Karlsruhe Institute of Technology
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Economic and Social Effects of Residential Electricity Tariff Design

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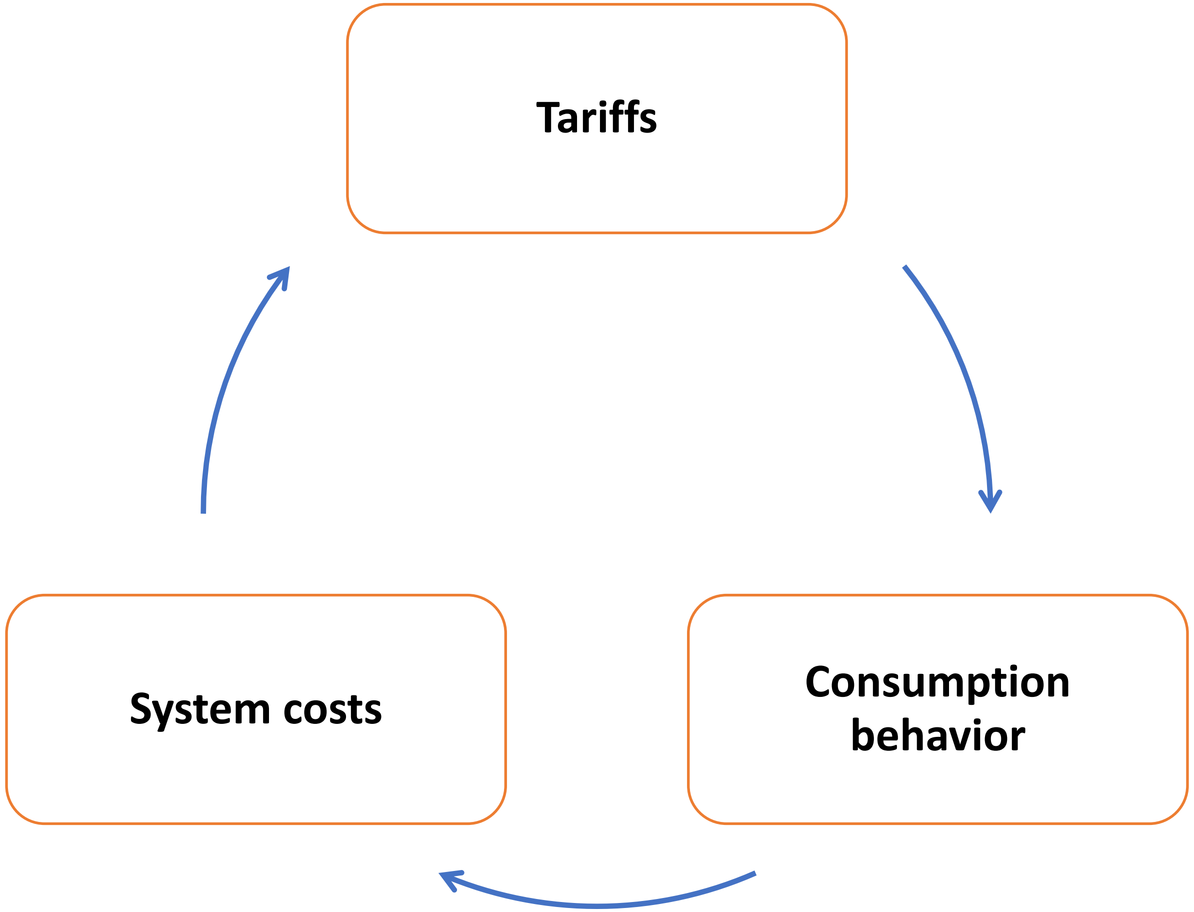
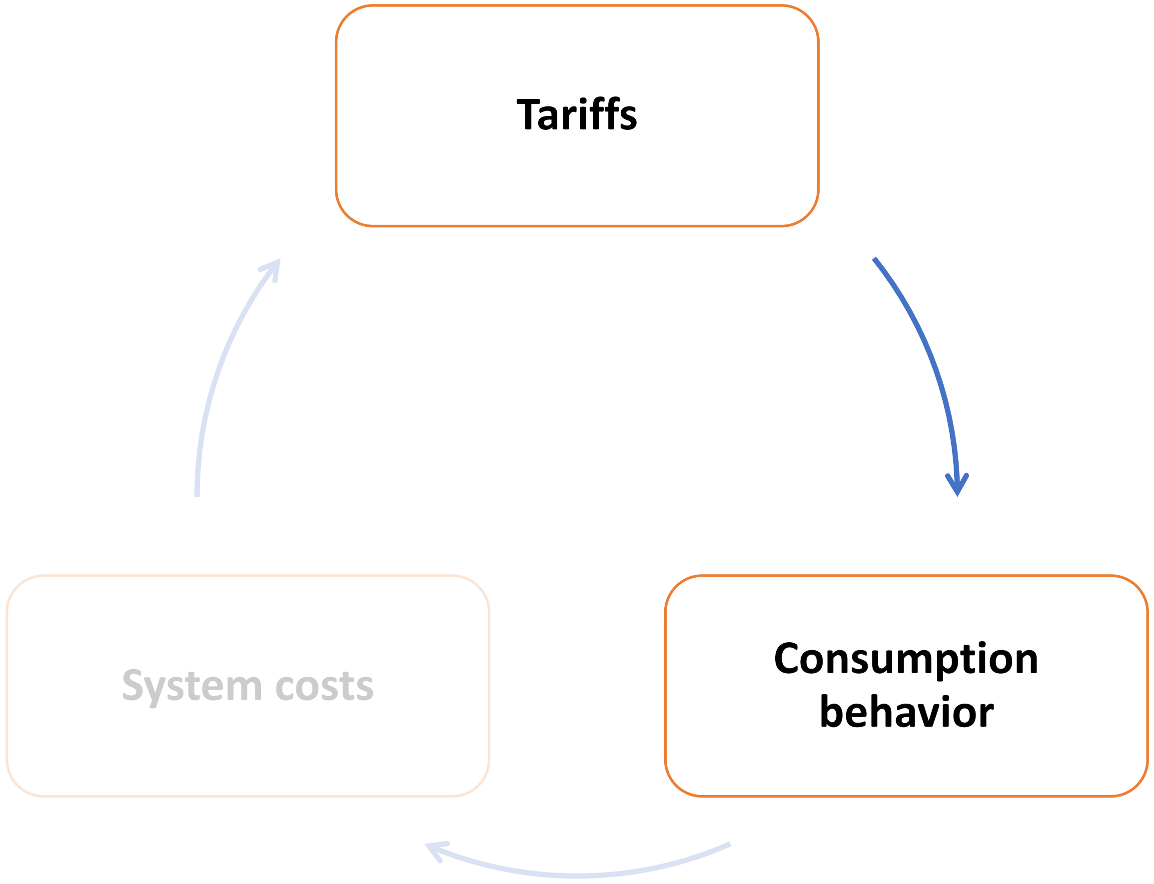
Electricity tariffs, customer behavior and system-wide costs are strongly connected



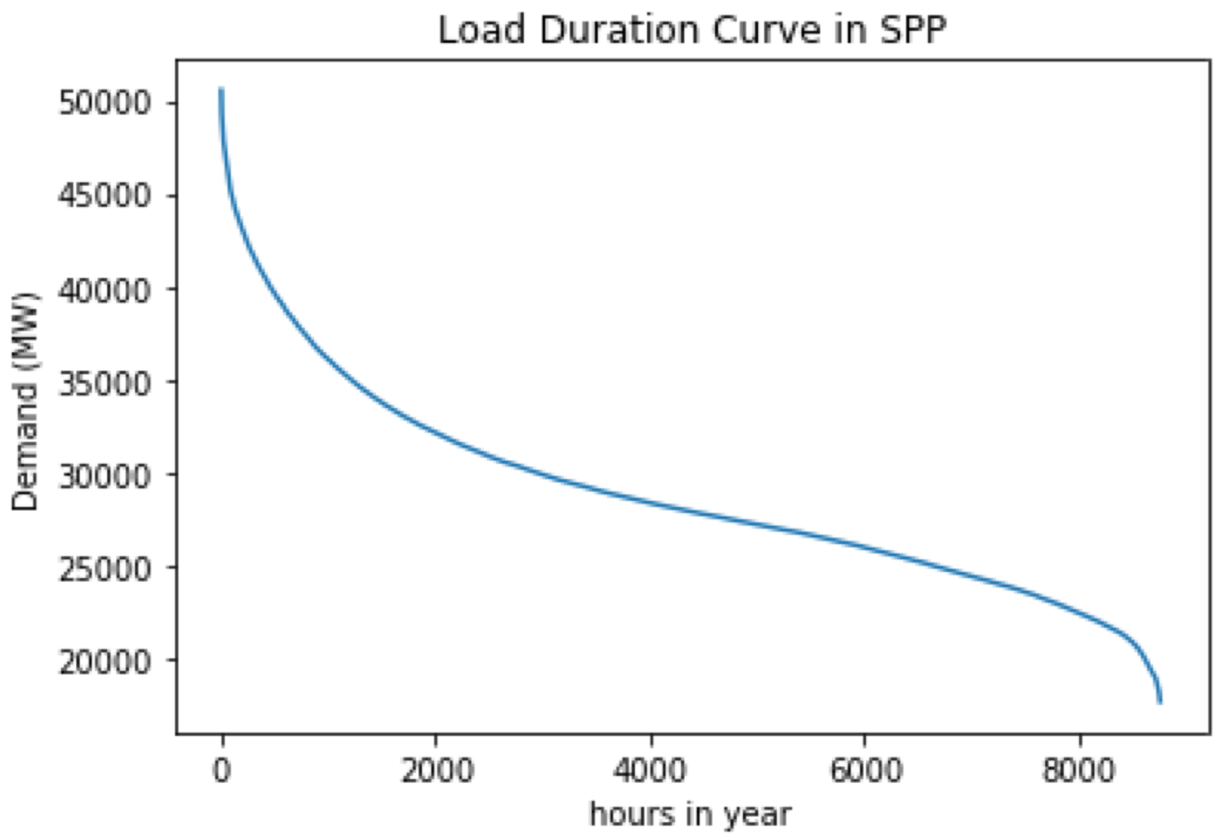
Prices influence how we consume electricity

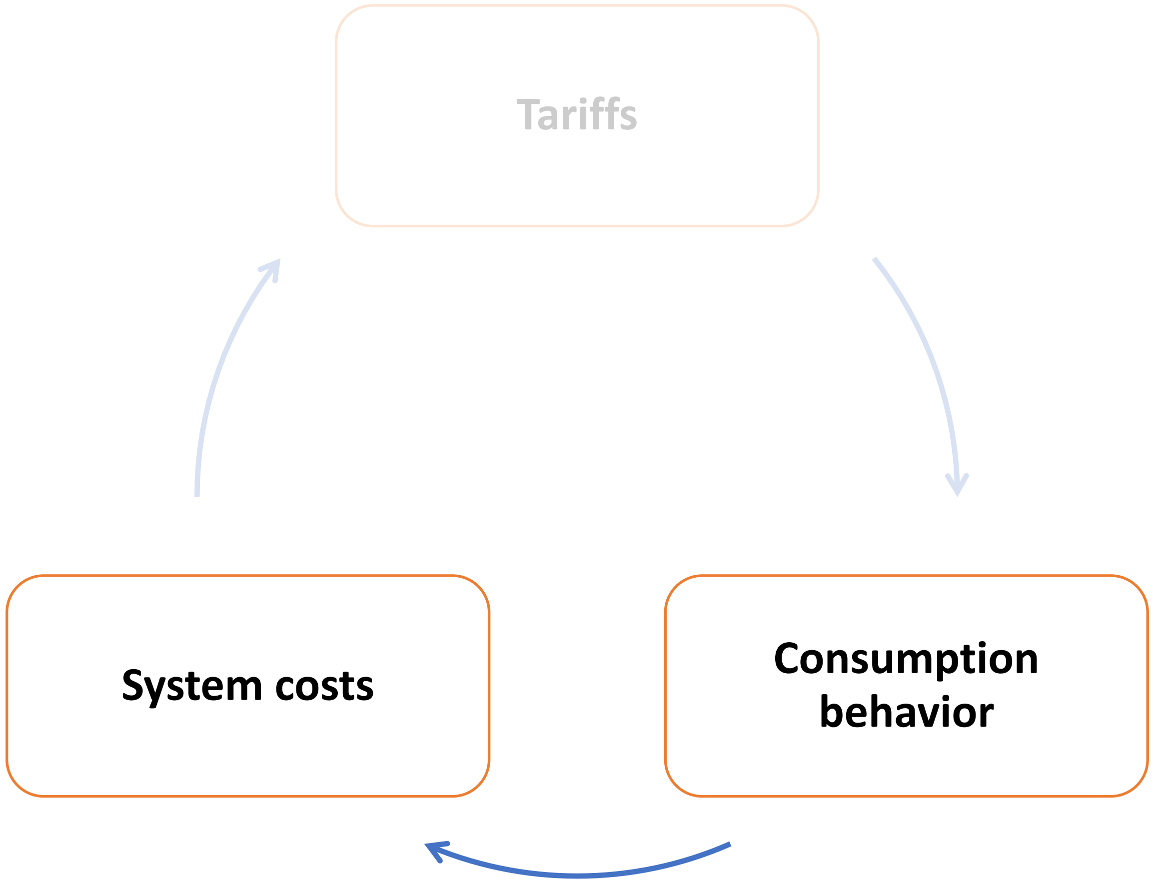
- Meta analysis of time-varying tariffs [Faruqui et al. 2017]
  - 337 treatments
  - 63 tariff pilots
  - nine countries
- Over 94% of treatments finding non-zero customer response
- *“Price-based demand response is real and predictable”*



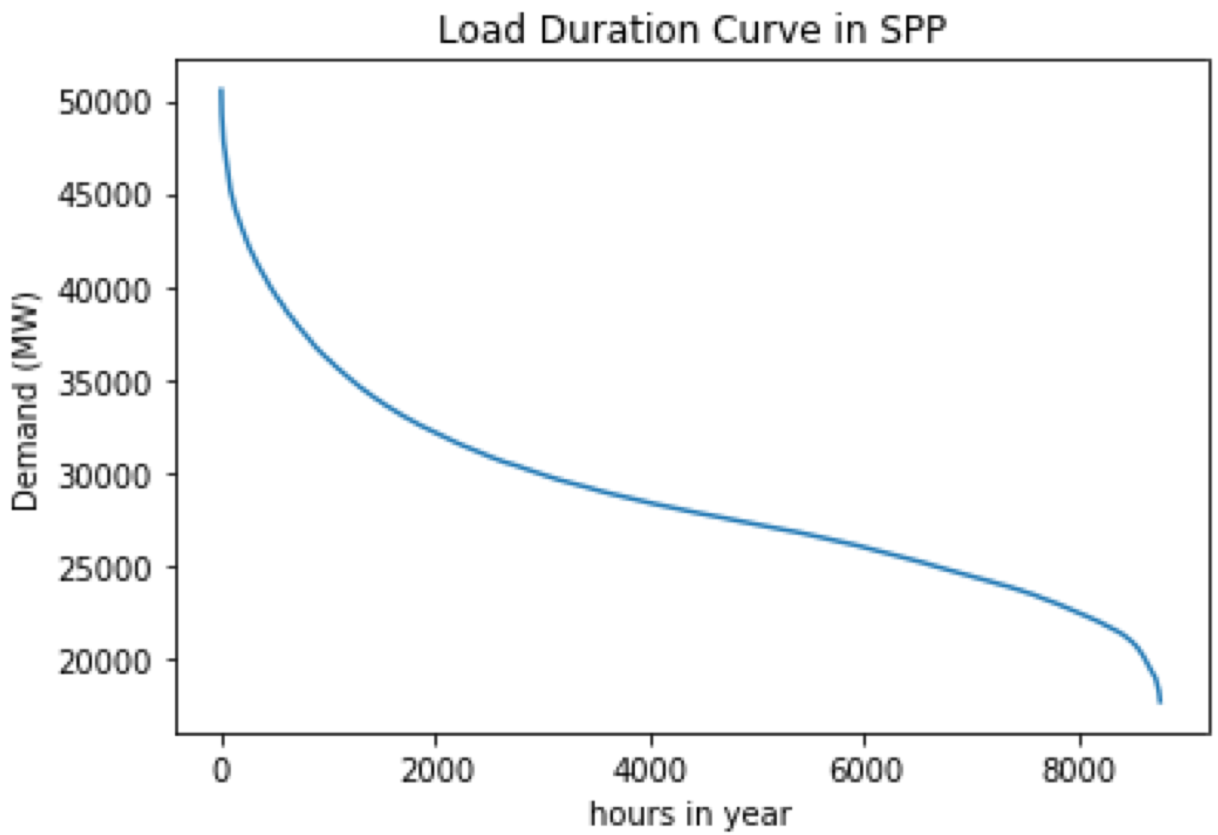
Faruqui, A., Sergici, S., & Warner, C. (2017). Arcturus 2.0 : A meta-analysis of time-varying rates for electricity. The Electricity Journal, 30(10), 64–72. doi:10.1016/j.tej.2017.11.003

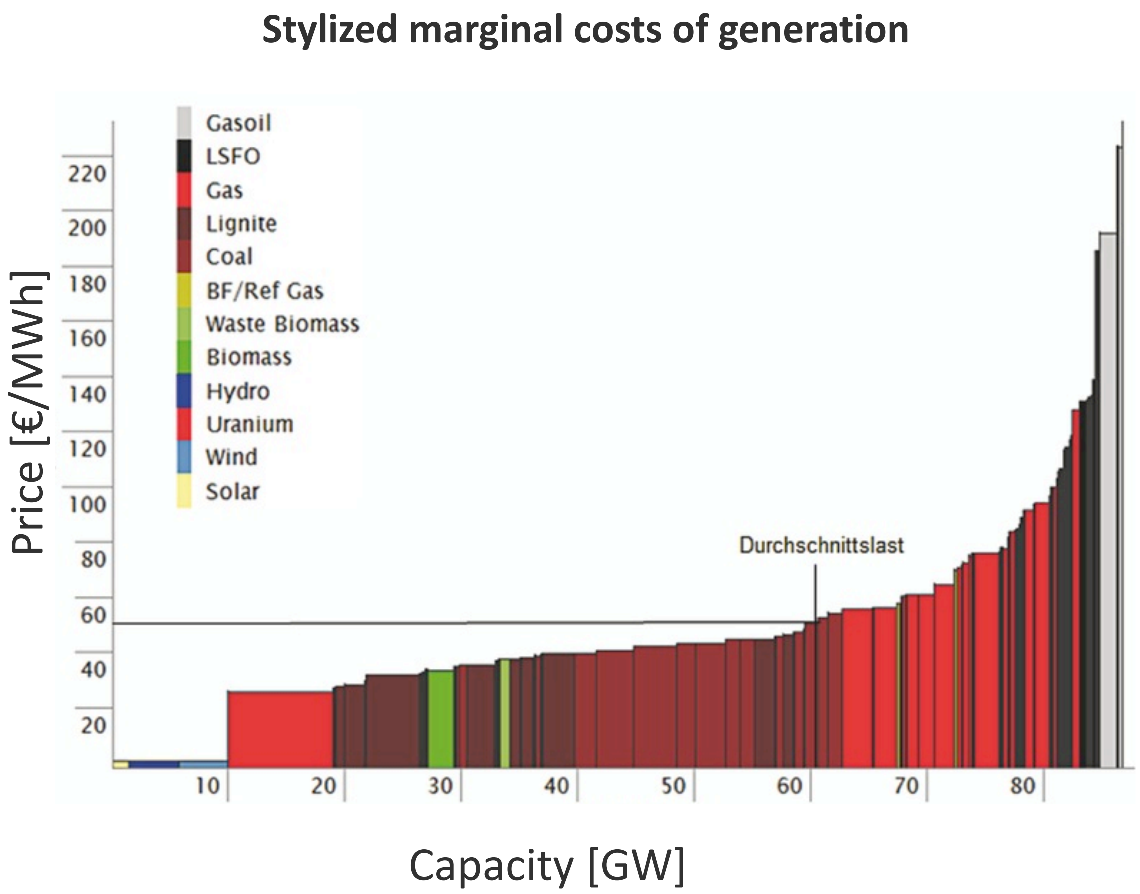
Consumption behavior determines system costs



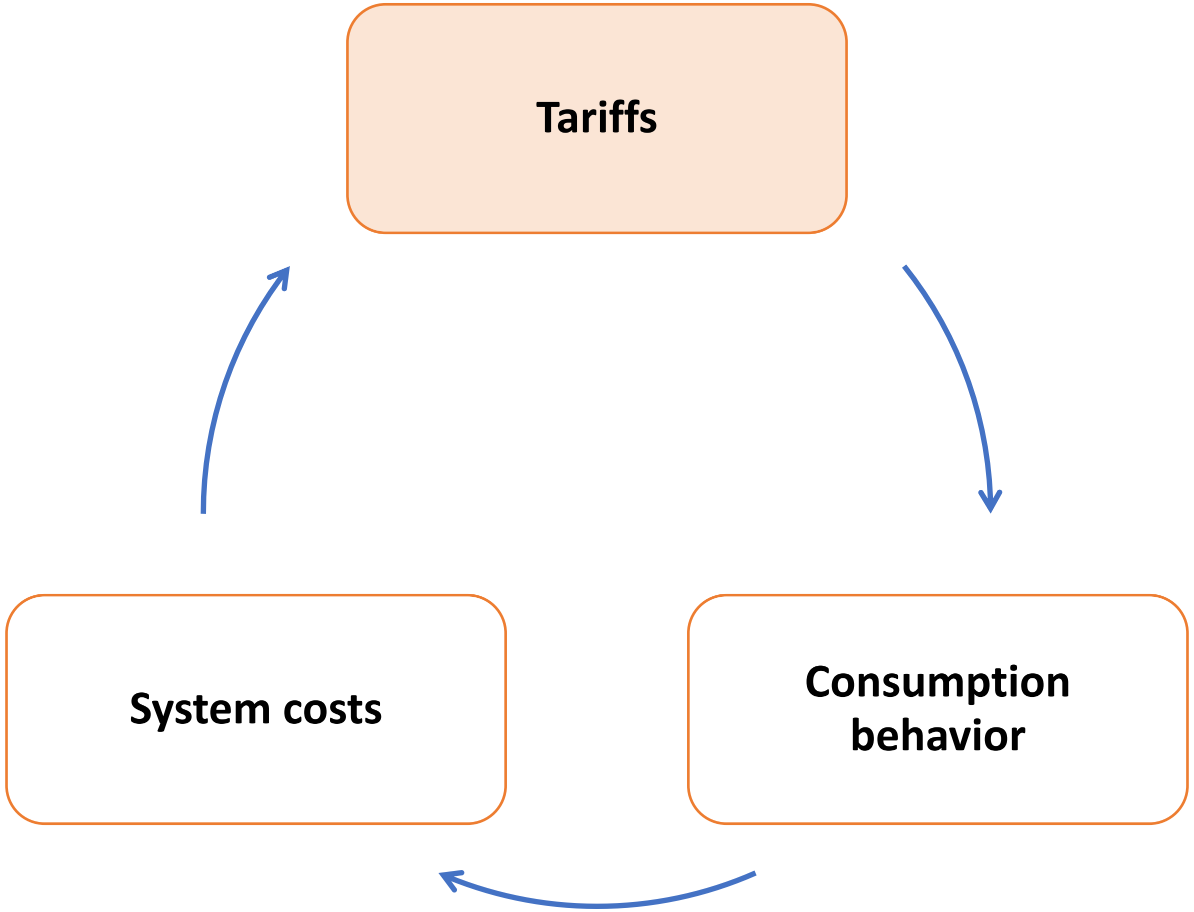


Consumption behavior determines system costs

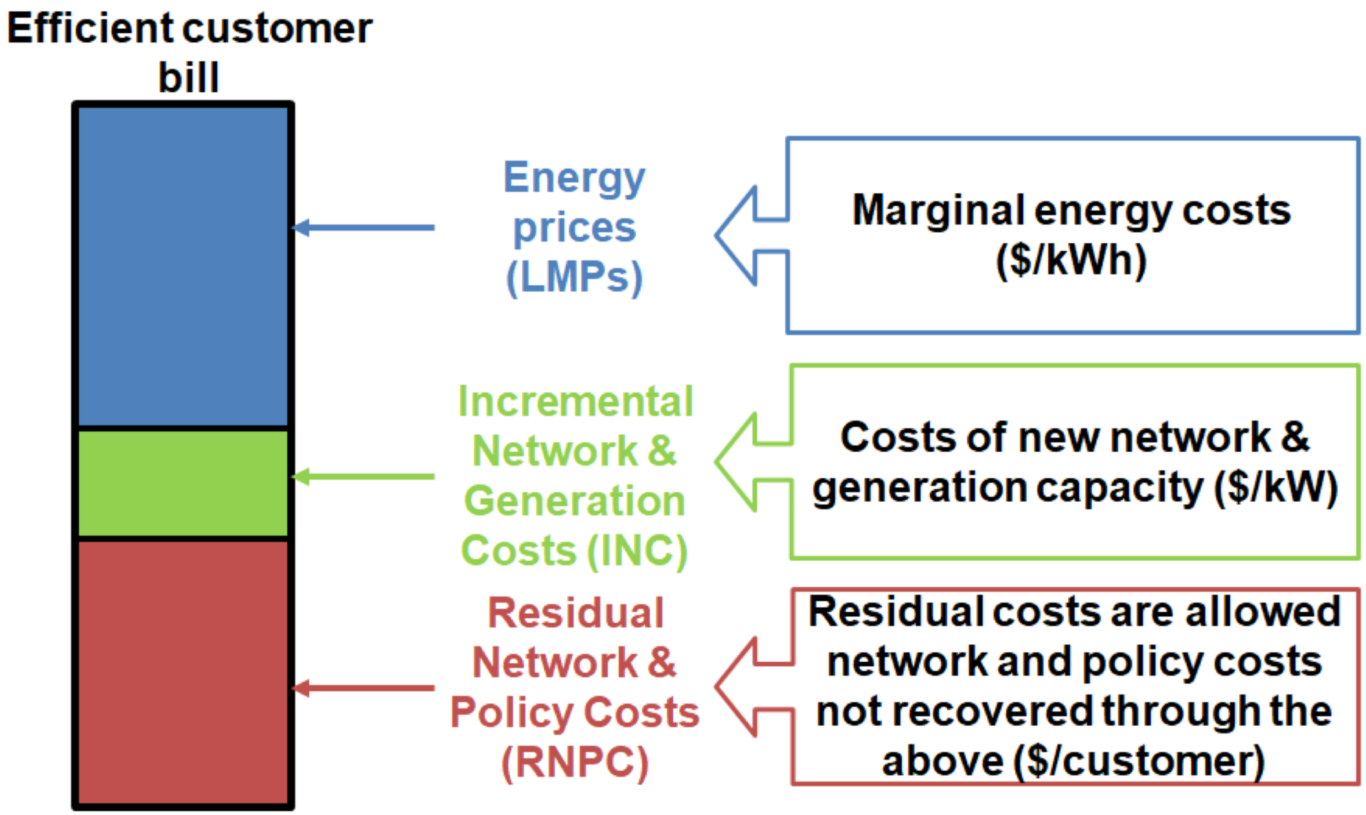




One key objective of tariffs design is to minimize overall system costs



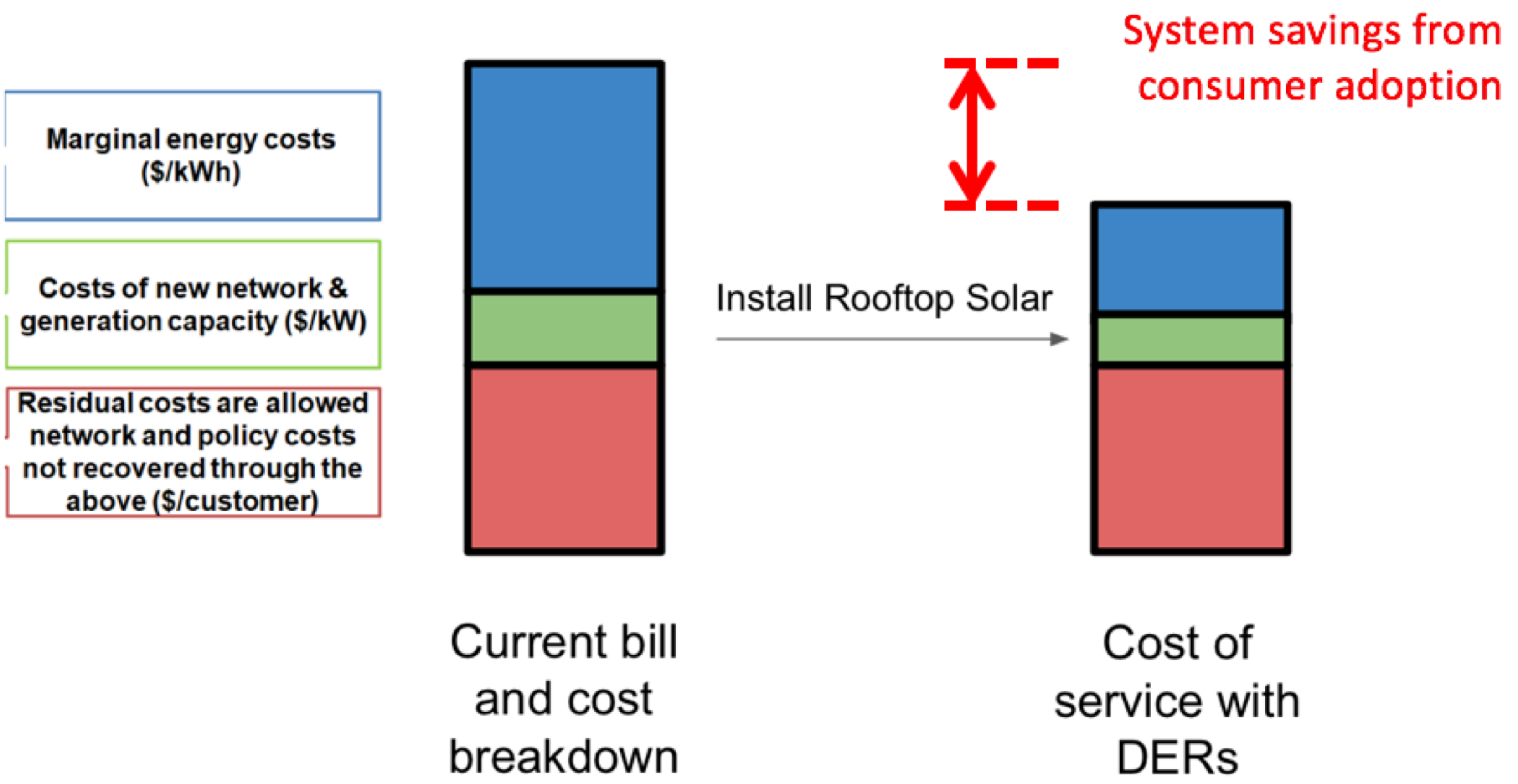
But current tariff designs have inefficiencies that increase system costs



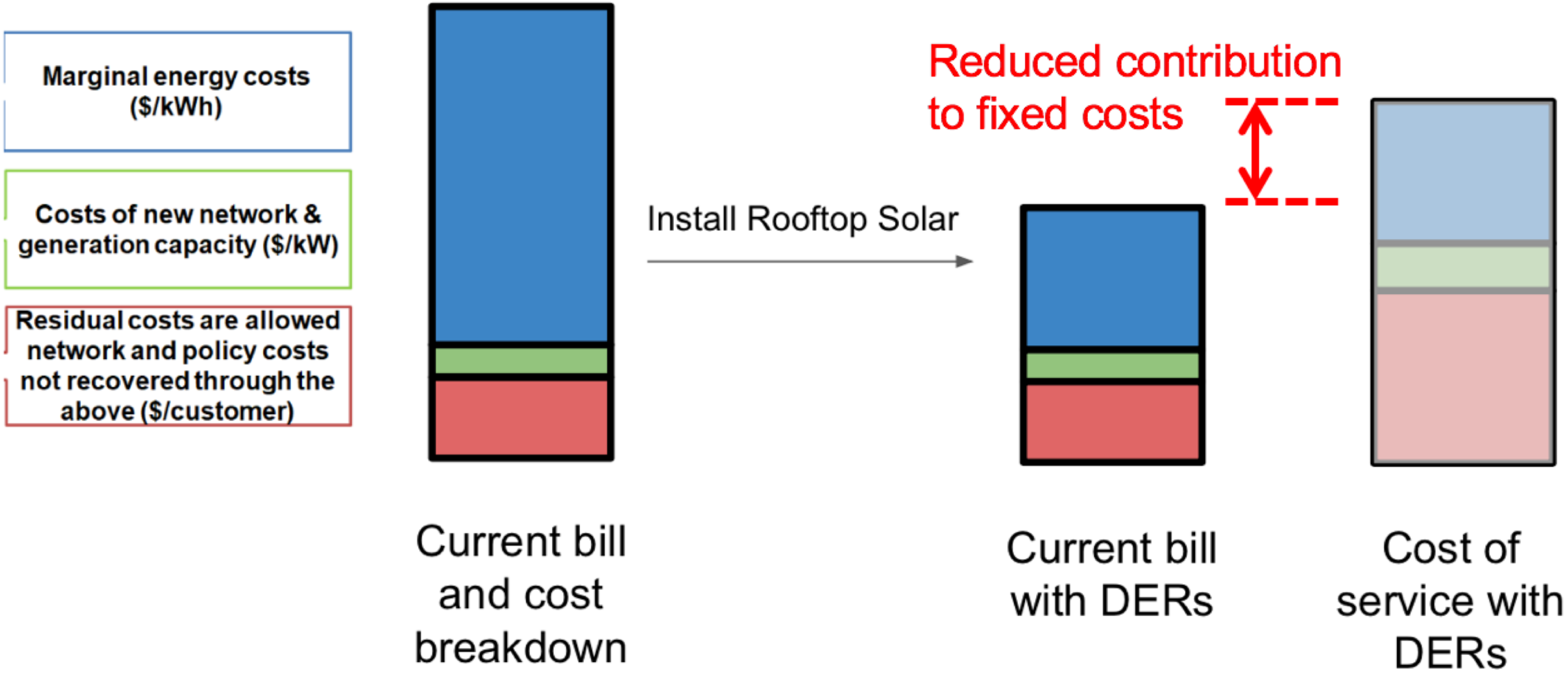
Three obvious inefficiencies with current rate design:

- Fixed costs recovered volumetrically
- Not time-based
- Not location-based

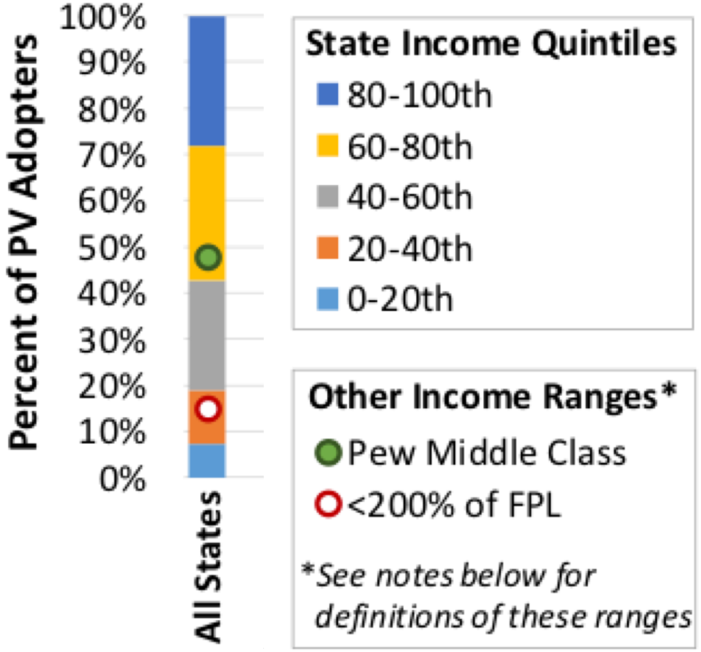
Dynamic inefficiencies are exacerbated by the growth of DERs

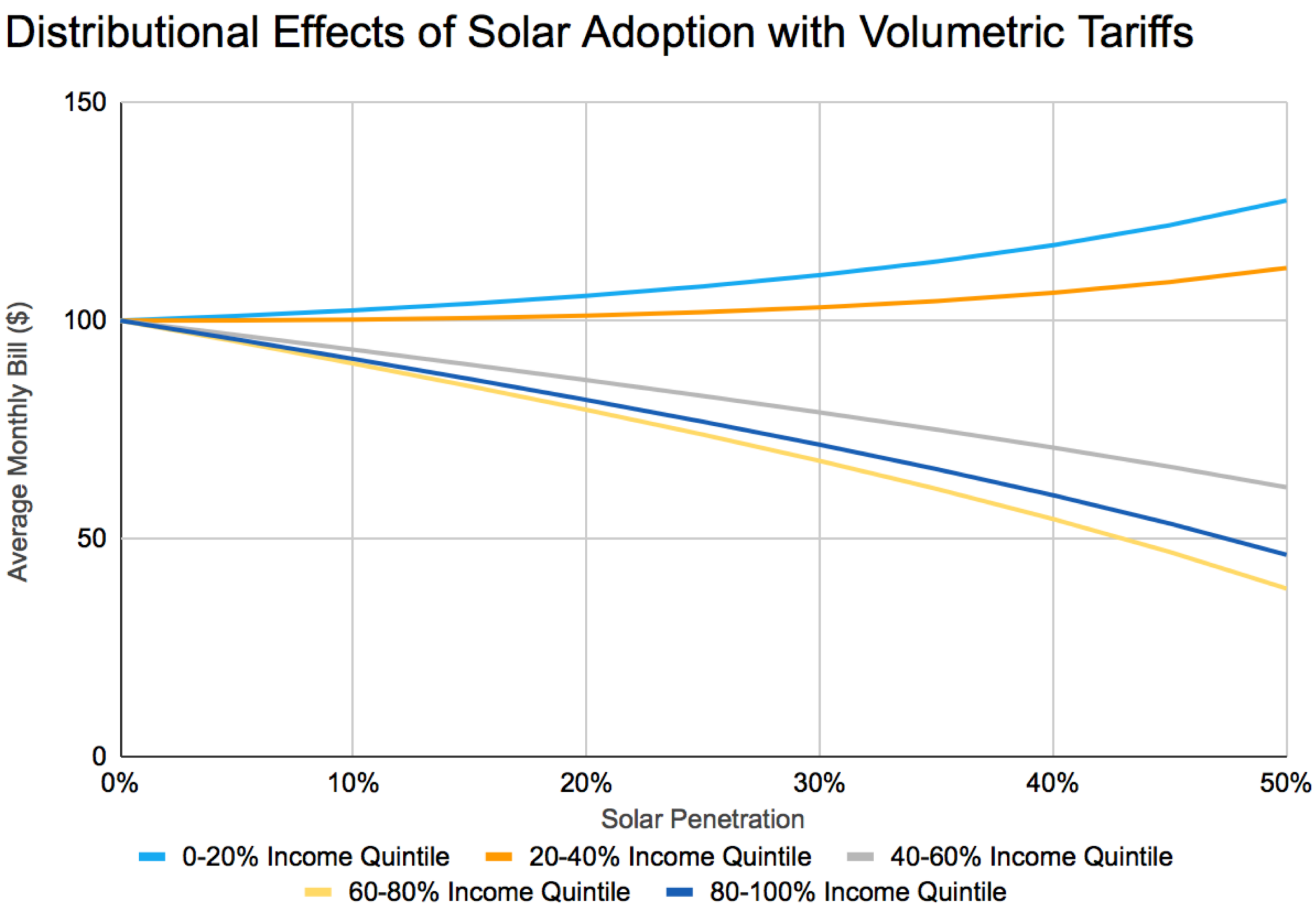


With inefficient tariffs, DER growth can raise or shift system costs

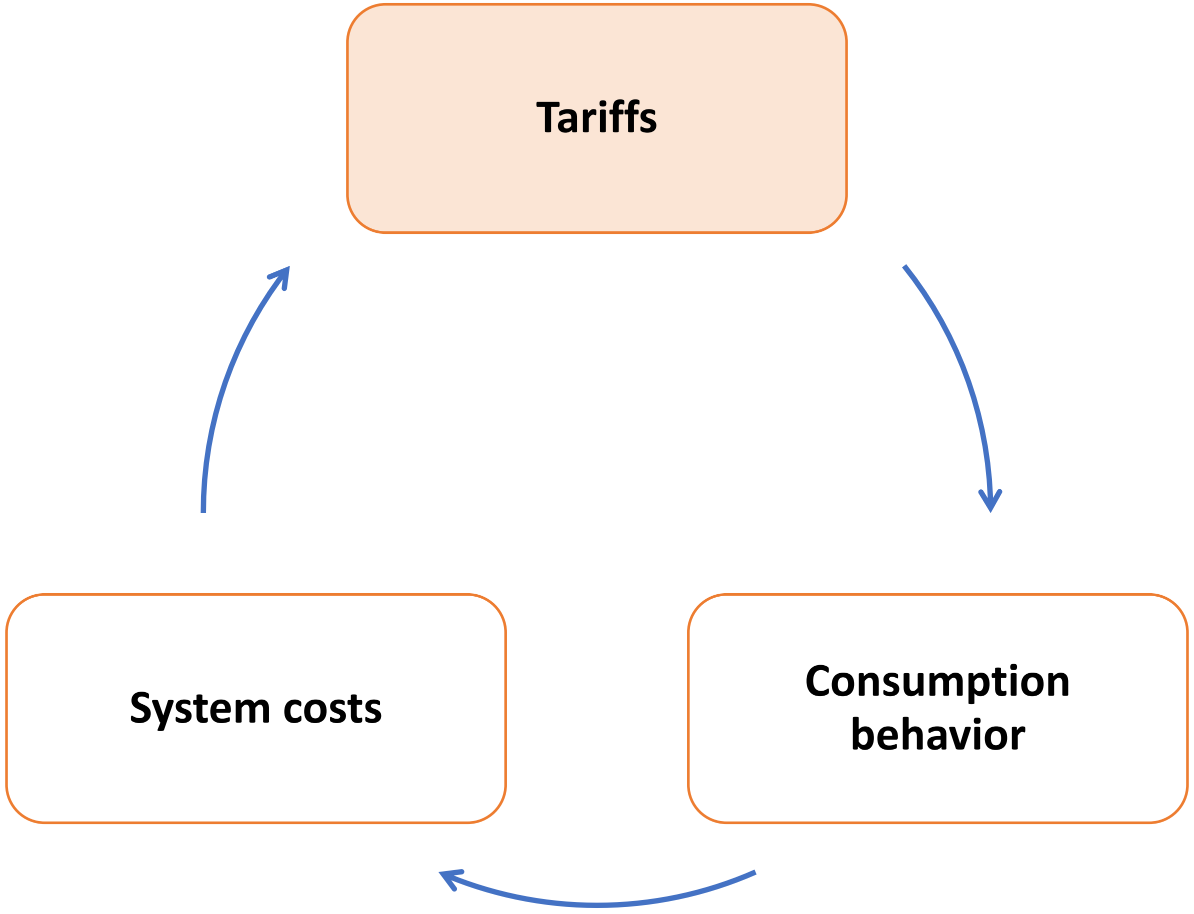


Inefficient tariffs have distributional impacts





Can some tariff designs help improve welfare?



Can some tariff designs help improve welfare?

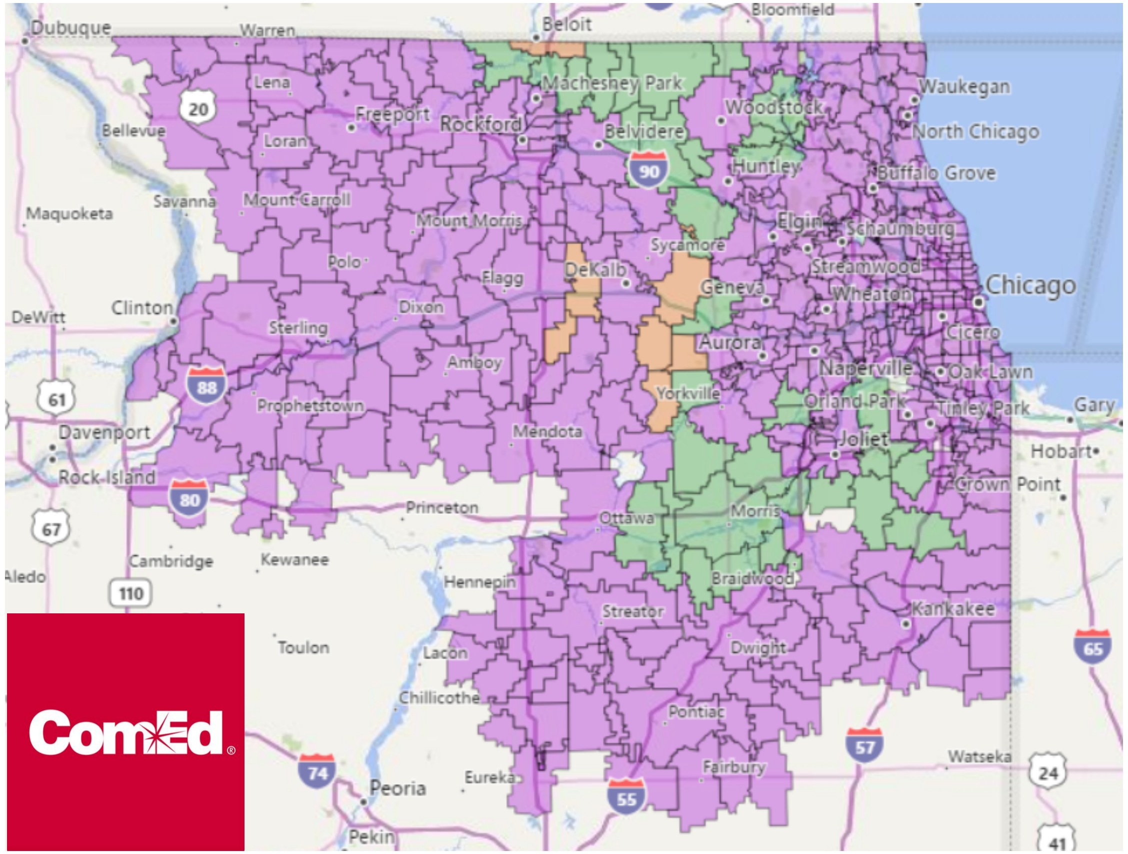
- Economic theory says yes. Many proposed improvements in existing literature.
- We test a few of these using hourly customer data.
- Then, we examine impacts on low-income customers and propose simple measures to mitigate impacts on low-income customers.

To evaluate alternative tariffs we use metering data from Chicago, USA

- 100.170 anonymized households
- Consumption January-December 2016
- 30-minute smart meter readings

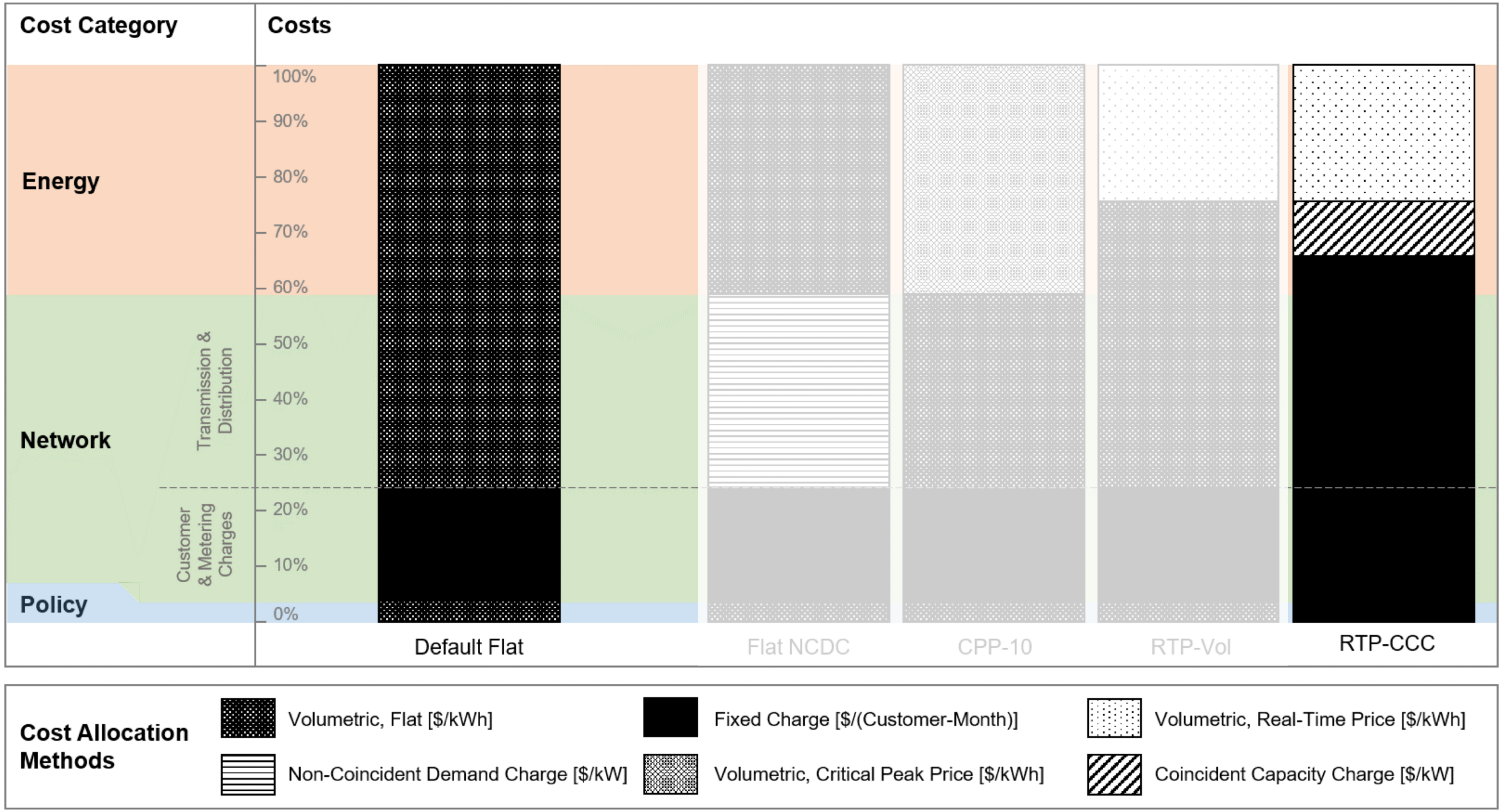
Housing type

- Heating type
- Geographic data: *9-digit zip*



Datenquelle: Commonwealth Edison, Citizens Utility Board Illinois

We create and evaluate five innovative tariffs designs



We compute tariff effects on customer expenditures and welfare for three scenarios

- **Elasticities**
  1. $\varepsilon = 0$
  2. $\varepsilon = -0{,}1$
  3. $\varepsilon = -0{,}3$

- **Formula**

$$d_{i,h}^{new} = d_{i,h}^{old} * \left(\frac{p_h^{new}}{p_h^{old}}\right)^{\varepsilon}$$

d: demand, i: customer,

h: hour, p: price

- **Rebalancing**

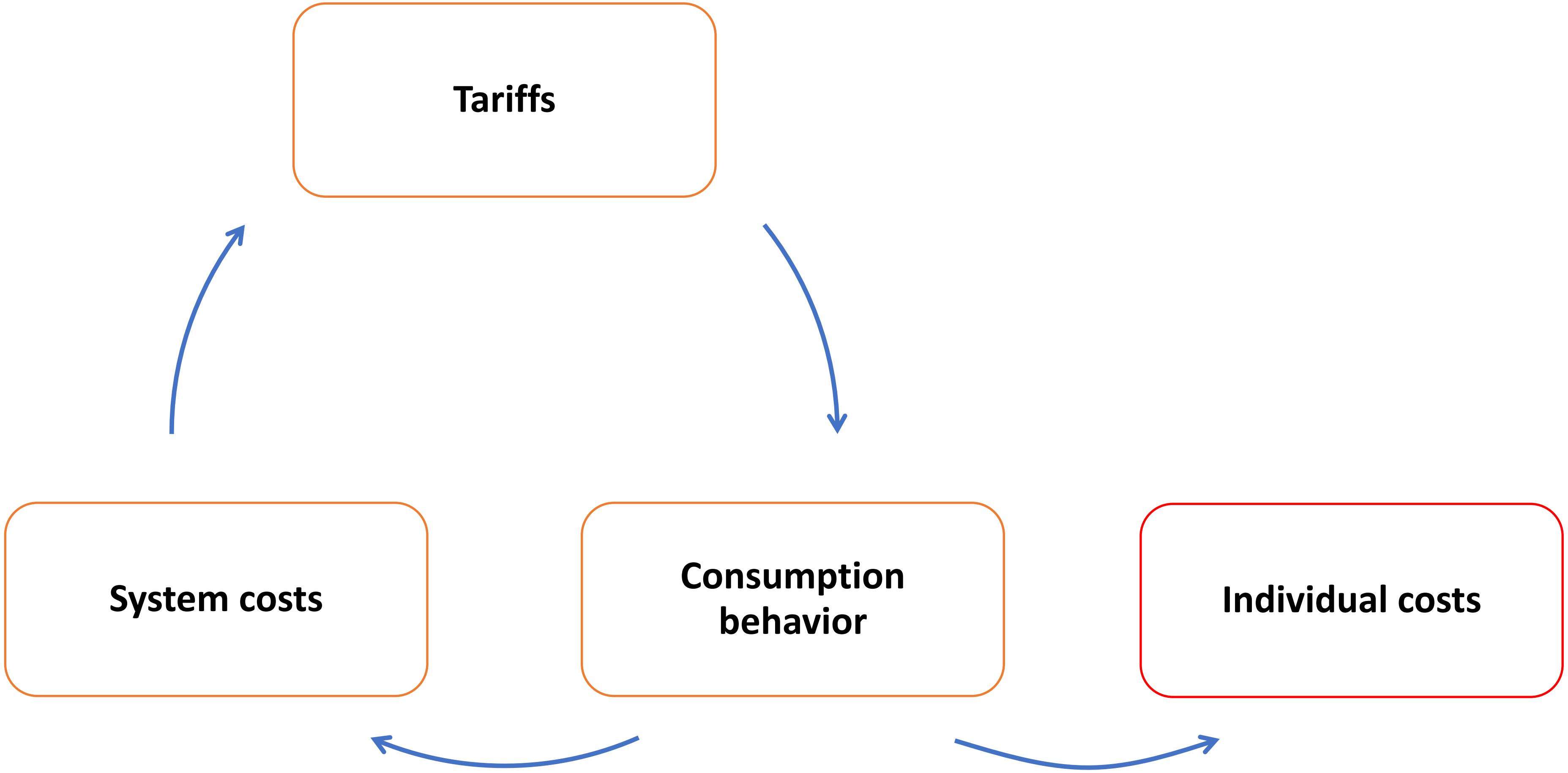
→ Adjustment of fixed charges to ensure full cost recovery for non-energy costs

Table 4: Aggregate change in consumer surplus by tariff

Elasticity Case	Flat-NCDC	CPP-10	RTP-Volumetric	RTP-CCC
ϵ = -0.1	\$983,429	\$445,683	\$125,181	\$10,036,693
ϵ = -0.3	\$3,130,361	\$1,478,859	\$390,054	\$29,237,459

\$100-300 / household / year

Yet: minimizing overall system costs is not the only objective



Minimizing overall system costs in not the only objective

EU regulators: strong concerns regarding unknown distributional effects of new tariffs [ACER 2016]

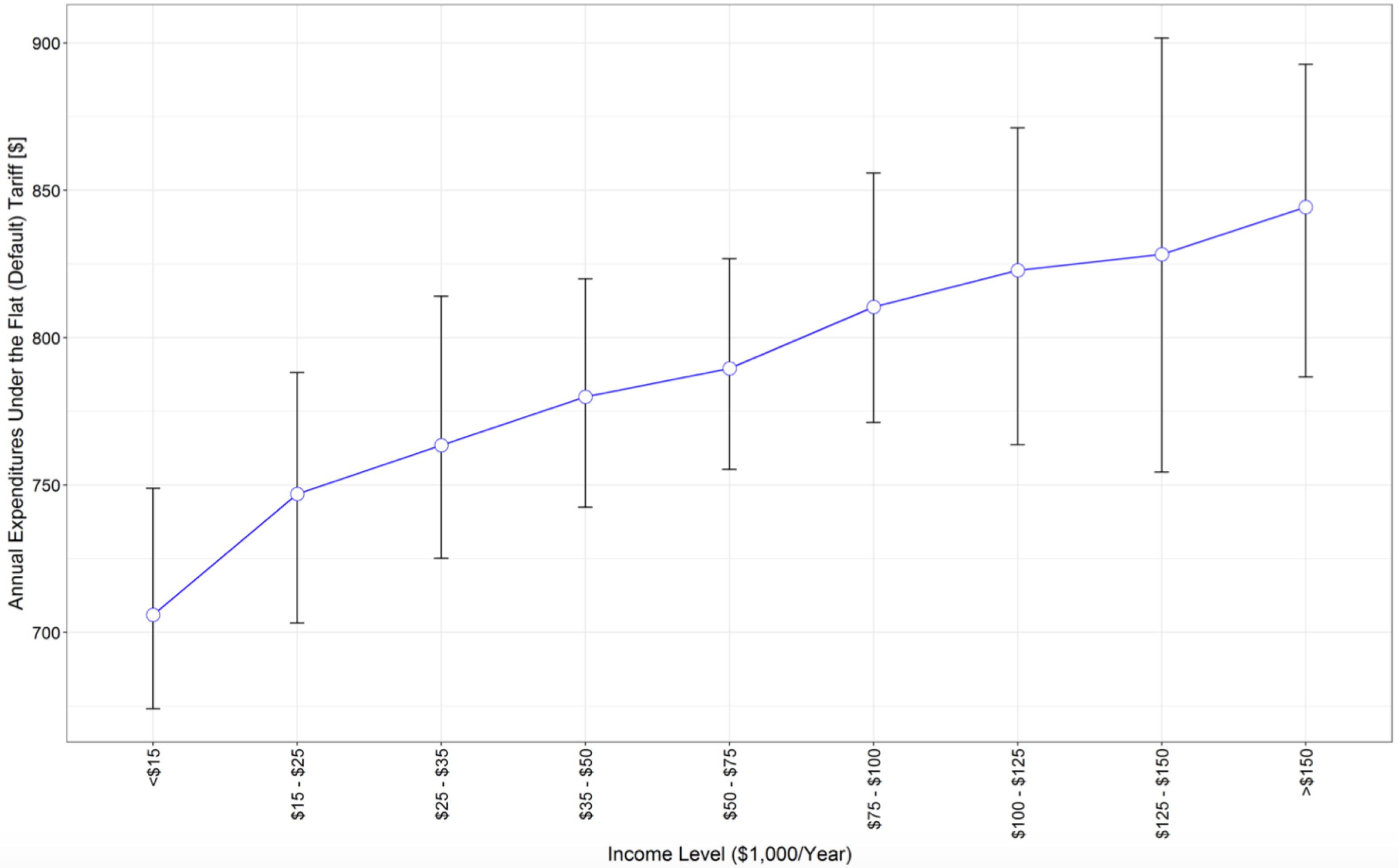
USA regulators: rejection of >80% of requests to increase fixed charges, frequently stating potential effects on low-income customers [Trabish 2018], [Proudlove et al. 2018]

→ Importance of assessing socioeconomic effects of new tariffs

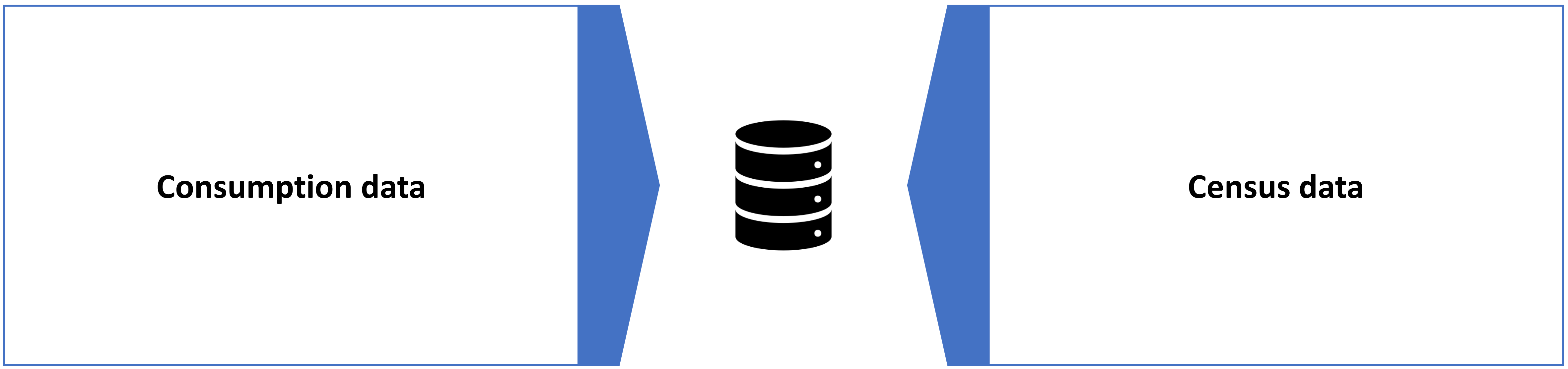
ACER Agency for the Cooperation of Energy Regulators, 2016. ACER Market Monitoring Report 2015 - Key Insights and Recommendations. Luxemburg.
Trabish, H. (2018): \Are regulators starting to rethink fixed charges?" https://www.utilitydive.com/news/are-regulators-starting-to-rethink-fixed-charges/530417/, accessed: 2018-10-22.
Proudlove, A., B. Lips, and D. Sarkisian (2018): \50 States of Solar: Q2 2018 Quarterly Report," Report, NC Clean Energy Technology Center.

Current tariffs in many U.S. locations help keep rates low for low-income customers

Figure 1: Annual electricity expenditures under the Flat (default) ComEd tariff



Matching consumption data with census data enables broad socioeconomic analyses



Socioeconomic data

Geographic data: Census Block Group (CBG)

Distribution of household income in each Census Block Group

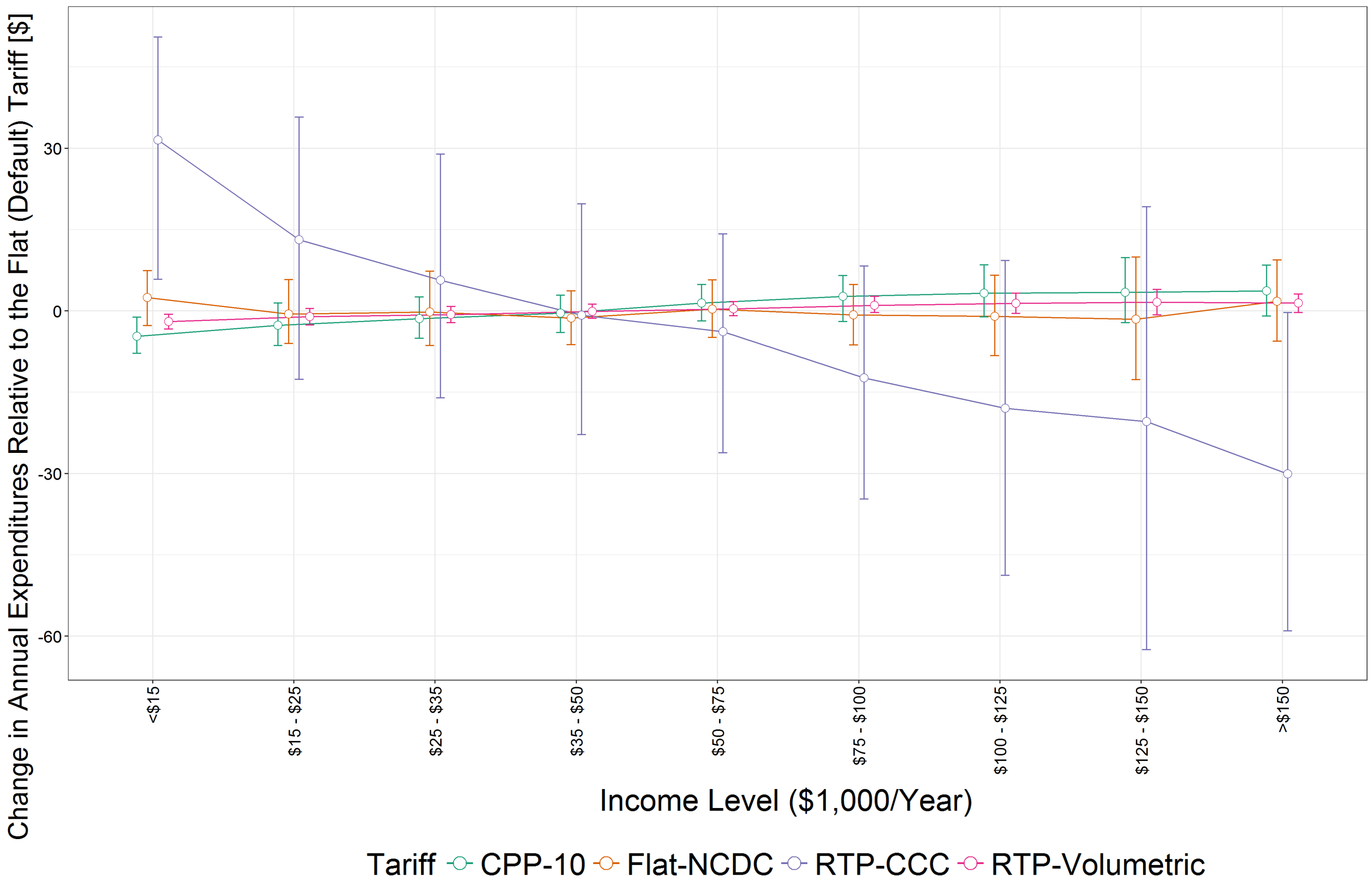
United States Census Bureau

- Nine discrete income classes
- Assumption: same income probability distribution for all households
- Bootstrapping to determine confidence intervals of results

Quelle: US Zensus 2010-2015

Effects of tariffs on electricity bills of low-income households (scenario: $\varepsilon = 0$)

Tariff changes	Effects on bills
Increased time-variability	↘
Increased fixed charges	↑
Capacity charges	?



Proposals for mitigating bill impacts: Progressive Fixed Charges

- Objective: Maintain overall system savings while avoiding undesired social effects
- Idea: Differentiating fixed charges according to certain customer criteria
- Two proposals for discriminating variables:
    1. Customer demand characteristics
    2. Customer income

Progressive fixed charges based on customer demand characteristics

Table 5: Average Profile Variables by Income

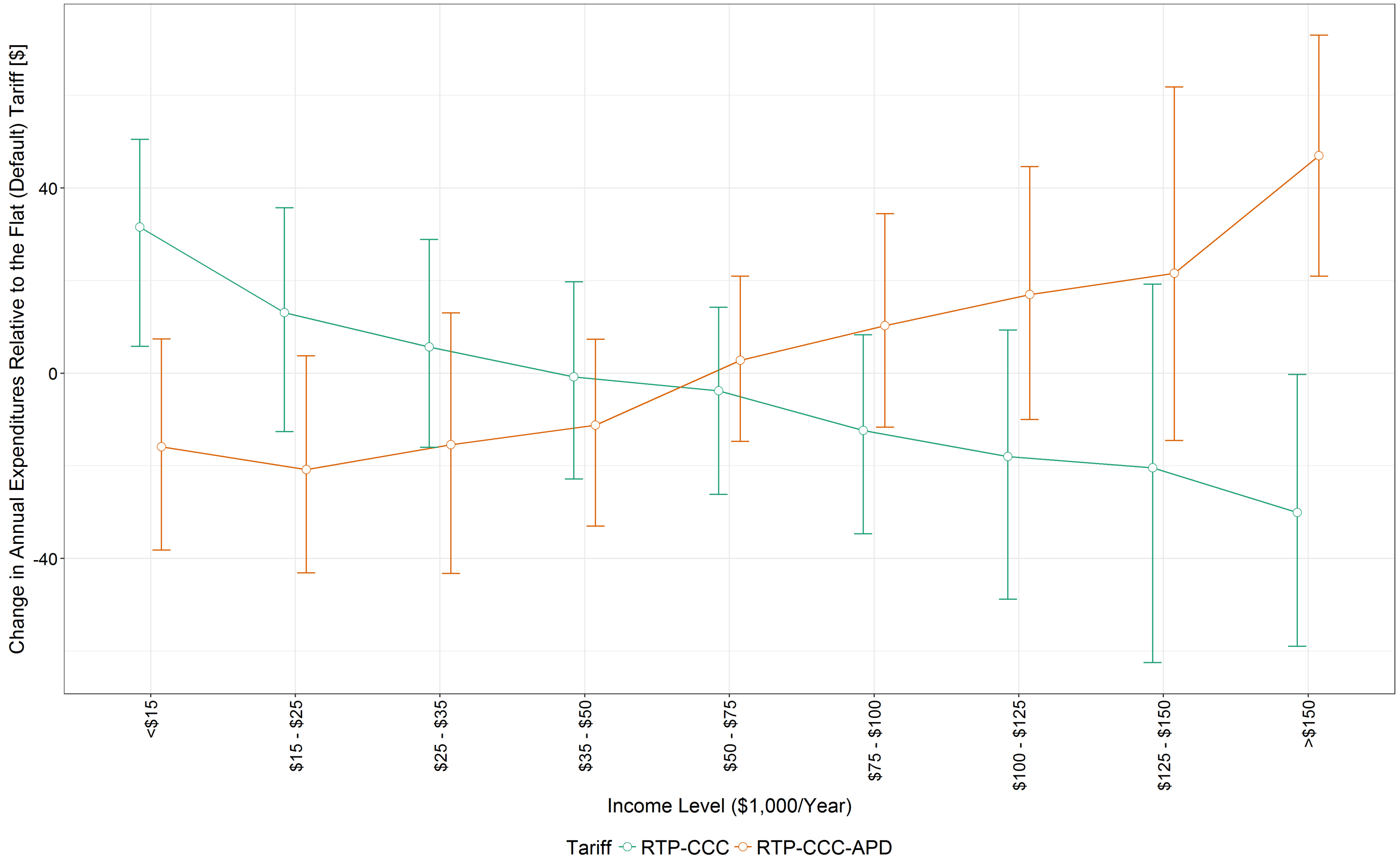
Income ($1,000 USD)	Average Monthly Consumption	Annual Peak Demand	Peak-To-Off-Peak Ratio	May Peak Demand	June Peak Demand	July Peak Demand	August Peak Demand	Consumption: 5:30PM-6:00PM	Consumption: 6:00PM-6:30PM	Consumption: 6:30PM-7:00PM
<$15	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
$15 – $25	1.07	1.03	0.95	1.05	1.06	1.05	1.05	1.08	1.08	1.08
$25 – $35	1.10	1.06	0.95	1.09	1.09	1.09	1.09	1.12	1.12	1.11
$35 – $50	1.12	1.09	0.95	1.12	1.13	1.13	1.12	1.15	1.15	1.15
$50 – $75	1.14	1.13	0.97	1.17	1.17	1.17	1.16	1.18	1.18	1.18
$75 – $100	1.18	1.17	0.97	1.22	1.22	1.22	1.21	1.23	1.23	1.23
$100 – $125	1.20	1.19	0.97	1.25	1.26	1.25	1.25	1.26	1.26	1.26
$125 – $150	1.21	1.21	0.98	1.27	1.28	1.27	1.27	1.28	1.28	1.27
>$150	1.25	1.29	1.02	1.36	1.35	1.34	1.33	1.32	1.33	1.32

Table 9: Average Profile Variables by Income

Income ($1,000 USD)	Average Monthly Consumption	Annual Peak Demand	Peak-To-Off-Peak Ratio	May Peak Demand	June Peak Demand	July Peak Demand	August Peak Demand	Consumption: 5:30PM-6:00PM	Consumption: 6:00PM-6:30PM	Consumption: 6:30PM-7:00PM
<$15	464.53	3.98	15.01	2.81	3.13	3.25	3.24	141.83	144.77	146.26
$15 – $25	496.02	4.11	14.31	2.94	3.30	3.42	3.40	153.56	156.47	157.87
$25 – $35	509.26	4.23	14.22	3.04	3.42	3.53	3.52	158.59	161.60	163.04
$35 – $50	521.05	4.33	14.22	3.13	3.54	3.65	3.63	163.53	166.58	167.96
$50 – $75	530.48	4.49	14.49	3.27	3.67	3.79	3.76	167.72	170.97	172.34
$75 – $100	546.66	4.63	14.51	3.41	3.83	3.94	3.92	174.55	177.91	179.21
$100 – $125	556.69	4.74	14.56	3.52	3.94	4.06	4.03	179.03	182.63	183.94
$125 – $150	561.76	4.82	14.73	3.58	4.01	4.12	4.10	181.42	185.09	186.39
>$150	578.45	5.14	15.34	3.82	4.23	4.35	4.32	187.63	192.09	193.67

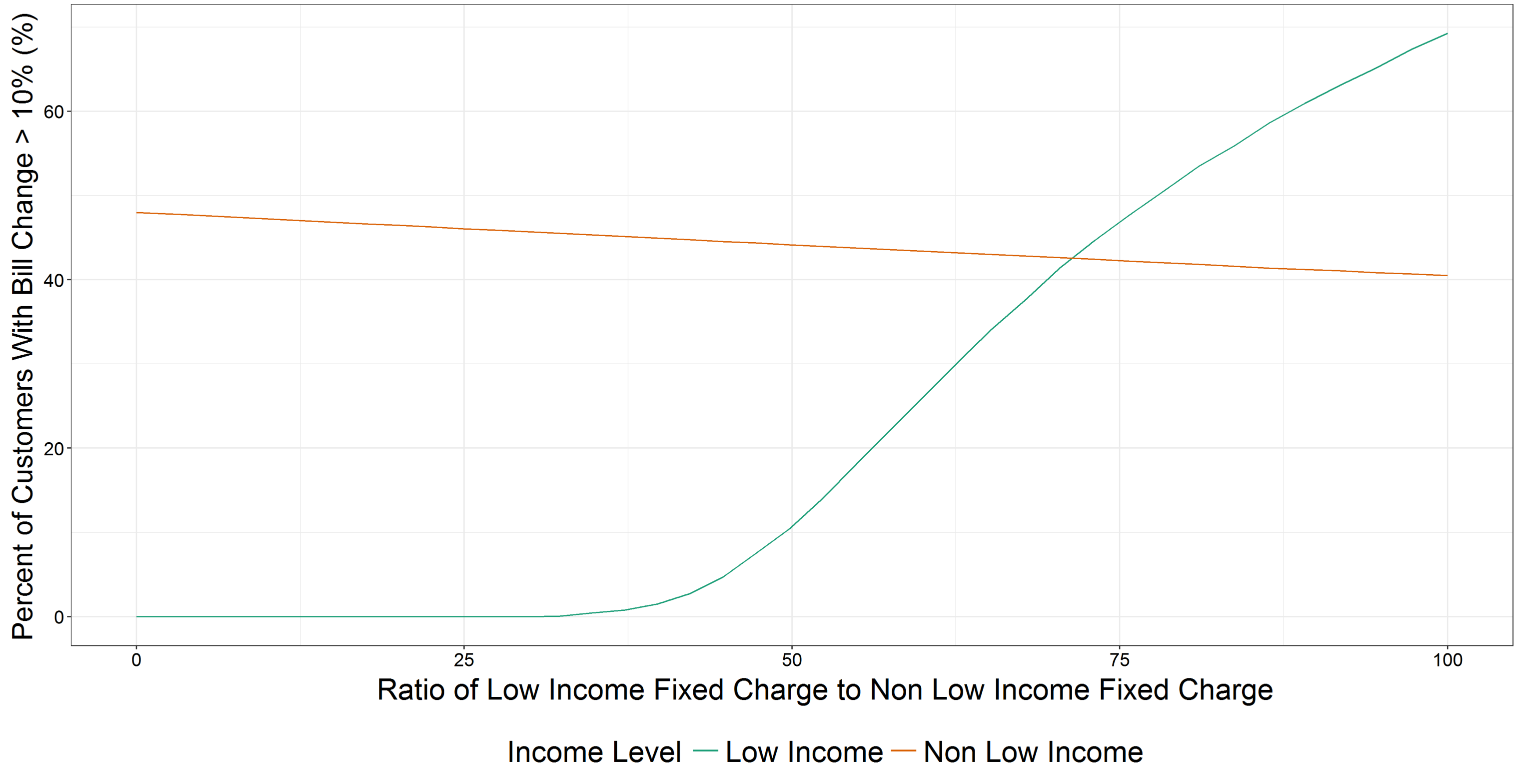
Progressive fixed charges based on customer demand characteristics

- Feasible with existing and available data
- Risk of Type 1 and Type 2 errors
- Inefficient incentives when changed frequently



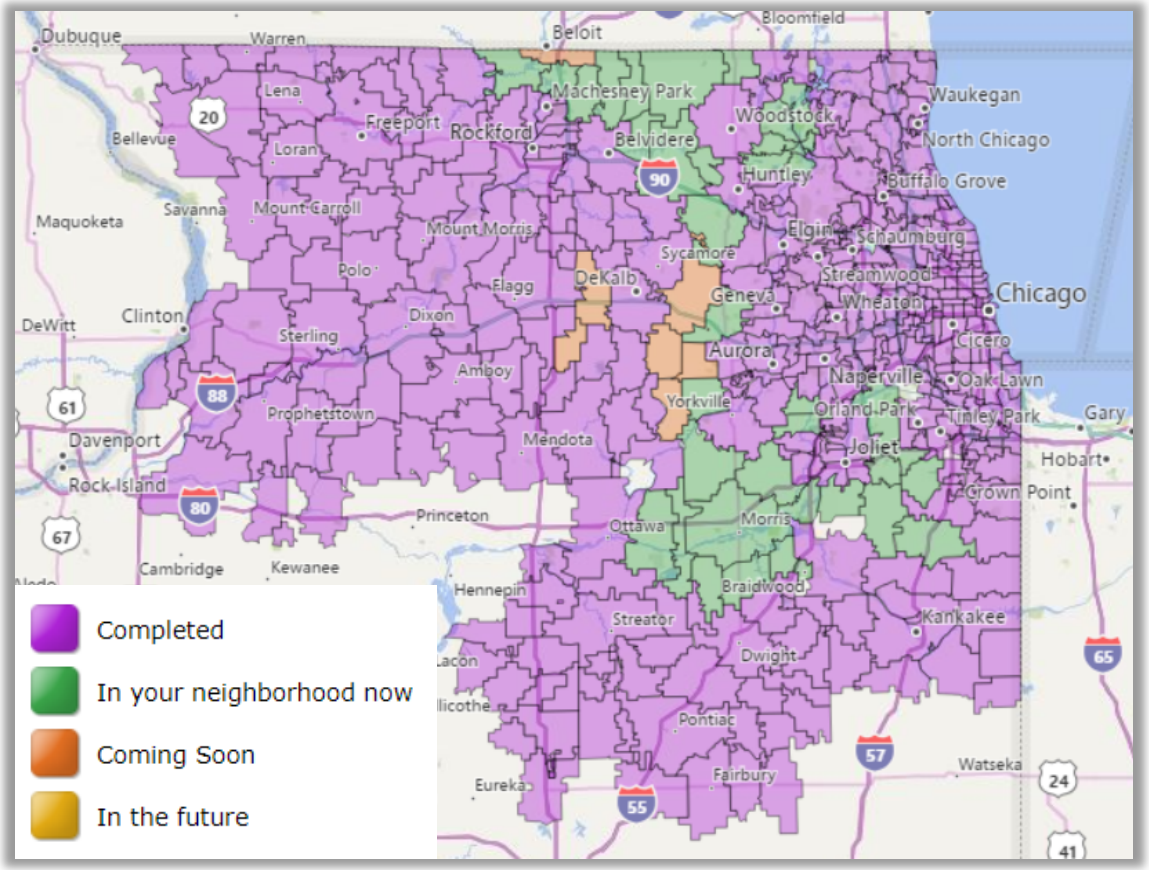
Progressive fixed charges based on customer income

- No Type 1 and Type 2 errors
- Granular control over distributional effects
- Additional sensitive customer data required



Limitations

- Consumption data
  - Cleaned according to "15/15 rule" before publishing
  - Not per se representative for US (or European) population
- Variable ''household income'' ignores number of residents in a household
- Assumptions for demand sensitivity:
  - All customer groups have the same elasticity
  - Customers react only to $/kWh-prices
  - Cross-price elasticity is zero



Conclusion

1. Any transition to new tariffs creates winners and losers.
2. Moving volumetric components towards more time-varying prices benefits low-income customers (on average).
3. Transitioning to higher fixed charges causes higher average expenditures for low-income customers on average.
4. Differentiating fixed charges according to customer criteria can mitigate some or all of the undesirable distributional impacts while maintaining the desired economic efficiency benefits.

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Thank you for your attention

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