IMPERIAL

Robust Prices for Heterogeneously Controllable Energy Communities

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My LinkedIn

Problem setup

I would like to join an Energy Community (EC), but I don't have controllable assets at home. I just want to respond to a time-varying tariff!

(privacy preserved, flexibility implicit via response to dynamic prices)

In our company we have some thermostatically controllable loads and PV panels, over which we grant the community manager (CM) full control.

(data shared with CM, flexibility explicit via direct load/generation control)

Community Manager (algorithm)

imports/exports energy from/to wholesale market when needed

welfare-maximising

Power setpoints $\{x_{nt}\}_{n\in\mathcal{N},t\in\mathcal{T}}$ → $\mathcal{N}$: Directly controllable agents

Dynamic prices $\{\pi_t\}_{t\in\mathcal{T}}$ → $\mathcal{M}$: Price-responsive agents

Market clearing (if we had full information)

1. Solve **primal** problem → get power setpoints for $\mathcal{N}$

$$\underset{\{x_i\}_{i\in\mathcal{N}\cup\mathcal{M}}}{\text{maximise}} \sum_{n\in\mathcal{N}} u_n(x_n) + \sum_{m\in\mathcal{M}} u_m(x_m) \quad \longleftarrow \text{Utility functions}$$

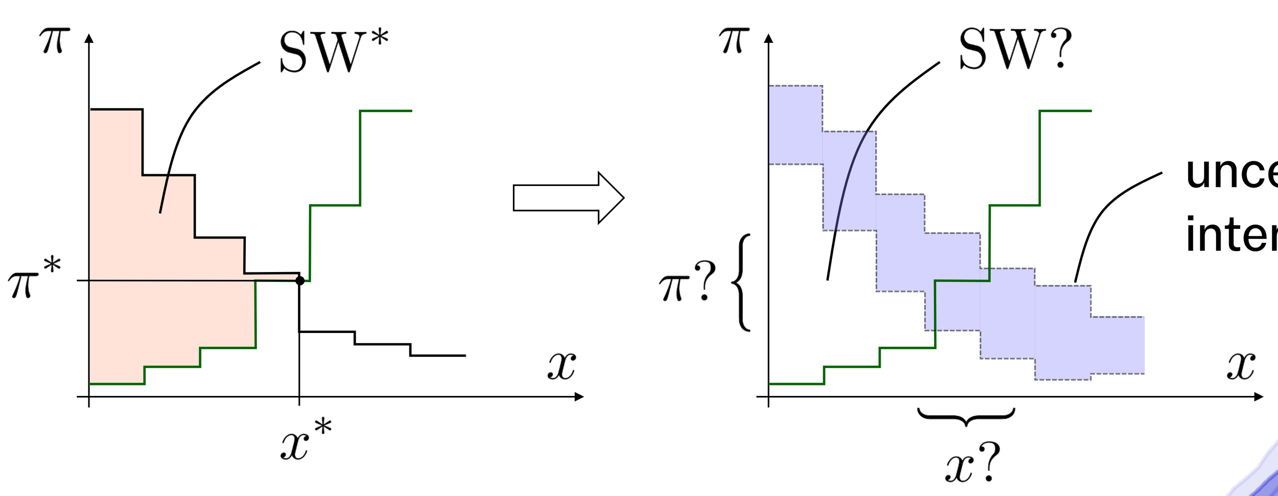
$$\text{subject to} \quad x_i \in \mathcal{X}_i \quad \forall i \in \mathcal{N}\cup\mathcal{M} \quad \longleftarrow \text{Individual constraints}$$

$$\sum_{i\in\mathcal{N}\cup\mathcal{M}} x_i = 0 \quad \longleftarrow \text{Coupling constr. (copper-plate)}$$

2. Solve **dual** problem → get prices for $\mathcal{M}$ (assuming convexity)

Market clearing (s.t. behavioural uncertainty)

Deterministic | Unknown utilities



If we **overestimate** the marginal utilities:

→ $\mathcal{M}$-agents will be charged too much!

If we **underestimate** the marginal utilities:

→ CM will incur financial loss!

In both cases: **social welfare loss**! ☹

Uncertainty quantification

Assume we have a training dataset $\mathcal{D} = \{\pi_{(i)}, X^*_{(i)}\}_{i\in[D]}$

STEP 1

Inverse Optimisation: Find the $\hat{\theta}$ that optimally fits the response X to each point in the data $\mathcal{D}$ [1].

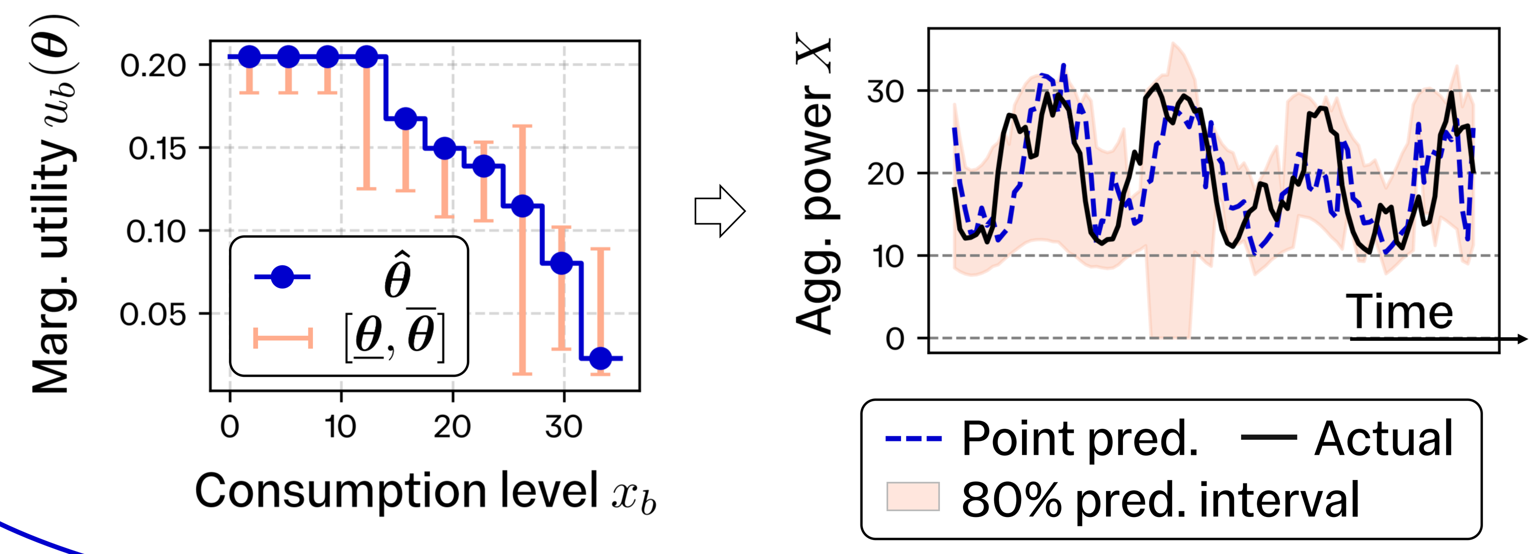
$$\underset{\{x_b\}_{b\in\mathcal{B}}}{\text{maximize}} \sum_{b\in\mathcal{B}} u_b(\boldsymbol{\theta})x_b - \pi X$$

$$\text{subject to} \quad 0 \le x_b \le \frac{\overline{X}(\boldsymbol{\theta}) - \underline{X}(\boldsymbol{\theta})}{|\mathcal{B}|}$$

$$\sum_{b\in\mathcal{B}} x_b = X$$

STEP 2

Conformal Prediction: Use validation dataset to calibrate the interval $[\underline{\boldsymbol{\theta}}, \overline{\boldsymbol{\theta}}]$ at a user-defined confidence (e.g. 80%) [2].



Robust price-setting problem

Assume **DA prices** are sent to **uncontrollable** agents the day before, while **controllable** agents are used for **real-time balancing**.

→ Solve a two-stage robust optimisation problem to find: What is ...

... the best set of DA dynamic price signals $\{\pi_t^{\text{DA}}\}_{t\in[0:24]}$ ...

... assuming the worst-case realisation of $\boldsymbol{\theta}$ ...

... for the next-day real-time market clearing?

$$\max_{\{\pi_t^{\text{DA}}\}_{t\in[0:24]}} \min_{\boldsymbol{\theta}\in[\underline{\boldsymbol{\theta}},\overline{\boldsymbol{\theta}}]} \max_{\{x_n\}_{n\in\mathcal{N}}} \text{SW}\left(\{\pi_t^{\text{DA}}\}_{t\in[0:24]}, \boldsymbol{\theta}, \{x_n\}_{n\in\mathcal{N}}\right)$$

To solve this problem, we used the **column-&-constraint generation** algorithm proposed in [3].

Energy Community Case Study:

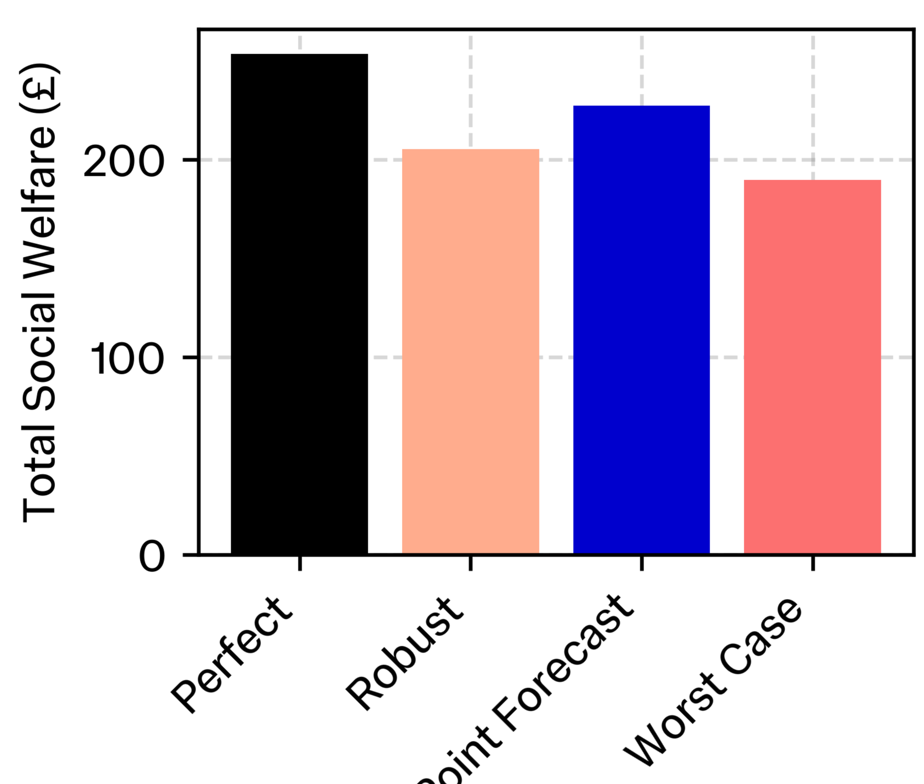
$\mathcal{N}$ = PV x25, EV x5

$\mathcal{M}$ = house x50

Single DA market clearing using different approaches:

Price of robustness
→ Robust approach is outperformed by point-forecast

Preliminary results



How to optimally operate an energy community in which only some of its participants are controllable & observable?

References

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