Charging for electricity distribution networks in scenarios of increased residential end-user electrification

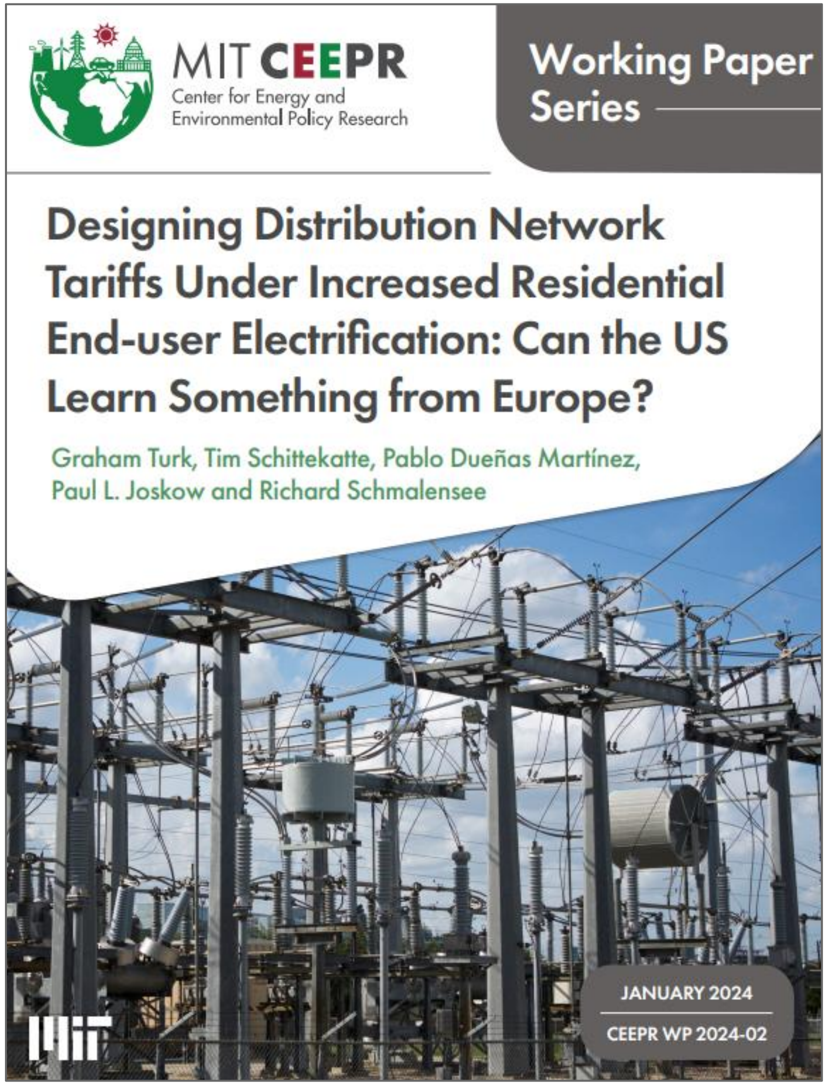
Tim Schittekatte (FTI Consulting/ MIT/ Florence School of Regulation)

Jointly with MIT colleagues Graham Turk, Pablo Duenas Martinez, P. Joskow and R. Schmalensee

14th Toulouse Conference on the Economics of Energy and Climate – 6 June 2024

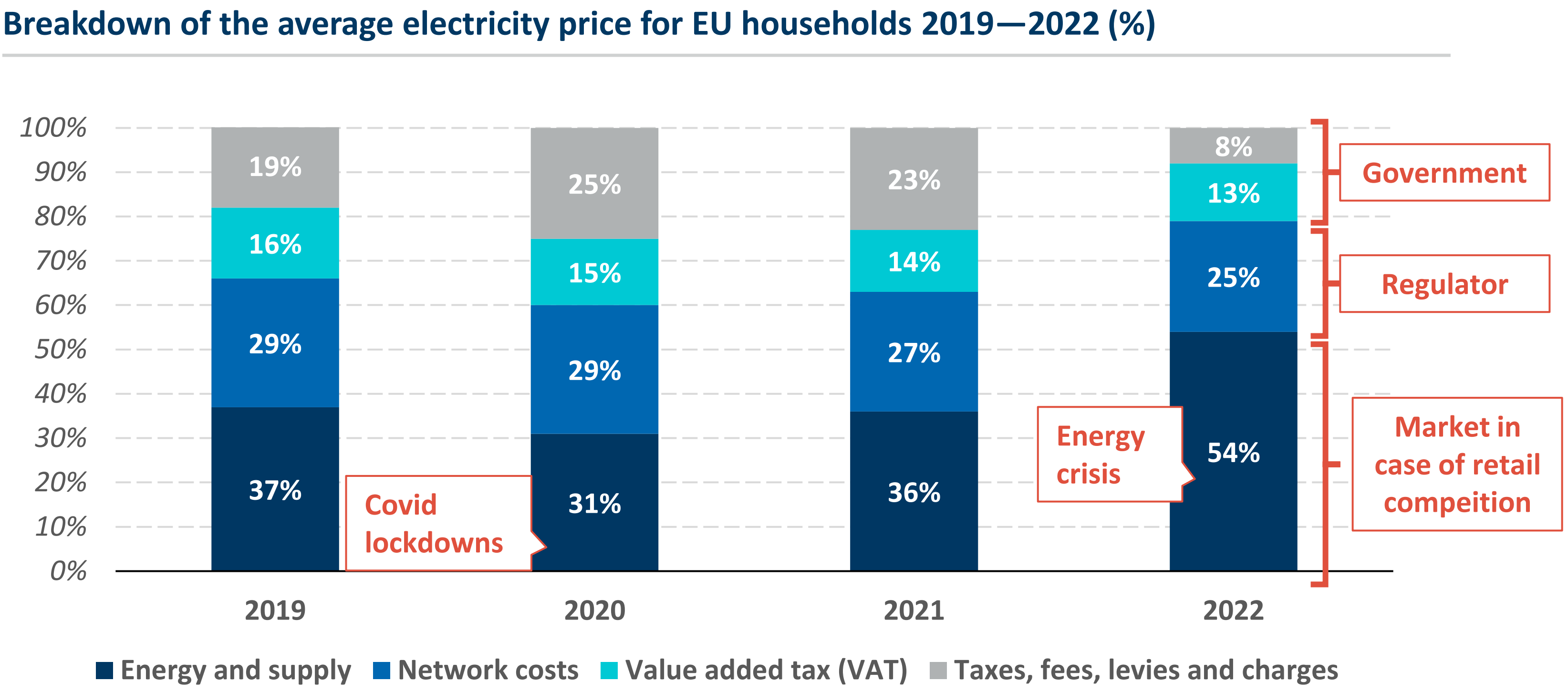
Setup presentation

- Motivation
- Theory and practice
- Methodology
- Results
- Conclusions



Motivation

Consumer bills consists of three components: energy, network and taxes & levies



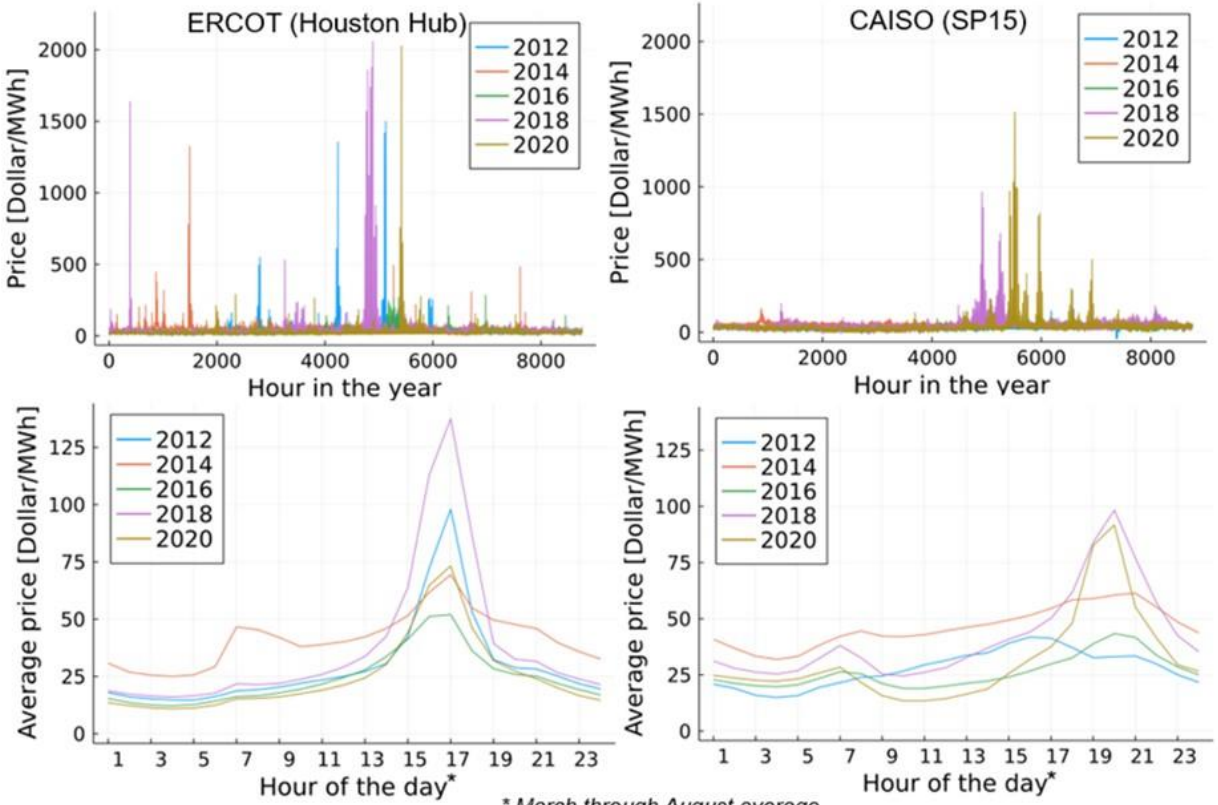
Source: ACER (2023) based on Eurostat

For most consumers, the majority of their electricity usage is charged for at a flat volumetric (€/kWh) rate that embeds the costs for the three components.

Two big pieces of the retail rate puzzle

The energy challenge

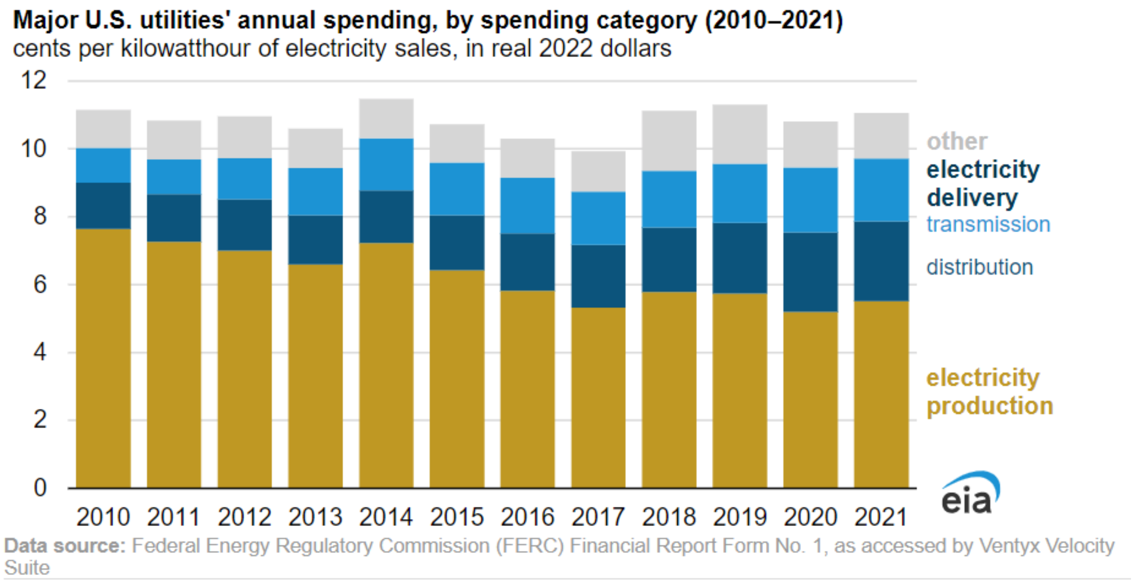
Retail customers do not see the often-substantial hour-to-hour variation in the marginal cost of electricity supply, reflected in spot wholesale prices



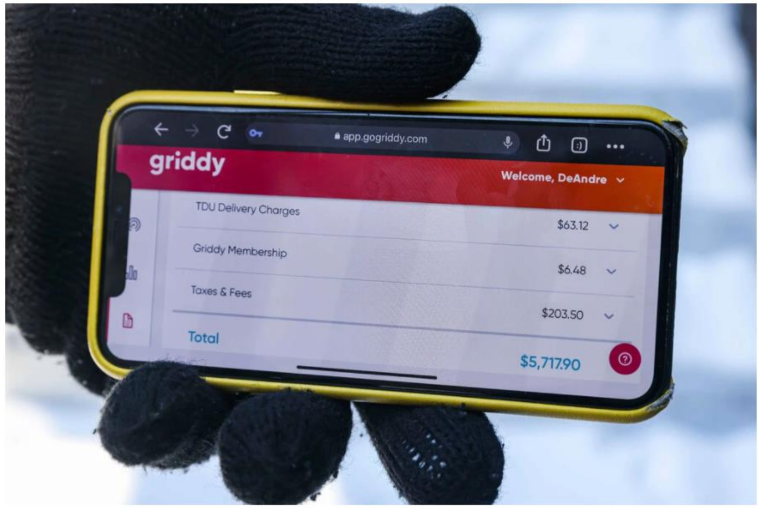
* March through August average

The network challenge

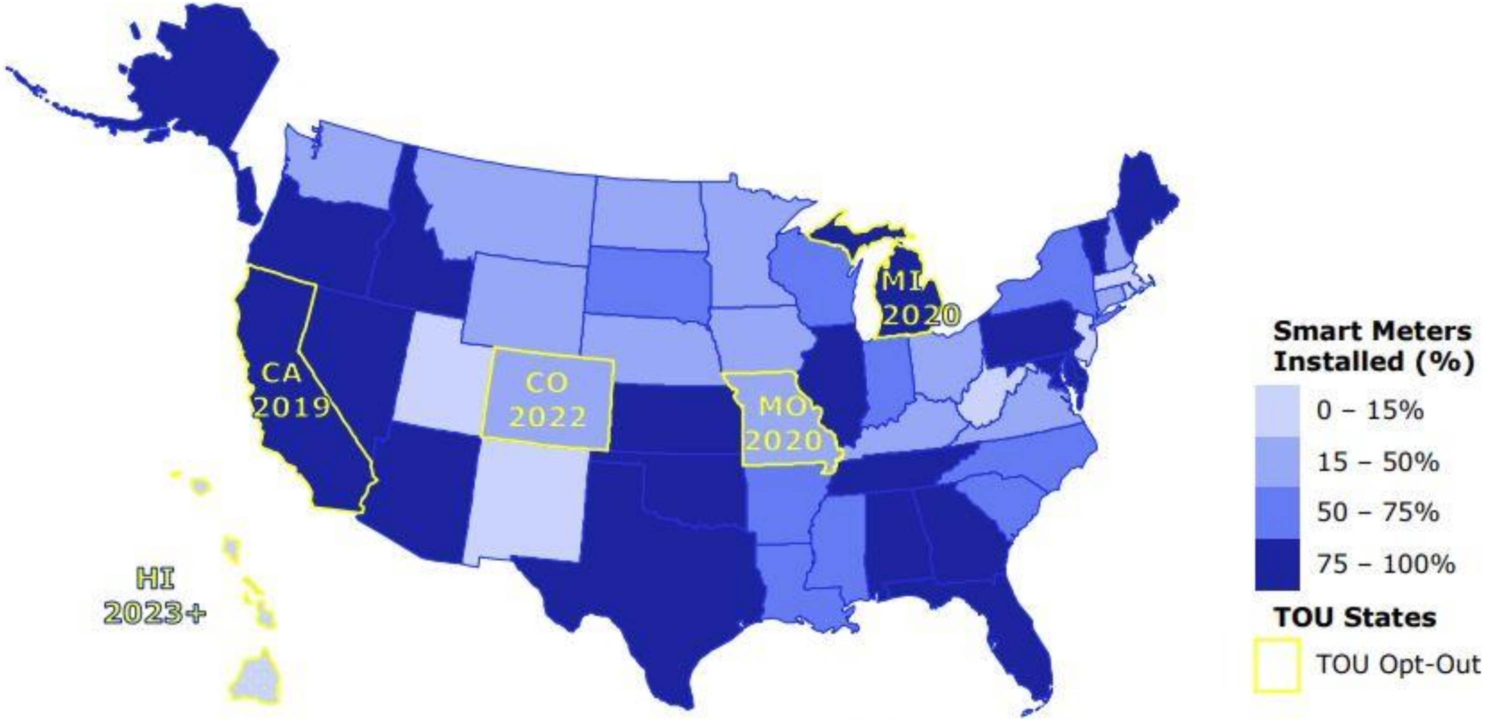
Investment-related costs are embedded into volumetric rates while in the short-run these costs are fixed and do not vary with instantaneous consumption



In the US, “real-time pricing” is less popular, but time-of-use (TOU) energy charges are on the rise



DeAndré Upshaw's bill rose to more than $5,000 during the cold weather, when his electricity was on intermittently at his apartment in Dallas. Lola Gomez/The Dallas Morning News, via Associated Press

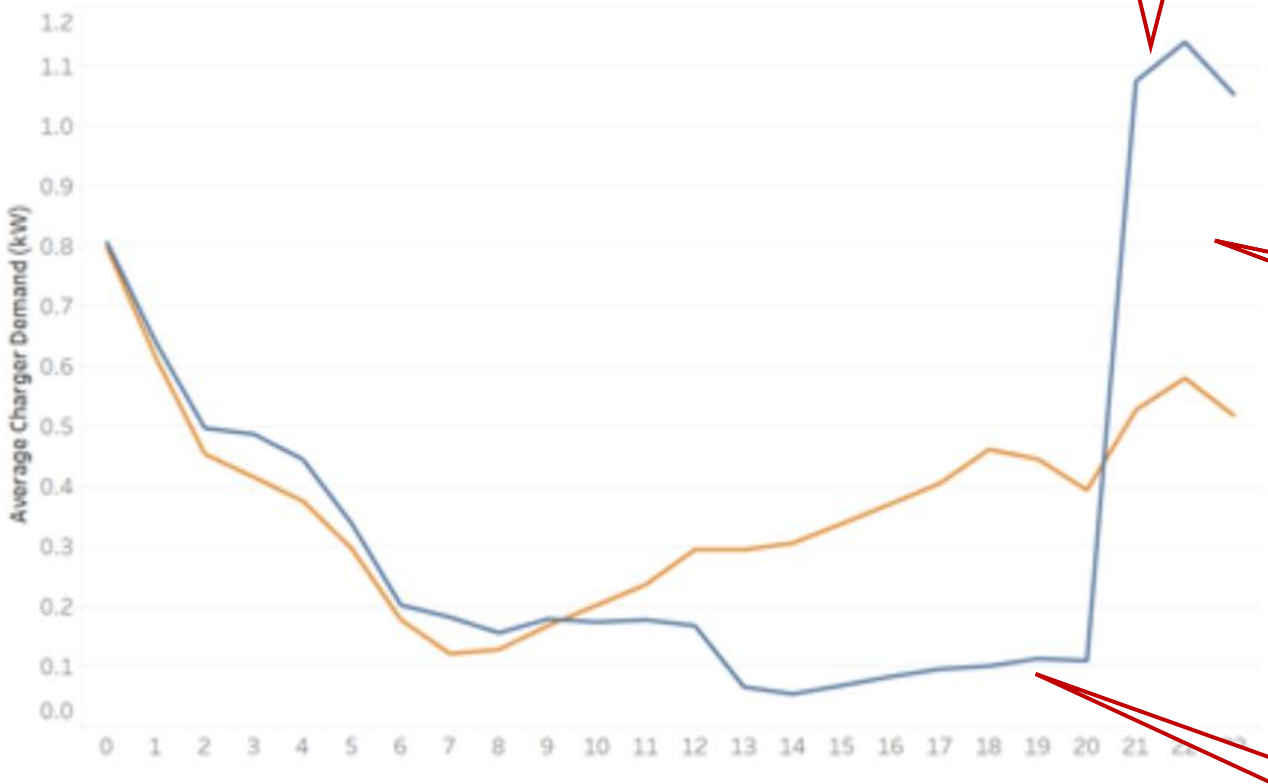


Adapted from: Cooper and Shuster, "Electric Company Smart Meter Deployments: Foundation for a Smart Grid," Institute for Electric Innovation, April 2021, p. 3.

Credit: Travis Kavulla

However, TOU energy charges can make the "network challenge" harder when not complemented with appropriate network tariffs

Off-peak starts



Programs lead to "snapback" demand from programmable devices responding to price

Peak price period

Green Mountain Power 2021 Integrated Research Plan

Theory and practice

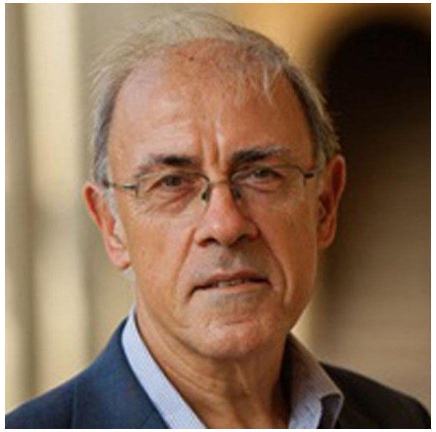
What are the (polar) alternatives?

Income-based fixed charges – US direction

Backward-looking approach:

- Focus on fully cost recovery
- Fits in low load growth context

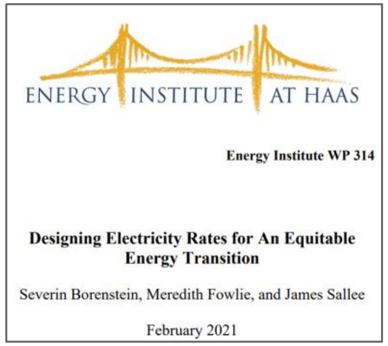
VS.



Granular capacity charges – EU direction

Forward-looking approach:

- Reflects future network costs and trying to find balance between investment and flexibility
- Fits in high load growth environment



ENERGY INSTITUTE AT HAAS

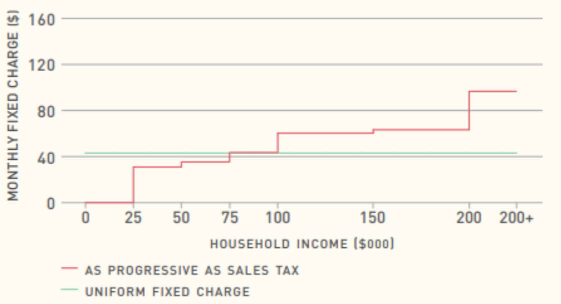
Energy Institute WP 314

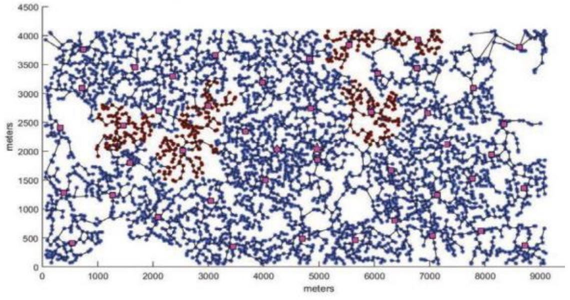
Designing Electricity Rates for An Equitable Energy Transition

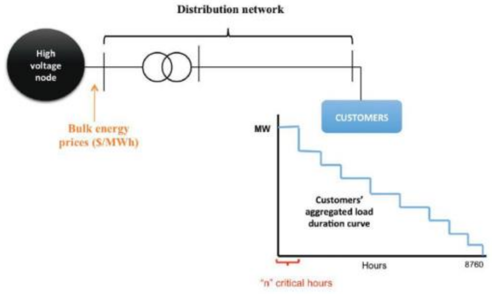
Severin Borenstein, Meredith Fowlie, and James Sallee

February 2021

FIGURE 10 Monthly Fixed Charge Schedules and Change in Annual Bills Under Income-Based Fixed Charge (SCE)



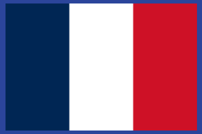




Several stakeholders maintain that long-run distribution marginal costs are not avoidable. For example, ratepayer advocates at TURN maintain that it is erroneous to assume that distributed energy resources could defer the majority of distribution upgrades which are intended to repair equipment, replace aging equipment, or harden the grid to prevent utility-caused ignitions. The California Large Energy Consumers Association (CLECA) cautions that the use of general rate case marginal costs for unspecified distribution benefits could lead to over-estimation of the benefits of avoided distribution costs. In light of these concerns, we also construct marginal cost estimates that assume an MDCC of zero.

The correct additional economic signal to be sent to network users should be based on each user's specifically foreseeable contribution to (or responsibility for) any estimated future investments in network assets. This cost-reflective network charge is consistent with the widely accepted principle of allocation of costs to the beneficiaries of the investments.

Capacity-based charges: a pragmatic (continental European) way in the middle?

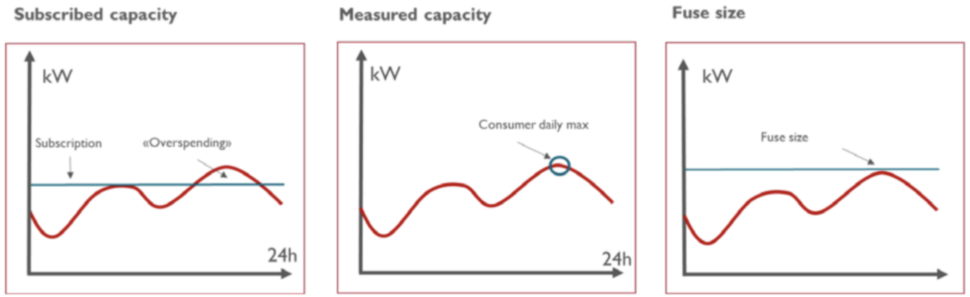
			
Measured or subscribed	Subscribed	Subscribed	Measured
Time differentiation	No	Two periods with very different prices	No
Absolute magnitude	About 20 euro/kW per year	About 25 euro/kW per year (adding up on and off-peak)	About 40 euro/kW per year


ACER
European Union Agency for the Cooperation of Energy Regulators

Report on Distribution Tariff Methodologies in Europe

February 2021

"While capacity charges, often also referred to as demand charges, rare in the US for residential and small commercial consumers, 13 of the 27 member states of the European Union had capacity charges for households in place in 2021."



Source:
NVE (2020)

Methodology

Our scope

- **Objective of the network tariff:**
  - Efficiency (cost-reflectiveness) ≈ passing-through the short-term marginal cost of electricity to end-users while limiting overinvestment in electricity networks

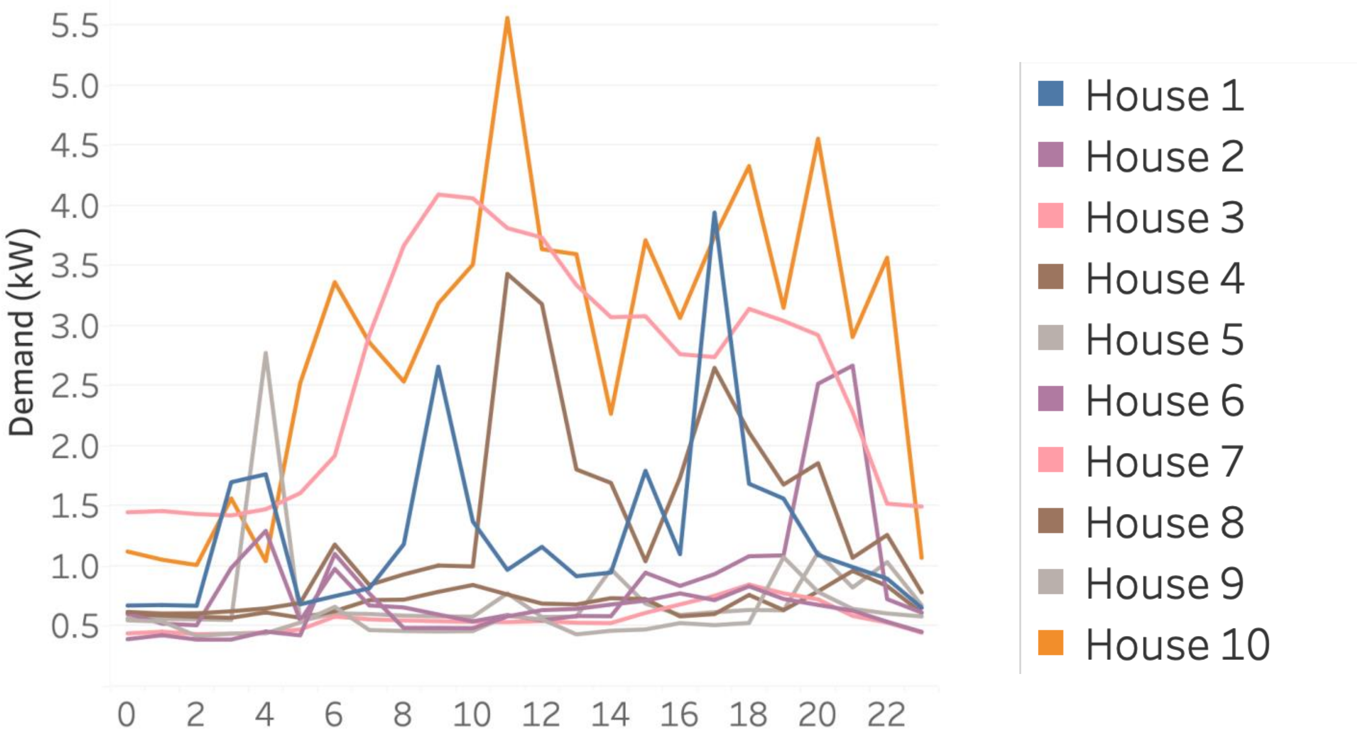
- **Real-world constraints:**
  - Redistributional impacts between end users
  - Simplicity and predictability
  - Non-discriminatory

- **We assume a world with price coordination only**
  - Alternative: local control by utility over electric appliances
    - Technical, behavioral and regulatory barriers

- **Special focus on the interaction between time-varying energy prices and the network tariff design (consumers react on the aggregate!)**

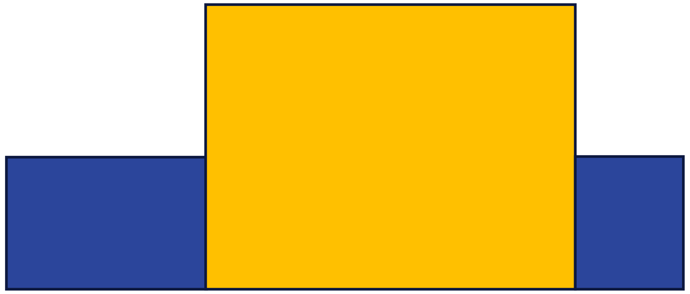
High-level overview methodology (1/7)

- We model **400 households** with **unique hourly load profiles** for one year



High-level overview methodology (2/7)

- We model 400 households with unique hourly load profiles for one year
- We assume the **energy prices to be exogeneous and reflected via a simple two-period TOU tariff** (peak: 8am-9pm weekdays, the remainder off-peak), no other distortions



High-level overview methodology (3/7)

- We model 400 households with unique hourly load profiles for one year
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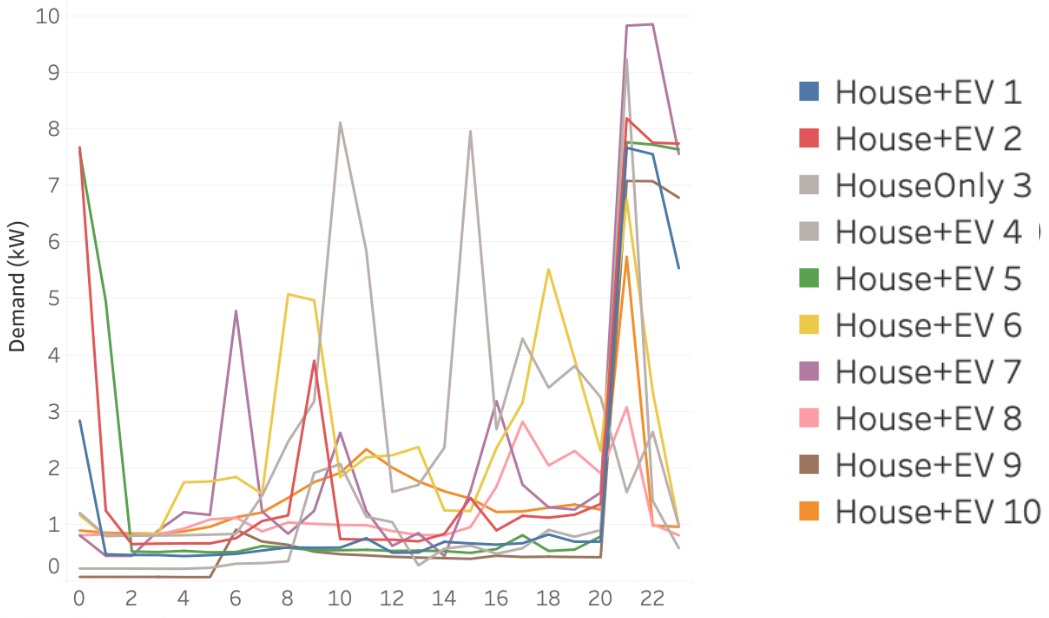
- We vary the rate of electrification over the households
  - Each **EV has a unique driving schedule that must be respected**:
  - EV load responds rationally to price signals (energy charge + network tariff) when plugged-in (**perfect foresight**) – MILP



High-level overview methodology (4/7)

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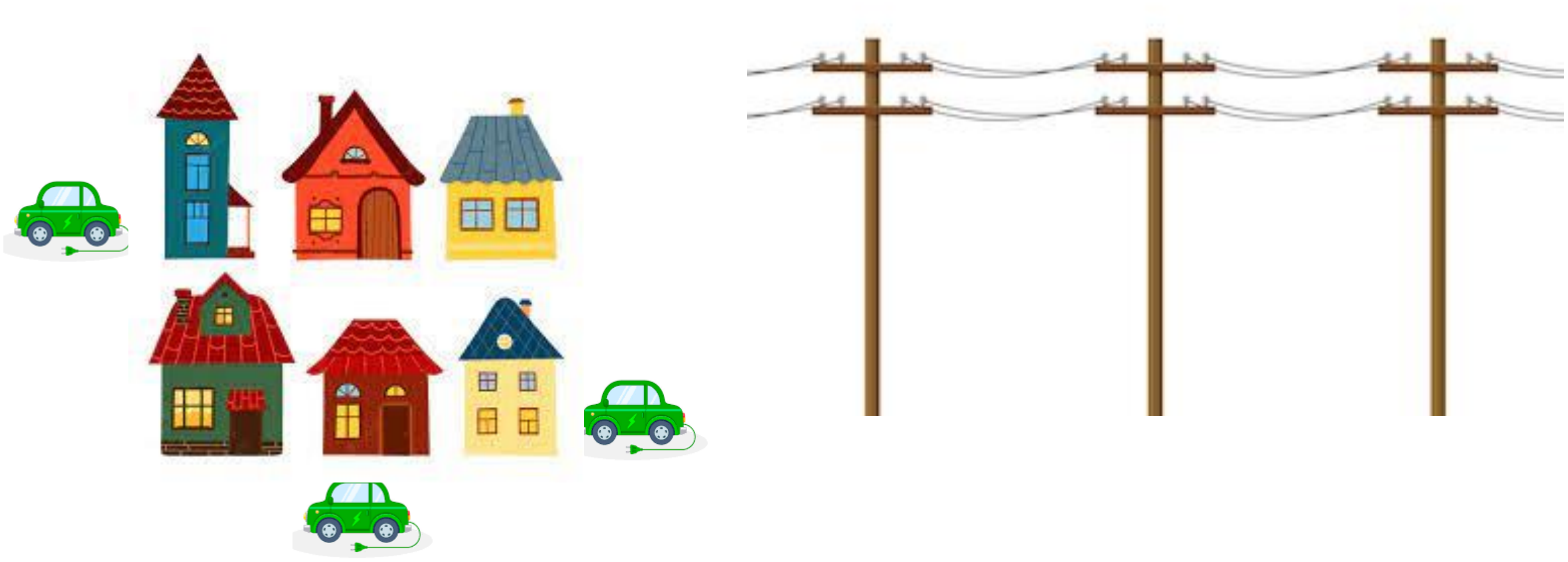
  - Each EV has a unique driving schedule that must be respected:
  - EV load responds rationally to price signals (energy charge + network tariff) when plugged-in (perfect foresight) – MILP
- We test **four standard formats network tariff designs**: fixed, volumetric, capacity, and subscription (with and without time differentiation)

Magnitudes under 0% of EV adoption

Tariff Type	Cost
Fixed charge	$1000 per year
Flat volumetric (baseline)	$0.11/kWh all hours
TOU volumetric 2-period	$0.07/kWh off-peak $0.18/kWh peak
Flat capacity/subscription	$158/kW-year
TOU capacity/subscription 3-period	$30/kW-year off-peak $70 /kW-year mid-peak $87/kW-year on-peak

High-level overview methodology (5/7)

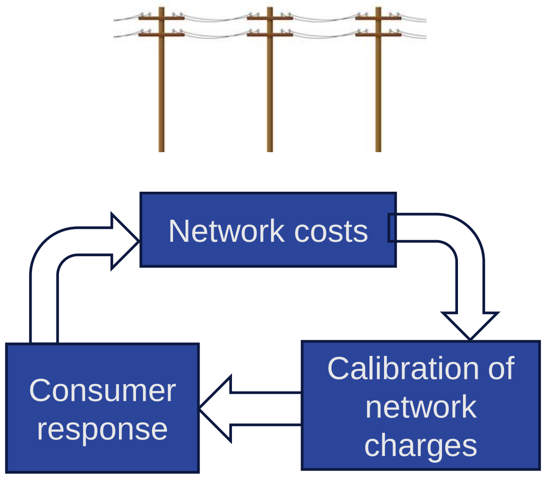
- We assume those 400 households are connected to **one feeder** and increases in the annual aggregated **coincident peak demand lead to linearly increasing network costs**

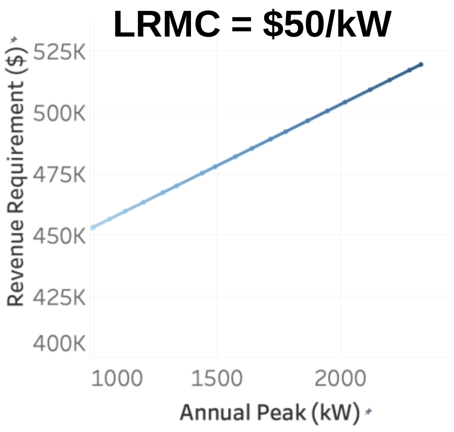


High-level overview methodology (6/7)

- We assume those 400 households are connected to one feeder and increases in the annual aggregated coincident peak demand lead to linearly increasing network costs

- The **revenue requirement** equals the base case network costs (no electrification) plus a constant (≈ LRMC) multiplied by the delta in coincident peak demand relative to the base case (iteration until equilibrium = cost recovery)





High-level overview methodology (7/7)

- We assume those 400 households are connected to one feeder and increases in the annual aggregated coincident peak demand lead to linearly increasing network costs

- The revenue requirement equals the base case network costs (no electrification) plus a constant (≈ LRMC) multiplied by the delta in coincident peak demand relative to the base case (iteration until equilibrium = cost recovery)

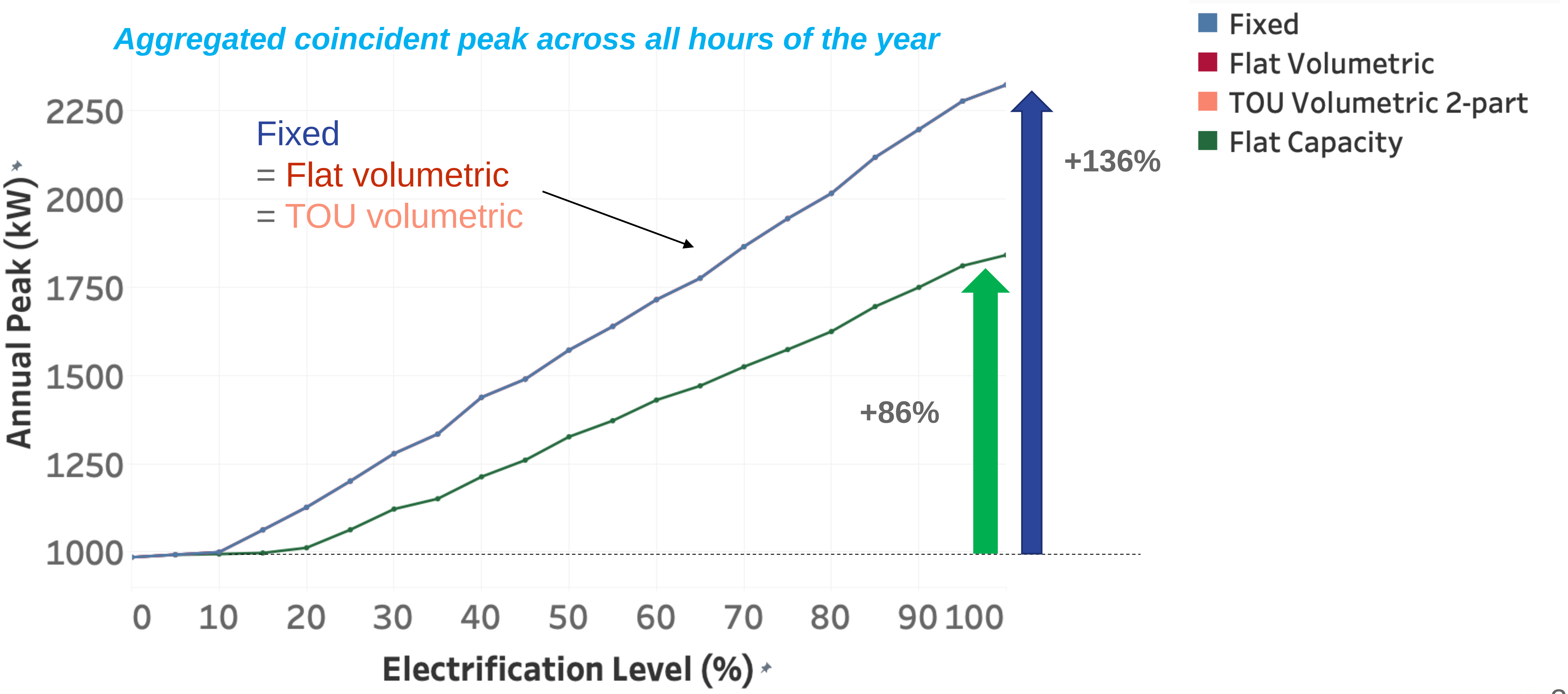
- We asses the results based on **three metrics**
  1. **Annual peak**: highest aggregate demand of all homes across the full year
     - Proportional to revenue requirement: total network cost to be collected through tariff

  2. **Levelized cost of EV charging**: $/kWh equivalent paid to charge EVs (even more important for heat pump due to cheap natural gas)

  3. **Change in network cost for non-EV owners**: Change in network cost for non-EV owners expressed in $/year relative to flat volumetric network tariff at 0% EV adoption

Results

What is the aggregated peak under each tariff at different electrification levels?



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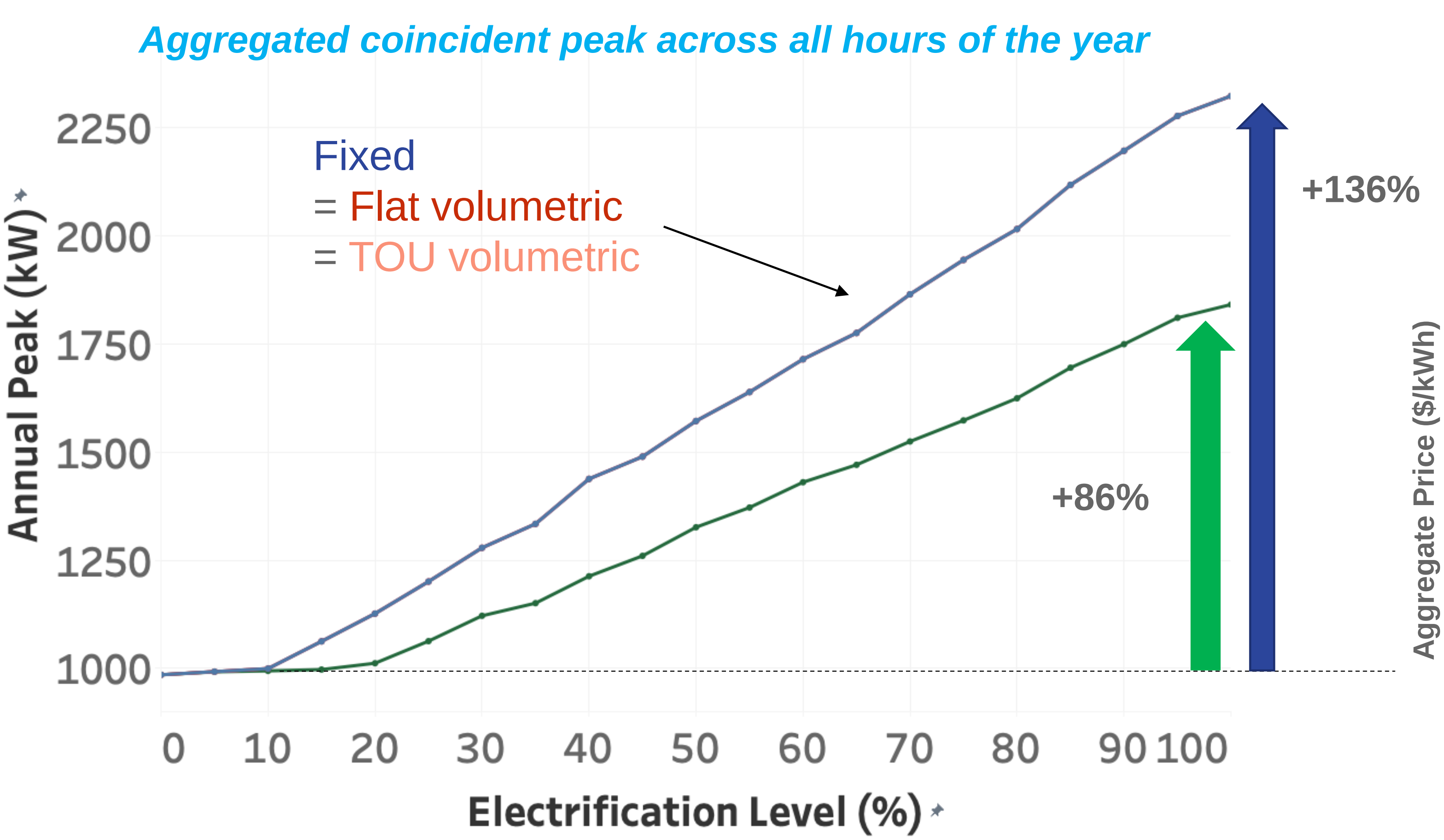
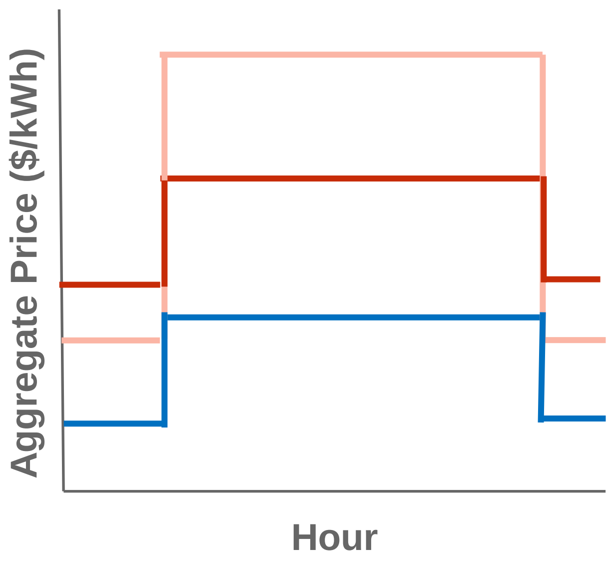
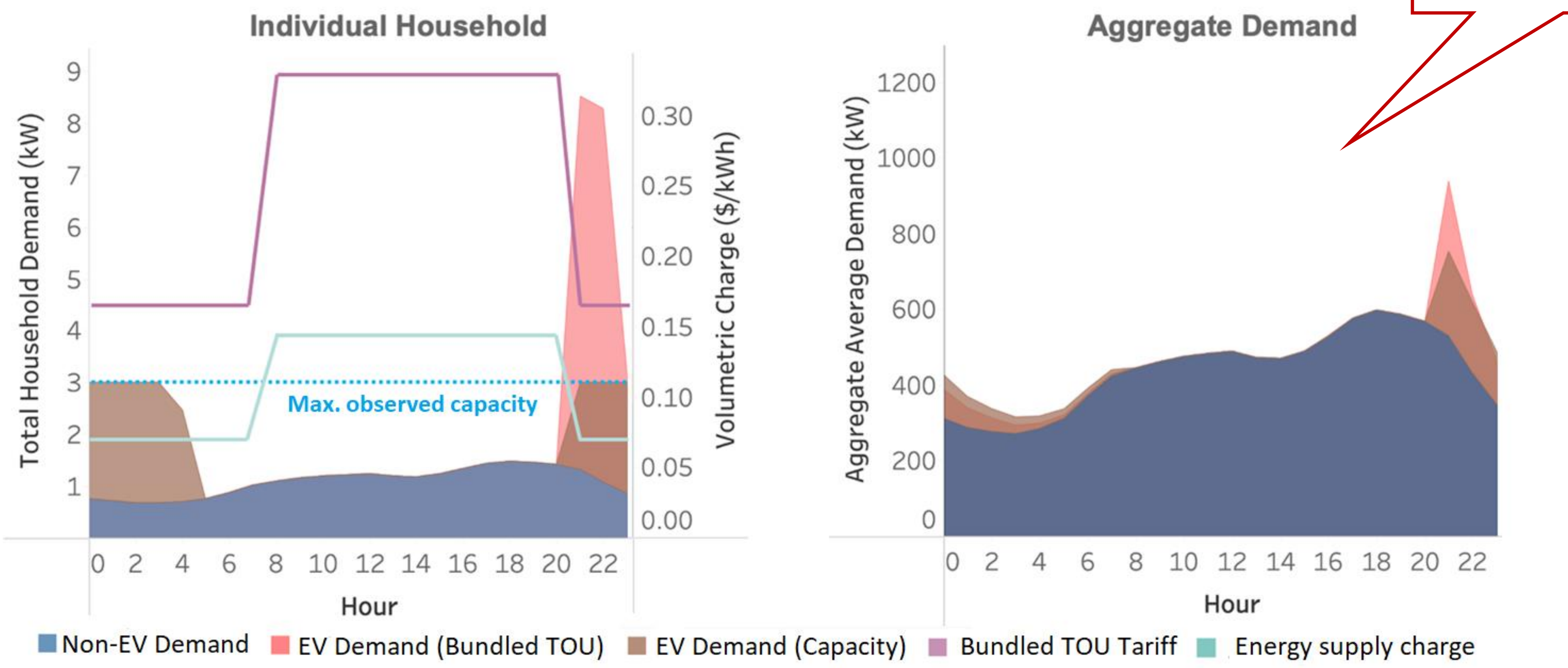


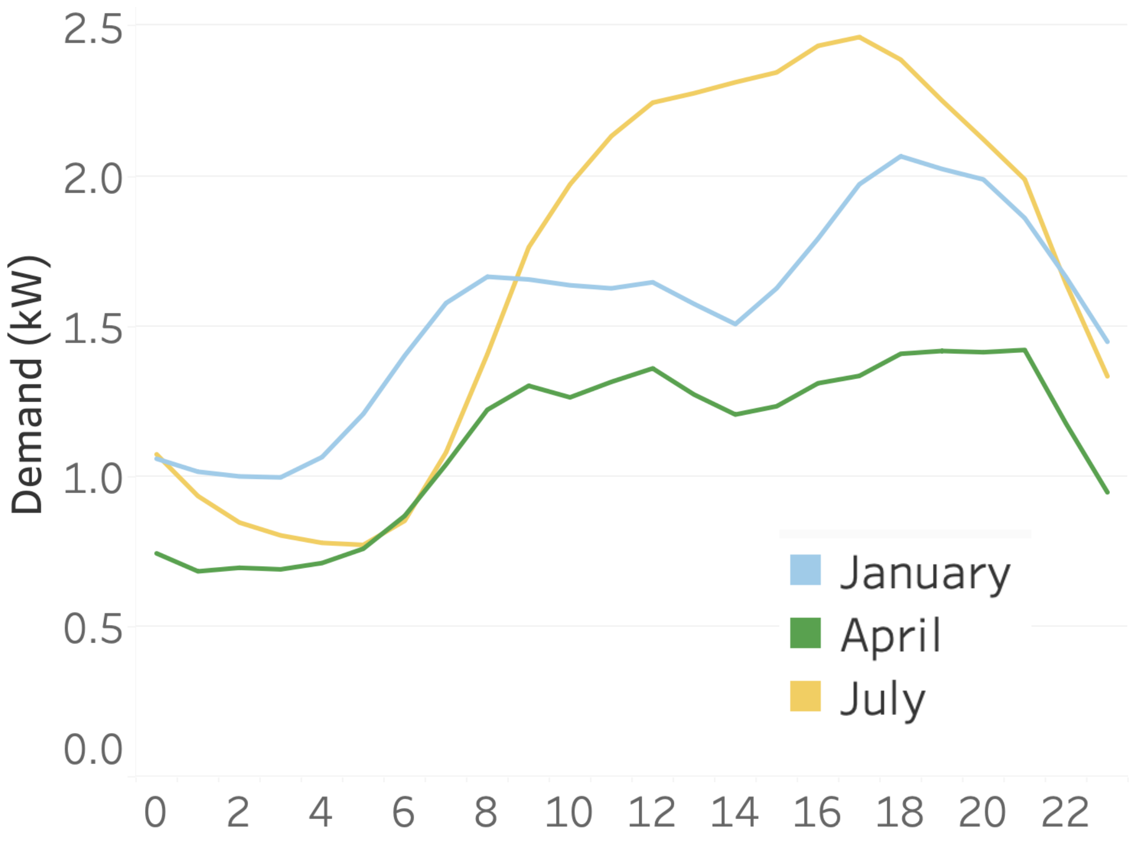


What is driving the peak up?

Results for an EV adoption level of 30% among the 400 households

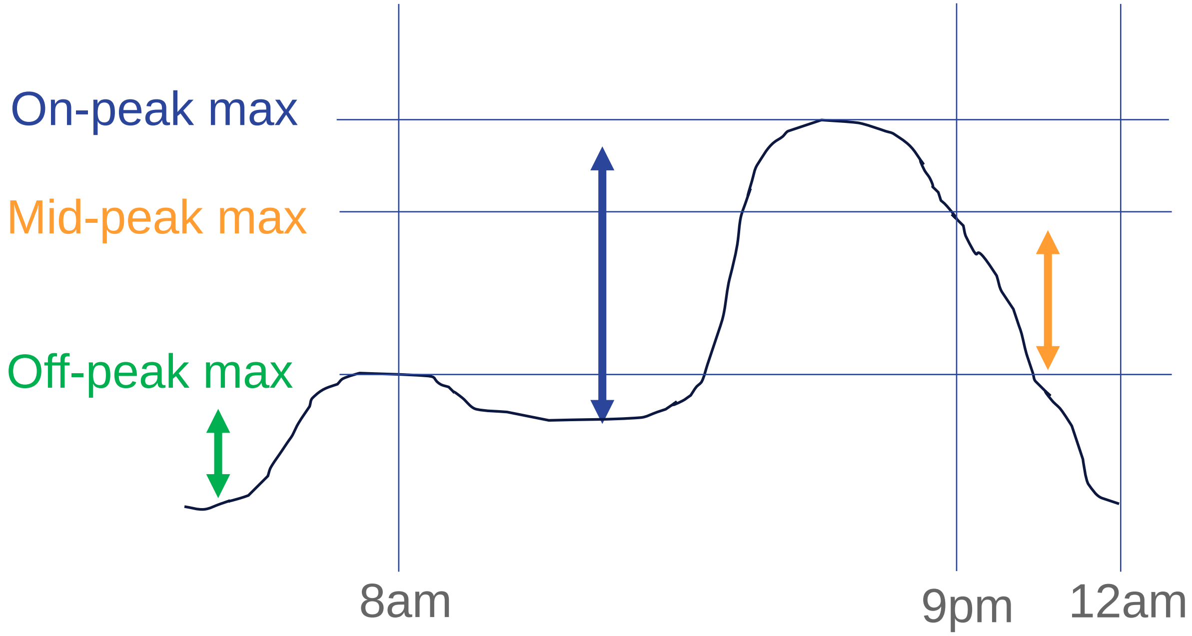


Can we do better with time/seasonal differentiation?

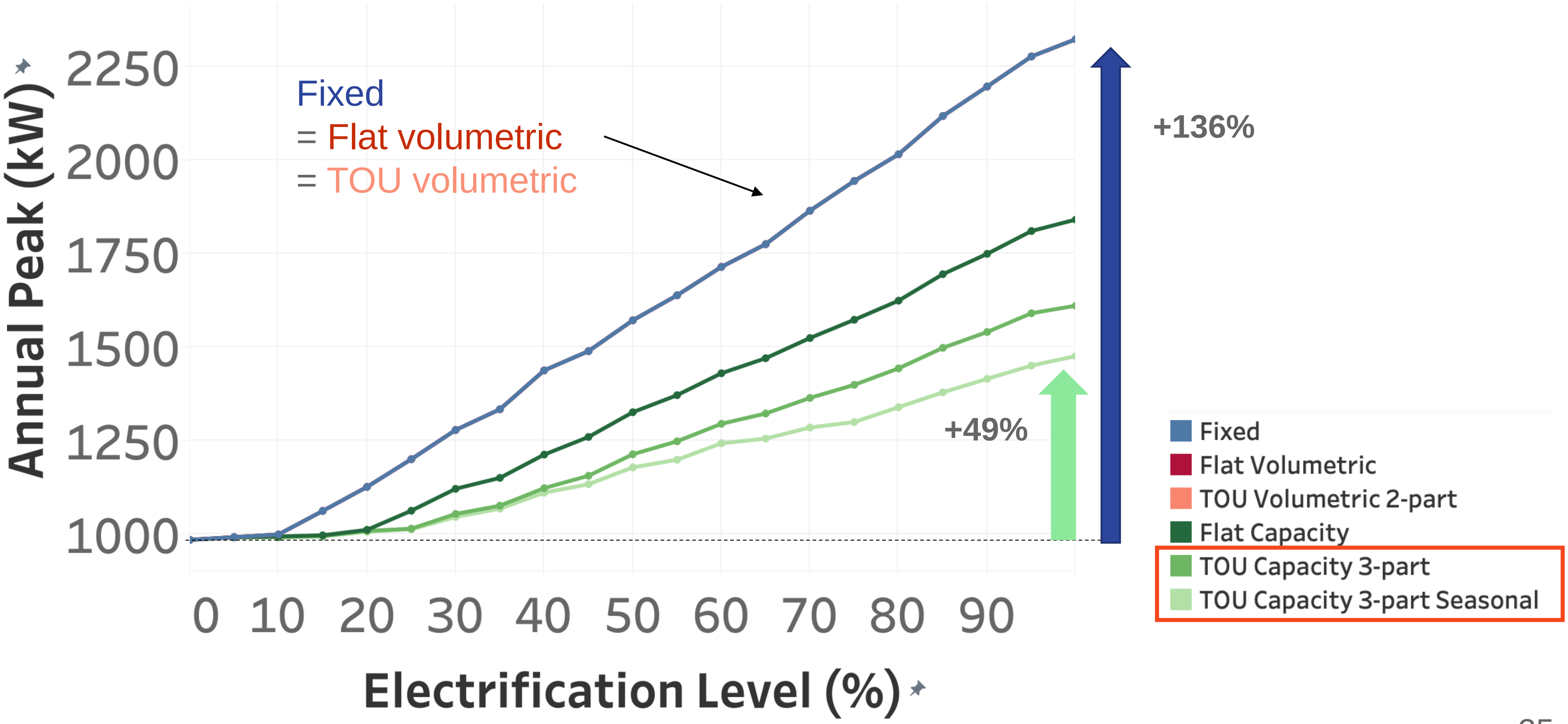


Demand of average house on peak day in each month at 0% adoption

If we have 3 separate capacity charges, midnight-8am is likely the MOST restrictive because has the lowest inelastic peak



How can we improve by considering intra-daily & seasonal variation?



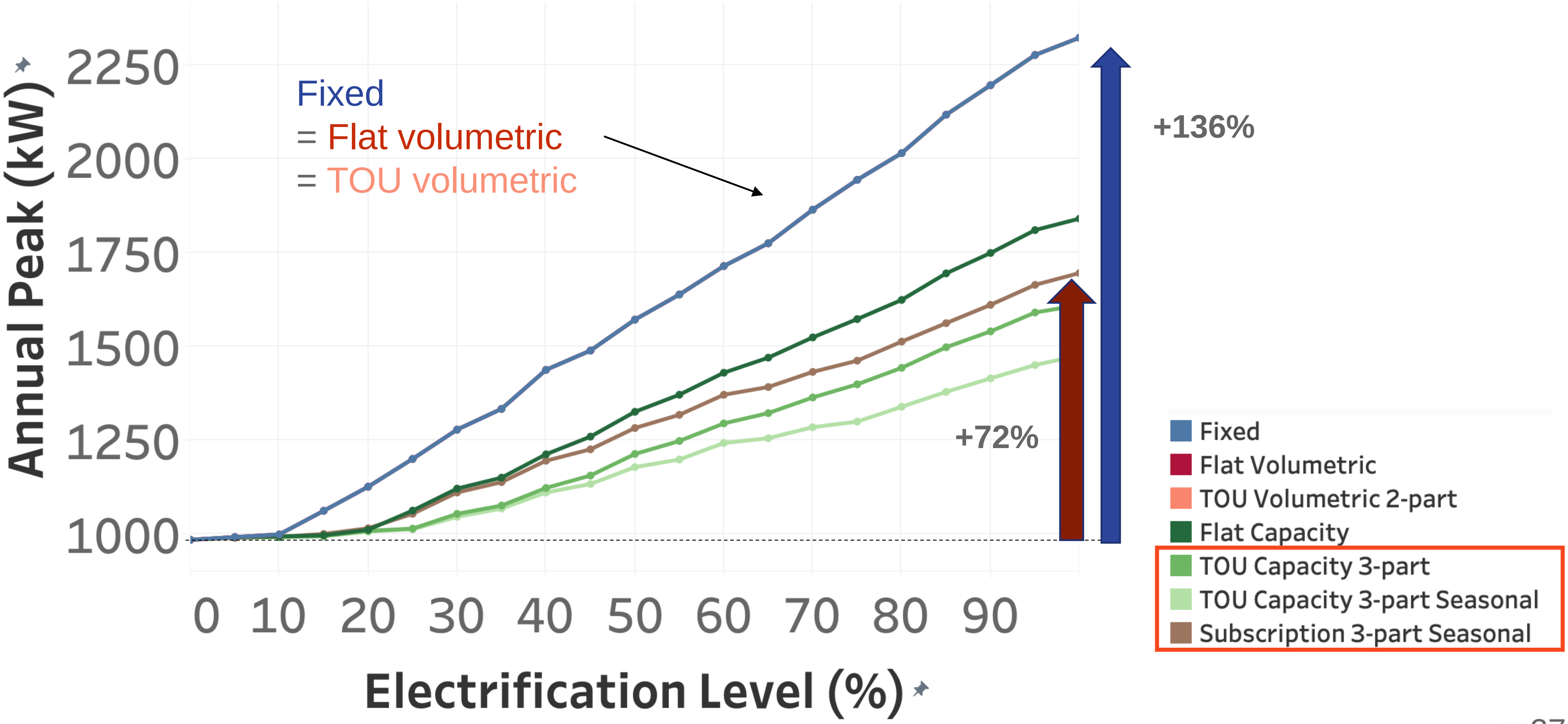
Can we do more realistic? A 3-part subscription

Methodology:

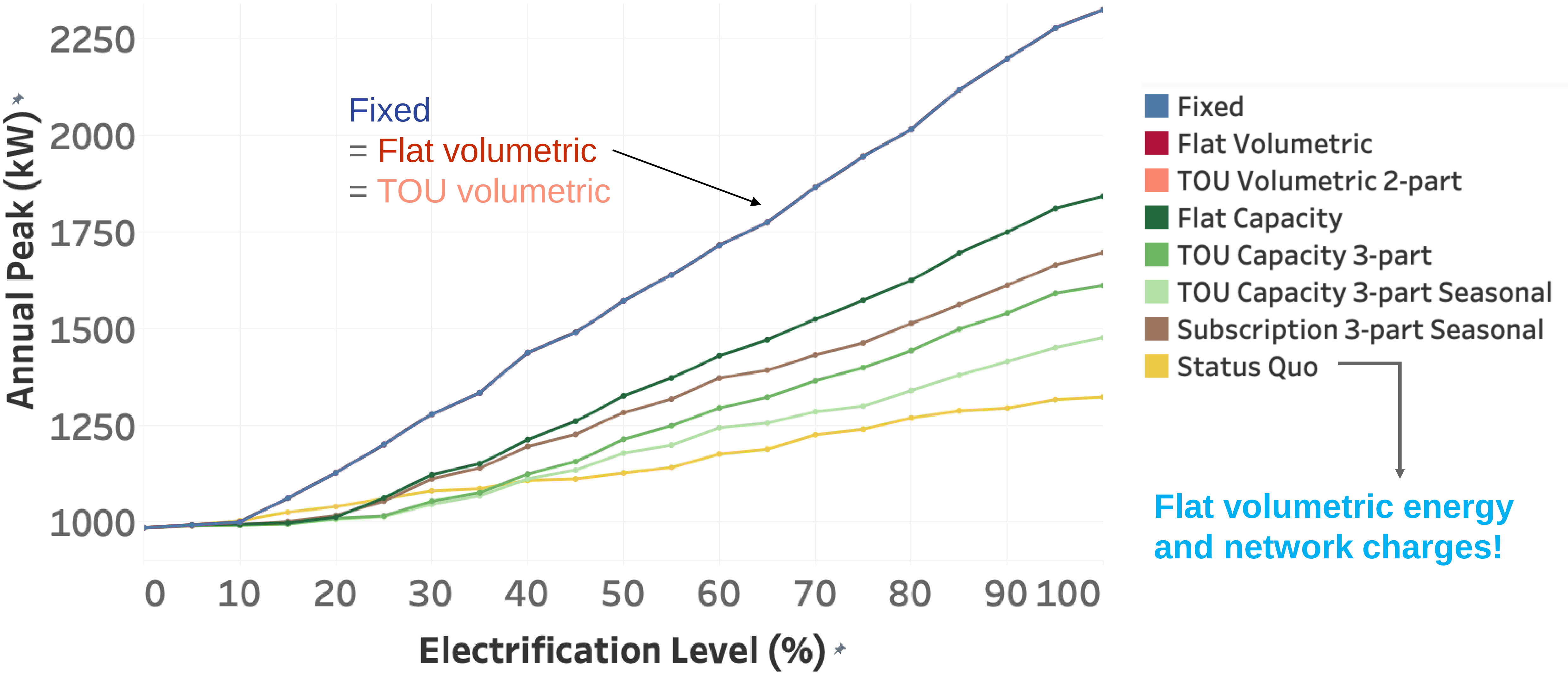
1. We run the optimization as for the 3-part capacity charge
2. We determine per consumer the peak usage in each of the 3 time-windows
3. Subscription value= peak usage + 2kW “buffer”
4. Run the optimization for each consumer again but now with a hard physical cap equal to the subscription value per time period

- Idea is that this is the “exercise” a consumer would do to determine its subscription
- Sensitive to the “buffer” value

How does a subscription tariff perform?

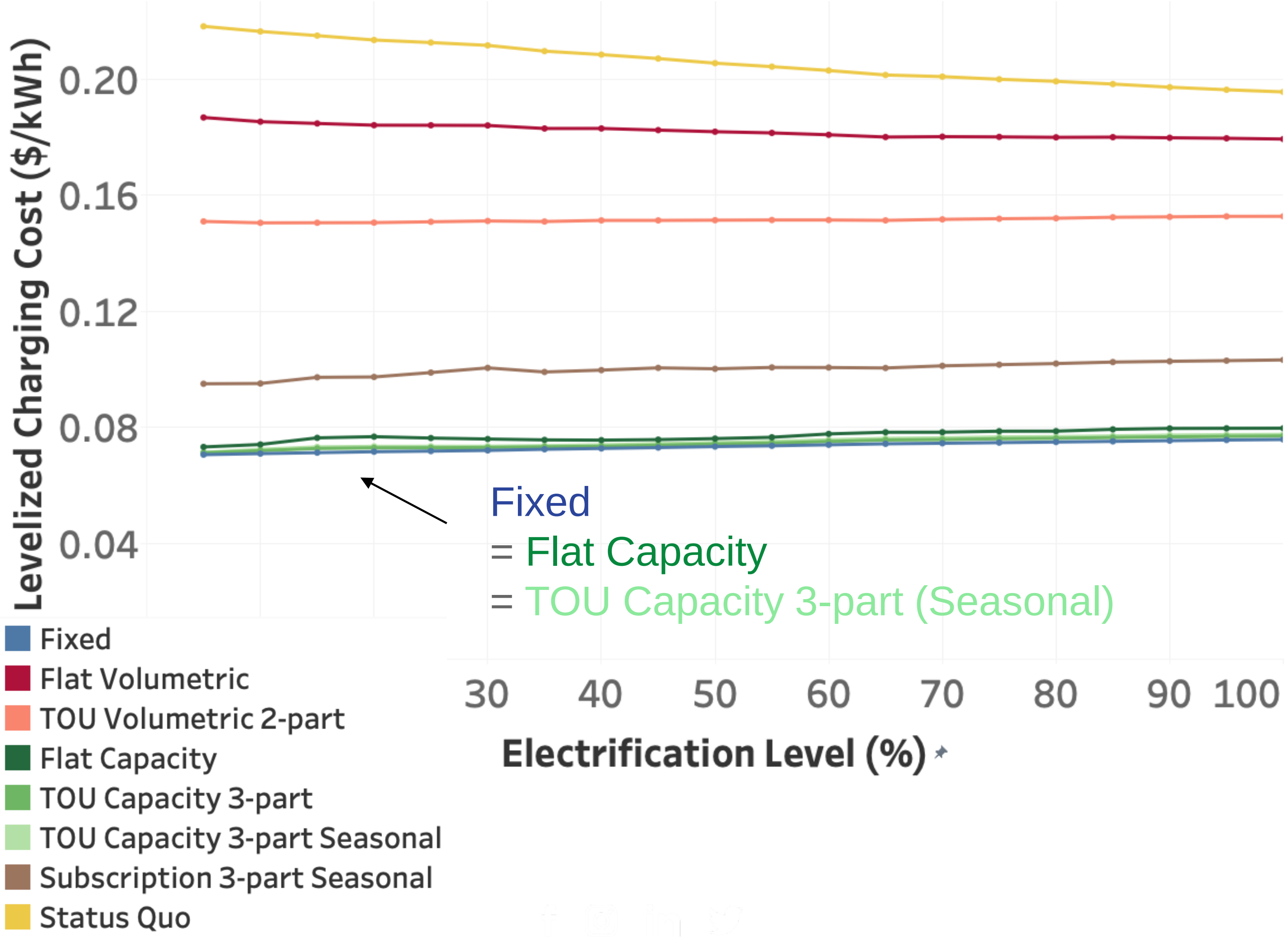


The paradox: the status quo

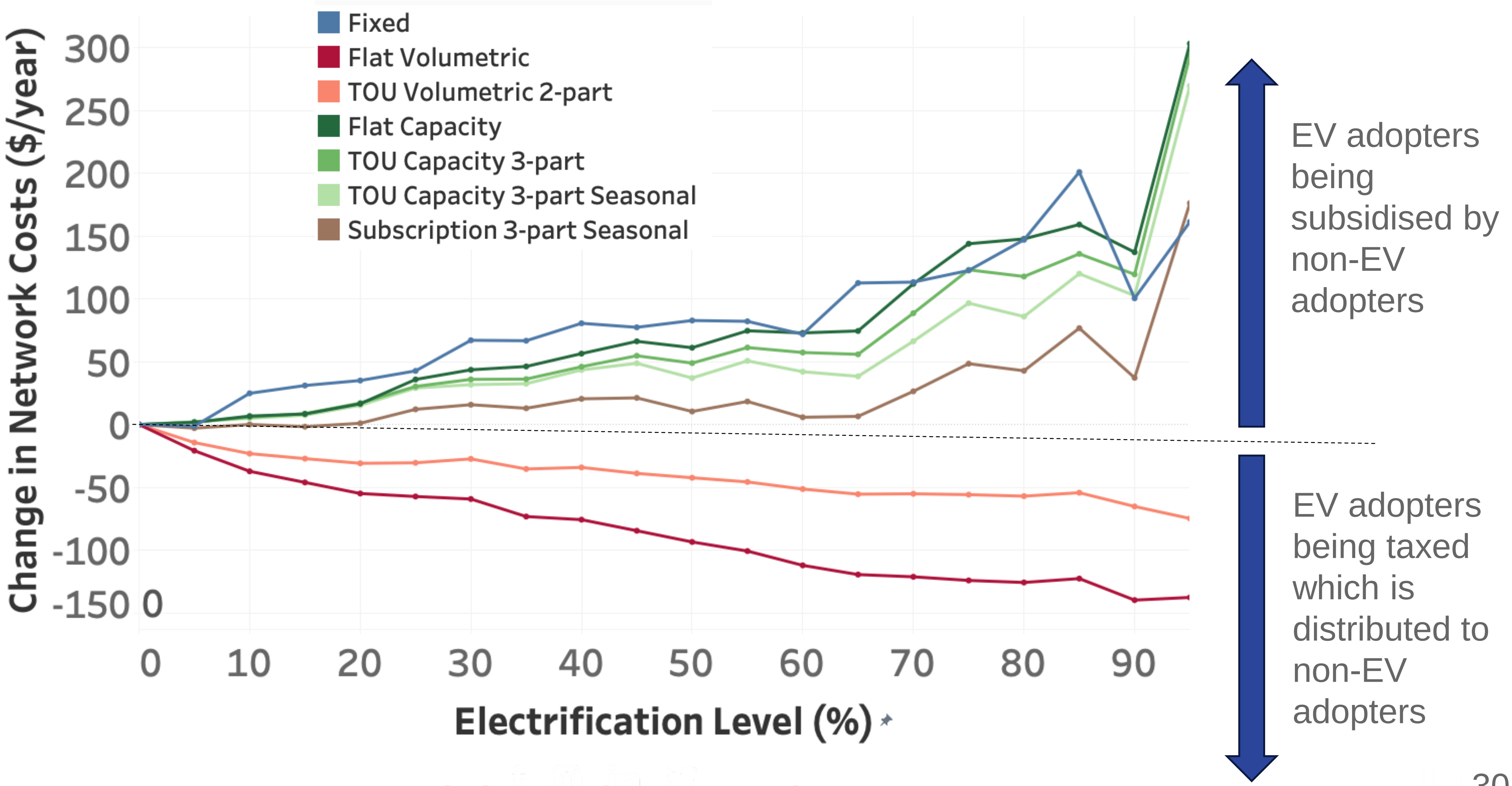


Flat volumetric energy and network charges!

But status quo is an unstable equilibrium

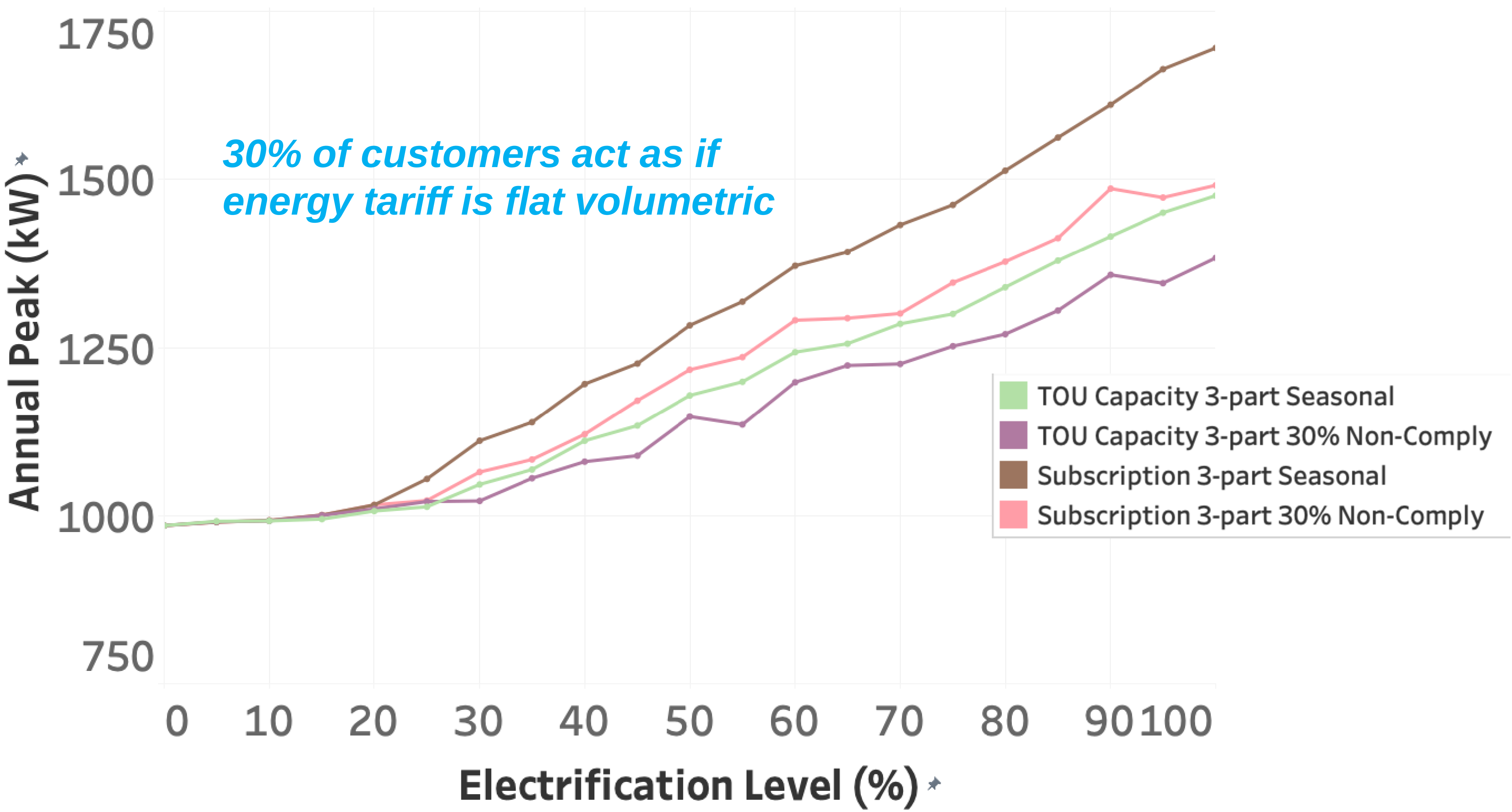


What are the distributional impacts on non-EV households under each tariff?

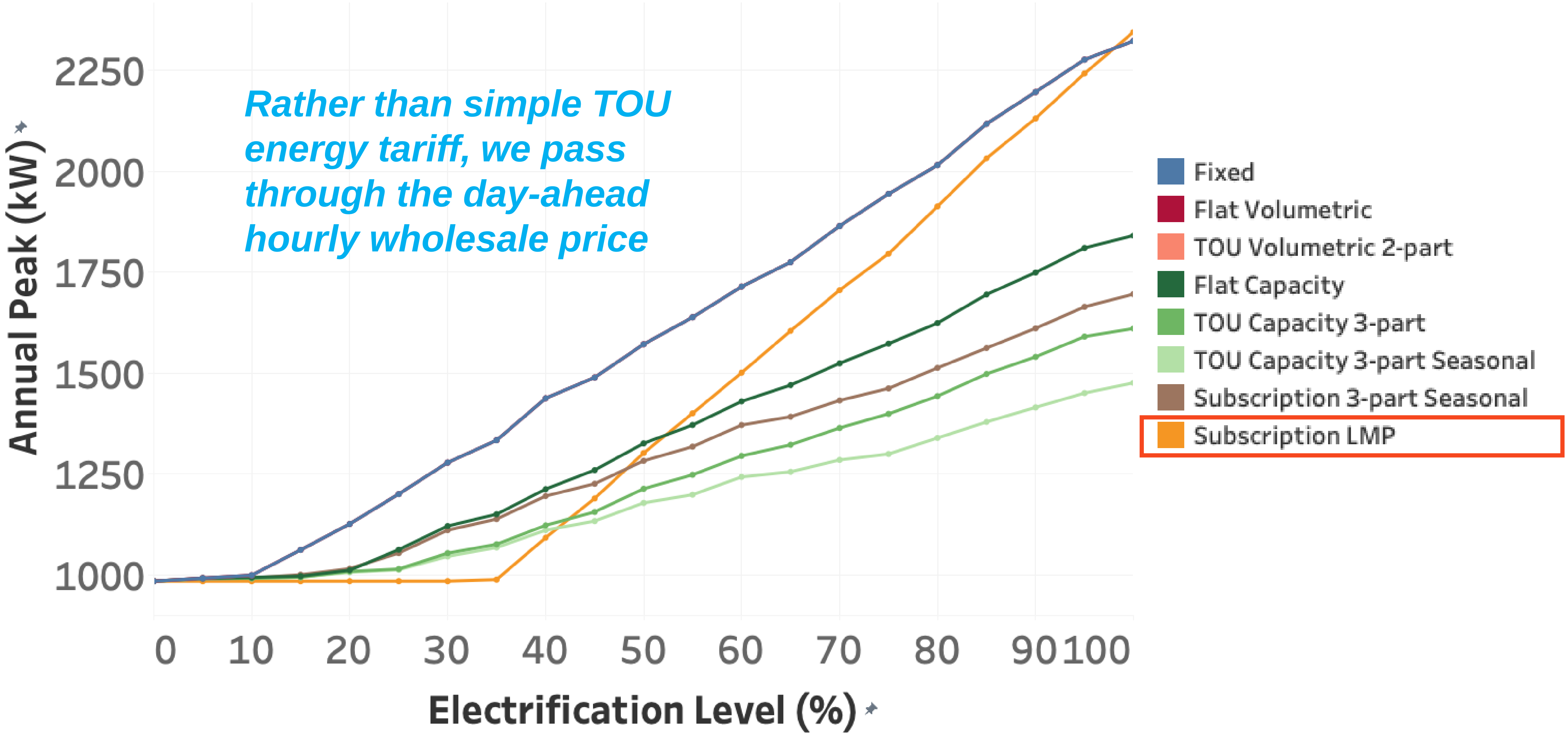


Strongly impact by assumed LRMC!

The good (antifragile) news: some consumers ignoring the rate design makes its performance better!



The bad news: if EV owners adopt dynamic energy prices the whole story becomes (even) more complicated



Capacity-based charges find a right balance between cost-reflectivity and distributional impacts…

Results for 50% EV adoption among the 400 households

Complexity ↓

Network Tariff	Annual Peak (kW)	Levelized Charging Cost ($/kWh)	Change in Network Cost for non-EV owners (%)
Fixed	1572	$0.07	63%
Status quo	1572	$0.18	-8%
1-part Demand Charge	1326	$0.08	12%
3-part Seasonal Subscription	1283	$0.10	13%
3-part Seasonal Demand Charge	1178	$0.07	8%

The higher the peak, the higher total network costs that need to be recuperated from all consumers

The lower the levelized charging costs, the more EV adoption is stimulated

Low distributional impacts are vital for the acceptability of the tariff

…with subscription charges capturing a large share of the benefits while having lower complexity

Conclusions

What are the key findings?

Increasing levels of renewables in the power system and ongoing electrification efforts increase the importance of electricity rate design, while smart meters and digitalisation enable consumers to respond to price signals

We see a slow but positive trend in better reflecting the value of electricity generation to consumers with **time-varying supply charges** in Europe. However, time-varying supply charges quickly leads to local issues if not **complemented with cost-reflective network charges** as electrification progresses:

1. **Purely volumetric network charges** (with or without time-differentiation) are not a good idea
   - No signal to limit aggregated peaks & makes electrification expensive
2. **Fixed network charges** also do not seem a good idea
   - No signal to limit aggregated peaks, foster electrification but can lead to distributional impacts when not differentiated.
3. **Capacity-based tariffs** perform well but might not be easy to implement. A three part-subscription based tariff seems like a pragmatic solution. The exact design needs tailoring to be effective.
   - Increase in aggregated peak limited & even better if some consumer ignore price signals
   - Fosters electrification & no exaggerated distributional effects

Other **long-run solutions complementing capacity-based network charges** include load control, discriminate rates to create randomness, auctions for network capacity, local price setting based on equilibria estimations, etc.

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