

# Assessment of TMY versus actual year solar generation and the suitability of TMY generation for assessment of residential solar performance

Accompanying Appendix Two to

Understanding the value of residential solar PV and storage in New Zealand

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Authors

Dr Allan Miller<sup>1</sup>, Dr Tim Crownshaw<sup>2</sup>, and Dr Gareth Gretton<sup>2</sup>

<sup>1</sup>www.millercl.co.nz

<sup>2</sup>EECA



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# Disclaimer

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# 1 Introduction

Throughout the analysis, the solar generation used is from a typical meteorological year (TMY), rather than the year from which the load profile has been selected. The reason for this is that solar generation varies from year to year, in the order of ±5-10% from a TMY depending on the year. The cash flow at the core of the solar model replicates the analysis, using the solar data, over 29 years. Any bias, up or down, in solar generation data from the same year as the load profile will be replicated and result in an accumulated error. Thus, the choice of a TMY should remove any such bias and accumulated error.

However, there is a concern that the use of a TMY solar generation may remove any inverse correlation of load with solar generation, and thereby introduce another error. The inverse correlation may exist from lowering electricity demand as sun rises due to such things as less lighting, less heating, and lower occupancy during the daytime.

This appendix investigates whether there could be a significant error introduced by using TMY solar generation. It approaches this in two ways, set out below:

- It begins by investigating the correlation between load and solar for all 47,045 load profiles. Section 2 sets out the reasons for this investigation, presents the results, and discusses the results.
- 2. Self-consumption and export with both TMY and 2023 solar data are examined. Section 3 sets out the reasoning behind this investigation, presents the results and a discussion.

The report is concluded with the findings of the suitability of TMY generation for assessment of residential solar performance.



# 2 The relationship between load and solar generation

# 2.1 Aim and method

Earlier, the idea that load and solar generation may be inversely correlated was introduced. Such an inverse correlation may affect the results of solar analysis if TMY solar generation is used rather than the solar generation that corresponds to the same time as the load, not to mention the same location. This section tests whether there is an inverse correlation between load and solar generation, the extent of the correlation, and whether this is consistent across all loads. By extension, if such a relationship does exist, it may be possible to give a qualitative statement on how this affects the analysis of solar when using TMY data. This section does not set out to quantify the effect on the analysis of solar, it simply tests for a consistent inverse correlation. Section 3 attempts to quantify any effect of correlation.

The correlation between load and solar for each of the 47,045 load profiles, by city and cluster, for both TMY and actual 2023 solar generation is assessed. This is then presented by:

- 1. The distributions of correlation coefficients of each individual load with TMY and 2023 solar generation from the corresponding city (Sub-section 2.2).
- 2. The distributions of the difference between the correlation coefficients of load correlated with TMY and 2023 solar generation from the corresponding city. These are also for each individual load (Sub-section 2.3).
- 3. Mean correlation values with correlations taken over daily load and generation, rather than half-hourly load and generation (Sub-section 2.4).
- 4. Finally, the correlations of load with solar generation over each city are assessed. In this case, TMY and 2023 solar generation are used, and the individual loads selected to represent each cluster and annual consumption are used (Sub-section 2.5).

In all correlations the Pearson correlation coefficient is used. Spearman and Kendall Tau correlation were attempted, but produced non sensical results. In the case of Spearman, this is likely due to the solar-load relationship not being monotonic.

Further, solar generation values of zero have been removed from the correlations because only the correlation when solar is generating is of interest.

# 2.2 Distributions of correlation coefficients over all load profiles

Figure 1 to Figure 4 show the distributions of correlation of load with solar generation for each load by cluster. These show the following:

- 1. In all cases the mean and median values of the correlations are negative. This means that load decreases as solar generation increases.
- 2. However, the mean and median values of the correlations are weak, according to the classifications in Table 1 below.
- 3. The strength of the correlations of load with both TMY and 2023 solar generation remain in the 'weak' range within the upper and lower quartiles.
- 4. However, correlations are almost always negative within the upper and lower quartiles.



- 5. In all cases the mean and median values of the correlations increase in magnitude of slope (they become more negative) when the 2023 solar generation is used.
- 6. There is considerable variation in correlation outside of the upper and lower quartiles, where some load has a medium negative correlation with solar generation, and some outliers have a medium positive correlation with solar generation.
- 7. There is variation between the mean correlations of the clusters, although they are always within the weak negative correlation range.
- 8. The correlations of load and solar in Queenstown appears to be stronger than the other cities, although they are still predominantly weak correlations. The exception to this is Cluster 3, which appears to have a milder correlation in Queenstown compared to the other cities. However, there are only 38 load profiles from Queenstown in Cluster 3, which may skew the results. Cluster 3 has low a daytime ratio, low morning peak ratio, and medium evening peak ratio, as set out in the "Selection of representative load profiles" appendix (Appendix Six).

### Table 1: Correlation strengths.

# **Correlation strengths**

Strength	Positive	Negative
Very weak	0.05	-0.05
Weak	0.20	-0.20
Medium	0.40	-0.40
Strong	0.75	-0.75

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Figure 2: Wellington correlation of load with solar.





Figure 3: Christchurch correlation of load with solar.



Figure 4: Queenstown correlation of load with solar.



# 2.3 Distributions of differences in correlation coefficients over all load profiles

The distributions of differences between correlation of load with 2023 solar generation and load with TMY solar generation are shown in Figure 5 to Figure 8. These results require careful interpretation, since they give the difference in slope between two often negative slopes.

- A negative difference indicates a shift of 2023 solar generation towards greater inverse correlation of load and solar, or a reduction in the correlation of load and solar if the correlation with TMY was positive.
- A Positive difference indicates a shift of 2023 solar generation towards greater correlation of load and solar, or a weakening of the inverse correlation of load and solar if the correlation with TMY was negative.

These present the information from the previous section in a different way, by assessing the difference in correlation coefficient for each individual load, then showing the distribution of differences. This provides more information by combining the TMY and 2023 solar generation. That is because it is not possible to consider the difference from individual points on the box-whisker plots from the previous section, as it is not known which points correspond to the same load profile. For example, it is not known whether the same load profile gave rise to the points that make up the median of each boxwhisker plot in Figure 1. Taking the difference between the TMY and 2023 correlations means that each point in Figure 5, for example, relates to the same load profile. The findings are the same, with the addition of:

9. Differences in correlations are usually negative, meaning that there is more inverse correlation of load and solar when solar generation from the same period as load is used. However, the differences are small and remain within the weak correlation range.





Figure 5: Auckland difference between correlation of load with 2023 solar and TMY solar generation.



Difference in correlations of Wellington load with solar, all solar above zero, full year,

Figure 6: Wellington difference between correlation of load with 2023 solar and TMY solar generation.





Figure 7: Christchurch difference between correlation of load with 2023 solar and TMY solar generation.



Difference in correlations of Queenstown load with solar, all solar above zero, full year,

Figure 8: Queenstown difference between correlation of load with 2023 solar and TMY solar generation.



# 2.4 Comparison of correlations over half-hourly and daily load and generation

The correlations presented in the previous sub-sections are of load and solar at half-hourly intervals. It was suggested that correlation over a longer period might produce more meaningful results since the effect of solar irradiation on temperature, and therefore on reducing load, may be more apparent. Table 2 gives the mean values of the correlations using half-hourly data, while Table 3 gives the mean values of the correlations using daily means of load and solar generation.

In general, the inverse correlations increase in strength with the daily mean values, although the increase is not consistent across clusters and cities (some actually decrease in strength for example). The main findings from the previous sub-sections hold.

As noted earlier in Sub-section 2.1, solar generation values of zero have been removed from the correlations because only the correlation when solar is generating is of interest. While tangential to the analysis, if solar values of zero are considered with half-hourly correlations, the inverse correlations shown generally weaken. This is due to generally lower load during night times, which correlates with no solar generation during the night. However, if daily intervals are used and night-time solar generation is considered, the inverse correlation between load and solar strengthens to medium values. The reason for this is the dominance of the seasonal patterns of load and solar generation, while load generally exhibits the opposite characteristics (low in the summer and high in the winter). This explains the stronger negative correlation at daily intervals when zero solar generation is considered.



### Table 2: Correlation of load and generation at half-hourly intervals.

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Cluster	Mean of correlation of load with solar data from*	Auckland	Wellington	Christchurch	Queenstown	Cluster description
A 11	TMY	-0.080	-0.099	-0.101	-0.119	
All	2023	-0.099	-0.117	-0.130	-0.147	
0	TMY	-0.051	-0.084	-0.081	-0.101	medium daytime & medium
U	2023	-0.065	-0.100	-0.110	-0.126	morning & medium evening
1	TMY	-0.111	-0.123	-0.119	-0.165	very high daytime & high
T	2023	-0.135	-0.145	-0.148	-0.205	morning & very high evening
2	TMY	-0.119	-0.117	-0.115	-0.127	very high daytime & low
2	2023	-0.149	-0.142	-0.142	-0.156	morning & very high evening
2	TMY	-0.080	-0.087	-0.104	-0.044	low daytime & low morning &
5	2023	-0.097	-0.108	-0.144	-0.064	medium evening
Λ	TMY	-0.060	-0.091	-0.095	-0.116	high daytime & high morning
4	2023	-0.074	-0.105	-0.120	-0.143	& high evening
F	TMY	-0.068	-0.086	-0.076	-0.097	high daytime & low morning
5	2023	-0.089	-0.105	-0.102	-0.124	& very high evening
c	TMY	-0.060	-0.101	-0.114	-0.097	very low daytime & very low
0	2023	-0.067	-0.126	-0.153	-0.125	morning & low evening
7	TMY	-0.099	-0.121	-0.132	-0.166	very high daytime & very high
	2023	-0.111	-0.130	-0.156	-0.199	morning & high evening

#### Annual correlations of half-hourly load and solar

(solar generation values of zero have been removed from the data before correlation)

\*calculated for each load profile

[ConfigF-ResultsTemplate-Part2-correlations.xlsx]'2. Cluster x City'

### Table 3: Correlation of load and generation over daily intervals.

#### Mean of correlation of Cluster Auckland Wellington Christchurch Queenstown **Cluster description** load with solar data from\* -0.070 TMY -0.120 -0.121 -0.131 All 2023 -0.097 -0.142 -0.192 -0.196 TMY -0.073 -0.137 -0.136 -0.162 medium daytime & medium 0 2023 -0.093 -0.205 -0.219 morning & medium evening -0.151 TMY -0.079 -0.118 -0.114 -0.101 very high daytime & high 1 2023 -0.110 -0.149 -0.182 -0.191 morning & very high evening -0.028 -0.069 -0.064 -0.063 very high daytime & low TMY 2 -0.080 morning & very high evening 2023 -0.115 -0.116 -0.121 TMY -0.055 -0.118 -0.132 -0.164 low daytime & low morning & 3 2023 -0.081 -0.143 -0.227 -0.229 medium evening TMY -0.092 -0.137 -0.136 -0.130 high daytime & high morning 4 2023 -0.102 -0.148 -0.203 -0.191 & high evening TMY -0.058 -0.105 -0.100 -0.124 high daytime & low morning 5 2023 -0.093 -0.133 -0.160 -0.191 & very high evening -0.050 TMY -0.020 -0.095 -0.106 very low daytime & very low 6 -0.195 2023 -0.032 -0.117 morning & low evening -0.134 TMY -0.101 -0.152 -0.148 -0.149 very high daytime & very high 7 2023 -0.218 -0.215 -0.105 -0.148 morning & high evening

Annual correlations of daily average load and solar (solar generation values of zero have been removed from the data before correlation)

\*calculated for each load profile

[ConfigF-ResultsTemplate-Part2-correlations.xlsx]'2. Cluster x City'



# 2.5 Correlations between load and solar generation for the individual loads selected to represent each cluster

The previous sub-sections presented distributions and summary statistics of correlations rather than correlations for individual loads. This is because there are far too many loads to examine individually. However, as discussed in the "Selection of representative load profiles" appendix (Appendix Six), individual load profiles are selected to represent each cluster (load type) at different consumption levels for each city. It is of interest to know how the correlations of these loads change with TMY and 2023 solar generation. These correlations are shown in Table 4.

These show a similar pattern to those presented previously:

- 1. Most correlations are negative and weak.
- 2. When 2023 solar generation is used, the strength of the correlation increases, although the correlation usually remains weak.

There are a small number of cases where the correlation weakens, and a small number of cases where the correlation is positive. This illustrates the large differences in load profiles even within clusters, and highlights one of the challenges of analysing solar performance. Generally, this indicates the importance of using a consumer's actual load profile rather than a representative one to produce results relevant to the consumer.



Table 4: Correlations of individual load profiles selected to represent each cluster, consumption level (two), and city with TMY and 2023 solar generation. Blank cells are where there was no load profile available to represent the cluster.

Cluster	Load	Consumption	Corre	elation of load v	vith TMY solar d	ata	Correlat	tion of load wit	th Actual 2023 so	olar data	Proportion by which the 2023 correlation has changed, related to the TMY correlation (2023 - TMY) / abs(TMY)			
Cluster L 0 0 0 1 1 1 1 2 2 2 2 2 2 2 2 3 3 3 3 4 4 4 4 4 4 5 5 5 5 5 6 6 6 6 6 7		(kwn pa)	Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown
0	1	8,000	-0.126	-0.104	-0.049	-0.015	-0.162	-0.195	-0.130	-0.014	-28%	-87%	-166%	3%
0	2	8,000	-0.172	-0.075	-0.051		-0.144	-0.108	-0.073		16%	-43%	-44%	
0	1	12,000	-0.125	-0.080	-0.061	-0.199	-0.145	-0.074	-0.117	-0.223	-16%	8%	-92%	-12%
0	2	12,000	-0.069	-0.124	-0.053		-0.082	-0.092	-0.065		-19%	26%	-22%	
1	1	8,000	-0.135	-0.156	-0.207	-0.175	-0.157	-0.182	-0.260	-0.200	-16%	-17%	-26%	-15%
1	2	8,000	-0.139	-0.097	-0.137		-0.134	-0.097	-0.160		3%	0%	-17%	
1	1	12,000	-0.195	-0.148	-0.215	-0.255	-0.211	-0.159	-0.265	-0.279	-8%	-7%	-23%	-10%
1	2	12,000	-0.167	-0.089	-0.051	-0.227	-0.201	-0.153	-0.092	-0.263	-21%	-72%	-81%	-16%
2	1	8,000	-0.137	-0.160	-0.174		-0.162	-0.179	-0.183		-18%	-12%	-5%	
2	2	8,000	-0.102	-0.174			-0.171	-0.181			-68%	-4%		
2	1	12,000	-0.101		-0.212	-0.094	-0.130		-0.236	-0.094	-28%		-11%	0%
2	2	12,000	-0.114		-0.178		-0.145		-0.197		-27%		-11%	
3	1	8,000	0.050	0.008			0.066	-0.040			32%	-584%		
3	2	8,000	-0.122	-0.004			-0.146	-0.020			-19%	-448%		
3	1	12,000	-0.112	-0.026	-0.121		-0.060	0.025	-0.177		47%	199%	-47%	
3	2	12,000			-0.244				-0.335				-37%	
4	1	8,000	-0.071	-0.131	-0.179	-0.038	-0.074	-0.126	-0.227	-0.053	-4%	3%	-27%	-41%
4	2	8,000	-0.072	-0.066	-0.160		-0.086	-0.003	-0.200		-20%	96%	-25%	
4	1	12,000	-0.137	-0.091	-0.030	-0.195	-0.134	-0.153	-0.023	-0.214	2%	-68%	25%	-10%
4	2	12,000	-0.191	-0.252	-0.099	-0.110	-0.208	-0.274	-0.104	-0.114	-9%	-9%	-6%	-4%
5	1	8,000	-0.095	-0.143	-0.211	-0.041	-0.091	-0.169	-0.269	-0.064	4%	-18%	-27%	-56%
5	2	8,000	-0.092	-0.119	-0.080		-0.082	-0.151	-0.176		11%	-27%	-119%	
5	1	12,000	-0.102	-0.146	-0.132	-0.041	-0.123	-0.189	-0.151	-0.073	-20%	-29%	-14%	-80%
5	2	12,000	-0.058	-0.130	-0.146	-0.133	-0.046	-0.141	-0.173	-0.172	21%	-8%	-19%	-30%
6	1	8,000			-0.081				-0.110				-36%	
6	2	8,000			-0.176				-0.236				-34%	
6	1	12,000			-0.122				-0.202				-66%	
6	2	12,000												
7	1	8,000	-0.120	-0.125	-0.171	-0.053	-0.109	-0.154	-0.194	-0.097	9%	-24%	-14%	-82%
7	2	8,000		-0.130	-0.093	-0.055		-0.126	-0.091	-0.091		3%	2%	-65%
7	1	12,000	0.026	-0.134	-0.128		0.011	-0.125	-0.126		-59%	7%	1%	
7	2	12,000	-0.139	-0.125	-0.175		-0.154	-0.141	-0.232		-11%	-13%	-33%	

#### Pearson correlation coefficient for the individual loads selected to represent each cluster, half-hourly load and solar Note that each city has a load selected from that city to represent the cluster. (solar generation values of zero have been removed from the data before correlation)

[ConfigF-ResultsTemplate-Part2-correlations.xlsx]'Pearson-raw-cluster\_correl\_sc2'



# 3 Change in self-consumption and exported energy between TMY and actual 2023 solar generation

The previous section demonstrated that load does reduce as solar generation increases, and that this relationship is accentuated when solar generation coincident in time (from the actual year) is used instead of TMY solar generation. However, the relationship between load and solar generation is generally weak with both TMY and 2023 solar generation. This section sets out to understand whether this relationship affects results when using TMY solar generation instead of generation from the same year as the load.

# 3.1 Basis for investigation and methodology

It is hypothesised that self-consumption will reduce and exported energy will increase when the actual solar generation at the location of a load is used instead of TMY solar generation. The reasons are:

- 1. As solar generation increases it has been shown that load generally decreases, and therefore there will be less load to self-consume. Thus, self-consumption will reduce.
- 2. Because of the decrease in load and increase in solar generation, exported energy will increase.

It is assumed that this effect will occur in unison at each half-hour, rather than with a delay. Thus, the solar model used in the main analysis is used to compute self-consumption and export at each half-hour. These are then summed over each month and a year so that the effect can be examined at these periods.

Other solar model outputs, particularly internal rate of return (IRR), are not examined in the main analysis as the decrease in self-consumption may be cancelled out by the increase in exports, depending on the relative retail and buyback prices. In turn, the effect hypothesised may not be as observable (there may be little to no change in IRR between the two solar data sources). This is itself a salient consideration, since IRR is the main measure of performance in the main report.

The following matrix in Table 5 is used to investigate the results. Note that the solar locations are those given in the main report (generally the centre of each city), while the load locations are the ICP locations. Clearly these vary from the solar locations over the geographical extent of the city, which may introduce an error in this analysis and thereby confound it.

The loads used to produce the results for Table 5 are those chosen to represent each of the eight clusters (two per cluster) and annual consumption level (8,000 kWh pa and 12,000 kWh pa). Hence there are potentially 32 tables (assuming each cluster has load in the city). In addition, Table 5 can be viewed over an entire year, or for each month. Rather than present each combination of table, a selection is presented in the results.



Table 5: Investigating the changes in self-consumption and export between TMY and actual 2023 solar generation. For selfconsumption, the values in the diagonal cells are expected to be negative. For export, the values in the diagonals are expected to be positive.

Load		Solar lo	cation	
location	Auckland	Wellington	Christchurch	Queenstown
Auckland	From actual 2023			
	solar generation			
	less from TMY			
	solar generation			
Wellington		From actual 2023		
		solar generation		
		less from TMY solar		
		generation		
Christchurch			From actual 2023	
			solar generation	
			less from TMY solar	
			generation	
Queenstown				From actual 2023
				solar generation
				less from TMY
				solar generation

For interest the non-diagonals of Table 5 are also completed. The vertical columns give the differences between self-consumption from 2023 and TMY solar data for load from each city, and solar generation from a different city. It is expected that the change in self-consumption and export should be in the same direction as the diagonals, but muted, since the solar generation is from a different location.

# 3.2 Changes in self-consumption and export as solar capacity is varied and as the load profile is varied

Results for a Cluster 0 load profile are shown in Table 6 for the four PV capacities assessed. Selecting a PV capacity of 5 kW-ac, results for each cluster load profile of 8,000 kWh pa consumption are given in Table 7, with a description of the clusters given in Table 8.

The general pattern from the results in Table 6 and Table 7 are almost the exact opposite of what was expected from the previous discussion. Included with each table, in the far column, is the annual generation in each city, and the change in generation from TMY to 2023, as a proportion of TMY. Evident from this is that the 2003 annual solar generation in three cities was lower than the TMY annual solar generation (solar generation by month for TMY and 2023 is given in Figure 9 to Figure 12 for each city). The only city where 2023 solar generation was higher is Queenstown. There appears to be a pattern where lower 2023 annual solar generation leads to lower export, whereas higher 2023 annual solar generation follows a similar pattern, although not as strong. Expressing this another way, the change in self-consumption and export appears to be correlated with the change in solar generation between TMY and 2023. Taking this further, it appears that the lower export resulting from lower solar generation, and to a lesser extent the lower self-



consumption, overshadow the differences expected from the negative relationship between load and solar, which should have been stronger with actual 2023 solar generation.



Table 6: Changes in self-consumption and export between actual 2023 and TMY for a Cluster 0 load at different PV capacities. The same load and solar city differences are bold purple.

(a)

			Self-consum	ption (kWh)			Expor	t (kWh)		Solar city
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	1,807	2,198	2,005	2,067	2,956	2,565	2,758	2,697	4,763
TNAV	Wellington	1,712	2,055	1,882	1,942	2,943	2,600	2,773	2,712	4,655
	Christchurch	1,743	2,069	1,957	1,975	2,942	2,616	2,728	2,709	4,685
	Queenstown	1,773	2,150	2,000	2,094	3,405	3,028	3,177	3,084	5,178
	Auckland	1,835	2,253	2,038	2,137	2,885	2,467	2,682	2,582	4,720
Actual 2022	Wellington	1,751	2,048	1,888	1,982	2,673	2,375	2,536	2,442	4,423
Actual 2023	Christchurch	1,754	2,120	1,917	2,037	2,903	2,537	2,740	2,621	4,657
	Queenstown	1,845	2,264	2,058	2,190	3,477	3,058	3,264	3,133	5,322
	Auckland	1.6%	2.5%	1.7%	3.4%	-2.4%	-3.8%	-2.8%	-4.2%	-0.9%
Actual less I MY as a	Wellington	2.2%	-0.3%	0.3%	2.0%	-9.2%	-8.6%	-8.6%	-10.0%	-5.0%
proportion of TMY	Christchurch	0.6%	2.5%	-2.0%	3.1%	-1.3%	-3.0%	0.4%	-3.3%	-0.6%
(2023 - TMY) / abs(TMY)	Queenstown	4.1%	5.3%	2.9%	4.6%	2.1%	1.0%	2.7%	1.6%	2.8%

Annual, Cluster 0, load 1 of 2, 8,000 kWh pa, PV capacity is 3 kW-ac

[ConfigF-ResultsTemplatePart1.xlsx]'F TMY & Actual'

#### Annual, Cluster 0, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

		-	Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,097	2,531	2,408	2,480	5,841	5,407	5,530	5,458	7,938
TNAV	Wellington	1,979	2,384	2,236	2,327	5,779	5,374	5,522	5,430	7,758
	Christchurch	2,020	2,402	2,321	2,371	5,788	5,406	5,487	5,437	7,808
	Queenstown	2,022	2,452	2,329	2,474	6,607	6,178	6,300	6,155	8,630
	Auckland	2,129	2,600	2,457	2,575	5,737	5,266	5,409	5,291	7,866
Actual 2022	Wellington	2,045	2,409	2,283	2,404	5,327	4,963	5,089	4,969	7,372
Actual 2025	Christchurch	2,014	2,467	2,296	2,456	5,748	5,295	5,466	5,306	7,762
	Queenstown	2,098	2,566	2,421	2,581	6,773	6,304	6,449	6,289	8,871
	Auckland	1.5%	2.7%	2.0%	3.8%	-1.8%	-2.6%	-2.2%	-3.1%	-0.9%
Actual less I MY as a	Wellington	3.4%	1.1%	2.1%	3.3%	-7.8%	-7.6%	-7.8%	-8.5%	-5.0%
proportion of TMY	Christchurch	-0.3%	2.7%	-1.1%	3.6%	-0.7%	-2.1%	-0.4%	-2.4%	-0.6%
(2023 - 11VIY) / abs(11VIY)	Queenstown	3.7%	4.7%	4.0%	4.3%	2.5%	2.0%	2.4%	2.2%	2.8%

(b)



# (c)

### Annual, Cluster 0, load 1 of 2, 8,000 kWh pa, PV capacity is 6 kW-ac

			Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,199	2,629	2,534	2,602	7,284	6,860	6,951	6,870	9,526
TNAV	Wellington	2,071	2,486	2,347	2,449	7,129	6,738	6,864	6,749	9,309
	Christchurch	2,113	2,505	2,435	2,490	7,193	6,810	6,877	6,807	9,370
	Queenstown	2,110	2,543	2,430	2,580	8,156	7,735	7,840	7,676	10,356
	Auckland	2,230	2,698	2,588	2,701	7,193	6,731	6,842	6,719	9,439
Actual 2022	Wellington	2,151	2,522	2,412	2,535	6,675	6,301	6,410	6,285	8,847
Actual 2025	Christchurch	2,106	2,570	2,419	2,582	7,183	6,717	6,866	6,699	9,314
	Queenstown	2,184	2,653	2,531	2,695	8,405	7,946	8,059	7,886	10,645
	Auckland	1.4%	2.6%	2.1%	3.8%	-1.3%	-1.9%	-1.6%	-2.2%	-0.9%
Actual less I MY as a	Wellington	3.9%	1.5%	2.8%	3.5%	-6.4%	-6.5%	-6.6%	-6.9%	-5.0%
	Christchurch	-0.4%	2.6%	-0.7%	3.7%	-0.1%	-1.4%	-0.2%	-1.6%	-0.6%
(2025 - 11017) / dDS(11017)	Queenstown	3.5%	4.3%	4.1%	4.4%	3.1%	2.7%	2.8%	2.7%	2.8%

[ConfigF-ResultsTemplatePart1.xlsx]'F TMY & Actual'

# Annual, Cluster 0, load 1 of 2, 8,000 kWh pa, PV capacity is 8.2 kW-ac

			Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,376	2,774	2,719	2,771	9,691	9,406	9,387	9,362	13,019
TNAV	Wellington	2,227	2,642	2,521	2,625	9,270	8,981	9,026	8,983	12,723
	Christchurch	2,271	2,659	2,606	2,661	9,430	9,141	9,168	9,142	12,805
	Queenstown	2,260	2,686	2,589	2,731	10,453	10,160	10,206	10,140	14,153
	Auckland	2,399	2,839	2,774	2,866	9,830	9,464	9,499	9,433	12,900
Actual 2022	Wellington	2,336	2,688	2,608	2,729	9,046	8,721	8,794	8,731	12,091
Actual 2025	Christchurch	2,262	2,724	2,611	2,763	9,663	9,247	9,326	9,242	12,730
	Queenstown	2,330	2,779	2,692	2,847	10,998	10,664	10,696	10,607	14,548
	Auckland	1.0%	2.4%	2.0%	3.4%	1.4%	0.6%	1.2%	0.8%	-0.9%
Actual less I MY as a	Wellington	4.9%	1.8%	3.5%	4.0%	-2.4%	-2.9%	-2.6%	-2.8%	-5.0%
	Christchurch	-0.4%	2.5%	0.2%	3.8%	2.5%	1.2%	1.7%	1.1%	-0.6%
(2025 - 11017) / dDS(11017)	Queenstown	3.1%	3.4%	4.0%	4.3%	5.2%	5.0%	4.8%	4.6%	2.8%

(d)



Table 7: Changes in self-consumption and export between TMY and actual 2023 for a 5 kW-ac PV capacity and different cluster loads (there was insufficient data to show Cluster 6). The same load and solar city differences are bold purple.

(a)

		•	Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,097	2,531	2,408	2,480	5,841	5,407	5,530	5,458	7,938
TNAV	Wellington	1,979	2,384	2,236	2,327	5,779	5,374	5,522	5,430	7,758
I IVI Y	Christchurch	2,020	2,402	2,321	2,371	5,788	5,406	5,487	5,437	7,808
	Queenstown	2,022	2,452	2,329	2,474	6,607	6,178	6,300	6,155	8,630
	Auckland	2,129	2,600	2,457	2,575	5,737	5,266	5,409	5,291	7,866
Actual 2022	Wellington	2,045	2,409	2,283	2,404	5,327	4,963	5,089	4,969	7,372
Actual 2025	Christchurch	2,014	2,467	2,296	2,456	5,748	5,295	5,466	5,306	7,762
	Queenstown	2,098	2,566	2,421	2,581	6,773	6,304	6,449	6,289	8,871
	Auckland	1.5%	2.7%	2.0%	3.8%	-1.8%	-2.6%	-2.2%	-3.1%	-0.9%
Actual less I MY as a	Wellington	3.4%	1.1%	2.1%	3.3%	-7.8%	-7.6%	-7.8%	-8.5%	-5.0%
	Christchurch	-0.3%	2.7%	-1.1%	3.6%	-0.7%	-2.1%	-0.4%	-2.4%	-0.6%
(2025 - 11017) / abs(11017)	Queenstown	3.7%	4.7%	4.0%	4.3%	2.5%	2.0%	2.4%	2.2%	2.8%

#### Annual, Cluster 0, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

[ConfigF-ResultsTemplatePart1.xlsx]'F TMY & Actual'

### Annual, Cluster 1, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

			Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	3,207	2,471	2,338	2,633	4,731	5,468	5,600	5,305	7,938
TNAV	Wellington	3,055	2,303	2,215	2,470	4,703	5,455	5,543	5,288	7,758
	Christchurch	3,134	2,337	2,219	2,507	4,674	5,471	5,589	5,301	7,808
	Queenstown	3,281	2,450	2,326	2,593	5,348	6,180	6,304	6,036	8,630
	Auckland	3,259	2,535	2,388	2,737	4,607	5,331	5,478	5,129	7,866
Actual 2022	Wellington	3,129	2,326	2,214	2,546	4,243	5,047	5,158	4,827	7,372
Actual 2025	Christchurch	3,222	2,353	2,257	2,579	4,540	5,409	5,505	5,183	7,762
	Queenstown	3,395	2,565	2,445	2,722	5,476	6,306	6,425	6,149	8,871
	Auckland	1.6%	2.6%	2.1%	3.9%	- <b>2.6</b> %	-2.5%	-2.2%	-3.3%	-0.9%
Actual less I MY as a	Wellington	2.4%	1.0%	0.0%	3.1%	-9.8%	-7.5%	-6.9%	-8.7%	-5.0%
proportion of TMY	Christchurch	2.8%	0.7%	1.7%	2.9%	-2.9%	-1.1%	-1.5%	-2.2%	-0.6%
(2023 - 11011) / abs(11011)	Queenstown	3.5%	4.7%	5.1%	4.9%	2.4%	2.0%	1.9%	1.9%	2.8%

(b)



# (c)

### Annual, Cluster 2, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

			Self-consum	ption (kWh)			Solar city			
Solar data source	Solar city		Load pro	ofile city			generation			
Solar data source TMY Actual 2023 Actual less TMY as a proportion of TMY (2023 TMY) (abc(TMY)		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,317	2,560	2,518		5,622	5,378	5,421		7,938
TNAV	Wellington	2,149	2,391	2,404		5,609	5,367	5,354		7,758
11011	Christchurch	2,211	2,448	2,412		5,597	5,360	5,396		7,808
	Queenstown	2,288	2,557	2,567		6,341	6,073	6,062		
	Auckland	2,338	2,617	2,548		5,527	5,249	5,318		7,866
Actual 2022	Wellington	2,225	2,421	2,419		5,147	4,951	4,954		7,372
Actual 2023	Christchurch	2,260	2,485	2,483		5,502	5,276	5,279		7,762
	Queenstown	2,369	2,666	2,682		6,501	6,205	6,188		
	Auckland	0.9%	2.2%	1.2%		-1.7%	-2.4%	-1.9%		-0.9%
Actual less I MY as a	Wellington	3.6%	1.3%	0.6%		-8.2%	-7.7%	-7.5%		-5.0%
	Christchurch	2.2%	1.5%	2.9%		-1.7%	-1.6%	-2.2%		-0.6%
	Queenstown	3.5%	4.3%	4.5%		2.5%	2.2%	2.1%		

[ConfigF-ResultsTemplatePart1.xlsx]'F TMY & Actual'

(d)

### Annual, Cluster 3, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

	Self-consumption (kWh)			Export (kWh)				Solar city		
Solar data source Solar	Solar city	Load profile city			Load profile city				generation	
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,445	2,490			5,494	5,449			7,938
TNAV	Wellington	2,330	2,356			5,428	5,402			7,758
	Christchurch	2,347	2,383			5,461	5,425			
	Queenstown	2,448	2,444			6,182	6,186			
	Auckland	2,515	2,553			5,351	5,313			7,866
Actual 2022	Wellington	2,409	2,401			4,963	4,971			7,372
Actual 2025	Christchurch	2,464	2,433			5,298	5,329			
	Queenstown	2,570	2,595			6,300	6,276			
	Auckland	2.9%	2.5%			-2.6%	-2.5%			-0.9%
Actual less I MY as a	Wellington	3.4%	1.9%			-8.6%	-8.0%			-5.0%
	Christchurch	5.0%	2.1%			-3.0%	-1.8%			
(2025 - 11017) / dDS(11017)	Queenstown	5.0%	6.2%			1.9%	1.4%			



# (e)

### Annual, Cluster 4, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

	Self-consumption (kWh)				Export (kWh)				Solar city	
Solar data source	Solar city		Load pro	ofile city		Load profile city				generation
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,663	2,455	2,212	3,120	5,276	5,484	5,727	4,819	7,938
TNAV	Wellington	2,513	2,305	2,063	2,898	5,244	5,453	5,694	4,860	7,758
	Christchurch	2,544	2,344	2,074	2,944	5,264	5,464	5,734	4,863	7,808
	Queenstown	2,689	2,419	2,139	3,082	5,941	6,211	6,491	5,548	8,630
	Auckland	2,734	2,513	2,260	3,149	5,132	5,353	5,606	4,717	7,866
Actual 2022	Wellington	2,577	2,362	2,066	2,960	4,796	5,010	5,307	4,412	7,372
Actual 2025	Christchurch	2,653	2,411	2,087	3,052	5,109	5,350	5,675	4,709	7,762
	Queenstown	2,784	2,547	2,249	3,209	6,086	6,324	6,622	5,662	8,871
	Auckland	2.7%	2.4%	2.2%	0.9%	-2.7%	-2.4%	-2.1%	-2.1%	-0.9%
Actual less I MIY as a	Wellington	2.5%	2.5%	0.1%	2.2%	-8.5%	-8.1%	-6.8%	-9.2%	-5.0%
	Christchurch	4.3%	2.9%	0.6%	3.7%	-3.0%	-2.1%	-1.0%	-3.2%	-0.6%
(2023 - TMY) / abs(TMY)	Queenstown	3.6%	5.3%	5.1%	4.1%	2.4%	1.8%	2.0%	2.1%	2.8%

[ConfigF-ResultsTemplatePart1.xlsx]'F TMY & Actual'

(f)

#### Annual, Cluster 5, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

	Self-consumption (kWh)				Export (kWh)				Solar city	
Solar data source	Solar city		Load pro	ofile city		Load profile city				generation
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	2,719	2,535	1,739	2,498	5,220	5,403	6,199	5,440	7,938
TNAV	Wellington	2,573	2,397	1,658	2,351	5,185	5,361	6,100	5,407	7,758
	Christchurch	2,603	2,412	1,648	2,387	5,205	5,396	6,160	5,421	7,808
	Queenstown	2,703	2,474	1,695	2,486	5,927	6,155	6,934	6,144	8,630
	Auckland	2,801	2,617	1,769	2,564	5,065	5,249	6,097	5,301	7,866
Actual 2022	Wellington	2,640	2,469	1,630	2,423	4,732	4,903	5,743	4,949	7,372
Actual 2025	Christchurch	2,678	2,510	1,662	2,470	5,084	5,252	6,100	5,292	7,762
	Queenstown	2,810	2,573	1,772	2,580	6,061	6,298	7,098	6,290	8,871
	Auckland	3.0%	3.2%	1.7%	2.7%	-3.0%	-2.8%	-1.6%	-2.6%	-0.9%
Actual less I MY as a	Wellington	2.6%	3.0%	-1.7%	3.1%	-8.7%	- <b>8.5</b> %	-5.9%	-8.5%	-5.0%
proportion of TMY	Christchurch	2.8%	4.0%	0.8%	3.5%	-2.3%	-2.7%	-1.0%	-2.4%	-0.6%
(2023 - 11017) abs(11017)	Queenstown	4.0%	4.0%	4.6%	3.8%	2.3%	2.3%	2.4%	2.4%	2.8%



# (g)

# Annual, Cluster 7, load 1 of 2, 8,000 kWh pa, PV capacity is 5 kW-ac

	Self-consumption (kWh)			Export (kWh)				Solar city		
Solar data source	Solar city		Load pro	ofile city		Load profile city				generation
		Auckland	Wellington	Christchurch	Queenstown	Auckland	Wellington	Christchurch	Queenstown	(kWh pa)
	Auckland	3,379	2,782	2,601	2,739	4,560	5,156	5,337	5,200	7,938
TNAV	Wellington	3,159	2,626	2,390	2,619	4,599	5,132	5,368	5,139	7,758
	Christchurch	3,230	2,657	2,421	2,654	4,578	5,151	5,387	5,154	7,808
	Queenstown	3,377	2,784	2,514	2,796	5,253	5,846	6,116	5,833	8,630
	Auckland	3,488	2,833	2,622	2,801	4,378	5,033	5,244	5,065	7,866
Actual 2022	Wellington	3,259	2,624	2,425	2,617	4,113	4,749	4,947	4,755	7,372
Actual 2023	Christchurch	3,332	2,677	2,476	2,672	4,430	5,085	5,285	5,090	7,762
	Queenstown	3,532	2,928	2,641	2,856	5,339	5,943	6,229	6,015	8,871
	Auckland	3.2%	1.8%	0.8%	2.3%	-4.0%	-2.4%	-1.7%	-2.6%	-0.9%
Actual less I MY as a	Wellington	3.2%	-0.1%	1.5%	-0.1%	-10.6%	-7.5%	-7.8%	-7.5%	-5.0%
	Christchurch	3.1%	0.8%	2.3%	0.7%	-3.2%	-1.3%	-1.9%	-1.2%	-0.6%
(2023 - 11011) / dbs(11011)	Queenstown	4.6%	5.2%	5.1%	2.1%	1.6%	1.7%	1.9%	3.1%	2.8%



# Table 8: Cluster descriptions.

<ul> <li>0 medium daytime &amp; medium morning &amp; medium evening</li> <li>1 very high daytime &amp; high morning &amp; very high evening</li> <li>2 very high daytime &amp; low morning &amp; very high evening</li> <li>3 low daytime &amp; low morning &amp; medium evening</li> <li>4 high daytime &amp; high morning &amp; high evening</li> <li>5 high daytime &amp; low morning &amp; very high evening</li> <li>6 very low daytime &amp; very low morning &amp; low evening</li> <li>7 very high daytime &amp; very high morning &amp; high evening</li> </ul>	Cluster	Characteristics
<ol> <li>very high daytime &amp; high morning &amp; very high evening</li> <li>very high daytime &amp; low morning &amp; very high evening</li> <li>low daytime &amp; low morning &amp; medium evening</li> <li>high daytime &amp; high morning &amp; high evening</li> <li>high daytime &amp; low morning &amp; very high evening</li> <li>high daytime &amp; low morning &amp; very high evening</li> <li>very low daytime &amp; very low morning &amp; low evening</li> <li>very high daytime &amp; very high morning &amp; high evening</li> </ol>	0	medium daytime & medium morning & medium evening
<ul> <li>2 very high daytime &amp; low morning &amp; very high evening</li> <li>3 low daytime &amp; low morning &amp; medium evening</li> <li>4 high daytime &amp; high morning &amp; high evening</li> <li>5 high daytime &amp; low morning &amp; very high evening</li> <li>6 very low daytime &amp; very low morning &amp; low evening</li> <li>7 very high daytime &amp; very high morning &amp; high evening</li> </ul>	1	very high daytime & high morning & very high evening
<ul> <li>3 low daytime &amp; low morning &amp; medium evening</li> <li>4 high daytime &amp; high morning &amp; high evening</li> <li>5 high daytime &amp; low morning &amp; very high evening</li> <li>6 very low daytime &amp; very low morning &amp; low evening</li> <li>7 very high daytime &amp; very high morning &amp; high evening</li> </ul>	2	very high daytime & low morning & very high evening
<ul> <li>4 high daytime &amp; high morning &amp; high evening</li> <li>5 high daytime &amp; low morning &amp; very high evening</li> <li>6 very low daytime &amp; very low morning &amp; low evening</li> <li>7 very high daytime &amp; very high morning &amp; high evening</li> </ul>	3	low daytime & low morning & medium evening
<ul> <li>5 high daytime &amp; low morning &amp; very high evening</li> <li>6 very low daytime &amp; very low morning &amp; low evening</li> <li>7 very high daytime &amp; very high morning &amp; high evening</li> </ul>	4	high daytime & high morning & high evening
<ul><li>6 very low daytime &amp; very low morning &amp; low evening</li><li>7 very high daytime &amp; very high morning &amp; high evening</li></ul>	5	high daytime & low morning & very high evening
7 very high daytime & very high morning & high evening	6	very low daytime & very low morning & low evening
	7	very high daytime & very high morning & high evening

[ConfigF-ResultsTemplatePart1.xlsx]'Clusters'





Auckland TMY, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,938 kWh)
Auckland 2023, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,866 kWh)

Figure 9: Auckland TMY and 2023 solar generation by month.



Wellington Rooftop Solar, Monthly Energy Generation, north facing with 30° tilt (ILR / AC capacity in brackets)

Wellington TMY, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,758 kWh)
 Wellington 2023, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,372 kWh)

Figure 10: Wellington TMY and 2023 solar generation by month.





Christchurch TMY, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,808 kWh)
 Christchurch 2023, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=7,762 kWh)





Queenstown Rooftop Solar, Monthly Energy Generation, north facing with 30° tilt (ILR / AC capacity in brackets)

Queenstown TMY, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=8,630 kWh)
 Queenstown 2023, north facing with 30° tilt (1.2 DC:AC ratio / 5.0 kWp-ac) (annual=8,871 kWh)





# 3.3 Assessing the relationship between change in self-consumption/export and change in solar generation across the four cities

The effect noted in the previous sub-section is tested by correlating the change in export and selfconsumption with the change in solar generation across the four cities, given in Table 9 for all clusters and loads with sufficient data. This shows:

- A strong correlation for export. This is not surprising as an export increase is the logical result of higher solar generation after self-consumption is accounted for.
- Correlations ranging from medium to strong, with one weak (Cluster 5, Load 1, 8,000 kWh pa) for self-consumption. This is also unsurprising as self-consumption would increase with higher solar generation depending on the coincidence of load with solar. Hence, for some loads the correlation will be strong, whereas others not quite as strong.

While discarded as a parameter for this investigation, the correlation of change in IRR is also shown in Table 9

• This shows consistently strong correlations, even stronger than export. This is expected, as it is solar generation that gives rise to a rate of return. Thus, an increase in solar generation should lead to a higher return.



Table 9: Correlation coefficients of changes in (a) export, (b) self-consumption, and (c) IRR with change in solar generation. Correlations are taken over four points, which relate to each of the four cities. A positive correlation is where the parameter (export, self-consumption, or IRR) increases as solar generation increases between TMY and 2023 over the four cities. Clusters and loads not shown had at least one missing from a city, thus the correlations could not be determined over the four cities. The columns 3, 5, 6, and 8.2 are the solar capacities.

Lorrelation of change in export with change in generation over all cities						
Cluster	Load	Annual consumption	3	5	6	8.2
0	1	8,000	0.944	0.981	0.990	0.997
0	1	12,000	0.974	0.986	0.990	0.996
1	1	8,000	0.981	0.996	0.993	0.988
1	1	12,000	0.977	0.989	0.995	0.988
1	2	12,000	0.996	1.000	1.000	0.994
4	1	8,000	0.960	0.988	0.991	0.989
4	1	12,000	0.996	0.988	0.988	0.984
4	2	12,000	0.985	0.988	0.990	0.976
5	1	8,000	0.965	0.987	0.989	0.989
5	1	12,000	0.928	0.990	0.987	0.986
5	2	12,000	0.955	0.983	0.977	0.979
7	1	8,000	0.941	0.976	0.970	0.972

# (a) Correlation of change in export with change in generation over all cities

[ConfigF-ResultsTemplatePart1.xlsx]'Solar-City Correlations'

(b)

### Correlation of change in self-consumption with change in generation over all cities

Cluster	Load	Annual consumption	3	5	6	8.2
0	1	8,000	0.629	0.507	0.488	0.493
0	1	12,000	0.877	0.557	0.398	0.252
1	1	8,000	0.963	0.871	0.806	0.627
1	1	12,000	0.842	0.772	0.807	0.829
1	2	12,000	0.991	0.997	0.992	0.973
4	1	8,000	0.343	0.366	0.450	0.712
4	1	12,000	0.972	0.937	0.933	0.947
4	2	12,000	0.938	0.850	0.795	0.697
5	1	8,000	0.117	0.159	0.174	0.258
5	1	12,000	0.931	0.888	0.942	0.892
5	2	12,000	0.804	0.694	0.693	0.703
7	1	8,000	0.824	0.698	0.603	0.312

[ConfigF-ResultsTemplatePart1.xlsx]'Solar-City Correlations'

Correlation of change	e in IRR with change i	n generation over all c	ities			
Cluster	Load	Annual consumption	3	5	6	8.2
0	1	8,000	0.987	0.995	0.994	0.993
0	1	12,000	0.995	0.996	0.992	0.964
1	1	8,000	0.998	1.000	0.998	0.982
1	1	12,000	0.997	0.997	0.998	0.990
1	2	12,000	0.998	1.000	1.000	0.995
4	1	8,000	0.987	0.996	0.999	0.993
4	1	12,000	0.997	0.994	0.996	1.000
4	2	12,000	0.998	0.997	0.996	0.987
5	1	8,000	0.981	0.994	0.998	0.994
5	1	12,000	0.991	0.995	0.999	0.991
5	2	12,000	0.991	0.994	0.998	0.992
7	1	8,000	0.985	0.989	0.995	1.000

[ConfigF-ResultsTemplatePart1.xlsx]'Solar-City Correlations'



# 3.4 Monthly change in self-consumption and export

The results have so far given annual self-consumption and export. This section presents the changes in self-consumption and export by month. As in the case of annual self-consumption and export from the previous sub-section, it is of interest to correlate the change in these parameters with changes in solar. Instead of correlations in annual changes between these parameters and solar over cities, the correlations in monthly changes are now performed over months. To prepare for the correlations with change in solar over months, the change in solar generation by month is calculated and shown in Figure 13 to Figure 16.

Since it is not practical to show all clusters and cities (32 graphs), a selection of clusters is made. Cluster 0 is selected because, with reference to Table 4, it shows large changes in correlation with TMY solar compared to correlation of load with 2023 solar. Most of the changes are negative (the inverse correlation strengthened with actual 2023 data), but some are positive (the correlation weakened with actual 2023 data). Figure 17 to Figure 20 show the results for each city. In each of these figures, *ps* gives the Pearson correlation coefficient of: (a) monthly change in self-consumption correlated with monthly change in solar generation; and (b) monthly change in export correlated with monthly change in solar generation.

Cluster 5 is also selected, as the changes in correlations are generally mild, except in the case of one load in Christchurch and all in Queenstown. Some loads in Auckland even give a weakening of correlation. Generally, most load profile combinations are represented. Figure 21 to Figure 24 show the results for each city.

A similar pattern is seen over all clusters, which is that the change in self-consumption has a mediumstrong correlation with change in solar generation by month, and that the change in export has a strong correlation with change in solar generation by month. This further validates the observations from the previous two sub-sections. That is, that changes in solar generation between TMY and actual generation overshadow the changes from the negative relationship between load and solar, a relationship that strengthens with solar generation from the same year as the load.

Occasional deviations from the general pattern of change in export are seen for some loads. Examples are:

- Auckland Cluster 0 12,000 kWh pa 1/2 and 2/2 May and July (Figure 17(b))
- Wellington Cluster 0, 12,000 kWh pa 1/2 July and August (Figure 18(b))
- Queenstown Cluster 0 12,000 kWh pa 1/2 June and July (Figure 20(b))
- Auckland Cluster 5 12,000 kWh pa 1/2 June (Figure 21(b))
- Wellington Cluster 5 12,000 kWh pa 1/2 May and June (Figure 22(b))
- Christchurch Cluster 5 12,000 kWh pa 2/2 May and June (Figure 23(b))
- Queenstown Cluster 5 12,000 kWh pa 2/2 June (Figure 24(b))

It is interesting that these all occur with the larger annual consumptions (12,000 kWh pa, not 8,000 kWh pa), and that they occur in winter months. A brief investigation of this phenomenon indicates that these are months where self-consumption is high, and export is lower. Thus, any change in export between TMY and 2023 is a change from a lower base, giving rise to a higher proportionate change. The concentration in winter months with 12,000 kWh pa loads is consistent, as load would be higher



in winter months, and with 12,000 kWh pa loads, would give rise to higher self-consumption and lower export.

These variations, and those in Table 4, serve to highlight the large differences between load profiles, which as identified in the "Selection of representative load profiles" appendix (Appendix Six) exist between clusters, and even within clusters.





Figure 13: Solar generation change for Auckland, giving the difference in monthly energy generation between 2023 and TMY as a percentage of TMY.



Figure 14: Solar generation change for Wellington, giving the difference in monthly energy generation between 2023 and TMY as a percentage of TMY.





Figure 15: Solar generation change for Christchurch, giving the difference in monthly energy generation between 2023 and TMY as a percentage of TMY.



Figure 16: Solar generation change for Queenstown, giving the difference in monthly energy generation between 2023 and TMY as a percentage of TMY.





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Figure 17: Auckland changes in (a) self-consumption and (b) export by month for Cluster 0 representative loads.





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Figure 18: Wellington changes in (a) self-consumption and (b) export by month for Cluster 0 representative loads.





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Figure 19: Christchurch changes in (a) self-consumption and (b) export by month for Cluster 0 representative loads.





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Figure 20: Queenstown changes in (a) self-consumption and (b) export by month for Cluster 0 representative loads.





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Figure 21: Auckland changes in (a) self-consumption and (b) export by month for Cluster 5 representative loads.





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Figure 22: Wellington changes in (a) self-consumption and (b) export by month for Cluster 5 representative loads.





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Figure 23: Christchurch changes in (a) self-consumption and (b) export by month for Cluster 5 representative loads.





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Figure 24: Queenstown changes in (a) self-consumption and (b) export by month for Cluster 5 representative loads.



# 4 Conclusion

It is concluded that there is a negative correlation between load and solar generation, both at halfhourly and daily resolution, but that this correlation is weak for most loads. It is also concluded that this correlation strengthens when solar generation from the same period as the load is used (2023 instead of TMY in this study). However, any error introduced from the stronger correlation of load and solar is overshadowed by the change in solar generation. In other words, the change in solar generation has more of an effect on the results (rate of return) than the increased relationship between load and solar generation.

In turn it is concluded that analysis with TMY solar generation is a suitable choice. This is particularly to avoid accumulated error from a specific, non TMY year, as outlined in the Introduction. It should be noted that this will give rise to some error in the results, making the IRR results slightly more positive, assuming that the retail price is significantly higher than the buyback price. However, in the analysis of solar generation's benefits, a greater source of error is likely to be the use of the same load profile over the cash flow analysis period (29 years in this study). Over this time the consumption patterns of a household are likely to change, caused by such things as:

- Changes in occupancy, especially time of occupancy and number of occupants.
- Changes in appliances, such as electrification of water heating and transport, which could give rise to higher self-consumption, and will certainly increase the overall consumption. The main report demonstrated that rates of return of solar increase as annual consumption increases.
- Consumers may deliberately alter their time-of-use of energy to maximise self-consumption and/or export, depending on the relative retail and buyback prices. This may also include the installation of a battery at a future time when they have reduced in price.