A Bilevel QP-PLP Approach to Demand Response Modulation between Consumers and a Single Electricity Seller

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Demand response:
What, why, when, how?

What and why?

Demand Response (DR) refers to situations where *consumers readjust their behaviors in reaction to some signals of the electricity providers.*

DR helps in many aspects including.... . .

- flexibility issues
- reliability issues
- improving profits
- sustainability issues and
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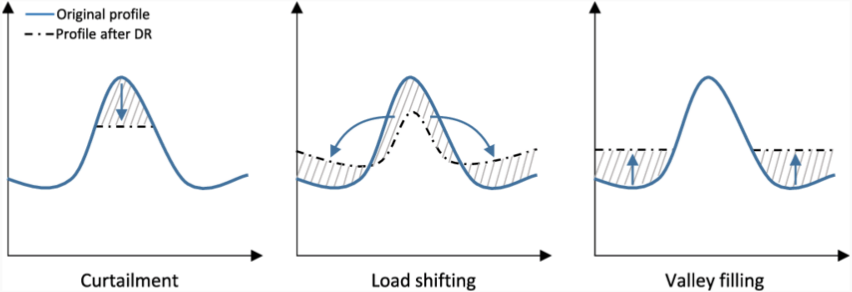
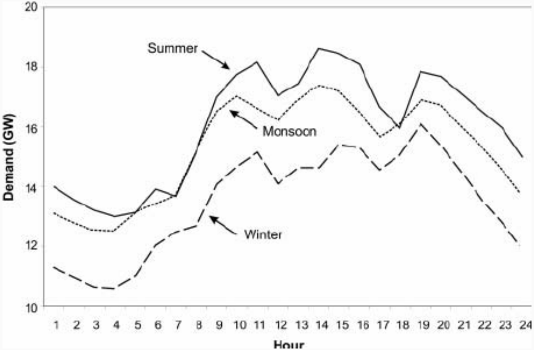

Original profile
Profile after DR
Curtailment
Load shifting
Valley filling

When?



In Thailand, the intensive use of electricity occurs during 9AM – 9PM. Hence the ideal solution could be to shift these loads to the off-peak hours.

How?

Q: How to force the consumers into the DR program ?

A: We give incentives.

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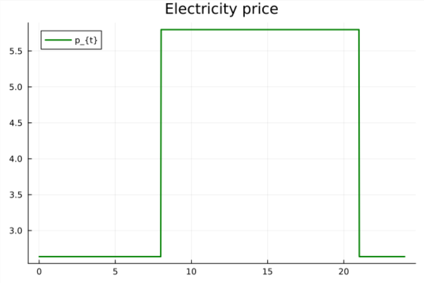

Higher on-peak prices forces the consumers to shift their loads... **HOPEFULLY!**

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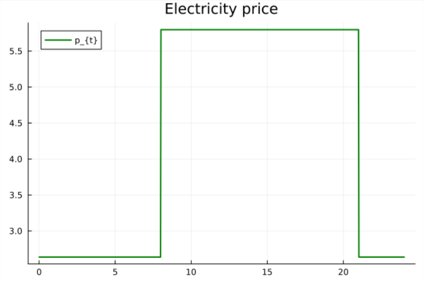

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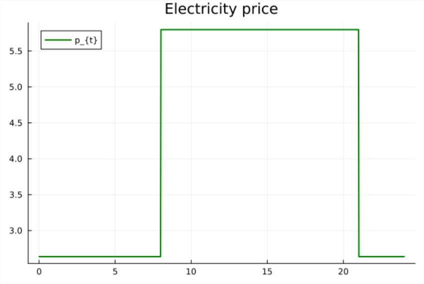

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Where do the missing demands go?

They need a new resources...

- the grid, when it is cheap,
- renewables,
  - solar panels
  - wind turbines
  - etc.
- exchange networks,
  - virtual power plant
  - storages
  - vehicles to grid
  - etc.

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Unilateral vs Bilateral Optimization

Attitude towards demand.

Q: Who are in charge of the demand?

A: The consumers. (Classical approach.)

The model: Find a strategy that maximizes their own utility.

$$\begin{aligned} \max_{c} \quad & util_p(c) \\ \text{s.t.} \quad & \text{physical constraints} \\ & \text{demand constraints} \\ & \text{storage constraints} \end{aligned}$$

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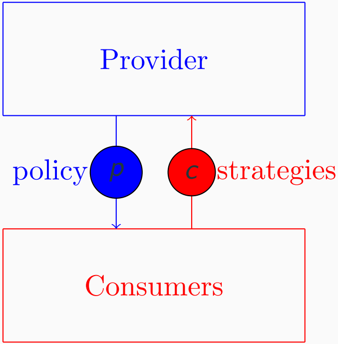

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The provider offers a policy.

The consumers response with their strategies.

The utilities of both actors were affected by both policy and strategies.

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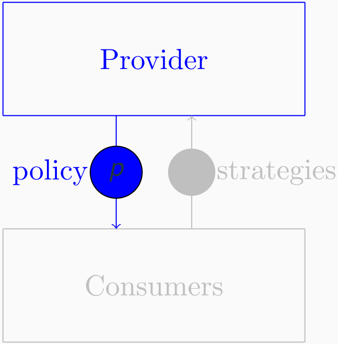

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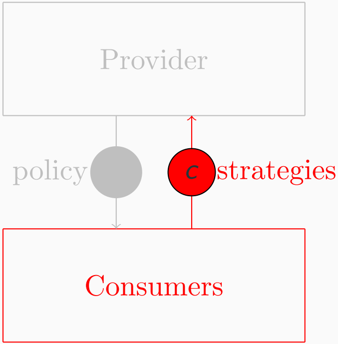

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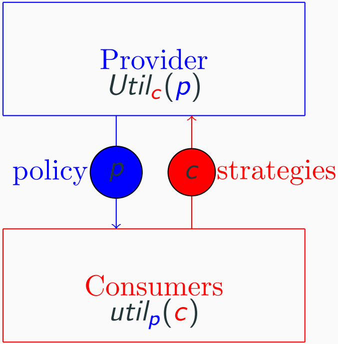

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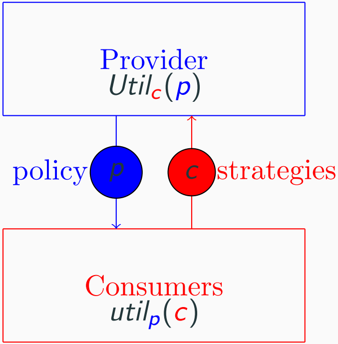

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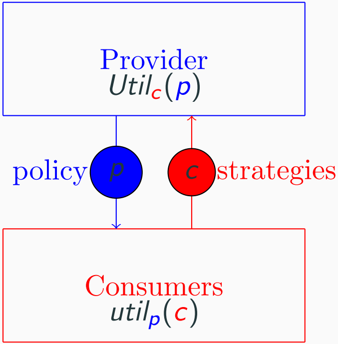

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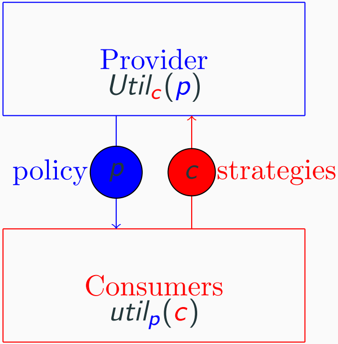

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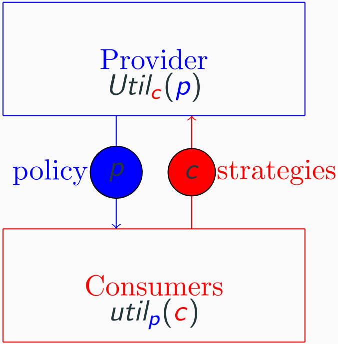

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Solution Method and Simulation

Solution method: Please bring your multipliers

The formulation of S_p is actually a linear program of strategy c, parametrized by the policy p.

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“QPCC” Nonconvex

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Treating QPCC

The parts in CC of the form

$$0 \leq F(u) \perp G(u) \geq 0$$

usually causes the constraint set to be nonconvexity and even nonconnected.

Here, we **branch** on the perpendicularity instead of having them as equality constraints.

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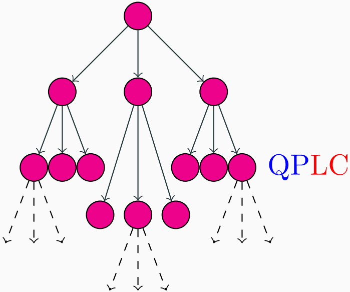
Maximization on a tree

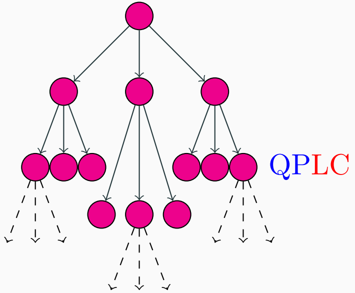


QPCC then reduces to a maximization on a tree,
where each node...

- represents a case in the perpendicularity, and
- is a QPLC

This is **solvable** with the **fast pruning algorithm** of `Gurobi`.

Maximization on a tree



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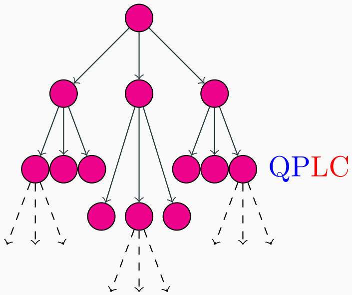

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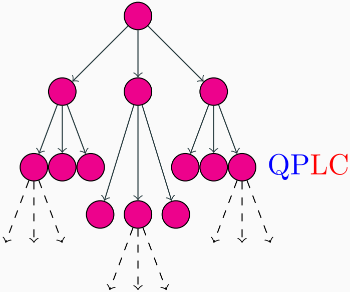

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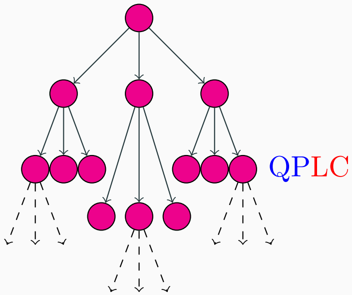

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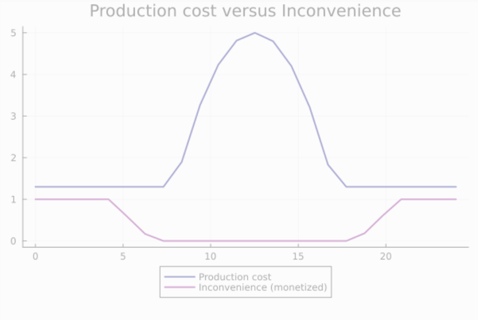

L: Cost and monetized inconvenience. R: Solar availability.

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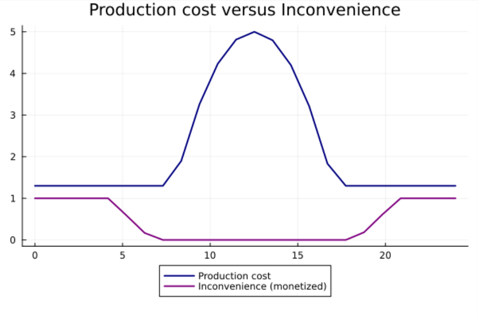

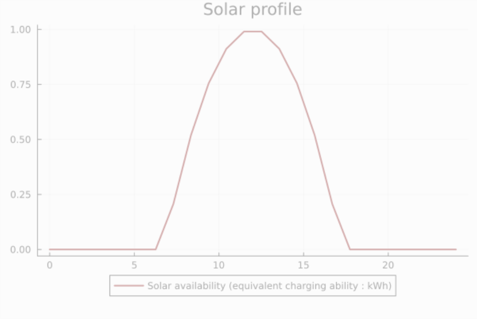

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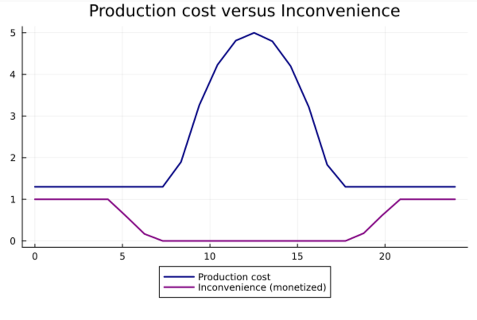

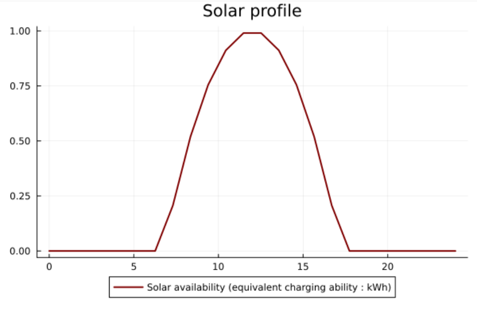

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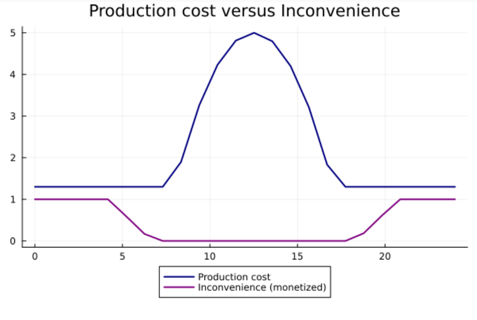

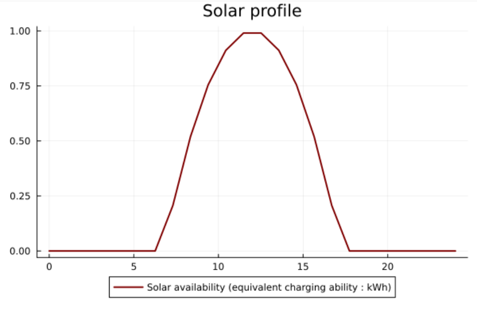

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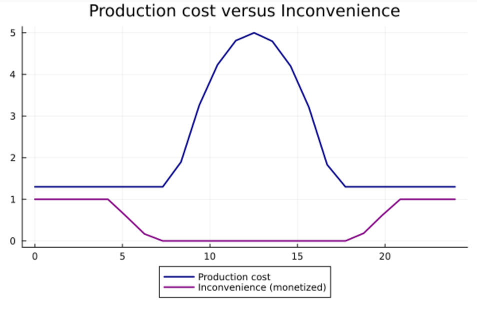
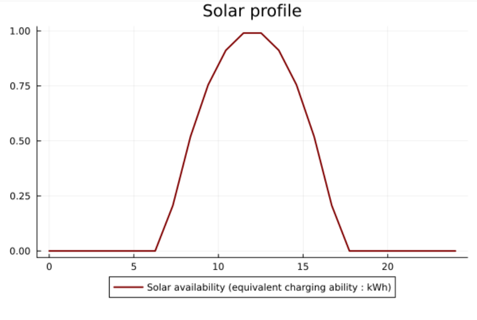
We implement our model on a tree using `Gurobi` through the `JuMP` package of `Julia`.

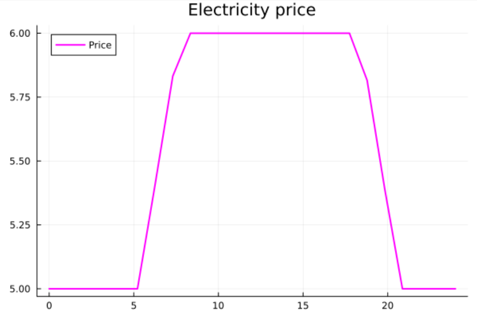


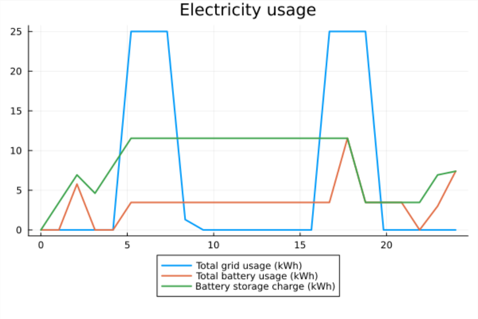


L: Cost and monetized inconvenience.

R: Solar availability.

Simulation results

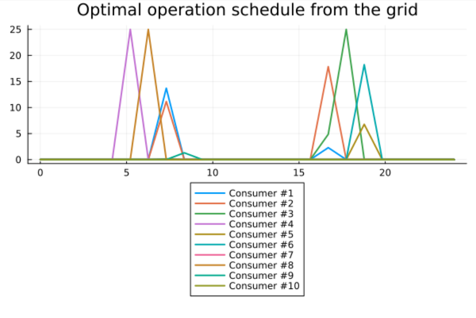


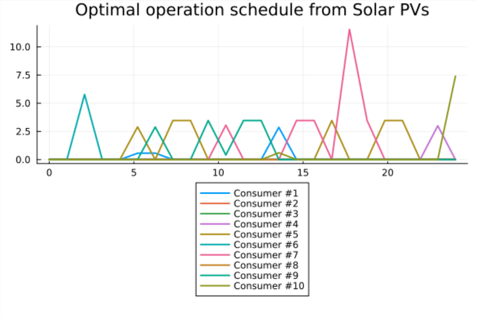


L: Optimal policy.

R: Optimal overall consumption.

Simulation results





L: Optimal grid consumption.

R: Optimal PV consumption.

Some remarks

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Here we list some important remarks:

- Stochasticity is not considered in the simulations, **but this can be easily implemented under chance constraints framework and** $\mathcal{N}(\mu, \sigma^2)$.
- The price upper bound $\bar{p}$ cannot be left off due to our demand constraints. **This is economical because the provider can raise the price as high as she wishes.**
  - △ A remedy: **Introduce competition — Start an electricity market!**

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Thank you for being here. ;)