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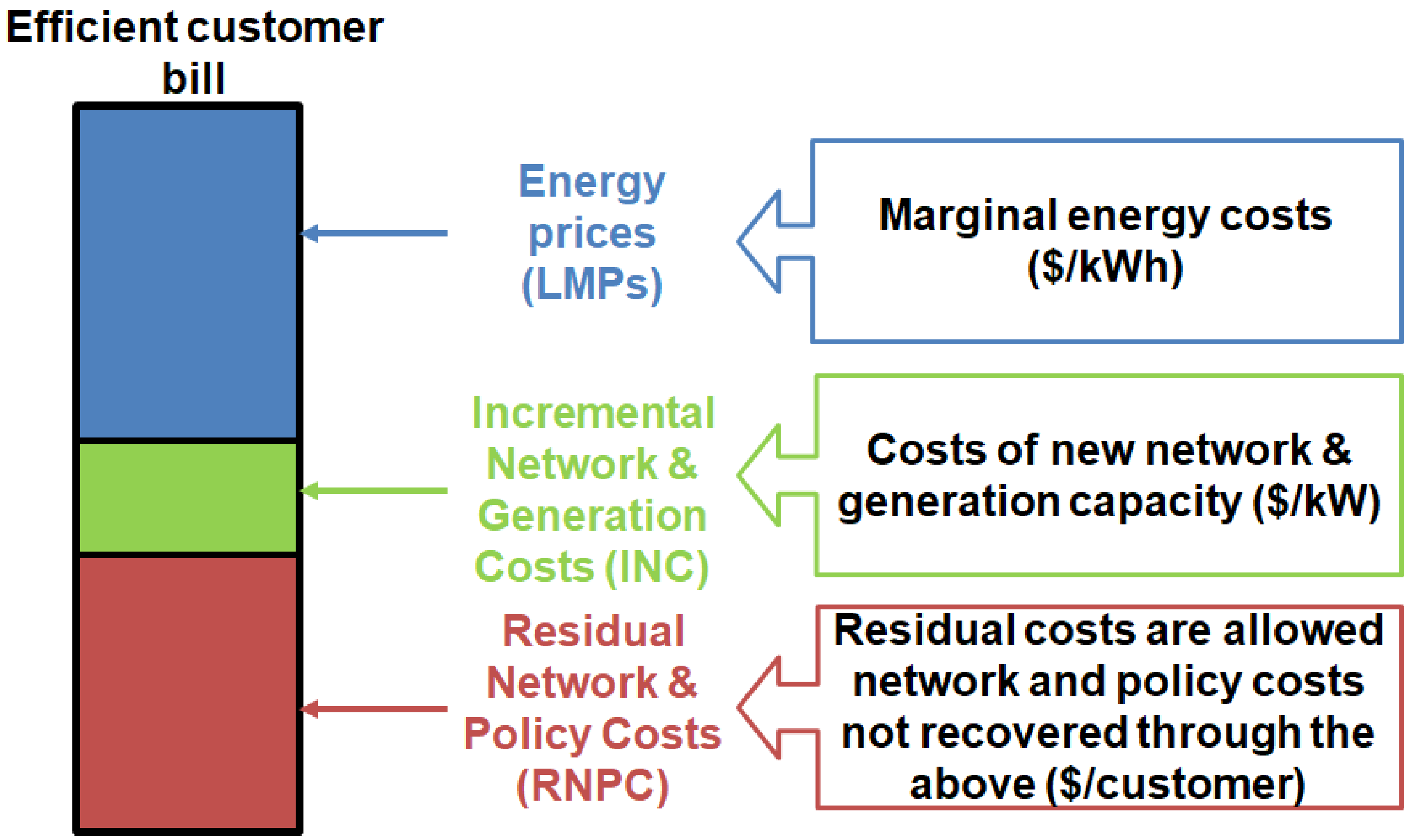
The Efficiency and Distributional Effects of Alternative Residential Electricity Rate Designs

Scott Burger, Christopher Knittel, Ignacio Pérez-Arriaga, Ian Schneider, Frederik vom Scheidt

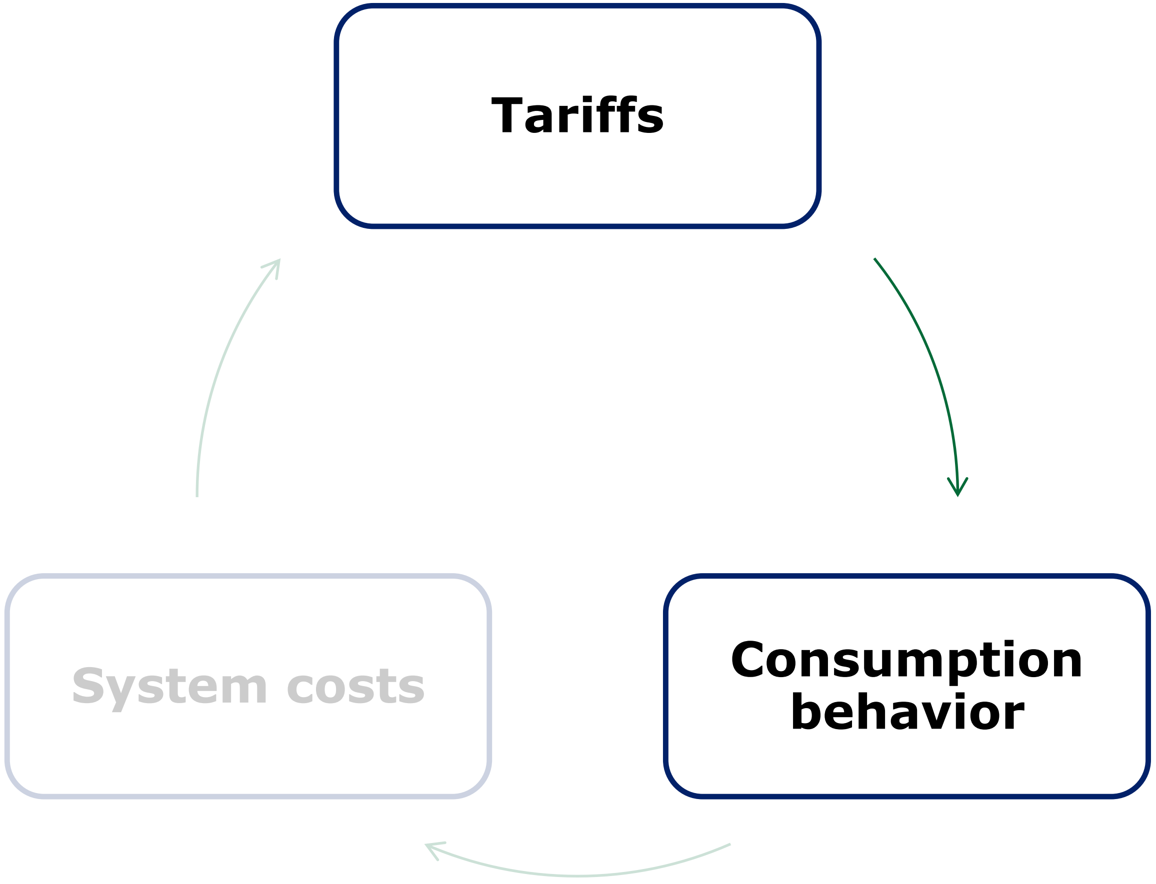
Current tariff designs have inefficiencies that increase system costs

- Three obvious inefficiencies with current rate design:
  - Fixed costs recovered volumetrically
  - Not time-based
  - Not location-based



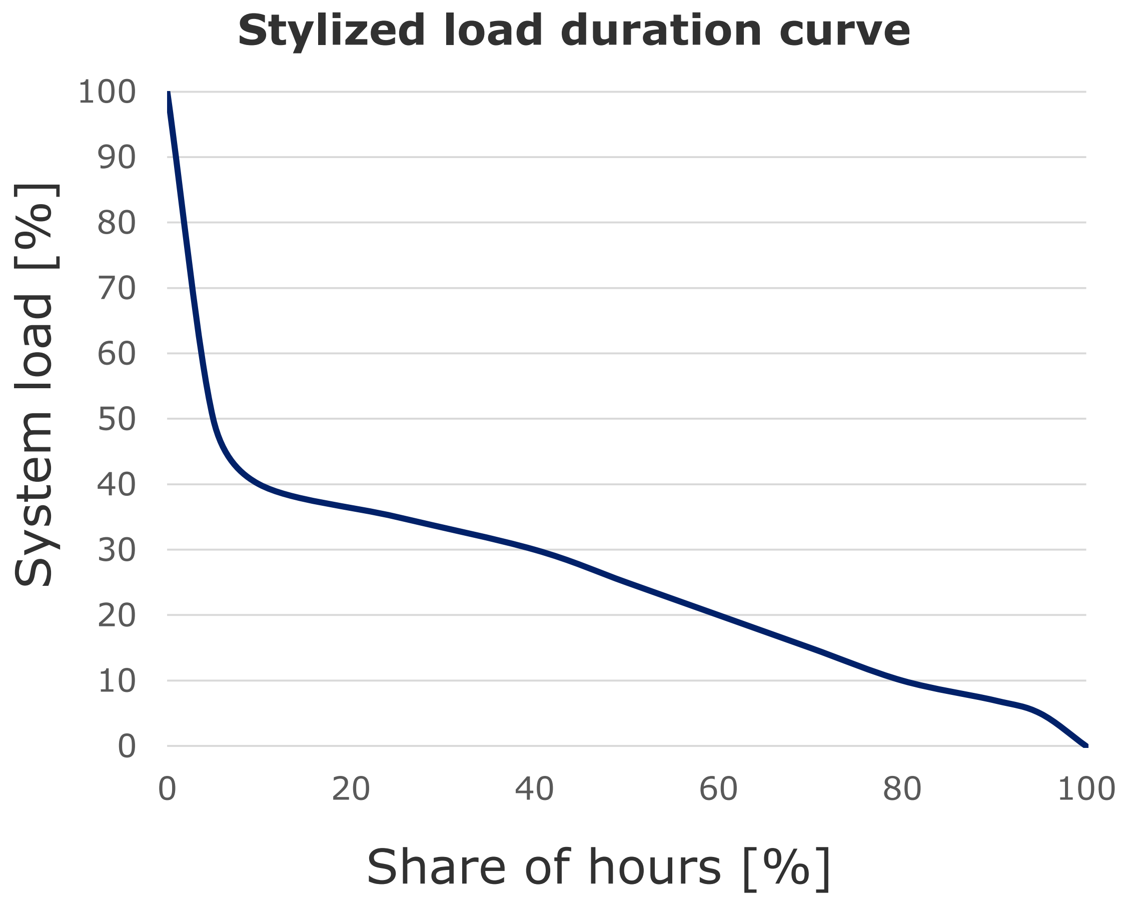
Prices influence how we consume electricity

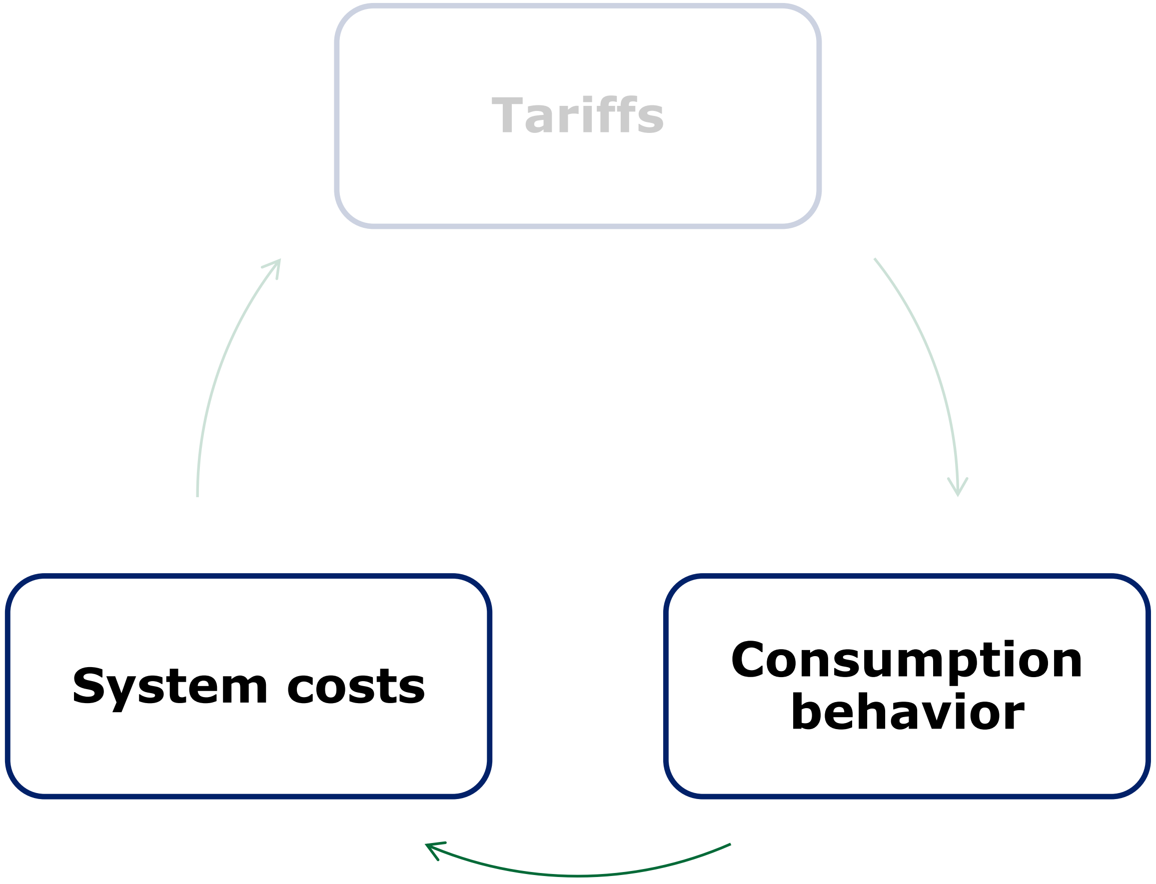
- Meta analysis of time-varying tariffs [Faruqui et al. 2017]
  - 337 treatments
  - 63 tariff pilots
  - nine countries
- Over 94% of treatments finding non-zero demand response
- *"Price-based demand response is real and predictable"*



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

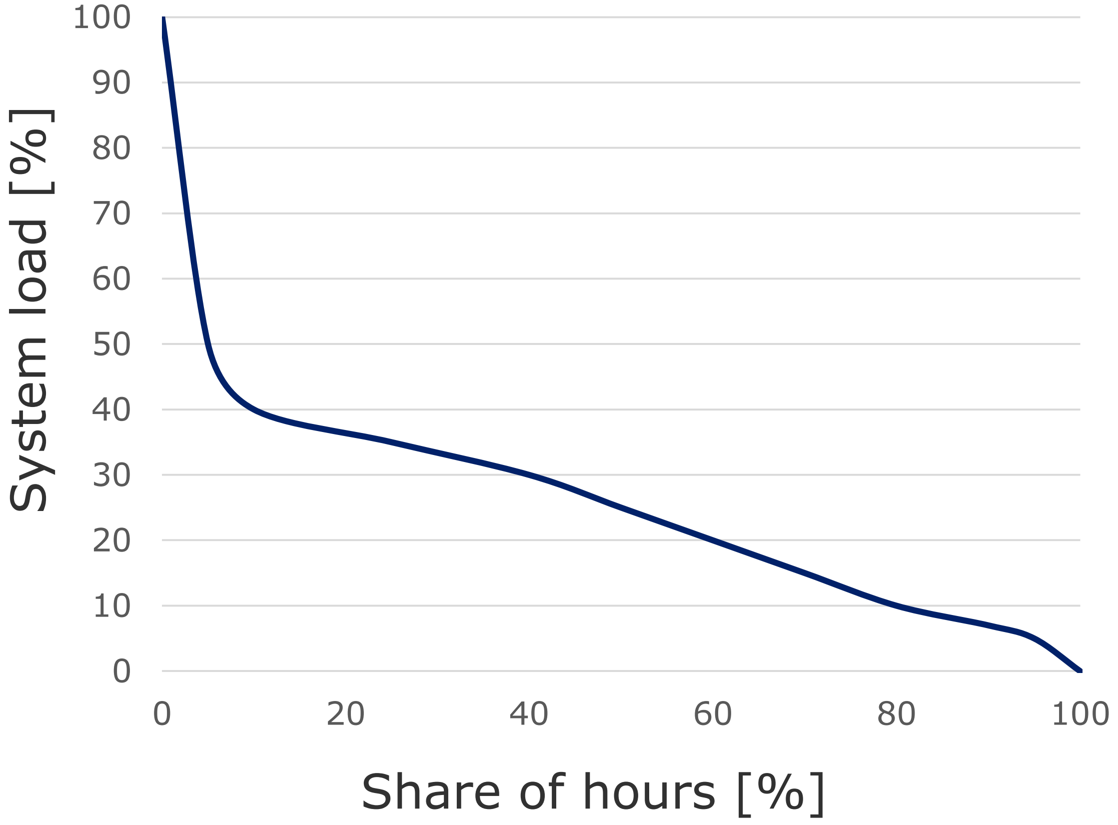
Consumption behavior determines system costs



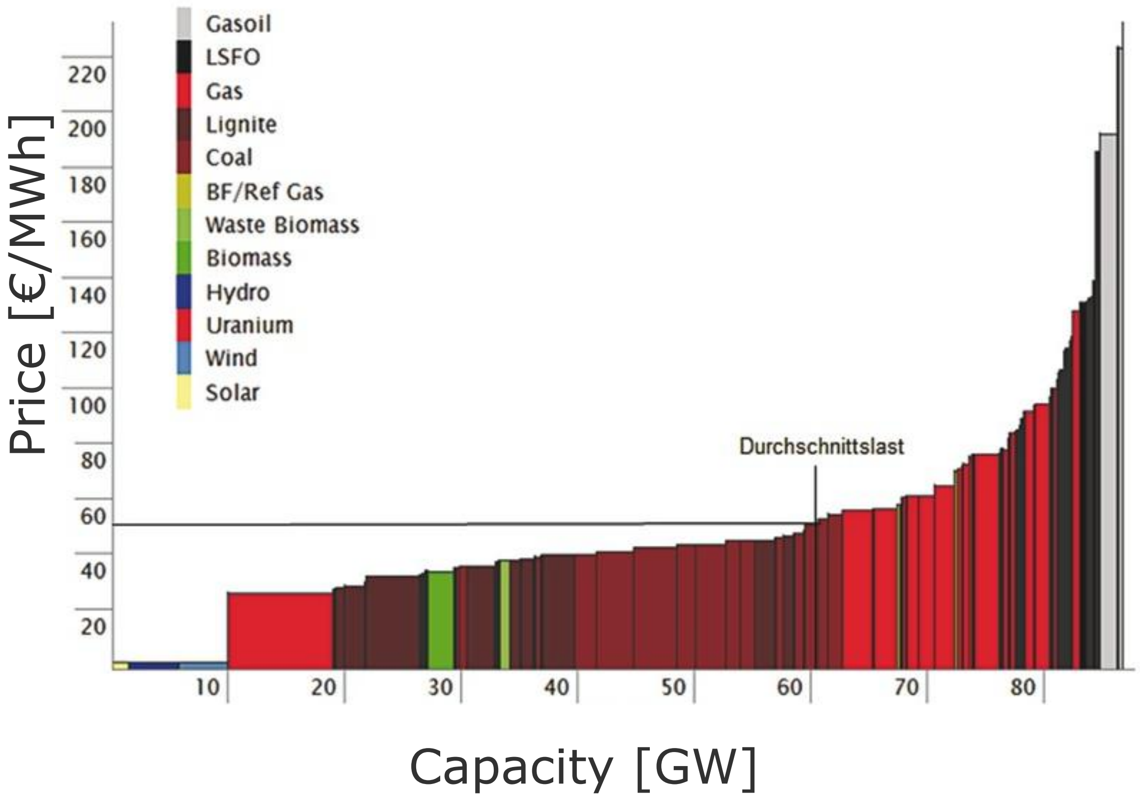


Consumption behavior determines system costs

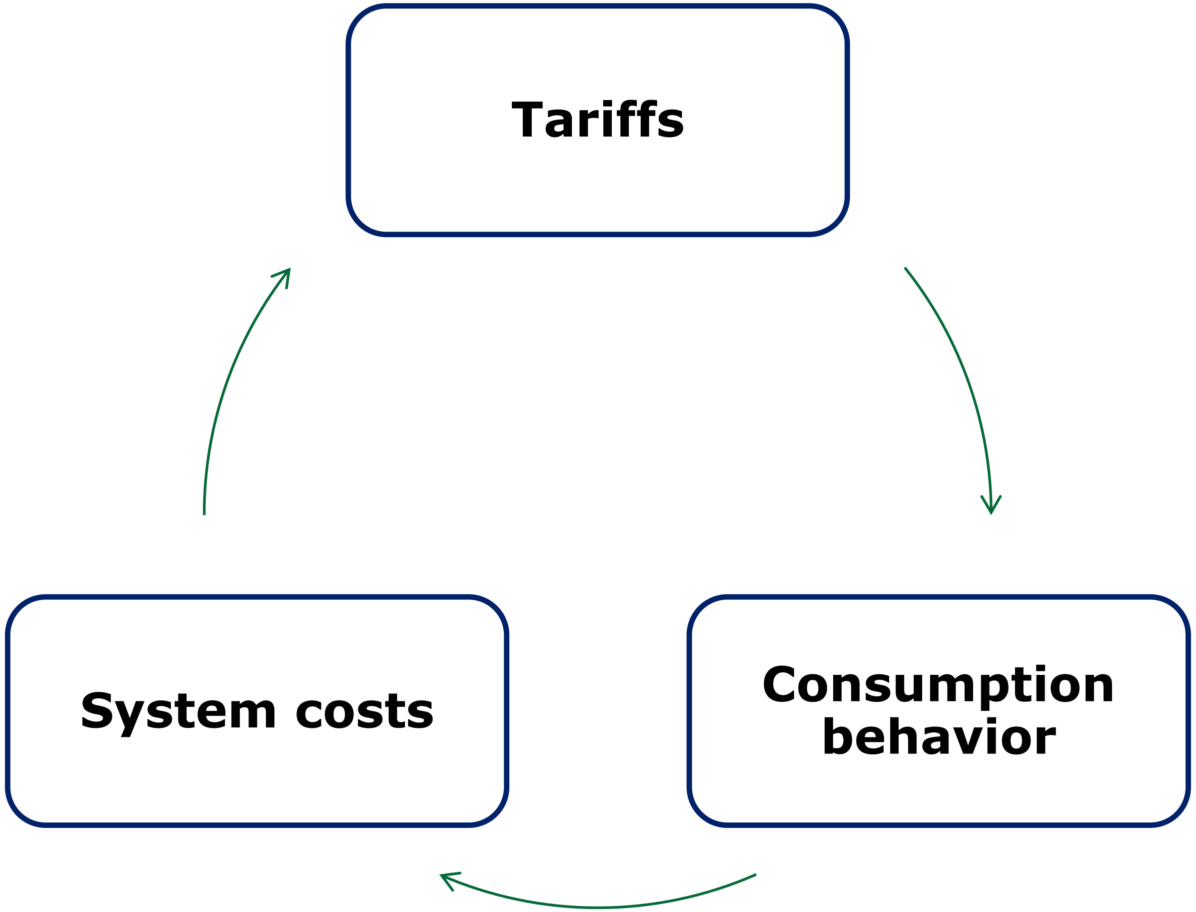
Stylized load duration curve



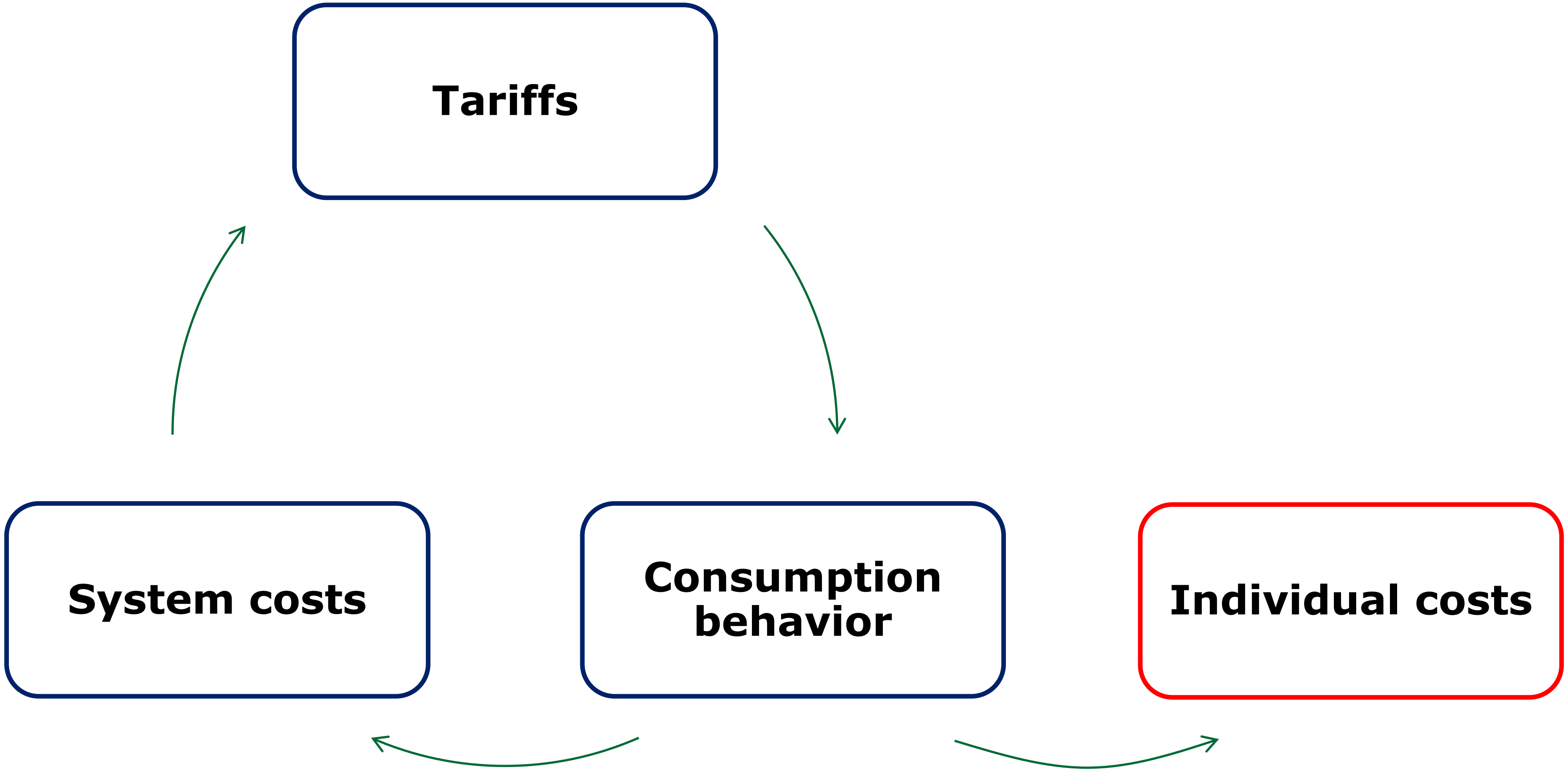
Stylized marginal costs of generation



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



Minimizing overall system costs in not the only objective



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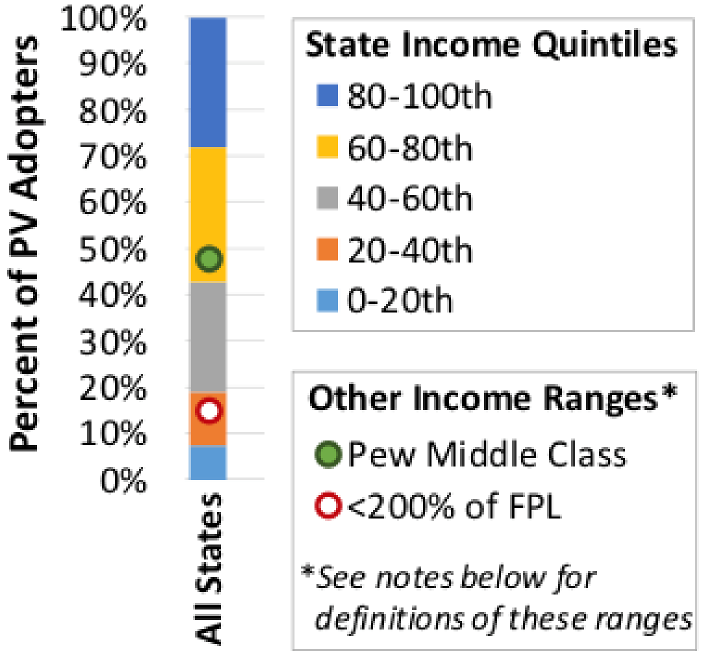
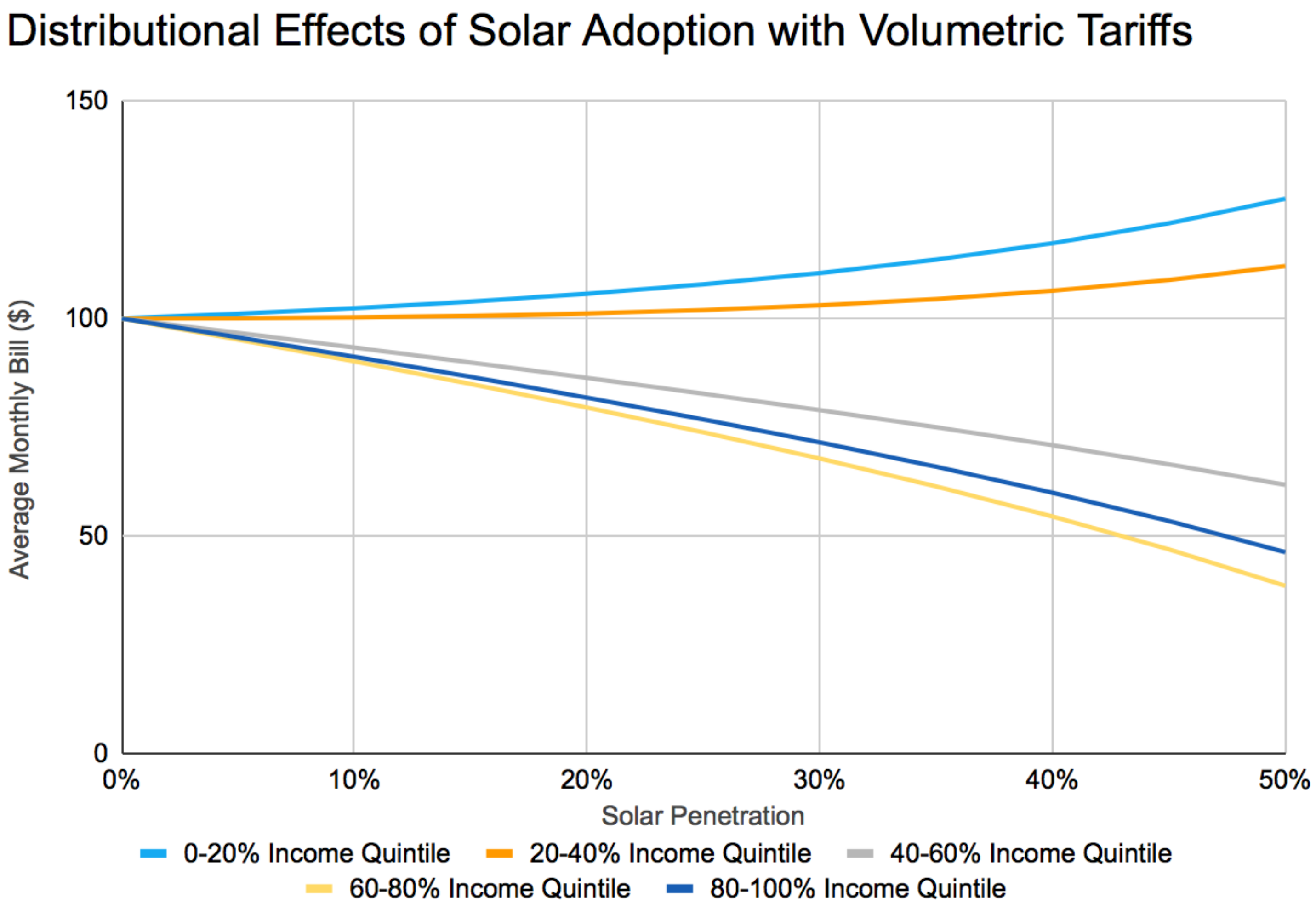




Barbose, G., N. Darghouth, B. Hoen, and R. Wiser (2018): "Income Trends of Residential PV Adopters: An analysis of household-level income estimates," Working paper, Lawrence Berkeley National Laboratory.

Minimizing overall system costs in not the only objective

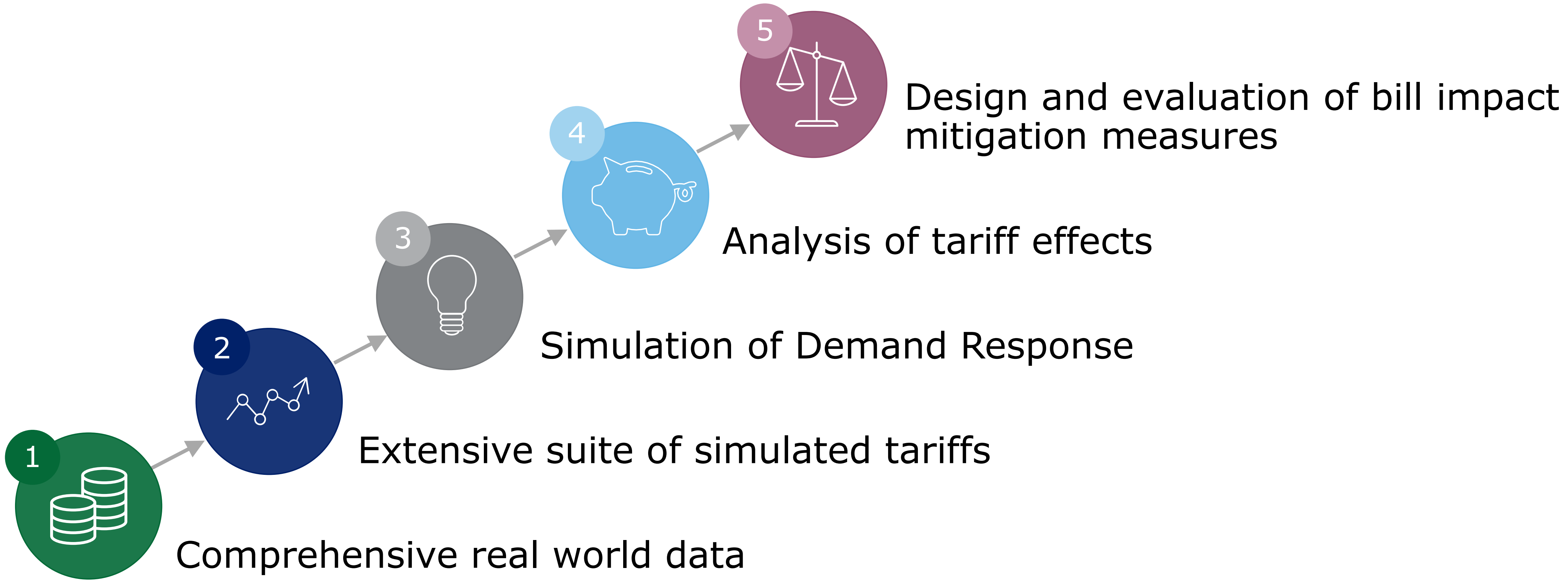
EU regulators: strong concerns regarding unknown distributional effects of new tariffs [ACER 2016]

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 **efficiency and distributional effects of electricity 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.

Methodology



Methodology

5. Design and evaluation of bill impact mitigation measures
4. Analysis of tariff effects
3. Simulation of Demand Response
2. Extensive suite of simulated tariffs
1. **Comprehensive real world data**

To evaluate tariffs we use metering data from Chicago, USA

100.170 anonymized households

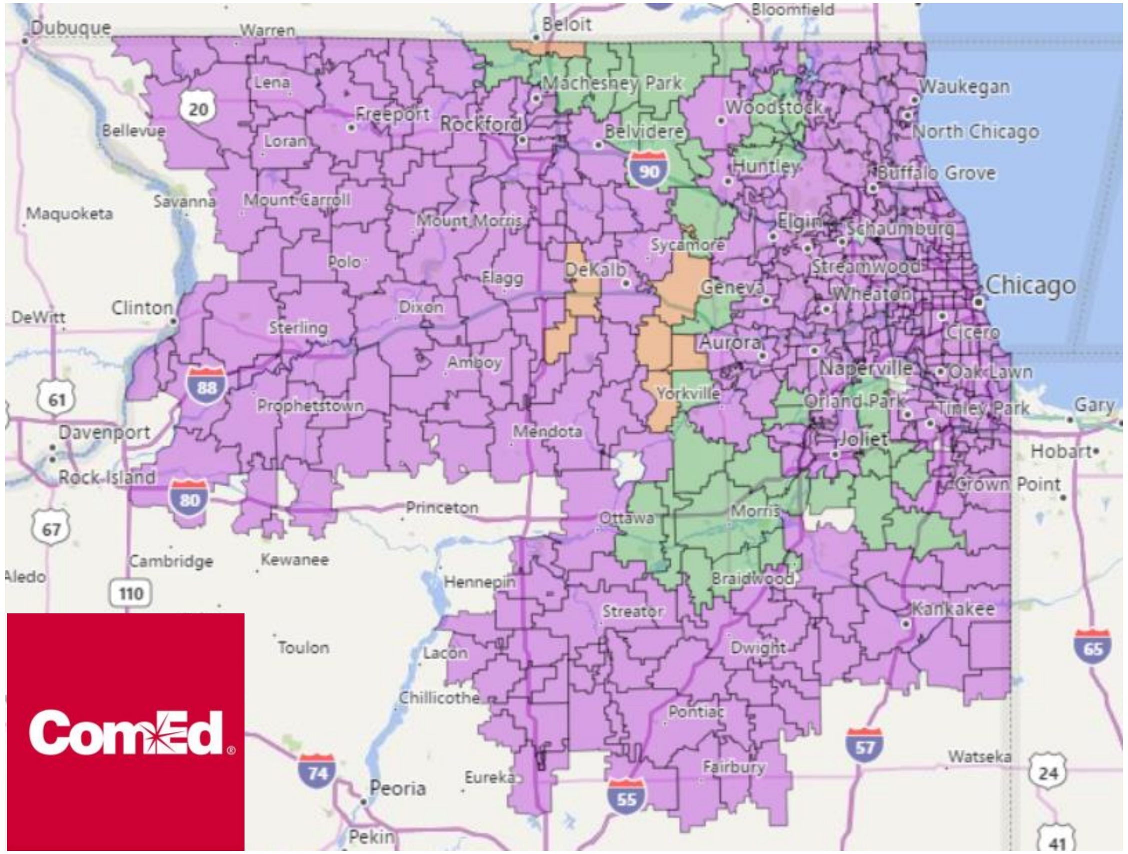
Consumption January-December 2016

30-minute smart meter readings

Housing type

Heating type

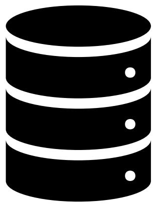
Geographic data: *9-digit zip*



Datenquelle: Commonwealth Edison, Citizens Utility Board Illinois

Matching consumption data with census data enables broad socioeconomic analyses

Consumption data



Census data

Socioeconomic data

Geographic data: Census Block Group (CBG)

Distribution of household income in each Census Block Group

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

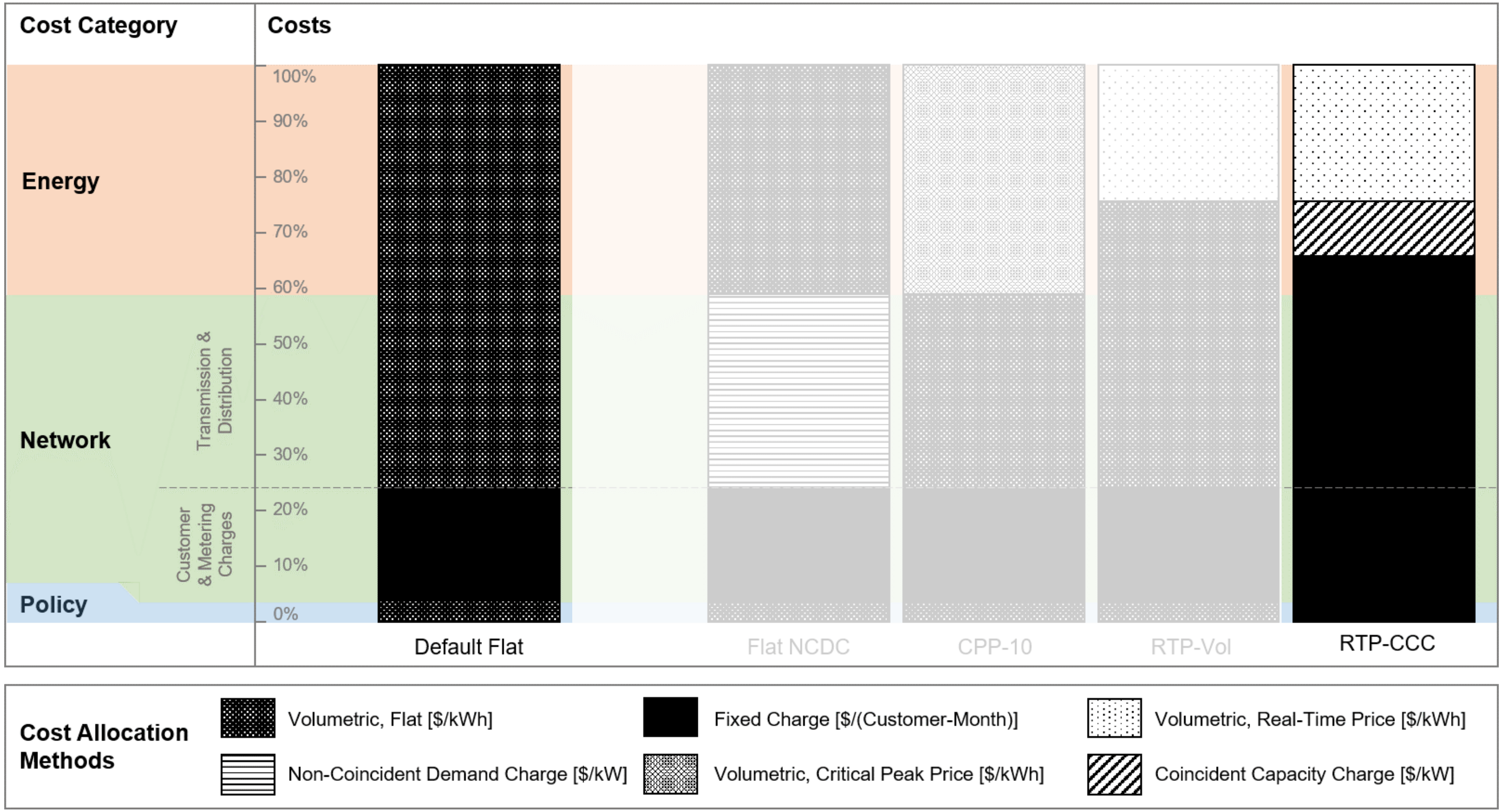
Quelle: US Zensus 2010-2015

Methodology

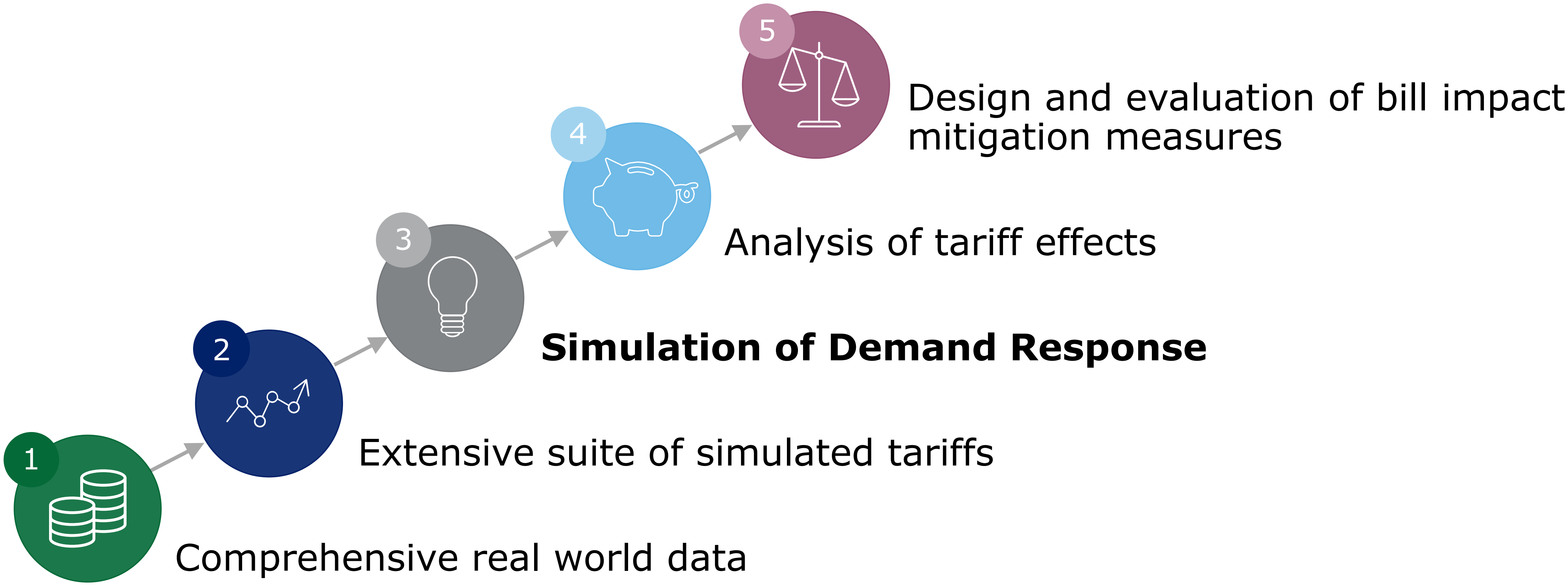
5. Design and evaluation of bill impact mitigation measures
4. Analysis of tariff effects
3. Simulation of Demand Response
2. **Extensive suite of simulated tariffs**
1. Comprehensive real world data

We recreate the Flat tariff as a benchmark, and design four new tariffs

All tariffs are designed to recover all costs for the utility



Methodology



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

New tariffs lead to substantial increases in overall consumer surplus

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

- **Formulas**

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

d: demand, i: customer, h: hour, p: price

- **Rebalancing**

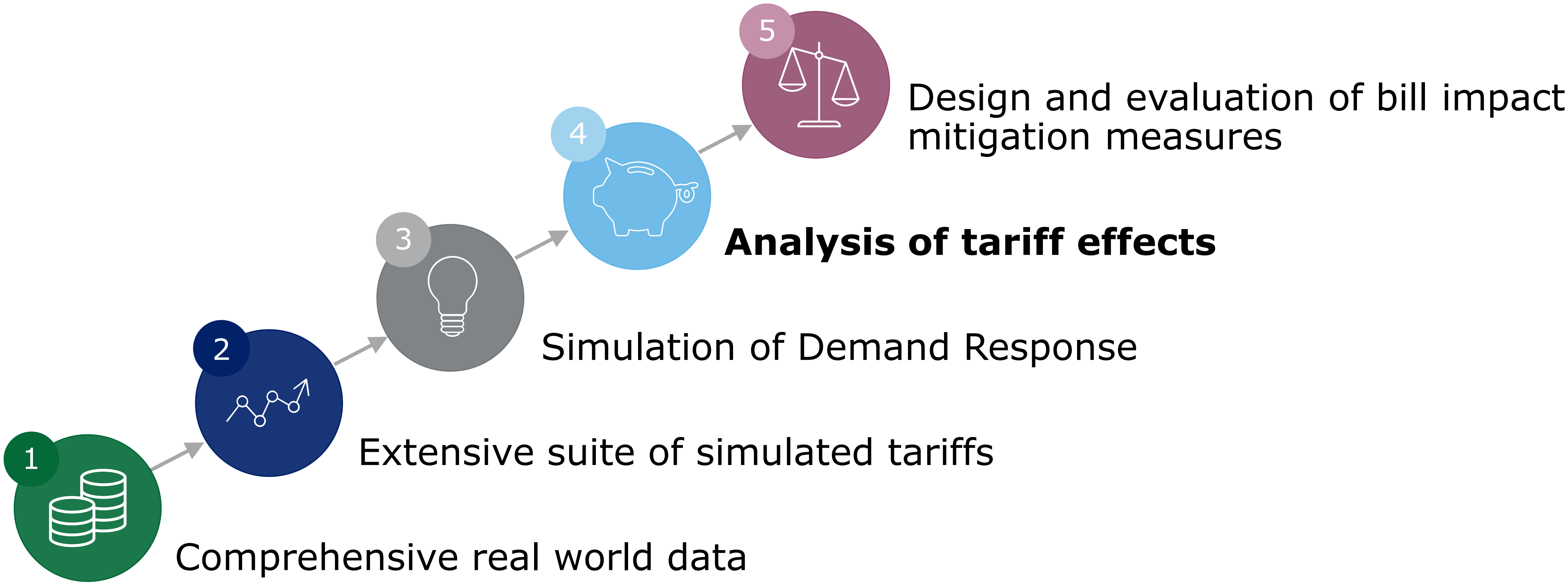
→ Adjustment of fixed charges to ensure full cost recovery for non-energy costs

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

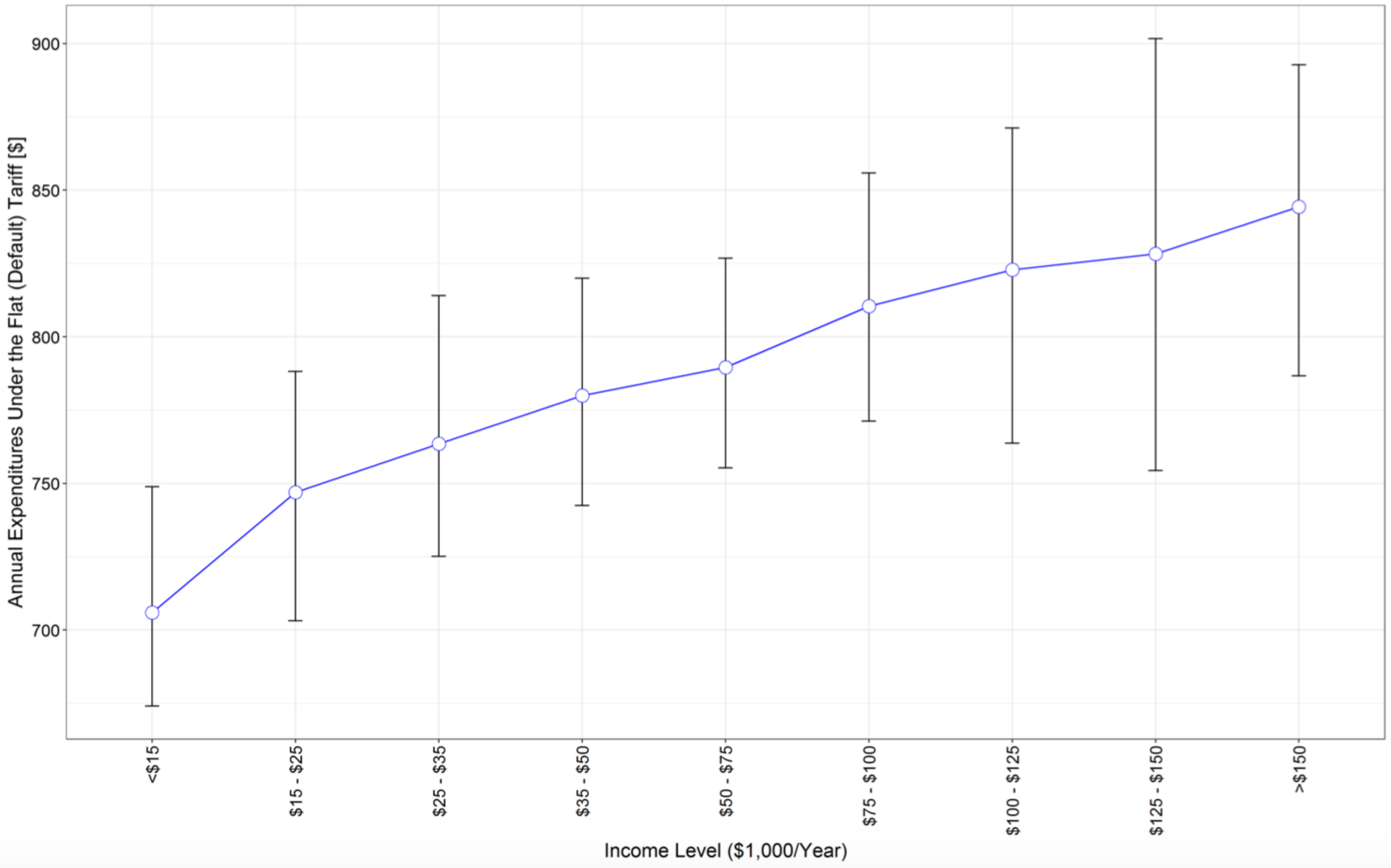
$100-300 / household / year

Methodology

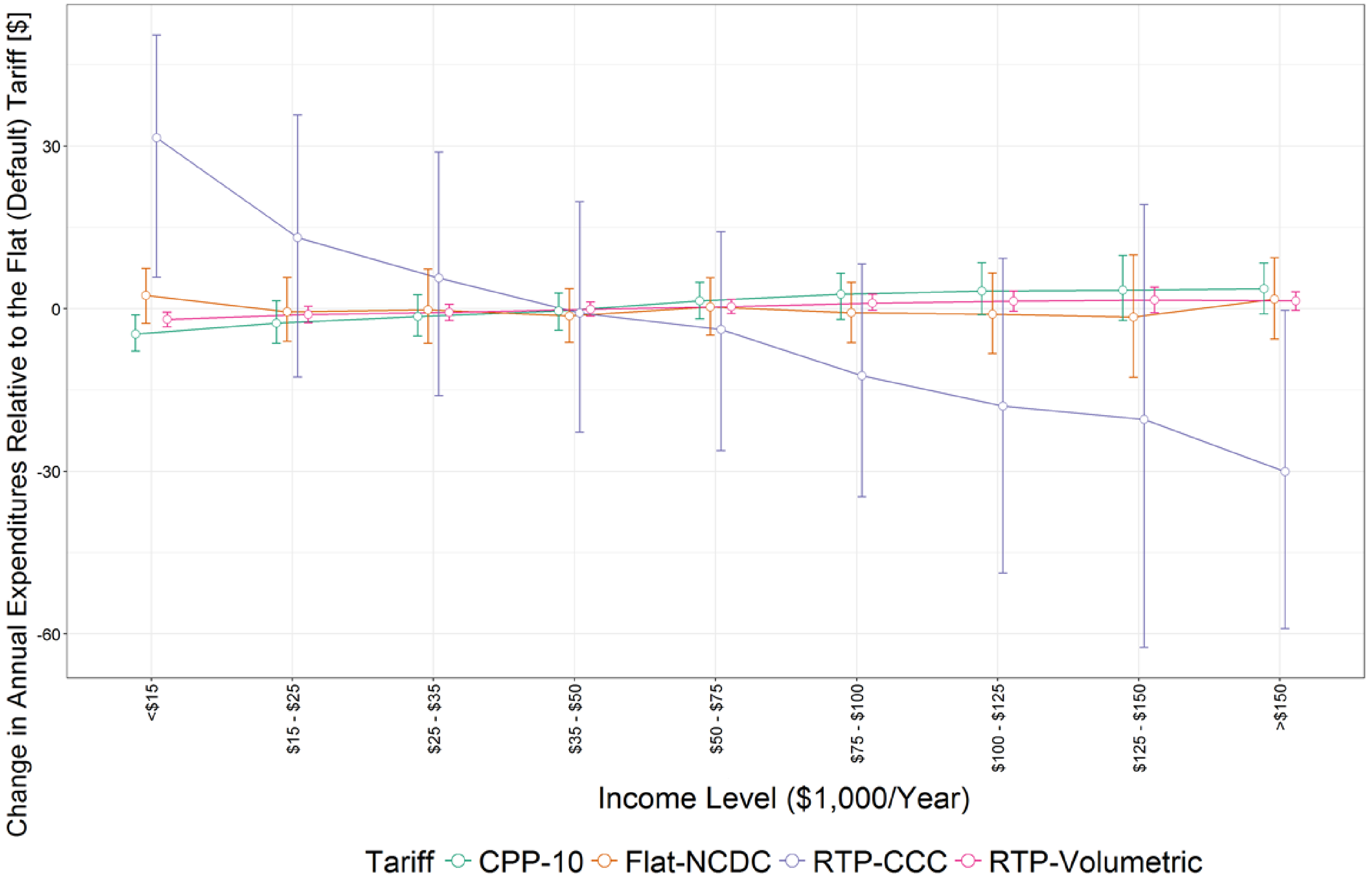


Current tariffs in many U.S. locations help keep rates low for low-income customers

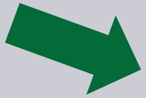
Figure 1: Annual electricity expenditures under the Flat (default) ComEd tariff

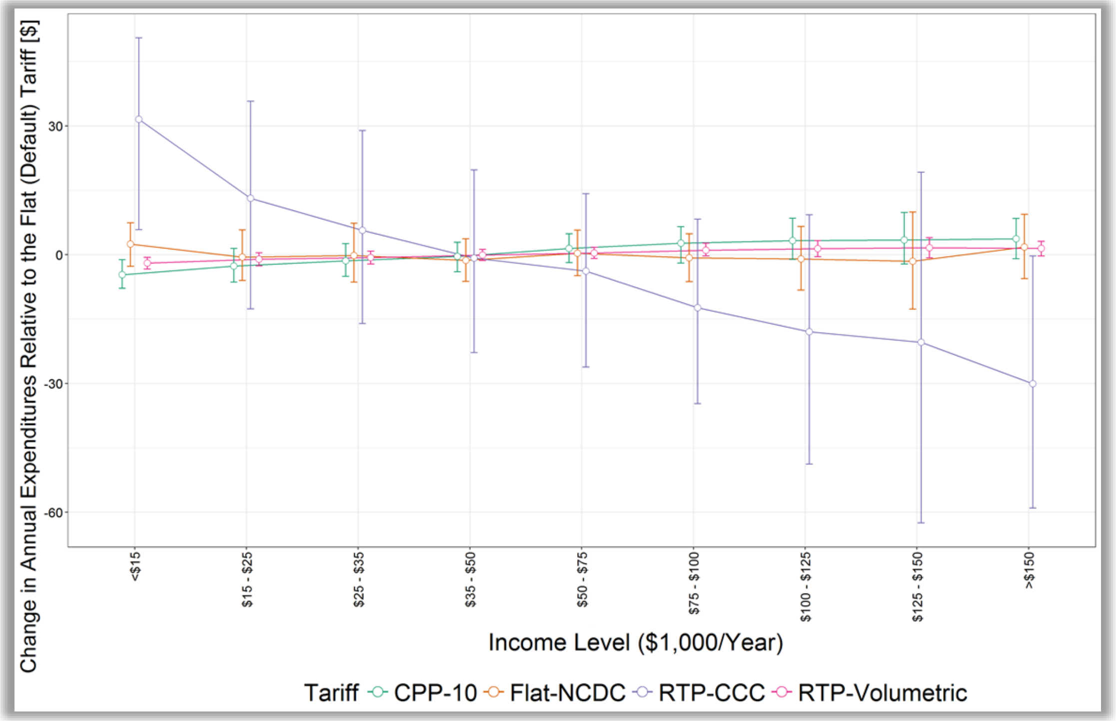


Effects of tariffs on electricity bills of low-income households (scenario: $\varepsilon = 0$)

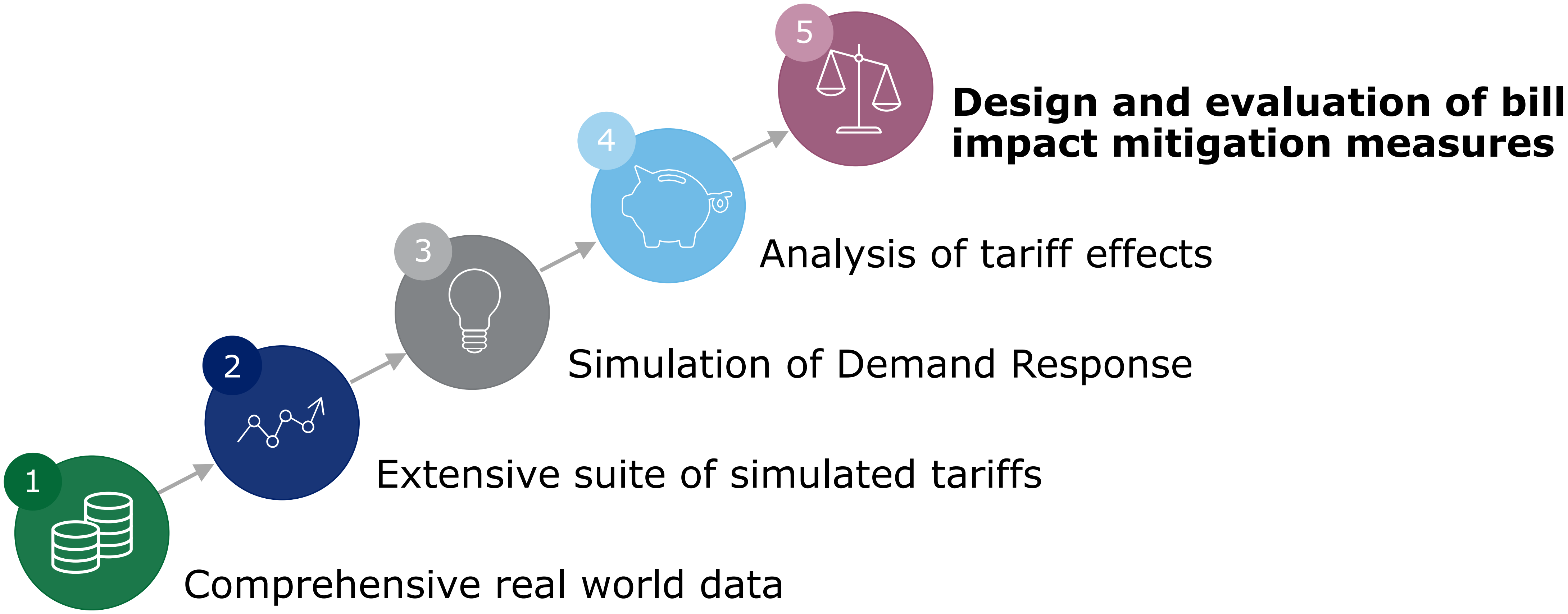


Effects of tariffs on electricity bills of low-income households (scenario: $\varepsilon = 0$)

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



Methodology



Proposals for mitigating bill impacts: Progressive Fixed Charges

- Objective: Maintain welfare improvements while avoiding undesired social effects
- Idea: Differentiating fixed charges according to certain customer criteria
- Three proposals for discriminating variables:
    1. Customer demand characteristics
    2. Customer income
    3. Customer geography

Progressive fixed charges based on customer demand characteristics

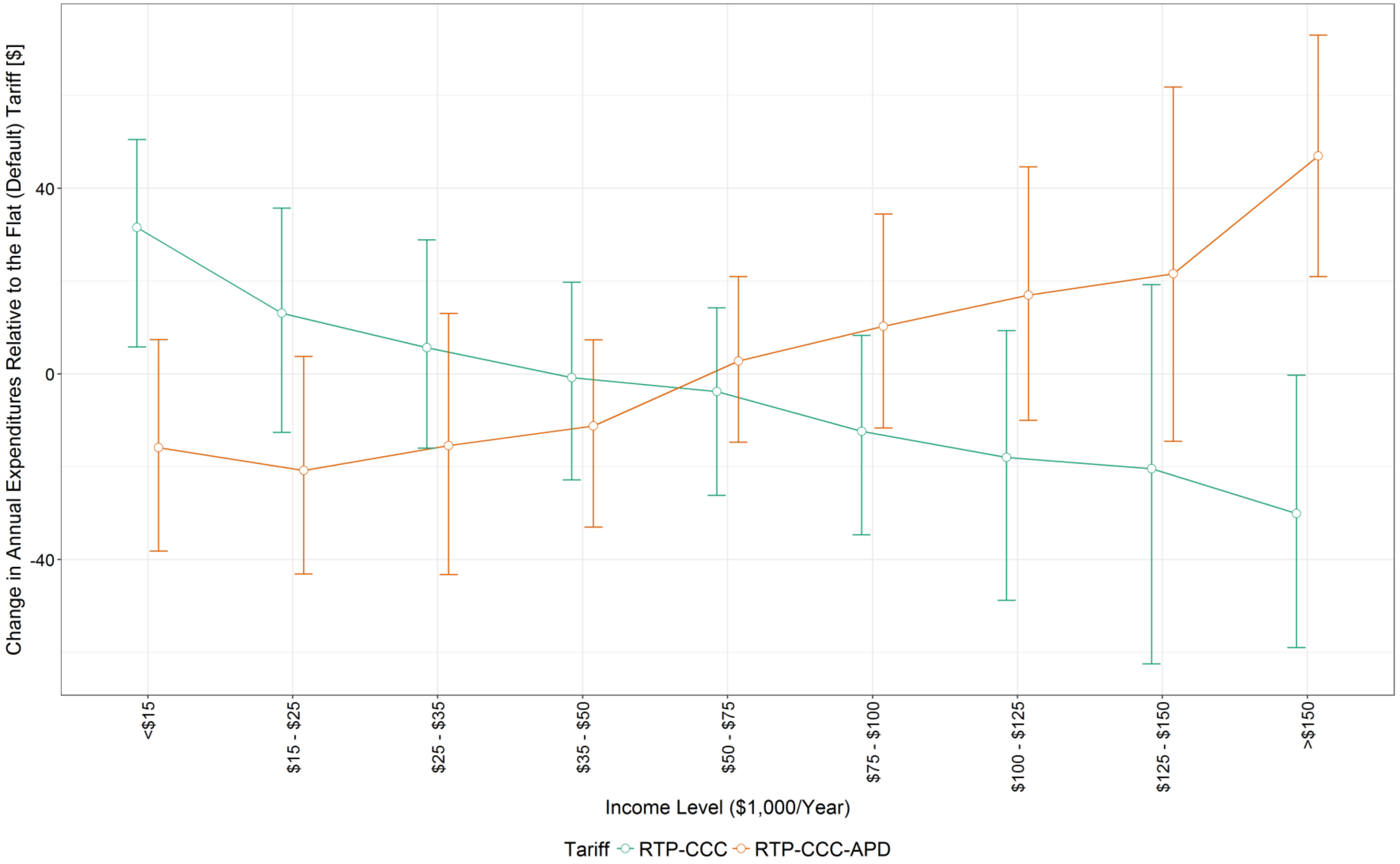
Table 5: Average Profile Variables by Income

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

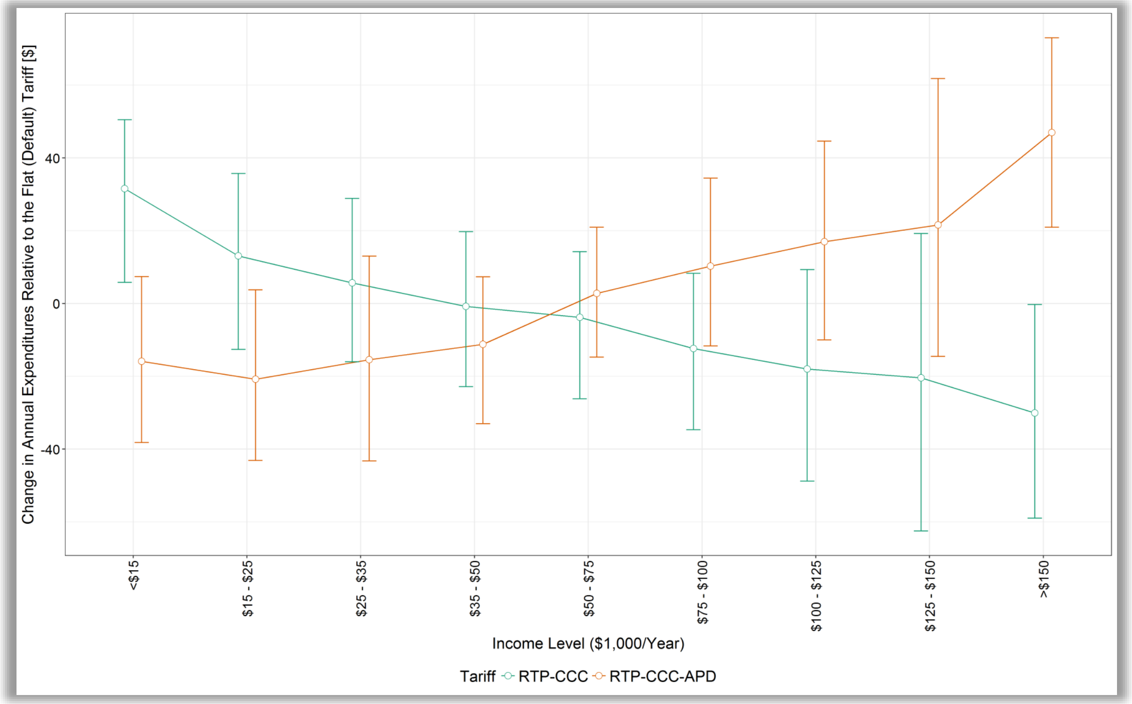
Income ($1,000 USD)	Average Monthly Consumption	Annual Peak Demand	Peak-To-Off-Peak Ratio	May Peak Demand	June Peak Demand	July Peak Demand	August Peak Demand	Consumption: 5:30PM-6:00PM	Consumption: 6:00PM-6:30PM	Consumption: 6:30PM-7:00PM
<$15	464.53	3.98	15.01	2.81	3.13	3.25	3.24	141.83	144.77	146.26
$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 individual annual peak demand (APD)

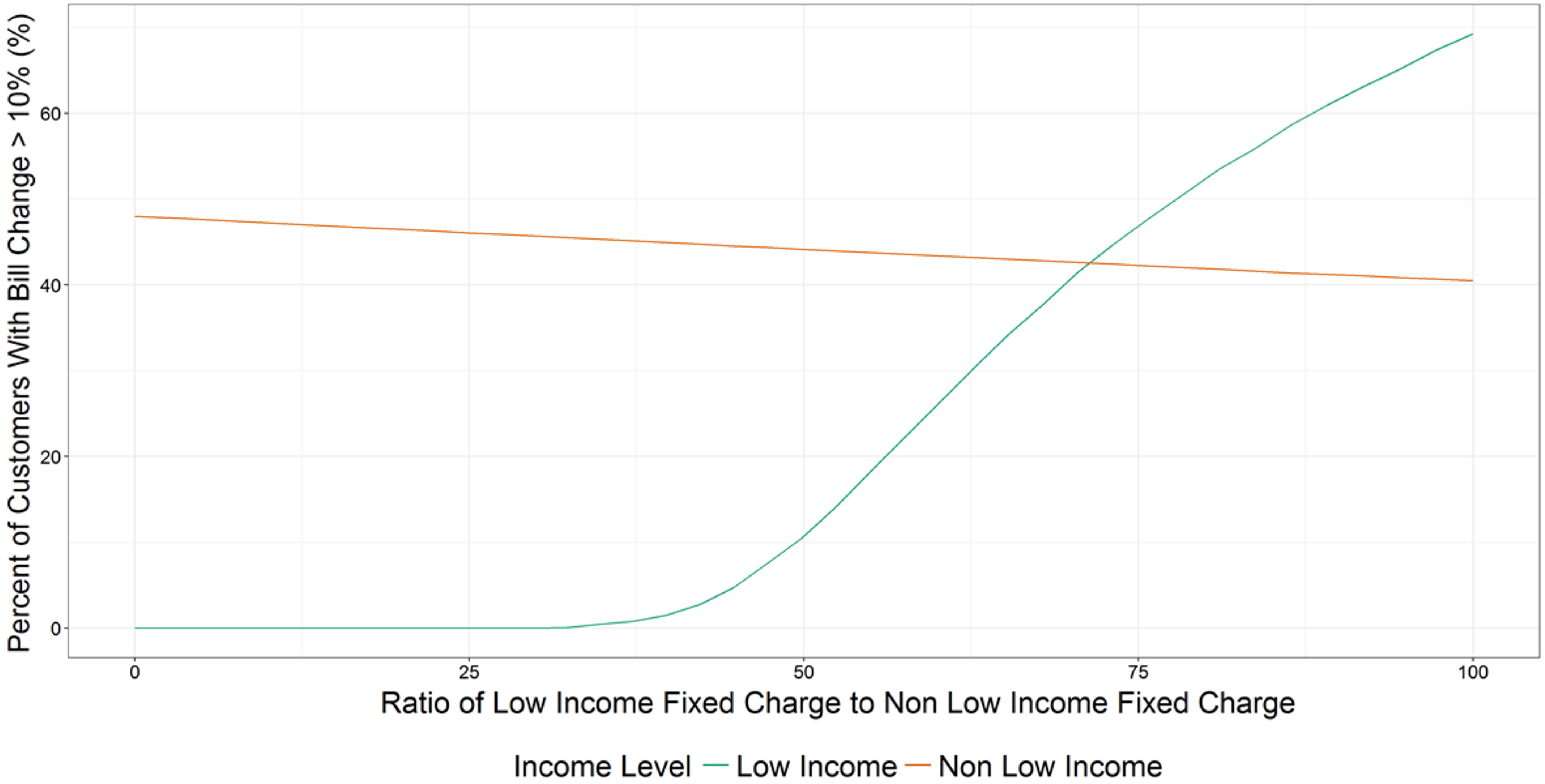


Progressive fixed charges based on individual annual peak demand (APD)

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

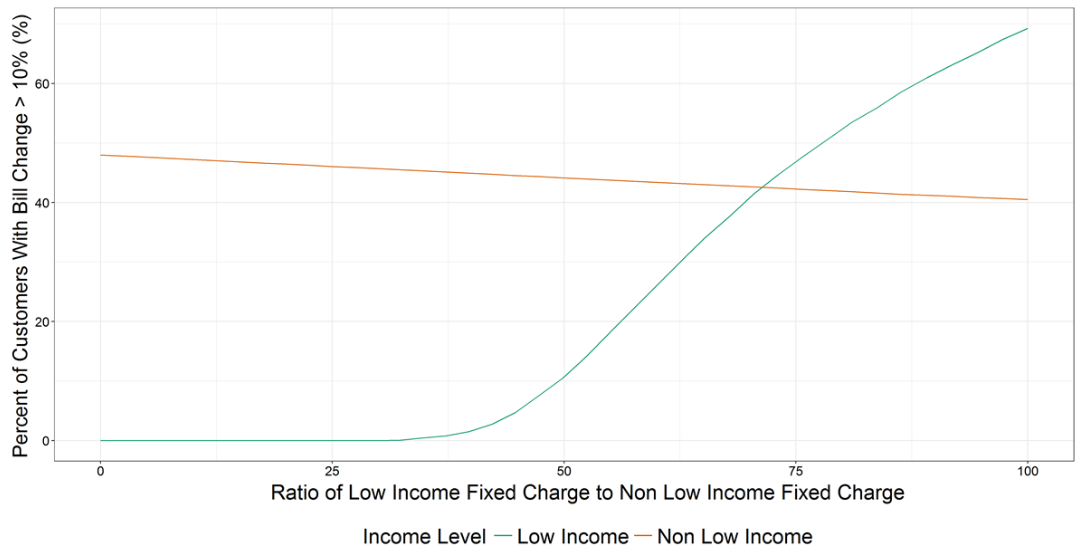


Progressive fixed charges based on individual customer income

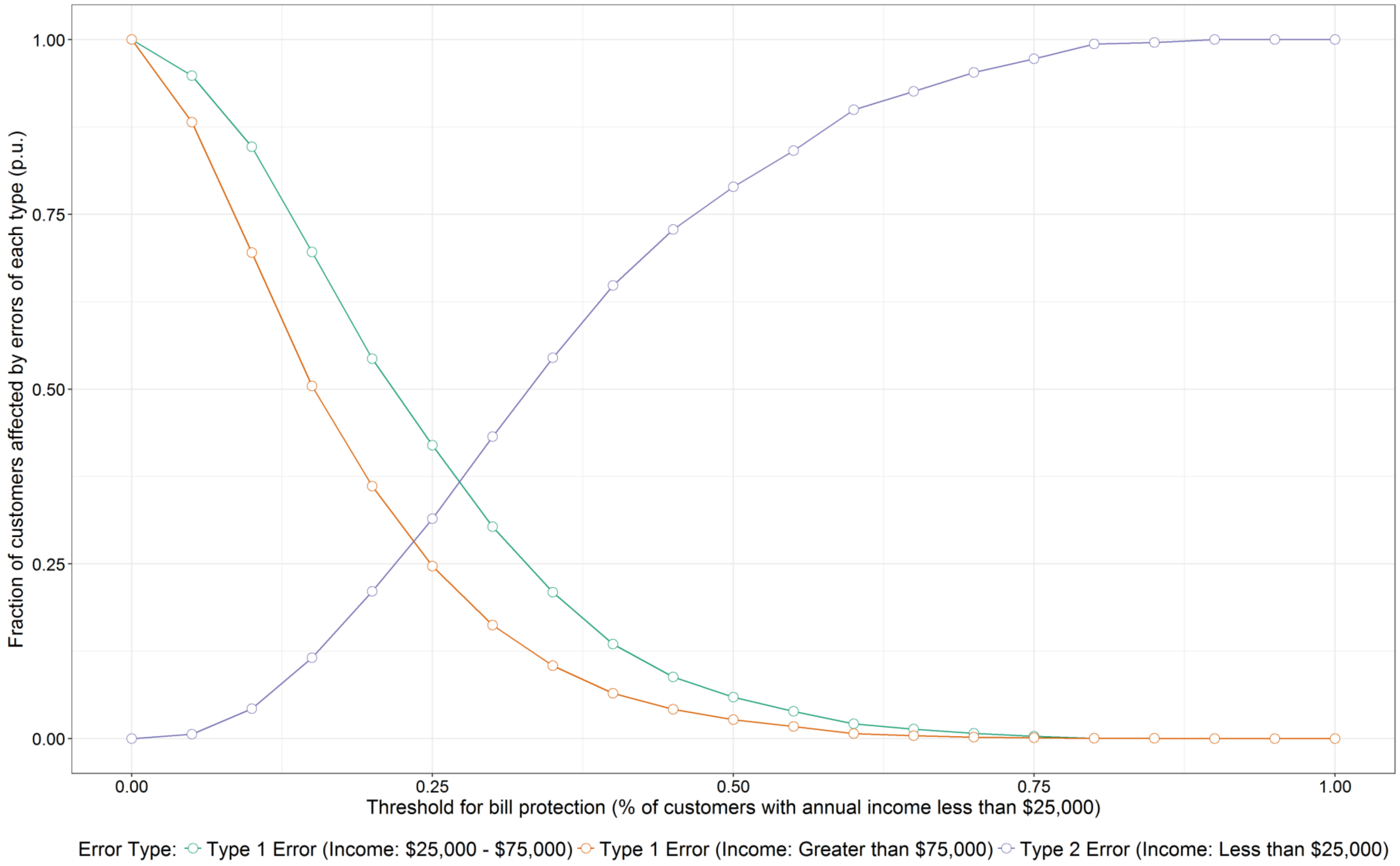


Progressive fixed charges based on individual customer income

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

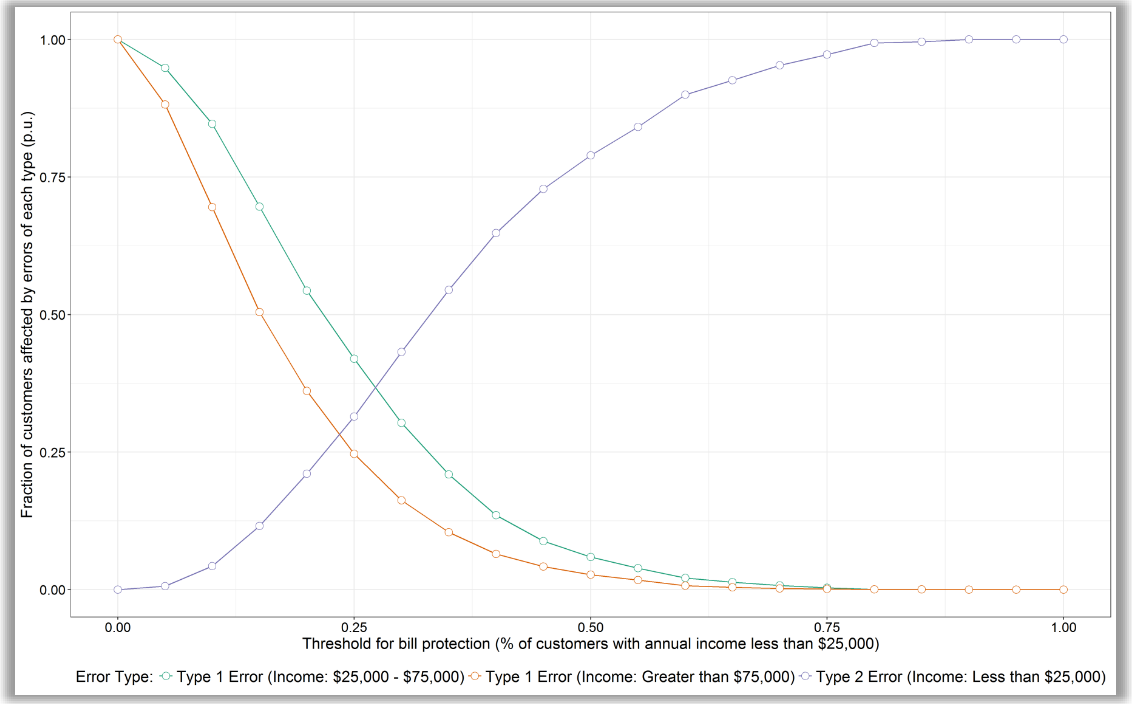


Progressive fixed charges based on customer geography



Progressive fixed charges based on individual customer income

- Feasible with existing and available data
- Risk of Type 1 and Type 2 errors
- Fixed charges could ultimately be reflected in rents or land values



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. The recovery of residual network and policy costs through volumetric rates appears to be a larger economic distortion than the recovery of energy costs through time invariant rates.
5. With relatively limited price elasticity, nearly all socioeconomic groups are likely to see average consumer surplus benefits in the transition to an efficient tariff.
6. 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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