PV based Solar Airconditioning

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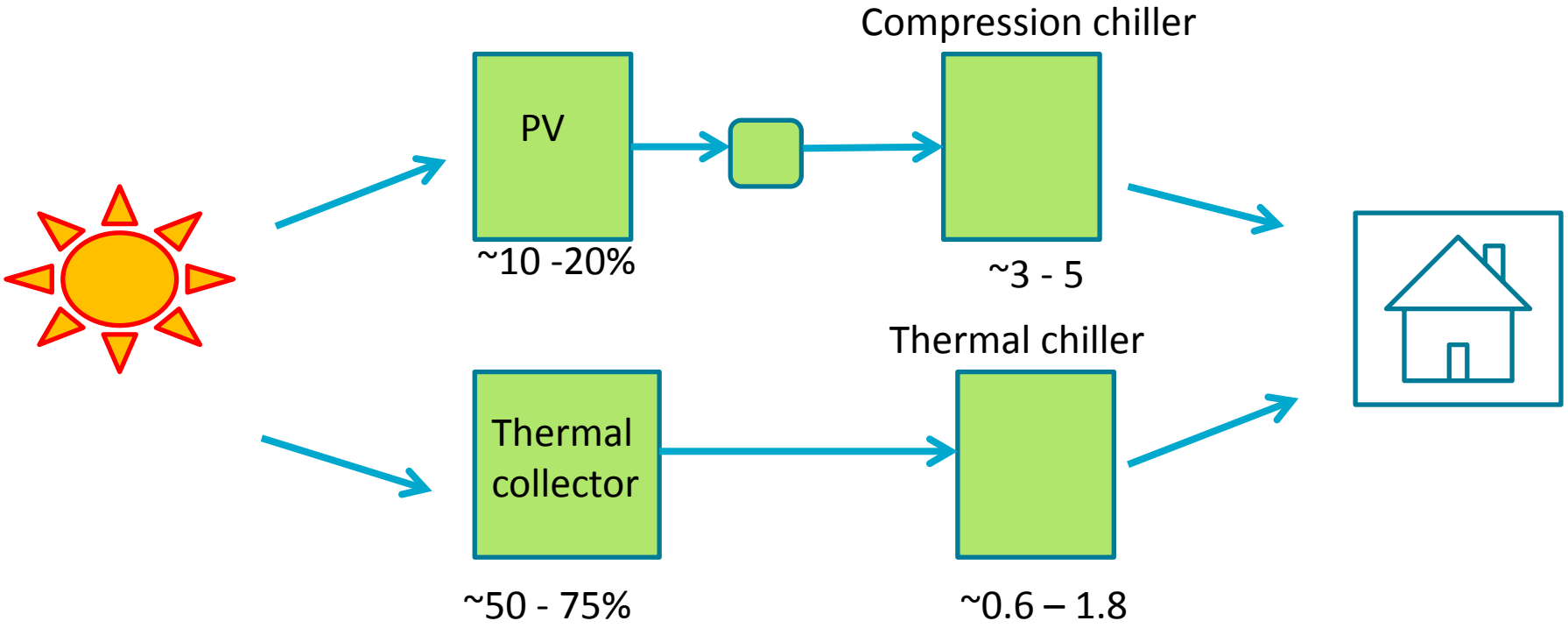
Overview

- Why PVAC
- Possible Options
- Current status
- Key Questions
- Optimization model results
- PVAC test results
- Summary

Solar Cooling Approaches

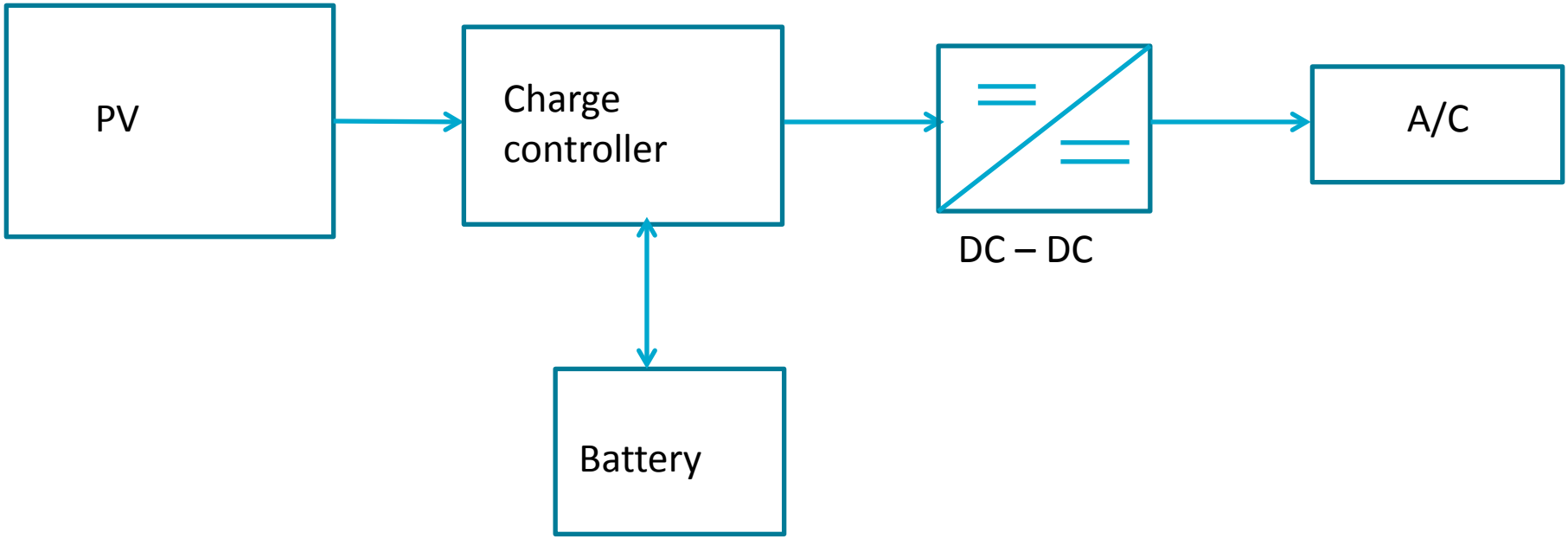


Main drivers for PV based air-conditioning

- Improving efficiency of PV systems
- Reduction in cost of PV systems

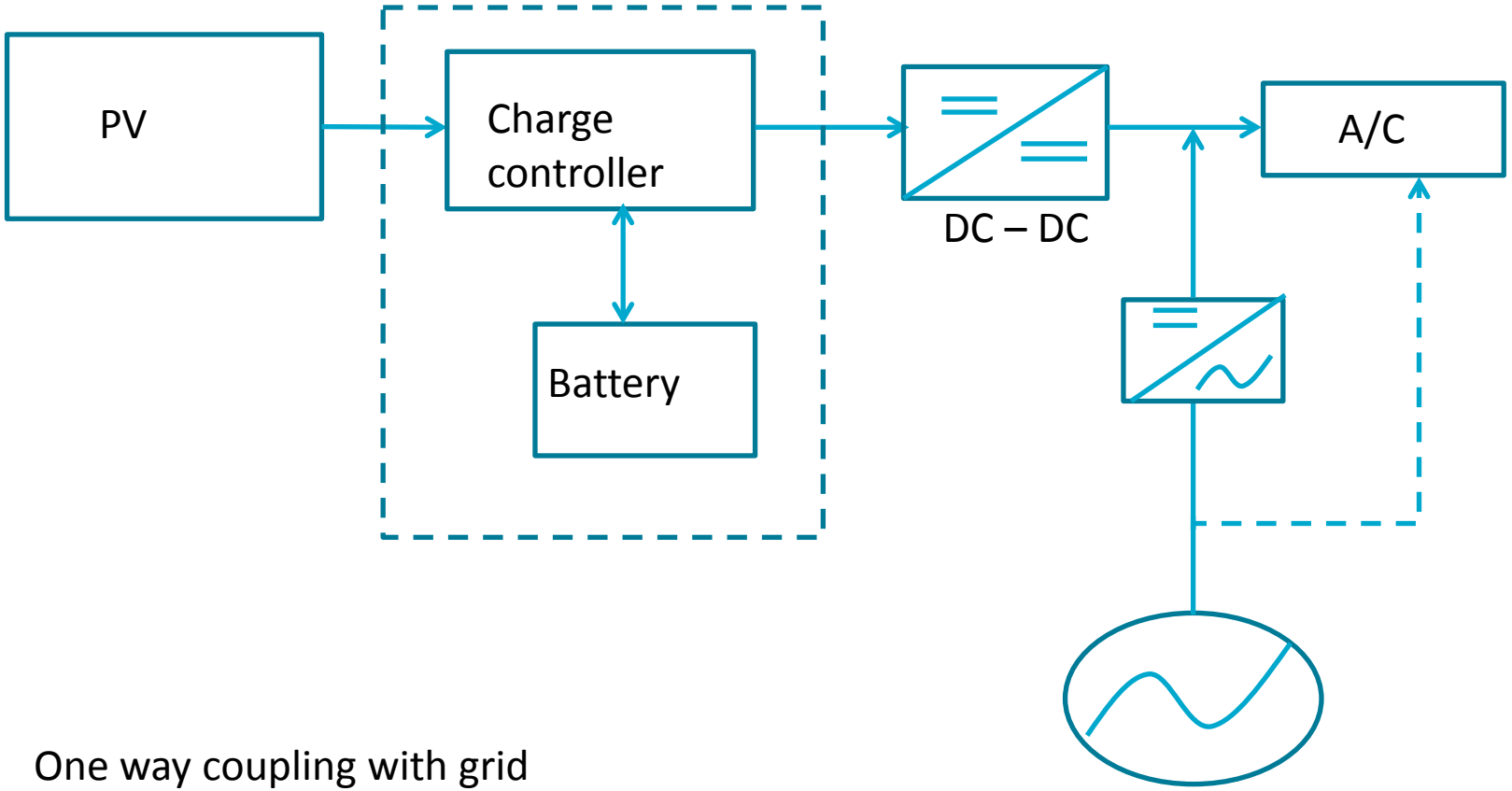
Possible Approaches

Option I : Off Grid system



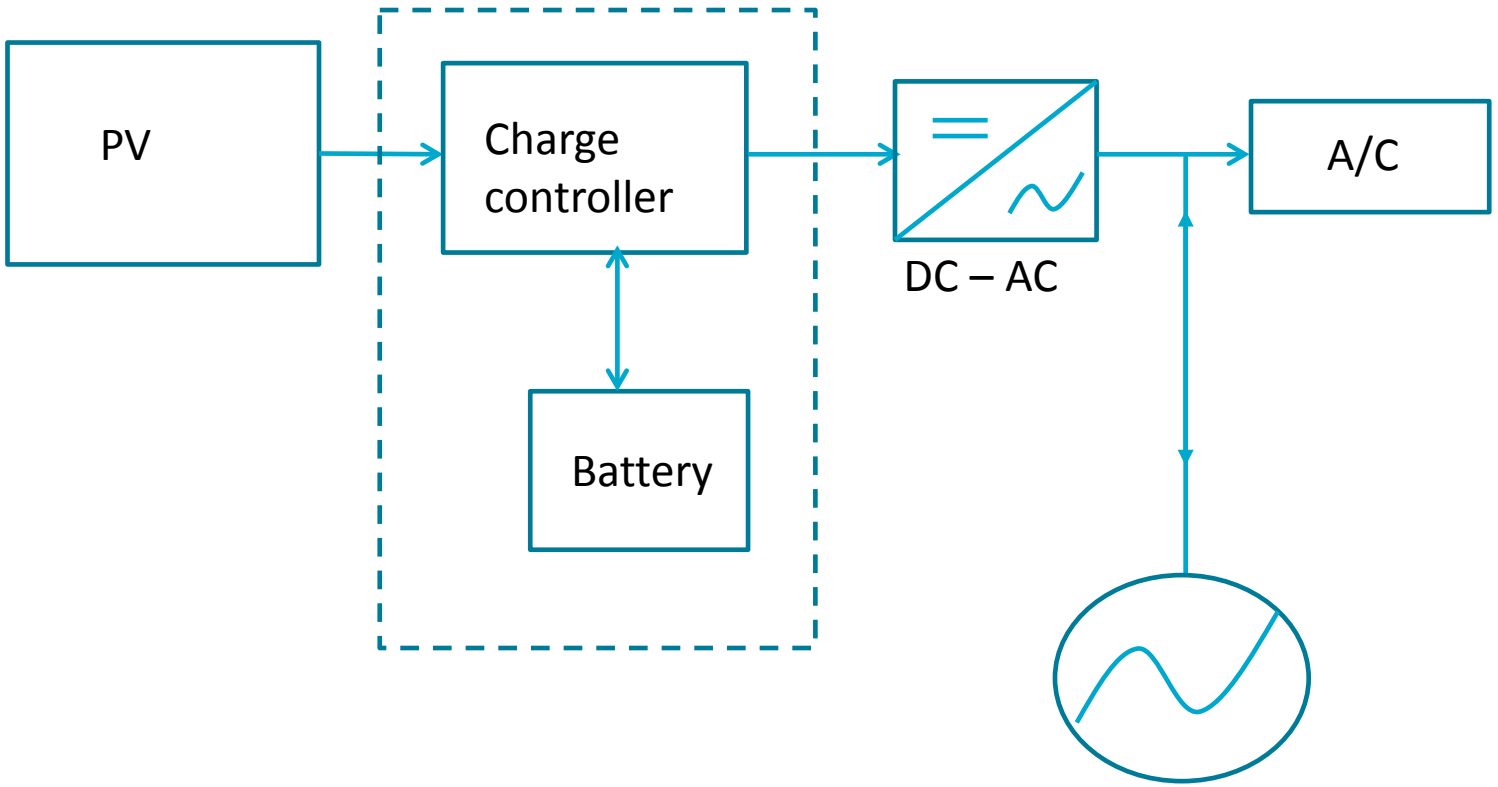
- DC based or AC based options possible
- Autonomy requirements guide the sizing constraints

Option II : Partially Grid connected system



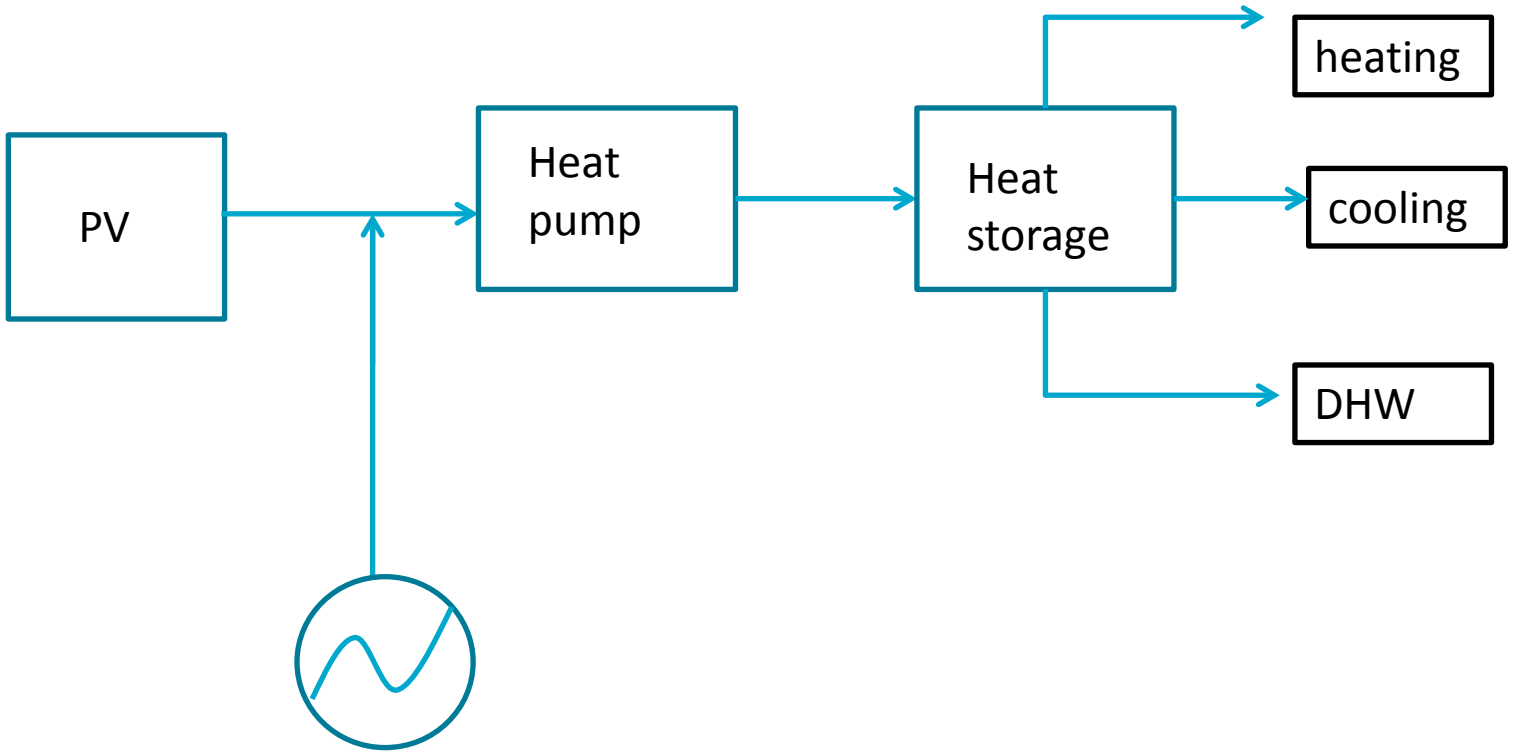
- One way coupling with grid
- No grid feed benefits

Option III : Grid connected system



- Similar to a residential PV system

Option IV : PV based heat generation



Current Status

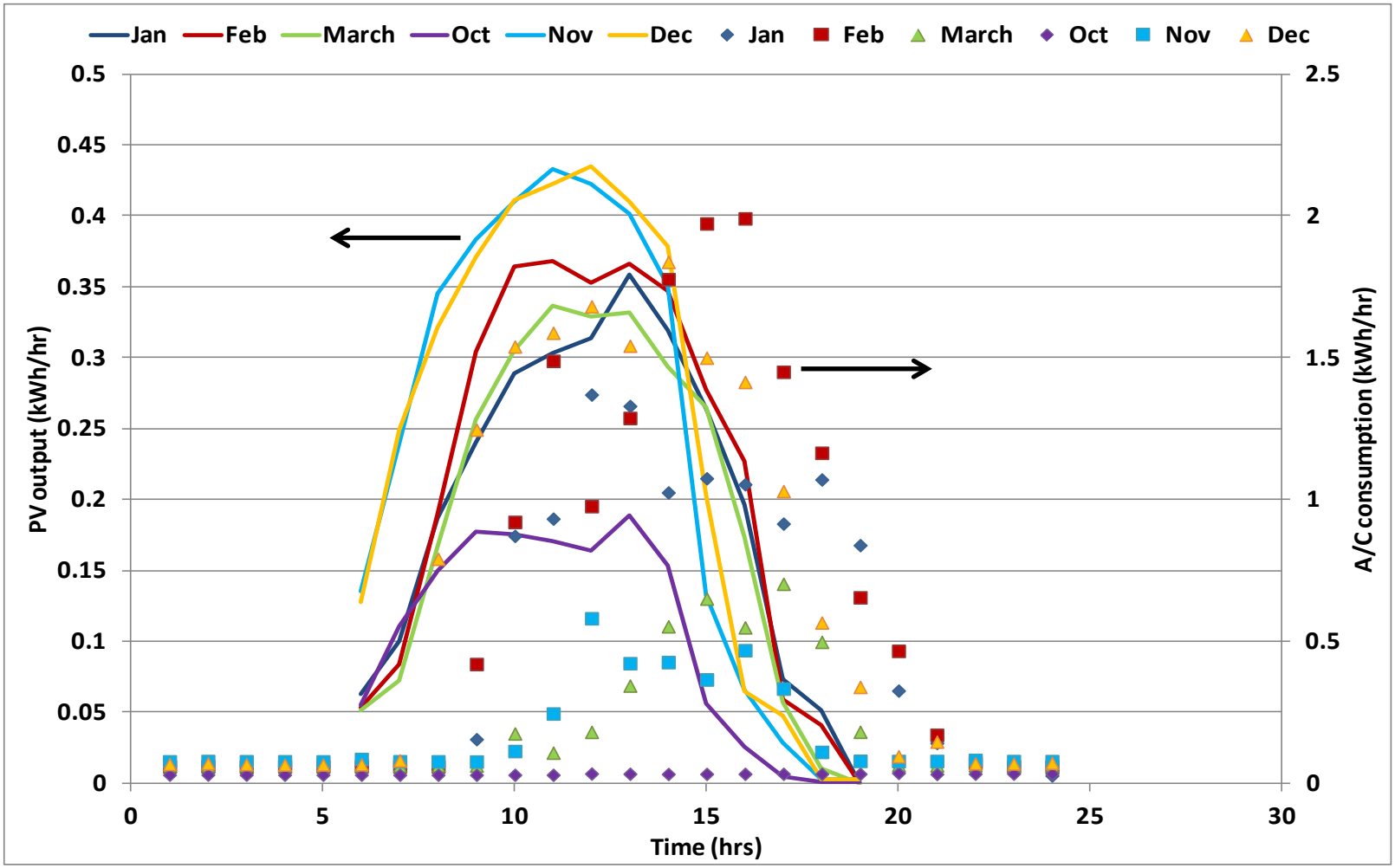
- Many components of the PVAC system available in the market.
- Commercial suppliers of “PV assisted airconditioning” exist (~ 10) – offerings range from residential units to rooftop commercial units.
- Compared to voluminous literature on thermally driven cooling systems, very few studies of PVAC system operational benefits, system sizing.
- IEA SHC task 53 started last week (18/03/2014) focussing on “new generation” solar cooling & heating systems including PV based cooling systems.

Key Questions

- A PV air conditioner economically attractive now? (Vs grid, Vs solar thermal)
- What are the Rules of thumb for sizing PV, storage?. (all options)
- Are there special benefits of a PVAC Vs grid connected residential PV?.
- Can this system be used for peak demand management? (grid connected)
- When does it make sense to use PV for heating?.

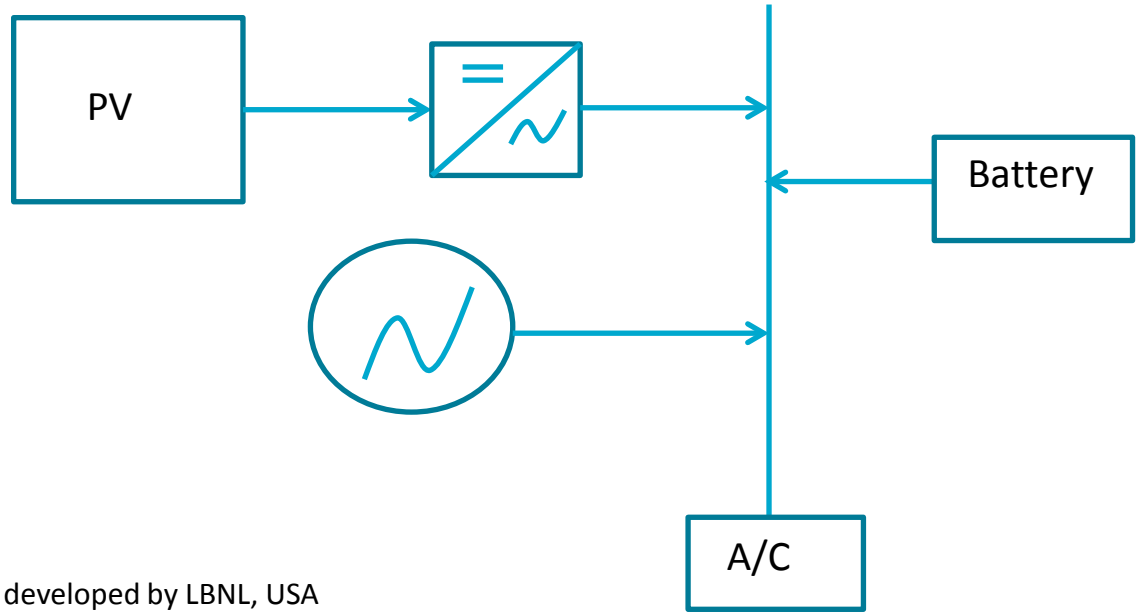
Case study - typical residential load

- One year hourly data of A/C load and PV generation for a Queensland house (from a different study -Residential Building Energy Efficiency Survey) used in this analysis.



Approach

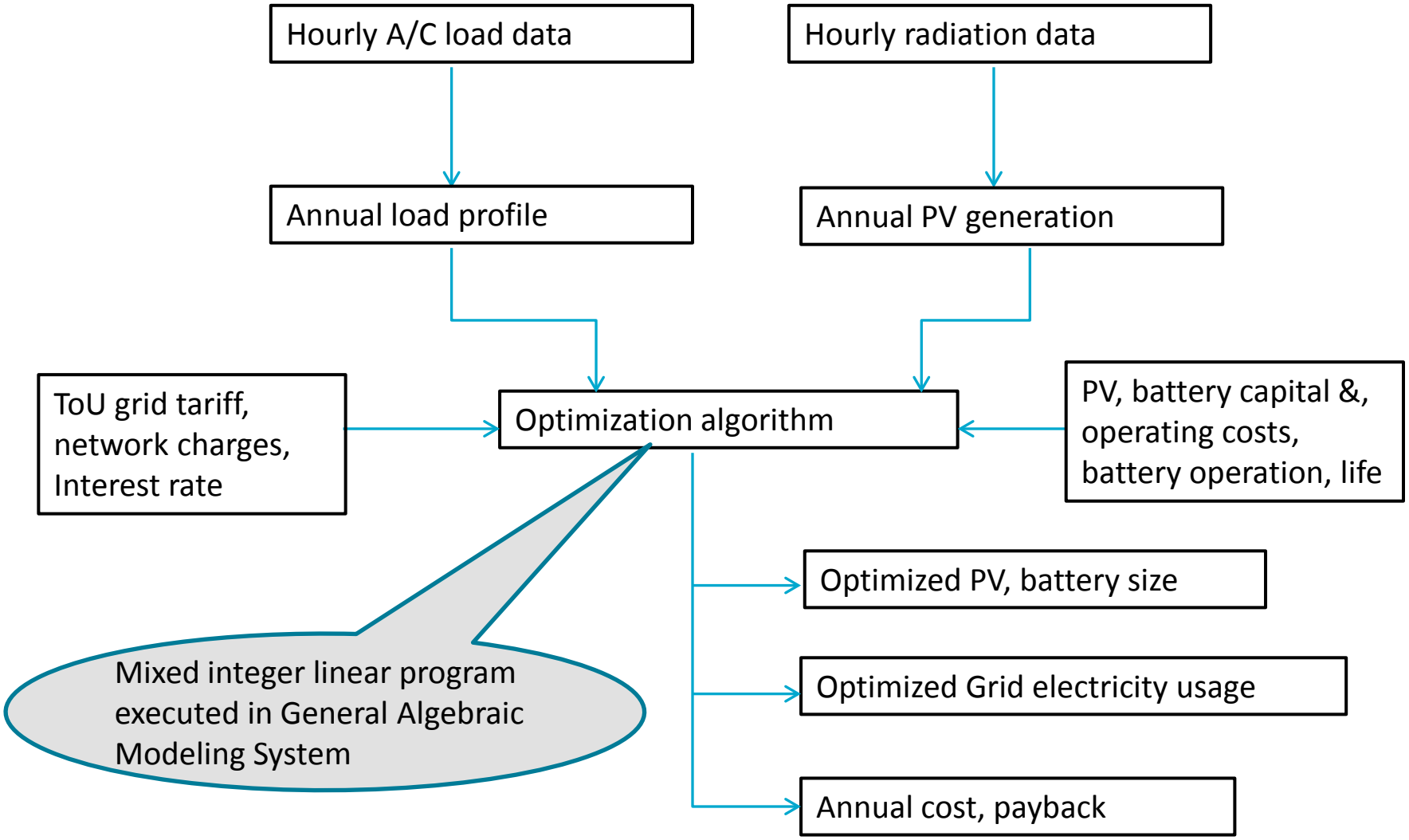
- Grid connected PVAC with storage.
- Model the system using Distributed Energy Resources –Consumer Adoption Model (DER – CAM+). This an economic and environmental optimization tool.
- Does optimal DER equipment selection and scheduling. Minimises annual energy costs, CO_2 emissions, or multiple objectives for given loads, resources and technology specifications



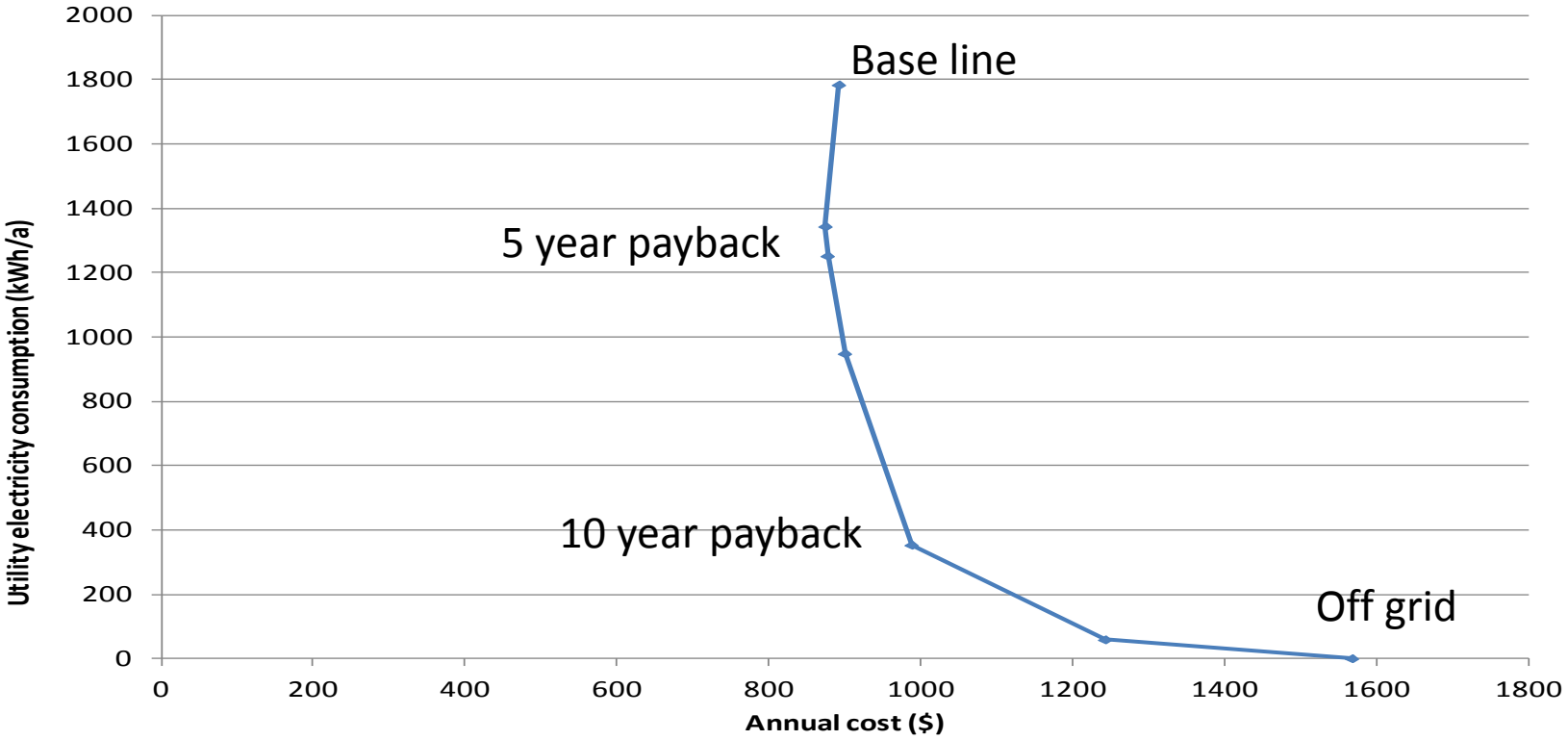
Base case -
Annual electricity consumption – 1783 kwh/year
Cooling load – 977 kW/year

+ developed by LBNL, USA

Flowchart

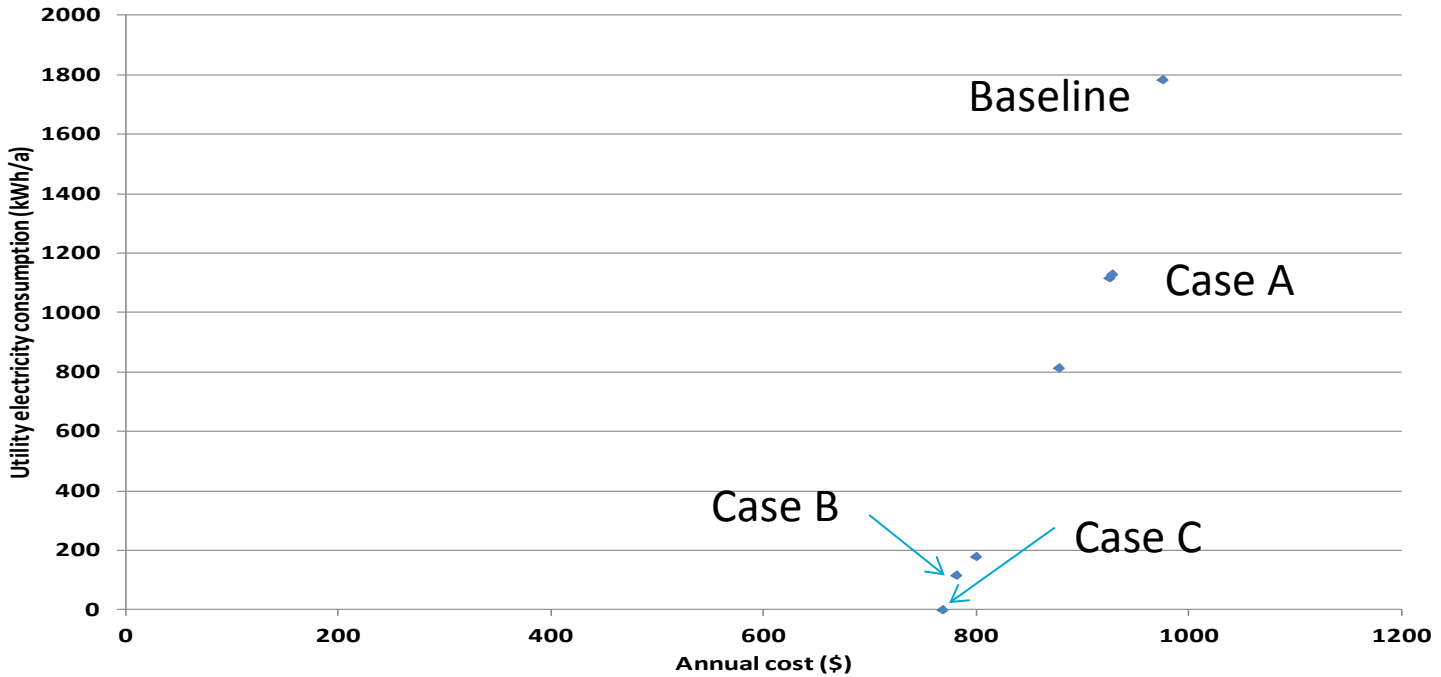

Hourly A/C load data
Hourly radiation data
Annual load profile
Annual PV generation
ToU grid tariff, network charges, Interest rate
Optimization algorithm
PV, battery capital &, operating costs, battery operation, life
Optimized PV, battery size
Optimized Grid electricity usage
Annual cost, payback
Mixed integer linear program executed in General Algebraic Modeling System

Results : Existing Scenario



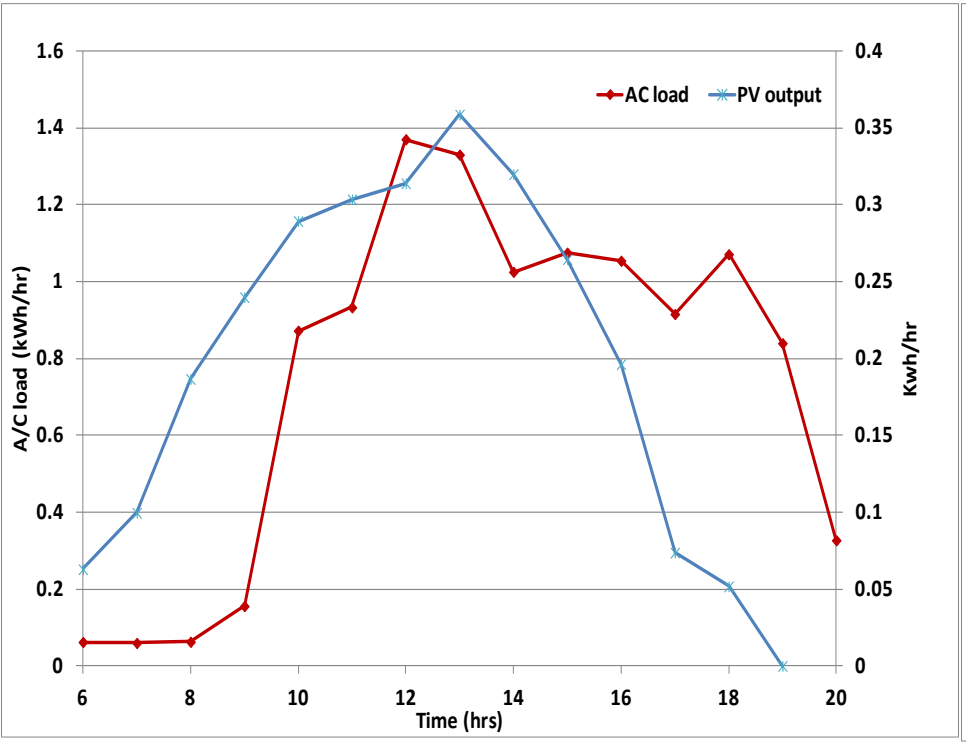
- Possible to reduce annual cost of system using PV & battery (e.g. 0.6 kW, 1.6 kWh)
- With current costs, its not economical to use this system as a means to reduce stress on grid
- This system would need 4.9 kW PV and 11.3kWh of battery to go off the grid (> 20 years payback)

Results : Projections

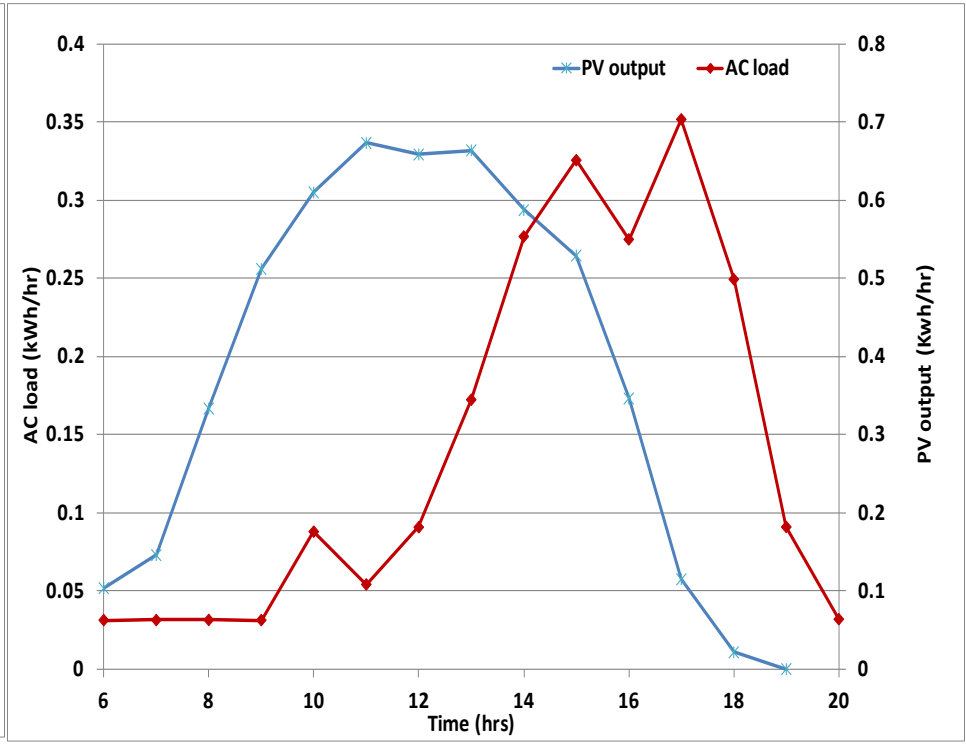


Scenario	PV /battery size	Reduction PV/battery cost	Electricity tariff	Payback (years)
Baseline	NA	NA	ToU	NA
Case A	0.3 kW /2.5 kWh	$2/W, $100/kWh	Network charges ($11.2/kW/month)	5
Case B	2.6 kW /6 kWh	50% reduction	Network charges	5
Case C	4.9 kW/11.5 kWh	> 50% reduction in PV, battery costs	Network charges	5

PV generation & A/C load Behaviour (from RBEES data)

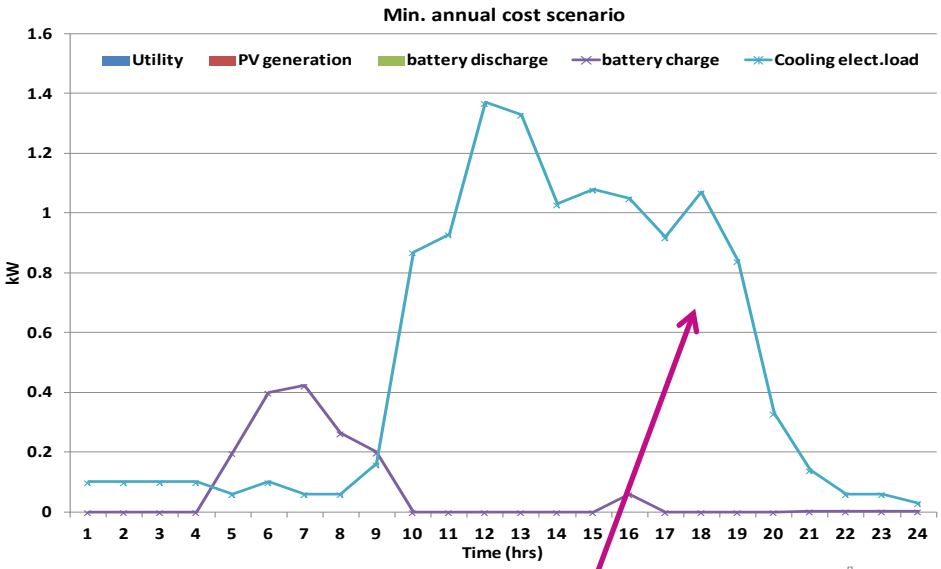


January - Week day



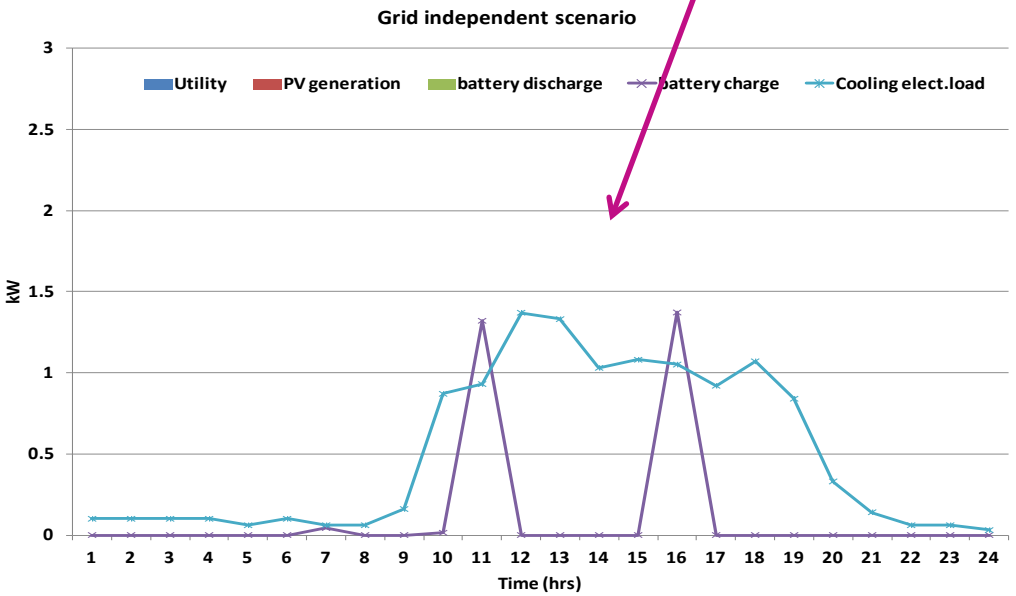
March - Week day

Resource Usage Behaviour - January

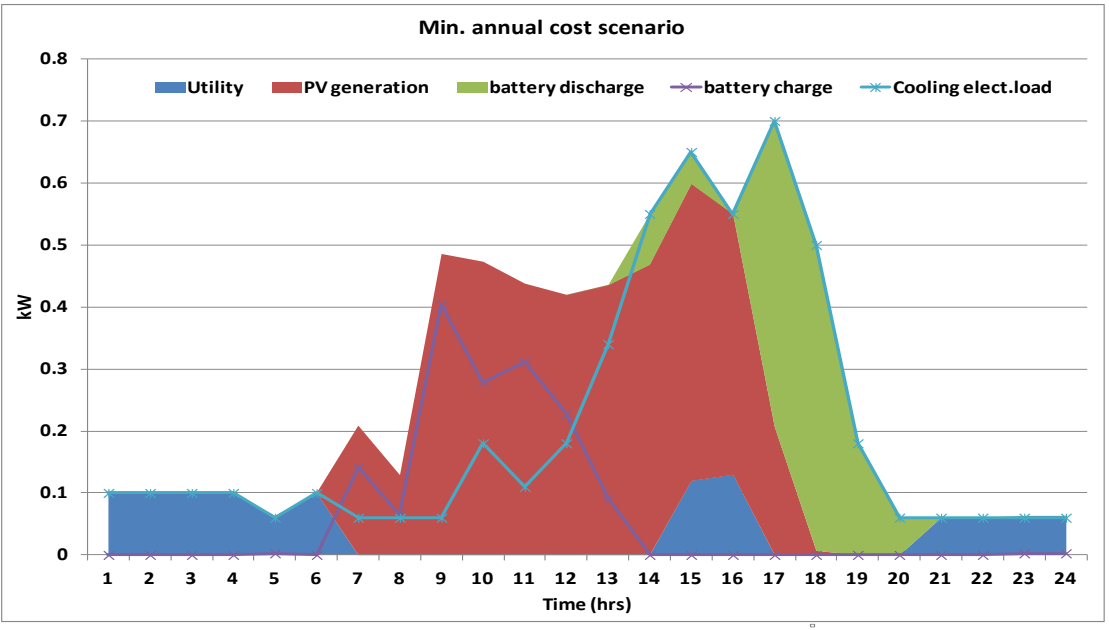


Peak generation from PV not used during the day! – can be better utilized with other loads

Reduction in peak utility consumption through storage



Resource Usage Behaviour - March



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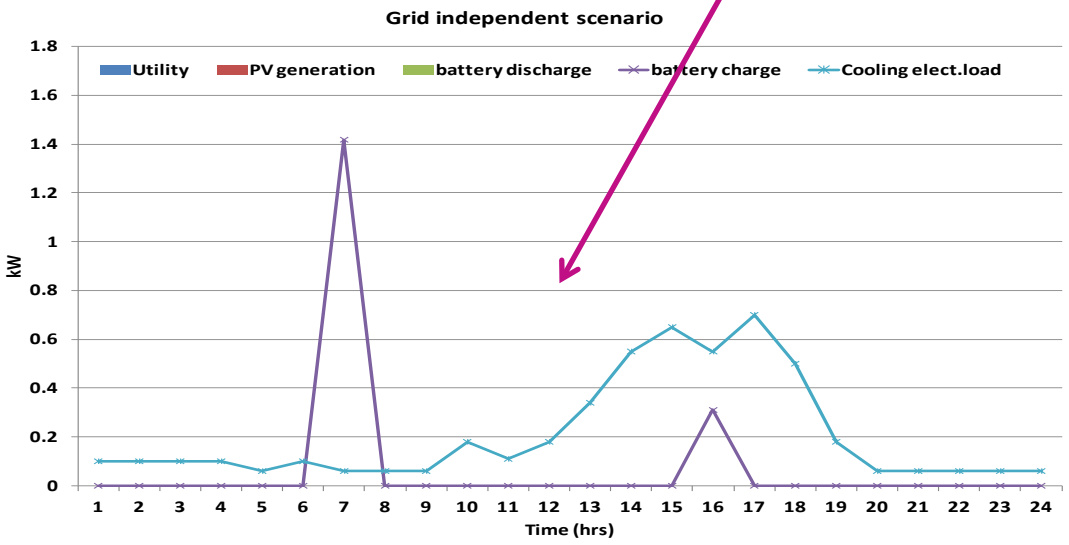


Key Questions (revisit)

- A PV air conditioner economically attractive now? (Vs grid, Vs solar thermal)

Using PV assisted airconditioning, reduction in annual cost of cooling possible. Larger payback periods, if this system has to operate Off grid.

- Are there special benefits of a PVAC Vs grid connected residential PV?.

No – from an economic perspective. Adding other loads could better justify investment on PV + storage.

- Can this system be used for peak demand management? (grid connected)

Test scope

Premise : By using the **entire** PV generation for meeting airconditioning needs, air conditioning load can effectively be **taken off the grid**.

Benefits :

- Avoid extreme peaks in electricity networks in hot days due to air conditioning
- A means to realize self consumption of PV

Approach :

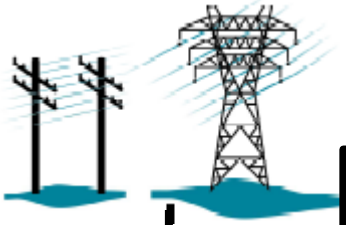
- Control airconditioner power and set points to match PV generation with minimal support from grid.

- Utilize existing features of a peak smart airconditioner

Demand response modes	DRM power consumption	Mandated by standard
DRM 1	Compressor off	Yes
DRM 2	50% load	No
DRM 3	75% of load	No

Test setup

PV



Grid

Indoor unit

Outdoor unit

Power converter

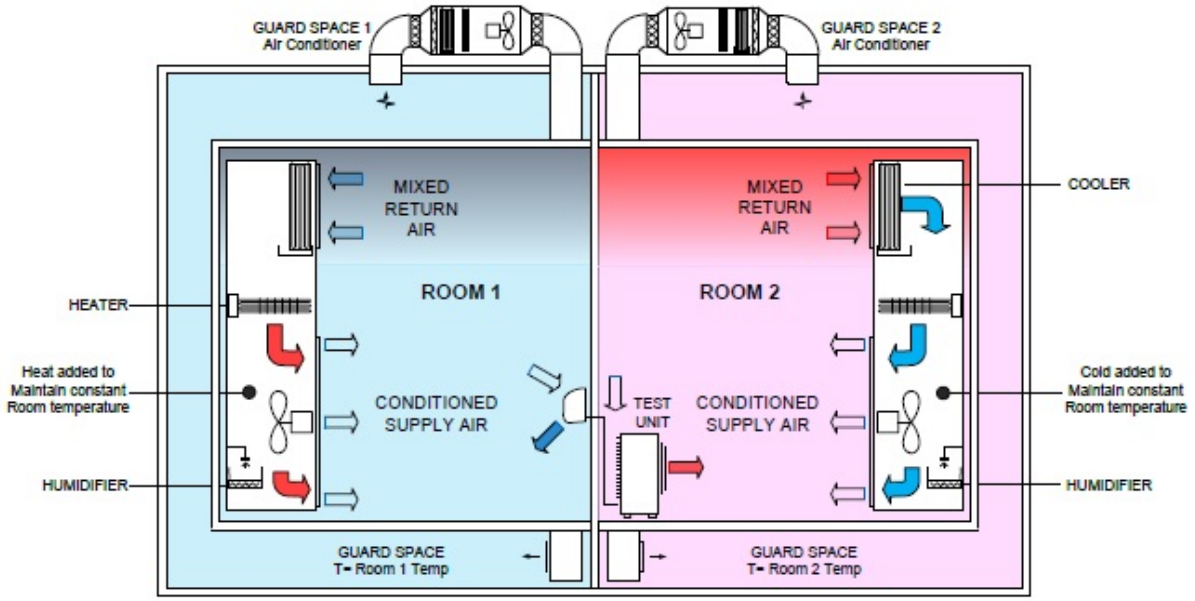
Battery (not used in tests)

Controller

Calorimeter rooms

Test System Details

- PV panels of 1.96 kWp capacity
- 1.3 kWe capacity peaksmart airconditioner with three demand response modes
- Embedded controller used in remote monitoring & building control applications

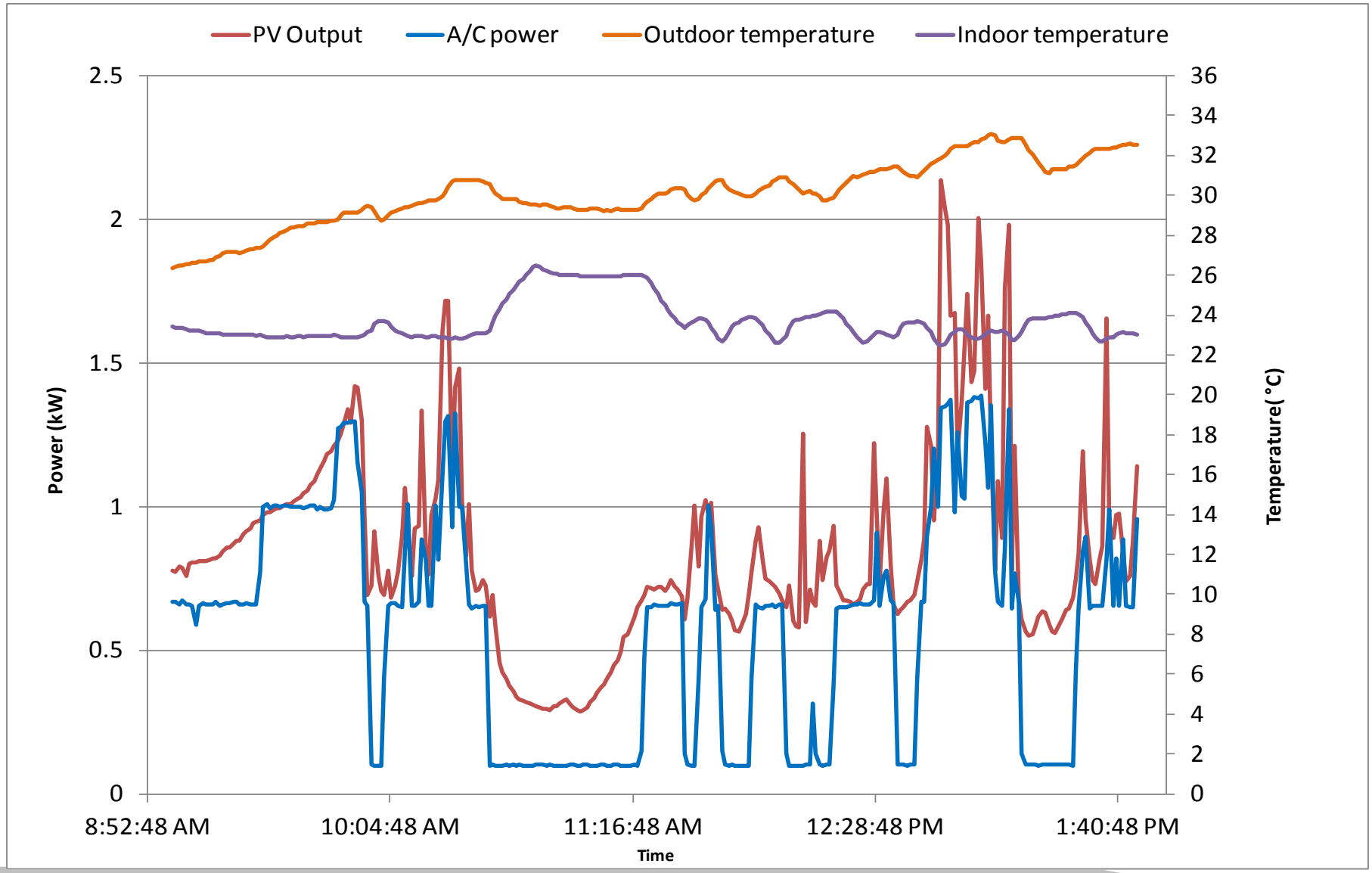


Balanced Ambient Calorimeter

Split System Air Conditioner - Cooling Test

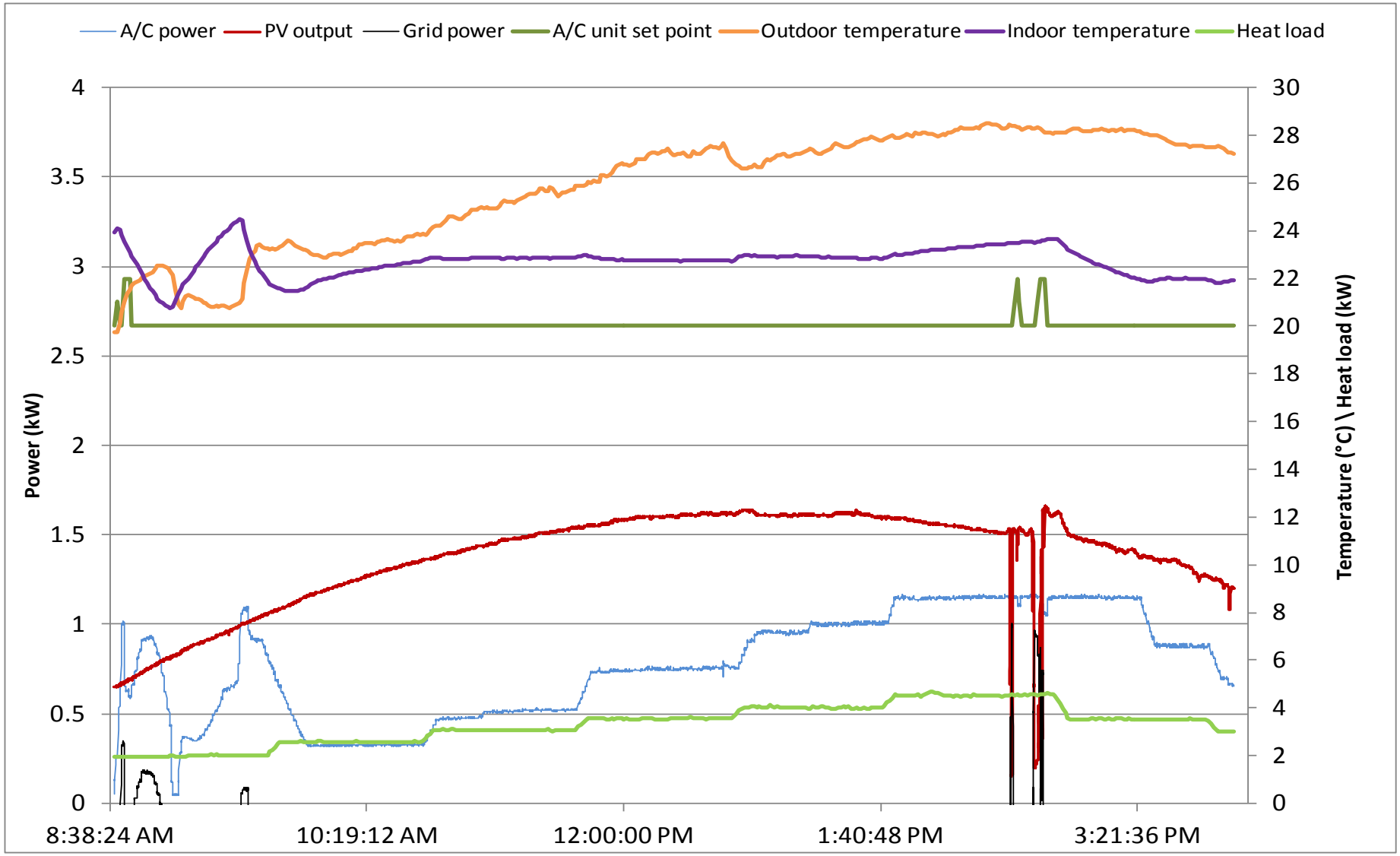
- Tests under controlled conditions for measuring room temperatures

Typical Results



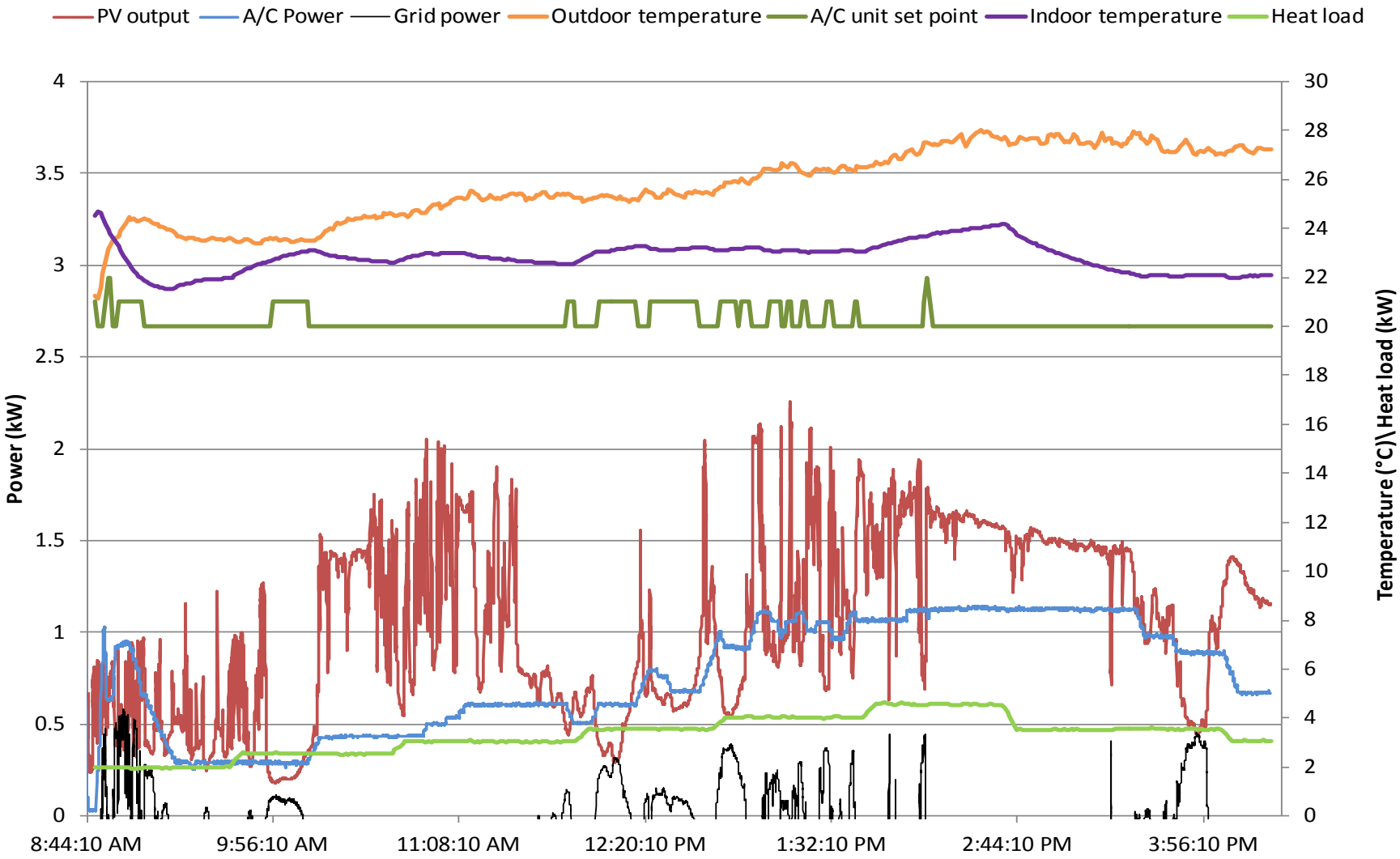
It's possible to match air conditioner operation to suit PV generation

Sunny Day



The unit can operate almost grid independent – No compromise on comfort

Overcast day



Grid provides backup avoiding A/C cycling –No compromise on comfort

Key Questions (revisit)

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• Are there special benefits of a PVAC Vs grid connected residential PV?.

No – from an economic perspective. Adding other loads could better justify investment on PV + storage.

YES – grid connected PVAC with controls can be used for peak demand management.

• Can this system be used for peak demand management? (grid connected)

YES -By controlling A/C output to match PV generation.

Summary

- Various configurations of PVAC systems possible (grid connected, one way coupled to grid, off grid, using PV to generate heat).
- Optimization of a grid connected PVAC system with storage reveals, 5 year payback for reducing utility consumption by 25%.
- For this system to be off grid and yet commercially attractive, drop in component cost required.
- Usage pattern of storage and PV shows use of other loads along with A/C can make these systems more attractive.
- Grid connected PVAC with controls can reduce peak demand from airconditioners on the utility grid. Tests were carried out to explore this possibility.
- This system maintained comfort conditions (through varying set points and utilizing demand response features of the airconditioner) with varying solar insolation levels.
- Grid behaved like a storage avoiding shut down of airconditioner during overcast days.

Acknowledgements

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Thank you