Assessing residential solar at different time scales

Accompanying Appendix One to:

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

Prepared by Dr Allan Miller

Prepared for the Energy Efficiency and Conservation Authority

31 May 2024

Disclaimer

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Introduction

This accompanying study presents analysis and results from assessing residential solar economics at different time scales. The purpose of this is to understand any error inherent in analysis at different time scales, and whether this might affect modelling of solar economics. The specific time scales of interest are half-hourly, since most metering data is half-hourly, and hourly, since the EECA Gen Less Solar Tool works on hourly intervals.

New Zealand, like most other countries, operates a net metering regime for distributed generation – residential photovoltaic solar (PV) being the interest in this case. Under net metering, electricity produced by the PV system is netted off the electricity used by the household before metering. Consequently, the reduction in household demand by the PV system is recognised through a lower volume of retail purchases over a given time period –time period is expanded on later. Further, if the net of PV generation and demand results in export, this results in sales of electricity at the export rate over a given time period. This is advantageous where retail prices for electricity consumption are higher than export rates for excess generation. [1]

[1] Net metering differs from gross metering which measures all PV generation separately to all household demand, and compensates the consumer for all PV generation at a feed in tariff rate. This was popular when feed in tariffs were substantially higher than retail supply tariffs, as the householder would benefit from substantially higher generation prices. This arrangement was common in Australia during the time of high soar subsidies. However, with the reduction in feed in tariffs as subsidies for solar have reduced, and as feed in rates reduce below retail rates, gross metering is less advantageous, and net metering more beneficial. That is because net metering allows for direct offset of consumption by PV generation, which thereby avoids the higher retail rate.

The New Zealand electricity market and reconciliation within it works on a half-hourly trading period basis, with trading period defined in the Electricity Industry Participation Code 2010 (the Code). In the definition of half-hour metering information, and various metering definitions, the Code effectively separates out generation of electricity and electricity conveyed to a load within a trading period. From a practical perspective, when a homeowner installs solar, the meter is changed to an import/export meter. Quite apart from the cost this meter adds to the solar installation, the meter records import and export in separate import and export registers.[2]

This separate metering occurs within a half-hourly period, as well as over all half-hours in a year. Hence, within any half-hour trading period where the net the load and solar alternate between import and export, the imported and exported amounts are recorded separately. Practically, all consumption is summed over the billing period at each time of use rate, and all exports are summed at the export rate (usually one, but some retailers have recently introduced different time of export rates). Such rapid variations in load and/or solar within a half hour that result in both import and export within a half-hour may be material where import and export prices differ, which is almost always the case. Solar analysis conducted at half-hourly or hourly resolution may not pick up these imports and exports within a half-hour adequately to clearly value them.

This study note sets out to understand the differences that may occur between import and export at different analysis time scales. It relates to single-phase PV systems only. Three phase systems are not considered, as they are prone to import/export differences due to different loading on each phase, but the same nominal solar export on each phase. This can lead to situations where one phase may be exporting, while another phase may be importing. Further, this study does not consider other situations that may lead to differences between desktop financial assessments and real inverter operation. These include Volt-VAr responses limiting active power (kW) export, and Volt-Watt responses also limiting active power export.

The study sets out an aim, discusses the method adopted, largely influenced by available data, presents the results, and provides a discussion of results and a conclusion.

Aim

To understand any error inherent in analysis at different time scales, and whether this might affect modelling of solar economics. The specific time scale of interest is half-hourly, since most metering data is half-hourly.

[2] Import refers to consumption from the electricity network/retailer. Export refers to generation of excess solar to the electricity network/retailer.

Method

Method summary

The desired method was to use high resolution load data and conduct an analysis with that data at its original resolution, then adjust it to 30-minute resolution. During the study hourly resolution was added, since the EECA Gen Less Solar Tool works on hourly intervals. The quantities assessed at each resolution would be:

- Total solar by year (S_y, kWh)
- Total load by year (L_y, kWh)
- Net solar exported by year (E_y, kWh and as a proportion of household load, E_y/L_y)
- Reduction in imported energy by year, (SC_y, kWh and as a proportion of household load, SC_y/L_y)
- Self-consumption of solar by year, according to SC_y/S_y

Available data

Clearly in the absence of time to undertake high-resolution measurements, a constraint on this study was the availability of data. However, the MBIE, Transpower, and EEA funded 'Renewable Energy and the Smart Grid' (GREEN Grid) research project, established in 2012 and led by the author, captured 1-minute load data from multiple circuits, PV, and incomers of 44 households in the Hawke's Bay and New Plymouth between about 2014 and 2018. This data was collected by one of the research partners of the GREEN Grid project, the Centre for Sustainability at the University of Otago, and was the initiative of Dr Rebecca Ford. After this, the Centre for Sustainability carried out a project to combine the recordings and make them openly available, led in particular by Dr Ben Anderson.[3]

This study obtained and assessed the available data from the household recordings, and selected seven households from the dataset that contained more than a full year of 1-minute load samples, and had fewer than 0.5% of data missing. The original intention was to use half-hourly solar data modelled by ANSA® for the wider residential-scale solar study. The advantage of this was that the characteristics of each solar installation were known. However, concerns with this were that it was half-hourly, not the same resolution as the load, it was not from the same locations as the load, and that it was typical meteorological year (TMY) data, not coincident with the load recordings. During the analysis of the load data, it became apparent that some of the households in the sample also had PV. Using this PV would remove the possible source of error of TMY data (but also introduce another possible error of that particular solar year being different to others, but which was considered to be less of an error). It would also ensure exact correlation in time and resolution with the load data. There were issues with the PV recording data, however. First, there was no information on the characteristics of the solar installations, such as capacity, tilt, orientation, and DC:AC ratio. Second, the solar recordings also had missing data.

The lack of information about the PV installations was considered to be less of a source of error compared to benefit of it being 1-minute resolution, from the same location and coincident with load recordings. Further, it was possible to at least estimate the AC capacity. Given this, the seven

[3] https://cfsotago.github.io/GREENGridData/

households selected earlier were correlated with PV recordings from the two locations, and those houses with sufficient overlap of load samples with PV samples were retained. A summary of these, is given in Table 1, with the practical outcome being that only the households from Taranaki could be considered, and even then, one of the houses only has a complete overlap with the solar of 200 days. This was considered to be far better than the overlap of 48 days at the most from the Hawke's Bay PV data. The concept of artificially extending the solar to other years was considered, but dismissed, on the grounds that it would negate one of the advantages of using the local PV recordings – that it was coincident with load. A further reason for excluding Hawke's Bay households from the analysis was that the Hawke's Bay solar generation had an estimated AC capacity factor of 0.137, which is very low for Hawke's Bay – expected to be more in the region of 0.16.

The Taranaki PV installation was estimated to be 5 kW based on the maximum generation from that circuit recorded, and had an estimated AC capacity factor ranging from 0.151 (2018) to 0.167 (2015).

Table 1: GREEN Grid data considered for the time scale analysis.

Household	Location	Annual Consumption (kWh)	Number of half-hours covered (17,520 half-hours per year)	Proportion of half-hours missing samples	Complete days of samples overlap with PV recordings from the same region (Household 24 for Taranaki, Household 28 for Hawke's Bay)
09	Taranaki	5,680	17,612	0.04%	201
17a	Taranaki	3,841	32,066	0.15%	377
18	Taranaki	9,597	18,106	0.04%	200
20	Taranaki	4,725	51,024	0.03%	193
32	Hawke's Bay	5,934	18,028	0.06%	48
37	Hawke's Bay	2,589	58,852	0.18%	46
45	Hawke's Bay	3,988	27,342	0.23%	42

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]Summary

After collection of the above data, the solar data was normalised and scaled to a range of capacities considered in the main study. The various quantities outlined in the 'Method summary' above where then calculated and summarised for each of the following resolutions:

- 1-minute load and solar
- 30-minute load and solar
- 60-minute load and solar

The results are summarised in the next section.

Results

Table 2 (a) summarises the result for the 30-minute resolution load and solar compared to the 1-minute resolution load and solar, as various solar capacities. Table 2 (b) summarises the 60-minnute resolution load and solar compared to the 1-minute load and solar, also at various solar capacities. As outlined in the Method section, the percentages in each cell are of the total load for the particular household.

Table 3 gives the detail of these tables for a 3 kWp-ac solar capacity, while Table 4 gives the details for a 6 kWp-ac system.[4]

[4] In the results in Table 3 and Table 4:

- Household 17a covers the period from 2 June 2014 (213 days) through 2015 (365 days) to 28 March 2016 (88 days), totalling 666 days.
- Household 20 covers the period from 2 June 2014 (213 days) to 11 June 2015 (162 days), totalling 375 days.
- Household 9 covers the period from 29 July 2014 (156 days) to 16 July 2015 (197 days), totalling 353 days.
- Household 18 covers the period from 2 June 2014 (213 days) to 11 June 2015 (162 days), totalling 375 days.

Table 2: Assessment of the change in export and retail volume reduction at different resolutions. Values are percentages of the total consumption of the household assessed – see Table 3 and Table 4 for details of this. (a) 30-minute analysis compared to 1-minute analysis. (b) 60-minute analysis compared to 1-minute analysis. Columns represent PV capacity (kWp-ac). Note that retail volume reduction (self-consumption reduction) as a percentage of the total consumption is the negative of solar export volume change – this is discussed in the Discussion and Conclusion Paragraph One. For example, the retail volume reduction change as a percentage of the total consumption for 3 kW solar and household 17a is 1.4%. Similarly, for all combinations, the sign is reversed.

(a)

Household	Solar export volume in the 30-minute load analysis compared to the 1-minute load analysis (negative means there is a lower assessed export)				
	3	5	6	8.2	10
17a (3,841 kWh pa)	-1.4%	-1.4%	-1.4%	-1.4%	-1.4%
20 (4,725 kWh pa)	-1.4%	-1.3%	-1.2%	-1.2%	-1.2%
09 (5,680 kWh pa)	-2.0%	-1.8%	-1.7%	-1.6%	-1.5%
18 (9,597 kWh pa)	-1.8%	-1.7%	-1.6%	-1.6%	-1.6%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsm]AllCombined

(b)

Household	Solar export volume in the 60-minute load analysis compared to the 1-minute load analysis (negative means there is a lower assessed export)				
	3	5	6	8.2	10
17a (3,841 kWh pa)	-2.2%	-2.2%	-2.2%	-2.3%	-2.4%
20 (4,725 kWh pa)	-2.1%	-2.0%	-2.0%	-2.0%	-2.0%
09 (5,680 kWh pa)	-2.6%	-2.5%	-2.5%	-2.5%	-2.6%
18 (9,597 kWh pa)	-2.2%	-2.2%	-2.2%	-2.3%	-2.4%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsm]AllCombined

Table 3: Results by year for each household, with an estimated 3 kWp-ac PV system. Total load values do not match the annual load due to missing days. Import reduction is the solar internal use – the reduction in the energy imported from the network at the retail price. Self-consumption is the solar internal use divided by the solar generation.

Household 17a: 3,841 kWh pa, Taranaki, nearly two years, 47 half-hours missing
Solar: 3 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	1,181	1,181	1,181	1,073	1,073	1,073	934	918	908	-1.5%	-2.4%	248	263	273	1.5%	2.4%	21%	22%	23%
2015	2,816	2,816	2,816	2,660	2,660	2,660	2,148	2,111	2,093	-1.4%	-2.1%	667	705	722	1.4%	2.1%	24%	25%	26%
2016	571	571	571	369	369	369	451	446	443	-1.5%	-2.2%	120	125	128	1.5%	2.2%	21%	22%	22%
Total	4,568	4,568	4,568	4,103	4,103	4,103	3,533	3,474	3,444	-1.4%	-2.2%	1,035	1,093	1,123	1.4%	2.2%	23%	24%	25%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 20: 4,725 kWh pa, Taranaki, one year, 17 half-hours missing
Solar: 3 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	1,038	1,038	1,038	1,341	1,341	1,341	631	606	597	-1.8%	-2.5%	408	432	442	1.8%	2.5%	39%	42%	43%
2015	1,236	1,236	1,236	1,159	1,159	1,159	880	868	861	-1.0%	-1.6%	356	368	375	1.0%	1.6%	29%	30%	30%
2016																			
Total	2,274	2,274	2,274	2,500	2,500	2,500	1,511	1,474	1,458	-1.4%	-2.1%	764	800	816	1.4%	2.1%	34%	35%	36%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 09: 5,680 kWh pa, Taranaki, one year, 7 half-hours missing
Solar: 3 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	994	994	994	1,173	1,173	1,173	622	585	579	-3.1%	-3.6%	372	409	415	3.1%	3.6%	37%	41%	42%
2015	1,469	1,469	1,469	1,733	1,733	1,733	1,049	1,027	1,017	-1.3%	-1.8%	420	442	452	1.3%	1.8%	29%	30%	31%
2016																			
Total	2,463	2,463	2,463	2,905	2,905	2,905	1,671	1,612	1,596	-2.0%	-2.6%	792	851	867	2.0%	2.6%	32%	35%	35%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 18: 9,597 kWh pa, Taranaki, one year, 7 half-hours missing
Solar: 3 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	1,094	1,094	1,094	2,947	2,947	2,947	612	555	544	-1.9%	-2.3%	482	539	550	1.9%	2.3%	44%	49%	50%
2015	1,266	1,266	1,266	2,542	2,542	2,542	845	804	793	-1.6%	-2.1%	421	463	474	1.6%	2.1%	33%	37%	37%
2016																			
Total	2,361	2,361	2,361	5,489	5,489	5,489	1,457	1,358	1,337	-1.8%	-2.2%	903	1,002	1,023	1.8%	2.2%	38%	42%	43%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Table 4: Results by year for each household, with an estimated 6 kWp-ac PV system. Total load values do not match the annual load due to missing days. Import reduction is the solar internal use – the reduction in the energy imported from the network at the retail price. Self-consumption is the solar internal user divided by the solar generation.

Household 17a: 3,841 kWh pa, Taranaki, nearly two years, 47 half-hours missing
Solar: 6 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	2,362	2,362	2,362	1,073	1,073	1,073	2,068	2,050	2,041	-1.7%	-2.6%	294	312	321	1.7%	2.6%	12%	13%	14%
2015	5,631	5,631	5,631	2,660	2,660	2,660	4,828	4,794	4,774	-1.3%	-2.0%	803	837	857	1.3%	2.0%	14%	15%	15%
2016	1,142	1,142	1,142	369	369	369	1,008	1,002	999	-1.6%	-2.2%	134	140	143	1.6%	2.2%	12%	12%	12%
Total	9,135	9,135	9,135	4,103	4,103	4,103	7,904	7,846	7,815	-1.4%	-2.2%	1,231	1,290	1,321	1.4%	2.2%	13%	14%	14%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 20: 4,725 kWh pa, Taranaki, one year, 17 half-hours missing
Solar: 6 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	2,077	2,077	2,077	1,341	1,341	1,341	1,596	1,576	1,566	-1.5%	-2.2%	481	501	511	1.5%	2.2%	23%	24%	25%
2015	2,472	2,472	2,472	1,159	1,159	1,159	2,065	2,054	2,046	-0.9%	-1.7%	407	418	426	0.9%	1.7%	16%	17%	17%
2016																			
Total	4,549	4,549	4,549	2,500	2,500	2,500	3,661	3,630	3,612	-1.2%	-2.0%	888	918	936	1.2%	2.0%	20%	20%	21%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 09: 5,680 kWh pa, Taranaki, one year, 7 half-hours missing
Solar: 6 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	1,988	1,988	1,988	1,173	1,173	1,173	1,535	1,507	1,498	-2.4%	-3.2%	452	481	490	2.4%	3.2%	23%	24%	25%
2015	2,938	2,938	2,938	1,733	1,733	1,733	2,416	2,395	2,381	-1.2%	-2.0%	522	543	557	1.2%	2.0%	18%	18%	19%
2016																			
Total	4,926	4,926	4,926	2,905	2,905	2,905	3,951	3,902	3,879	-1.7%	-2.5%	975	1,024	1,047	1.7%	2.5%	20%	21%	21%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Household 18: 9,597 kWh pa, Taranaki, one year, 7 half-hours missing
Solar: 6 kWp-ac

	Solar (kWh)			Load (kWh)			Export (kWh)					Import reduction (kWh)					Self-consumption		
Load resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	30-min load	60-min load	1-minute	30-minute	60-minute	30-min load	60-min load cf	1-minute	30-minute	60-minute
Solar resolution	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	1-minute	30-minute	60-minute	cf 1-min load	cf 1-min load	1-minute	30-minute	60-minute	cf 1-min load	1-min load	1-minute	30-minute	60-minute
2014	2,188	2,188	2,188	2,947	2,947	2,947	1,541	1,488	1,472	-1.8%	-2.3%	648	700	717	1.8%	2.3%	30%	32%	33%
2015	2,533	2,533	2,533	2,542	2,542	2,542	2,001	1,964	1,948	-1.5%	-2.1%	531	569	585	1.5%	2.1%	21%	22%	23%
2016																			
Total	4,721	4,721	4,721	5,489	5,489	5,489	3,542	3,452	3,419	-1.6%	-2.2%	1,179	1,269	1,302	1.6%	2.2%	25%	27%	28%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]YearlyDetail

Table 5: Assessment of the change in export and retail volume reduction at different resolutions, with values as percentages of the 1-minute value. Columns represent PV capacity (kWp-ac).

(a)

Household	Solar export volume in the 30-minute load analysis compared to the 1-minute load analysis (negative means there is a lower assessed export)					Retail volume reduction in the 30-minute analysis compared to the 1-minute analysis (positive means there is a higher assessed retail volume				
	3	5	6	8.2	10	3	5	6	8.2	10
17a (3,841 kWh pa)	-1.7%	-0.9%	-0.7%	-0.5%	-0.4%	5.7%	5.0%	4.8%	4.4%	4.2%
20 (4,725 kWh pa)	-2.4%	-1.1%	-0.8%	-0.6%	-0.4%	4.7%	3.7%	3.5%	3.2%	3.0%
09 (5,680 kWh pa)	-3.5%	-1.6%	-1.2%	-0.8%	-0.6%	7.4%	5.6%	5.0%	4.4%	4.0%
18 (9,597 kWh pa)	-6.8%	-3.2%	-2.5%	-1.7%	-1.4%	10.9%	8.2%	7.6%	6.8%	6.4%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]Inputs&SummaryResults

(b)

Household	Solar export volume in the 60-minute load analysis compared to the 1-minute load analysis (negative means there is a lower assessed export)					Retail volume reduction in the 60-minute analysis compared to the 1-minute analysis (positive means there is a higher assessed retail volume				
	3	5	6	8.2	10	3	5	6	8.2	10
17a (3,841 kWh pa)	-2.5%	-1.4%	-1.1%	-0.8%	-0.7%	8.6%	7.5%	7.3%	7.1%	7.1%
20 (4,725 kWh pa)	-3.5%	-1.7%	-1.3%	-0.9%	-0.8%	6.9%	5.7%	5.5%	5.4%	5.3%
09 (5,680 kWh pa)	-4.5%	-2.3%	-1.8%	-1.3%	-1.0%	9.4%	7.9%	7.4%	7.1%	6.9%
18 (9,597 kWh pa)	-8.2%	-4.3%	-3.5%	-2.5%	-2.0%	13.3%	10.9%	10.4%	9.7%	9.4%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsx]Inputs&SummaryResults

Discussion and Conclusion

As shown in the results, there is clearly a difference as the resolution of data lowers. Table 2 deliberately gives the change as a percentage of total household consumption over the period assessed. As expected, this shows the same percentage change for export and import reduction, but in opposite directions. This would appear to indicate that there is no net effect on financial assessment of PV at different resolutions. However, when the price for retail electricity is different to that of exported generation there will be a difference. In fact, retail price is always higher than the export price, hence there will be error in PV assessment as the resolution of analysis lowers.

Assessing the solar by a percentage of household consumption does obscure the real impact on both import and export. Table 5 shows these as percentages of the 1-minute resolution value in each case. This shows much larger differences, especially for retail volume reduction. This also shows a general pattern of higher error at lower PV capacities. These differences are significant, given that PV economics are determined entirely from export volume multiplied by export price and retail volume reduction multiplied by retail price. The retail volume reduction is particularly significant because retail price is always higher than the export price.

To better understand how these differences affect the financial results of PV analysis at different resolutions, Table 6 shows the results for one particular house. This was conducted prior to receiving the load profiles for this study, and hence uses an example load profile, but one that is real. While this is essentially anecdotal rather than a rigorous analysis of a range of household types, the results indicate quite small differences in IRR.

Table 6: Differences in financial performance measures at difference resolutions for a particular household, considered similar to HH18. Analysis is based on discounted values over 31 years at 5%, no battery, no diverter, and no timer, and 5 kWp-ac PV north facing with a 20 degree tilt in Christchurch. Light induced degradation in PV generation is included. The retail prices used are Octopus prices for Christchurch.

	1-minute analysis, estimated from the 30-minute analysis using proportions from HH18 with a 5 kW PV system	30-minute analysis, actual results, dicounted to present value	60-minute analysis, estimated from the estimated 1-minute analysis using proportions from HH18 with a 5 kW PV system
Income discounted to present value			
Export sales	$10,954	$10,602	$10,485
Retail cost savings	$5,739	$6,211	$6,367
Costs discounted to present value			
PV capital cost	-$13,610	-$13,610	-$13,610
PV O&M cost	-$1,514	-$1,514	-$1,514
NPV	$1,569	$1,688	$1,728
NPV difference from 1-minute value	0.0%	7.6%	10.2%
IRR	5.97%	6.04%	6.06%
IRR difference from 1-minute value	0.0%	1.2%	1.6%

[Self_consumption_versus_resolution_results-with tables-with local solar.xlsm]Impact on financial results

We therefore conclude that analysis at a lower resolution (half-hourly or hourly) will show a more positive benefit of PV than PV will actually provide. However, IRR differences at different resolutions appear to be quite small – roughly 1-2% higher IRRs are achieved at 30-minute resolution compared to 1-minute resolution. We also conclude that the more positive benefit of PV will be more pronounced at lower PV capacities, and will vary by household consumption, with higher consuming households having higher error in general, especially if consumption is generally high during the day including morning and evening peak periods.

This last conclusion stands to reason, as the higher the consumption, the greater the retail load reduction potential there is, particularly if this retail consumption occurs during the daytime. Figures 1-4 show the load profiles of each household. What is clear is that Household 20 has lower consumption during the day, with more shifted into the night when there is no solar. This household also has the lowest error in retail consumption reduction.

To help understand why resolution makes a difference, Figures 7-9 show the load profiles for single days at each resolution. The difference between 1-minute resolution and 30-minnute resolution load in Figure 9 (a) and (b) illustrates why retail cost savings are higher with 30-minute resolution analysis compared to 1-minute analysis. For example, for the two 30 minute periods after 12:00 this clearly shows net load alternating between import and export in the 1-minute resolution data (a), but only reduced load in the 30-minute resolution load (b).

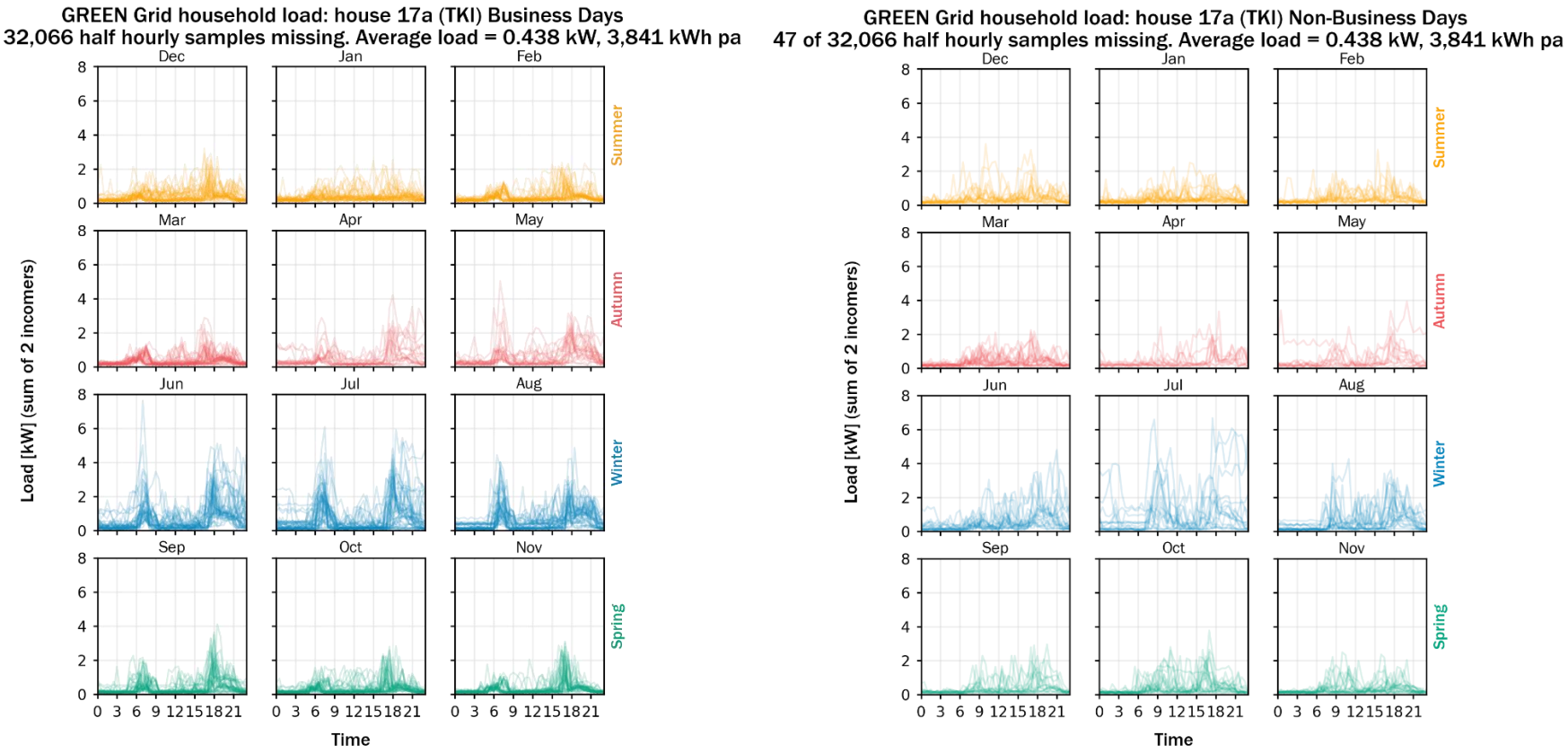


Figure 1: Load profile of Household 17a.

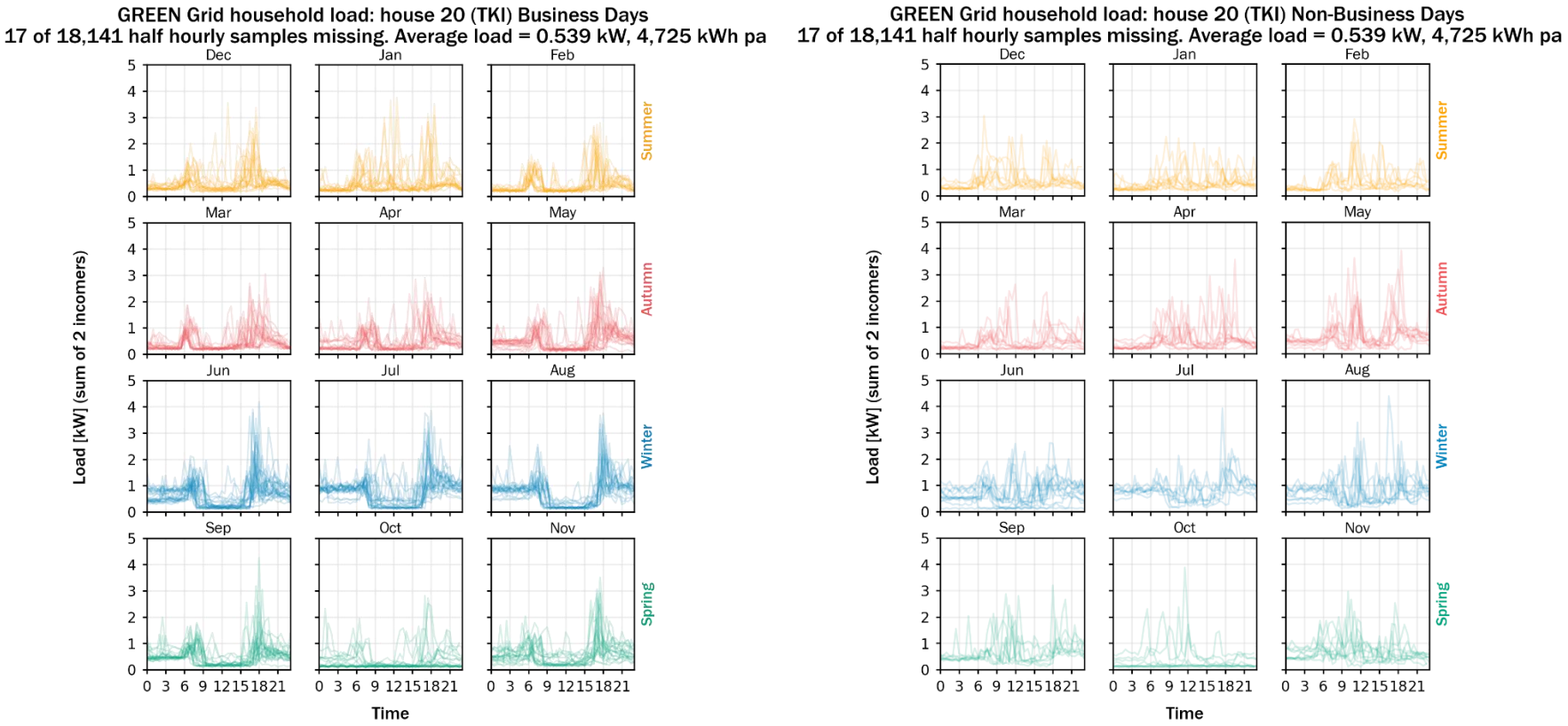


Figure 2: Load profile of Household 20.

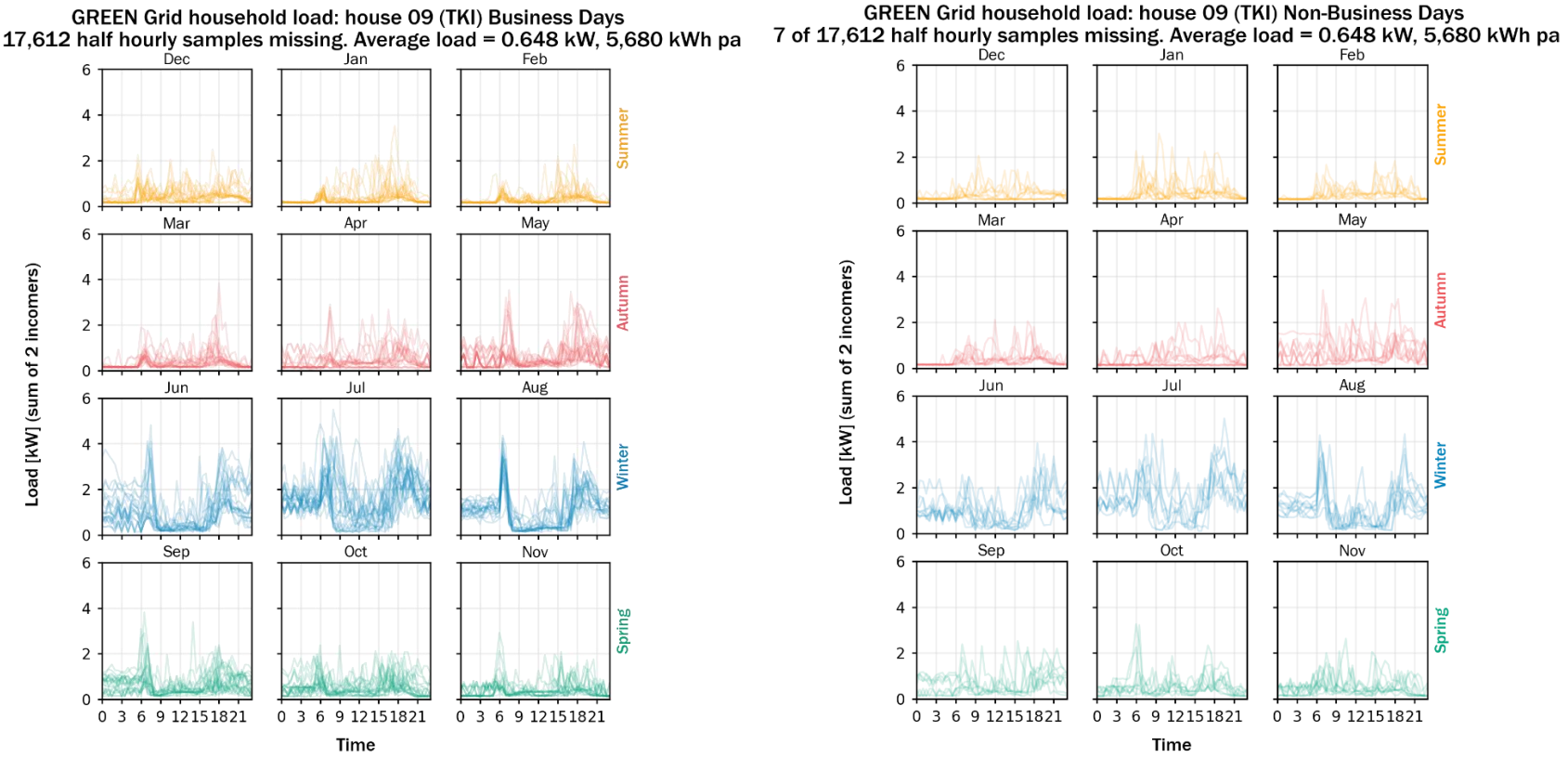


Figure 3: Load profile of Household 09.

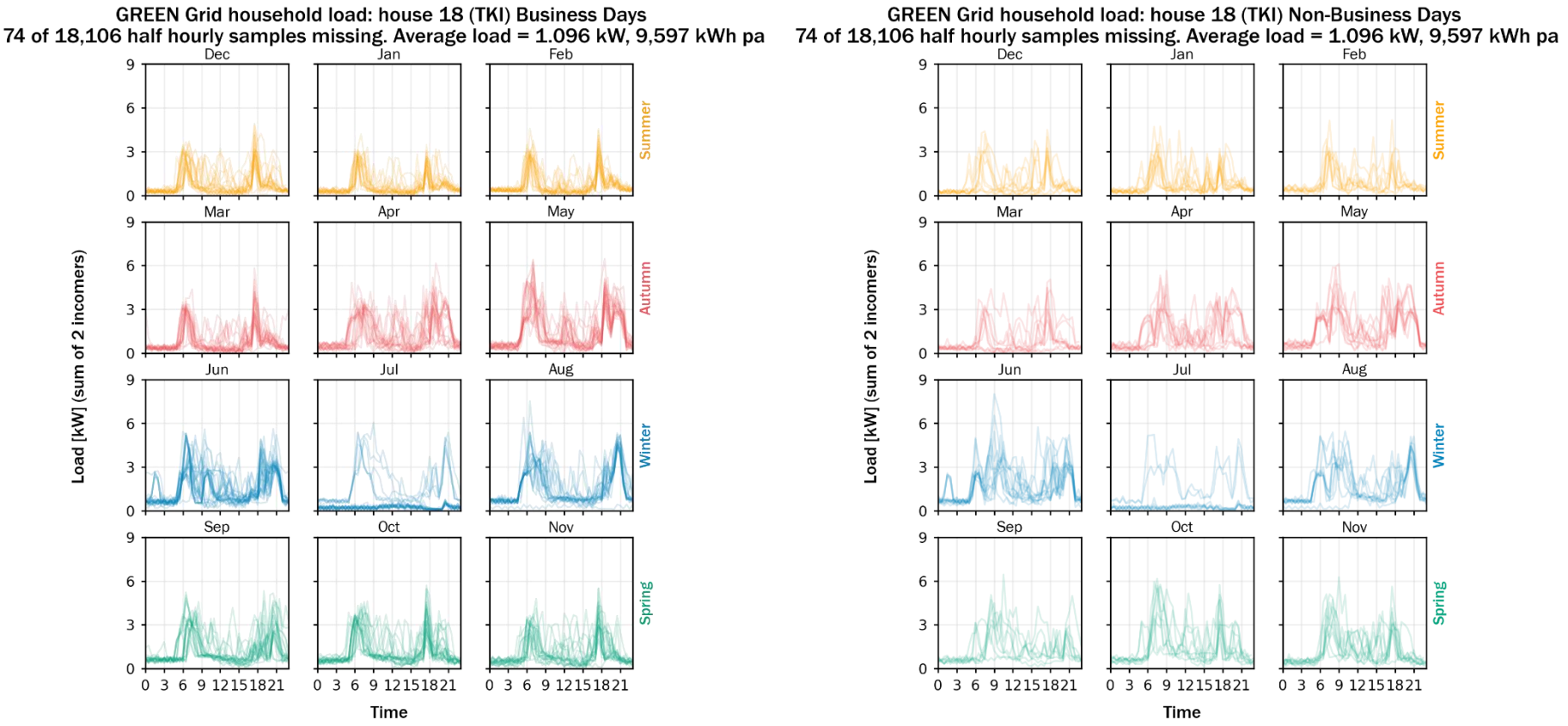
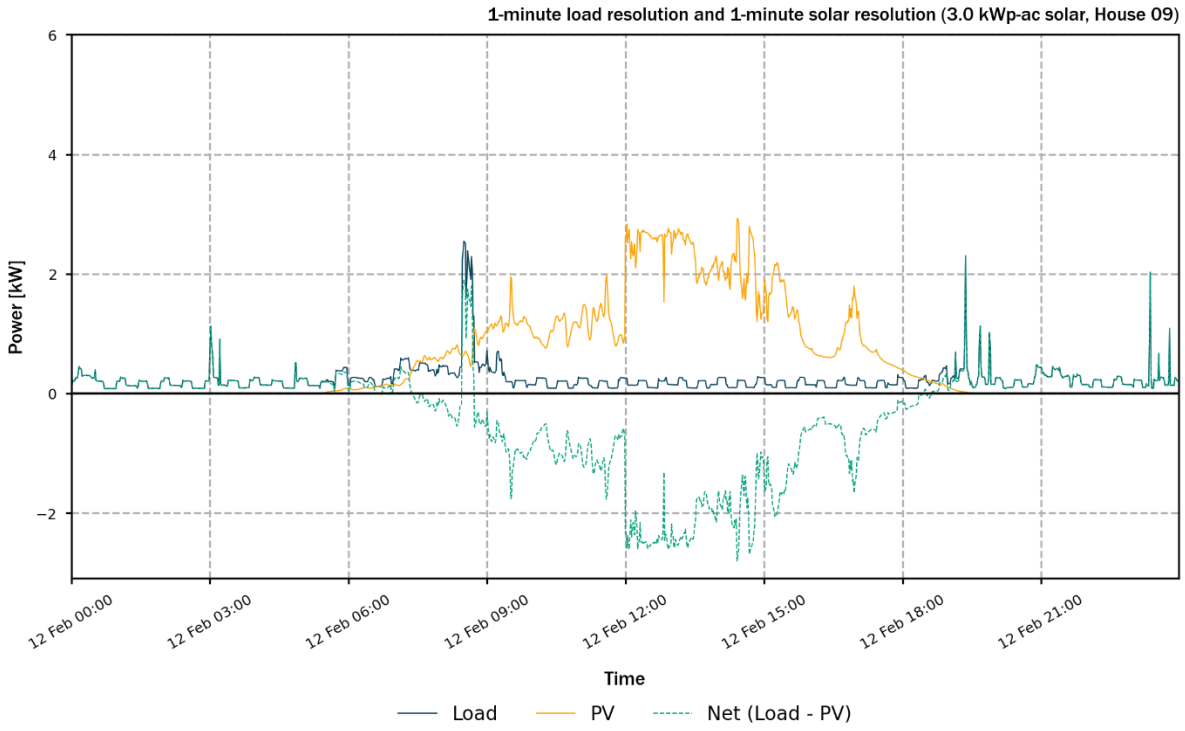
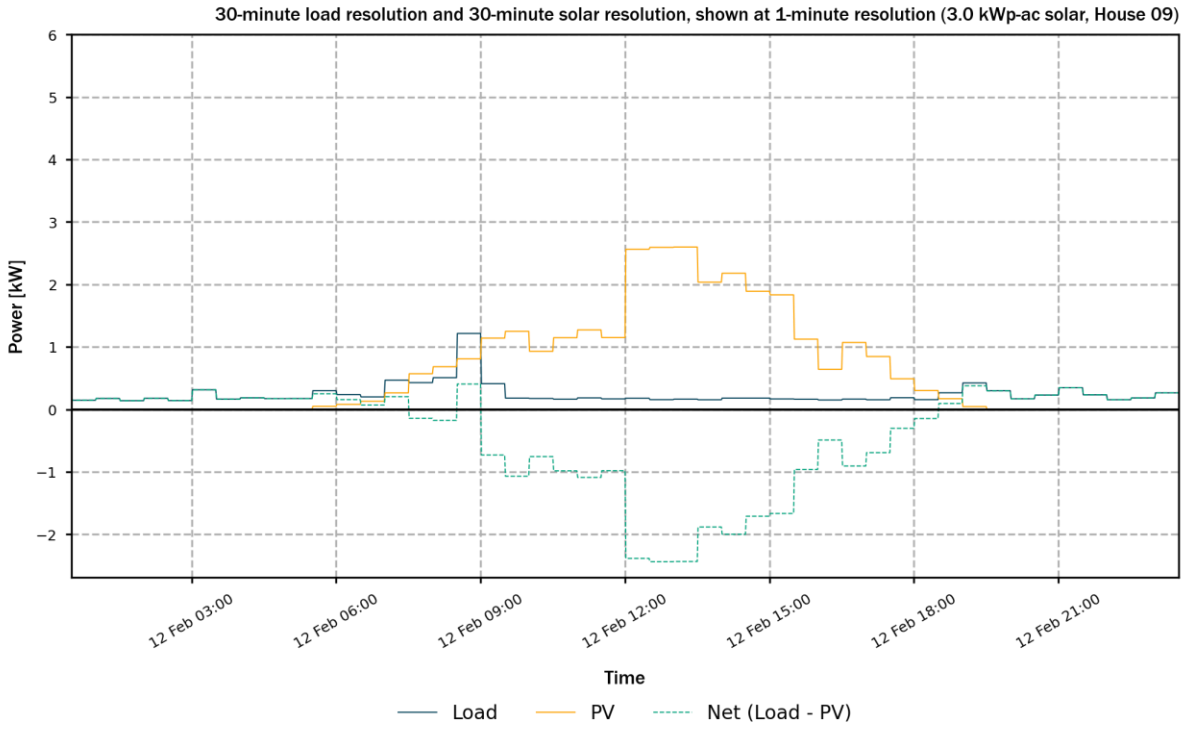


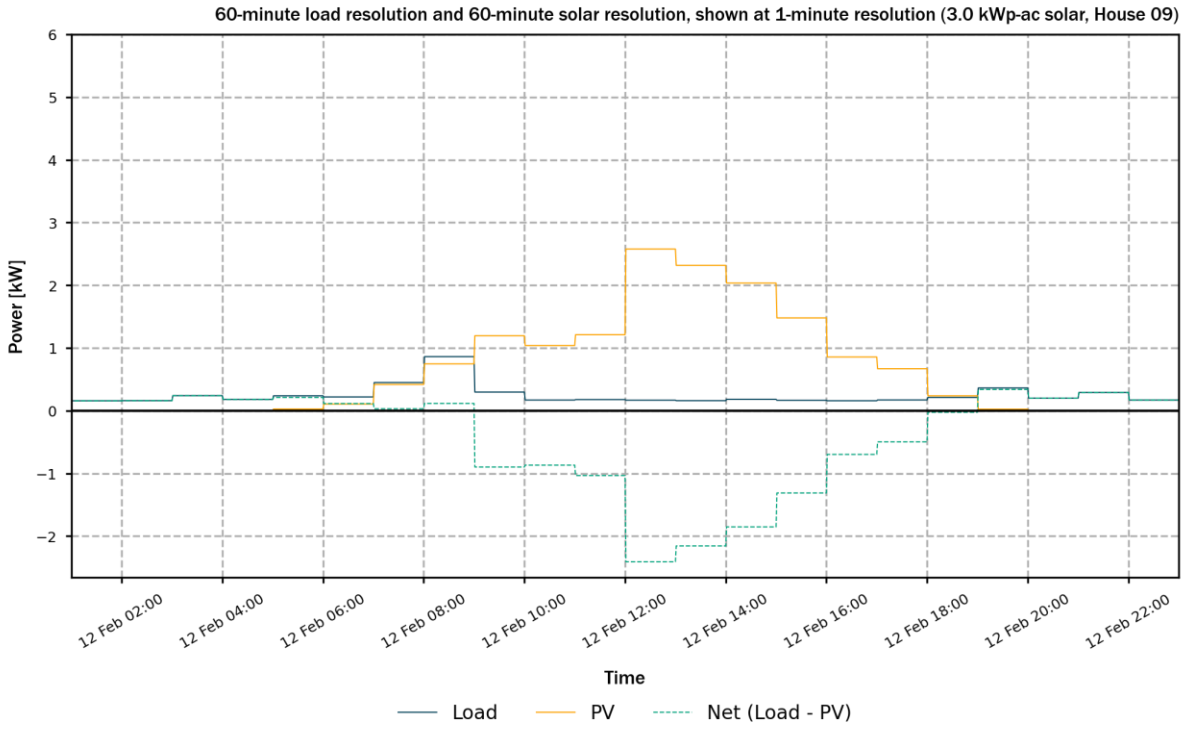
Figure 4: Load profile of Household 18.


1-minute load resolution and 1-minute solar resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
4
2
0
−2
12 Feb 00:00
12 Feb 03:00
12 Feb 06:00
12 Feb 09:00
12 Feb 12:00
12 Feb 15:00
12 Feb 18:00
12 Feb 21:00
Time
Load
PV
Net (Load - PV)

(a)

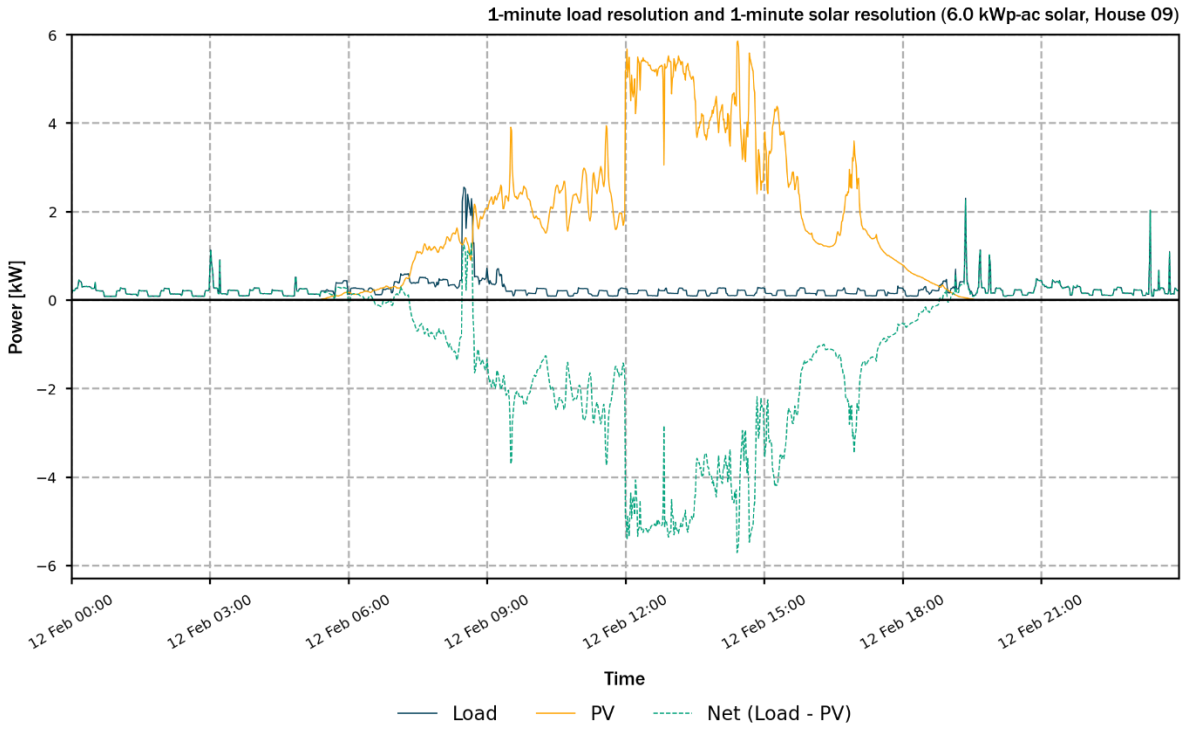

30-minute load resolution and 30-minute solar resolution, shown at 1-minute resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
5
4
3
2
1
0
−1
−2
12 Feb 03:00
12 Feb 06:00
12 Feb 09:00
12 Feb 12:00
12 Feb 15:00
12 Feb 18:00
12 Feb 21:00
Time
Load
PV
Net (Load - PV)

(b)

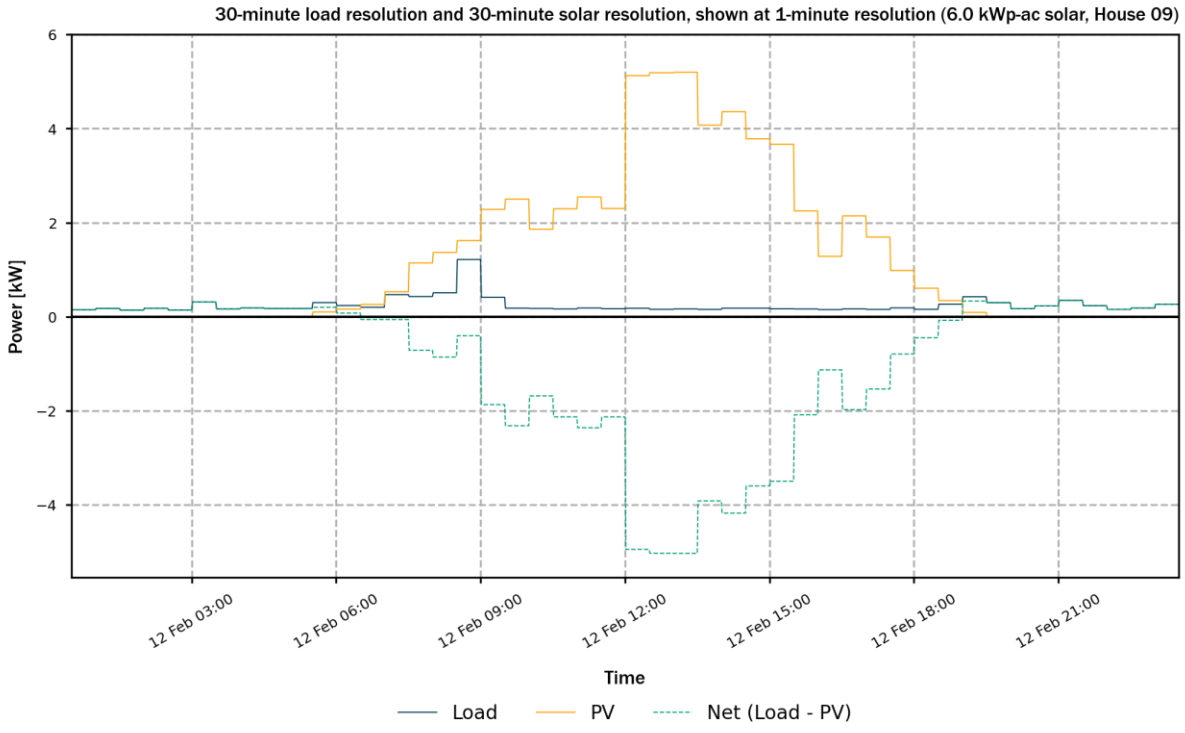


(c)

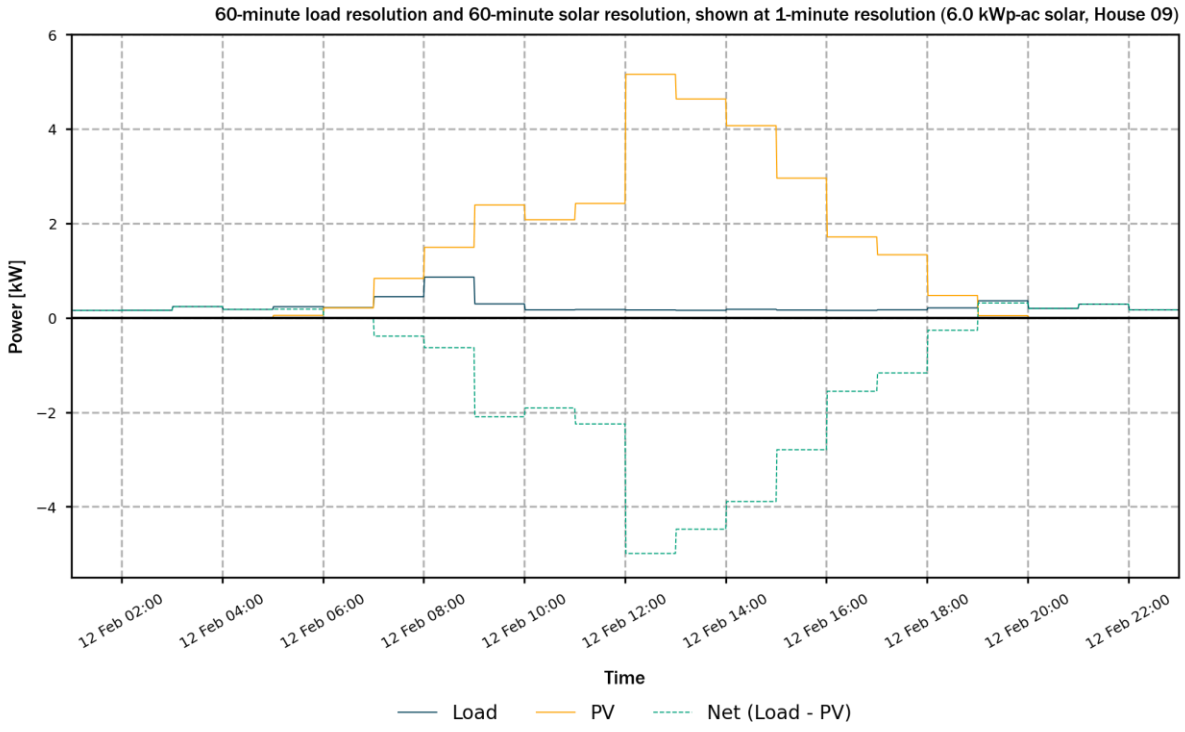
Figure 5: Household 09 load on 12 February with a 3 kW PV system, shown at: (a) 1-minute resolution; (b) 30-minute resolution; and (c) 60 minute resolution.


1-minute load resolution and 1-minute solar resolution (6.0 kWp-ac solar, House 09)
Power [kW]
6
4
2
0
−2
−4
−6
12 Feb 00:00
12 Feb 03:00
12 Feb 06:00
12 Feb 09:00
12 Feb 12:00
12 Feb 15:00
12 Feb 18:00
12 Feb 21:00
Time
Load
PV
Net (Load - PV)

(a)

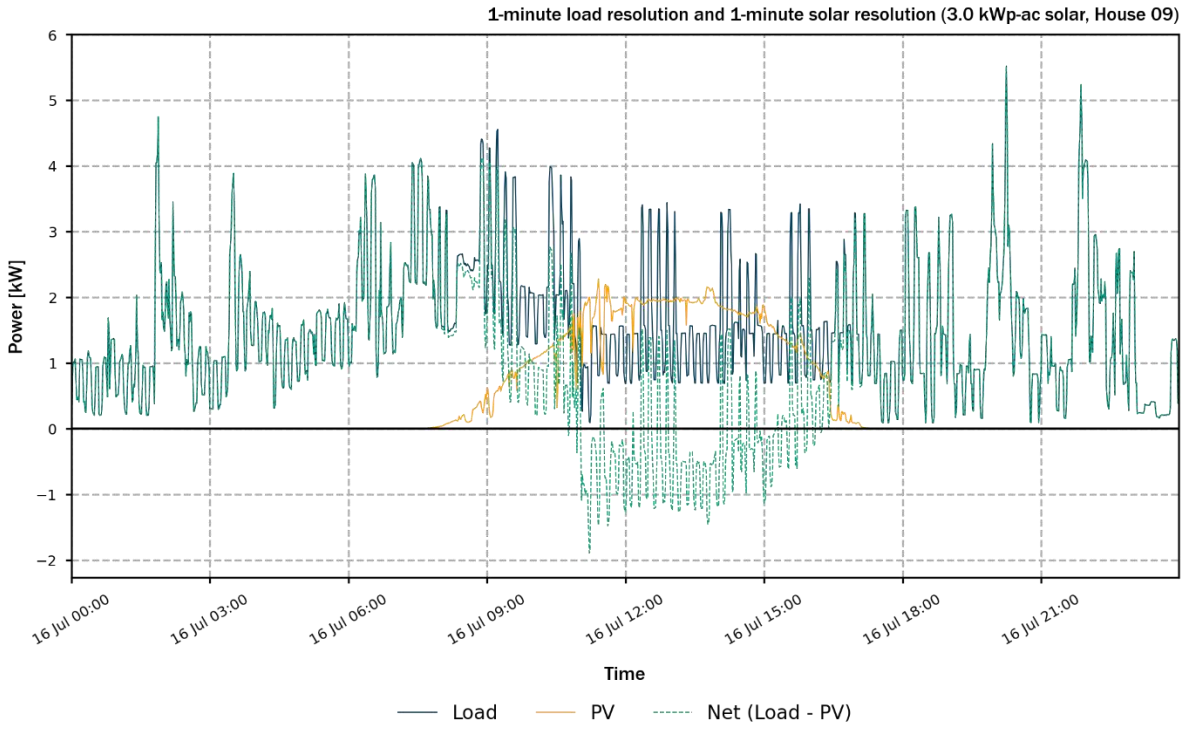

30-minute load resolution and 30-minute solar resolution, shown at 1-minute resolution (6.0 kWp-ac solar, House 09)
Power [kW]
6
4
2
0
−2
−4
12 Feb 03:00
12 Feb 06:00
12 Feb 09:00
12 Feb 12:00
12 Feb 15:00
12 Feb 18:00
12 Feb 21:00
Time
Load
PV
Net (Load - PV)

(b)

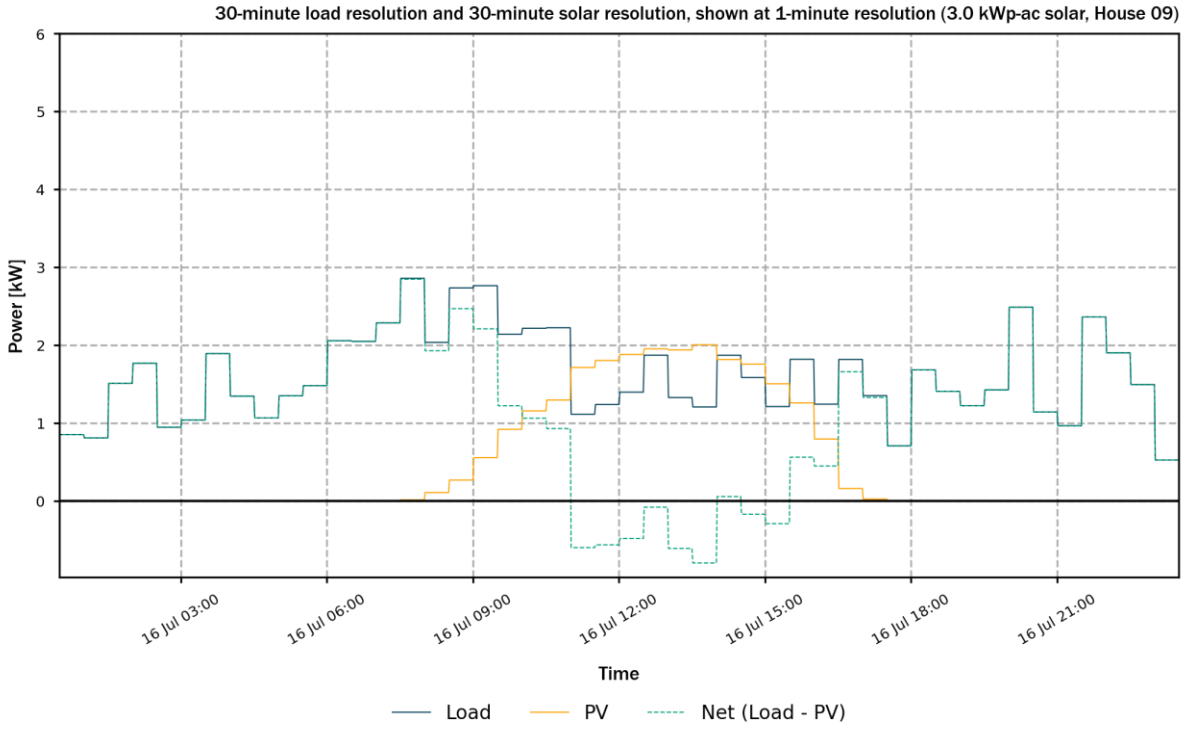


(c)

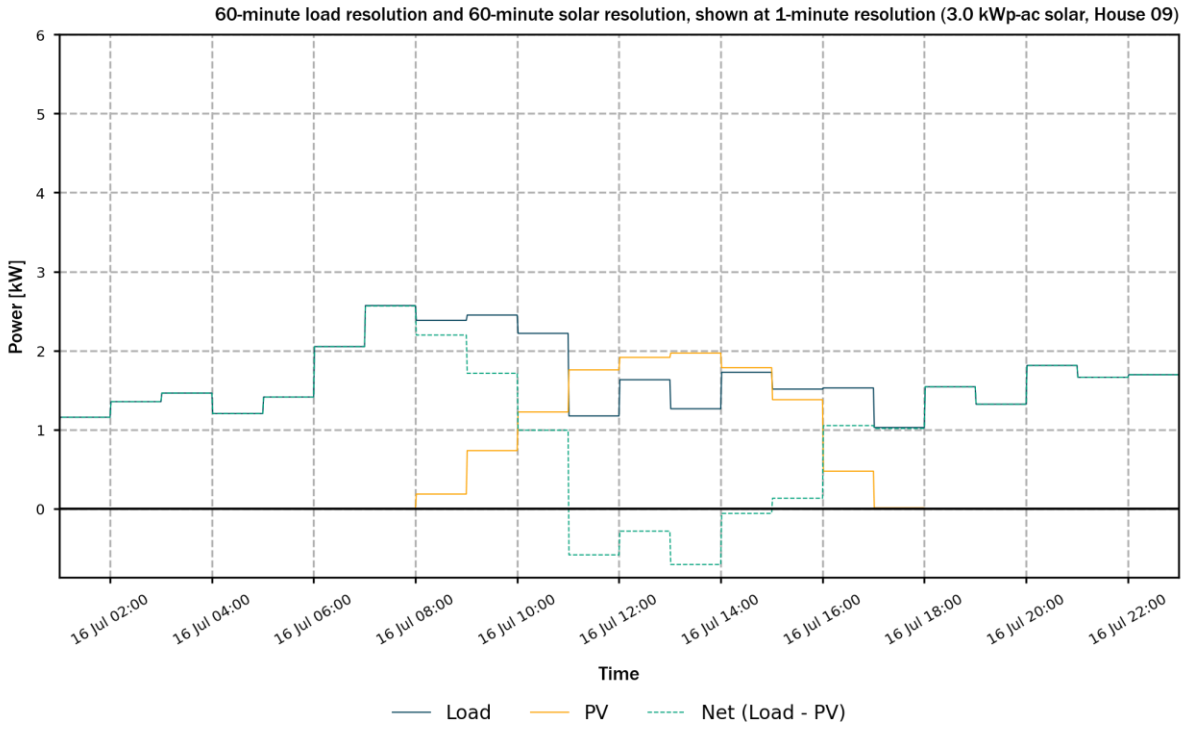
Figure 6: Household 09 load on 12 February with a 6 kW PV system, shown at: (a) 1-minute resolution; (b) 30-minute resolution; and (c) 60 minute resolution.


1-minute load resolution and 1-minute solar resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
5
4
3
2
1
0
−1
−2
16 Jul 00:00
16 Jul 03:00
16 Jul 06:00
16 Jul 09:00
16 Jul 12:00
16 Jul 15:00
16 Jul 18:00
16 Jul 21:00
Time
Load
PV
Net (Load - PV)

(a)

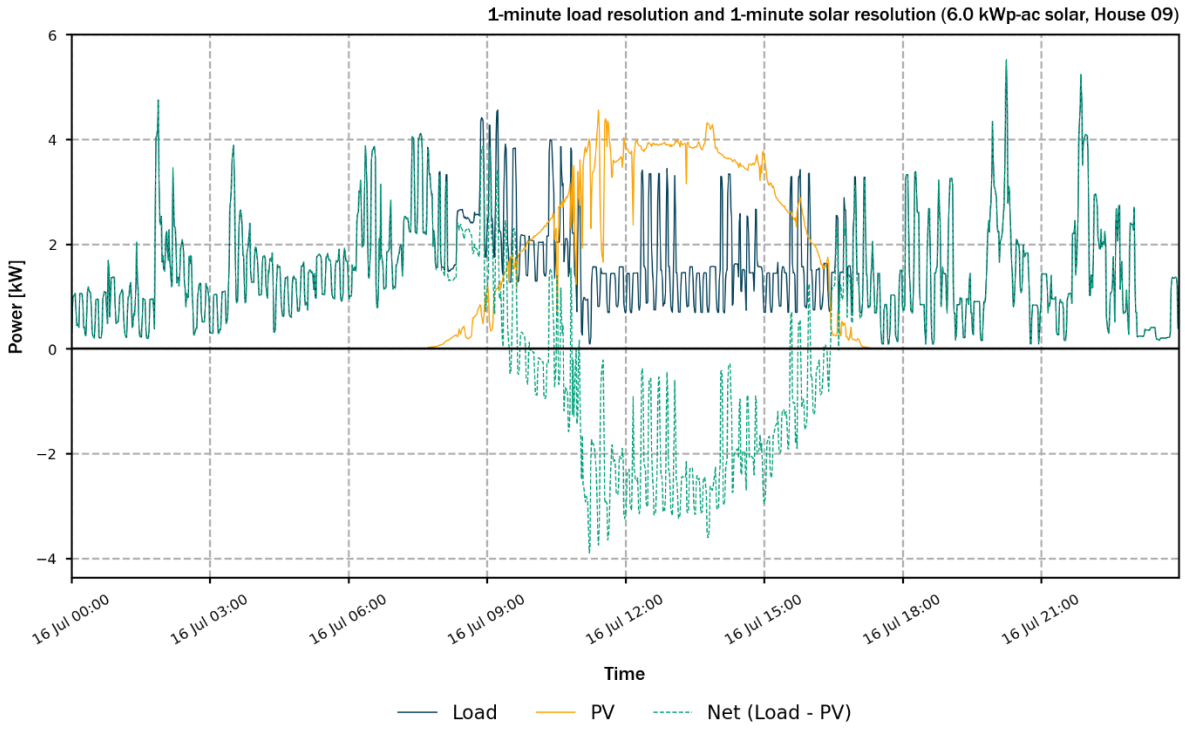

30-minute load resolution and 30-minute solar resolution, shown at 1-minute resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
5
4
3
2
1
0
16 Jul 03:00
16 Jul 06:00
16 Jul 09:00
16 Jul 12:00
16 Jul 15:00
16 Jul 18:00
16 Jul 21:00
Time
Load
PV
Net (Load - PV)

(b)

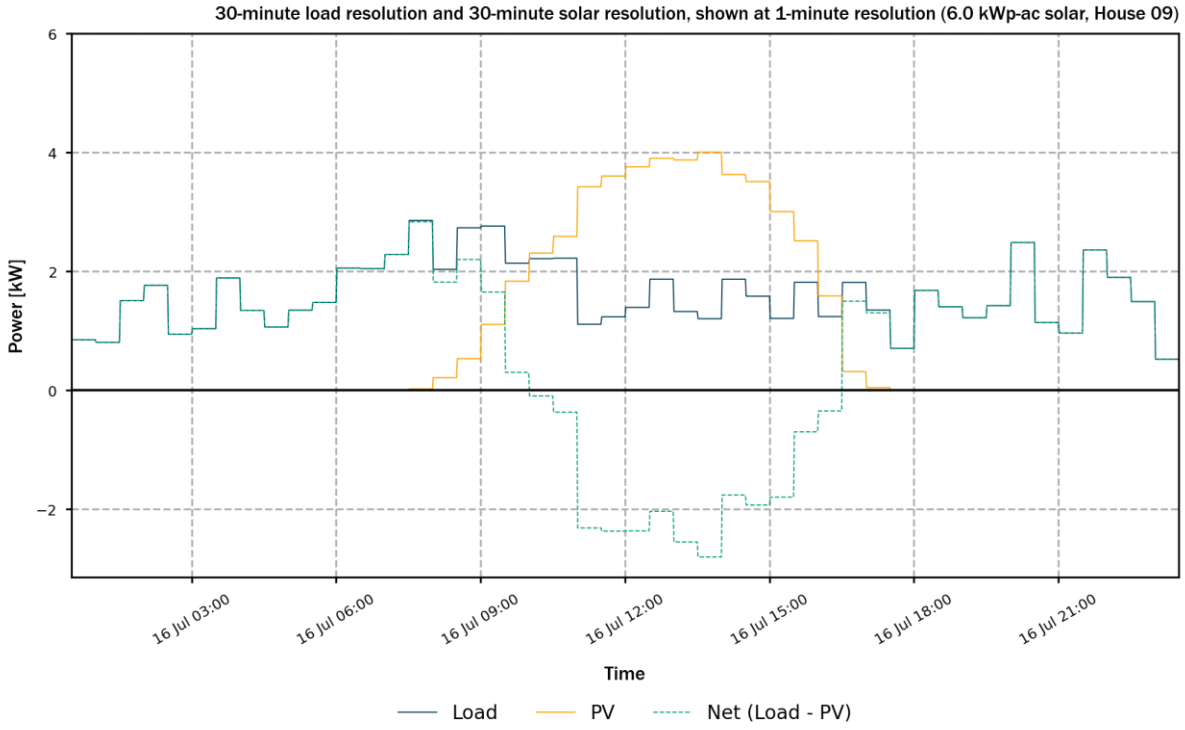


(c)

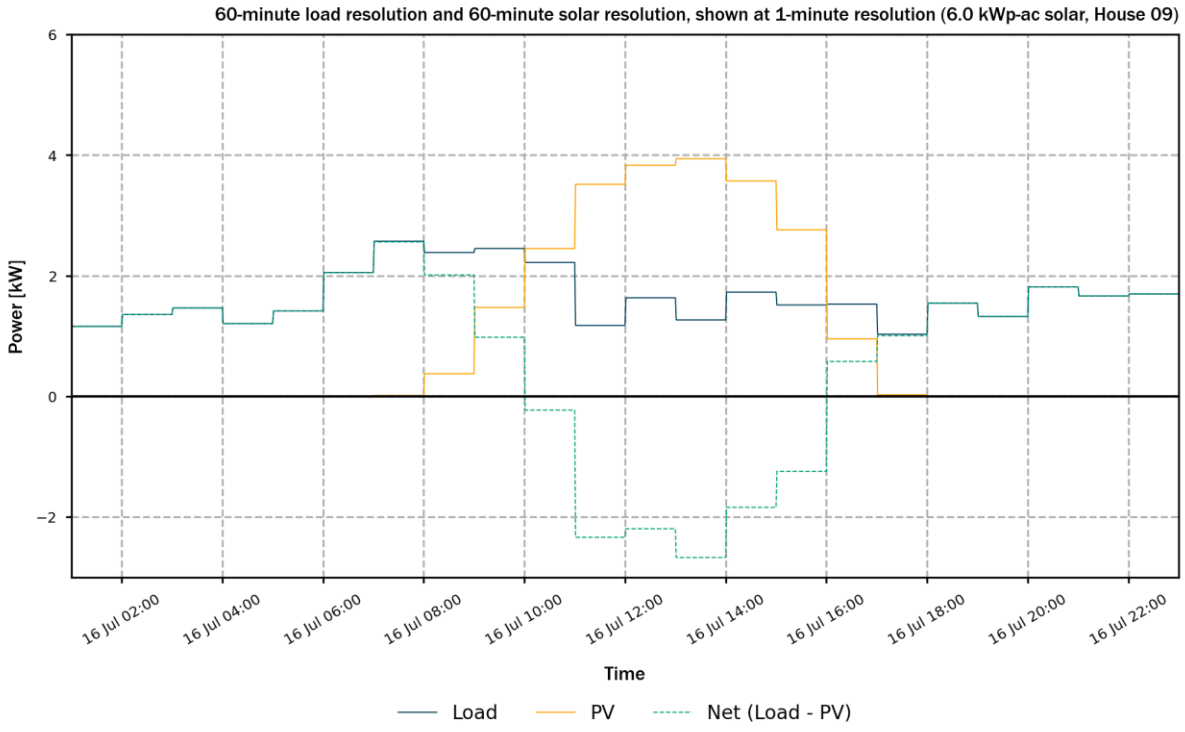
Figure 7: Household 09 load on 16 July with a 3 kW PV system, shown at: (a) 1-minute resolution; (b) 30-minute resolution; and (c) 60 minute resolution.


1-minute load resolution and 1-minute solar resolution (6.0 kWp-ac solar, House 09)
Power [kW]
6
4
2
0
−2
−4
16 Jul 00:00
16 Jul 03:00
16 Jul 06:00
16 Jul 09:00
16 Jul 12:00
16 Jul 15:00
16 Jul 18:00
16 Jul 21:00
Time
Load
PV
Net (Load - PV)

(a)

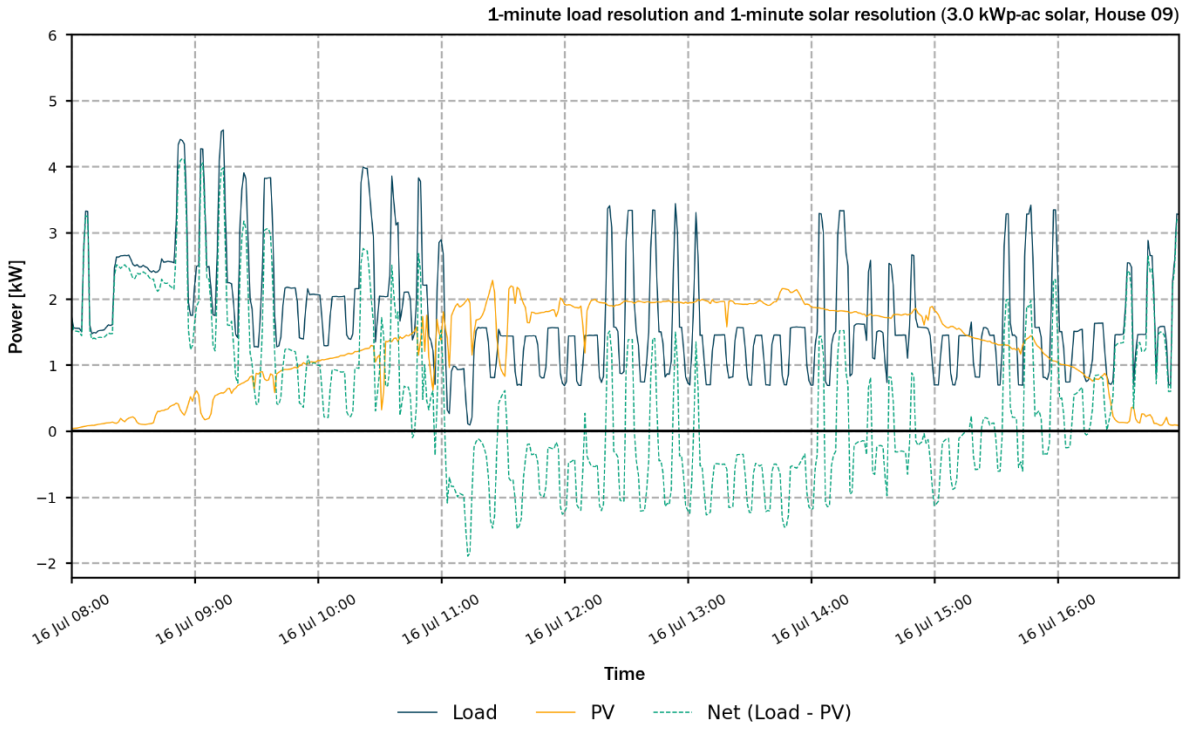

30-minute load resolution and 30-minute solar resolution, shown at 1-minute resolution (6.0 kWp-ac solar, House 09)
Power [kW]
6
4
2
0
−2
16 Jul 03:00
16 Jul 06:00
16 Jul 09:00
16 Jul 12:00
16 Jul 15:00
16 Jul 18:00
16 Jul 21:00
Time
Load
PV
Net (Load - PV)

(b)

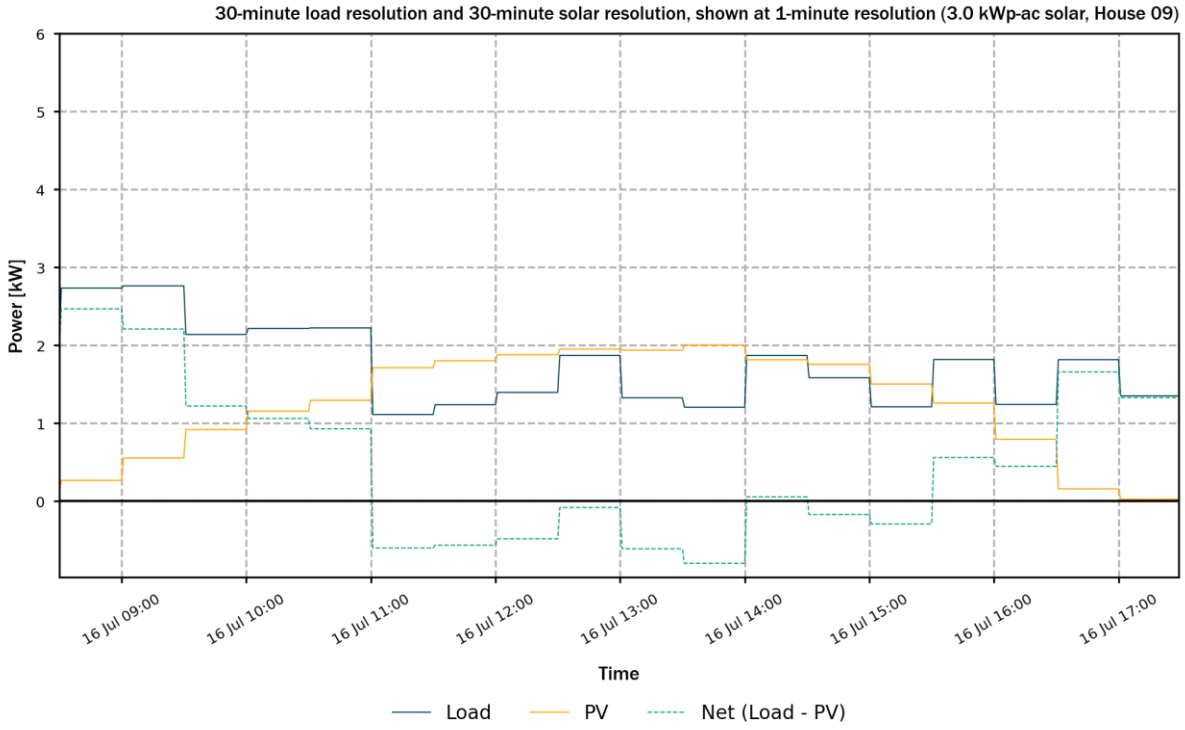


(c)

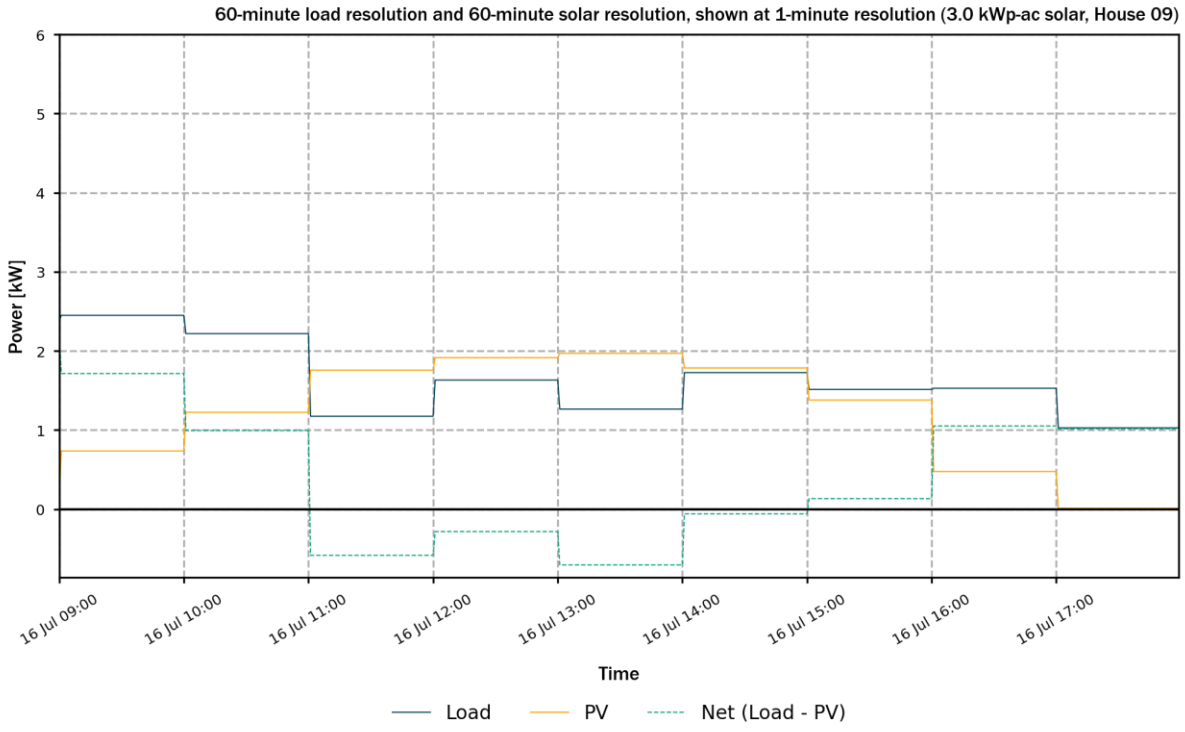
Figure 8: Household 09 load on 16 July with a 6 kW PV system, shown at: (a) 1-minute resolution; (b) 30-minute resolution; and (c) 60 minute resolution.


1-minute load resolution and 1-minute solar resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
5
4
3
2
1
0
−1
−2
16 Jul 08:00
16 Jul 09:00
16 Jul 10:00
16 Jul 11:00
16 Jul 12:00
16 Jul 13:00
16 Jul 14:00
16 Jul 15:00
16 Jul 16:00
Time
Load
PV
Net (Load - PV)

(a)


30-minute load resolution and 30-minute solar resolution, shown at 1-minute resolution (3.0 kWp-ac solar, House 09)
Power [kW]
6
5
4
3
2
1
0
16 Jul 09:00
16 Jul 10:00
16 Jul 11:00
16 Jul 12:00
16 Jul 13:00
16 Jul 14:00
16 Jul 15:00
16 Jul 16:00
16 Jul 17:00
Time
Load
PV
Net (Load - PV)

(b)



(c)

Figure 9: Household 09 load on 16 July with a 3 kW PV system, zoomed in on the period when the PV system is generating. Shown at: (a) 1-minute resolution; (b) 30-minute resolution; and (c) 60 minute resolution.