Techno-economic Analysis of Residential PV-battery Self-consumption

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Agenda

- Motivations
- Methodology
- Results
- Conclusions

- In Australia, the average residential utility bill per year rose by 70% between 2008 and 2014

Figure 1: Real indexed residential retail prices - historical and forecast [1]

Motivations

- Total installed capacity of PV-battery systems projected to increase from 5 GW in 2017 to 19.7 GW in 2037.
- AEMO projects solar PV annual cost decline of 1.5% up till 2040
- Battery storage price predicted to fall from approx. 0.40 $/kWh in 2016 to around 0.15 $/kWh in 2040
- FiT rates fallen to around 8-10 c/kWh

Results in... Increased self-consumption!

Research Aims

- To perform a techno-economic analysis of residential PV-battery systems
- To demonstrate the benefits of using an optimisation-based energy management strategy over that of some commonly employed heuristics.

Methodology

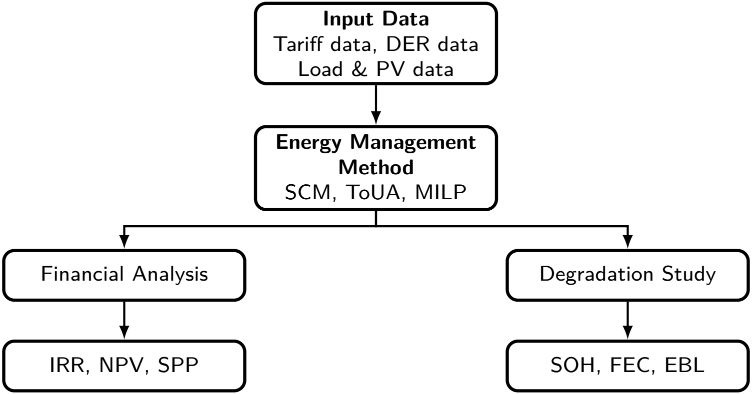


Figure 2: Framework

Input Data

Table 1: Retail Charges (Origin Energy - Essential energy distribution zone) [2]

Tariff Type	Fixed charge ($/day)	All Usage (c/kWh)	Off peak Usage (c/kWh)	Shoulder Usage (c/kWh)	Peak Usage (c/kWh)	Feed-in Tariff (c/kWh)
Flat	1.551	31.317	-	-	-	9.0
ToU	1.551	-	21.340	37.147	38.588	9.0

Table 2: PV and Battery Size Combinations (Solar Home Data) [3,4]

Solar PV Size (kWp)	Battery Size (kWh)	Battery Type
3 - 4	6.5 (LG Chem RESU 6.5)	Lithium-ion
5 - 6	9.8 (LG Chem RESU 10)	Lithium-ion
7 - 10	14 (Tesla Power Wall 2)	Lithium-ion

Table 3: Cost Parameters

Cost Parameter	Value
Annual electricity price inflation, e	3%
Discount rate, d	5%
System lifespan, $\mathcal{N}$	20 years

SimSES Degradation Model

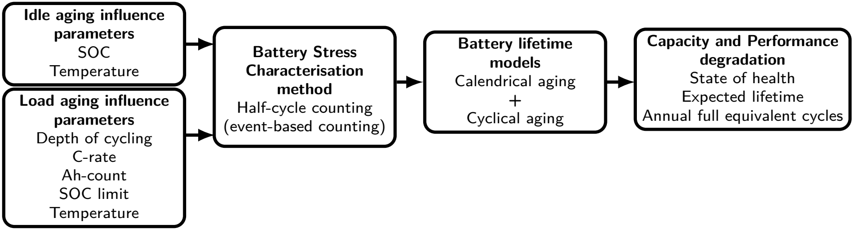


Figure 3: SimSES battery degradation model [5]

Optimization Model - HEMS

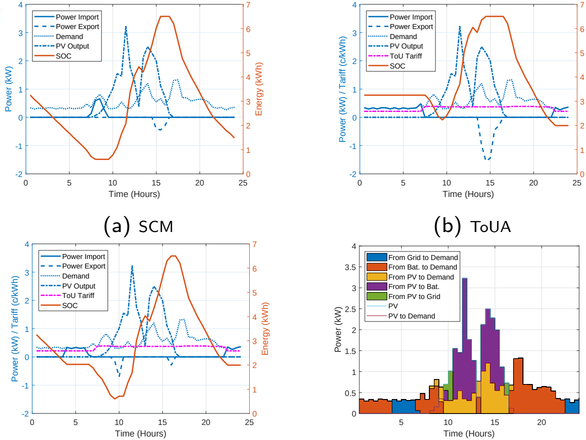
Objective Function (MILP):

$$\underset{\substack{p^{\mathrm{g+}}_{d,h}, p^{\mathrm{g-}}_{d,h}, p^{\mathrm{b+}}_{d,h}, p^{\mathrm{b-}}_{d,h},\\ d^{\mathrm{g}}_{d,h}, s^{\mathrm{b}}_{d,h}, e^{\mathrm{b}}_{d,h},}}{\text{minimise}} \sum_{d \in \mathcal{D}} \left[\sum_{h \in \mathcal{H}} T^{\mathrm{flat/ToU}} p^{\mathrm{g+}}_{d,h} - T^{\mathrm{fit}} p^{\mathrm{g-}}_{d,h} \right] \quad (1)$$

subject to:

1. Power balance constraint
2. Battery SOC constraint
3. Maximum grid connection limits
4. Upper and lower limit on continuous variables

Results - Energy Scheduling



(a) SCM (b) ToUA

(c) MILP (ToU) (d) House demand

Figure 4: Daily Scheduling for Customer 47 (4 kWp PV, 6.5 kWh Battery), Day 1

Results - Economic Viability

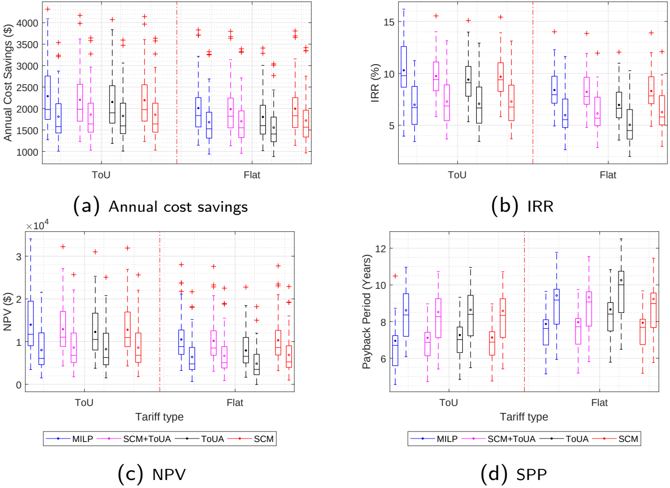


Figure 5: FI with PV-battery systems, perfect (●) and imperfect forecast (○)

Results - Battery Profitability

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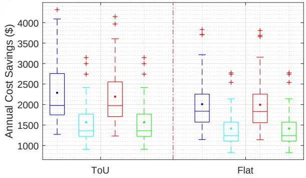
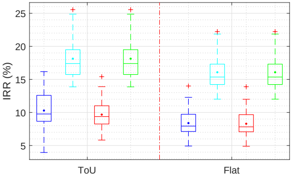
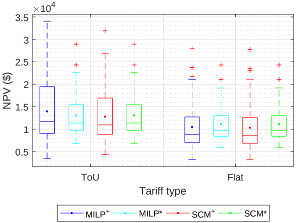


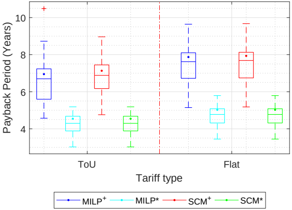
(a) Annual cost savings



(b) IRR



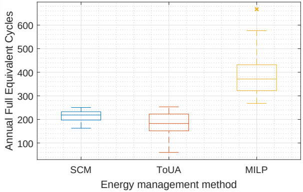
(c) NPV



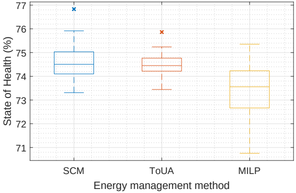
(d) SPP

Figure 6: FI with PV ($*$) and with PV-battery ($+$) systems, perfect (●) forecast

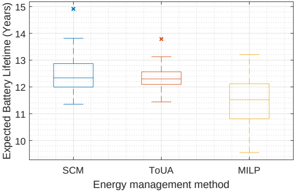
Results - Degradation



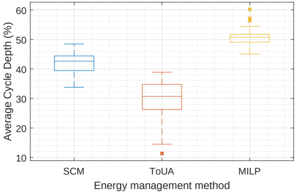
(a) FEC



(b) SOH



(c) EBL



(d) DOC

Figure 7: Battery degradation results

Conclusions

To conclude...

- Well-tuned heuristic strategies can give faster, near-optimal solutions when compared to a principled optimisation technique.
- Investing in PV alone is currently more profitable than investing in a PV-battery system.
- Rule-based heuristics show better battery aging performance compared to MILP.

For future work...

- We will employ different machine learning methods to provide fast online battery schedules, given customer historic PV and demand data.

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The End

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Thank you!
Any Questions?

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