Solar Electricity Production in Nova Scotia

Analysis of Curtailment of Solar Power at a Large Commercial Facility

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NSCC Applied Energy Research

- Work with partners to solve practical problems and advance sustainable energy products and services.
- Provide learning opportunities for students and faculty.

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Community Solar Data Project

- Gather high-frequency, near-real-time data on solar electricity production from installations around Nova Scotia.
- Make the data available for researchers through a data portal.
- Make the data visible to the public for educational purposes.
- Develop solar electricity analytics and forecasting capability for Nova Scotia.

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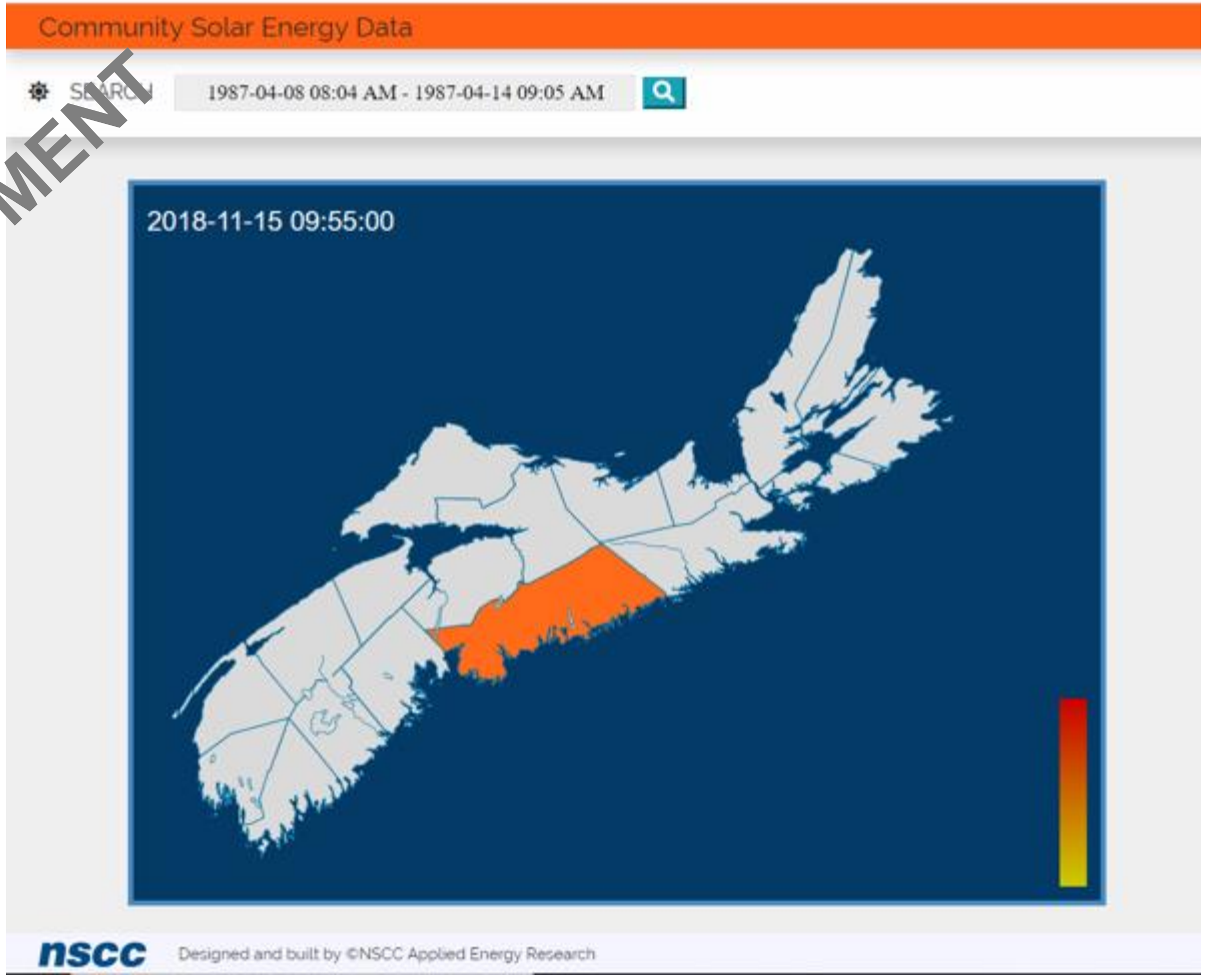
Community Solar Data Website



DRAFT IN DEVELOPMENT

Where the public can view solar energy production and forecast data.

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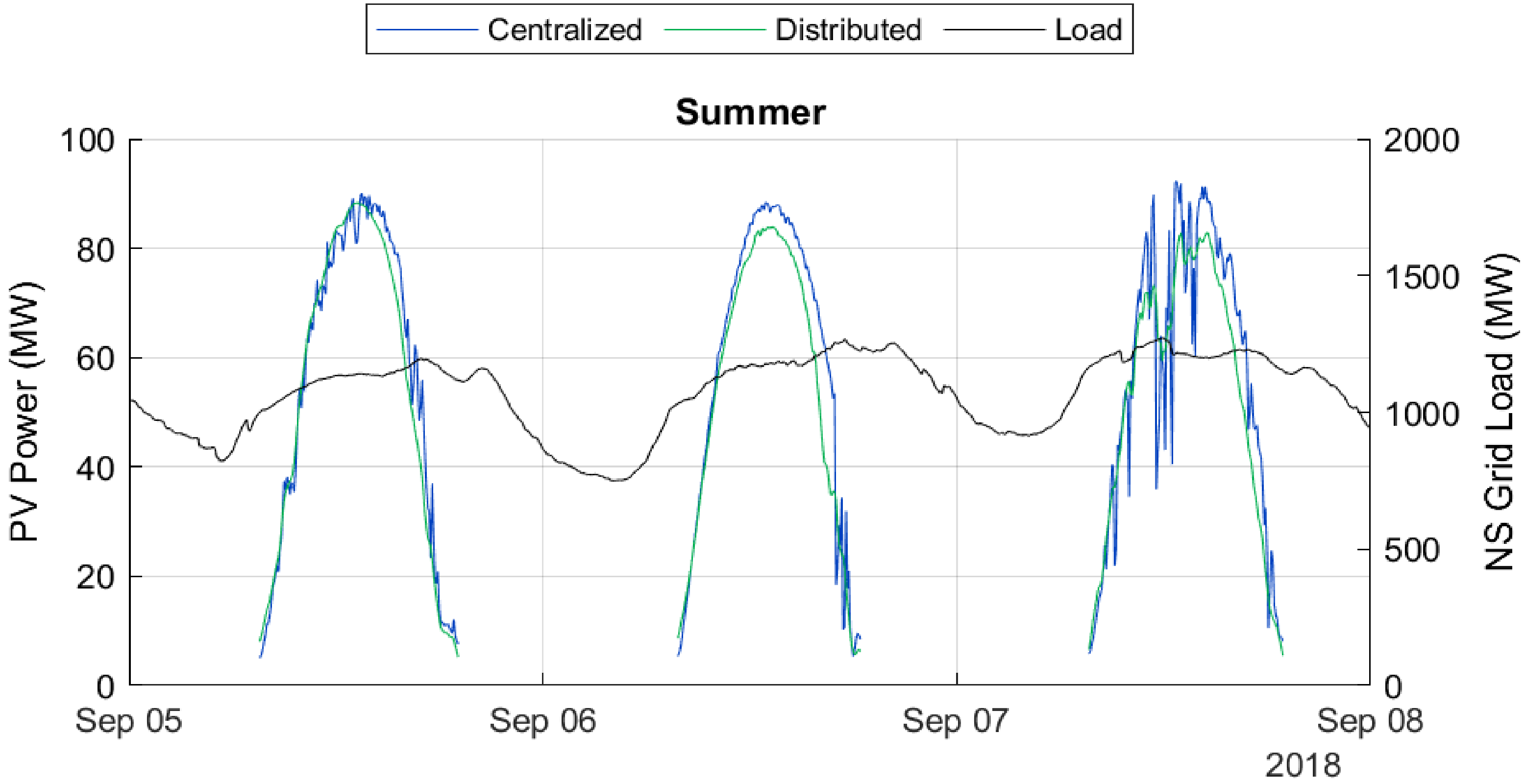
Dalhousie Research Partnership

At the Renewable Energy Storage Lab (RESL), Dr. Lukas Swan and Bryan Ellis are using the solar data for research.



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Partners

With thanks to IKEA for sharing data.

Example research: Analysis of Curtailment at Ikea Store in Dartmouth, Nova Scotia

- The IKEA store in Dartmouth opened with a rooftop solar PV system in 2017.
- Due to net-metering legislation, this system is restricted from back-feeding solar electricity production to the Nova Scotia Power grid. (100 kW limit)
- IKEA Canada has provided solar production and building load data to the Community Solar database.
- NSCC Applied Energy Research analyzed this data.

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Goals

- Estimate amount of solar energy being curtailed.
- Estimate solar reduction in peak demand charges.
- Identify patterns in solar production and building load.

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IKEA Solar PV System Details

- Solar PV system size:
  - Array capacity = 838 kW_{dc}
  - 28 x 24kWac Fronius inverters = 672 kW_{ac}
  - DC/AC ratio = 1.26
- Data Source:
  - 5-minute time-step data
  - Solar production: Fronius inverter data monitoring
  - Grid load: smart meter
- Analysis:
  - 1 year of data (June 18, 2018 – June 18, 2019)

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Methods- Step 1 – Develop SolarFit Dataset

Goal: develop non-curtailed solar production data to compare with curtailed IKEA system data

System match

- Selected a residential system from Community Solar Database:
  - Located in HRM to ensure equivalent solar resource
  - Same inverter type as IKEA (Fronius)

Determine scaling factor

- Determined scaling factor to match production between residential and Ikea systems:
  - Divided the size of the IKEA system by the size of the residential system to get an initial estimate
  - Ikea/residential system = 672,000 kW_{dc}/7,600 kW_{dc} = ~88 scaling factor

Refinement

- Refine scaling factor to better reflect the IKEA system:
  - Select IKEA solar days that did not appear to have curtailment
  - Tested values ±5 from our initial estimate of 88
  - Applied correlation and sum of squared error measurements between Ikea and residential system during daylight hours (9am-6pm)

Result

- Non-curtailed solar production data to compare with the curtailed IKEA system data:
  - Final scaling factor of 87
  - Strong correlation (r = .85) with the IKEA data during daylight hours (9am-6pm) on non-curtailing days

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Methods – Step 2 – Estimate Curtailment

Goal: estimate the amount of solar electricity production curtailed in 1 year

Identify curtailment

- Determine when curtailment occurs:
  - Identify time intervals where the building reaches its minimum.
  - Minimum is between 45 kW and 70 kW to ensure no backfeed.

Estimate curtailment

- Calculate aggregate amount of curtailed energy:
  - Difference between the modelled and actual production
  - Only if the difference is greater than 0
  - Sum these values over time (e.g. days, months)

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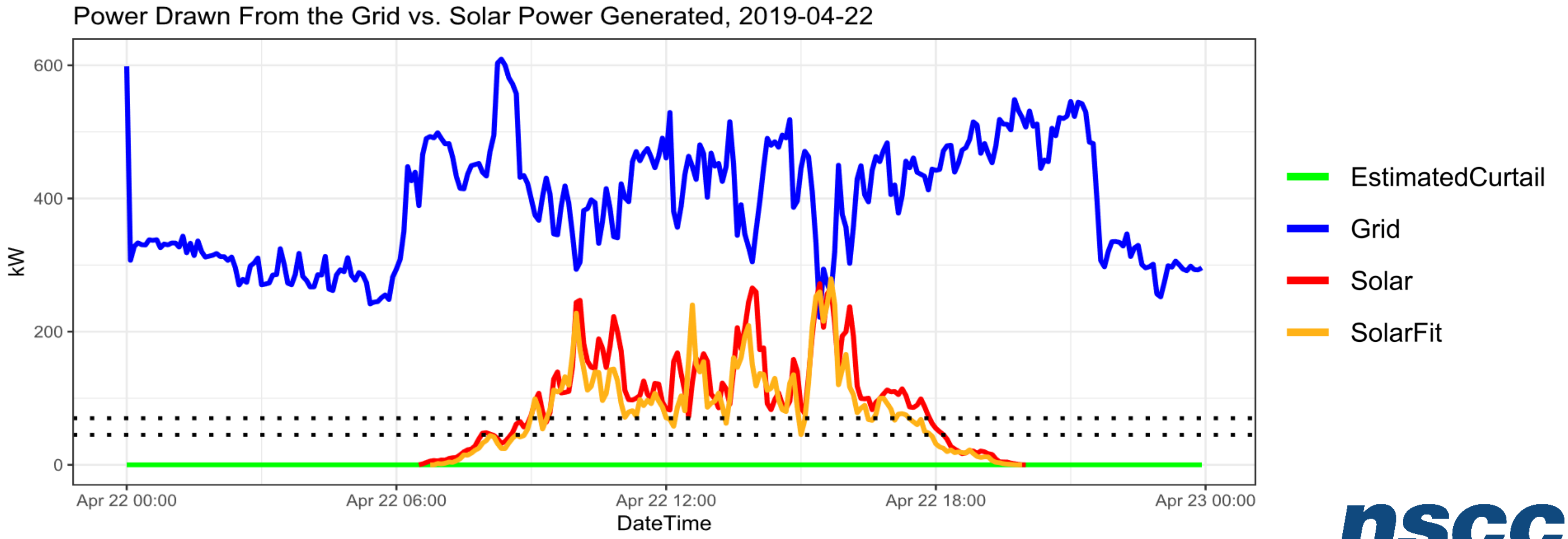
Some examples of curve fitting

No Curtailment

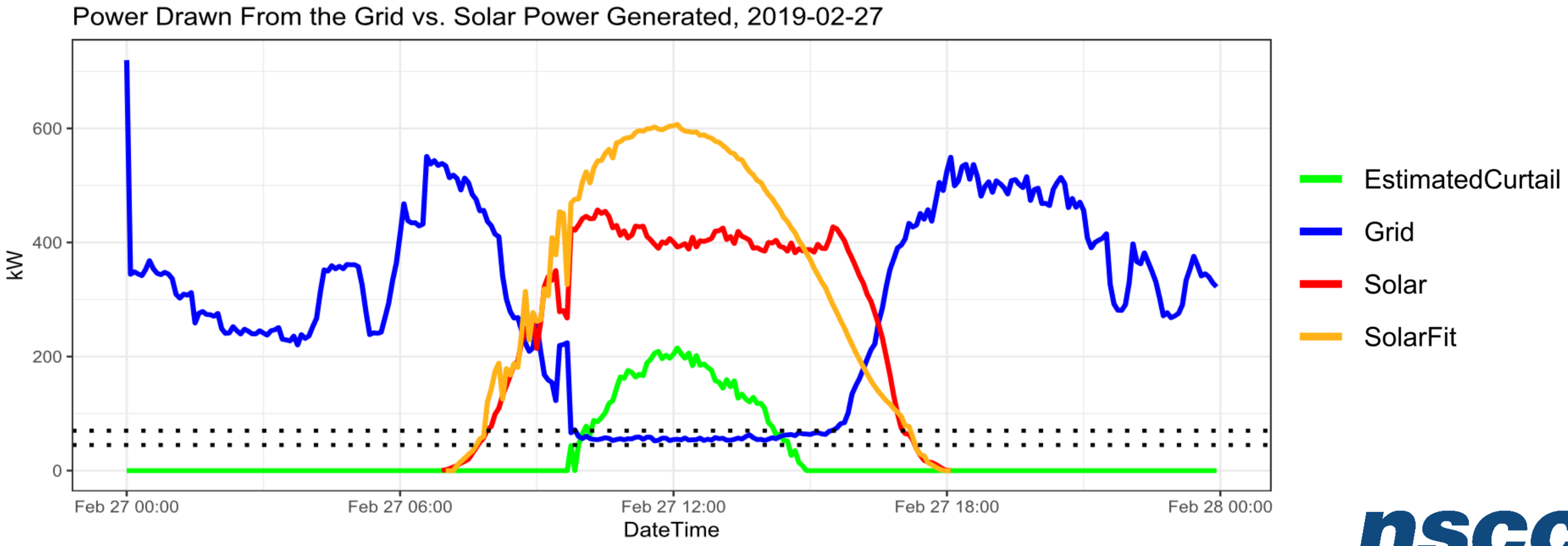
The indicator of curtailment is when the power taken from the grid (blue line) falls within the minimum range, as indicated by the dotted black lines. No curtailment occurs on this day.



Some examples of curve fitting

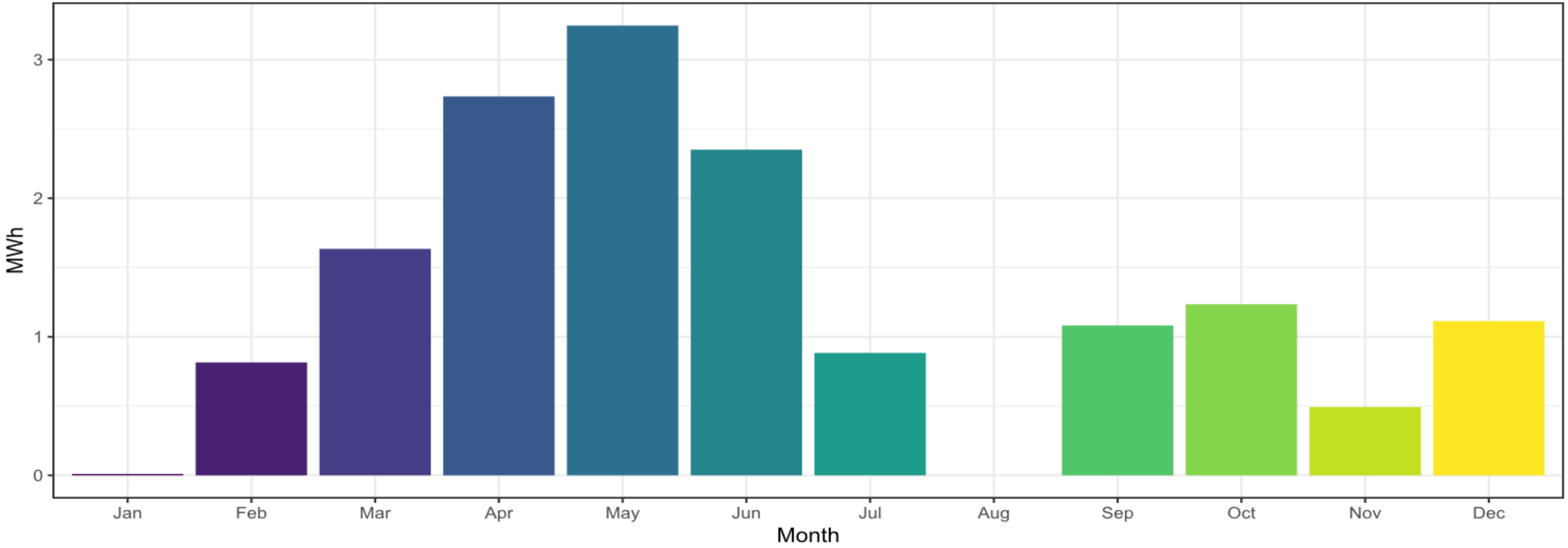
Curtailment

The indicator of curtailment is when the power taken from the grid (blue line) falls within the minimum range, as indicated by the dotted black lines. Curtailment occurs between approx. 10 am and 4 pm on this day.



Findings - Curtailment

Total Curtailment by Month



- **Most curtailment happens from March to June with peak curtailment in May**
- **No curtailment occurs in August likely due to high cooling loads**
- **Very little curtailment in January likely due to low solar resource and high heating loads**
- **December has higher curtailment than January due to holiday closures.**

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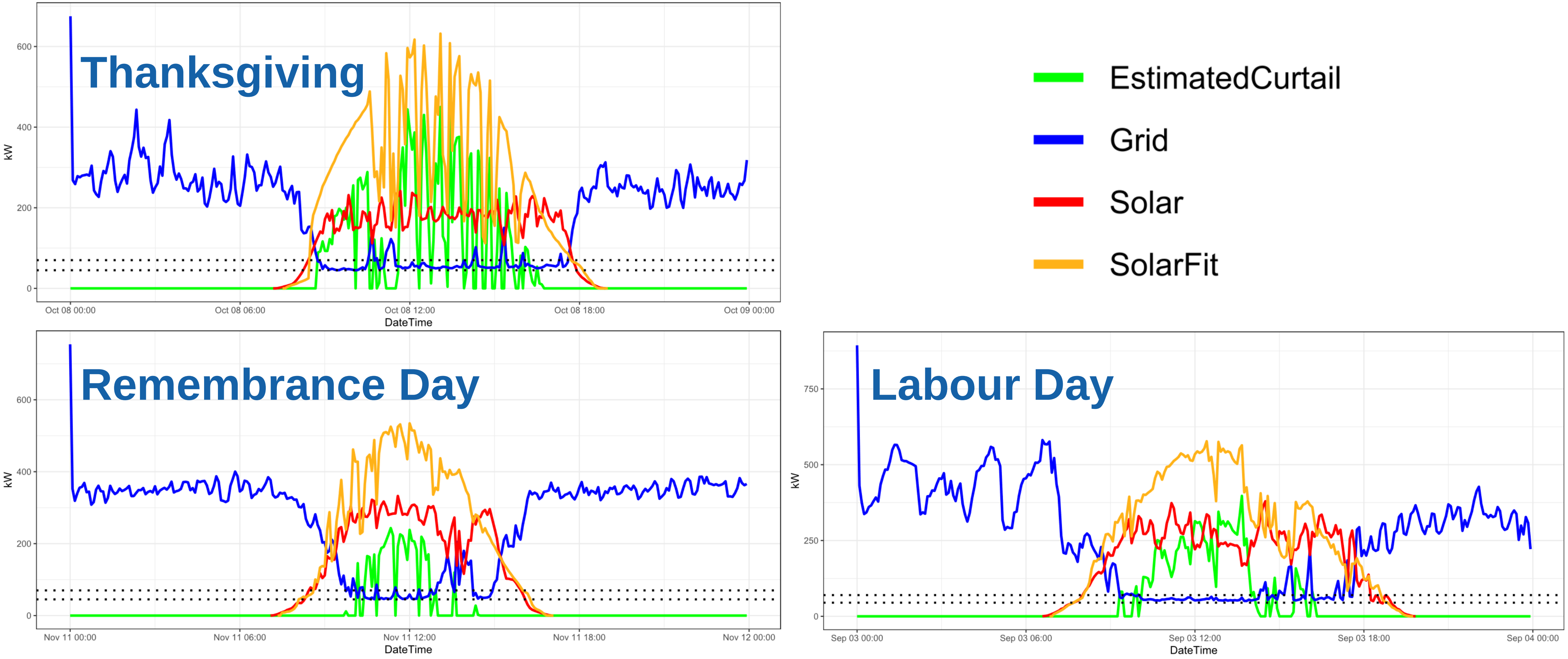
Findings - Curtailment

Holidays make many of the most curtailed days



- The store is closed, so the building load remains constant night and day
- Solar is more likely to be curtailed due to lower building load

Findings - Curtailment

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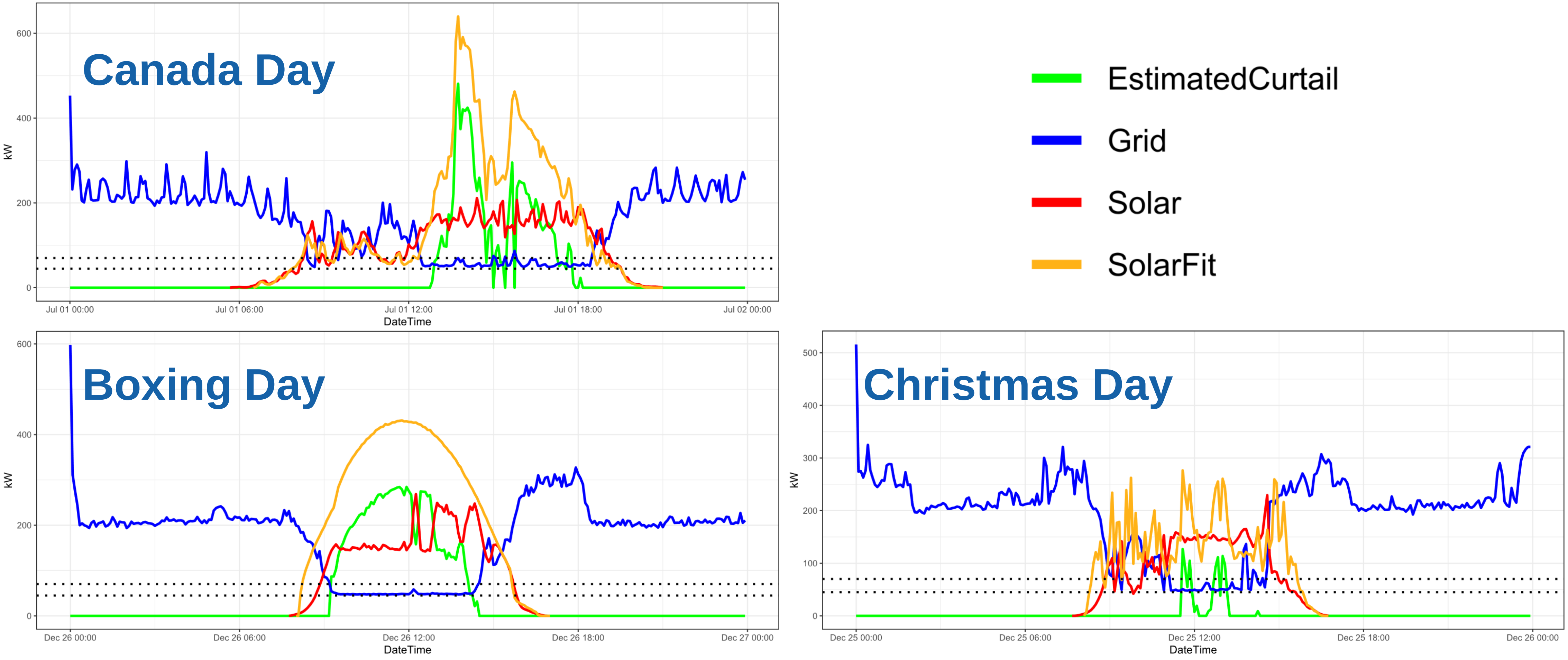

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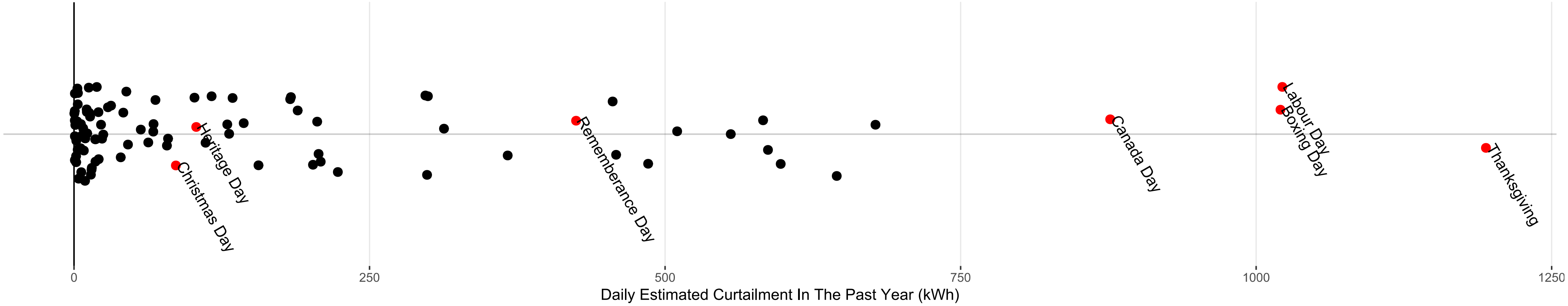
Findings – Curtailment

Annual Curtailment Estimates

- 95 days with estimated curtailment between June 18, 2018 and June 18, 2019
- Holidays are an indicator of larger curtailments, likely due to store closures
- Peak curtailment on Thanksgiving Day 2018 with approximately 1,194 kWh estimated to have been curtailed. 4 holidays represent the days with the highest curtailment and total 26% of the total curtailment for the year.

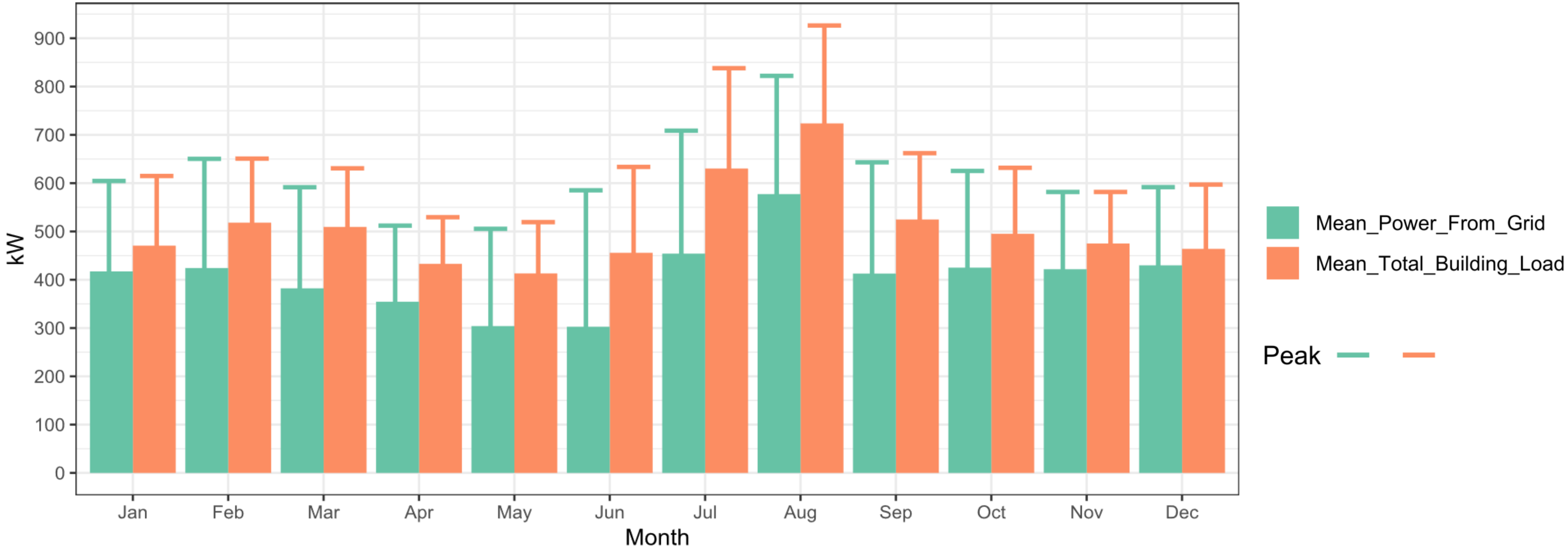


- Total building consumption (solar + grid) = 4,449,167 kWh
- Total grid consumption = 3,567,241 kWh equivalent to $311,527 @ $0.08733/kWh (NSP General Tariff)
- Total solar produced = 881,926 kWh equivalent to $77,018 @ $0.08733/MWh (NSP General Tariff) (20% of building consumption)
- Estimated total curtailment = 15,598 kWh (~1.8% of total solar produced) equivalent to

  $1,362 @ $0.08733/kWh (NSP General Tariff)

Findings – Demand Savings from Solar

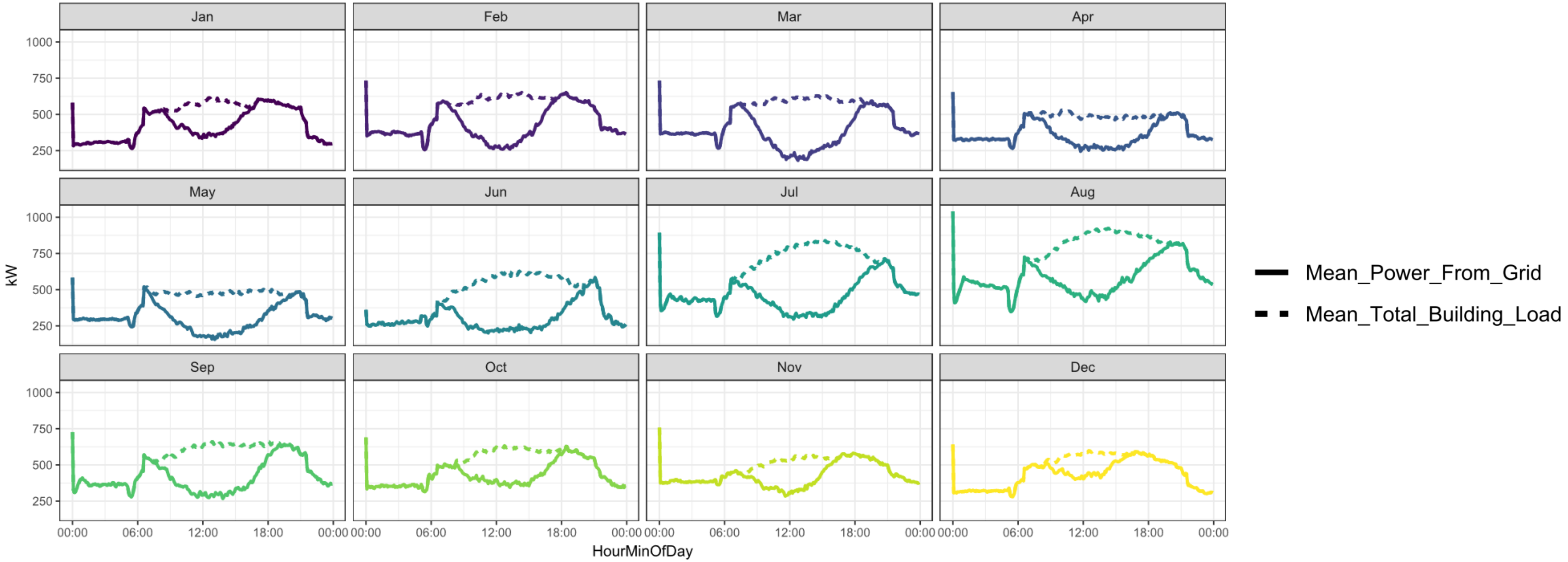
Building and Grid Mean and Peak Loads *(excluding midnight outliers)



- The mean and peak building loads (orange) are calculated by adding the grid loads (green) and the solar production (not shown).
- Solar production increases during the summer months when the solar resource is higher.
- The peak loads are 5-minute interval peaks for each month.
- Throughout the winter, spring and fall months, the building and grid peaks are almost equivalent, suggesting that solar does not contribute much to demand savings.
- During the summer months (June – August), demand savings of about 100 kW are realized on average, saving IKEA about $500-$1,500/month (@ $10.497/kW NSP General Tariff)

Findings – Demand Savings from Solar

Mean Monthly Building and Grid Loads By Time of Day



- The area between the total building load (dashed line) and the grid consumption (solid line) is the energy offset by the solar PV system
- Total building load is highest between approx. 14:00h-16:00h in July and August @ ~875 kW due to an increased cooling load in the building – this aligns with strong solar production
- During winter months, the peak energy usage starts before and continues after solar kicks in

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Next Steps for Community Solar Database

Developing the database, interface and research projects.

- Automate the addition of new solar power systems to the database.
- Set up login credentials for the data portal for more researchers to access data.
- Invite more researchers to use the data.
- Build the public-facing website for education.
- Invite advisors and testers for the website and data.
- Develop ways to provide value to solar generators as clients.

Next Steps for Community Solar Database

Developing the database, interface and research projects.

- NSCC's own next research projects:
  - Analyzing effect of time-of-day rates on solar revenue
  - Comparing real performance with models to show bankability of solar electricity
  - Estimating the impact of snow on production to improve revenue estimates and forecast models.

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Thank you!

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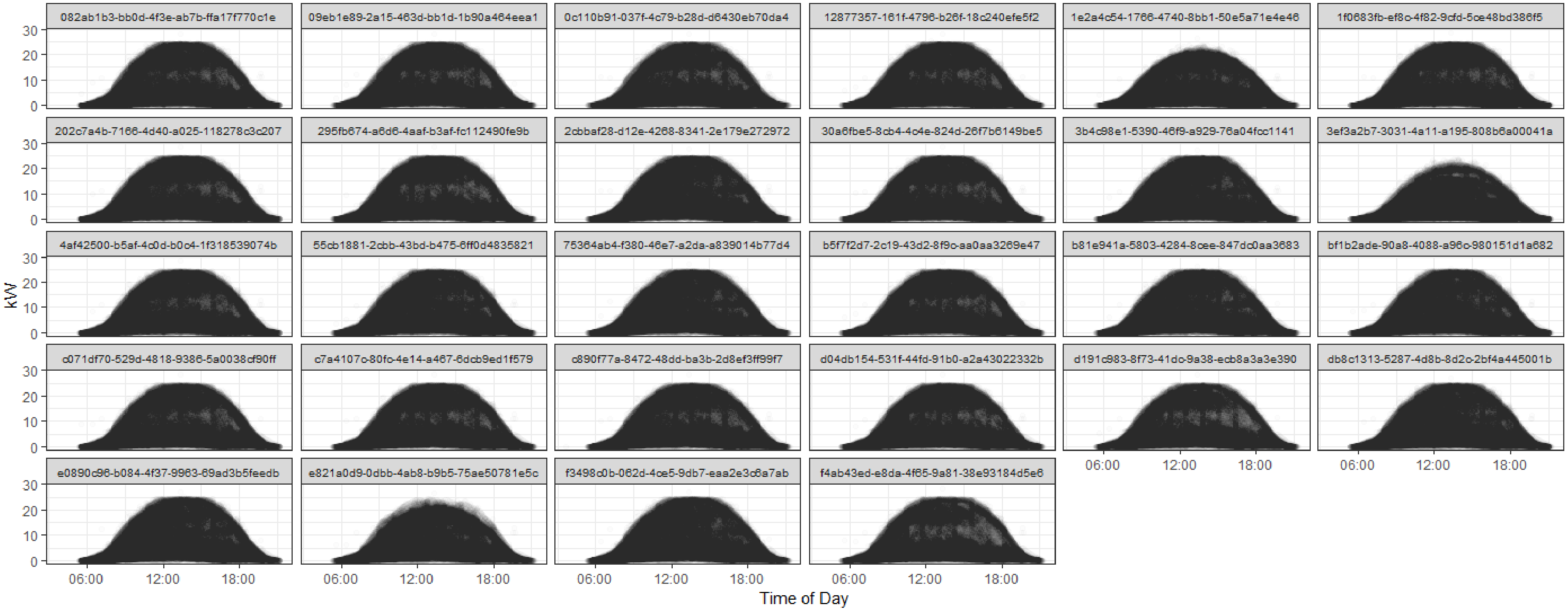
Findings – DC/AC Ratio Clipping

Distribution of Solar Production By Inverter Devices



- Flat lines at the top of graph indicate clipping at 24 kW (inverter size). This occurs for most inverters due to an DC/AC ratio of more than 1 (i.e. solar array is sized larger than inverter capacity). This means there is sometimes more power coming to the inverters than it can handle, leading to a cap at the top of some curves.
- Three of the devices are producing slightly less than the others, and do not appear to reach the peak inverter capacity. These sub-arrays likely contain fewer solar modules.