Transitions Pathways and Risk Analysis for Climate Change Mitigation and Adaptation Strategies

Empowering consumers to produce and store clean energy at the local level: Transition pathways for a low-carbon power system in Greece

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INTRODUCTION

Recent analysis on the **EU Member States** spot markets has shown that with **demand-flexibility**:

- **Consumers** enjoy **significant** consumption (and financial) **savings**

- **Generators** are burdened with **loss** of income due less energy sales

Consequence: For vertically integrated entities that combine both generation & retailing operations under one corporate roof, the financial results are fundamentally negative.

Research Question

How can **Self-Consumption** & **Demand-Flexibility** be brought into the Greek **power market?**

I. Which **policies** can drive a **transition pathway** for a power system that is based on the **notion** of consumers **generating**, **storing** and **consuming** clean energy **locally**?

II. How could potential **costs-benefits** be **fairly distributed** to both **consumers** and power **market actors**?

Our Rationale (1/3)

Developing new **Business Models (BMs)** that **incentivize** all involved **actors** to incorporate **demand-side flexibility** into the **markets** that can valorize it

Change in **distribution** of electricity demand

Re-shaping the electricity system

Our Rationale (2/3)

STARTING POINT

No significant changes in:

- the **current** regulatory framework,
- the **current** operation of the power market.

Incorporation of Demand-Response signals into the **retailing operations** of the **utilities**

✓ Extra tool for the retailers' trades in the day-ahead, intra-day and real-time (where they exist) markets,

✓ Minimization of costs during short-term electricity procurement.

Our Rationale (3/3)

However…

Demand-Response (DR) by itself is **unlikely** to incentivize consumers to **invest** in new technological capabilities:

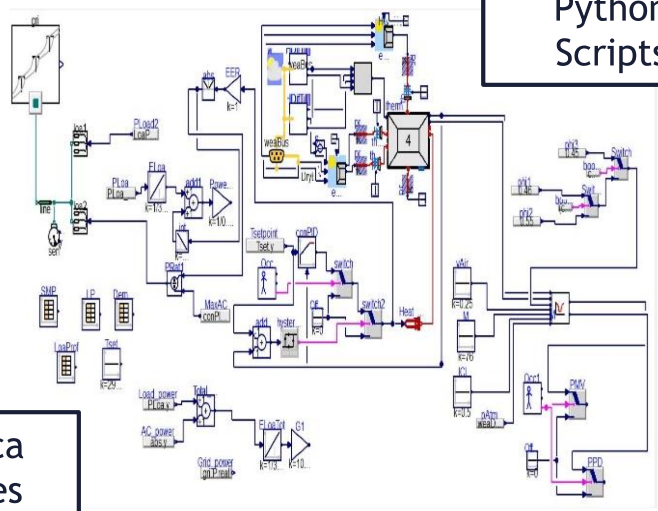
The public is expected to adopt according to a value stemming from increased consumption of electricity generated onsite from renewable resources.

When **self-consumption** is **economically** rational, consumers may **invest** in technologies that **increase** their **demand flexibility** to increase the **proportion** of the **self-produced** electricity they consume.

Application (1/3)

Dymola 2018 FD01

Python Scripts



Modelica Libraries

DREEM
Dynamic Demand-Response Simulation Model

Dynamic simulation between:

- Building envelope properties
- Indoor environment,
- HVAC control systems,
- Thermal comfort,
- Renewable self-consumption,
- Price signals.

Novelty

- Combining **electricity storage** with **smart thermostat** capabilities (so far only used for increasing energy efficiency in buildings),
- **Control algorithms** to maximize the benefits from self-consumption & DR.

APPLICATION (2/3)

Increasing the **value** of **flexibility** through provision of **services to the grid**

- **Maintaining thermal comfort** → **BAU Scenario**
- **PV self-consumption with Storage** → ***What If*** **Scenario #1**
- **PV self-consumption with Storage + Demand-Response in retailing operations** → ***What If*** **Scenario #2**

Application (3/3)

Increasing the **value** of **flexibility** through provision of **services to the grid**

BAU Scenario

***What If* Scenario #1**

***What If* Scenario #2**

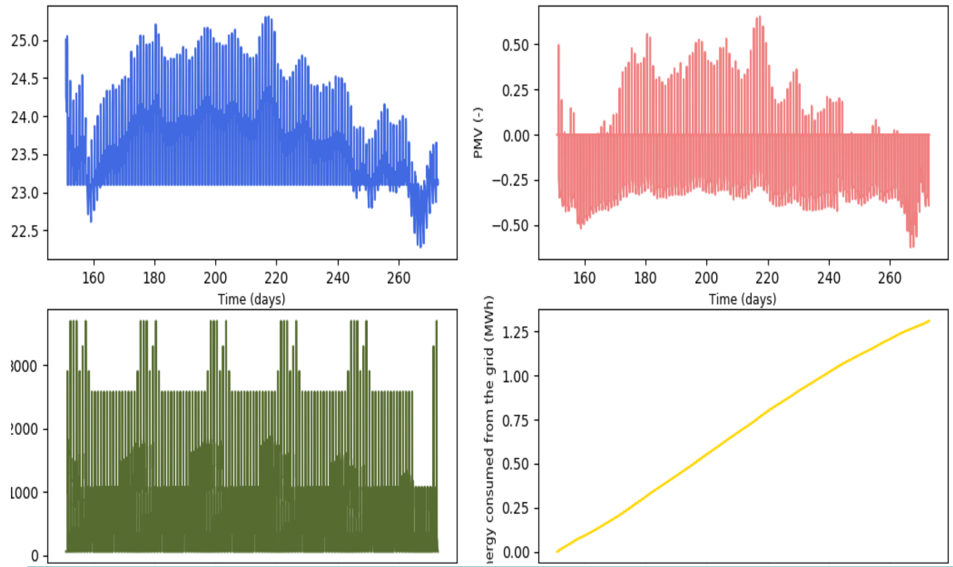
DREEM
Dynamic Demand-Response Simulation Model

PV, Storage, Smart-grid devices with Automation Control Systems

Exploring **self-consumption** & **DR** scenarios preserving **energy services** & **thermal comfort** of consumers

Evaluation of **benefits** for **consumers** & **utilities**

BAU Scenario

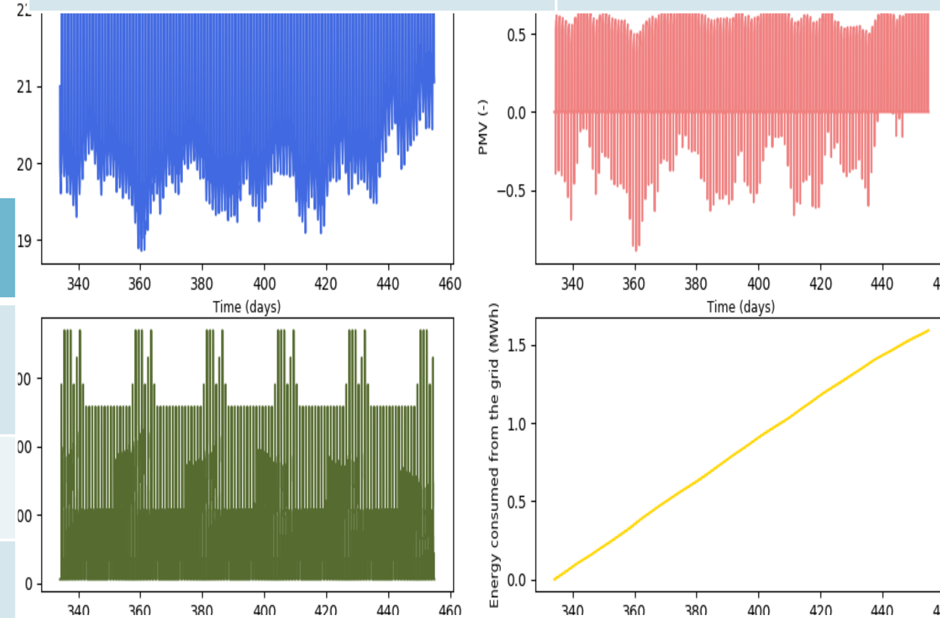


Period 1 (June – September)

Electricity absorbed from the grid	1.30 MWh
Charges	€123.97
Thermal comfort	Acceptable levels

Period 2 (December – March)

Electricity absorbed from the grid	1.60 MWh
Charges	€150.67
Thermal comfort	Acceptable levels



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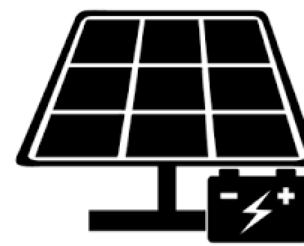
What If Scenario #1 (1/3)

"What if"…

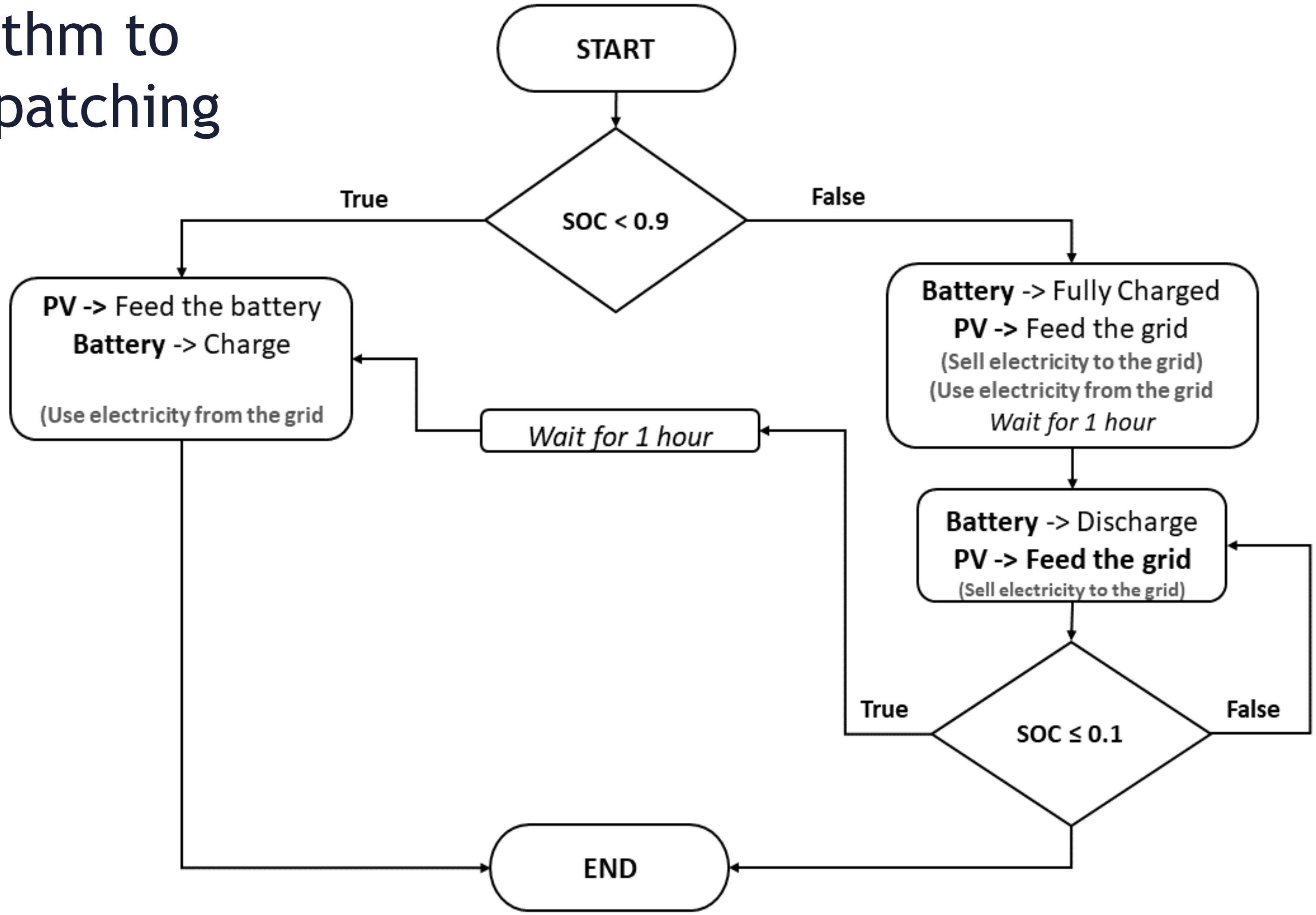
…we allow PV Self-Consumption with storage to be regulated in Greece?



Subsidizing solar PV & battery

What If Scenario #1 (2/3)

Heuristic algorithm to **control** the dispatching of the battery



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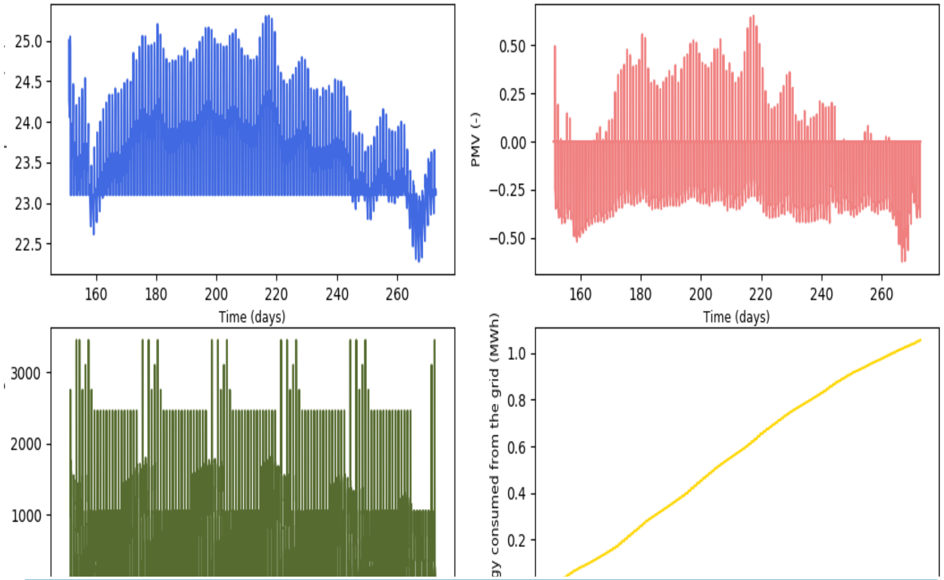
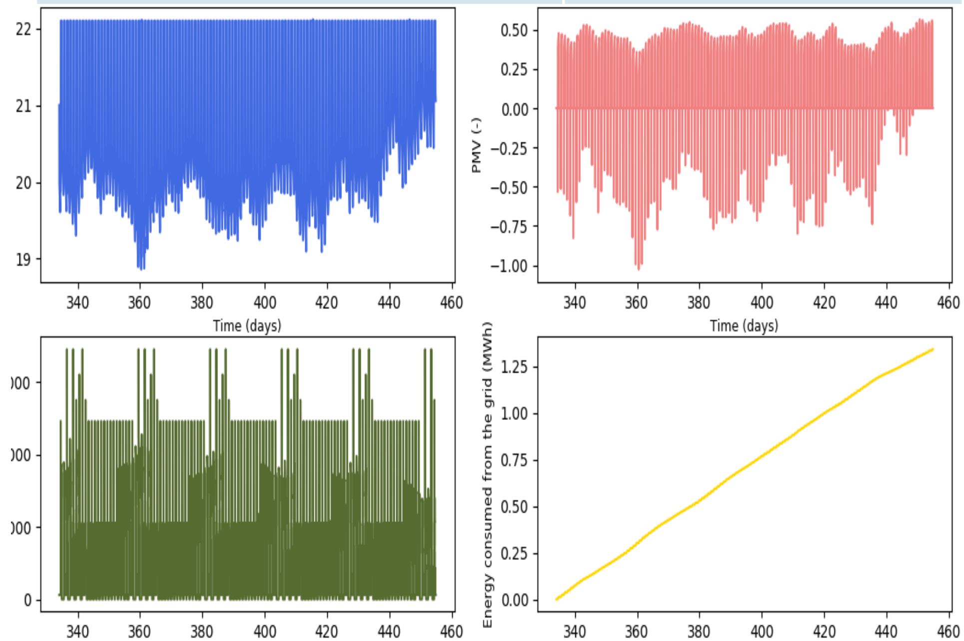
What If Scenario #1 (3/3)



Period 1 (June – September)	
Electricity absorbed from the grid	1.04 MWh (-20%)
Charges	€106.62 (-14%)
Thermal comfort	Acceptable levels

Period 2 (December – March)	
Electricity absorbed from the grid	1.34 MWh (-17%)
Charges	€137.38 (-9%)
Thermal comfort	Acceptable levels



What If Scenario #2 (1/6)

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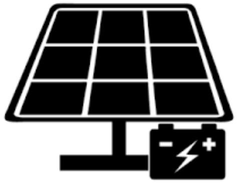
"What if"…

…we allow PV Self-Consumption with storage & Demand-Response to be regulated in Greece?



- **Subsidizing** solar PV & battery
- **Price signals** through the retailing operations of the utilities

WHAT IF SCENARIO #2 (2/6)

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We assume a central planner / utility – that operates as retailer

The planner solves a learning problem: ….to find the DR signals that maximize its benefit.

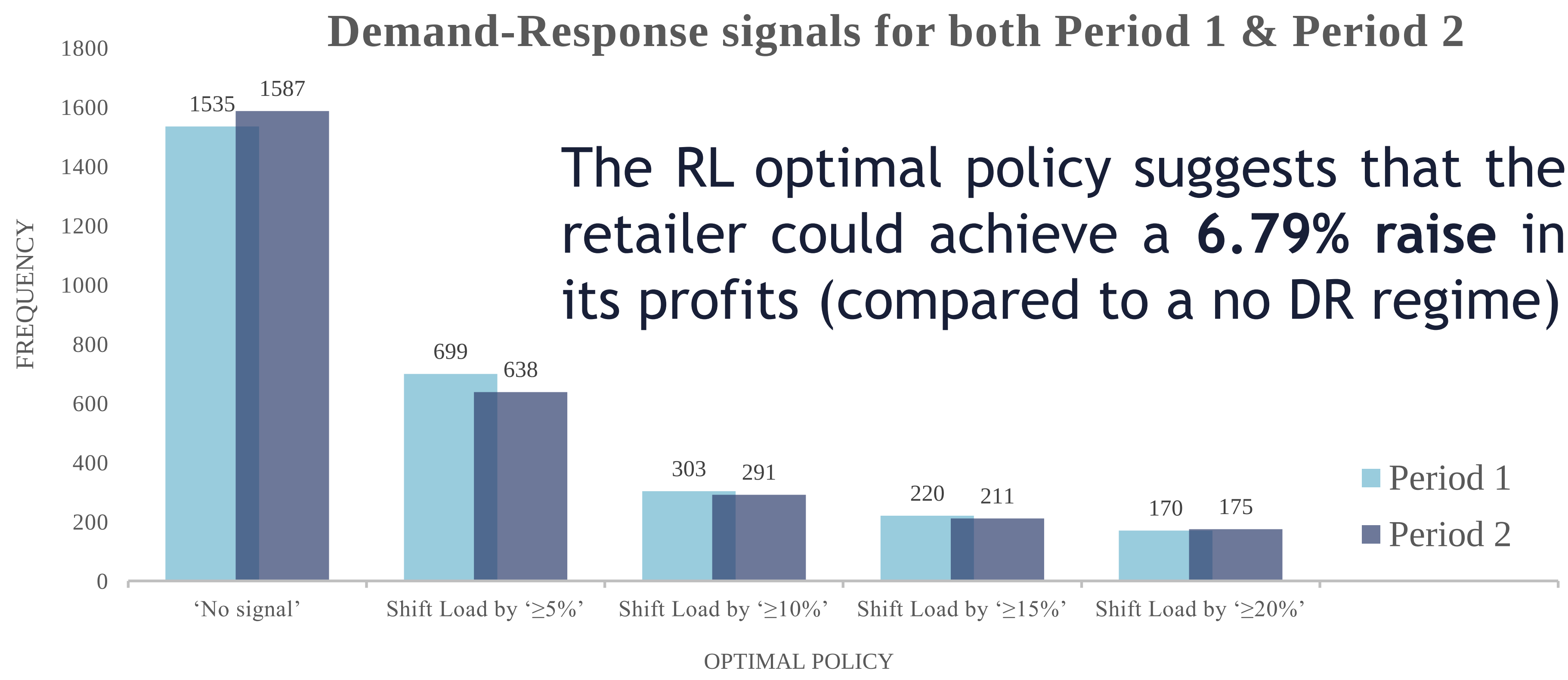
Limitation: the response of the consumers to its DR signals are not (a priori) known

Python Implementation

To solve this problem, we employ **Reinforcement Learning (RL)** in order to "teach" the retailer the optimal policy to maximize its revenues.

WHAT IF SCENARIO #2 (3/6)

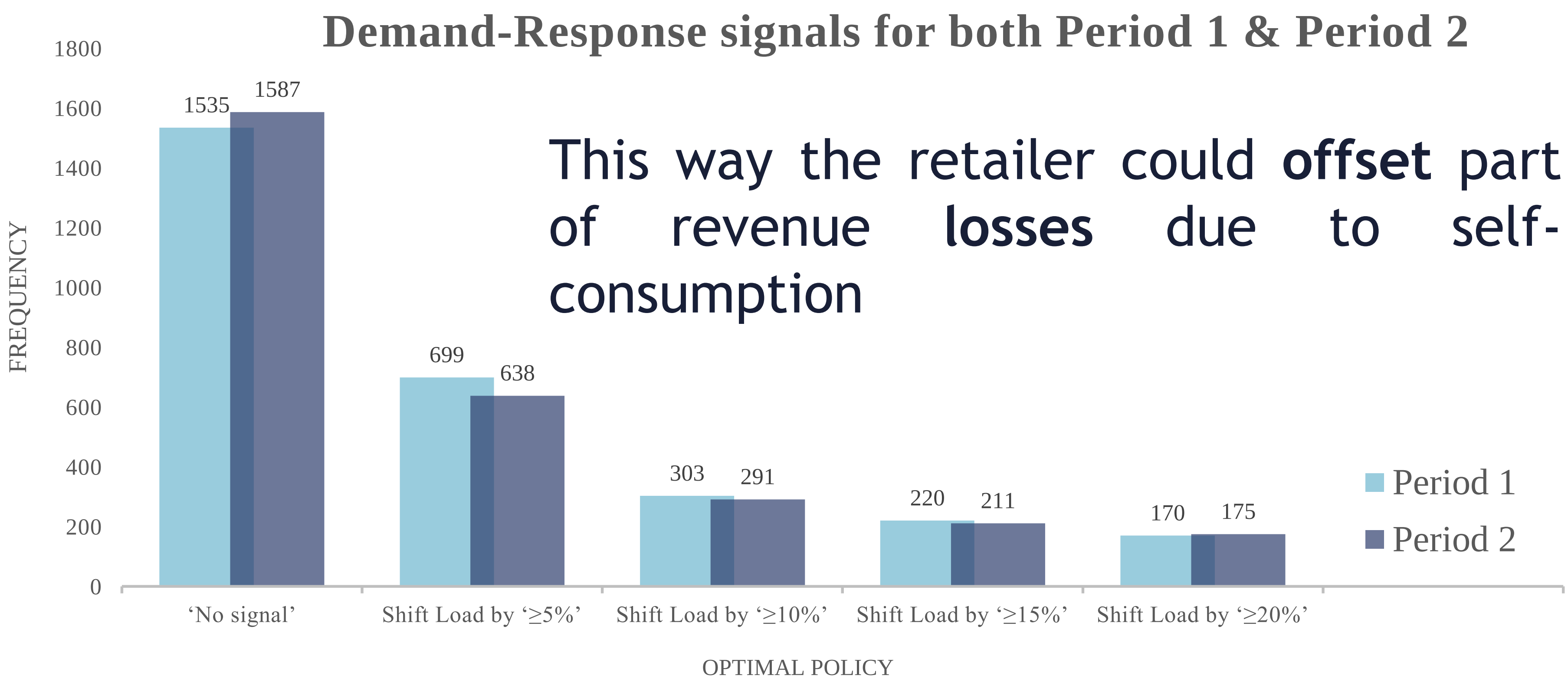
Frequency of Demand-Response signals according to the RL optimal policy and based on **historical data** of **2015**.



The RL optimal policy suggests that the retailer could achieve a **6.79% raise** in its profits (compared to a no DR regime)

What If Scenario #2 (4/6)

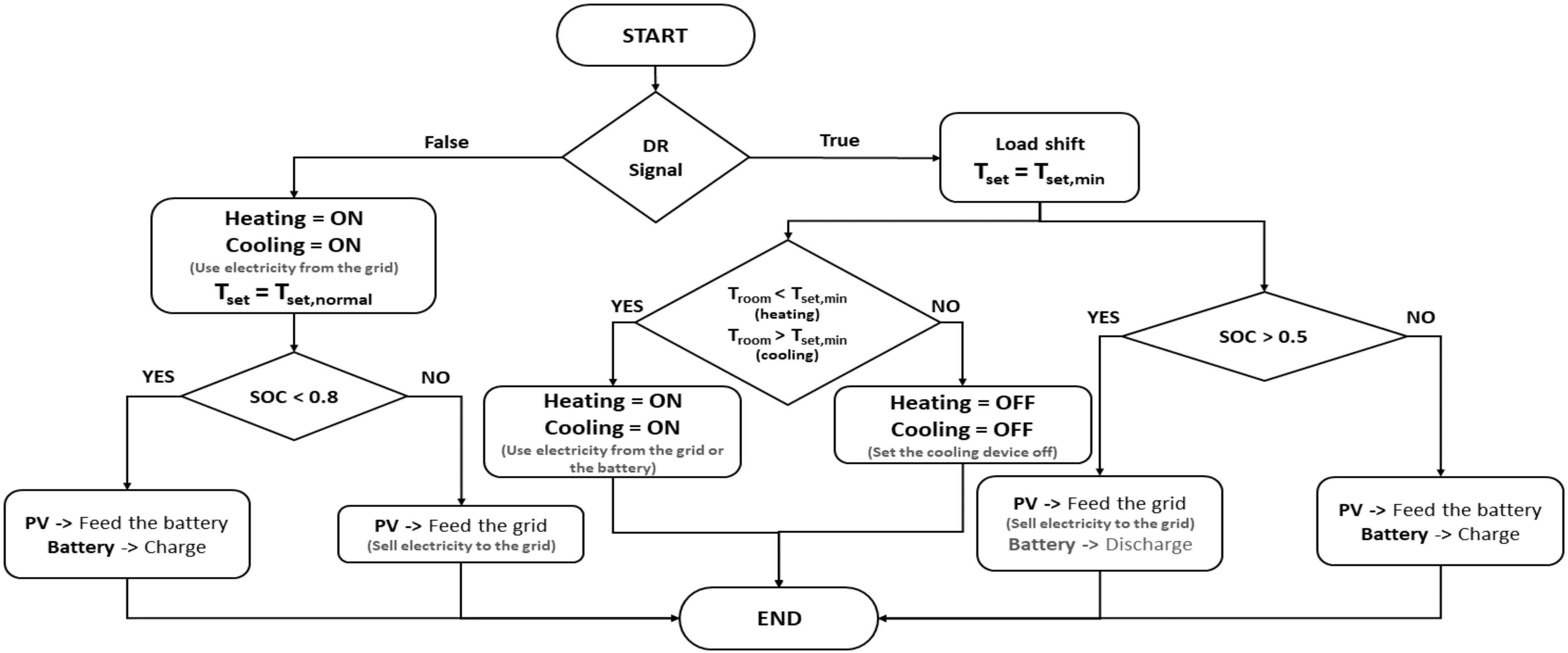
Frequency of Demand-Response signals according to the RL optimal policy and based on **historical data** of **2015**.



This way the retailer could **offset** part of revenue **losses** due to self-consumption

WHAT IF SCENARIO #2 (5/6)

Heuristic **DR** algorithm to **control** the dispatching of the battery & the compliance of the consumers to the signals



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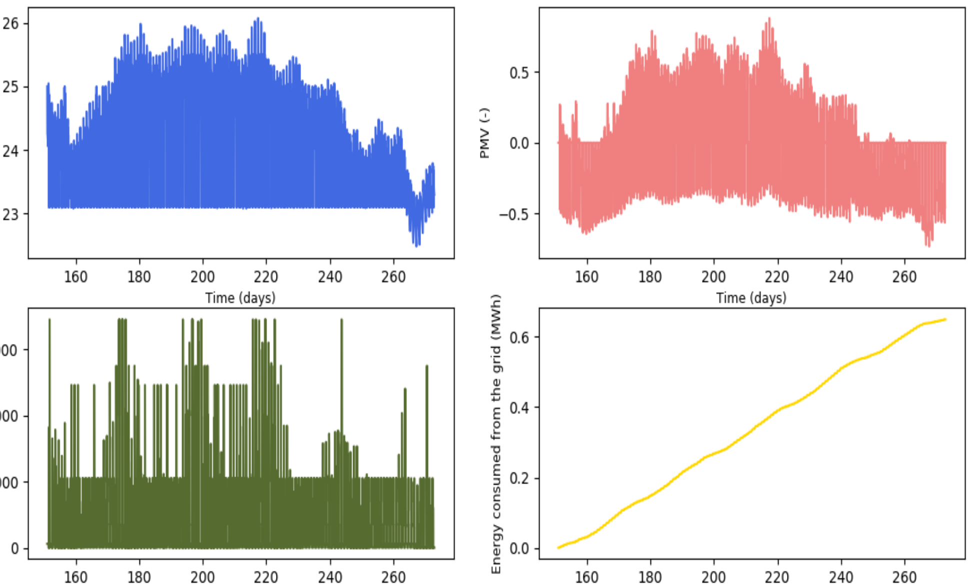
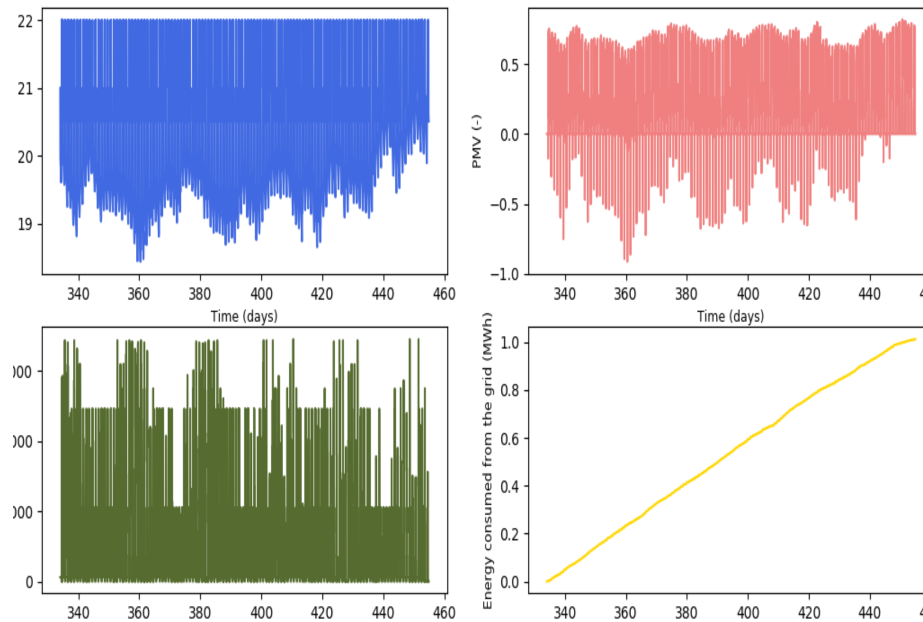
What If Scenario #2 (6/6)



Period 1 (June – September)	
Electricity absorbed from the grid	0.70 MWh **(-45%)**
Charges	€66.64 **(-42%)**
Thermal comfort	**Acceptable levels**

Period 2 (December – March)	
Electricity absorbed from the grid	1.00 MWh **(-35%)**
Charges	€103.34 **(-30%)**
Thermal comfort	**Acceptable levels**



Key Messages (1/4)

- As expected the **benefits** of Self-Consumption & Demand-Response for **consumers** come from:
  - ✓ **less** electricity absorbed from the **grid**,
  - ✓ optimal **control strategies** to benefit from self-consumption & price signals,

- As, also, acknowledged by similar studies in the scientific literature:
  - ✓ The revenues of utilities decrease due to **energy savings**.

KEY MESSAGES (2/4)

However:

- Through Demand-Response & price signals the utilities could **offset part** of their losses,

- Through the promotion of energy saving technologies they will **avoid** the costs of **penalties** (i.e. non-compliance with the recently introduced Energy Efficiency Obligation schemes - EEOs).

New and more **sustainable** BMs will arise for the utilities

Key Messages (3/4)

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- ✓ Flexibility to increase self-consumption can be brought to the market **without** a need:
  - I. for significant **changes** in the **current market design**,
  - II. for consumers to **sacrifice** thermal **comfort** and energy **services**,
- ✓ The value of flexibility enablers (i.e. small-scale PV, smart thermostats, controllers, etc.) is increased
- ✓ Counterbalance the phase out of FiTs → new incentives for investing in small-scale PV.

Key Messages (4/4)

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Although the shift to a DR regime seems logical:

- it is not inevitable in terms of consumer behavior,
- it is a **game-changer**, as the implementation of **new BMs** in the electricity market captures new value on the supply side by coupling it to the demand side,
- it should be evaluated together with the fact that it helps **decrease** the **frequency** and **magnitude** of <u>peak generation events</u> that stress the distribution network.

For more information…

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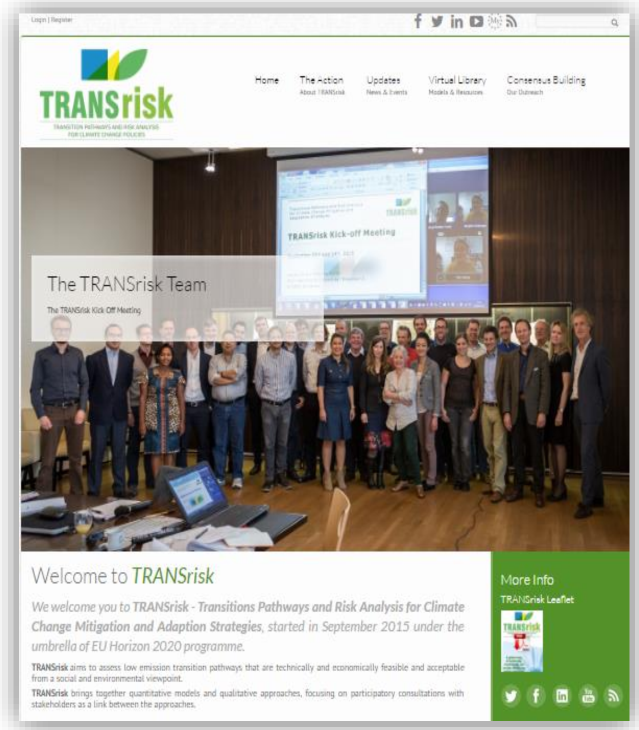
The presented work has been implemented in the context of the D6.4 **“Identifying Innovation Policy Options in Transition Pathways”** of the Horizon 2020 EC funded project **TRANSrisk**



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For more information…

TEESLab, the energy modelling, strategy and policy analysis laboratory of **University of Piraeus** (UNIPI).

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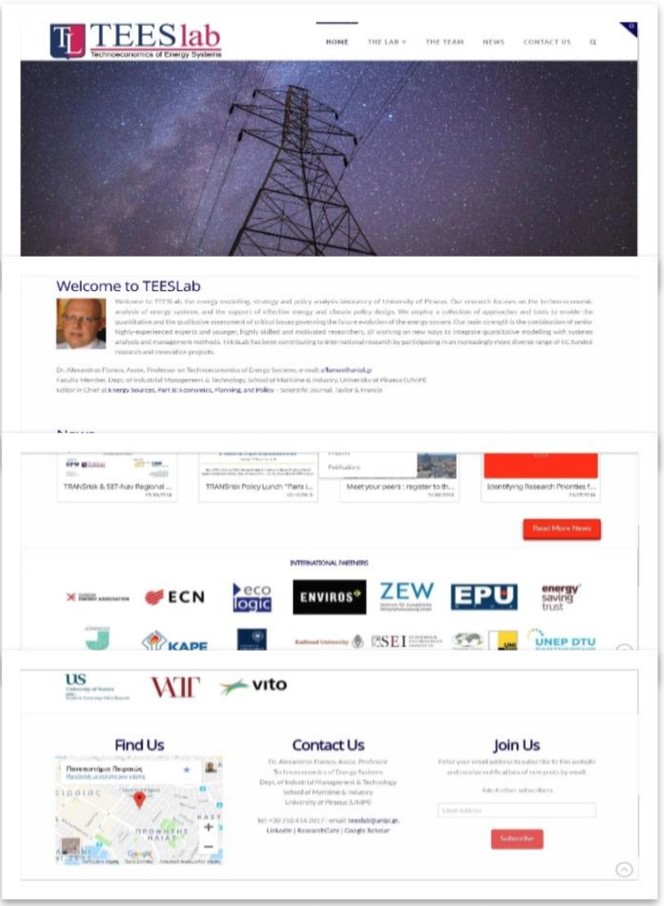

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Thank you !