Smart Microgrid with Electric Vehicles

Modelling and Simulating Social Systems with MATLAB

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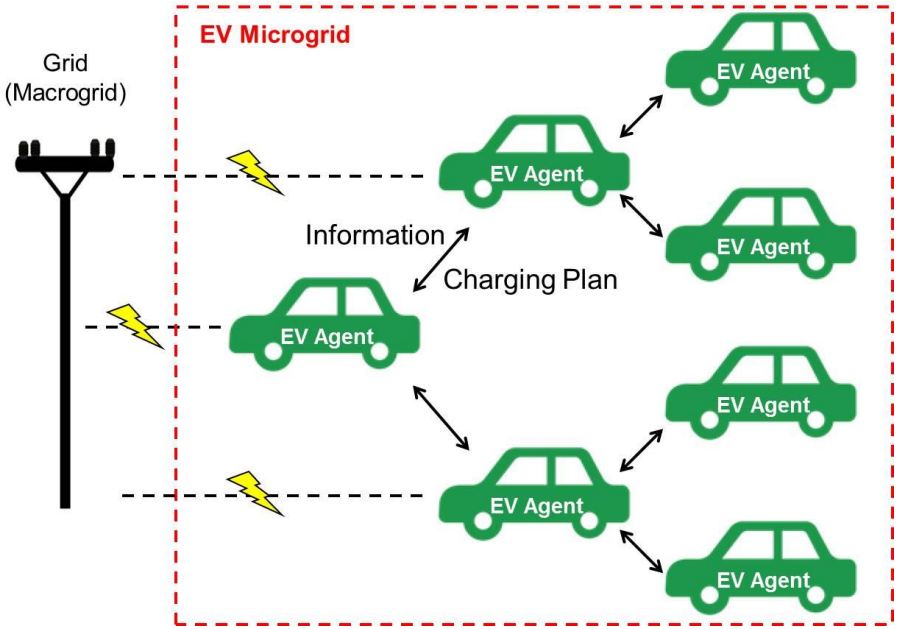
PRESENTATION OVERVIEW

1. Model



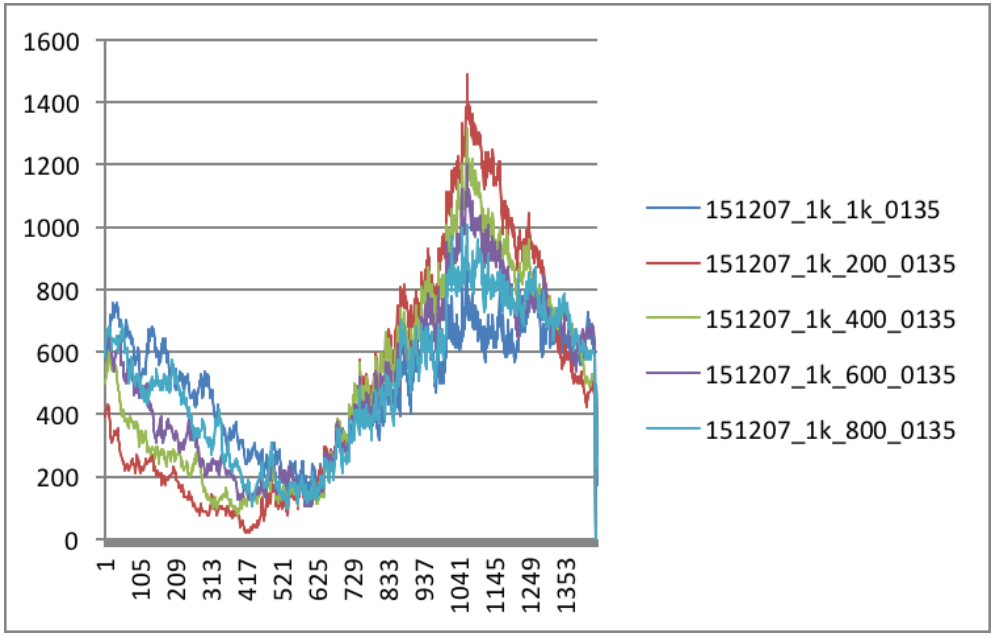
2. Implementation

- Driving Profile
- SOC

MATLAB

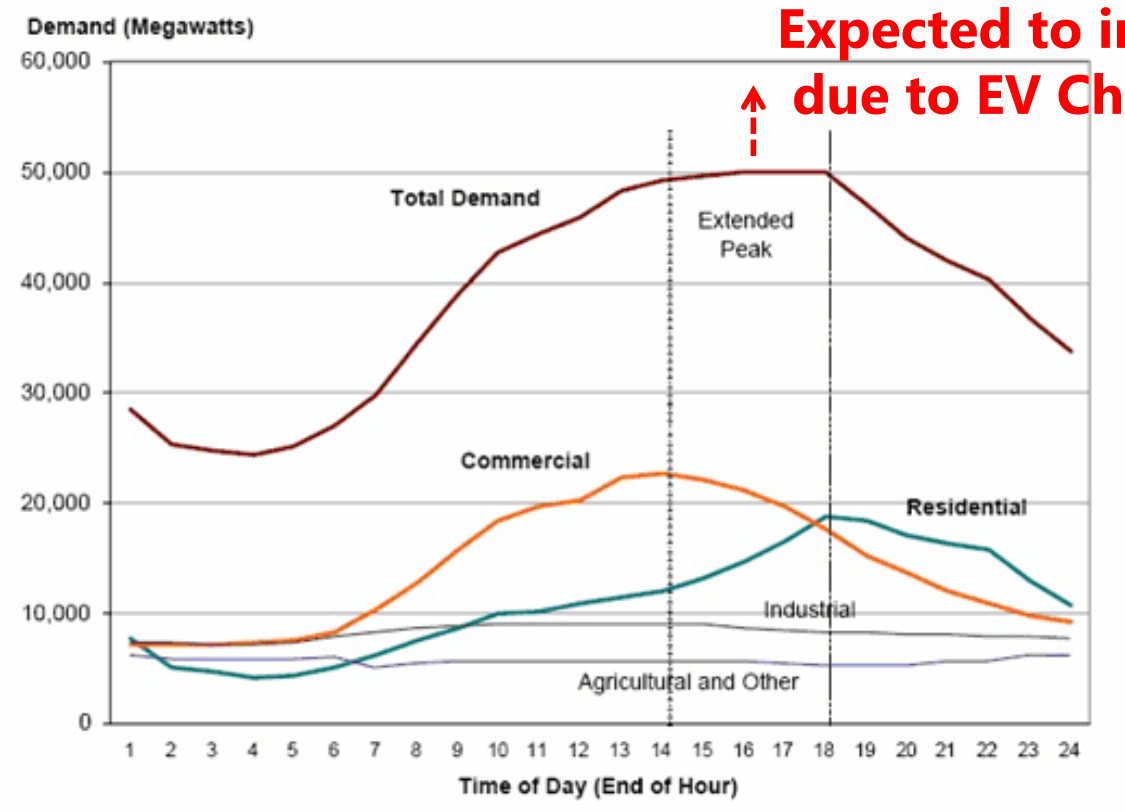
- Power
- Cost

3. Results and Discussion



- Improved Grid Robustness
- Reduced Cost

INTRODUCTION



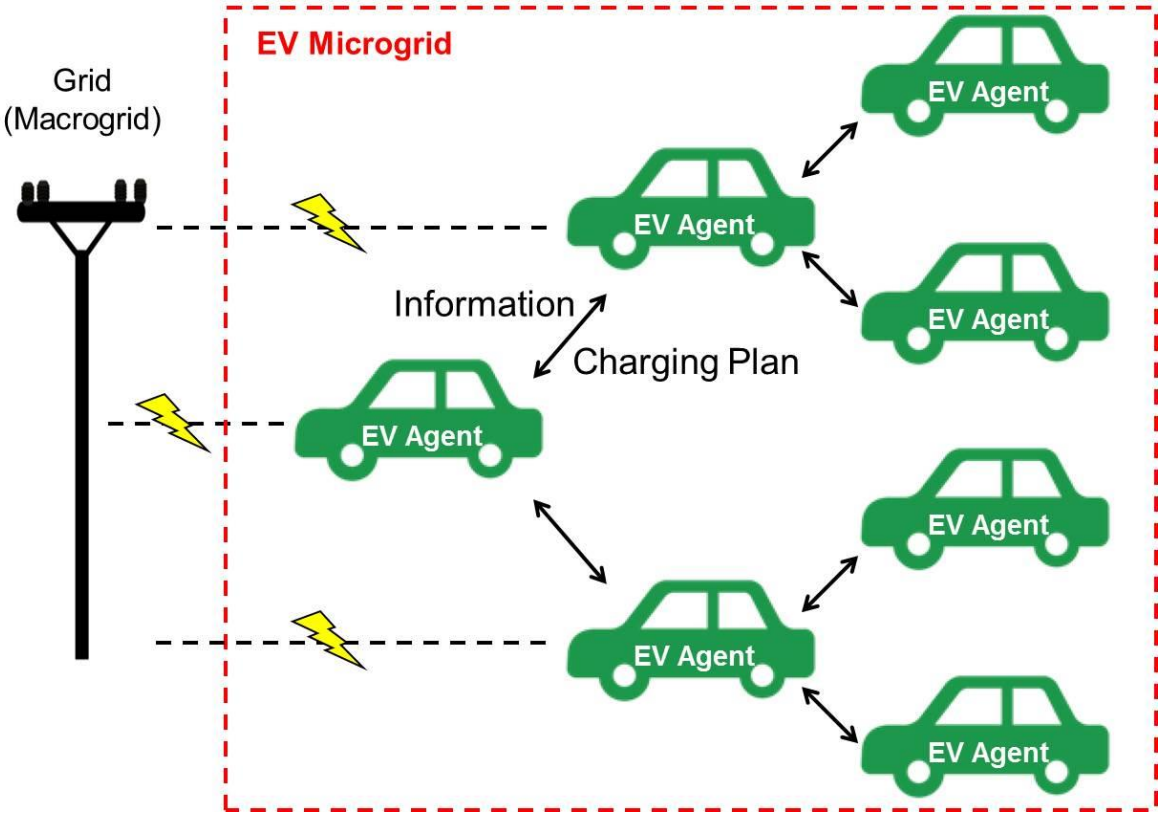
Solutions

- Increasing generation

-> Underutilization of Facilities

- Managing demand effectively

MODEL



EV Agent Model

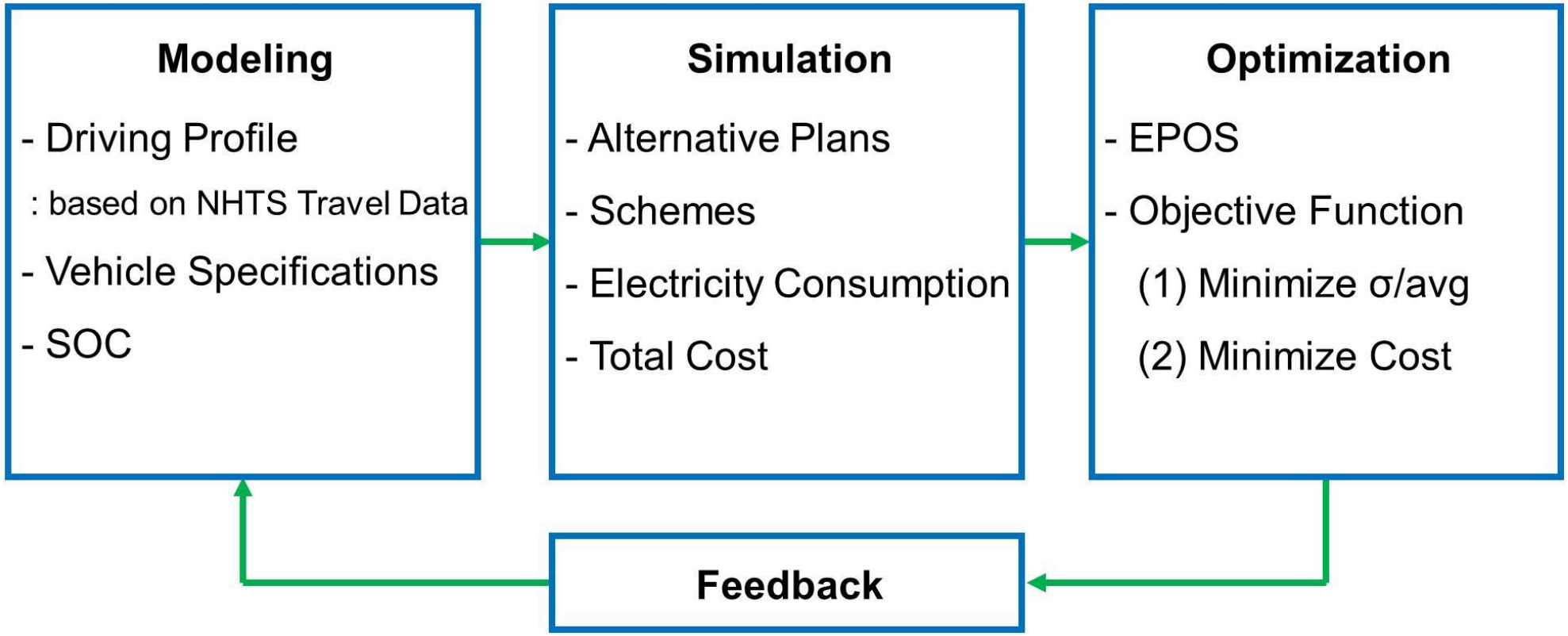
Every EV receives a charging plan from ***EV agent***

Our interests
: **alleviating peak load** by shifting power consumption of some EVs (improving grid robustness)
: **reducing cost** of charging

Assumptions

- EVs only charge at home
- EVs start charging immediately
- All vehicles are Tesla Model S (2015 85D)
- Our analysis is based on electricity pricing and driving profile in Texas

IMPLEMENTATION



IMPLEMENTATION

Modeling

- Driving Profile
  : based on NHTS Travel Data
- Vehicle Specifications
- SOC

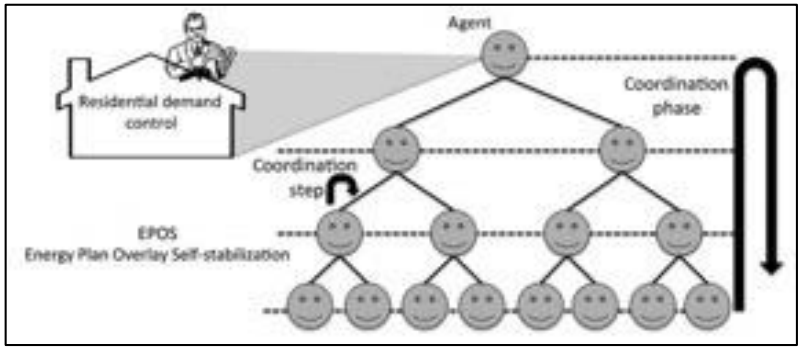
Simulation

- Alternative Plans
- Schemes
- Electricity Consumption
- Total Cost

Optimization

- EPOS
- Objective Function
  (1) Minimize σ/avg
  (2) Minimize Cost

Feedback



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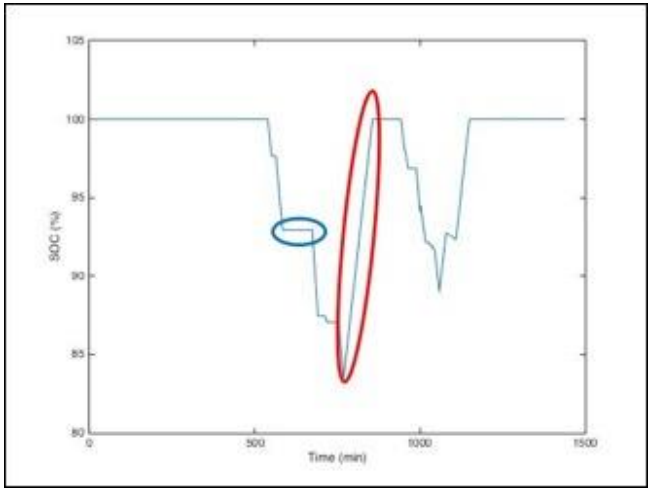
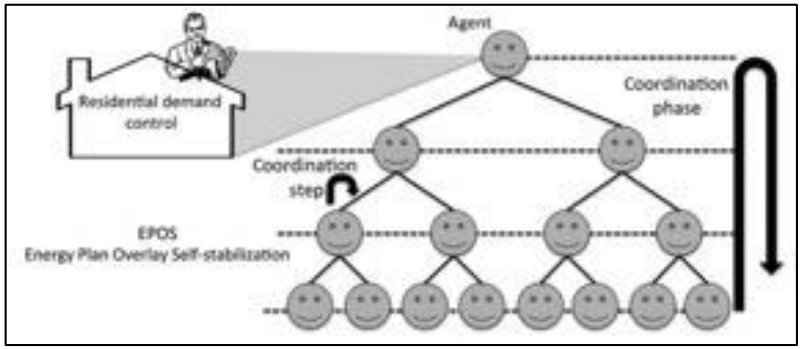
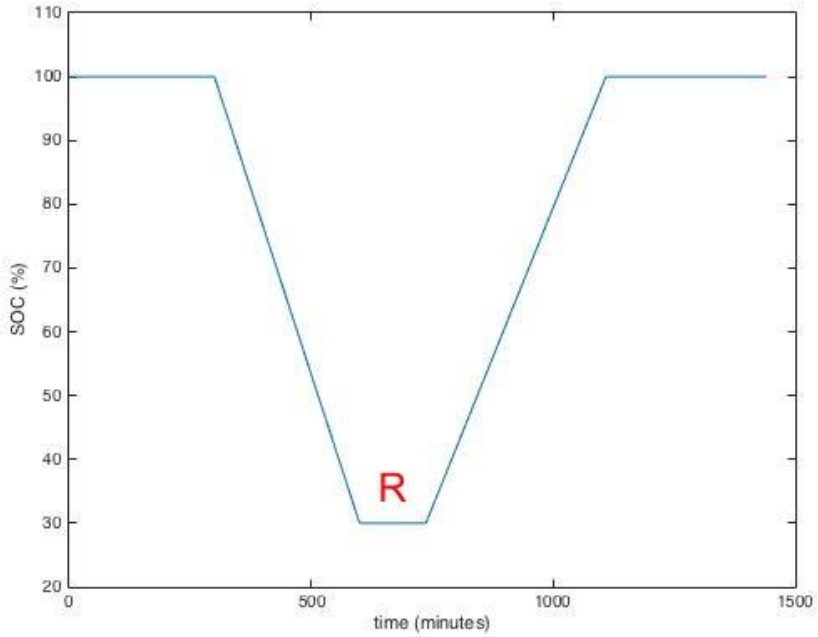
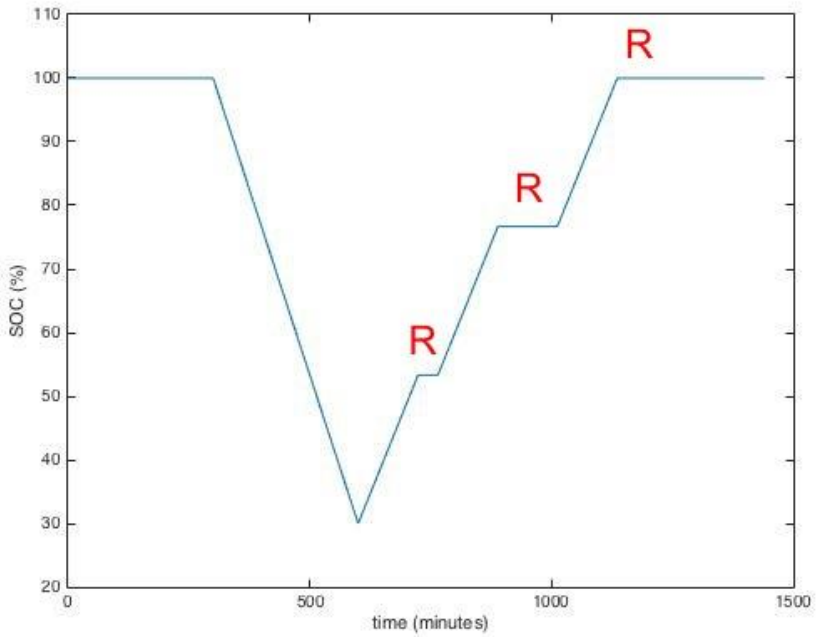




Alternative Plans





	Start	Number of Steps
Original Plan	Immediate	1
Alternative Plan 1	Random	1
Alternative Plan 2	Immediate	2
Alternative Plan 3	Random	2
Alternative Plan 4	Immediate	3
Alternative Plan 5	Random	3

RESULTS: PRELIMINARY EXPERIMENT

Original

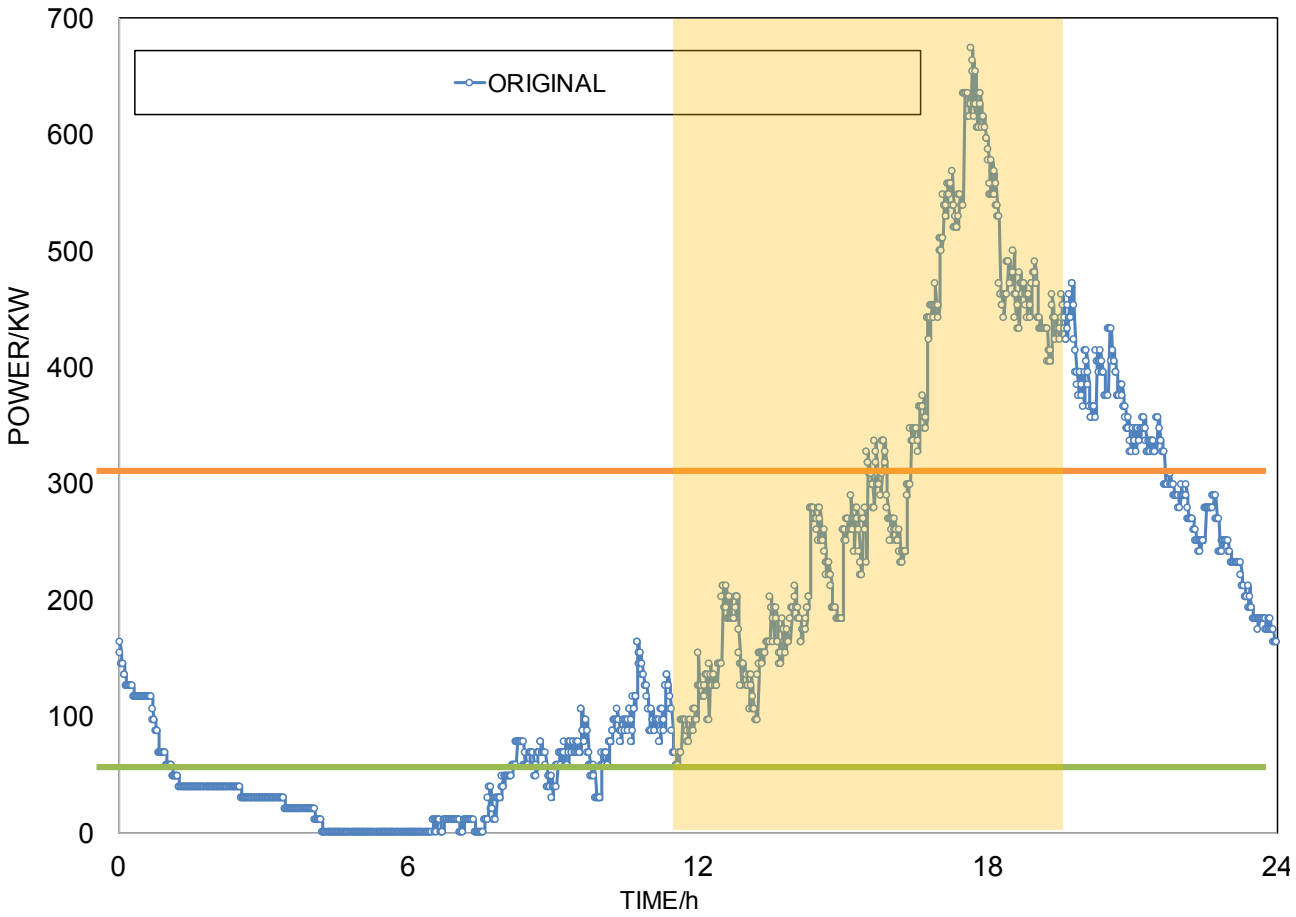
- **Peak - Valley**

-> Robustness of the grid

- **Off-Peak Pricing**

-> Cost for the customers

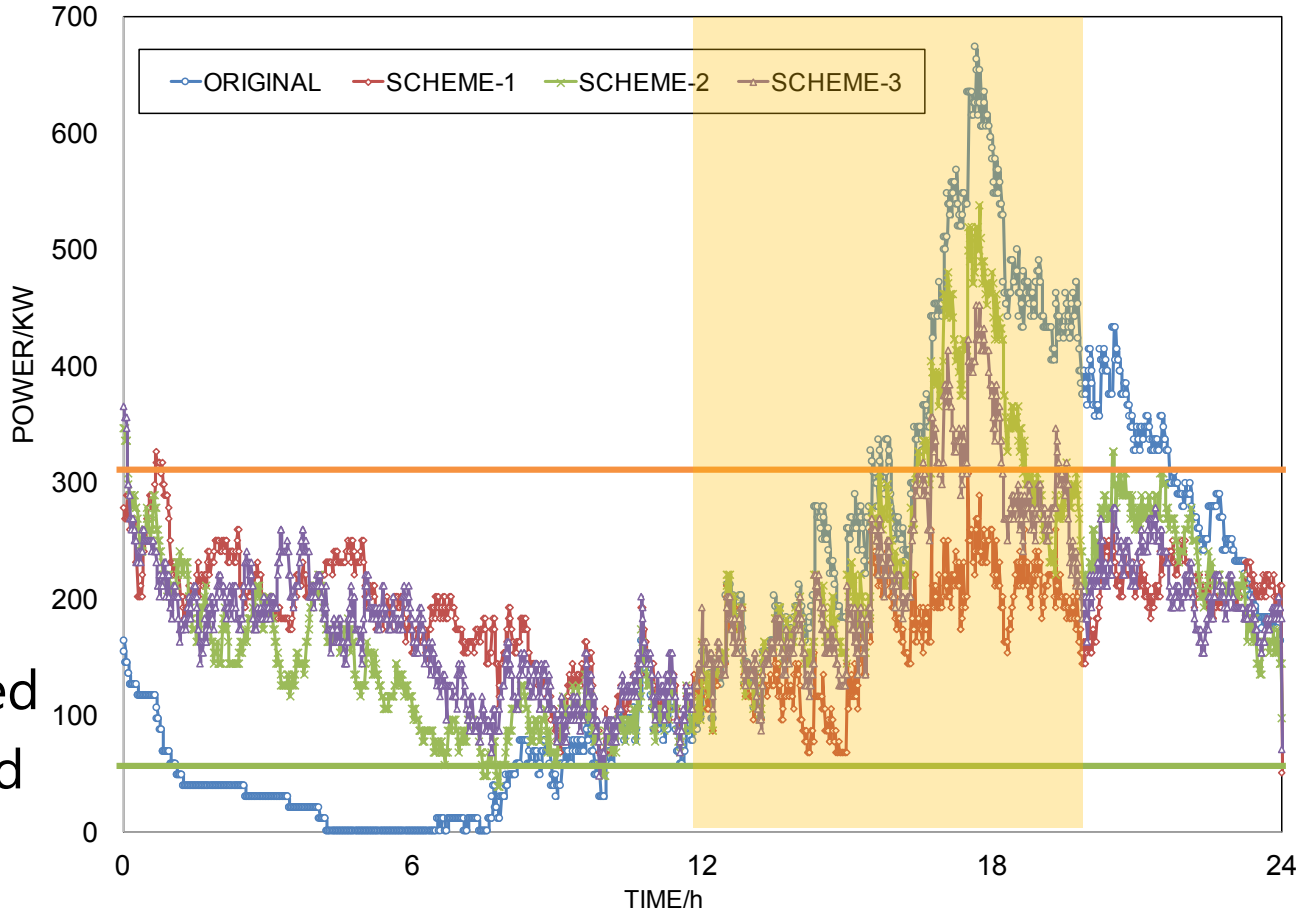
- **Diurnal Driving**



RESULTS: PRELIMINARY EXPERIMENT

Results

- Optimization for Robustness
- Scheme 1 (0,1,1,1)
  : AP1 most effective
- Schemes 2 (0,2,2,2) and 3 (0,4,4,4)
  : Improvement expected if first steps determined randomly
- Optimization for cost



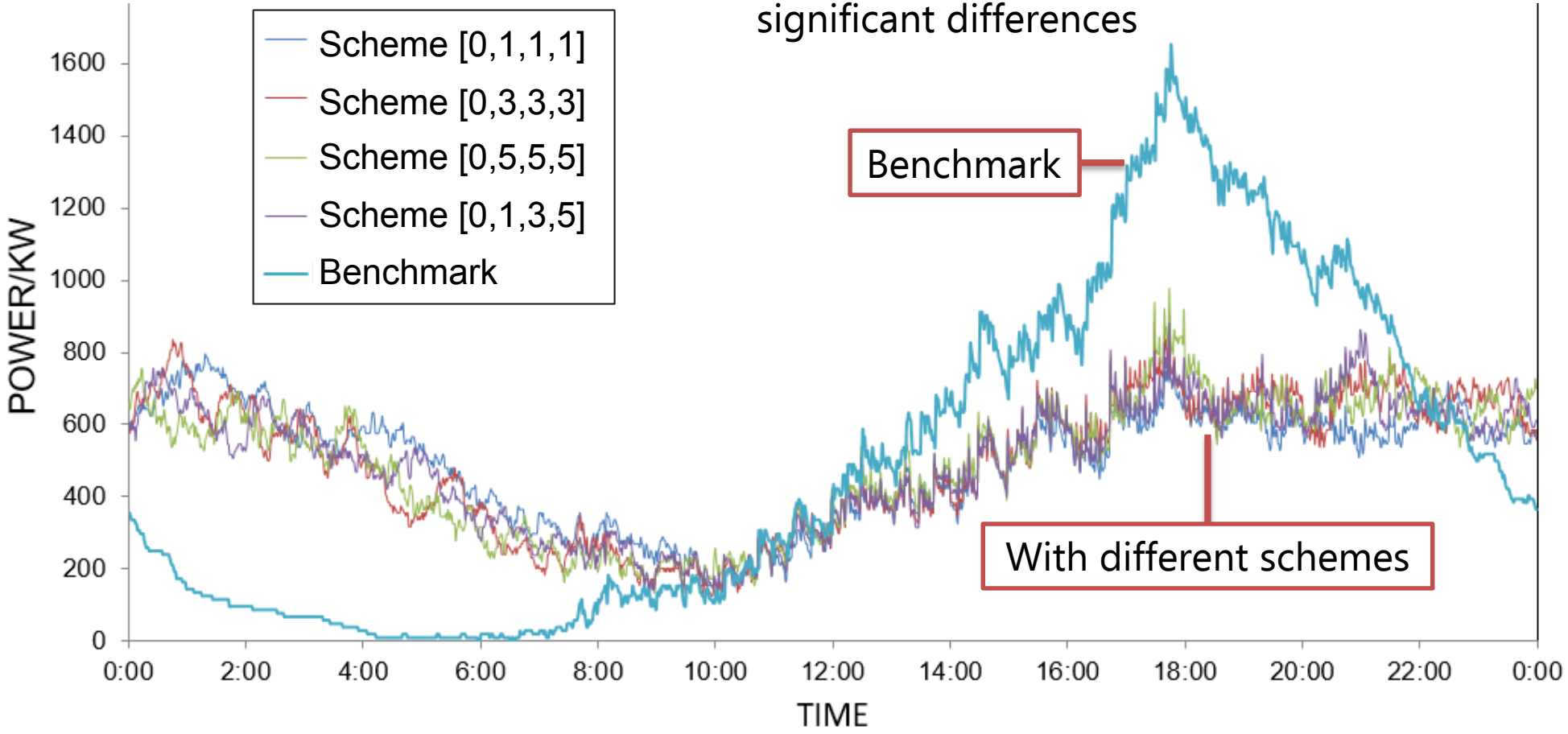
Plan	Start	Steps
0	Immediate	1
1	Random	1
2	Immediate	2
4	Immediate	3

RESULTS: IMPROVING ROBUSTNESS

	Start	Steps
Benchmark	**Immediate**	**1**
Alternative Plan 1	**Random**	**1**
Alternative Plan 3	**Random**	**2**
Alternative Plan 5	**Random**	**3**

(a) All four schemes with **alternative plans** can significantly **improve robustness** throughout the day

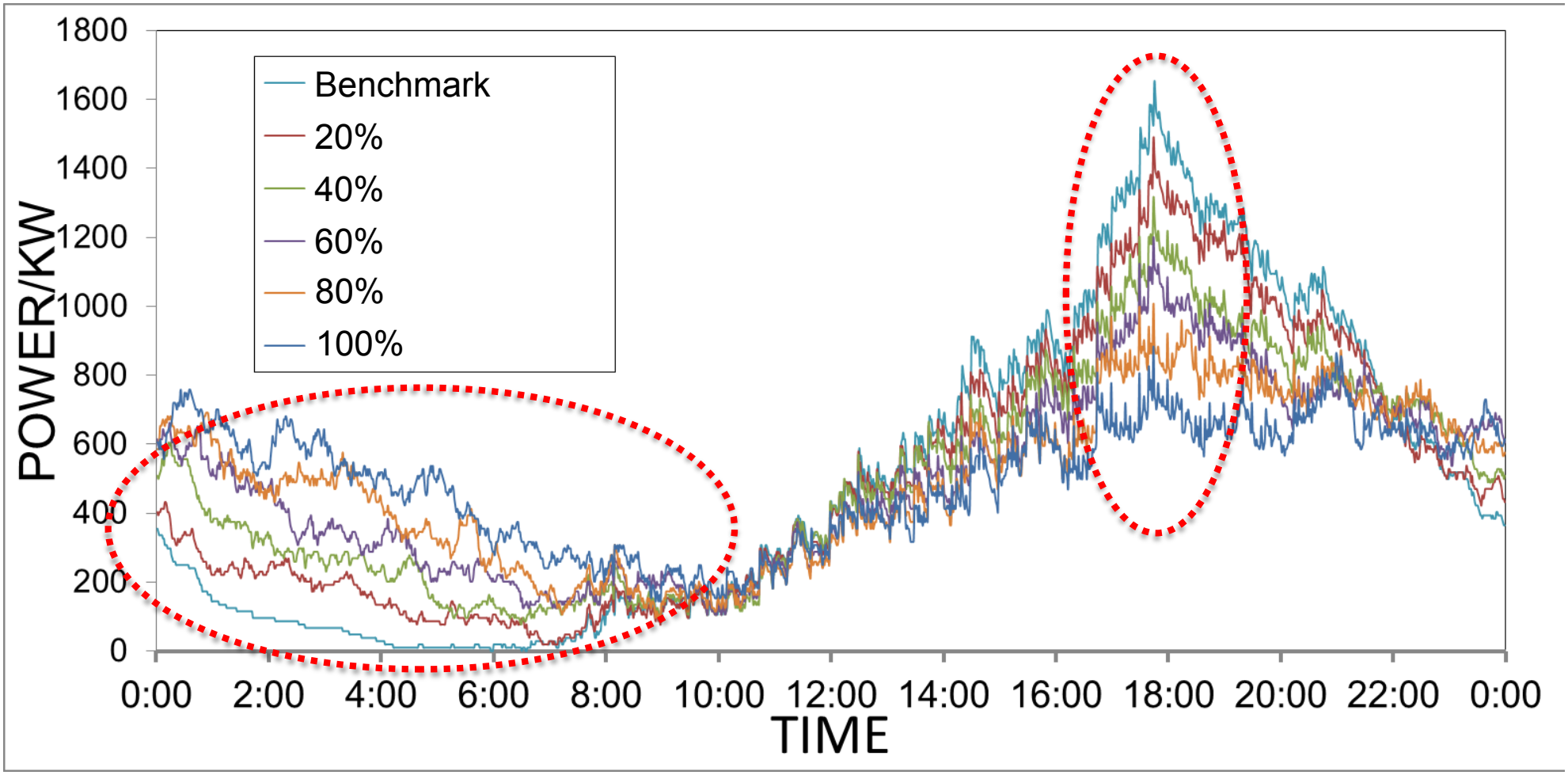
(b) The **number of charging steps** in alternative charging plans **does not** make significant differences



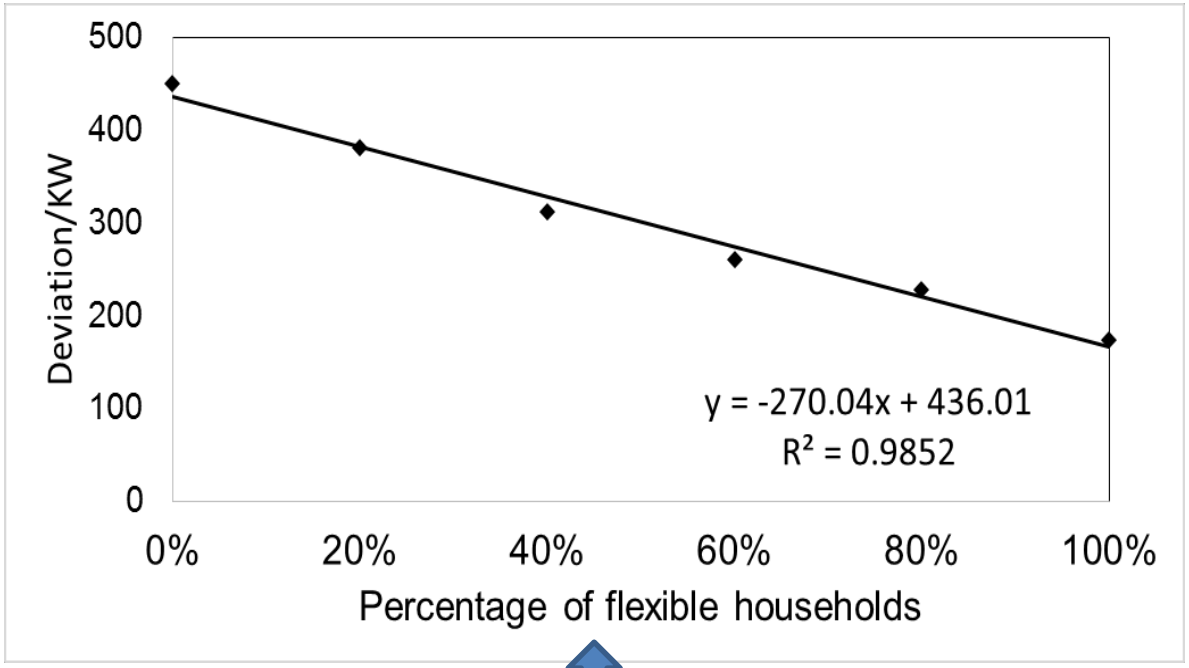
RESULTS: IMPROVING ROBUSTNESS

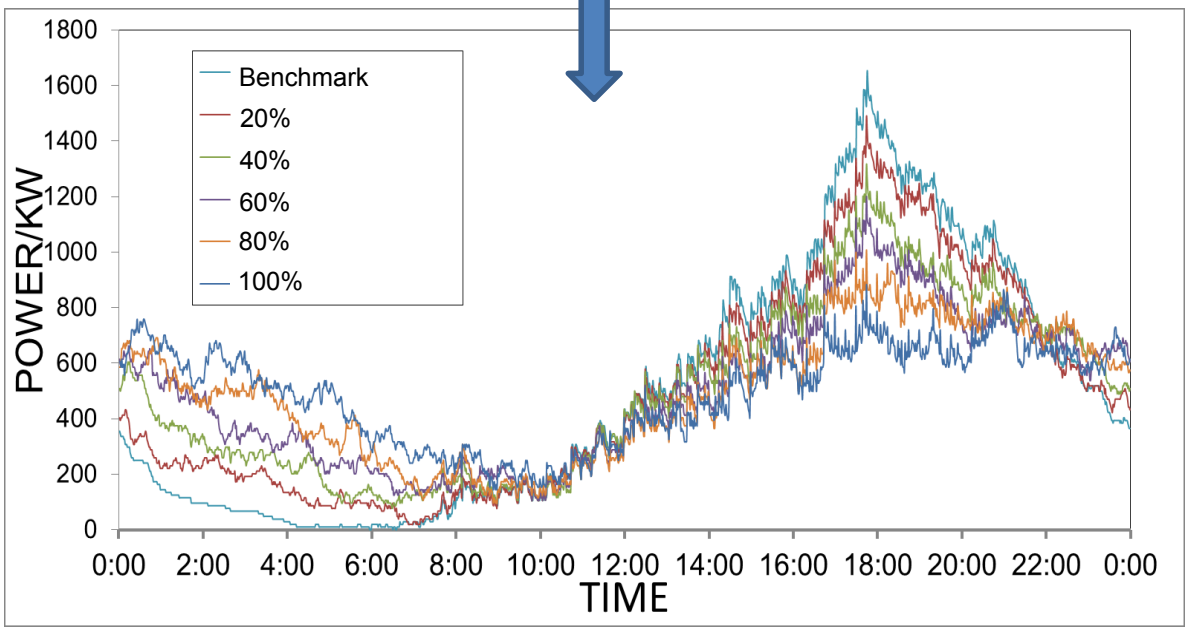
Experiment Variables	Values
Number of "Flexible" EVs	0%, 20%, 40%, 60%, 80%, 100%
Scheme	[0, 1, 3, 5]

(c) The **more EVs** accept alternative plans, the **more robust** the grid becomes



RESULTS: IMPROVING ROBUSTNESS



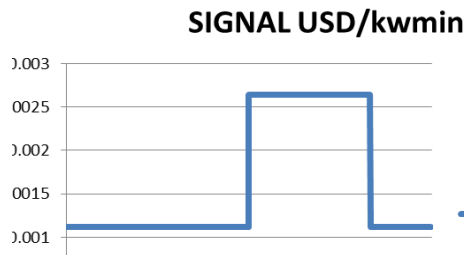


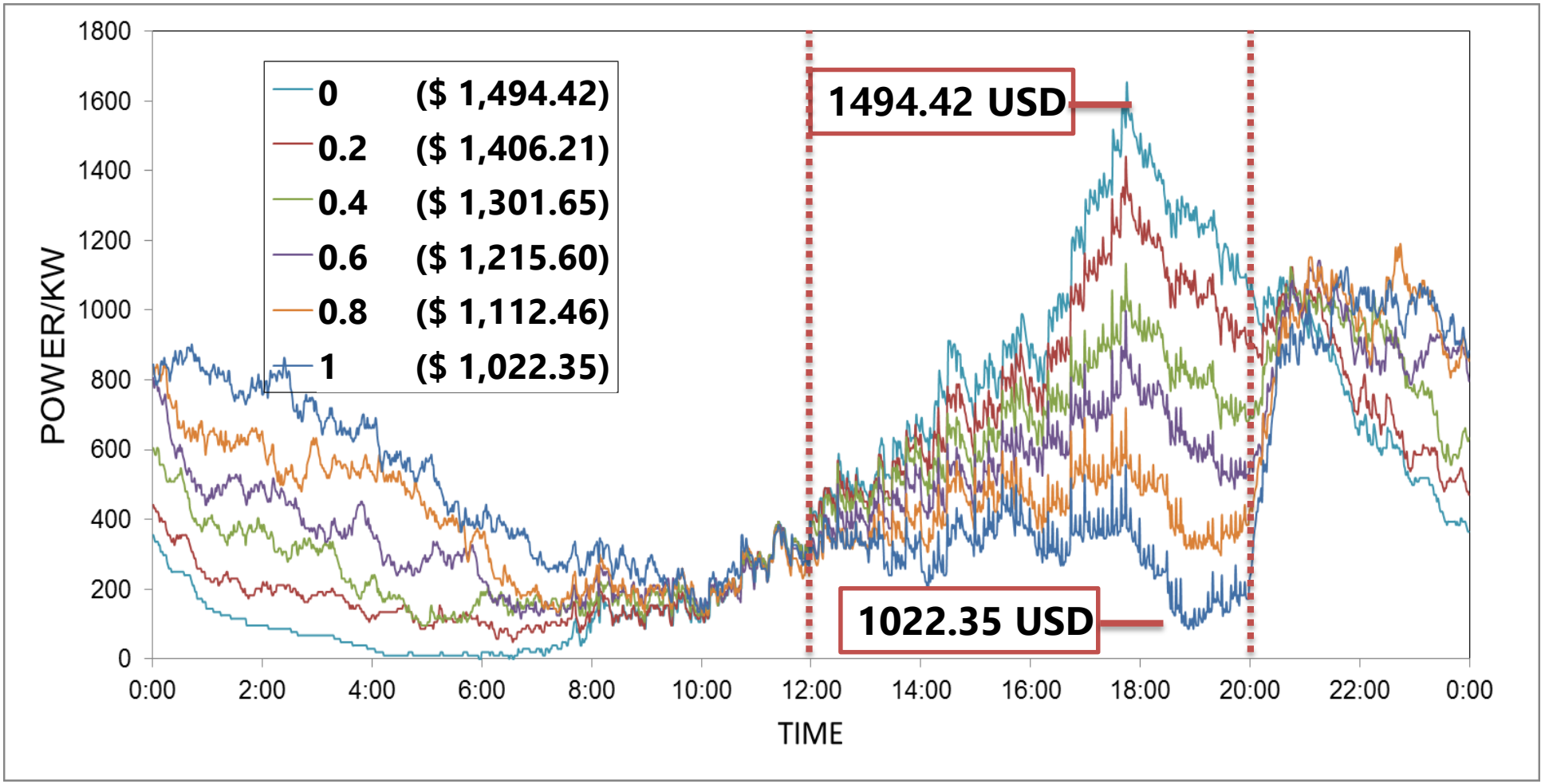
(d) The grid robustness, measured in standard deviation, has a **negative near-linear correlation** with the percentage of flexible EVs

RESULTS: MINIMIZING COST

(a) **Cost decreases** as optimization is performed. (**32.6%** cost saved, when best and worse cases are compared)

(b) **The higher** the percentage of flexible EVs, **the lower** the total cost





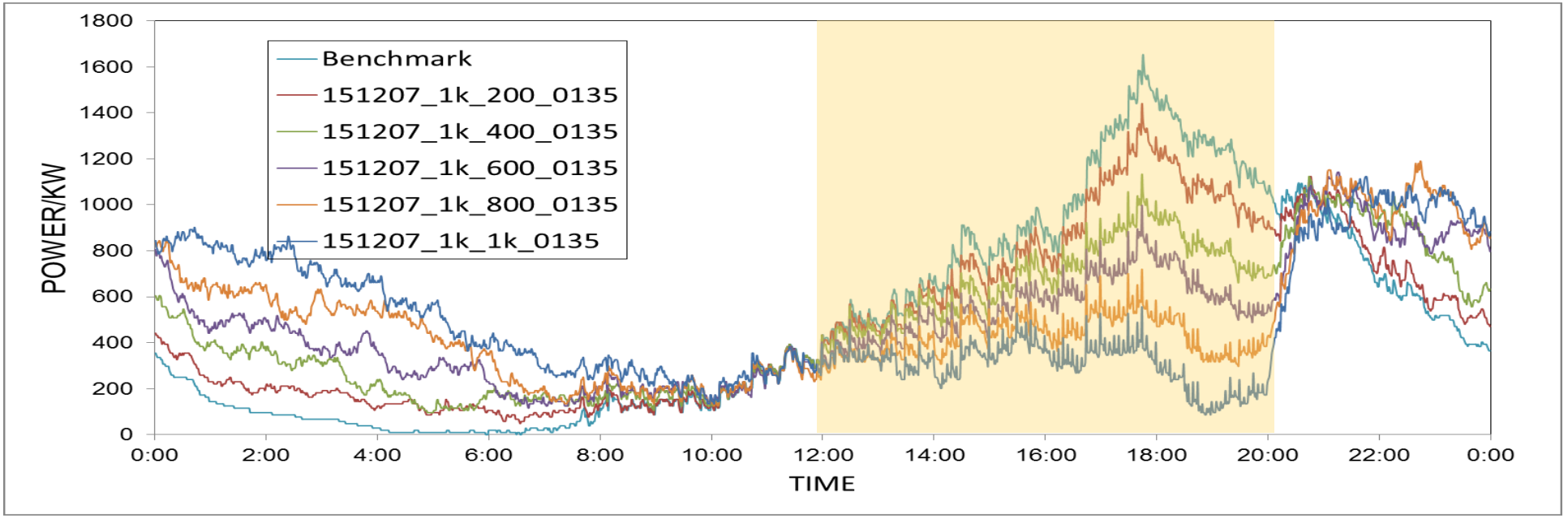
Results: Minimizing Cost

(c) Cost minimization has an **impact on grid robustness**

! Can be a positive influence

! Can be a negative effect (when too many EVs participate)

Flexibility	0% (benchmark)	20%	40%	60%	80%	100%
Average/KW	496.037804	495.924392	495.804309	495.644197	495.597498	495.55747
SDV/KW	450.0195038	366.037821	295.897607	255.979446	259.316847	277.148421



SUMMARY AND OUTLOOK

Conclusion

(1) Our smart microgrid improves grid robustness significantly by assigning alternative charging plans to EVs

As more EVs participate,

(2) Robustness ↑

(3) Total energy cost ↓, but robustness might ↓

Outlook

(1) Optimization of both cost and robustness

(2) Easy execution in real life

SOURCES

[1] Image on Page 1: https://www.teslamotors.com/model-charging
[2] Power Consumption Graph on Page: R. E. Brown, J. G. Koomey, Electricity Use in California: Past Trends and Present Usage Patterns (2002)