



Smart Microgrid with Electric Vehicles

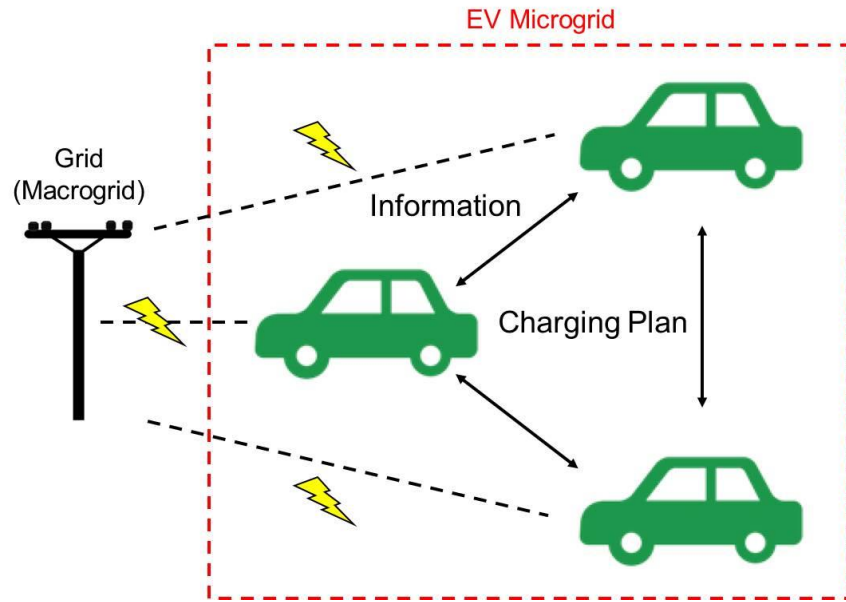
Modelling and Simulating
Social Systems with MATLAB

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PRESENTATION OVERVIEW

1. Model



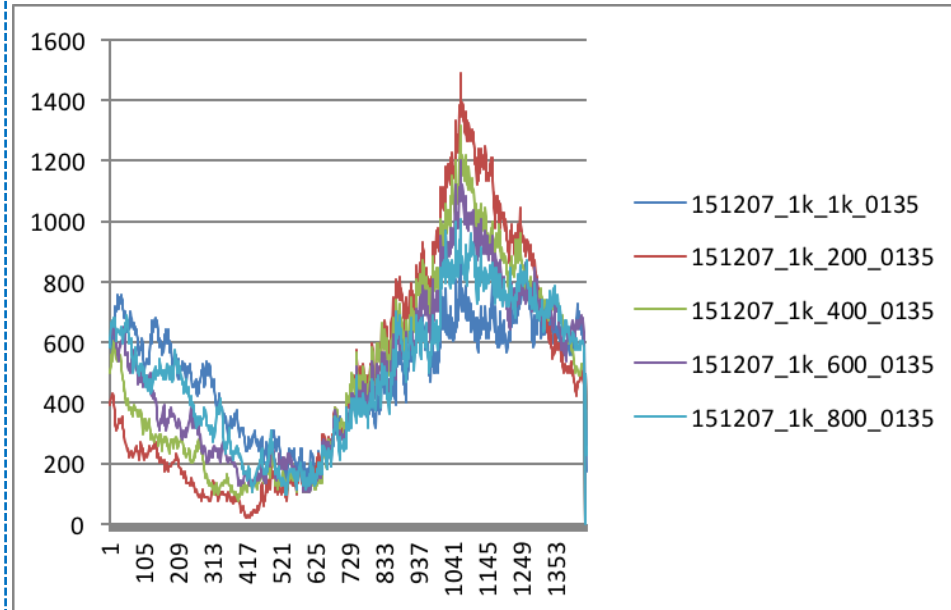
2. Implementation

- Driving Profile
- SOC



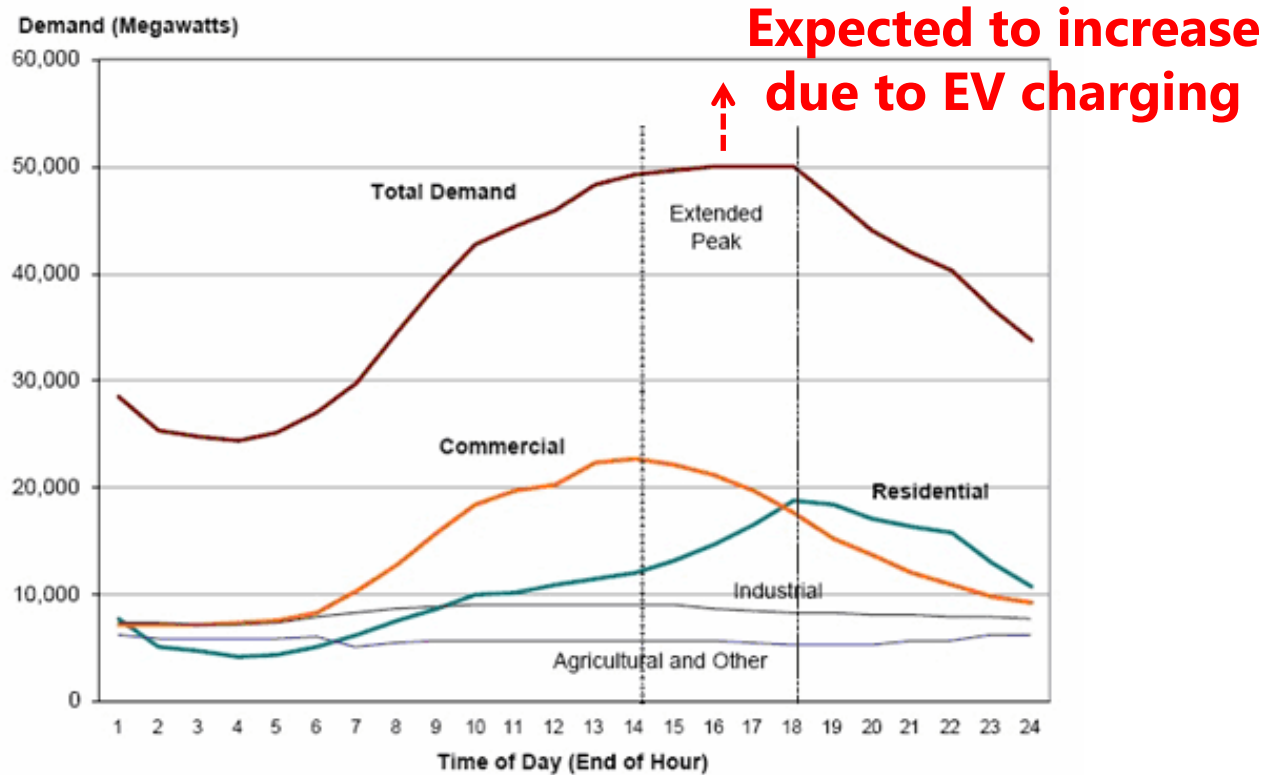
- Power
- Cost

3. Results and Discussion



- Improved Grid Robustness
- Reduced Cost

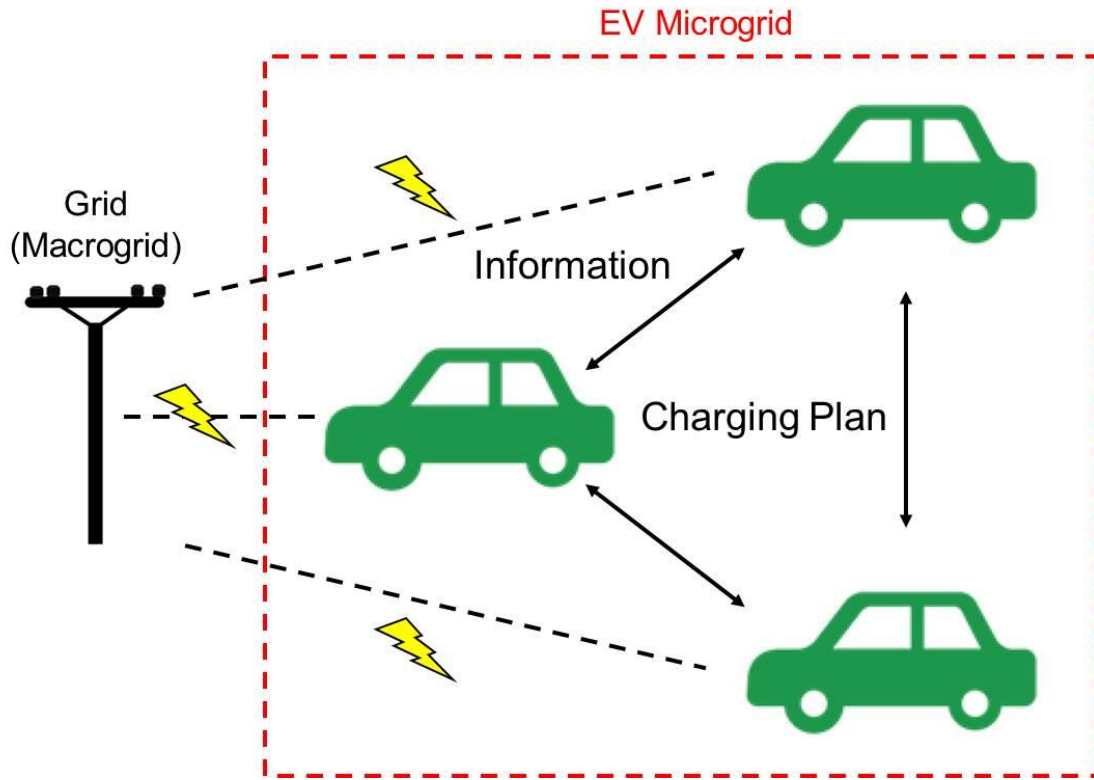
INTRODUCTION



Solutions

- Increasing generation
 - Managing demand effectively
- > Underutilization of Facilities

MODEL



EV Agent Model

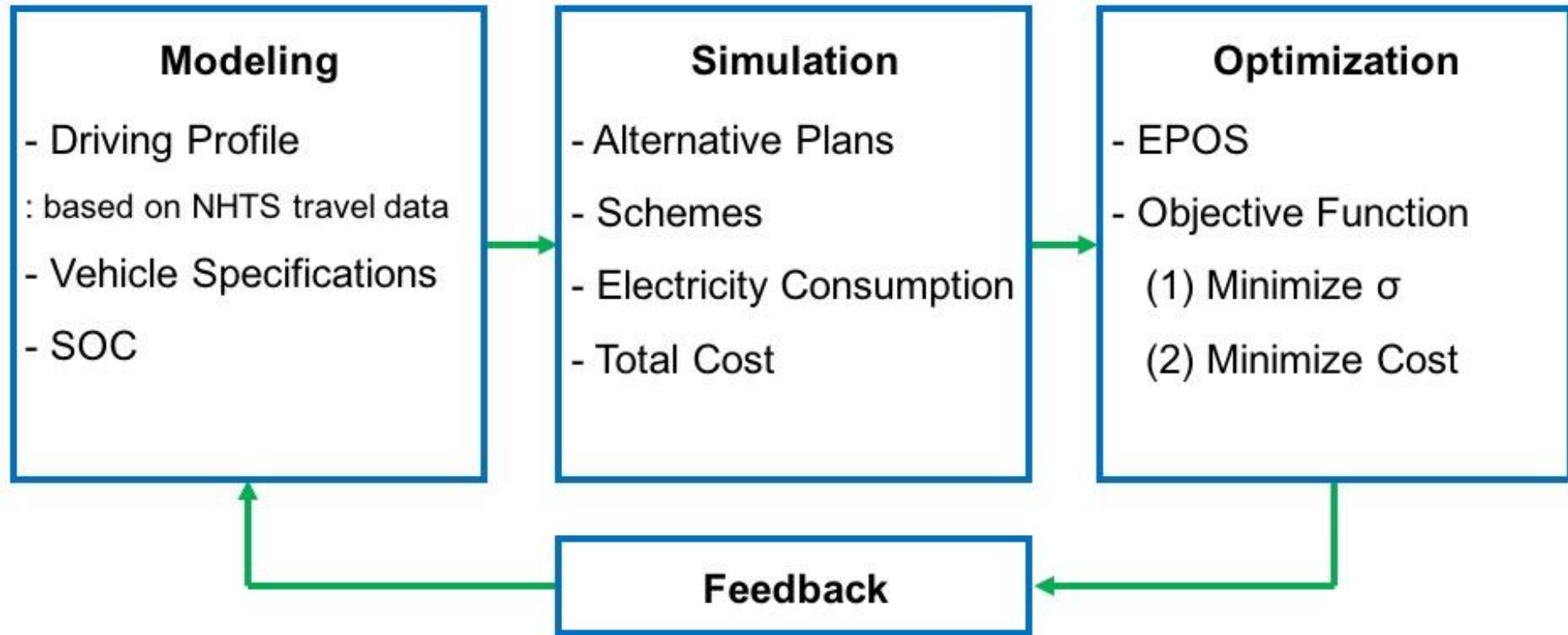
Every EV receives a charging plan from ***EV agent***

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
- 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

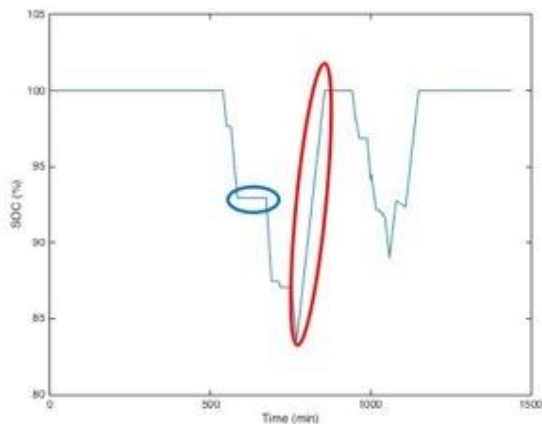
Simulation

- Alternative Plans
- Schemes
- Electricity Consumption
- Total Cost

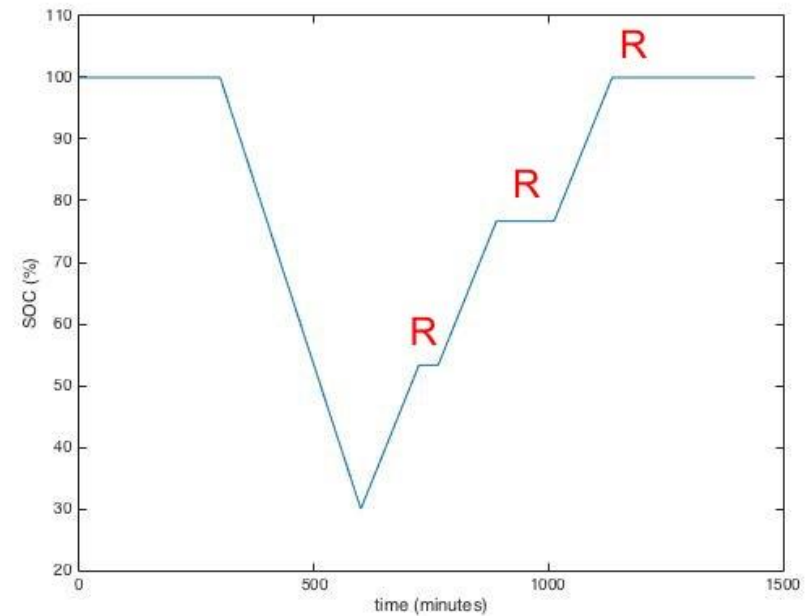
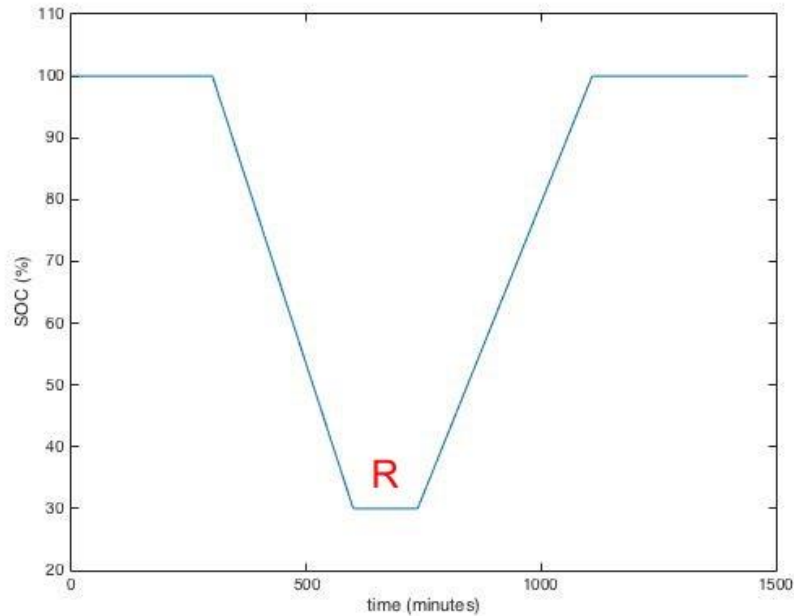
Optimization

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

Feedback



ALTERNATIVE PLANS

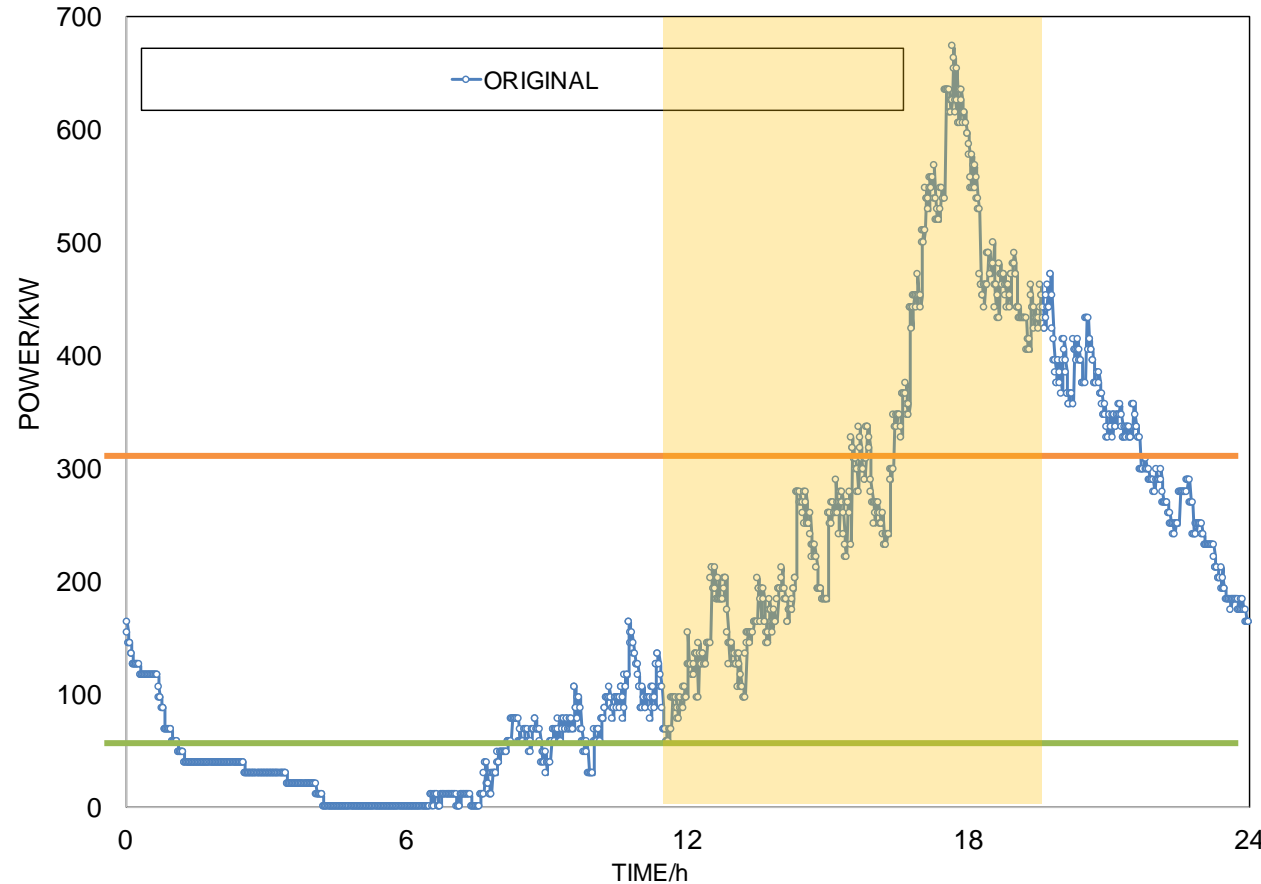


	Start	Number of Steps
Original Plan	Immediate	1
Alternative Plan 1	Random	1
Alternative Plan 2	Immediate	2
Alternative Plan 3	Random	2
Alternative Plan 4	Immediate	3
Alternative Plan 5	Random	3

RESULTS: PRELIMINARY EXPERIMENT

Original

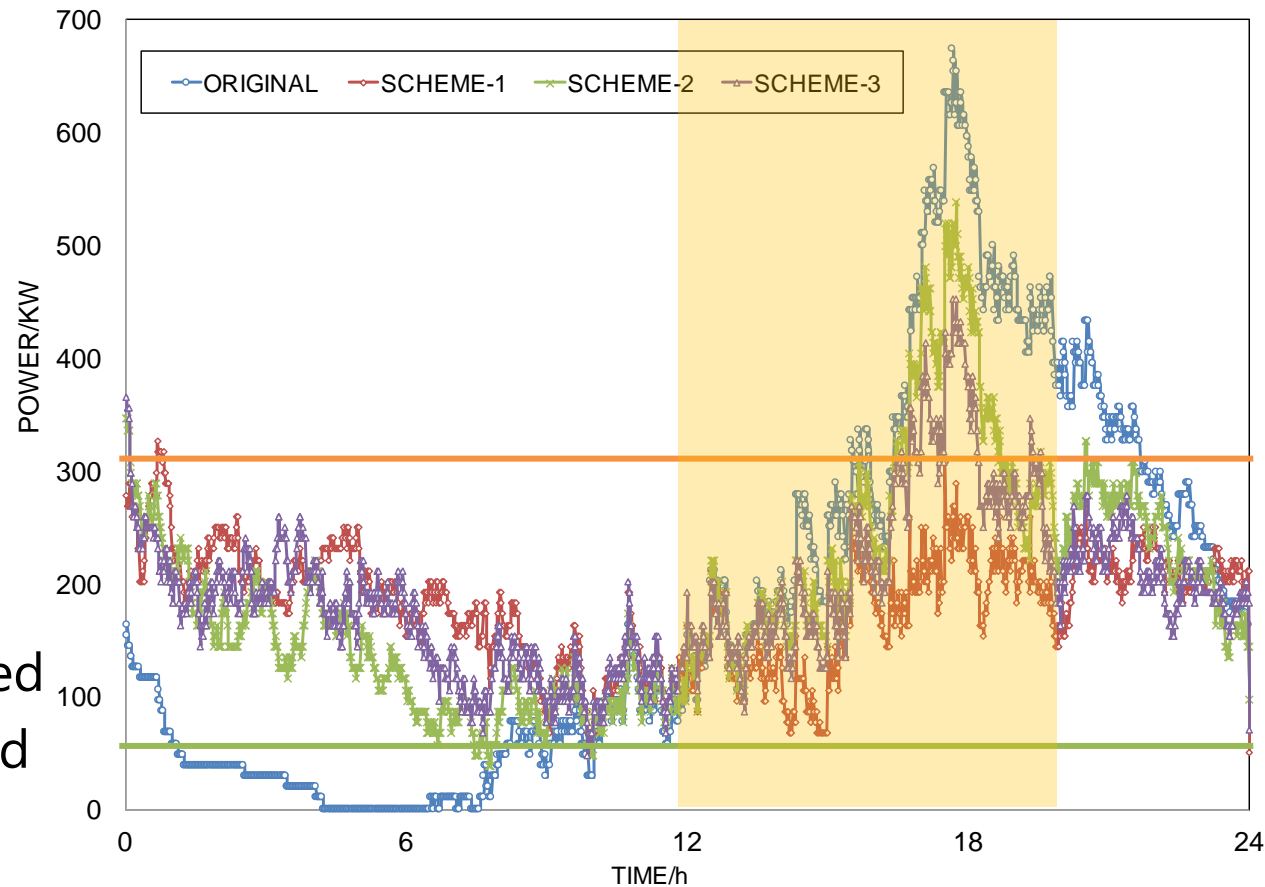
- **Peak - Valley**
-> Robustness of the grid
- **Off-Peak Pricing**
-> Cost for the customers
- **Diurnal Driving**



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

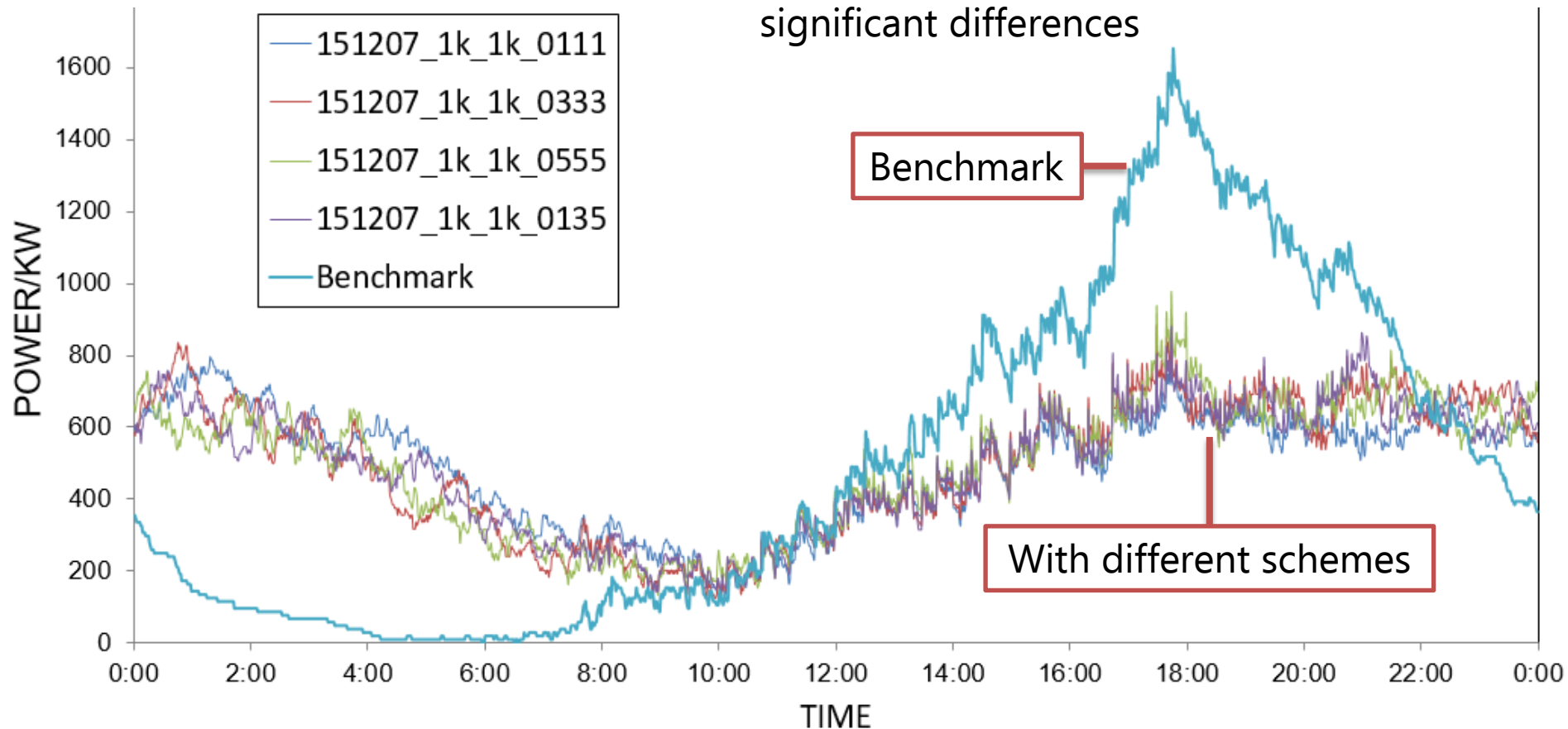


Plan	Start	Steps
0	Immediate	1
1	Random	1
2	Immediate	2
4	Immediate	3

RESULTS: IMPROVING ROBUSTNESS

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

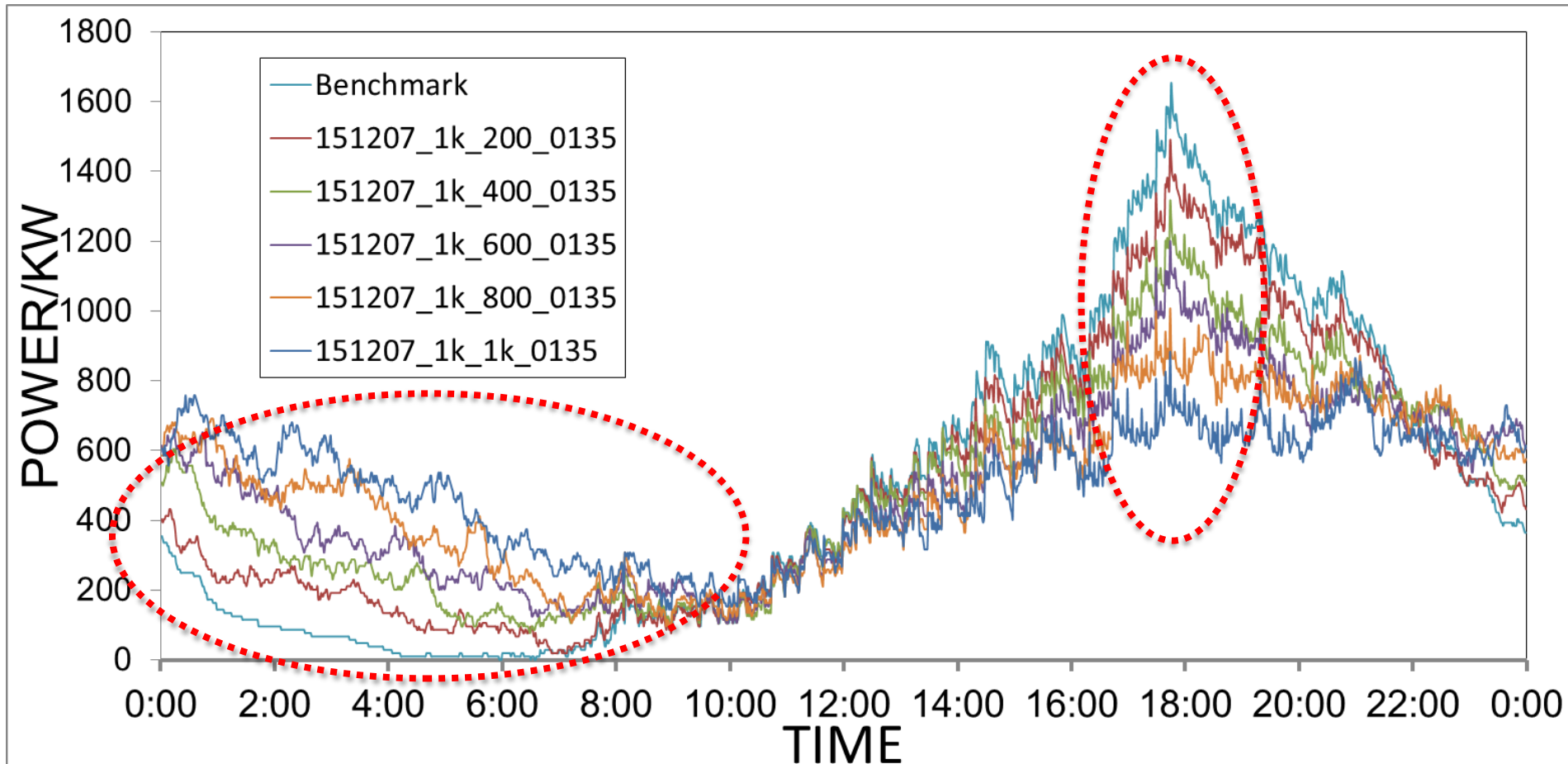
- (a) All four schemes with **alternative plans** can significantly **improve robustness** throughout the day
- (b) The **number of charging steps** in alternative charging plans **does not** make significant differences



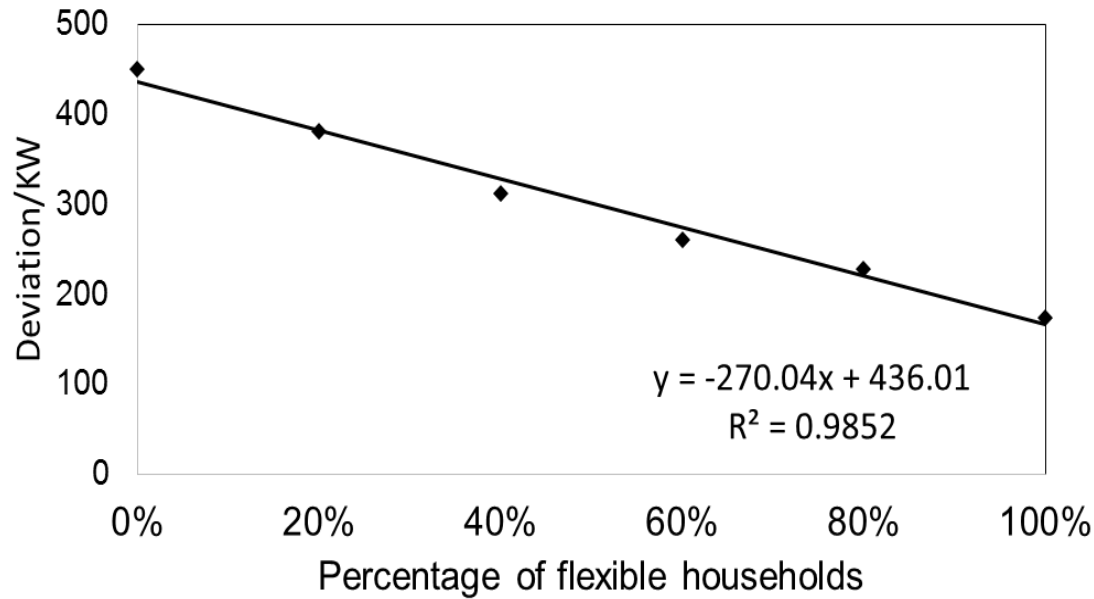
RESULTS: IMPROVING ROBUSTNESS

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

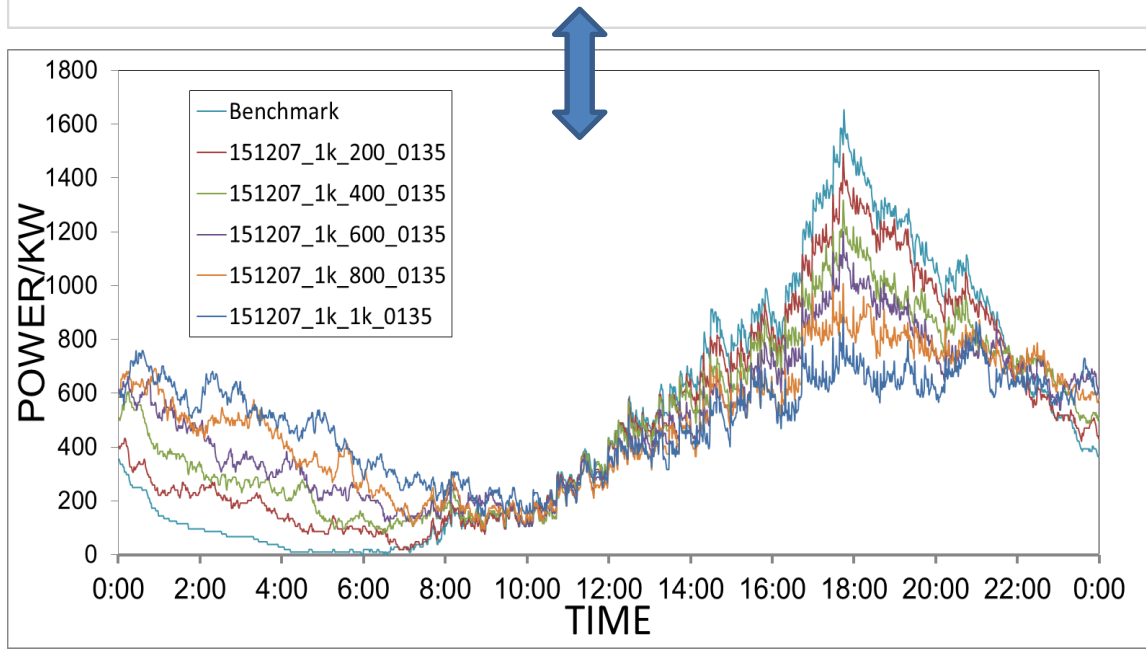
(c) The **more EVs** accept alternative plans, the **more robust** the grid becomes



RESULTS: IMPROVING ROBUSTNESS



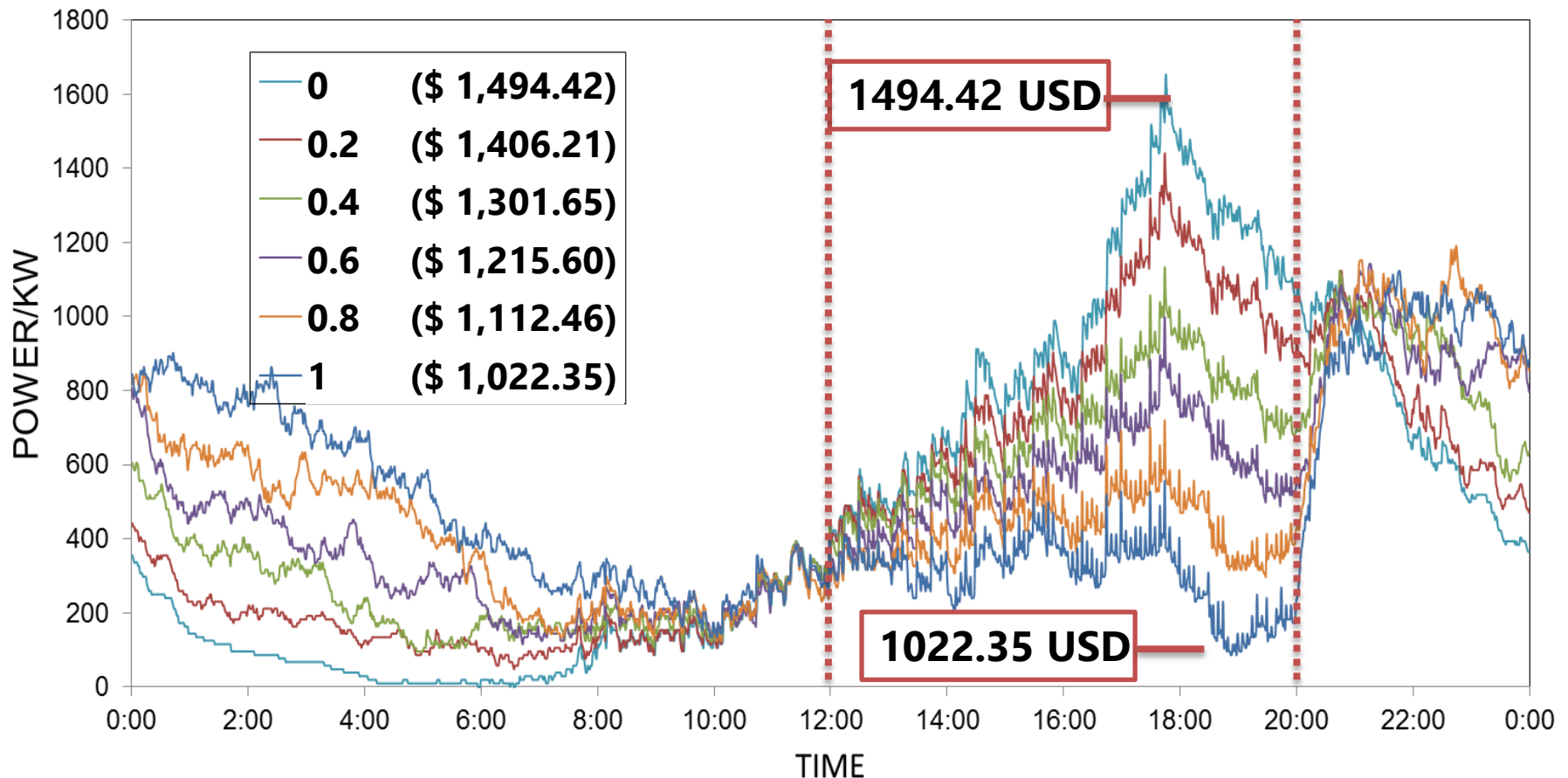
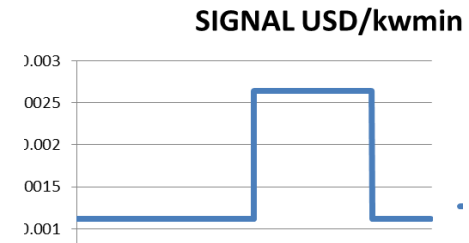
(d) The grid robustness, measured in standard deviation, has a **negative near-linear correlation** with the percentage of flexible EVs



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



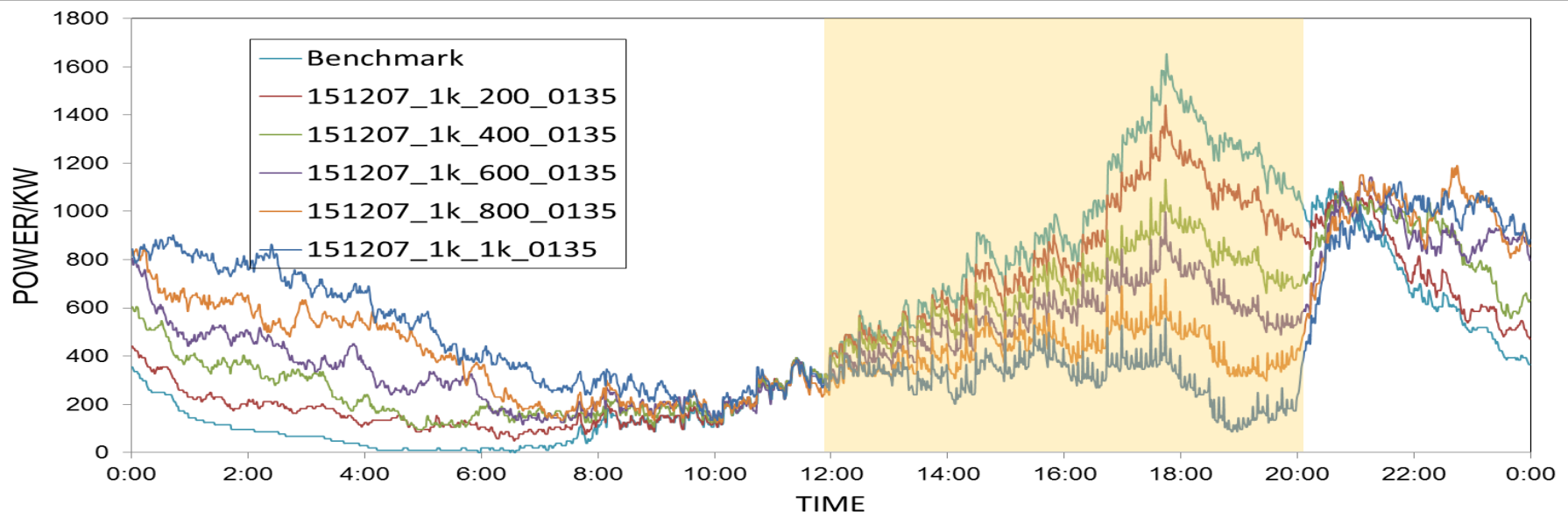
RESULTS: MINIMIZING COST

(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 \uparrow
- (3) Total energy cost \downarrow , but robustness might \downarrow

Outlook

- (1) Optimization of both cost and robustness
- (2) Easy execution in real life

REFERENCES

[1] Image on Page 1: <https://www.teslamotors.com/model-charging>

[2] Power consumption graph on Page 3: R. E. Brown, J. G. Koomey, Electricity Use in California: Past Trends and Present Usage Patterns (2002)