub-meter chiller electricity consumption data can also be seen in **Figure 1** between 17 October 2018 and 24 January 2019.

As can be seen in **Figure 2**, there is a significant drop in the chiller electricity consumption after the upgrade. However, this drop cannot be clearly discerned whether it is due to the chiller upgrade or due to the impacts of COVID-19.

COVID-19 impacts on the hotel operation must be assessed as a potential Non-Routine Event (NRE) to help determine Energy Savings from the chiller upgrade.

This case study will investigate the use of the NRE-A Requirements document to address the impacts of COVID-19 on the hotel's operation.

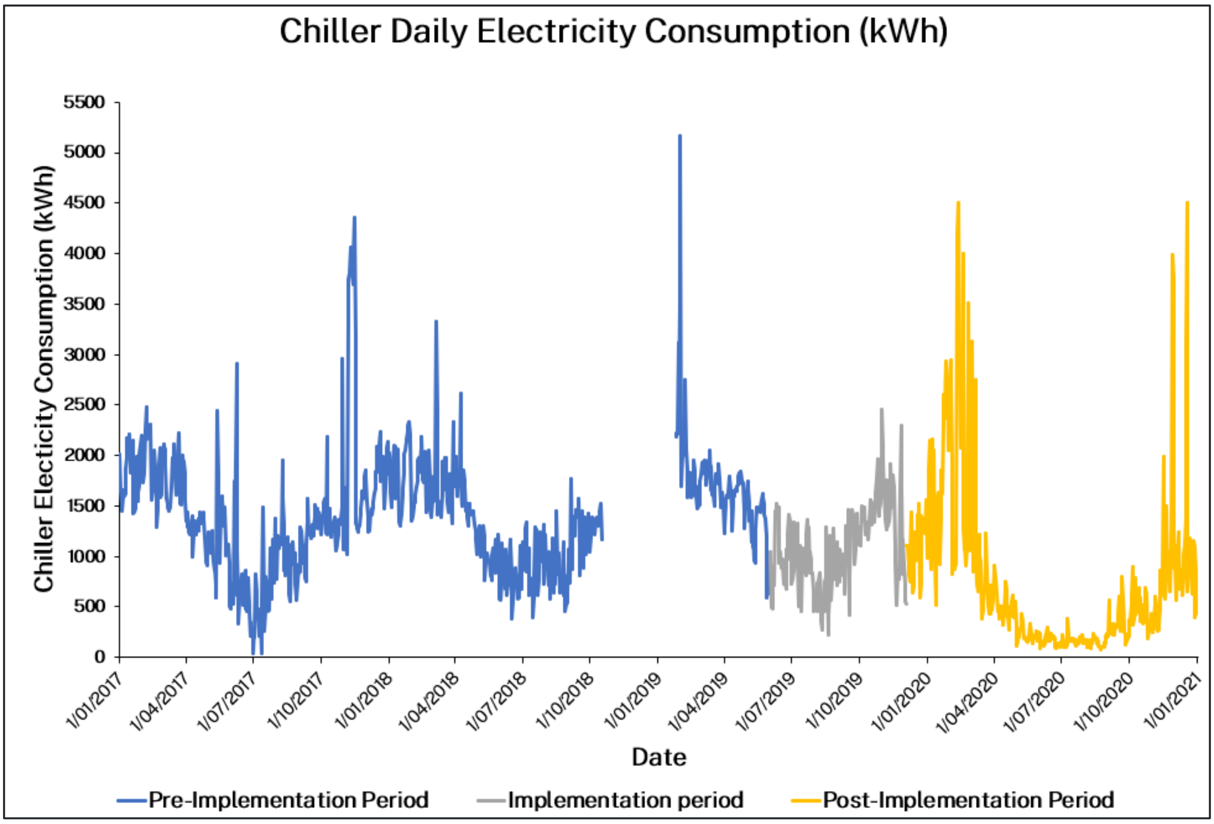

Figure 1: Chiller's daily electricity consumption

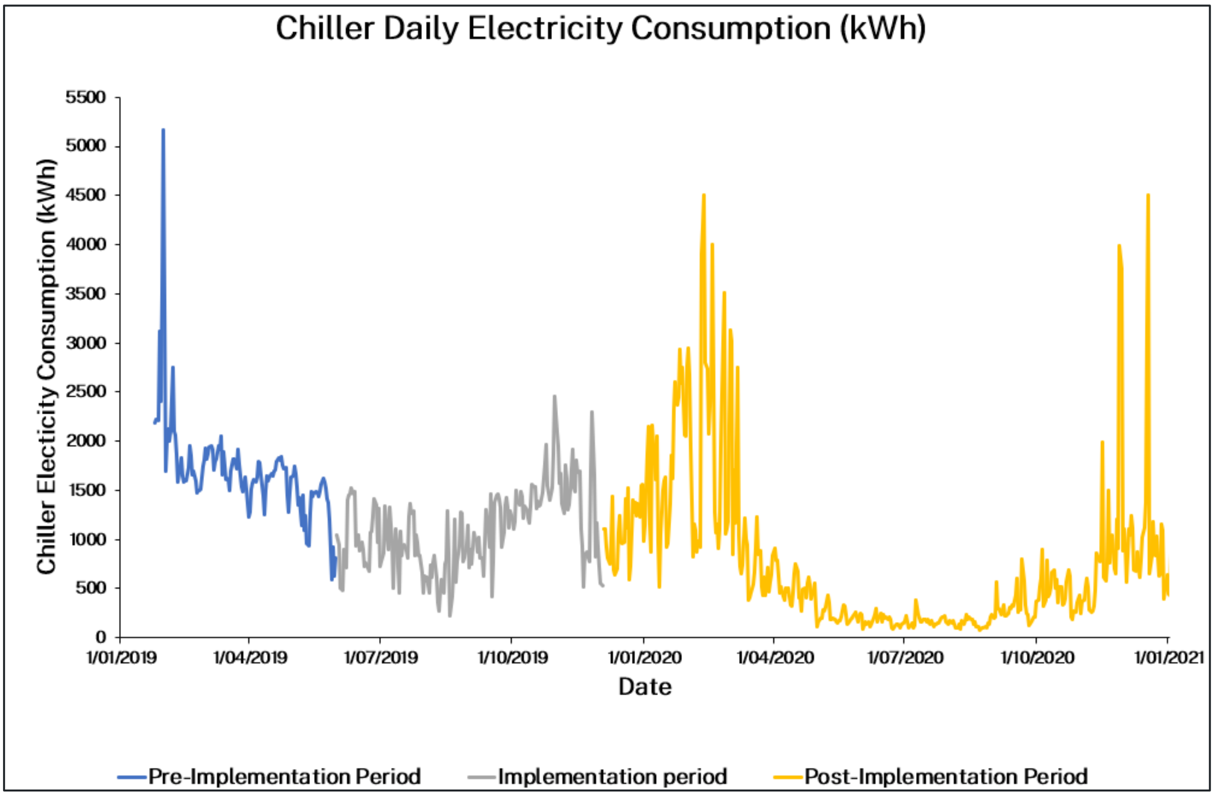

Figure 2: Drop in chiller's electricity consumption due to the implementation and/or COVID-19 impacts

Project data identification

Available data

The chiller electricity consumption data was sub-metered as depicted in **Figure 1**. Information on the available data for the dependent variable (chiller electricity consumption) and potential Independent Variables is provided in **Table 1** below.

Table 1: Available information on electricity consumption and potential Independent Variable data

Data	Data source	Data frequency	Nominal Dates covered	Periods of missing data
Chiller electricity consumption (kWh)	Hotel sub-meter	Daily	1 Jan 2017 to 6 May 2022	17 Oct 2018 to 24 Jan 2019
Occupancy	Hotel registration records	Monthly	Jan 2017 to April 2022	None
Level 2 kitchen hot water (kL)	Hotel sub-meter	Daily	1 Jan 2017 to 6 June 2022	Multiple*
Level 3 kitchen hot water (kL)	Hotel sub-meter	Daily	8 July 2018 to 13 June 2022	Multiple*
Level 2 kitchen cold water (kL)	Hotel sub-meter	Daily	1 Jan 2017 to 16 June 2022	Multiple*
Level 3 kitchen cold water (kL)	Hotel sub-meter	Daily	1 Jan 2017 to 16 June 2022	11 to 13 Sept 2021
Level 4 gym hot water (kL)	Hotel sub-meter	Daily	1 Jan 2017 to 13 June 2022	Multiple*
Level 4 gym cold water (kL)	Hotel sub-meter	Daily	1 Jan 2017 to 22 May 2022	16 to 30 Oct 2019, 11 to 13 Sept 2021
Ambient temperature - Min (Degree C)	Closest BOM weather station	Daily	1 Jan 2017 to 20 June 2022	Multiple*
Ambient temperature - Max (Degree C)	Closest BOM weather station	Daily	1 Jan 2017 to 20 June 2022	None
Rainfall (mm)	Closest BOM weather station	Daily	1 Jan 2017 to 20 June 2022	None
Solar exposure (MJ/m^2)	Closest BOM weather station	Daily	1 Jan 2017 to 20 June 2022	26 Nov 2017, 2 Feb 2022

* Multiple means many consecutive days over several periods

Project's Site Constants:

1. Number of rooms
2. Chilled water set point

Measurement Boundary:

- The entire cooling system of the hotel that is serviced by the chiller (IPMVP Option B – retrofit isolation, all parameter measurement).

Possible Independent Variables:

The daily minimum and maximum ambient temperatures can be used to calculate the daily average temperature (by taking the average of the two).

Daily average temperature values are then used to determine Cooling Degree Days (CDD) and Heating Degree Days (HDD) which can be used as Independent Variables.

The weather data included rainfall and solar exposure. However, when considered as potential Independent Variables, they resulted in unacceptable t-statistics.

As seen in **Table 1**, significant data gaps mean that the following variables cannot be considered as suitable Independent Variables:

- Level 2 kitchen hot water (kL)
- Level 3 kitchen hot water (kL)
- Level 2 kitchen cold water (kL)
- Level 4 gym hot water (kL)

Note that no data was available on the chiller's thermal load.

Monthly hotel occupancy records and daily water consumption data (hot and cold water) in various parts of the hotel may be used as Independent Variables.

NRE identification

The nature, duration, and permanence of the NRE

The NRE came into effect during March 2020. As shown in **Figure 3**, the hotel occupancy had still not returned to pre-COVID levels as of April 2022.

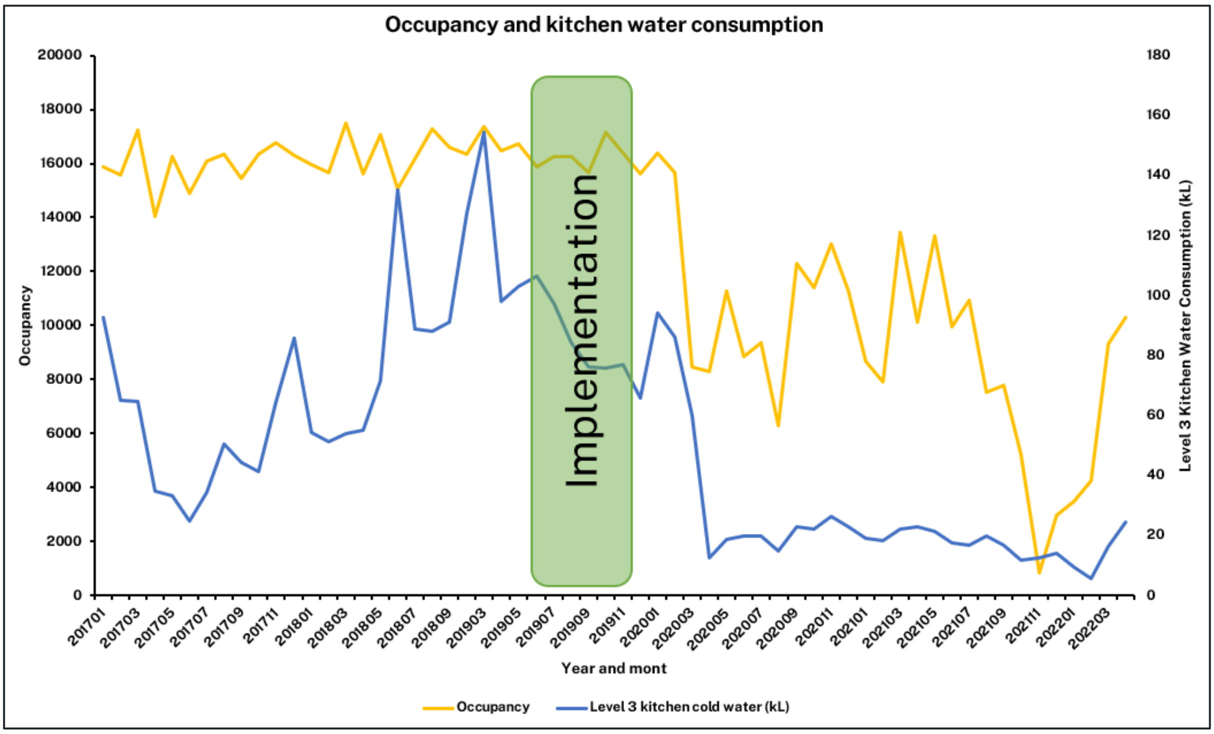

Figure 3: Occupancy and kitchen cold water consumption over time

The root cause and specific cause of the NRE are shown in **Table 2**.

Table 2: Root cause and specific cause of the NRE

Identification of the Non-Routine Event	
Root cause	**Specific cause**
COVID-19 Pandemic	Changes in occupancy patterns (figure 2)

For the purpose of using the Project Impact Assessment with Measurement and Verification (PIAM&V) method to calculate Energy Savings and create Energy Savings Certificates (ESCs), the NRE could be considered as permanent.

However, it would also be reasonable to expect that the hotel occupancy will eventually return to pre-COVID levels, with public health orders and travel restrictions largely removed.

For the sake of this example however, we chose not to wait for occupancy to fall back to pre-COVID "normal" and continued to use the NRE-A Requirements.

Evidence of the NRE

Evidence of the NRE includes:

- Public health orders,[1] for example:
  - 20 March 2020, international arrivals closed to non-citizens and non-residents.
  - 27 March 2020, all arrivals in Australia required to undertake mandatory 14 days self-isolation at designated quarantine facilities.
  - 30 April 2022, lifting of mandatory quarantine for international arrivals.
- The change in site occupancy, coincident with the start of COVID impacts as shown in **Figure 3**.

[1] For reference: https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp2021/Chronologies/COVID-19AustralianGovernmentAnnouncements

Following the NRE-A Requirements

Since the COVID-19 pandemic impacts started immediately after the upgrade, impacting the Measurement Period for the Operating Energy Model, the NRE-A requirements must be followed.

The flowchart in **Figure 4** below shows the steps to follow when applying the NRE-A Requirements. Drawn in dotted black lines over the flowchart are the steps followed in this case study. Each step from the “Summary of Requirements” section in the NRE-A Requirements document is explained in more detail in the following text.

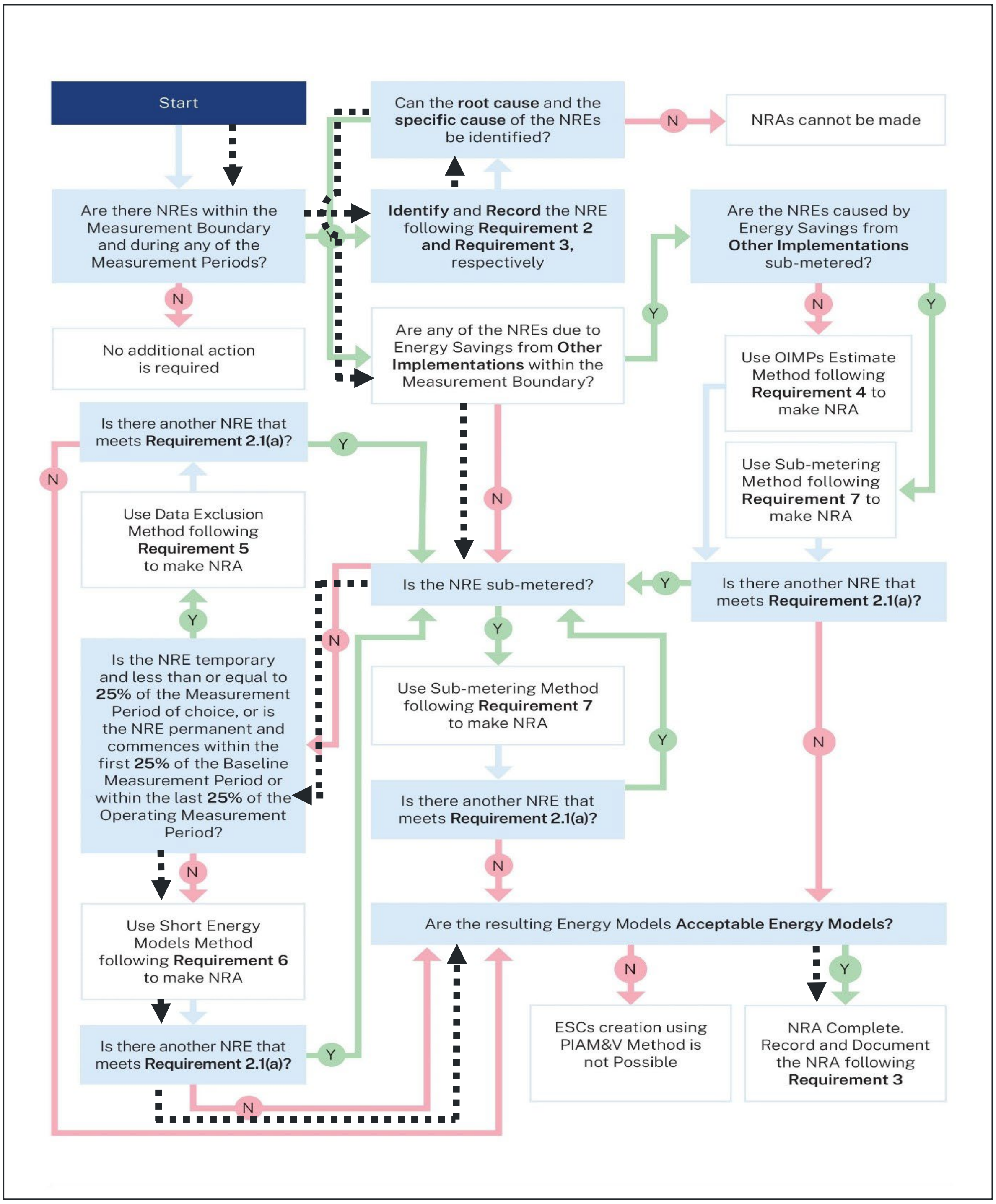

Figure 4: Application of the NRE-A Requirements flowchart to the hotel example

***STEP 1** Can the Observations impacted by the NREs be avoided in the Energy Models' Measurement Periods by waiting until the changes in energy consumption caused by the NREs are concluded?*

No. For the purpose of this example, the option of waiting until changes in energy consumption caused by the NRE are concluded is not considered.

***STEP 2** Identify any changes in energy consumption that amount to NREs in accordance with Requirement 2. Any of the following will constitute NREs:*

(a) Temporary or permanent events affecting energy consumption that are not modelled by any of the Independent Variables or the Site Constants.
(b) Energy Savings from Other Implementations (OIMPs).

As discussed above, COVID-19 has caused permanent changes in the hotel occupancy. These changes could not be modelled by any of the Independent Variables or Site Constants. Therefore, Requirement 2(a) applies.

Additionally, requirement 2.4 in the NRE-A Requirements states that "If any Measurement Period occurs during COVID, an ACP must provide evidence of whether COVID has caused any NREs and define the COVID-Impacted Period."

***STEP 3** Can the root causes and specific causes of the NREs be identified?*

(a) If "yes", then record the root causes and specific causes of the identified NREs in accordance with Requirement 3, then go to step 4.
(b) If "no", then NRAs cannot be made.

Yes. In this case, COVID has impacted the hotel operation as a root cause with the specific cause identified as the changes in occupancy as depicted in **Figure 5**.

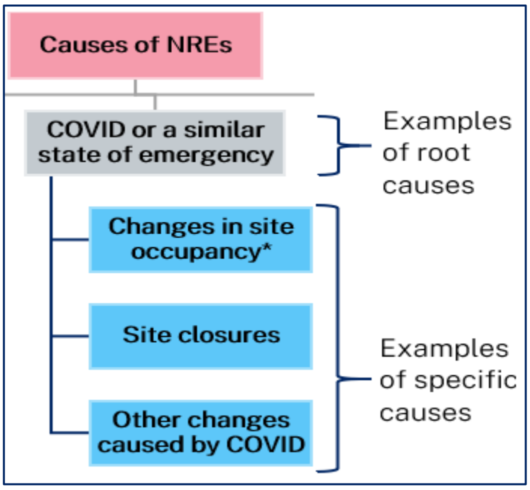

Figure 5: Examples of root and specific causes of NREs (Part of Figure 2 - NRE-A Requirements)

As explained above, public health orders and records of changes in site occupancy coincident to the start of COVID impacts as shown in **Figure 3** are used as evidence.

***STEP 4** Are any of the identified NREs caused by Energy Savings from OIMPs within the Measurement Boundary as per Requirement 2.1(b)*

No. The NRE is not caused by Other Implementations (OIMPs).

If "No", then go to step 6.

STEP 5 *Is there another NRE that meets Requirement 2.1(a)?*

This step is skipped (as per the answer to Step 4)

STEP 6 Is the NRE sub-metered?

No. There is no sub-metering installed to measure the impacts of the NRE. COVID has impacted the entire hotel operation, including occupancy.

STEP 7 *(Testing for the Data Exclusion Method)*

Is the NRE temporary and amounting to less than or equal to 25% of the Measurement Period of choice? Or is the NRE permanent and commencing within the first 25% of the Baseline Energy Model Measurement Period or within the last 25% of the Operating Energy Model Measurement Period?

No to either scenario. As discussed above, the COVID impact is considered permanent, as was shown in **Figure 2**. Occupancy is below the expected values for the entire operating period following the start of COVID. Therefore, the NRE did not commence within the last 25% of the Operating Energy Model Measurement Period.

STEP 8 *Use the Short Energy Models Method in accordance with Requirement 6 to make NRAs, then go to step 5.*

In this case the Short Energy Models Method is applied as described in the following section. There are no other NREs, so it is not necessary to return to step 5.

STEP 9 *Finally, are the resulting Energy Models Acceptable Energy Models in accordance with 7A.5B1(c) of the ESS Rule?*

(a) If "yes", then go to step 10.
(b) If "no", then Energy Savings Certificates (ESCs) cannot be created.

Yes. The Short Energy Models satisfy the minimum statistical requirement as per Table A22 of Schedule A to the ESS Rule (as shown in **Table 3**). Level 3 kitchen cold water usage was used as a proxy Independent Variable to probe changes in hotel occupancy.

Table 3: Summary of the Short Energy Models statistical analysis

	Baseline		Operating		Acceptable requirements
Number of observations	11		9		Number of observations > 4 x Number of Independent Variables
Adjusted R^2	0.825		0.685		> 0.5
CV_{RMSE}	0.041		0.199		< 0.2
	Level 3 kitchen cold water (kL)	CDD	Level 3 kitchen cold water (kL)	CDD	
t-statistic	-2.7	7.0	2.0	4.3	Absolute Value > 2

***STEP 10** Record and maintain documentary evidence of all adjustments to the NREs in accordance with Requirement 3.*

Documentary evidence includes:

- Occupancy records
- Energy data
- Independent Variables data

Application of Requirement 6 - Short Energy Models Method

To make an NRA using the Short Energy Models method, both Measurement Periods must either be "inside" or "outside" the NRE – which is the COVID-19 impacted period. This is in accordance with Requirement 6.4.

Since the baseline is entirely outside of COVID-19, the Short Energy Models Measurement Periods must both be outside of COVID-19.

Short Energy Models

Operating Measurement Period

The Operating Energy Model Measurement Period outside the NRE (before COVID-19 impacts) was chosen to be from 5/12/2019 to 14/3/2020.

It was not possible to build an acceptable Operating Energy Model using daily data. It is possible, however, to build an acceptable weekly Operating Energy Model using part of the data before the COVID-19 period (**Figure 6**).

CDD and kitchen 3 cold water are used as Independent Variables.

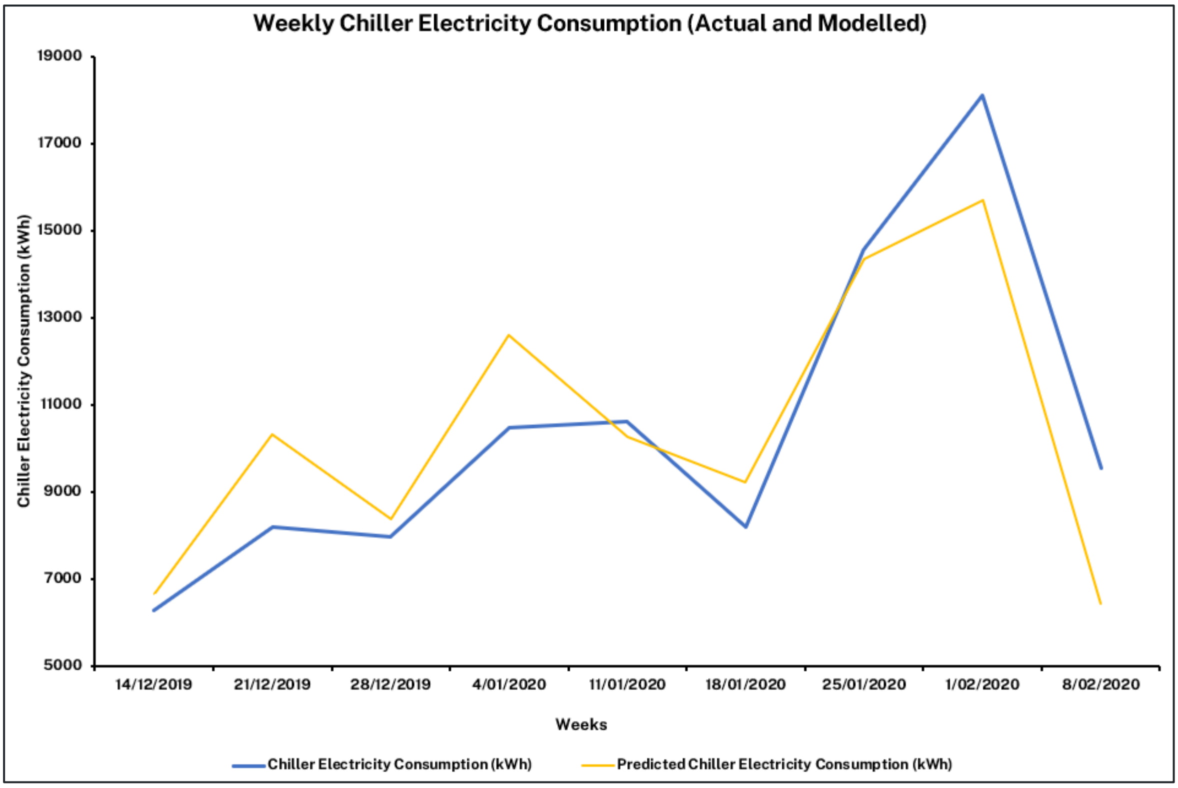

Figure 6: Weekly Short Operating Energy Model

Baseline Measurement Period

In accordance with Requirements 6.9 and 6.10, the Baseline Energy Model Measurement Period must cover a time period with a similar season and range of Independent Variables, and a similar length to that used in the Operating Energy Model Measurement Period.

It was possible to identify such a period and build an acceptable weekly Baseline Energy Model using the same Independent Variables of the Operating Energy Model as shown in **Figure 7** below.

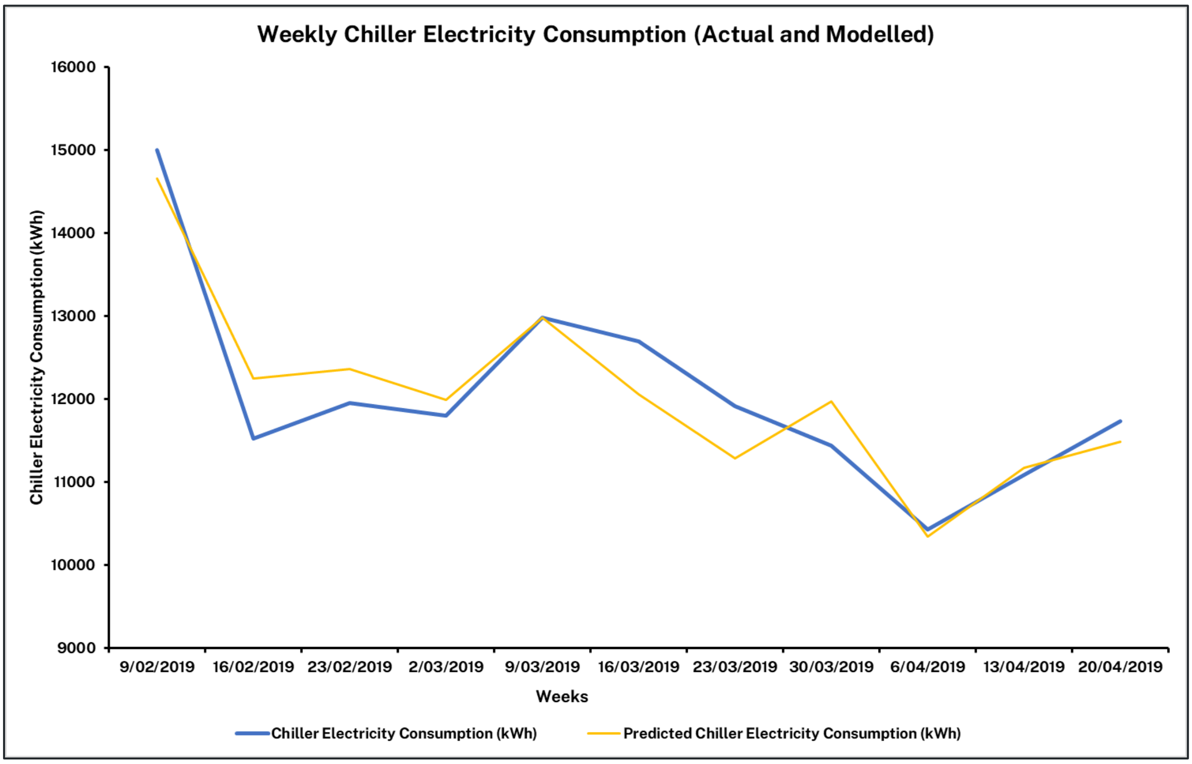

Figure 7: Weekly Short Baseline Energy Model

Normal Year

The Normal Year is selected as 2017.

Note that the Normal Year must be chosen to be before the COVID-19 impact. This is to be consistent with the basis on which the Short Energy Models have been developed where both Short Energy Models must be outside of COVID-19 impacts.

Short Energy Models analysis

The two Short Energy Models are compared in **Table 4** below. The models:

- Cover less than 75% of a Full Operating Cycle (as per Requirement 6.8)
- The ranges of Independent Variables are similar (as per Requirement 6.9)
- The length of the shorter Measurement Period of one Energy Model is at least 70% of the Measurement Period of the other Energy Model (requirement 6.10)

Table 4: Short Energy Models comparison

Condition	Baseline		Operating		Normal year	
Number of Observations	11		9		52	
Number of Independent Variables	2		2			
Are number of Observations > 4 times the number of Independent Variables?	Yes		Yes			
	Level 3 kitchen cold water (kL)	CDD	Level 3 kitchen cold water (kL)	CDD	Level 3 kitchen cold water (kL)	CDD
Minimum value of Independent Variable	18.1	33.2	12.2	51.9	3.7	0
Maximum value of Independent Variable	39. 5	81.7	25.7	87.5	25.2	91.7

Energy Savings calculation

When selecting 2017 as the Normal Year and applying the Effective Range Adjustment Factor (ERAF), the Energy Savings are 56,140 kWh. The Energy Savings would have only been 8,236 kWh without applying the ERAF.

The Effective Range calculations of the two Short Energy Models are shown in **Table 5**.

Table 5: Effective Range of the Short Energy Models

	Level 3 kitchen cold water (kL)	CDD
Baseline		
Minimum value	18.1	33.2
Maximum value	39. 5	81.7
Range	21.4	48.5
Lower limit	17.0	30.8
Upper limit	40.5	84.1
Effective Range	23.5	53.3
Operating		
Minimum value	12.2	51.9
Maximum value	25.7	87. 5
Range	13.5	35.6
Lower limit	11. 5	50.1
Upper limit	25.7	87.4
Effective Range	14.2	37.3

Table 6 below, shows the Energy Savings in each week of the Normal Year.

Table 6: Calculations of Normalised Energy Savings using the Short Energy Models method

Week ending	Level 3 kitchen cold water (kL)	CDD	Adjusted baseline chiller electricity consumption (kWh)	Adjusted operating chiller electricity consumption (kWh)	Normalised savings within effective range Chiller Sub-meters (kWh)	Normalised savings with ERAF (kWh)
7/01/2017	21.100	55.50	12,915	8,748	4,166	4,166
14/01/2017	22.185	84.75	15,213	16,662	-	- 1,398
21/01/2017	19.020	77.35	14,845	13,772	1,073	1,073
28/01/2017	20.790	72.05	14,283	12,942	1,341	1,341
4/02/2017	19.970	77.95	14,823	14,219	604	604
11/02/2017	16.365	91.65	16,204	16,662	-	- 264
18/02/2017	**14.425**	**66.00**	**14,261**	**9,418**	**-**	**3,229**
25/02/2017	16.165	56.85	13,388	7,581	-	5,161
4/03/2017	14.585	52.10	13,119	5,865	-	4,984
11/03/2017	12.520	40.40	12,320	2,198	-	2,572
18/03/2017	16.220	59.55	13,604	8,298	-	4,753
25/03/2017	15.855	66.45	14,192	9,974	-	3,582
1/04/2017	14.425	55.45	13,403	6,684	-	4,480
8/04/2017	8.925	29.35	11,686	1,771	-	-
15/04/2017	4.535	23.30	11,518	4,688	-	-
22/04/2017	9.890	37.75	12,298	703	-	589
29/04/2017	8.140	25.80	11,456	2,932	-	-
6/05/2017	7.690	22.50	11,220	3,926	-	-
13/05/2017	5.080	7.40	10,185	8,641	-	-
20/05/2017	8.875	15.85	10,592	5,285	-	-
27/05/2017	10.800	15.45	10,418	4,797	-	-
3/06/2017	7.935	2.45	9,572	9,047	-	-
10/06/2017	4.840	0.80	9,666	10,425	-	-
17/06/2017	5.935	2.70	9,740	9,596	-	-
24/06/2017	5.540	0.20	9,566	10,366	-	-
1/07/2017	3.910	-	9,670	10,919	-	-
8/07/2017	3.655	2.25	9,871	10,414	-	-
15/07/2017	8.105	-	9,360	9,629	-	-
22/07/2017	7.760	0.90	9,459	9,502	-	-
29/07/2017	13.205	2.60	9,195	7,388	-	-
5/08/2017	5.975	4.95	9,920	9,001	-	-
12/08/2017	16.905	10.20	9,540	4,281	-	-
19/08/2017	10.780	8.70	9,870	6,552	-	-
26/08/2017	10.870	-	9,156	8,780	-	-
2/09/2017	8.980	-	9,296	9,360	-	-
9/09/2017	11.920	11.40	10,006	5,502	-	-
16/09/2017	10.710	24.20	11,136	2,557	-	-
23/09/2017	11.615	22.90	10,963	2,616	-	-
30/09/2017	8.415	42.75	12,814	1,545	-	-
7/10/2017	7.545	24.85	11,422	3,361	-	-
14/10/2017	8.780	41.65	12,697	1,372	-	-
21/10/2017	10.620	34.60	11,988	111	-	-
28/10/2017	9.230	35.20	12,139	161	-	-
4/11/2017	13.130	40.55	12,287	2,424	-	2,620
11/11/2017	13.710	23.55	10,862	1,803	-	-
18/11/2017	16.430	40.95	12,076	3,542	-	2,529
25/11/2017	12.545	46.95	12,850	3,903	-	3,819
2/12/2017	25.240	64.15	13,312	12,262	1,050	1,050
9/12/2017	24.830	47.05	11,952	7,704	-	3,247
16/12/2017	16.755	68.00	14,252	10,652	-	3,470
23/12/2017	14.250	77.25	15,189	12,280	-	1,874
30/12/2017	15.295	72.15	14,697	11,279	-	2,658
Total					8,236	56,140

The following example uses one observation (week 18/2/2017) to illustrate the process of calculating the ERAF.

In accordance with Requirement 6.12, the ERAF is calculated using the following formula

$$\text{ERAF} = 1 - |3.0 * \text{POER}|$$

Where POER is the Percentage Outside Effective Range. The POER is calculated using the following formulas

$$POER = \frac{Min-a}{R}; \qquad Or \qquad POER = \frac{b-Max}{R}$$

Where, as per Requirement 6 text:

Min: is the minimum value of the Short Energy Model's Effective Range.

Max: is the maximum value of the Short Energy Model's Effective Range.

a: is the value of the Independent Variable of a time period at the Modelling Frequency where the Independent Variable is less than the minimum value of the Short Energy Model's Effective Range.

b: is the value of the Independent Variable of a time period at the Modelling Frequency where the Independent Variable is greater than the maximum value of the Short Energy Model's Effective Range.

R: is the range of the Short Energy Model's Effective Range determined as follows:

$$R = Max - Min$$

As per Table 5, the values of the Independent Variables for the week 18/2/2017 were: Level 3 kitchen cold water = 14.4 and CDD = 66.

Level 3 kitchen cold water value was outside the Baseline Energy Model's Effective Range, while the CDD value was not. Therefore, the POER can be calculated as follows:

$$POER = \frac{Min - a}{R} = \frac{17 - 14.4}{23.5} = 0.11$$

Therefore, $POER_{Max} = 0.11$

Therefore, the ERAF can be calculated as follows:

$$\text{ERAF} = 1 - |3.0 * 0.11| = 0.67$$

Finally, Table 7 below summarizes the Energy Savings calculation using the ERAF:

Table 7: Example calculation of Energy Savings for one Observation (Week) using the ERAF

Adjusted baseline chiller electricity consumption (kWh)	**14,261**
Adjusted operating chiller electricity consumption (kWh)	9,418
Savings without using the ERAF (kWh)	4,843
Savings after applying the ERAF (kWh)	$4{,}843 * 0.67 = 3{,}229$