ASIA-PACIFIC SOLAR RESEARCH CONFERENCE

The Potential for PV Self-Consumption for Hot Water Systems in Australia

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PV Self-Consumption for Hot Water Systems in Australia

Aims

- Be compliance as the solar hot water systems (with 60 % solar contribution).
- Meet the legionella condition (reach 60 C every 24 hours at 45% level of the tank) using a 5kW system.

Hot water market in Australia

- There are 4 main categories sorted by their dominance
  1. Electric water heaters (powered from grid electricity)
  2. Gas water heaters
  3. Solar thermal with electric or gas boosting
  4. Heat pumps (powered from grid electricity)

MUST BE DESIGNED BASED ON 60% RENEWABLE ENERGY CONTRIBUTION IN ZONE 3 ACCORDING TO AS/NZ 4234

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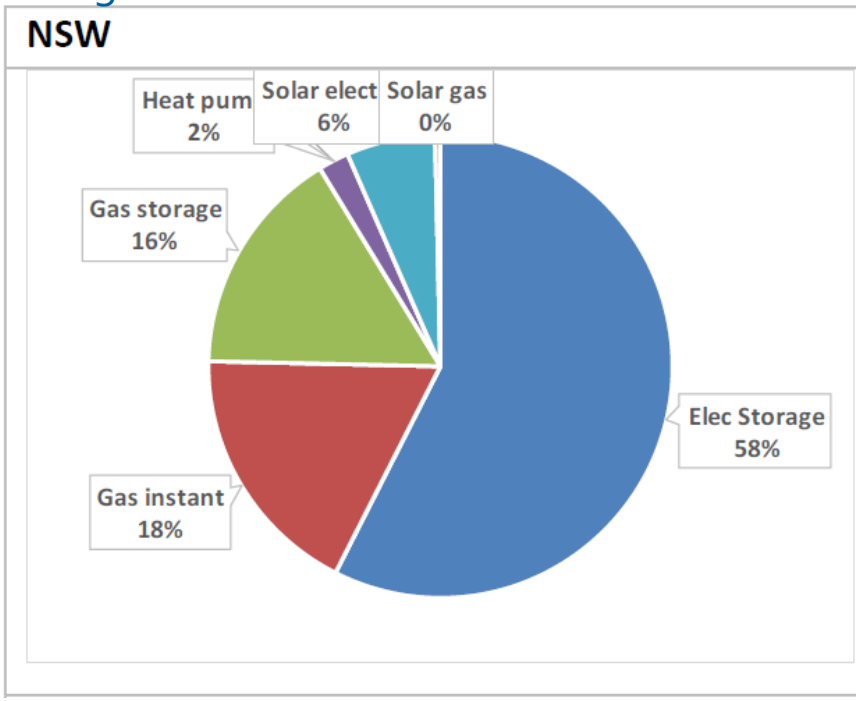
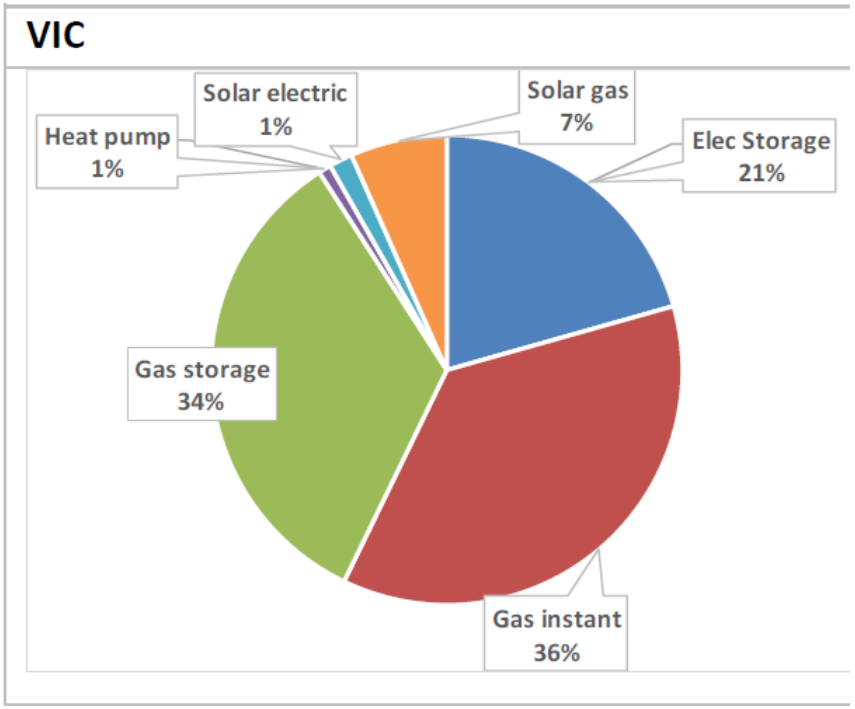
3- Evacuated tube with gas booster

4- split type

Hot water market in Australia

- Distribution of technologies is different from one state to another
- Electric and gas systems are still account for about 75% of the hot water market
- The graphs below belong to 2018 but the penetration of solar thermal is reducing by electric heat pumps which consumes 75% less electricity and much more compatible with PV generation

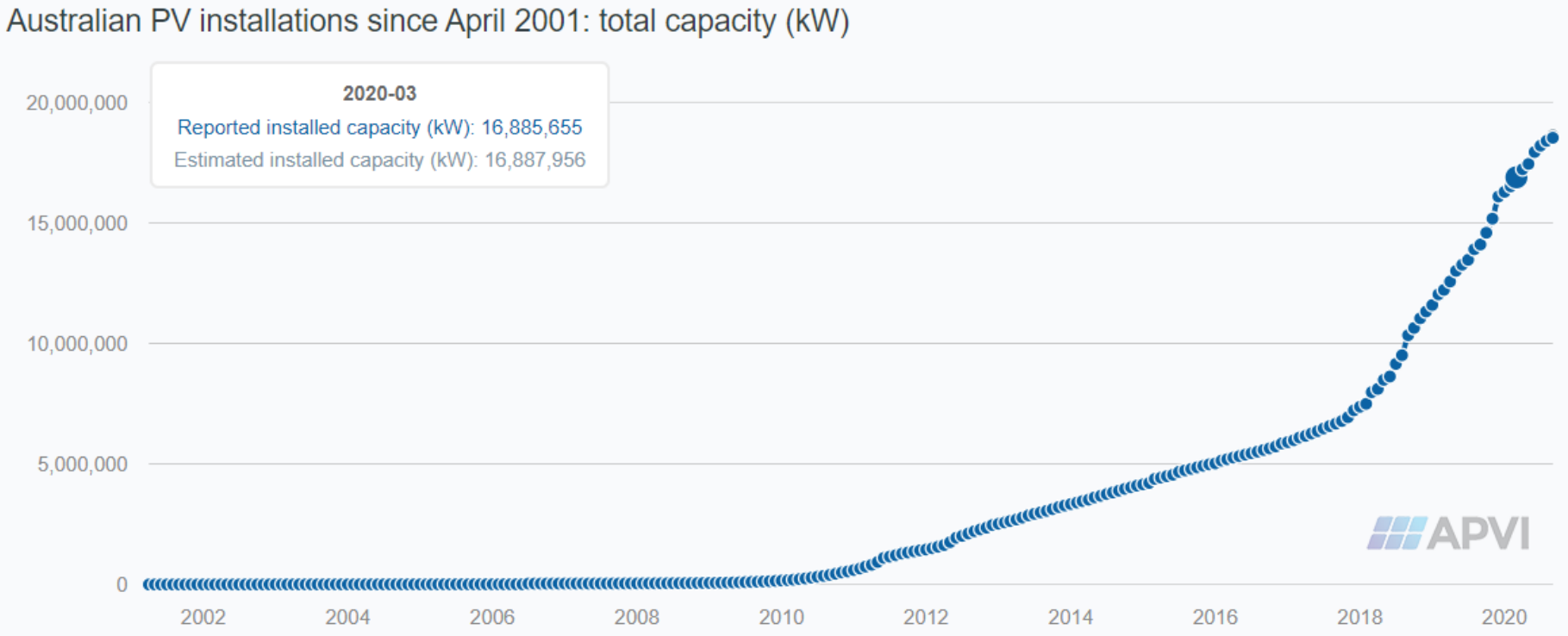




Ref: Policy Framework for Hot Water Systems in Australia & New Zealand 2018 (https://www.energyrating.gov.au/) & https://www.energyrating.gov.au/products/water-heating#product-information & http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations

PV market in Australia

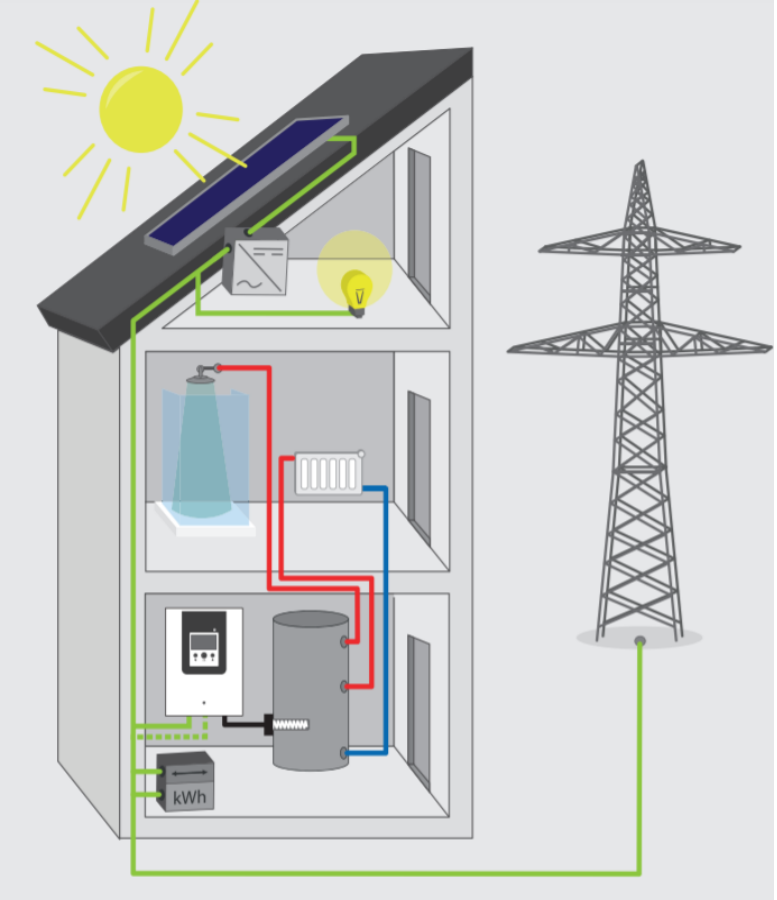
- As of 30 September 2020, there are over 2.56 million PV installations in Australia, with a combined capacity of over 18.5 gigawatts
- However, around 50 to 70% of household PV generation is exported to the grid*



*https://www.sustainability.vic.gov.au/You-and-your-home/Save-energy/Solar-power#:~:text=Typically%20around%2030%20to%2050,is%20exported%20to%20the%20grid.

Key Research Questions

- To what percentage the PV export to the grid can be minimized if integrated with the hot water system in the house
- Can a PV-driven hot water system meet
  - the requirement of 60% annual energy savings compared to electric heaters in Zone 3 and Zone 4 of Australia under AS 4234 modelling approach with TRNSYS
  - The Legionella bacterial control requirement in AS 3498 and AS 4234 (i.e. 60C at 45% level on the tank)
  - Minimum hot water delivery temperature of 45C per AS 4234
  - The maximum excess PV supplied to tank (i.e. this will determine the element capacity in the real field as typical element sizes in industry are 1.8, 3.6, and 4.8 kW)



Assumptions for a case study

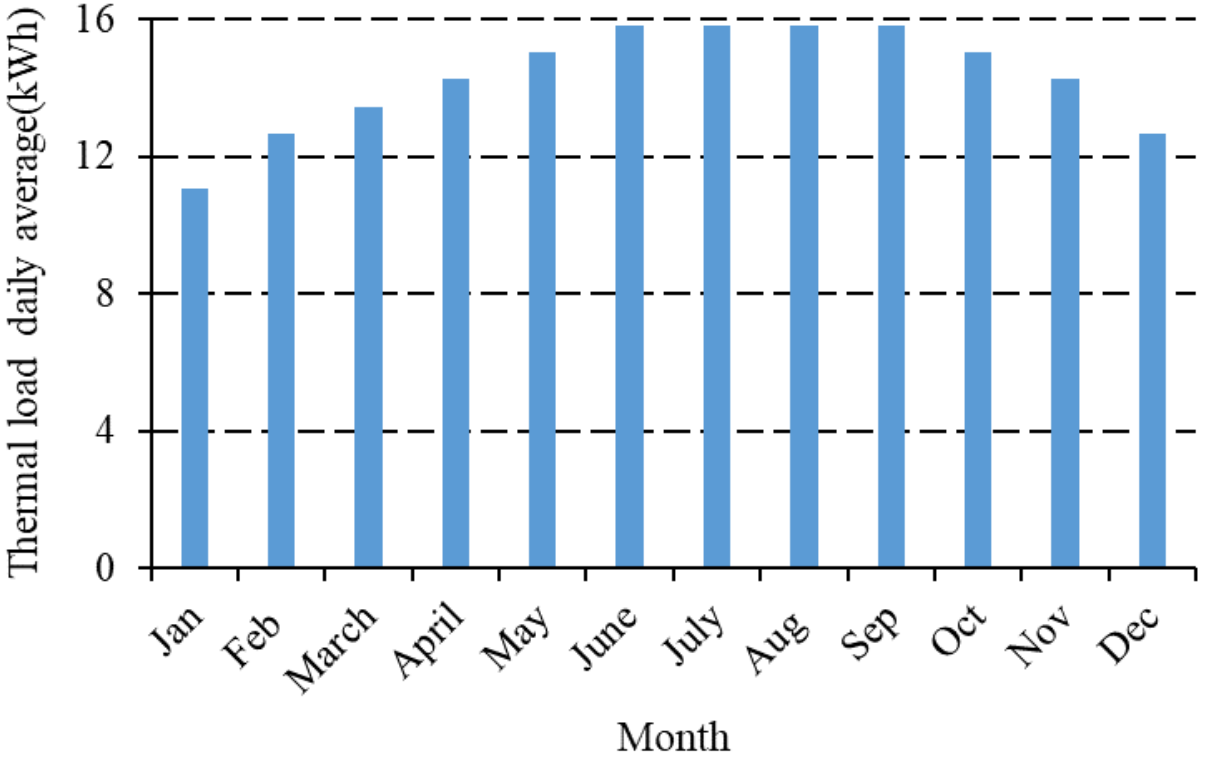
- PV system size: 5 kW peak output
- Location: 4 Australian Zones
- Storage tank size: 315L with 2.49 kWh/day heat loss based on AS 4692 test report
  - Option 1: PV element at the bottom of tank (no legionella or auxiliary element)
  - Option 2: PV element at the middle of tank-45% level (no legionella or auxiliary element)
  - Option 3: PV element at the bottom of tank (with legionella and auxiliary element)
  - Option 4: PV element at the middle of tank-45% level (with legionella and auxiliary element)
- Legionella element: This element is at 45% level on the tank to heat up the tank every 24 hours up to 60C if the tank has not reached to 60C already in the past 24 hours
- Auxiliary element: This physically is the same element as legionella element. However, in addition to the legionella function, it helps the design of PV hot water tank to maintain the delivery temperature above 45C.

1 2, 4 3

Modelling Assumptions for a case study

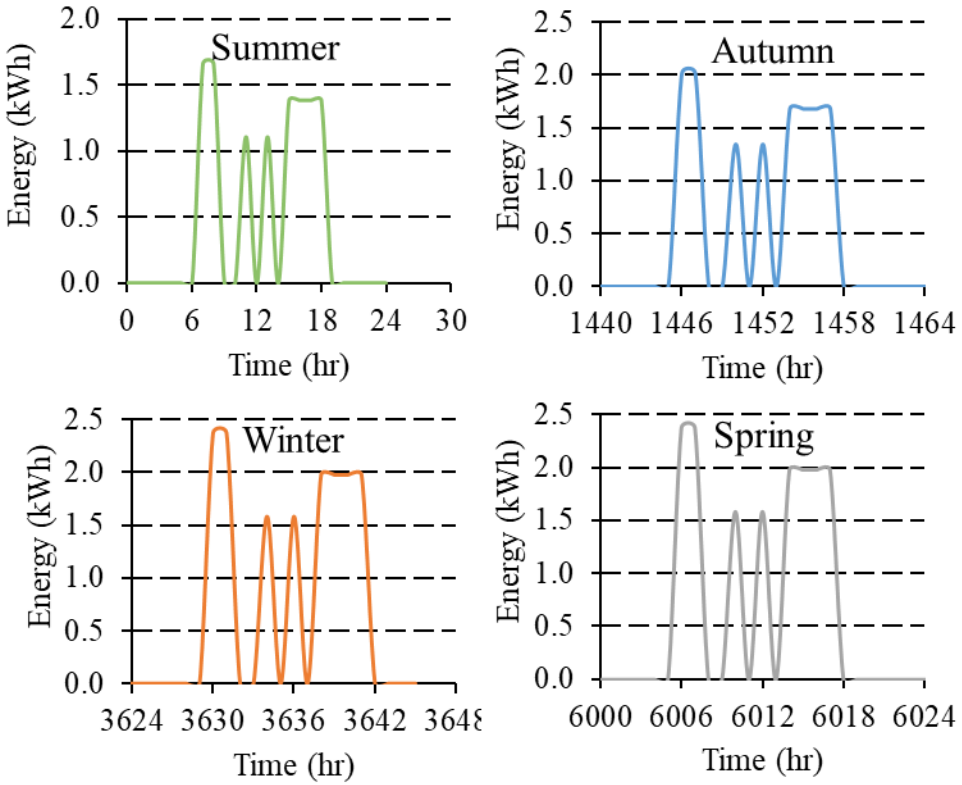
- Cut-off temperatures:
  - T_top_cut: Excess PV will charge the storage tank as long as the temperature at top of the tank is kept less than 60C (i.e. T_top_cut=60C). This parameter is then altered to 70, 80, and 90C to evaluates its effect on the PV contribution to the hot water demand.
  - T_aux_cut: This is a set point at which the auxiliary element is going to be activated until the temperature at auxiliary element reaches 60C. This set point is going to be determined based on parametric studies to ensure delivery temperature does not drop below 45C. Given there is bout 45% volume of tank water between auxiliary element and top of tank, the set point has to be set above 45C based on top temperature of tank so that to ensure delay in energy transition from middle of tank to top does not result in failure (i.e. delivery temperature less than 45C from top of the tank)

Assumptions for a case study



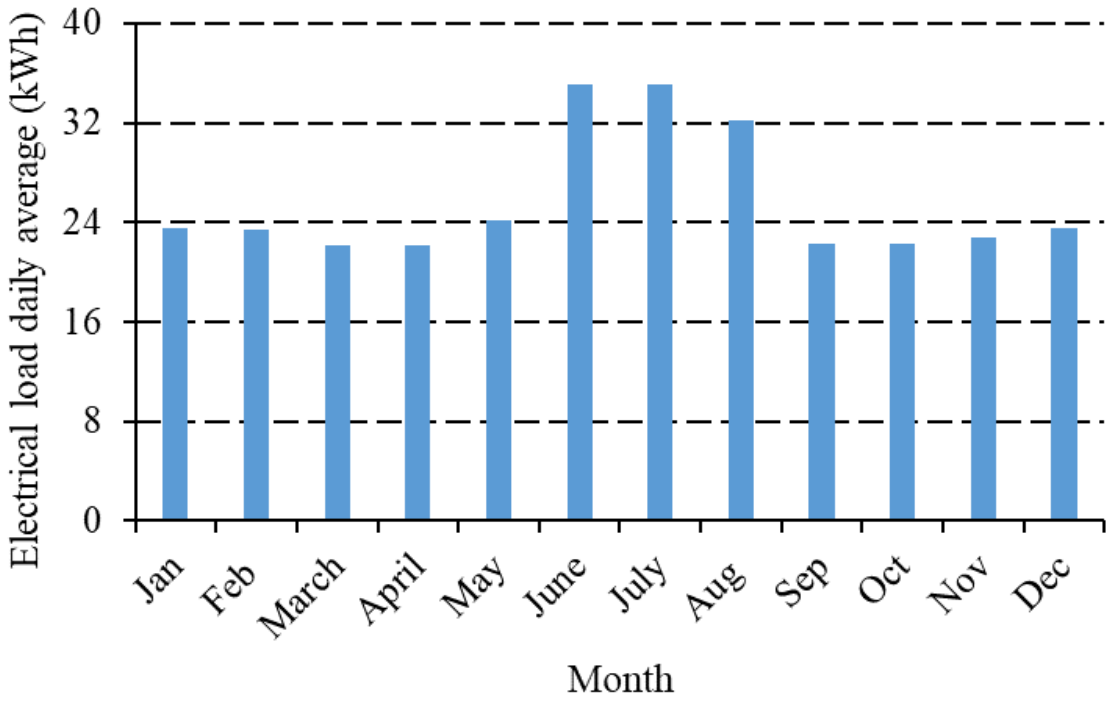
Hot water load profile in Sydney

Assumptions for a case study



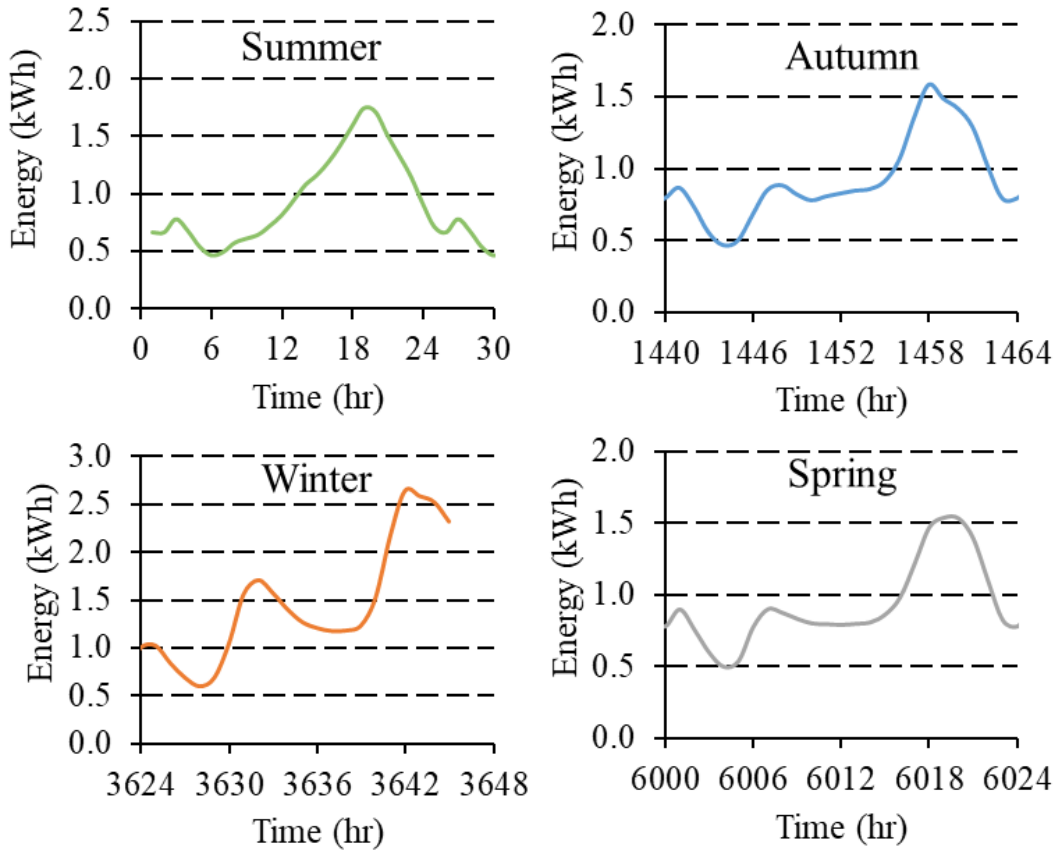
Hot water load profile in Sydney- 24 hours cycle in each season

Assumptions for a case study



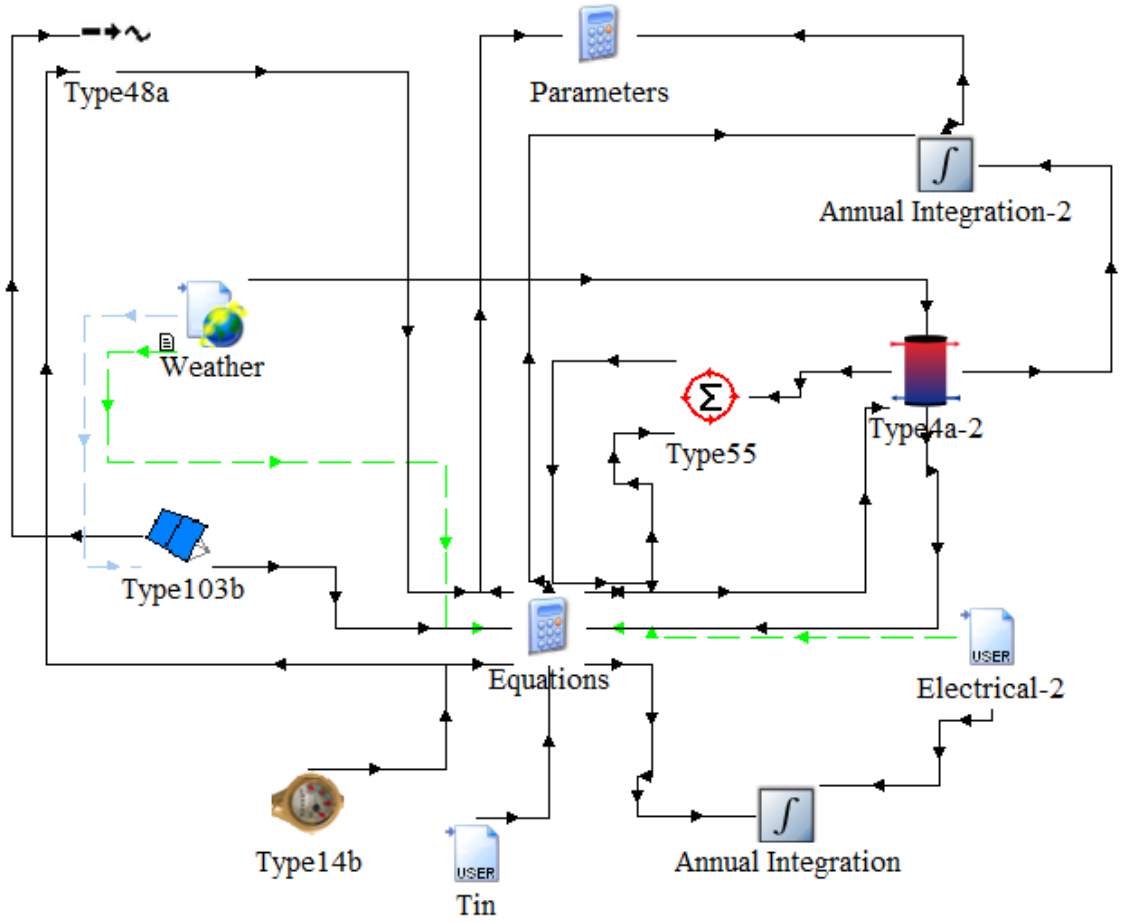
Electrical load profile in Sydney

Assumptions for a case study



Electrical load profile - 24 hours cycle in each season

Solar PV driven hot water storage tank- TRNSYS model

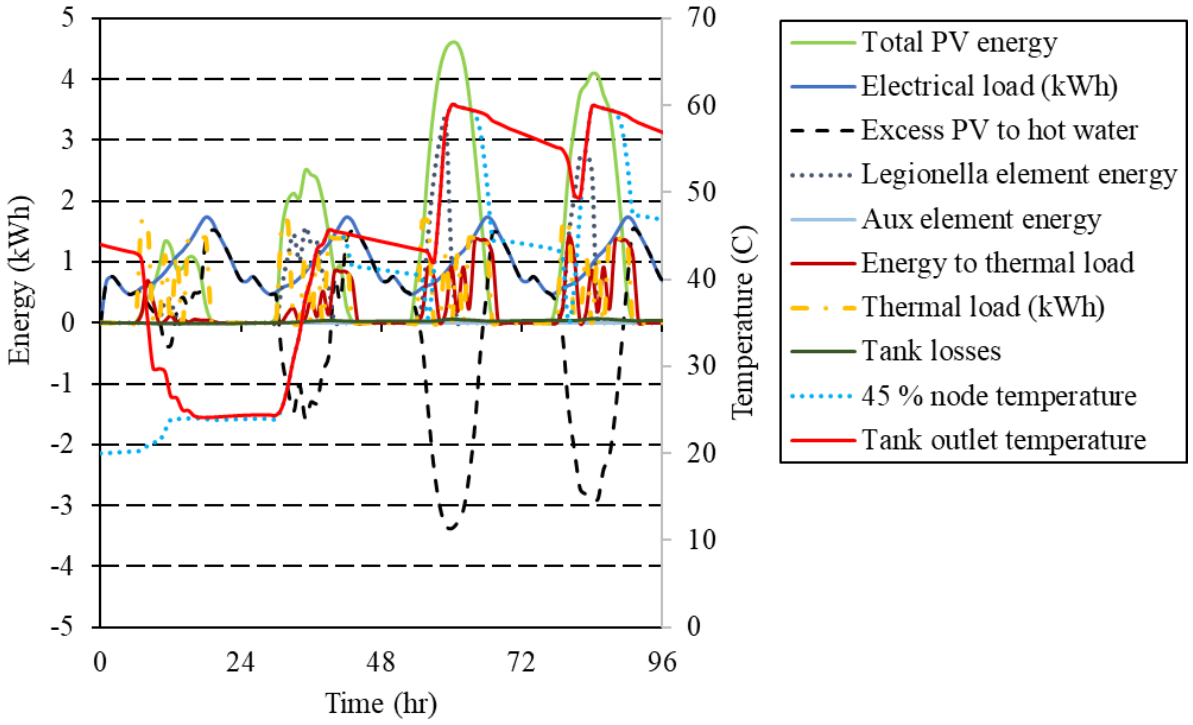


- TRNSYS schematic diagram

List of assumptions

- Element electric to thermal efficiency: 100%
- Piping loss is neglected
- Inverter is 95% efficient.
- Tank: is a fixed inlet/ fixed outlet, stratified tank with 15 nodes. All nodes are symmetric in this 315 L tank.
- Solar PV array size is 5KW. 18 PV panels were used in the model/ the suntech 280 Watt monocrystalline PV panel (model number STP280S-20/Wew) was employed in the analysis.

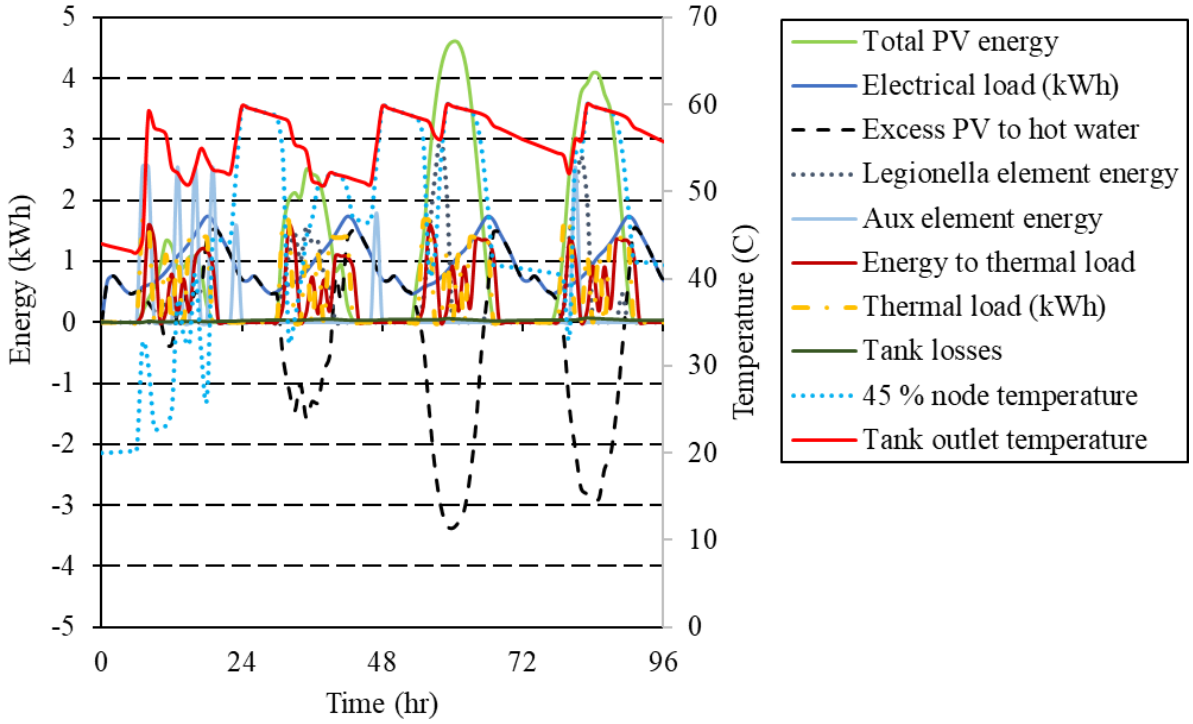
Results and discussions- hourly results – option 1 in Sydney at 60 C



Tank auxiliary heating from PV	3046
Auxiliary energy (legionella) from grid during night	0
Extra auxiliary heater energy to keep the minimum delivery temperature above 45C	0
Tank losses	-259
Tank to load energy	2781

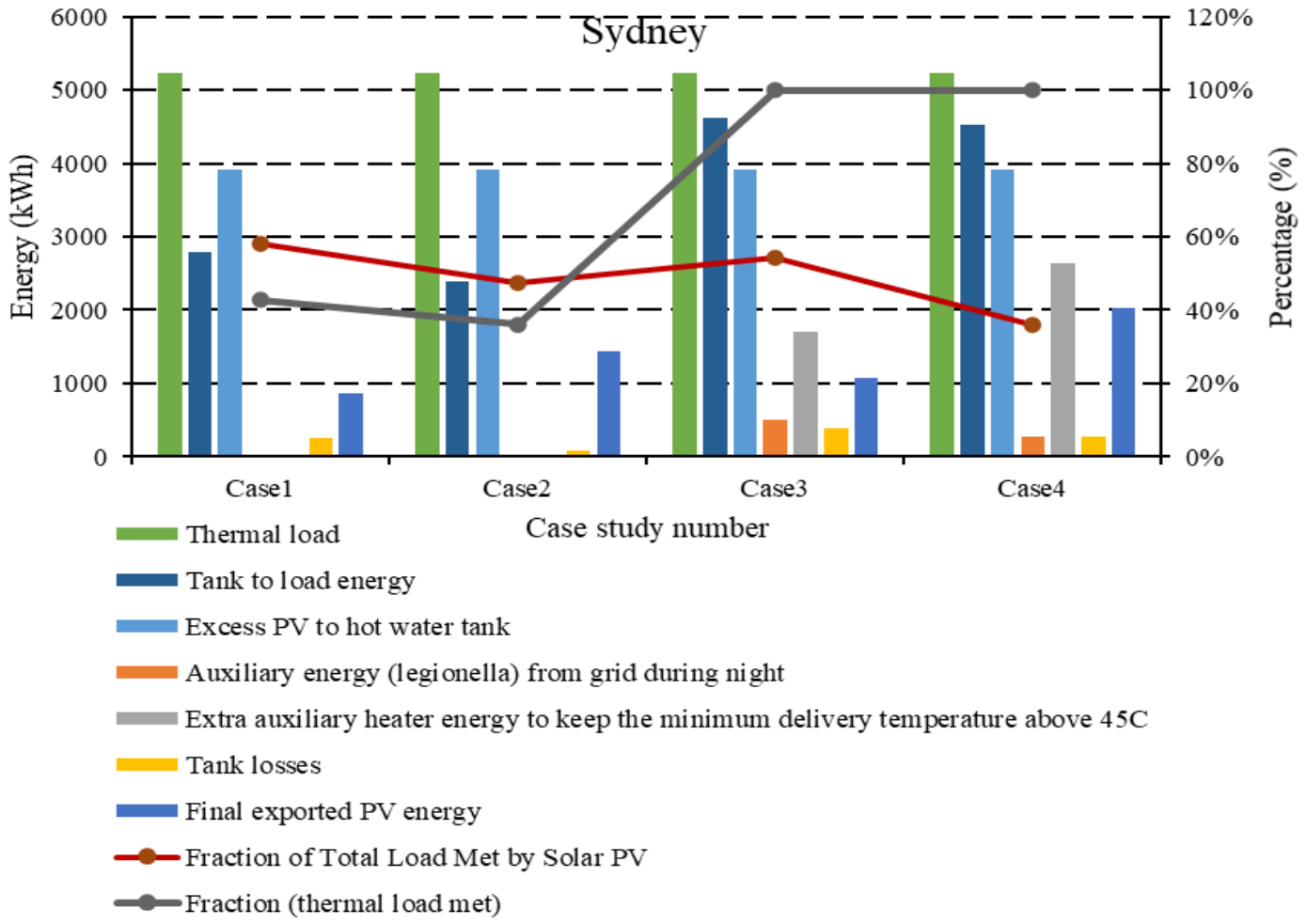
Recall - Option 1: PV element at the bottom of tank (no legionella or auxiliary element)

Results and discussions- hourly results – option 3 in Sydney at 60 C

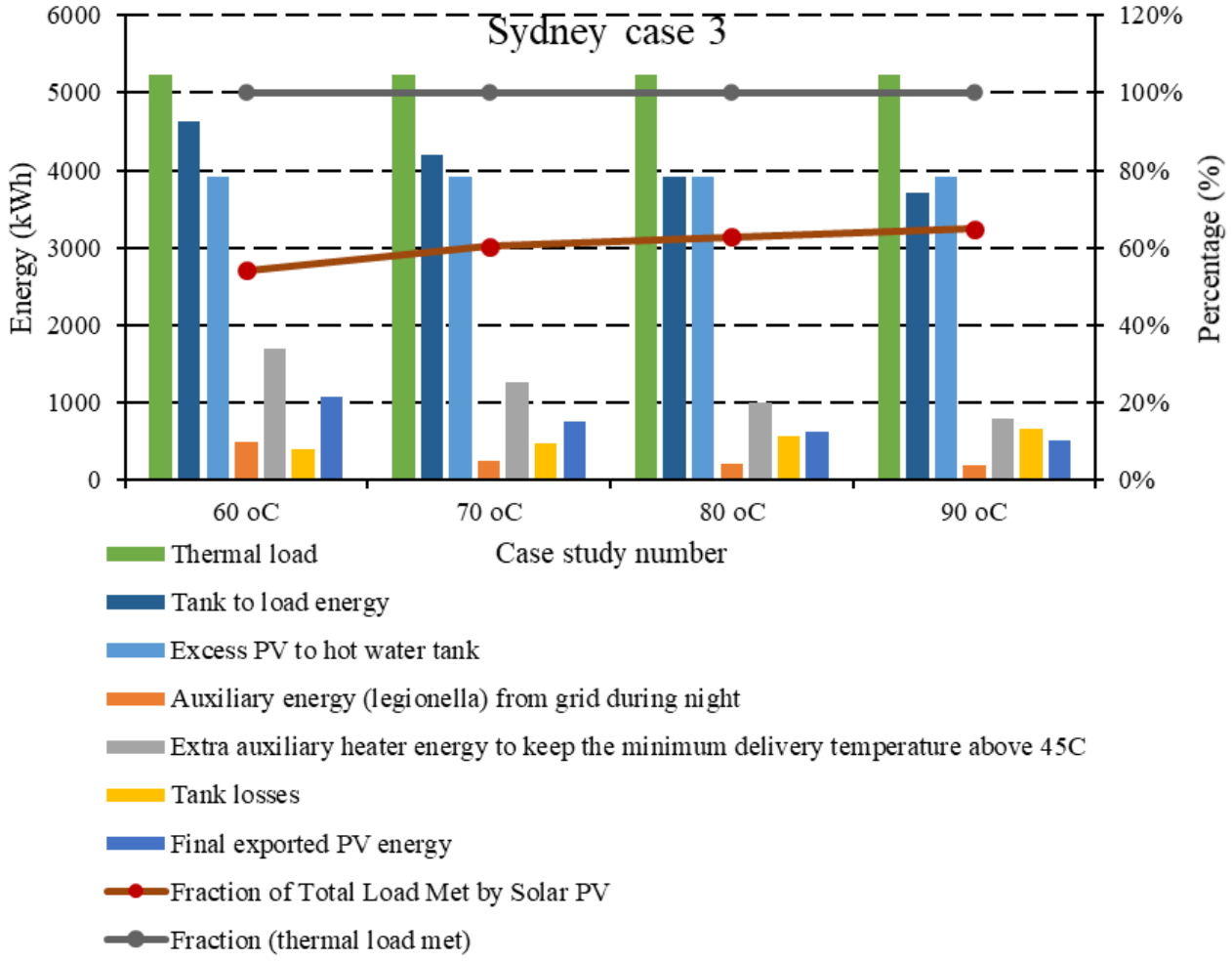


Tank auxiliary heating from PV	2829
Auxiliary energy (legionella) from grid during night	495
Extra auxiliary heater energy to keep the minimum delivery temperature above 45C	1698
Tank losses	-392
Tank to load energy	4627

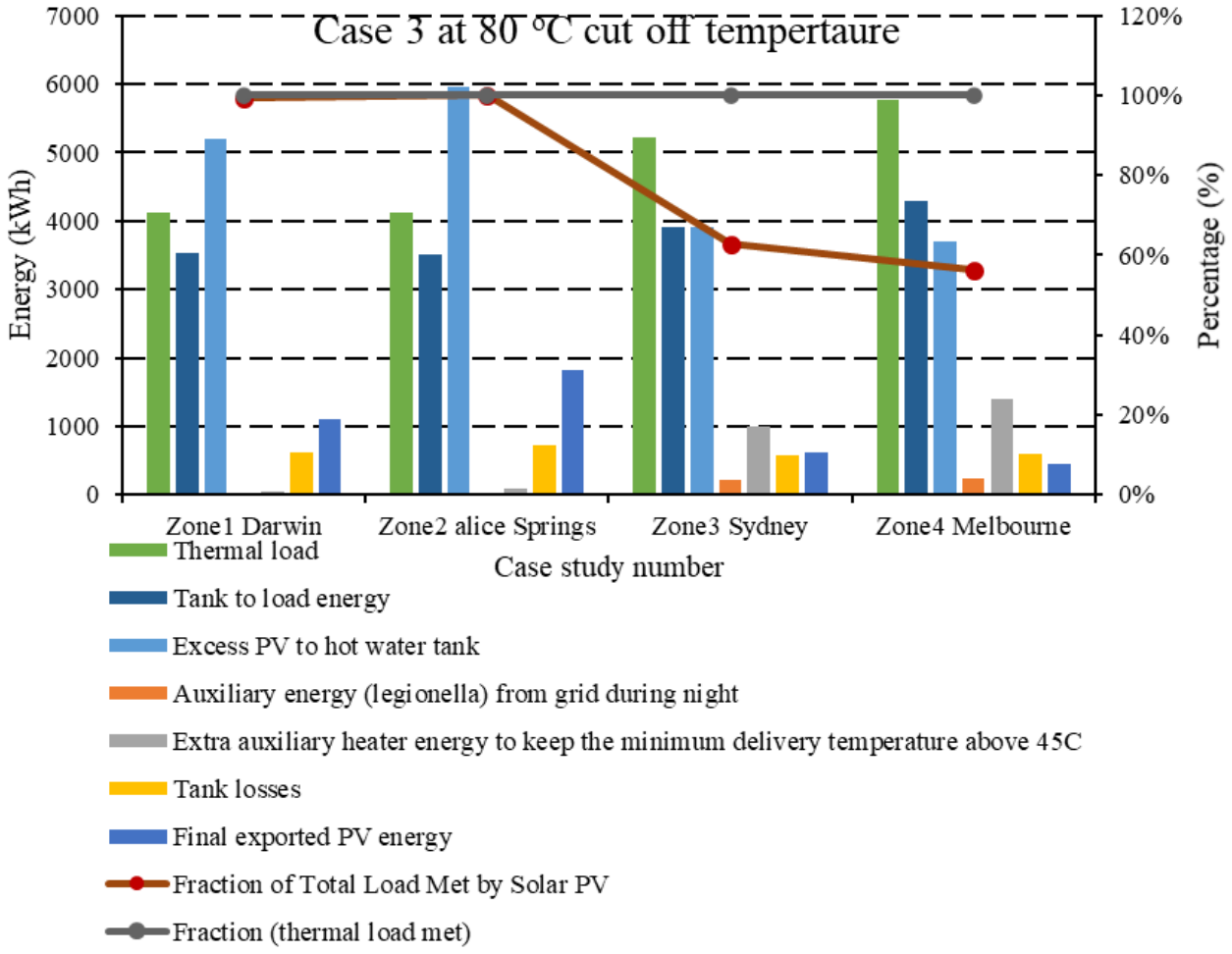
Results and discussions- annual results for 4 design options in Sydney at 60 C



Results and discussions- annual results for option 3 with 4 set points



Results and discussions- annual results for option 3 in 4 zones



Concluding Remarks

1. The PV element alone is not sufficient to meet legionella and/or thermal load (i.e. with an exception of zone 1 and zone 2 in Australia). Extra source of energy (i.e. grid, battery) is necessary for compliance of PV hot water system.
2. The additional sources from the grid/battery will reduce the solar contribution as some part of the energy is already supplied by auxiliary elements that reduce the solar contribution.
3. The best combination for the PV element and auxiliary element found to be the bottom and middle (i.e. 45% level as the minimum level for legionella compliance) of the tank, respectively.
4. To maximize the solar contribution, the maximum tank top temperature must be set to 80C. Going beyond 80C did not have any further positive impact on the solar contribution.
5. PV energy can meet 100 % of the full load in zone 1 and zone2 while meeting up to 63 % in zone 3 and 58% zone4.

Questions?