Tariff design with electromobility and DERs

What are the economic principles applied when electric vehicles are connected with DERs? Insights from a Californian case study.

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version

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OUTLINE

1. VEDECOM
   1.1 - VEDECOM in brief

2. Introduction
   2.1 - Context
   2.2 – Electricity tariff decomposition

3. Methodology and input data
   3.1 – Model description
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4. Results

5. Conclusion

OUTLINE

VEDECOM

A lead French ITE devoted to decarbonized mobility research.

1. VEDECOM IN BRIEF

VEhicule DEcarboné et COmmunicant et sa Mobilité:

- Founded in 2014 ;
- French ITE (Institut pour la Transition Energétique);
- Public and private co-investment;
- Dedicated to individual, decarbonized and durable mobility;
- Develop researches in disruptive technologies;

ÉLECTRIFICATION DES VÉHICULES

DÉLÉGATION DE CONDUITE & CONNECTIVITÉ

MOBILITÉ & ÉNERGIE PARTAGÉES

VÉHICULE | ÉCO-MOBILITÉ

FORMATION

Entreprises / Companies — Recherche / Research — Institutionnels / Institutional

FONDATEURS / FOUNDERS

DONATEURS / DONORS

EN COLLABORATION AVEC / IN COLLABORATION WITH

SOUTENU PAR / SUPPORTED BY

50 members & partners from different sectors **collaborate** on **pre-competitive** and **pre-normative research projects**

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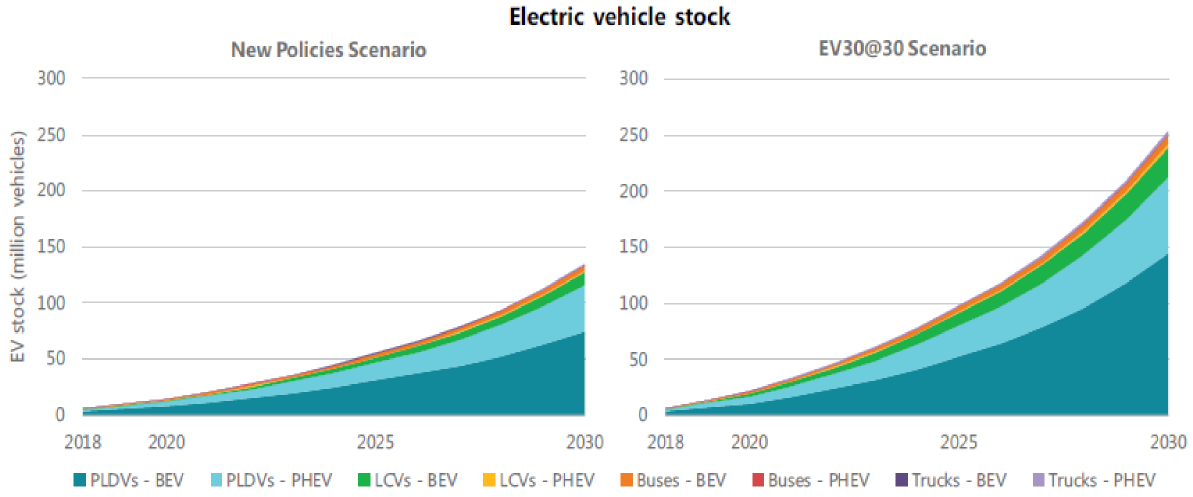
INTRODUCTION

A reflection about the electricity rates actual context.

Automotive Industry

Increase of electric vehicles sales:

- Decarbonization of transport sector (CO2 emission restrictions).
- Supported by public policy (Subsidies)



Source: EV Outlook, 2019

What are the existing tariff types?

Electricity Industry

Decarbonization of electricity sector:

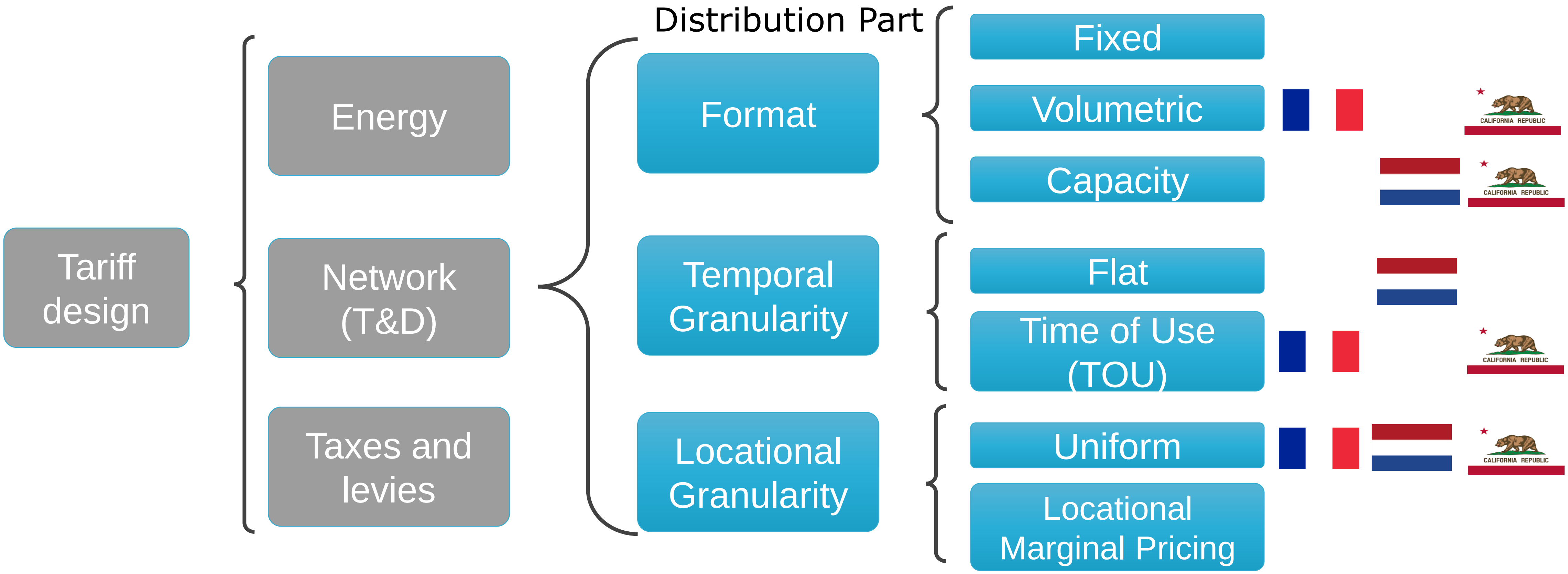
- Rapid development of wind and solar energy (PV).
- Increasing flexibility needs to avoid duck curve.
- Increasing adoption of stationary batteries (BESS).

Are EVs a threat in this context?

- Context of decrease of electricity consumption.
- But important contribution to peak consumption.
- Opportunity as new flexibility source with V2G.
- In the flexibility market, are EVs and batteries competing or complementary?

What are the tariff roles?

- Reflect user's total consumption (demand and energy).
- Recover utility costs due to previous investments.
- Avoid cost-shifting due to the spiral of death.
- Push a specific type of DERs (PV with feed-in tariffs)

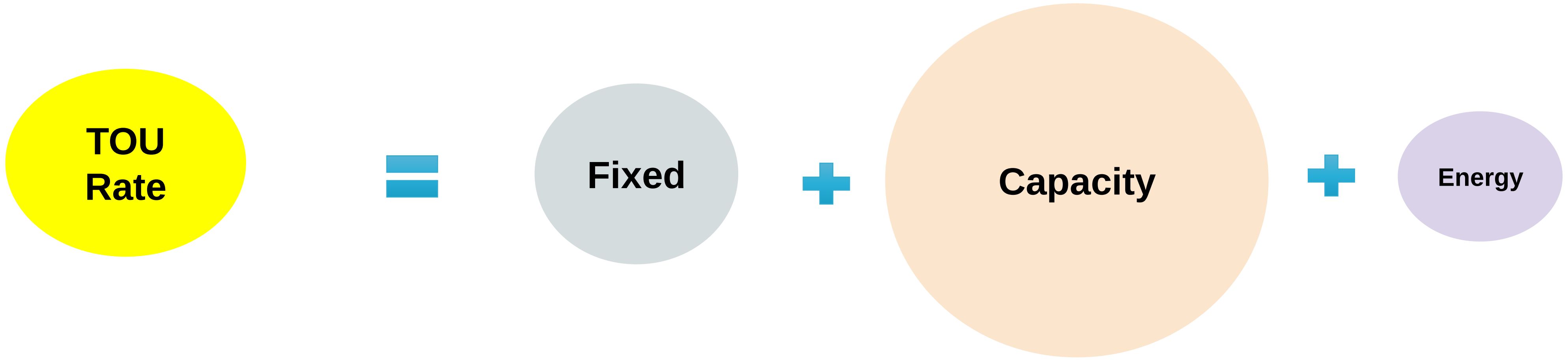


Which are “the best” tariffs?

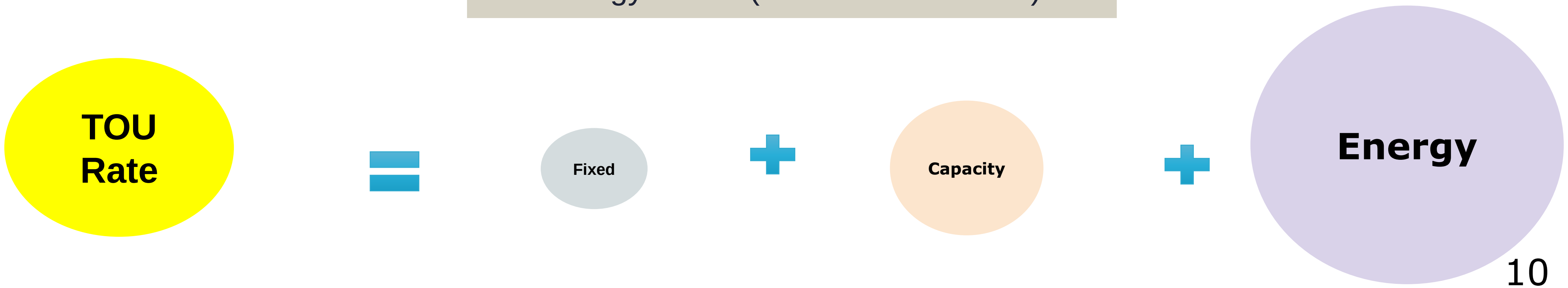
2 – INTRODUCTION

2.2 – Electricity tariff decomposition (From South California Edison)

Capacity based (TOU-B and TOU-D)



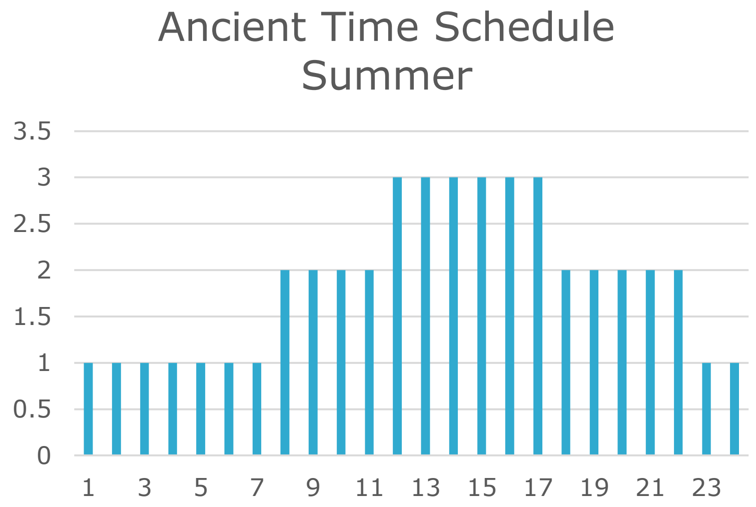
Energy based (TOU-R and TOU-E)

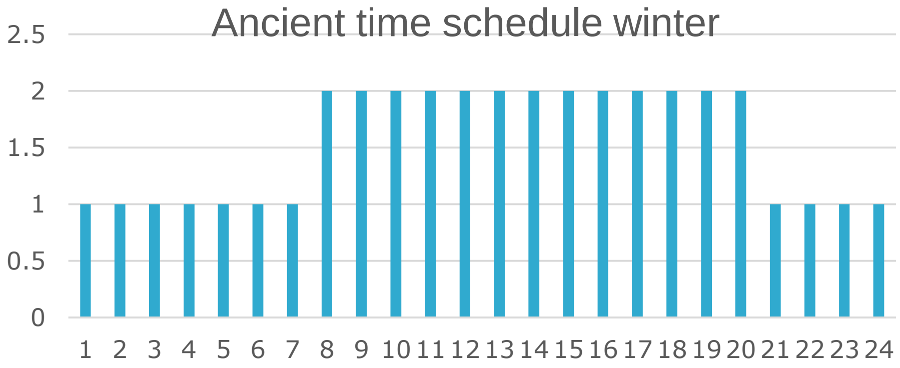


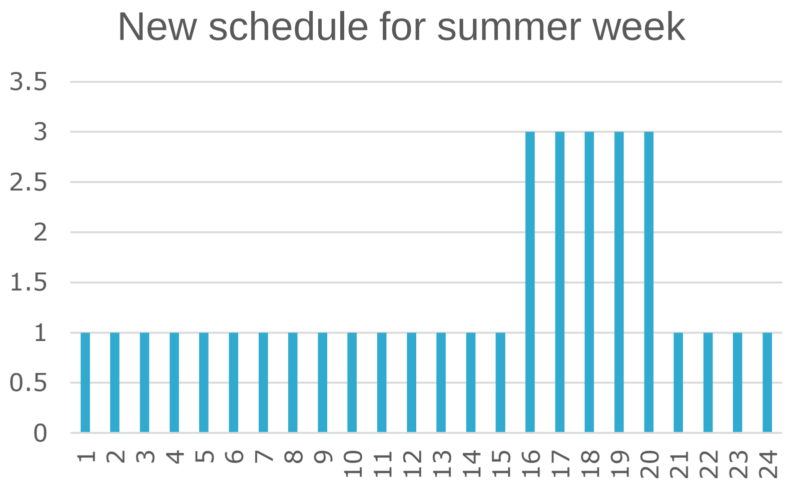
2 – INTRODUCTION

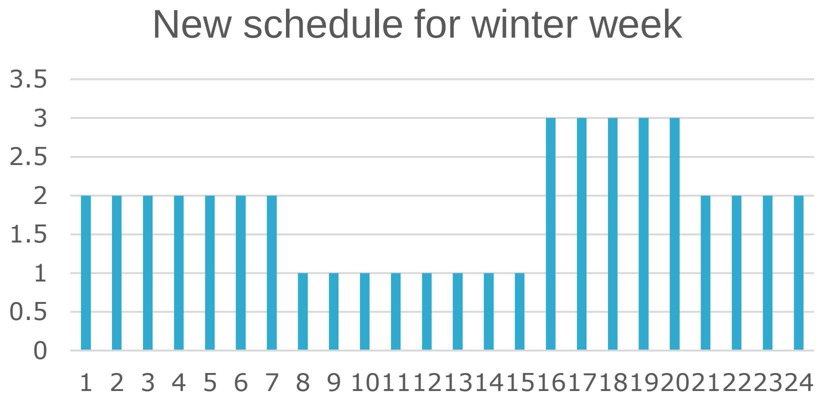
2.2 – Electricity tariff decomposition (From South California Edison)

From (TOU-B and TOU-R)	To (TOU-D and TOU-E)









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METHODOLOGY AND INPUT DATA

3 – METHODOLOGY AND INPUT DATA

3.1 Model description*

DER-CAM

BERKELEY LAB
Bringing Science Solutions to the World

Coupling model

Avoided cost model (ACM)

PUBLIC UTILITIES COMMISSION
EUREKA
STATE OF CALIFORNIA

Energy+Environmental Economics

- Charge and Discharge strategies
- Demand reduction
- Net Present Value
- Avoided cost
- Cost-shifting
- EVs Remuneration

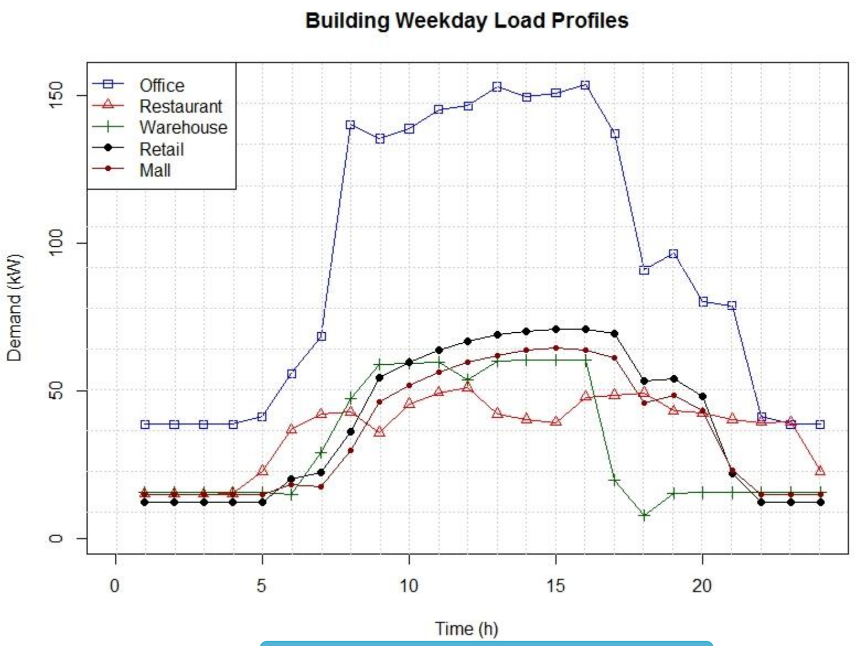
*Methodology proposed by Boampong, R. and Brown, D. ,2020.

DERCAM Mathematical modelling* (MILP) of the local microgrid:

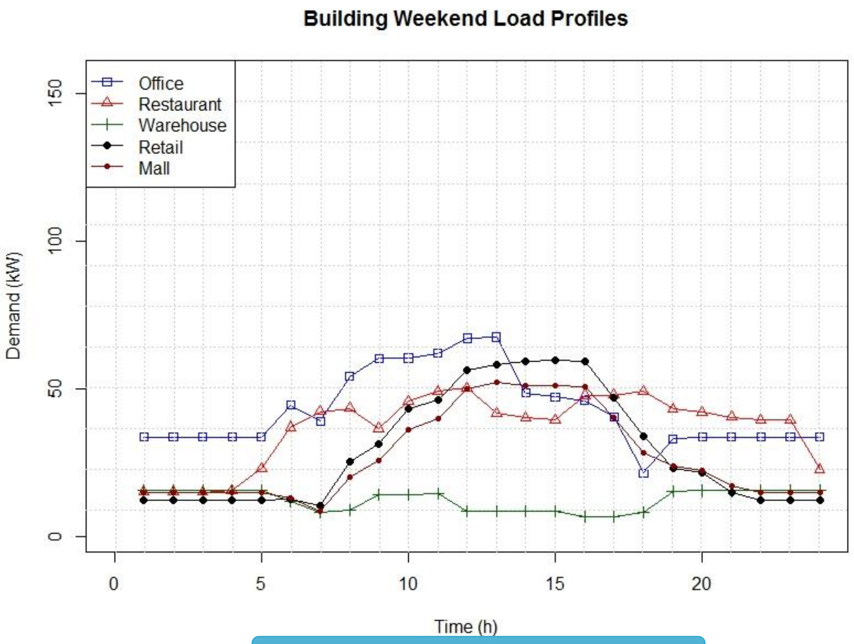
$$Min\ c_{total} = c_{elec} + c_{DER} + c_{EV} - \sum_{m}\sum_{d}\sum_{h} GenS_{PV,m,d,h} \cdot TEx_{m,d,h}$$

Main inputs parameters:

- Load profiles commercial and industrial (C&I) sites in Los Angeles area (Source: OpenEI)



R-squared = 0.86



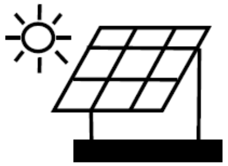
R-squared = 0.73

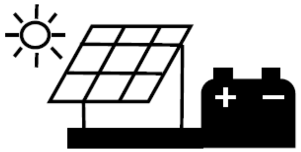
*See the annex to verify the constraints.

Main inputs parameters:

- Exogenous DER (Distributed energy resources) sizing methodology:
  - PV (Photovoltaic panels) : Amount needed to offset 50% of the annual on-site consumption.
  - BESS (Battery Energy System Storage): Amount needed to shave the evening peak when there is low or no PV production.
  - EV: Equivalent to the BESS method, but constrained to the charging station maximum power and user's battery range needs.

- Endogenous DER methodology:
  - The amount of DER installed is chosen by the model to maximize the private economic gains.





OUTLINE

RESULTS

The results according to each type of investment.

Exogenous Investments

Average electricity cost changes:

- New tariffs (with later on peak periods) reduce considerably the electricity savings.
- PV+BESS and PV+BESS+EV have similar electricity costs reduction moving from the ancient tariffs without DERs to all tariffs with DERs.

Net present value (Over 20 Years → PV lifetime):

- The new tariffs diminish the private economic gains.
- Energy tariffs have higher and positive NPV in most of cases due to the high valuation of PV generation.

Cost-shifting (Private savings – system avoided costs) :

- On the other hand, capacity tariffs decrease the cost shifting value by increasing avoided system costs and reducing private savings.

Endogenous investments

Net present value:

- The highest NPV possible is achieved under TOUR (ancient energy tariff → on peak period synchronized with PV generation).

Cost-shifting :

- The lowest cost shifting is found under TOUD (the new capacity tariff).

EVs:

- They are found in all facilities when coincidental tariffs (capacity and energy) are applied. Showing high NPV and low cost shifting.
- The remuneration for bill management services can be higher as well under these type of tariffs.

OUTLINE

CONCLUSION

5. CONCLUSION

Conclusion

EVs as a DER:

- EVs have helped in the mix to enhance private economic gains in the majority of cases.
  - → EVs and batteries can work together to support the facility grid.
  - Cost shifting can be reduced with EVs.

EVs stack remuneration:

- Varying between 380$ – 1208$.
- The remuneration can attract more users, which can reduce the gain via competition among EV owners.

Policy recommendations:

- To increase private gains →TOU-R (Energy Based)
- To reduce cost-shifting → TOU-D (Capacity Based)
- Increase EVs remuneration → Coincidental tariffs.

Future Research

Change the tariff power rate:

- Analyze buildings with power demand higher than 200 kW (SCE ToU GS-3).

Simulate for more building load units:

- Verify the result's robustness.
- Check the mean, standard deviations and percentiles.

INSTITUT VEDECOM
DU VÉHICULE DÉCARBONÉ ET COMMUNICANT ET DE SA MOBILITÉ

Thank you for your attention
Merci de votre attention

Together to accelerate the mobilities of tomorrow!

	Solar PV	Battery	Electric Vehicles
Fixed cost	-	500$ (Beck et al.)	7 kW V2G DC Charging Station: 3850 $/Station
Variable cost	2100 $/kWac (NREL)	465 $/kWh (Doroudchi et al.)	-
Lifetime	20 years (Beck et al)	10 years (Tesla Powerwall)	10 years
O&M	0.66 $/kW (McLaren et al.)	0 (Beck et al.) Already included.	10% of the variable cost
Subsidy	-	250$/kWh (SCE incentive program)	50% of fixed costs (workplace SCE rebate)

Exogenous investment: The DERs sizing is chosen by an external method with a fixed amount.

Objective: **Isolate the impact of changes in tariffs on the private and system value of the technologies.**

Average percentage total electricity costs change						
PV						
Baseline	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
TOUB	-36.96	-29.73	-26.07	-51.32	-36.18	-31.14
TOUR	-34.44	-27.69	-24.26	-47.79	-33.69	-29.00
PV+BESS						
Baseline	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
TOUB	-53.83	-46.07	-47.67	-64.59	-54.12	-52.11
TOUR	-50.11	-42.88	-44.29	-60.12	-50.34	-48.45
PV+EV						
Baseline	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
TOUB	-44.19	-34.07	-41.00	-57.20	-44.27	-44.89
TOUR	-41.17	-31.76	-38.10	-53.27	-41.21	-41.75
PV+EV+BESS						
Baseline	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
TOUB	-50.93	-42.89	-43.71	-62.46	-50.62	-48.20
TOUR	-47.42	-39.93	-40.62	-58.15	-47.10	-44.82

Net present value of exogenous investment (NPV over 20 Years → PV Lifetime)						
	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
PV	-20640.59	-68789.06	-97049.76	74538.03	-27052.80	-57748.64
PV+BESS	48472.83	-17518.00	-11572.96	113722.96	33772.43	22572.24
PV+EV	-11580.23	-71684.12	-44290.0105	71759.16	-17767.32	-20134.68
PV+EV+BESS	39320.49	-25651.27	-26989.87	103851.69	19142.23	3589.77

Cost-Shifting (Annual system avoided costs - Annual private savings)						
	TOUB	TOUD	TOUD Coin	TOUR	TOUE	TOUE Coin
PV	10950.47	6972.51	4637.12	18855.49	10420.74	7884.37
PV+BESS	14543.71	8003.65	8854.76	20838.97	12541.68	11662.50
PV+EV	13268.14	8936.15	9722.05	19201.95	9611.37	9532.17
PV+EV+BESS	14292.07	9381.03	8948.76	19837.43	11769.98	10402.64

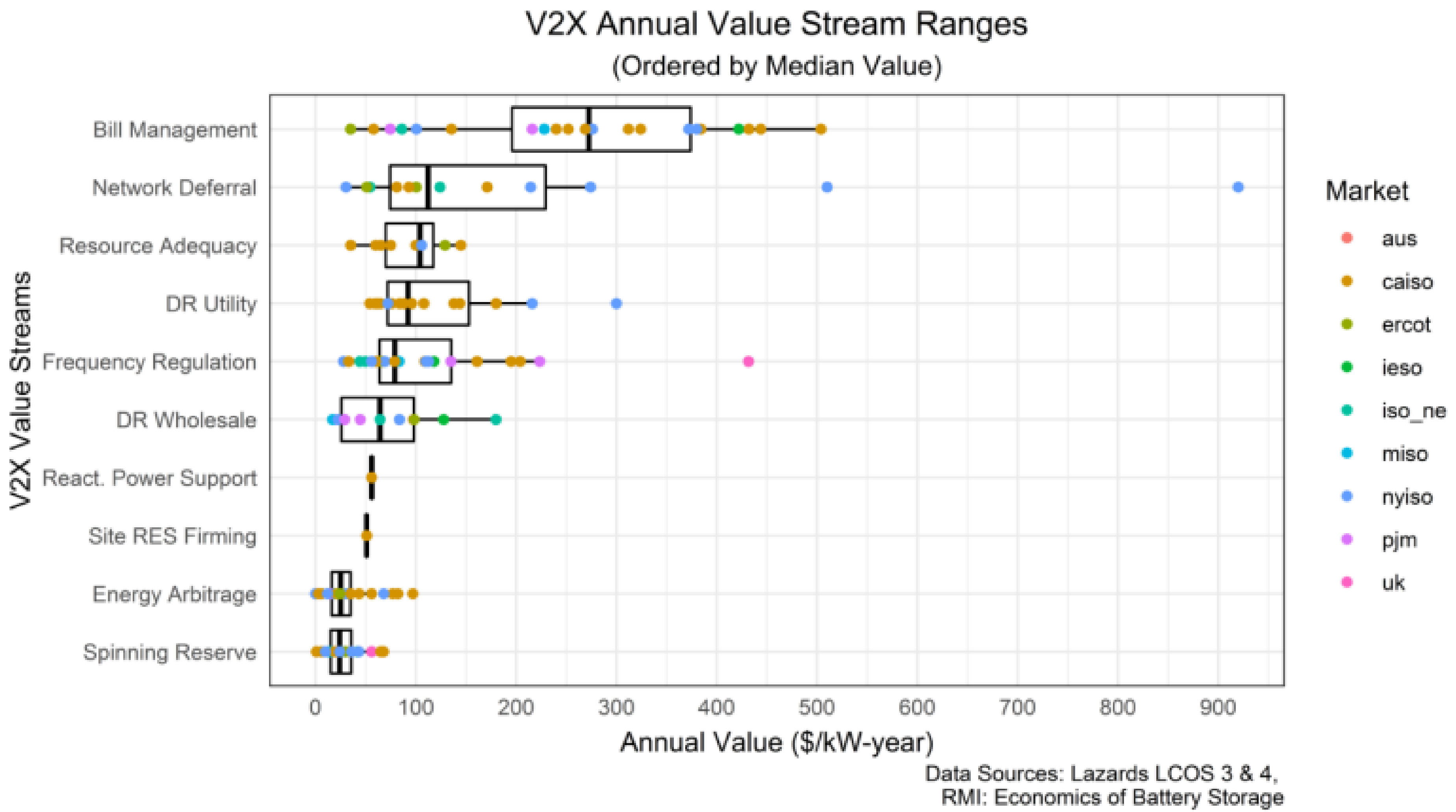
Endogenous investment: The DER optimal sizes are chosen by the model.

Objective: **Find the optimum net private investment with the available DERs**.

Endogenous case						
	TOUB (4)	TOUD (3)	TOUD Coin (5)	TOUR (2)	TOUE (3)	TOUE Coin (5)
PV (kW)	68.60	32.20	0.00	92.20	77.20	67.40
BESS (kWh)	168.40	83.20	2.20	134.80	235.20	192.80
EV (kWh)	69.60	69.80	475.40	46.40	164.20	162.40
NPV ($)	73228.5	30717.6	90233.3	125622.7	55558.0	64107.6
Cost-Shifting ($)	13287.19	6312.19	6513.09	20543.06	7704.44	8388.03
EV Remuneration ($/EV)	380.24	752.25	1208.05	775.72	641.17	939.70

- Final EV Profit:
  - The EV remuneration is formed by the energy payment, battery degradation and the EV standalone gains for the facility (Energy costs without EV – Energy costs with EV).

EV payments breakdown in $						
	TOUB (4)	TOUD (3)	TOUD Coin (5)	TOUR (2)	TOUE (3)	TOUE Coin (5)
EV energy	276.82	415.03	1936.76	845.71	1513.45	932.00
Bat Deg	146.78	224.82	1076.53	508.73	875.80	542.29
EV Remun	214.25	787.00	7392.20	197.00	391.33	1087.80
Total P EV	380.24	752.25	1208.05	775.72	641.18	939.70



Source: Thompson, A. and Perez Y., 2019

DERCAM Mathematical modelling (MILP) of the local microgrid:

$$Min\ c_{total} = c_{elec} + c_{DER} + c_{EV} - \sum_{m}\sum_{d}\sum_{h} GenS_{PV,m,d,h} \cdot TEx_{m,d,h}$$

Where:

$$c_{elec} = \sum_{m} TF_m + \sum_{m}\sum_{d}\sum_{h} UL_{m,d,h} \cdot TE_{m,d,h} + \sum_{s}\sum_{m\in s}\sum_{p} TP_{s,p} \cdot \max\left(UL_{m,(d,h)\in p}\right)$$
$$+ \sum_{m} TPNC_m \cdot \max\left(UL_{m,d,(h)\in NonCoin}\right) + \sum_{m} TPC_m \cdot UL_{m,d,(h)\in Coin}$$

$$c_{DER} = \sum_{i} (CFixcost_i \cdot Pur_i + CVarcost_i \cdot Cap_i) \cdot An_i + Cap_i \cdot DEROMFix_i$$

$$c_{ev} = \sum_{m}\sum_{h} P_{EV} \cdot \left(\frac{E_{m,h}^{r\to c}}{SCEff_{k=\{EV\}}} - E_{m,h}^{c\to r} \cdot SDEff_{k=\{EV\}}\right) + \sum_{m}\sum_{h} EVCL \cdot EVFRC \cdot (SIn_{k=\{EV\}} + SOut_{k=\{EV\}} + E_{m,h}^{r\to c} + E_{m,h}^{c\to r})$$

*See the annex to verify the constraints.

ANNEX: MODEL CONSTRAINTS

Microgrids energy balance:

$$load_{m,d,h} + \sum_k \frac{SIn_{k,m,d,h}}{SCEff_k} = \sum_k SOut_{k,m,d,h} \cdot SDEff_k + GenU_{PV,m,d,h} + UL_{m,d,h} \; \forall \text{ m, d, h.}$$

PV output constraint:

$$GenU_{PV,m,d,h} + GenS_{PV,m,d,h} \leq \frac{Cap_i}{ScPeakEff_{PV}} \cdot ScEff_{PV,m,h} \cdot SI_{m,d,h} \; \forall \text{ m, d, h: i} \in \{\text{PV}\}$$

$$\frac{CAP_{PV}}{ScPeakEff_{PV}} \leq ScArea_{PV}$$

Storage constraints:

$$Cap_k \cdot \underline{SOC_k} \leq \sum_{n=0}^{h} (SIn_{k,m,d,n} - SOut_{k,m,d,n}) \cdot (1 - \varphi_k) \leq Cap_k \cdot \overline{SOC_k} \; \forall \text{ k, m, d, h.}$$

$$SIn_{k,m,d,h} \leq Cap_k \cdot SCEff_k \; \forall \text{ k, m, d, h.}$$

$$SOut_{k,m,d,h} \leq Cap_k \cdot SDEff_k \; \forall \text{ k, m, d, h.}$$

General constraints:

$$UL_{m,d,h} \leq psb \cdot M \; \forall \text{ m, d, h.}$$

$$GenS_{PV,m,d,h} \leq (1 - psb) \cdot M \; \forall \text{ m, d, h}$$

$$Cap_i \leq Pur_i \cdot M \; \forall \text{ i}$$

$$An_i = \frac{IR}{1 - \left(\frac{1}{(1+IR)^{Lt_j}}\right)} \; \forall \text{ i}$$

$$C \leq BAUCost + \sum_i (CFixcost_i \cdot Pur_i + CVarcost_i \cdot Cap_i) \cdot \left(An_i - \frac{1}{PBPeriod}\right)$$