



Centre for Energy and  
Environmental Markets



# Solar Apartment Model

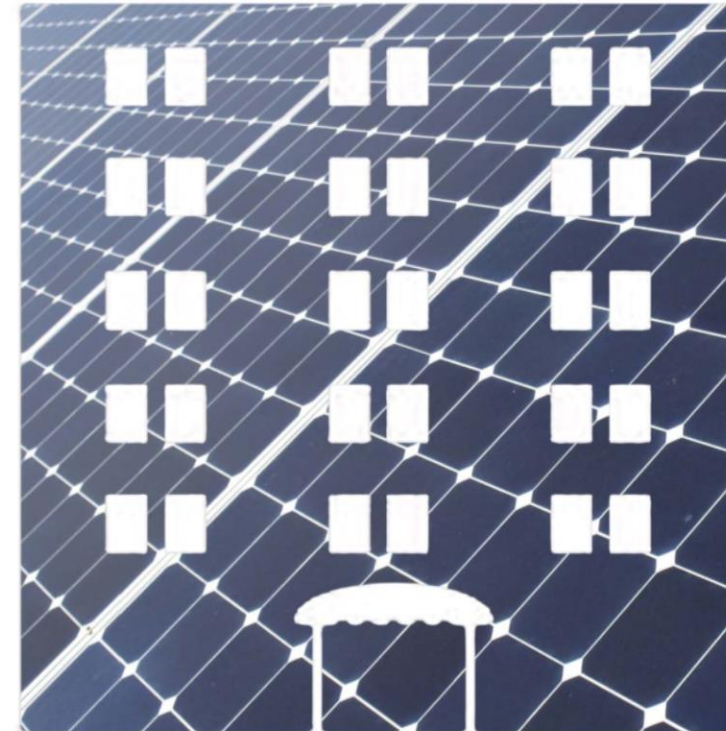
Mike Roberts



# Background

- A 3-year “Solar Apartments” project funded by Energy Consumers Australia and CRC for Low Carbon Living, exploring opportunities and barriers for increasing PV deployment on Australian apartment buildings
- Developed a Python tool (*morePVs*) multi-occupancy residential energy PV and storage
- Report published April 2019 – available from [www.ceem.unsw.edu.au](http://www.ceem.unsw.edu.au)

## Photovoltaics on Apartment Buildings



## Project Report



ENERGY  
CONSUMERS  
AUSTRALIA



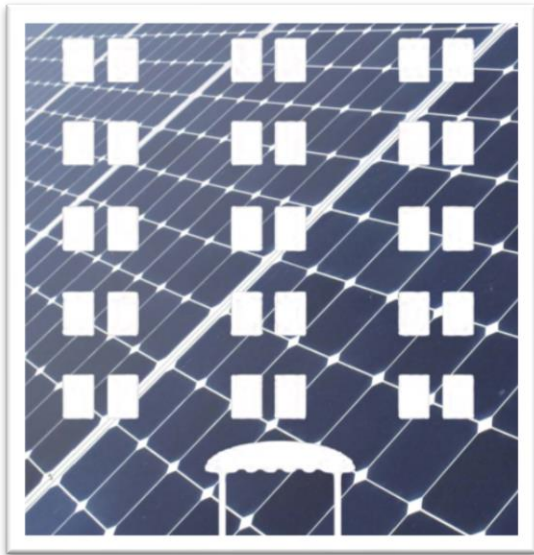
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UNSW  
SYDNEY



# Why model Solar Apartments?



- Big untapped PV opportunity
- Complexity of strata decision-making
- A need for clear, accurate information
- Multiple technical arrangements
- Multiple financial options
- High Variability and Building-Specificity:
  - Rooftop PV Capacity
  - Load profiles
  - Existing electrical infrastructure





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EnergySharing View Window Help

Energy Sharing


Local Energy Sharing UNSW Center for Energy and Environmental Markets

Model

- Load Data
- Solar Data
- Arrangement
- Tariffs
- Batteries
- Review
- Results
- Save / Load

### LUOMI

by Naomi Stringer, Luke Marshall




This model is commonly used to simulate small embedded networks and local energy sharing schemes with small numbers of participants. It allows for a central battery, and solar and load data for each participant.

Select

### Apartment Model

by Mike Roberts



This model is designed to handle large embedded networks in apartment blocks and high density residential complexes. It allows for the calculation of energy flows between many participants, and the sharing of a central solar and battery resource.

Selected ✓



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# Potential Users

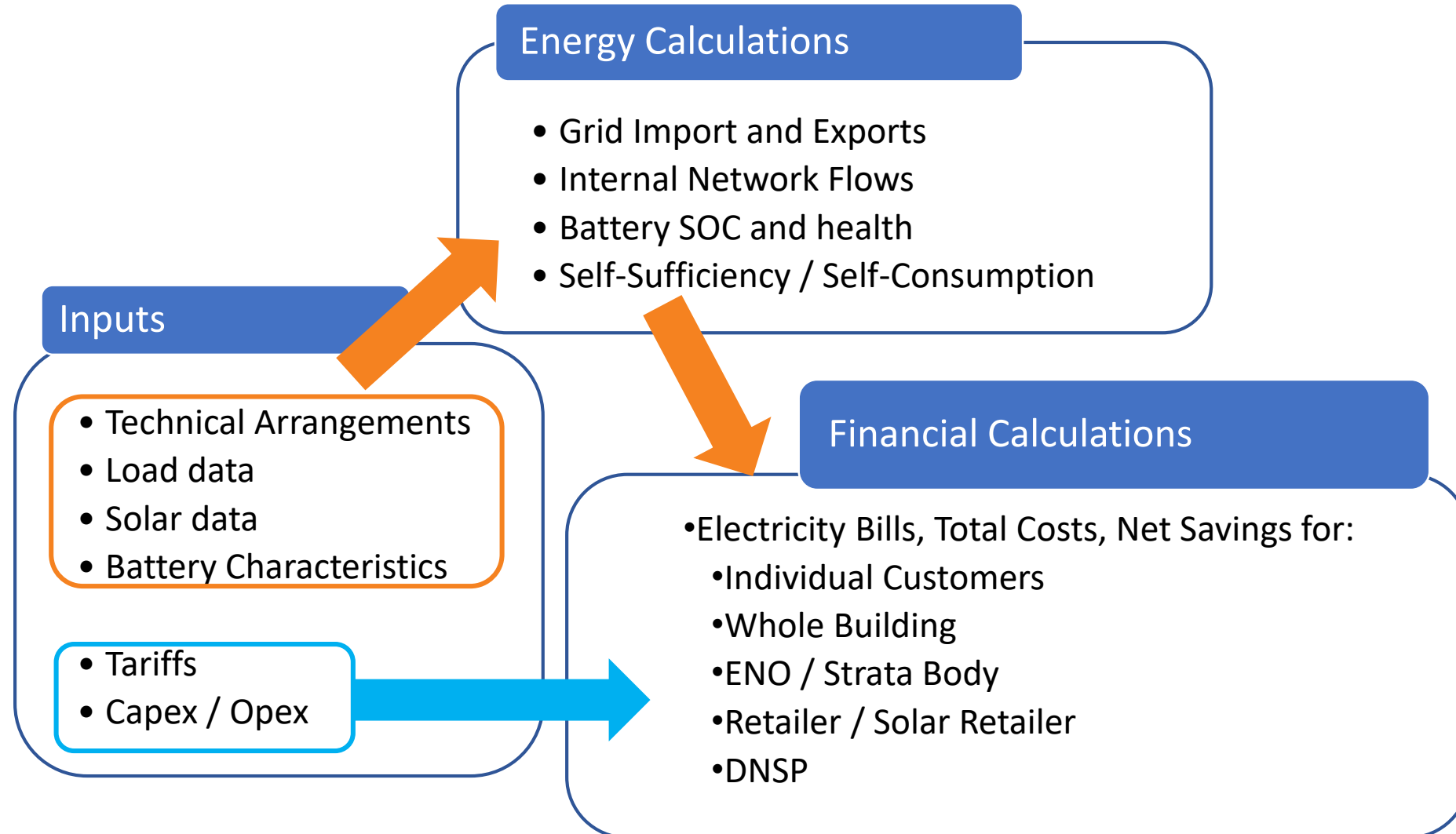
## To inform customer decision making:

- Strata bodies – apartments / community title
- Advocacy / Advice agencies
- Local Councils
- Community Housing
- Energy Consultants

## To assist planning:

- ENO's / ENM's / ENSP's
- Retailers

# Model Outline



# Input Data

EnergySharing View Window Help

Energy Sharing

Local Energy Sharing UNSW Center for Energy and Environmental Markets

- Model
- Load Data**
- Solar Data
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- Tariffs
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- Results
- Save / Load

### Data Import

Select File Start Import

### Available Load Files

- load\_profiles\_3.csv
- load\_profiles\_2.csv
- load\_profiles\_5.csv
- load\_profiles\_4.csv
- load\_profiles.csv
- load\_profiles\_demo.csv





EnergySharing View Window Help

Energy Sharing

Local Energy Sharing UNSW Center for Energy and Environmental Markets

- Model
- Load Data
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Data Import

Available Solar Files

- solar\_profiles\_3.csv
- solar\_profiles\_2.csv
- solar\_profiles\_5.csv
- solar\_profiles\_4.csv
- solar\_profiles.csv
- solar\_profiles\_demo.csv

Select File Start Import



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# Technical Arrangements

# PV Installation Arrangements

The screenshot shows the EnergySharing web application interface. The browser title is "Energy Sharing" and the page header includes "Local Energy Sharing" and "UNSW Center for Energy and Environmental Markets". A sidebar on the left contains navigation options: Model, Load Data, Solar Data, Arrangement (highlighted with a red circle), Tariffs, Batteries, Review, Results, and Save / Load. The main content area is titled "Arrangement" and displays seven options in a grid:

- Embedded Network**: Central solar only. Select
- Common Property**: Central Building Load. Select
- Behind the Meter Individual / Common**: Each Participant has a solar system + common solar system. Select
- Behind the Meter Shared / Common**: A single solar system's output is split between all residents and the common property. Select
- Behind the Meter Shared**: A single solar system's output is split between all residents but not used to power the common property. Select
- Behind the Meter PPA / Common**: A single solar system's output is split between all residents and the common property. Generation is paid for under a PPA. Select
- Behind the Meter PPA**: A single solar system's output is split between all residents but not used to power the common property. Generation is paid for under a PPA. Selected ✓

Below the grid is the "Input Data" section, which includes fields for "Selected Load File:" and "Selected Solar File:", and a "Configure Data Sources" button.

# PV Installation Arrangements

BAU

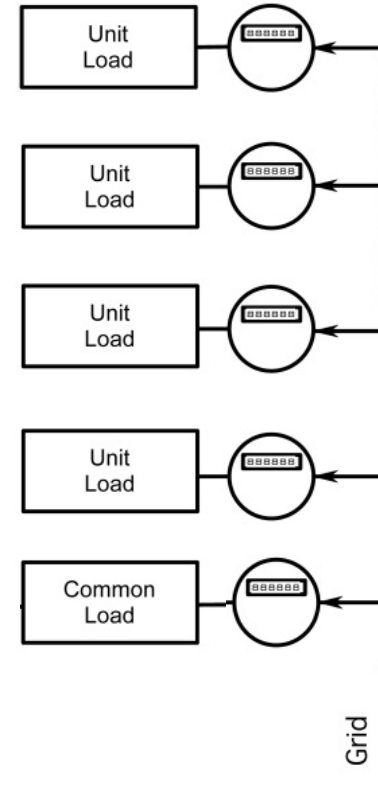
Individual  
BTM

Shared  
BTM

Embedded  
Network

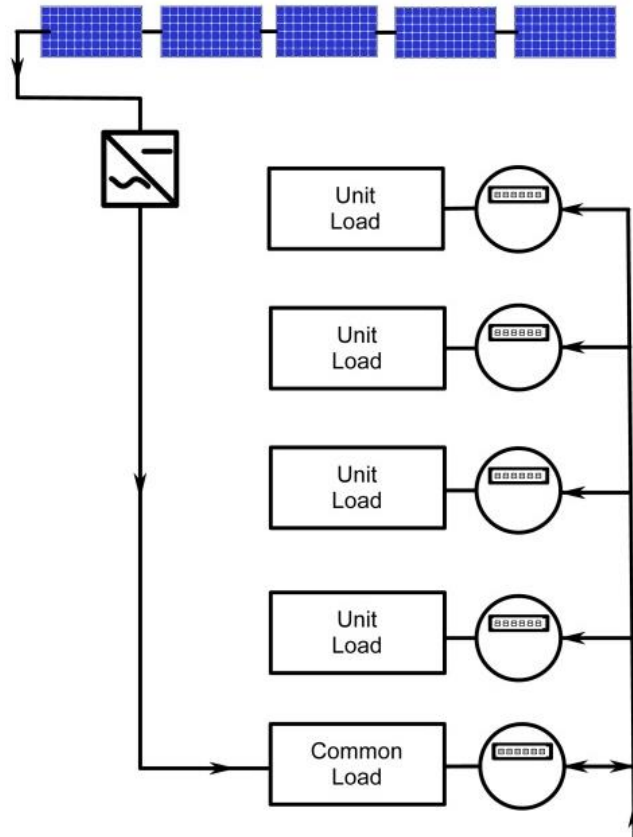
# BAU

- All Customers on-market with a retailer of their choice
- No PV

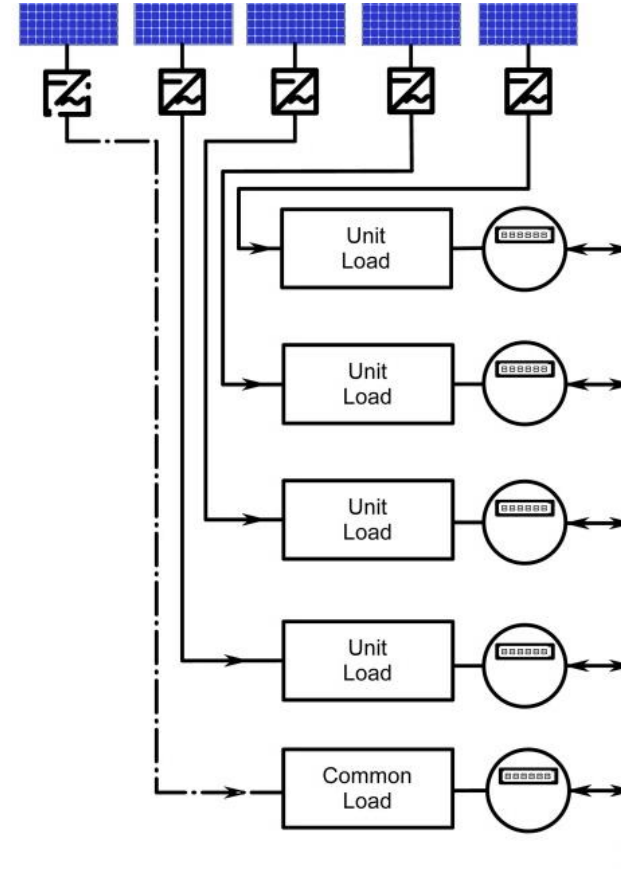


Not implemented in Beta

# Individual Behind The Meter

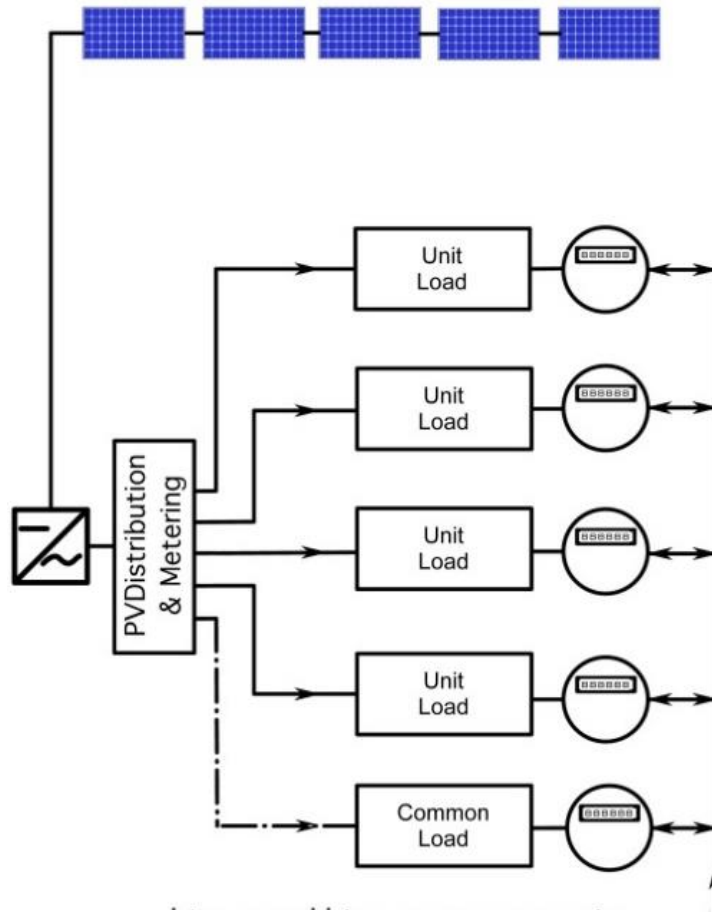


Common Property



Units (& Common Property)

# Shared Behind the Meter



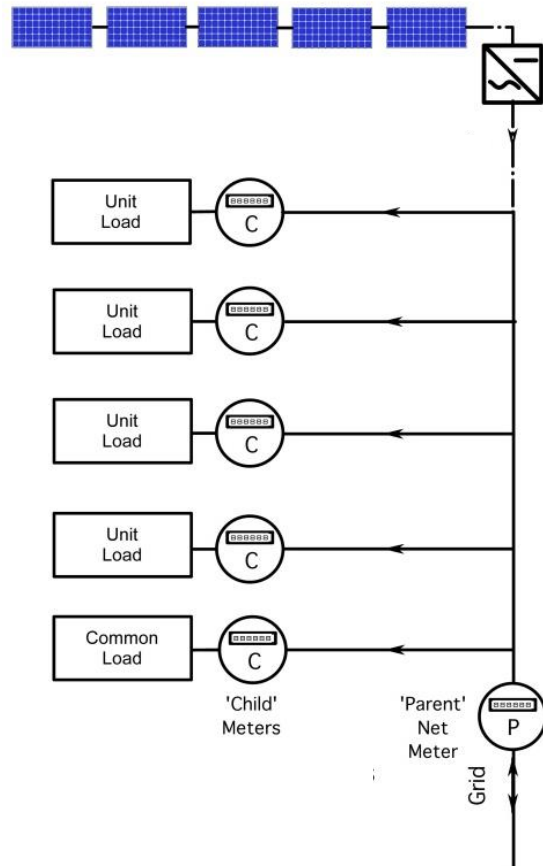
- All Customers on-market with a retailer of their choice
- PV distributed BTM by 'Solar retailer' (e.g. Allume)
- Units or Units + CP
- Generation allocated proportional to instantaneous load

Solar PPA with 2 rates:

- Solar consumption at Solar tariff
- Export at rate = FiT

Or capex and opex paid by strata body

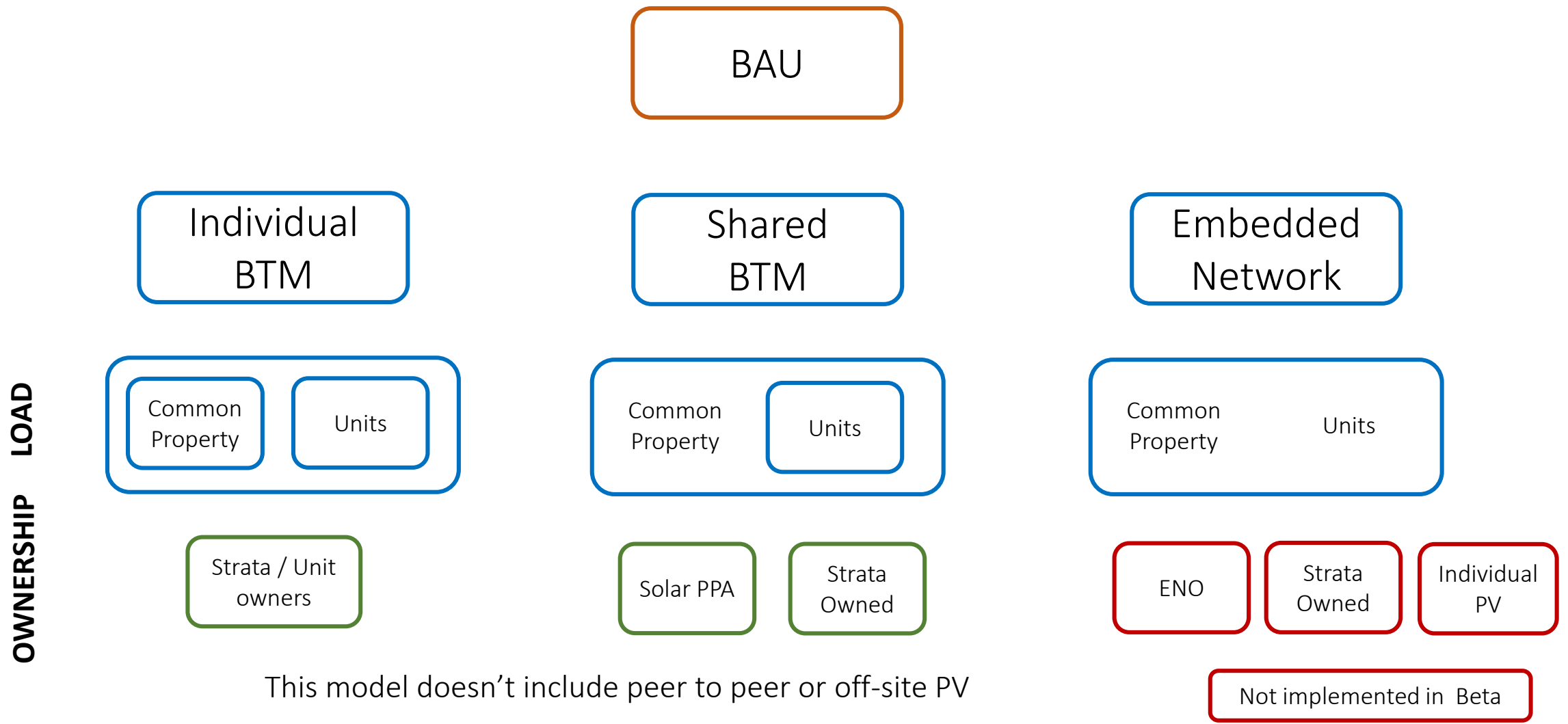
# Embedded Network



- All Customers off-market (buy from ENO)
- Shared PV owned by ENO or by Strata Body
- ENO purchases from retailer at 'Parent Tariff'
- (Individual PV not in this model)



# PV Installation Arrangements



# Tariffs

Energy Sharing

Local Energy Sharing UNSW Center for Energy and Environmental Markets

- Model
- Load Data
- Solar Data
- Arrangement**
- Tariffs
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- Review
- Results
- Save / Load

Select
Select
Select

Behind the Meter PPA

A single solar system's output is split between all residents but not used to power the common property. Generation is paid for under a PPA.

Select

Input Data

Selected Load File: W\_small\_building\_profile\_kWh\_week.csv

Selected Solar File: W\_max\_pv\_week.csv

Configure Data Sources

Central Solar / Load

Central Solar Profile

pv

Common Property Solar Profile

[Select]

Common Property Load Profile

[Select]

Participants

Participant ID	Tariff Type	Load Data	Solar Data		
ID	Select One	Select One	Select One		
Participant 1	EASO_Flat_15pc	W01	no_solar	Show Data	Remove
Participant 2	EASO_Flat_15pc	W02	no_solar	Show Data	Remove
Participant 3	EASO_Flat_15pc	W03	no_solar	Show Data	Remove

Add New Participant



# Tariffs

- Customer Retail Tariffs
- Solar Tariff (for Solar PPA)

- Parent Tariff (for EN)
- Network Tariff

Not implemented in Beta

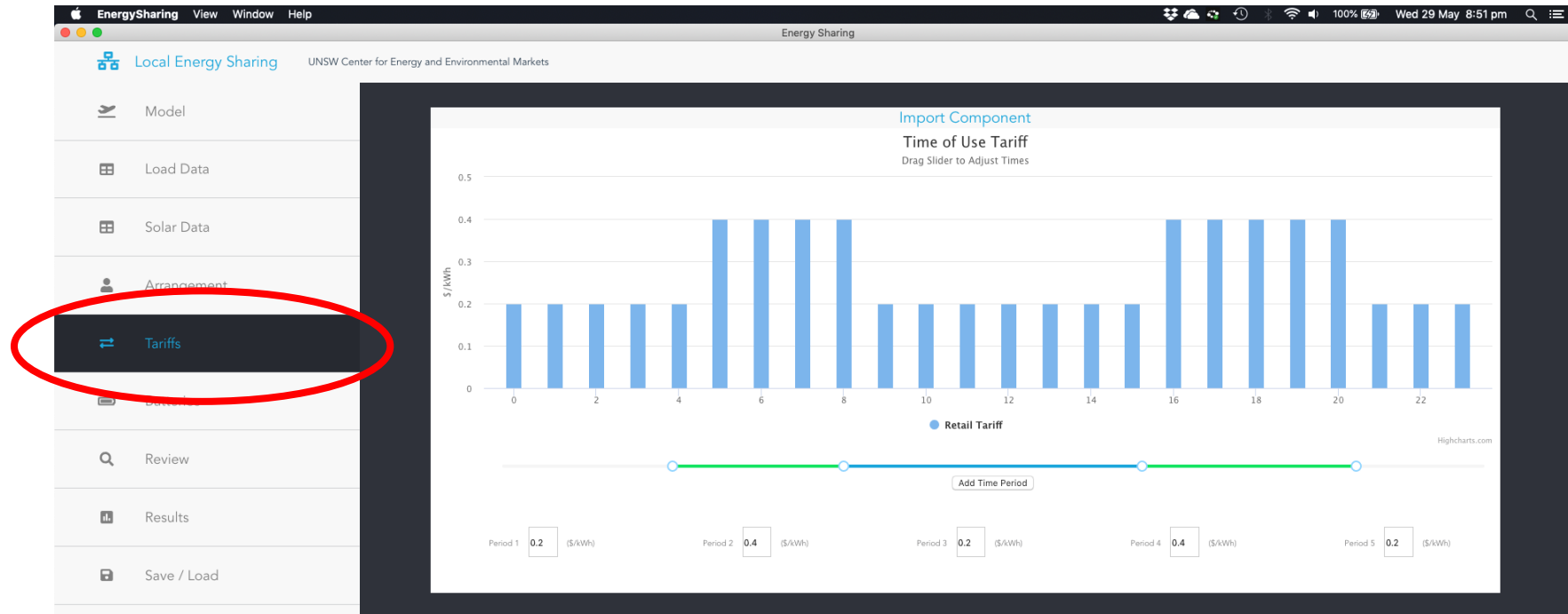
The screenshot shows a web application interface with three main sections: 'Input Data', 'Central Solar / Load', and 'Participants'.

- Input Data:** Shows 'Selected Load File: W\_small\_building\_profile\_kWh\_week.csv' and 'Selected Solar File: W\_max\_pv\_week.csv'. A blue button labeled 'Configure Data Sources' is on the right.
- Central Solar / Load:** Contains three dropdown menus: 'Central Solar Profile' (set to 'pv'), 'Common Property Solar Profile', and 'Common Property Load Profile'.
- Participants:** A table with columns for 'Participant ID', 'Tariff Type', 'Load Data', and 'Solar Data'.

Participant ID	Tariff Type	Load Data	Solar Data	Actions
Participant 1	EASO_Flat	W01	no_solar	Show Data, Remove
Participant 2	EASO_Flat_15pc	W02	no_solar	Show Data, Remove
Participant 3	EASO_TOU	W03	no_solar	Show Data, Remove

A red circle highlights the 'Tariff Type' dropdown menu, which is open and shows a list of options including 'user\_interface', 'EASO\_Flat', 'EASO\_Flat\_15pc', 'EASO\_Flat\_20pc', 'EASO\_Flat\_25pc', 'EASO\_TOU', 'EASO\_TOU\_15pc', 'EASO\_TOU\_20pc', 'EASO\_TOU\_25pc', 'EASO\_TOU\_15pc\_FIT12', 'EASO\_TOU\_15pc\_FIT8', and 'EA225'. A blue button 'Add New Participant' is located below the table.

# Tariffs: *user\_interface*



- Flat rate
- TOU rates – multiple periods and rates
- Block tariffs
- Fixed charges
- Demand charges

# Capex / Opex / Finance

## PV CAPEX:

- System \$
- Inverter \$
- Inverter Lifetime

## EN Capex / Opex:

- Capex \$ / unit
- Capex \$ / building
- Opex \$ / unit

## Battery Capex:

- Total System or \$/kWh
- Inverter cost
- Battery Life (cycles / yrs)
- Inverter Life (years)

## Financial Settings:

- Discount % Rate
- Amortization Term

Not implemented in Beta



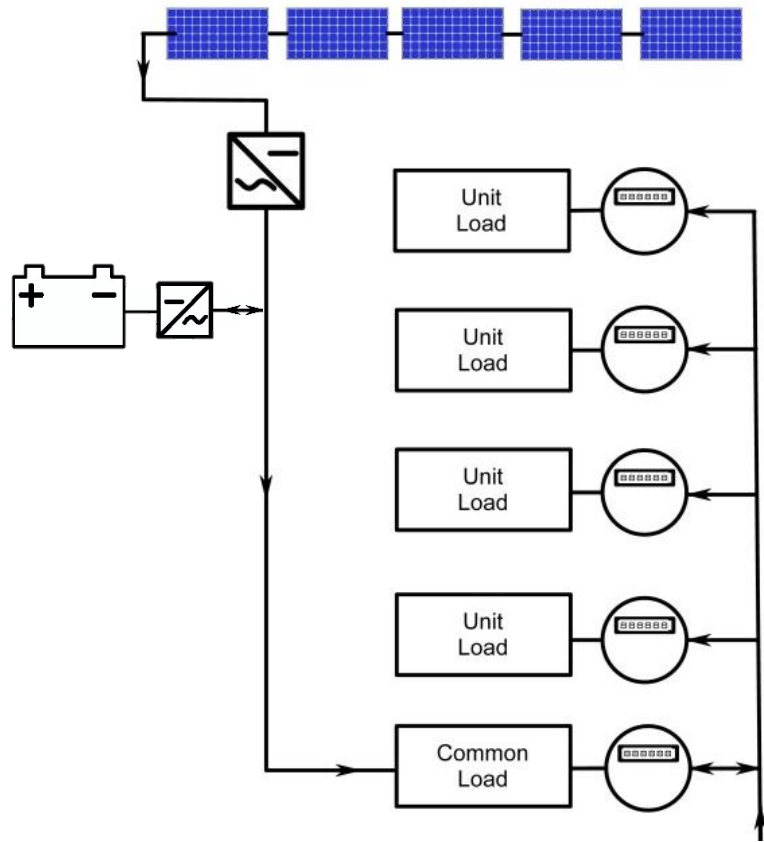
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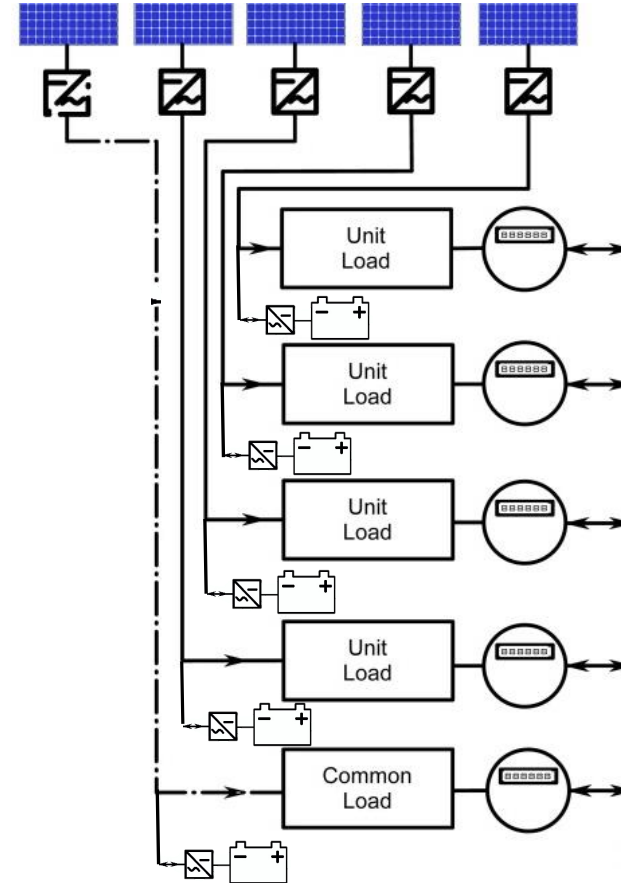
# Batteries



# Individual Battery - BTM



Common Property

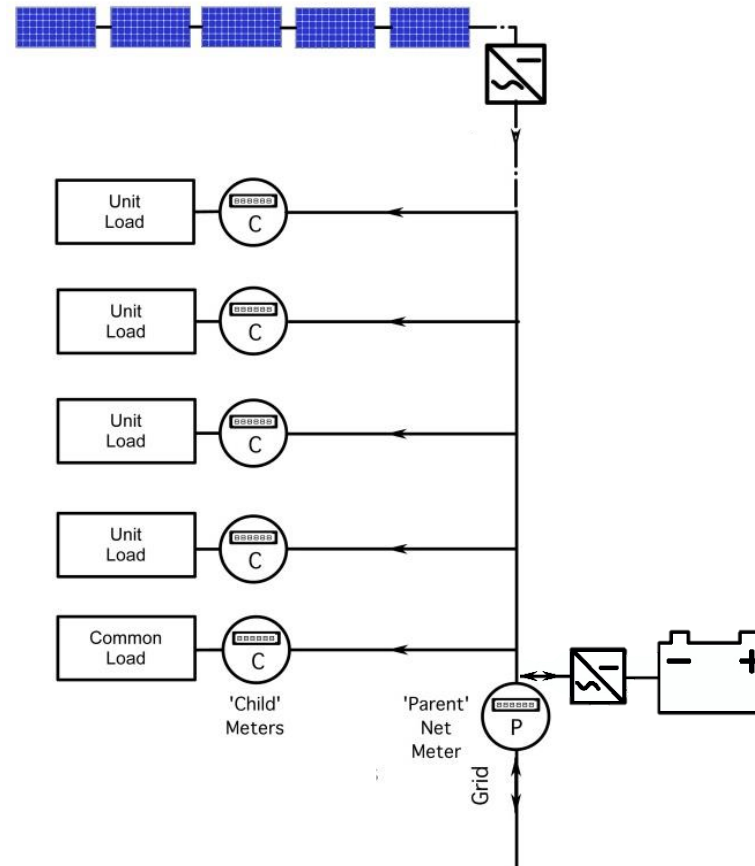


Units (& Common Property)

Individual batteries (AC coupled)

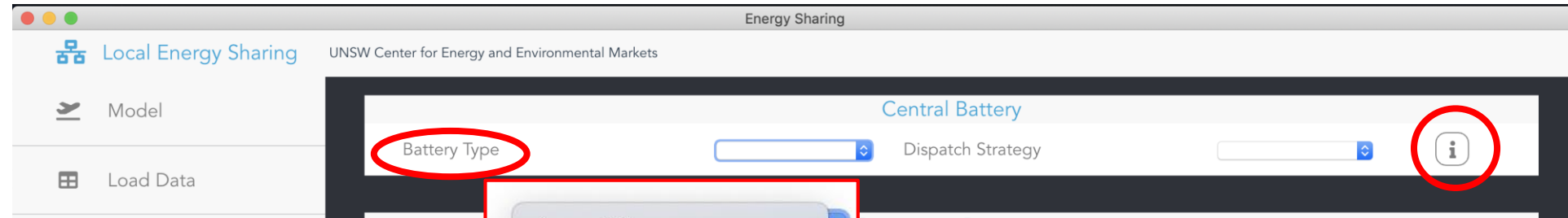


# Central Battery - Embedded Network



Central battery (AC coupled)

# Batteries



## Battery Info

Not user-definable in Beta

Battery ID	Capacity (kWh)	Max Charge kW	Cycle Efficiency	Max DoD	Max SoC	Max Cycles	Cost
pw_26	26	9.848	0.89	1	0.9	7300	26000
pw_52	52	19.697	0.89	1	0.9	7300	52000
pw_78	78	29.545	0.89	1	0.9	7300	78000
pw_104	104	39.394	0.89	1	0.9	7300	104000
pw_scale	1	0.378787879	0.89	1	0.9	7300	
powerwall2_1	13.2	5	0.89	1	0.9	7300	12500
powerwall2_2	26.4	10	0.89	1	0.9	7300	24000
powerwall2_3	39.6	15	0.89	1	0.9	7300	34500
powerwall2_4	52.8	20	0.89	1	0.9	7300	45000

# Batteries

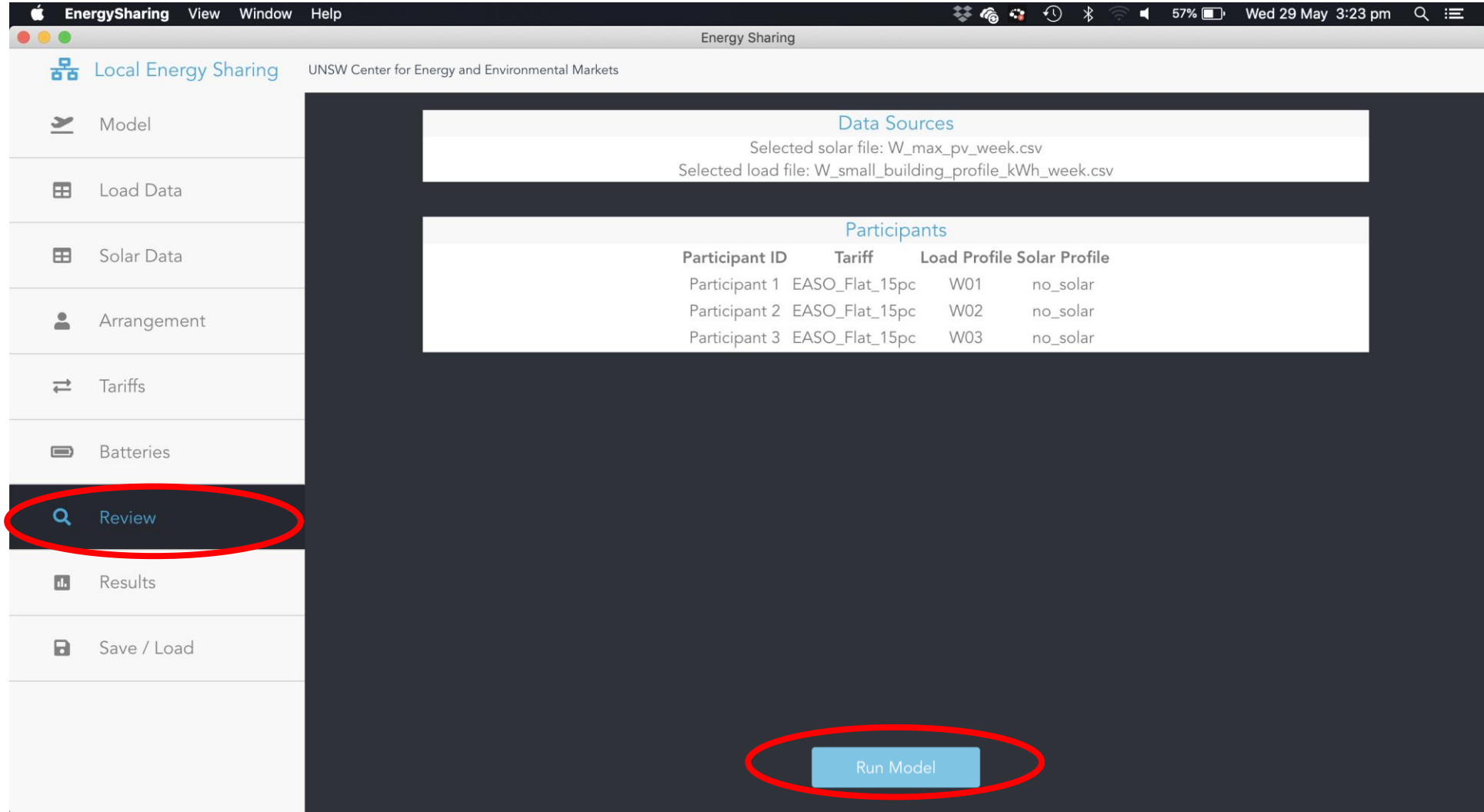
The screenshot shows a web interface for 'Energy Sharing' with a sidebar on the left containing a list of battery identifiers. The main content area is titled 'Central Battery' and 'Participant Batteries'. In the 'Central Battery' section, the 'Dispatch Strategy' dropdown menu is highlighted with a red circle. Below this, the 'Participant Batteries' section shows three participants, each with a 'Battery Type' dropdown, a 'Dispatch Strategy' dropdown, and a 'Capacity (kWh)' input field. 'Participant 2' and 'Participant 3' have 'Add Battery' buttons.

- ✓ ed1700\_cmax\_dmax
- ed1700\_c20\_d20
- ed1730\_cmax\_dmax
- ed1630\_c20\_d20
- ch\_ed1630\_cmax\_d20
- ch\_ed1700\_cmax\_dmax
- sc1700\_c20\_dmax
- sc1700\_cmax\_dmax
- dc1700\_c20\_dmax
- dc1700\_cmax\_dmax
- pdt\_pps\_80
- pdt\_pps\_85
- pdt\_pps\_90
- pdt\_pps\_95
- pdt\_ch\_80
- pdt\_sc\_80
- pdt\_sc\_75
- pdt\_sc\_70
- pdt\_sc\_65
- pdt\_sc\_60
- pdt\_sc\_55
- pdt\_sc\_50
- pdt\_sc\_45
- pdt\_sc\_40
- pdt\_sc\_35
- pdt\_sc\_30

- Control Strategies:**
- PV charge / evening discharge
  - Charge priority / evening discharge
  - Single Cycle
  - Double Cycle
  - Peak Demand Threshold

Not user-definable in Beta

# Review



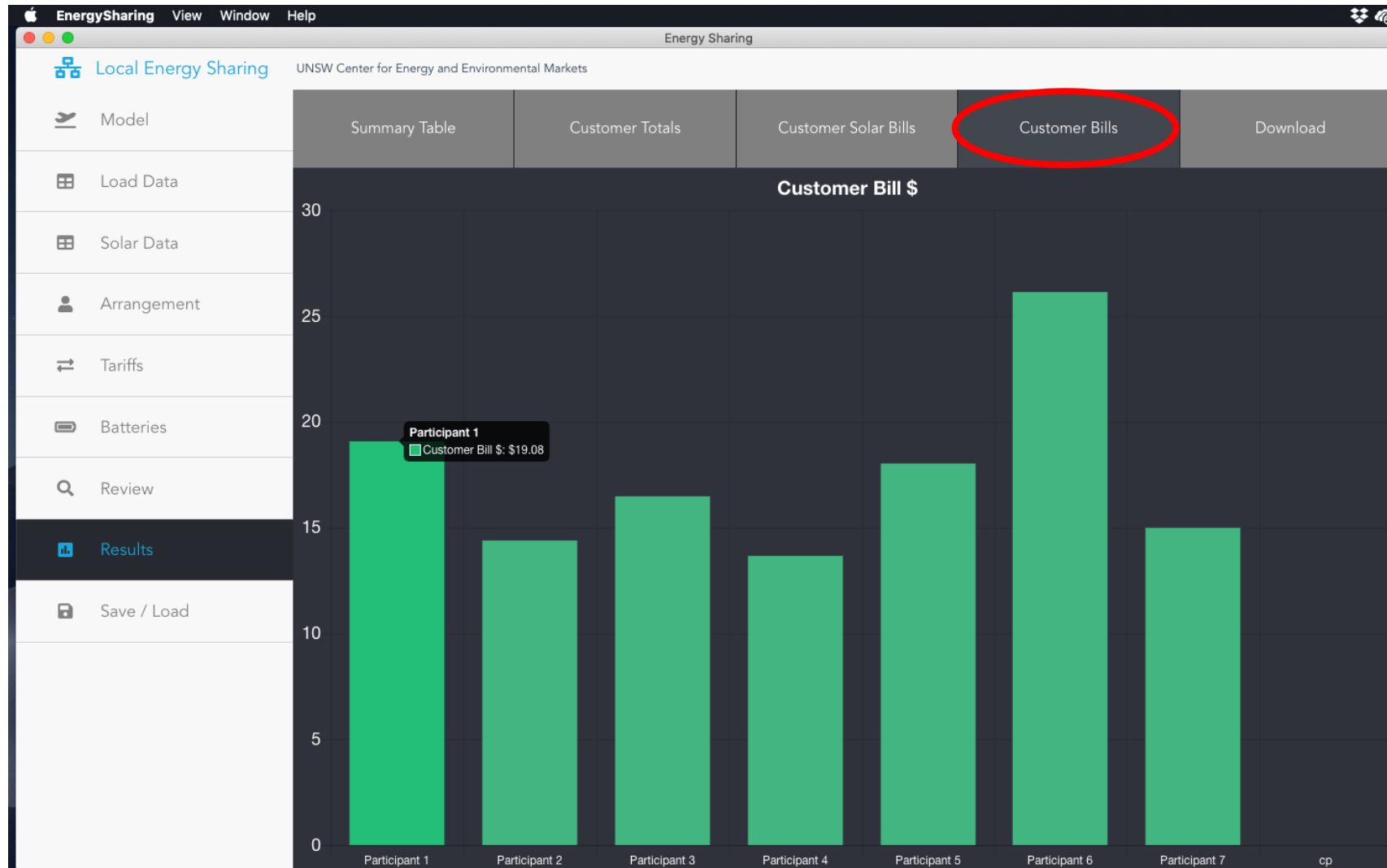
The screenshot shows the EnergySharing application window. The title bar reads "EnergySharing" and "Energy Sharing". The main window title is "Local Energy Sharing" and the subtitle is "UNSW Center for Energy and Environmental Markets". A sidebar on the left contains several menu items: Model, Load Data, Solar Data, Arrangement, Tariffs, Batteries, Review (highlighted with a red circle), Results, and Save / Load. The main content area displays "Data Sources" with selected files: "W\_max\_pv\_week.csv" and "W\_small\_building\_profile\_kWh\_week.csv". Below this is a "Participants" table with the following data:

Participant ID	Tariff	Load Profile	Solar Profile
Participant 1	EASO_Flat_15pc	W01	no_solar
Participant 2	EASO_Flat_15pc	W02	no_solar
Participant 3	EASO_Flat_15pc	W03	no_solar

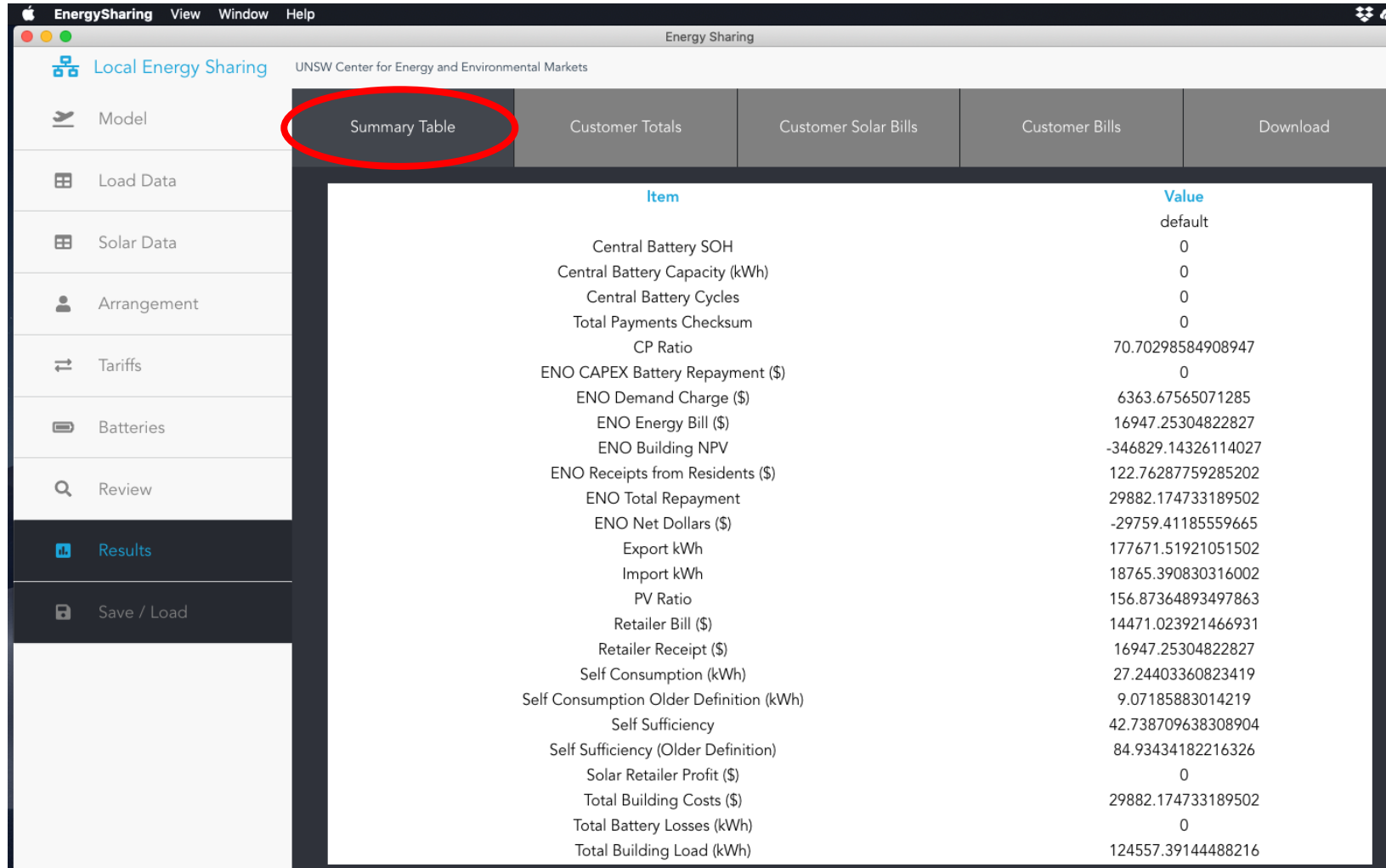
At the bottom of the main content area, a blue "Run Model" button is highlighted with a red circle.

# Results

# Results



# Results



The screenshot shows the 'EnergySharing' application window. The 'Summary Table' tab is selected and circled in red. The table displays various energy-related metrics and their values.

Item	Value
Central Battery SOH	0
Central Battery Capacity (kWh)	0
Central Battery Cycles	0
Total Payments Checksum	0
CP Ratio	70.70298584908947
ENO CAPEX Battery Repayment (\$)	0
ENO Demand Charge (\$)	6363.67565071285
ENO Energy Bill (\$)	16947.25304822827
ENO Building NPV	-346829.14326114027
ENO Receipts from Residents (\$)	122.76287759285202
ENO Total Repayment	29882.174733189502
ENO Net Dollars (\$)	-29759.41185559665
Export kWh	177671.51921051502
Import kWh	18765.390830316002
PV Ratio	156.87364893497863
Retailer Bill (\$)	14471.023921466931
Retailer Receipt (\$)	16947.25304822827
Self Consumption (kWh)	27.24403360823419
Self Consumption Older Definition (kWh)	9.07185883014219
Self Sufficiency	42.738709638308904
Self Sufficiency (Older Definition)	84.93434182216326
Solar Retailer Profit (\$)	0
Total Building Costs (\$)	29882.174733189502
Total Battery Losses (kWh)	0
Total Building Load (kWh)	124557.39144488216

# Results – Summary Table

## Energy Metrics:

- Total load (kWh)
- CP Ratio (%)
- Total Generation (kWh)
- PV Ratio (%)
- Self-Consumption (%)
- Self-Sufficiency (%)
- Total Import (kWh)
- Total Export (kWh)

## Battery Metrics:

- Total Cycles
- State of Health (%)
- Total Losses (kWh)

## Financial Metrics:

- Total Energy Costs for whole building(\$)
- Average Resident Bill (\$)
- Average Resident Total Cost (\$)
- CP Bill (\$)

## Embedded Network Financials:

- Demand Charge (\$)
- Total Bill (\$)
- Capex Repayments (\$)
- Total EN Payments, Receipts, Net Profit (\$)

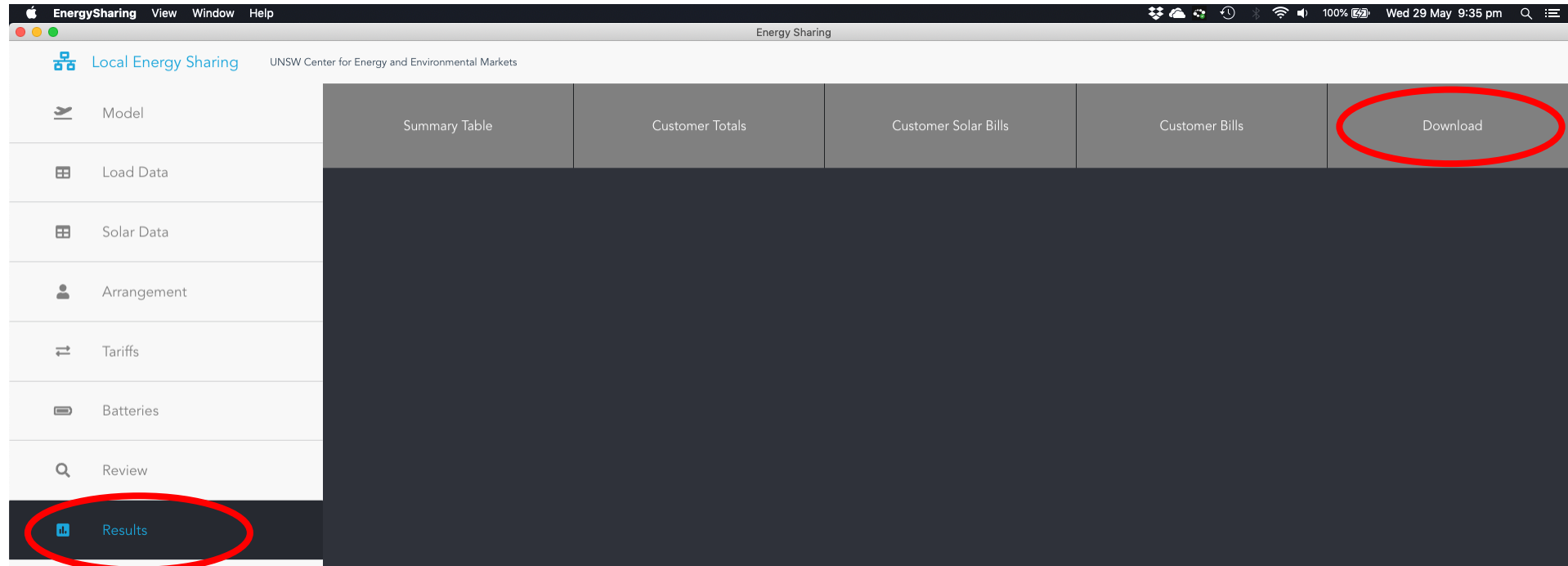
## External Financials:

- ? Retailer Receipts and Payments (\$)
- ? DNSP Receipts (\$)

Not implemented in Beta

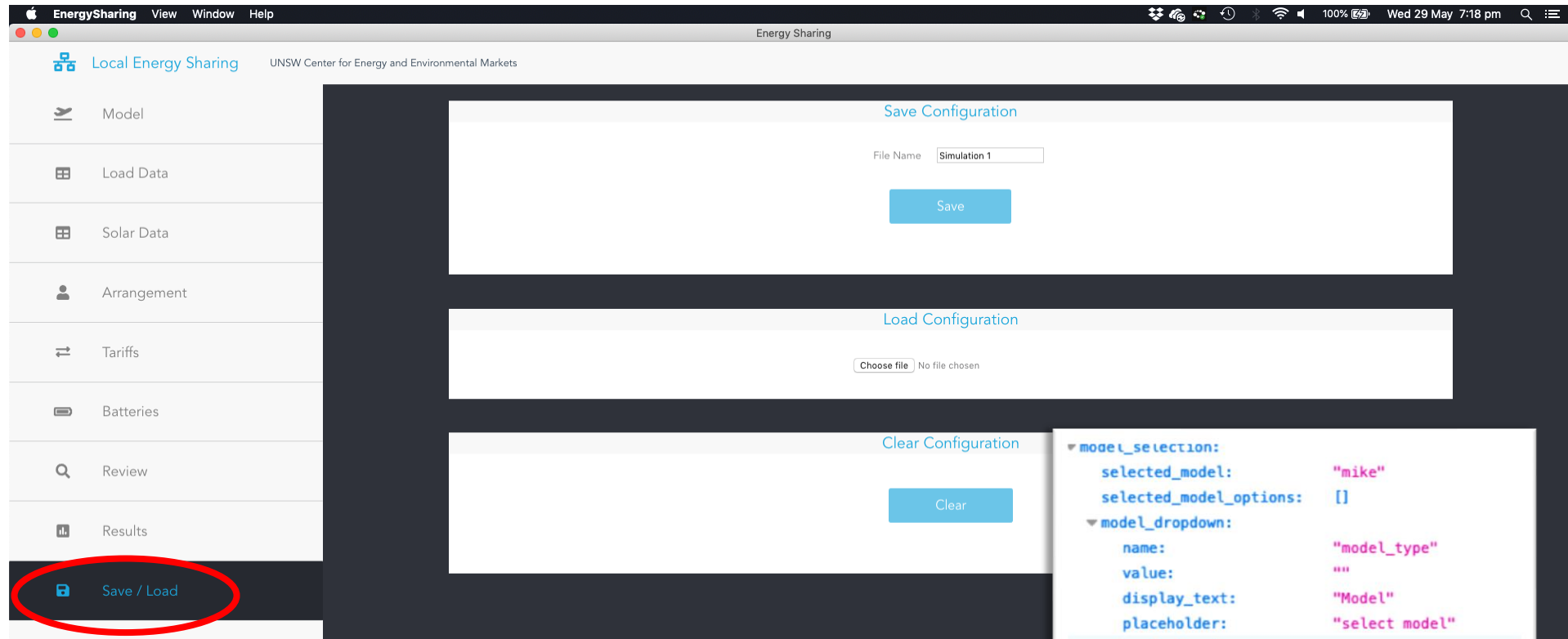


# Download results



Not implemented in Beta

# Save configuration file



The screenshot shows the EnergySharing web application interface. The top navigation bar includes 'EnergySharing', 'View', 'Window', and 'Help'. The main content area is titled 'Local Energy Sharing' and 'UNSW Center for Energy and Environmental Markets'. A sidebar on the left contains menu items: Model, Load Data, Solar Data, Arrangement, Tariffs, Batteries, Review, and Results. The 'Save / Load' menu item is circled in red. The main content area is divided into three sections: 'Save Configuration' with a 'File Name' input field containing 'Simulation 1' and a 'Save' button; 'Load Configuration' with a 'Choose file' button and 'No file chosen' text; and 'Clear Configuration' with a 'Clear' button. A JSON data preview is shown on the right side of the interface, displaying configuration details for 'model\_selection' and 'network\_dropdown'.

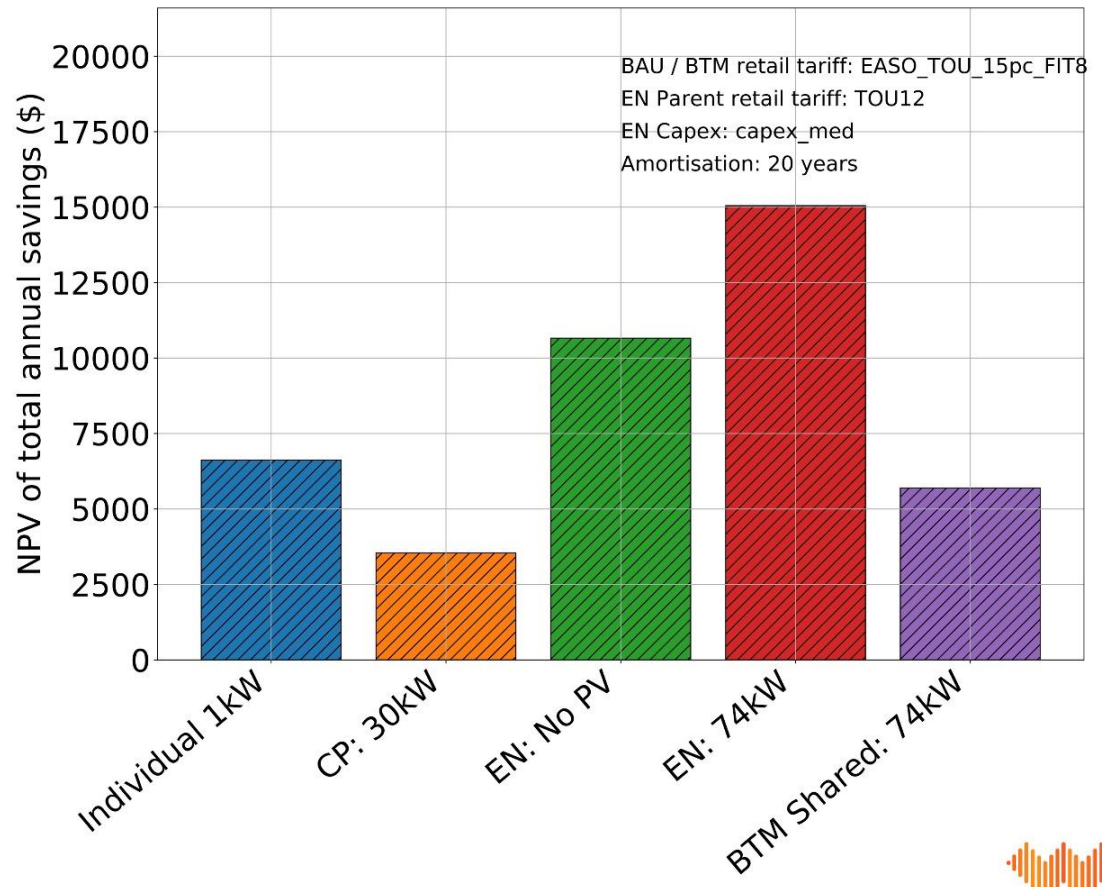
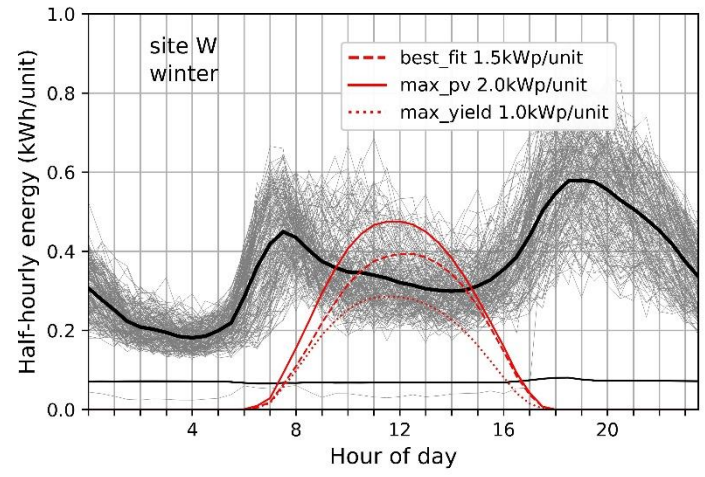
```
model_selection:  
  selected_model: "mike"  
  selected_model_options: []  
network_dropdown:  
  name: "network_type"  
  display_text: "Network Type "  
  value: ""  
  dropdown_key: "network_type"  
  placeholder: "select model"
```

Not fully implemented in Beta

# Example Results

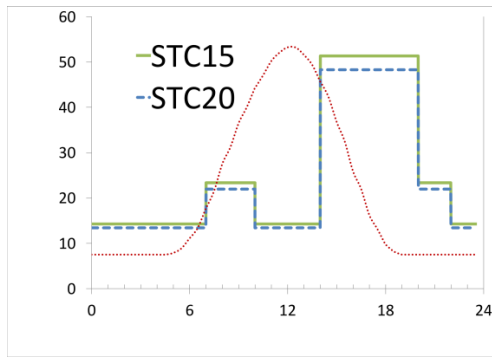
# Case Study W

72 apartments  
3 floors  
Lifts, carparks, etc  
CP is 22% of load

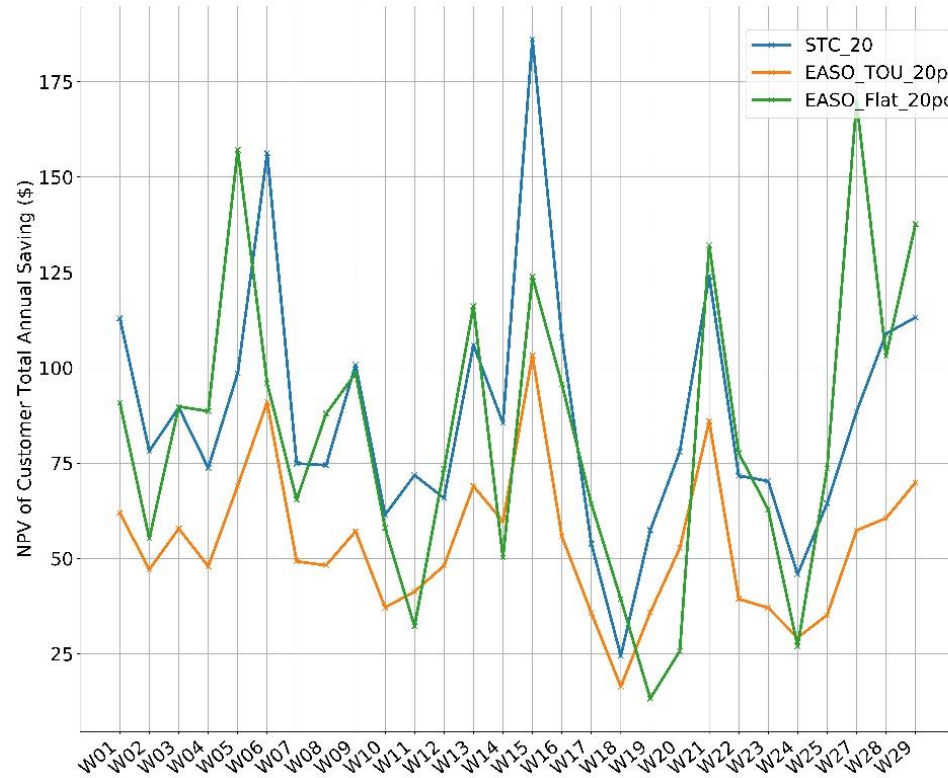


# Case Study W – Embedded Network

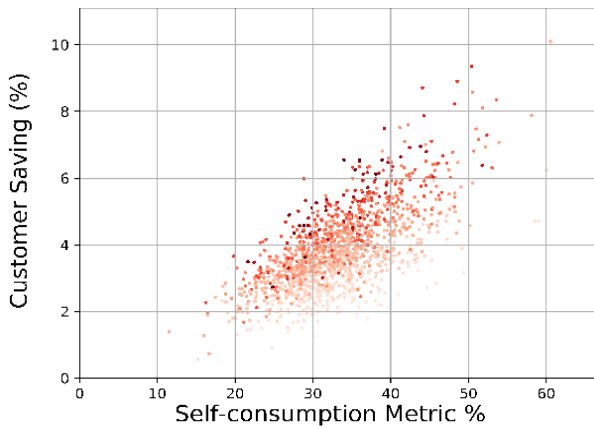
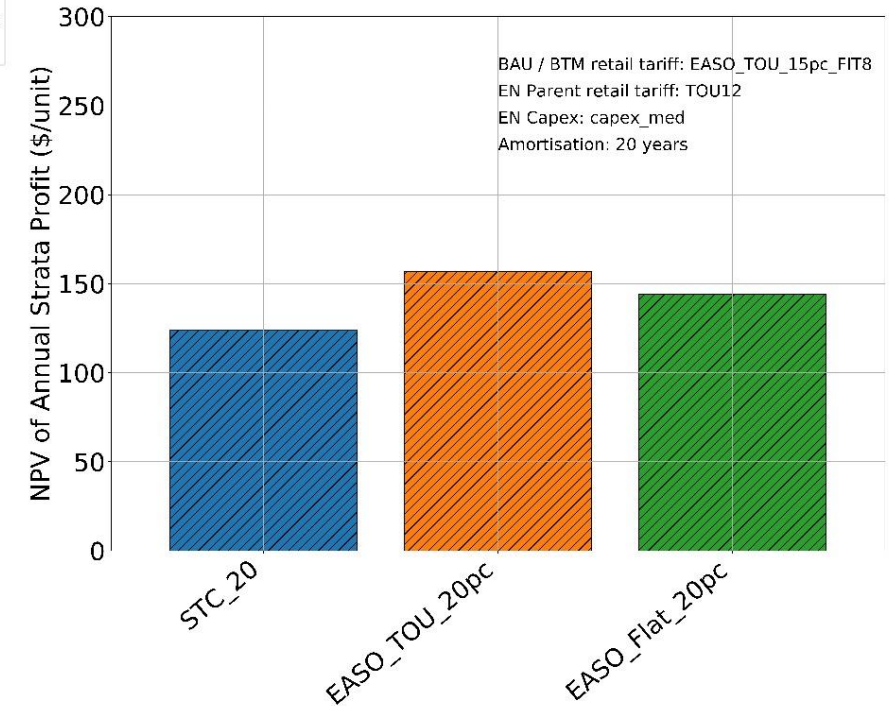
## Solar TOU Tariff (STC)



## Customer Benefit



## ENO Profit



# Further Development ?

# Possible Extensions

## Tariff Functionality:

- ? Tariff structures
- ? Tariff tool compatibility

## Beyond Apartments:

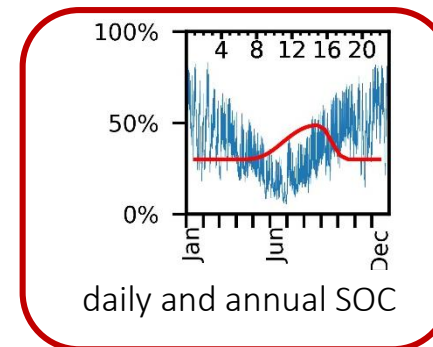
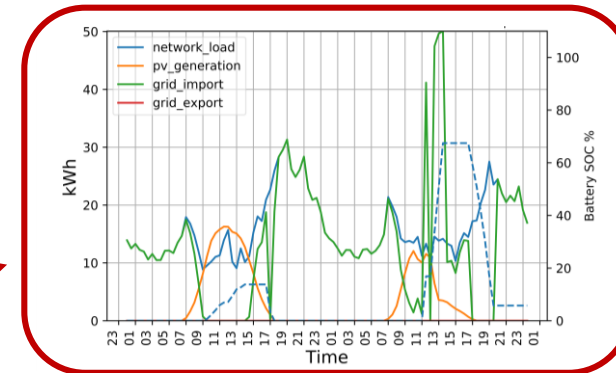
- ? Individual PV & Battery in EN
- ? 'Horizontal' Strata / Townhouses
- ? Microgrids

## Results:

- ? Timeseries data
- ? Battery Usage
- ? Other metrics

## Interface:

- ? Presentation
- ? Functionality





## Questions & Suggestions ?

- M.B. Roberts, A. Bruce, and I. MacGill, *A comparison of arrangements for increasing self-consumption and maximising the value of distributed photovoltaics on apartment buildings*. Solar Energy, under review.
- M.B. Roberts, A. Bruce, and I. MacGill, *Impact of shared battery energy storage systems on photovoltaic self-consumption and electricity bills in apartment buildings*. Applied Energy, 2019. **245**: p. 78-95.
- M.B. Roberts, N. Haghdadi, A. Bruce, and I. MacGill, *Characterisation of Australian apartment electricity demand and its implications for low-carbon cities*. Energy, 2019. **180**: p. 242-257.
- M.B. Roberts, A. Bruce, and I. MacGill, *Opportunities and barriers for photovoltaics on multi-unit residential buildings: Reviewing the Australian experience*. Renewable and Sustainable Energy Reviews, 2019. **102**: p. 95-110.