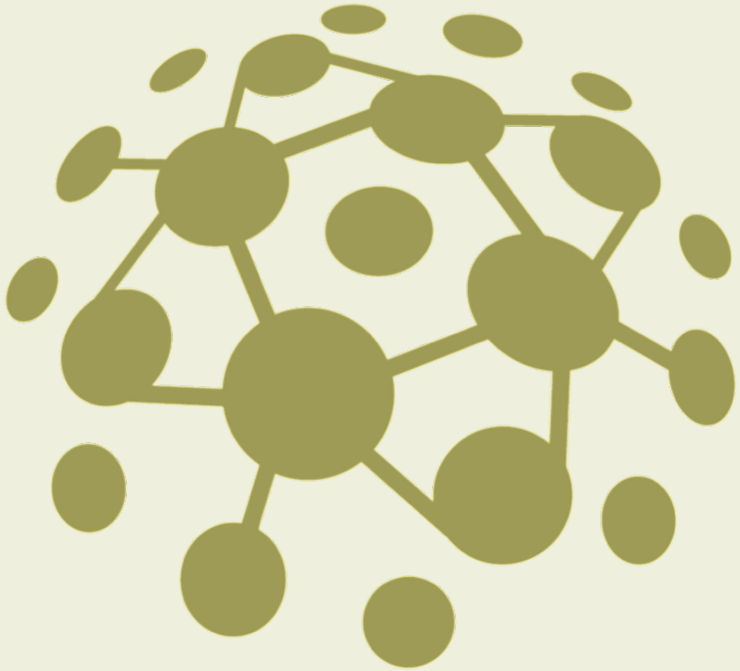

IMPACT OF PEAK, FIXED, AND VOLUMETRIC NETWORK TARIFFS ON RESIDENTIAL CUSTOMERS' ELECTRICITY EXPENDITURES BASED ON LOAD PROFILES AND SOCIO-ECONOMIC CHARACTERISTICS

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Agenda

An analysis of real household load data to inform pending decisions about new regulatory schemes

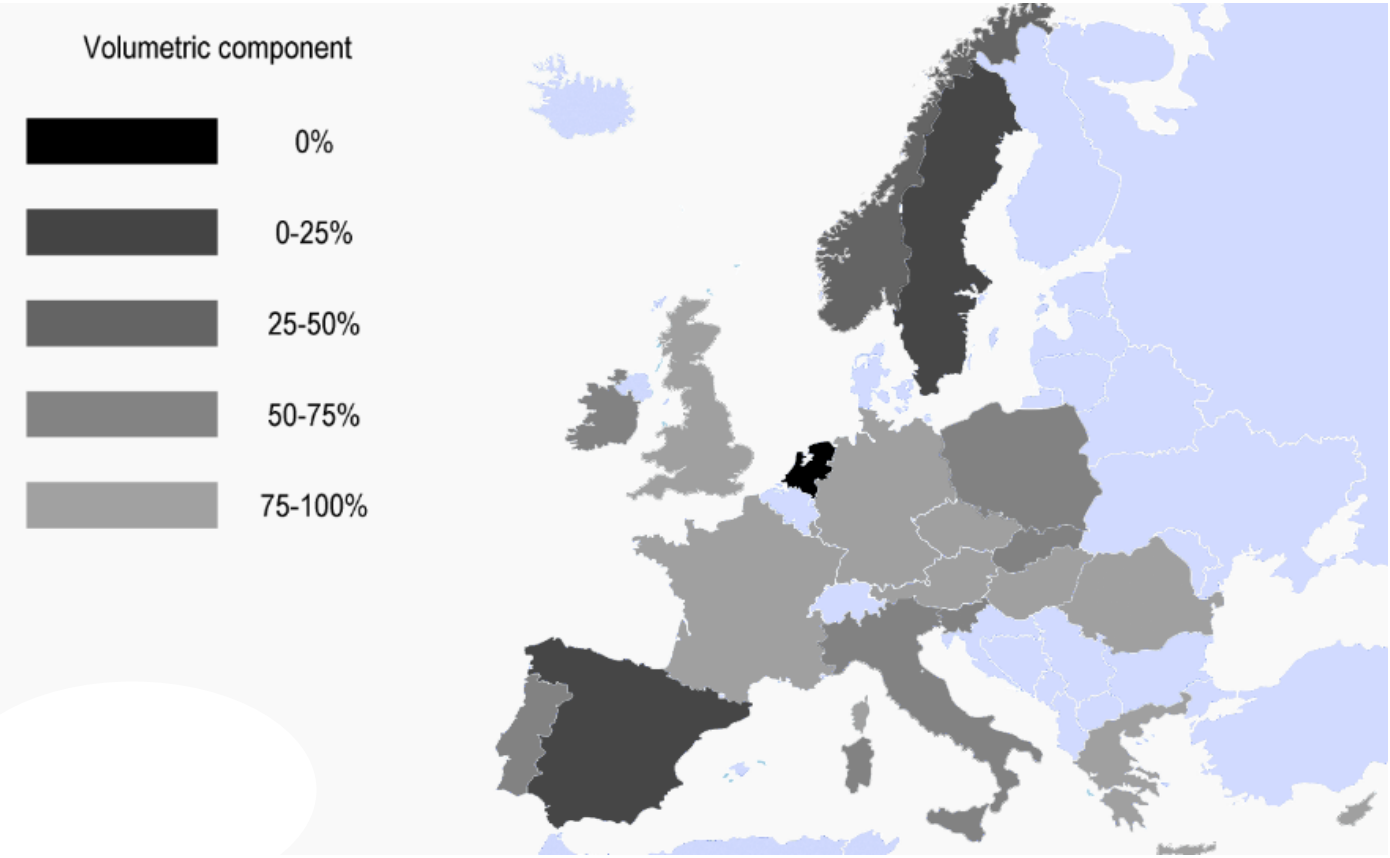
- How are residential network tariffs set?
- Why will adaption be needed?
- How could future network tariffs look like?
- What will be the impact of new tariffs on households?

Setting network tariffs – How is it done?

Regulator can use:

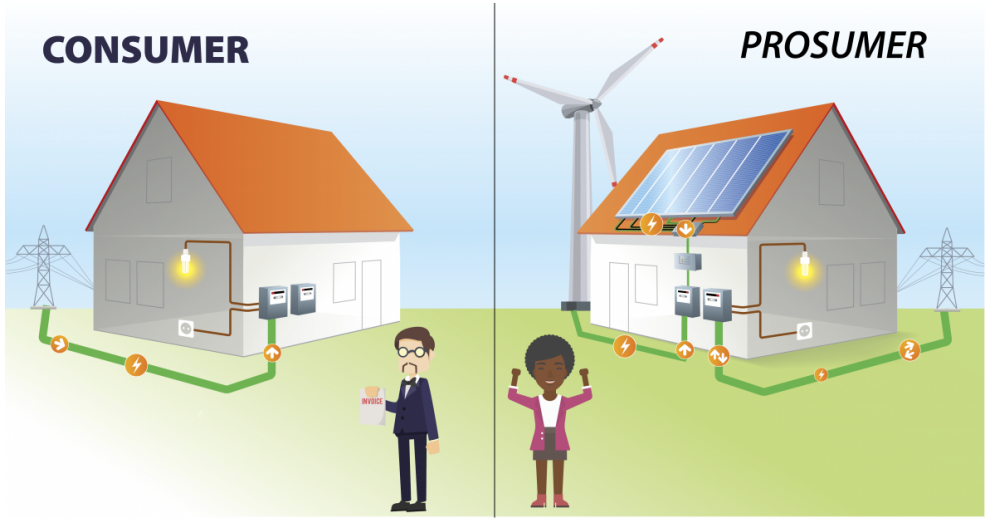
- volumetric energy charges - charging customers for the amount of consumed electricity; €/kWh
- fixed charges per customer - independent of their energy consumption but possibly varying over households based on their contracted capacity, but not relying on actual load measurements; €/per household per year
- peak demand charges - based on the actual measured capacity; €/kW peak load

Portion of volumetric component in European regulatory schemes



Why are prosumers likely to introduce imbalance under volumetric tariffs?

- Revenues from grid tariffs need to equal CAPEX and OPEX of transmission/distribution
- Thus if significant amounts of consumed electricity are not purchased over the grid, but produced by PV chargeable volumes decrease
- and consequently charges per kWh need to increase to compensate decreasing contribution from prosumers



Source: Office of Energy Efficiency and Renewable Energy, graphic by Sarah Harman

Prosumers are important for future energy system, but:

CAPEX and OPEX are not volume-driven:

- costs are capacity driven - (almost) no marginal costs for additional kWh transported via the grid
- prosumers therefore account for the (~) same costs to the TSO/DSO, but contribution to cost recovery decreases significantly. Thus if significant amounts of consumed electricity are not purchased over the grid, but produced by PV chargeable volumes decrease

Prosumers are usually more privileged:

- PV, e-cars, in-home batteries, ... all require specific property rights (roofs, garages, ...) and financial capacities
- if costs of power grids are shifted towards lower income classes, then acceptance of the population for the energy transition is at risk

Smart Metering – possible solution?

Smart metering of households' electricity consumption in many EU nations until 2019

Gives "load profiles" of households, i.e. consumption during small time intervals

Therefore, tariffs based on measured capacity demand - peak load in kW - can be used

Research questions

1. What is the impact of peak load based tariffs on household budgets?

2. Is the sign and magnitude of the impact associated with specific household characteristics?

3. and therefore: can peak load based tariffs be introduced right away or may these induce disproportional burdens for some?

Energy Data

765 households

15-minutes load profiles

April 2010 – March 2011

Sociodemoraphics

Some characterstics,including ameneties and type of household

Income and additional ameneties for 406 households

Method

We simulate possible tariff scenarios and their impact based on load profile of 765 Austrian households

Tariffs

Scenario	**Description** (overall network costs are recovered through)	**Fixed charge** (per household per year)	**Energy charge** (per kWh)	**Peak/capacity charge** (per kW peak)
reference	tariff as applied in Austria in 2016	€24.60	€0.043	–
f100	100% flat tariff	€178.05	–	–
pa100	100% peak charge, based on the average of the 12 monthly measured peak loads	–	–	€39.07
pm100	100% peak charge, based on the one maximum load	–	–	€29.59
e100	100% energy charge, only based on consumed volume	–	€0.050	–
f50/e50	50% from fixed charges and 50% from consumed volume	€89.02	€0.025	–
f50/pa50	50% from fixed charges and 50% from peak charges (average of the 12 monthly peaks)	€89.02	–	€19.53
f50/pm50	50% from fixed charges and 50% from peak charges (one maximum load)	€89.02	–	€14.79
pa50/e50	50% from peak charges (average of the 12 monthly peaks) charge and 50% from consumed volume	–	€0.025	€19.53
pm50/e50	50% from peak charges (one maximum load) and 50% from consumed volume	–	€0.025	€14.79
f/pa/e*	14% from fixed charges, 43% from consumed volume and 43% from peak charges (average of the 12 monthly peaks)	€24.60	€0.022	€16.83
f/pm/e*	14% from fixed charge, 43% from consumed volume and 43% from peak charges (one maximum load)	€24.60	€0.022	€12.75

Main results: relative difference in network costs

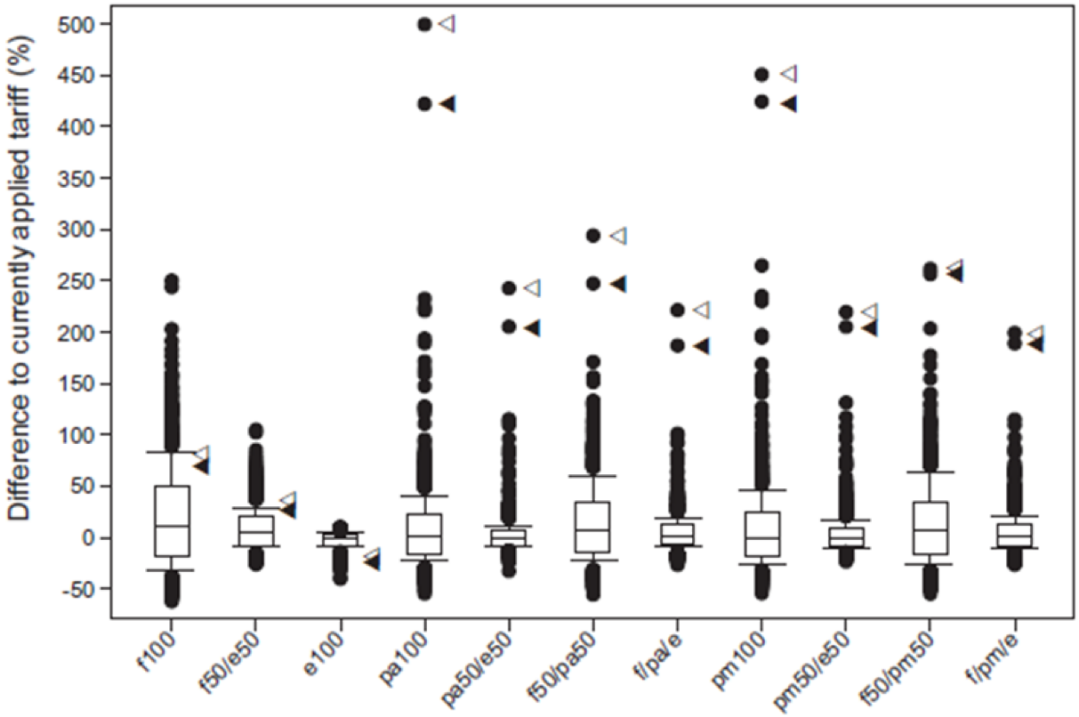


Figure 1: Change in annual network expenditure under different tariff scenarios. The full sample of 765 households is analyzed in each of the scenarios.The bottom of each box is the 25^{th} percentile, horizontal line in the middle of each box represents the median and the top of each box is the 75^{th} percentile, vertical lines outside of the box (whiskers) end at 10^{th} and 90^{th} percentiles, the dots are considered as outliers. For illustration the two households with the highest increase in network expenditures under scenarios including a peak component are marked by open and filled triangles.

Main results: effects of household characteristics on relative difference of their network costs

	f100	f50/e50	e100	pa100	pa50/e50	f50/pa50	f/pa/e	pm100	pm50/e50	f50/pm50	f/pm/e
Nr_persons	-15.643***	-6.564***	2.515***	-6.275***	-1.880***	-10.959***	-3.782***	-7.351***	-2.418***	-11.497***	-4.245***
	(1.354)	(0.568)	(0.218)	(1.312)	(0.626)	(1.096)	(0.605)	(1.383)	(0.656)	(1.143)	(0.639)
Square	-0.173***	-0.073***	0.028***	-0.085**	-0.029	-0.129***	-0.049***	-0.050	-0.011	-0.112***	-0.034*
	(0.042)	(0.018)	(0.007)	(0.041)	(0.019)	(0.034)	(0.019)	(0.043)	(0.020)	(0.035)	(0.020)
Dummy_square	-8.391**	-3.521**	1.349**	-3.664	-1.158	-6.028**	-2.157	-3.384	-1.018	-5.888*	-2.036
	(3.641)	(1.528)	(0.585)	(3.528)	(1.683)	(2.948)	(1.626)	(3.720)	(1.765)	(3.074)	(1.718)
Pool	-23.022***	-9.661***	3.701***	-12.790**	-4.545*	-17.906***	-7.098***	-15.572***	-5.935**	-19.297***	-8.296***
	(5.860)	(2.459)	(0.942)	(5.678)	(2.709)	(4.745)	(2.617)	(5.987)	(2.841)	(4.947)	(2.765)
Sauna	-2.238	-0.939	0.360	9.864**	5.112**	3.813	4.096**	16.102***	8.231***	6.932*	6.784***
	(4.430)	(1.859)	(0.712)	(4.292)	(2.048)	(3.587)	(1.978)	(4.526)	(2.148)	(3.740)	(2.090)
Solarium	-12.620	-5.295	2.029	9.739	5.884	-1.440	3.327	9.265	5.647	-1.677	3.123
	(10.398)	(4.363)	(1.672)	(10.075)	(4.806)	(8.420)	(4.643)	(10.624)	(5.041)	(8.779)	(4.905)
Rural	-18.723***	-7.856***	3.010***	-7.644	-2.317	-13.183***	-4.584**	-6.262	-1.626	-12.493***	-3.988*
	(4.827)	(2.025)	(0.776)	(4.677)	(2.231)	(3.909)	(2.155)	(4.932)	(2.340)	(4.075)	(2.277)
House	-15.212***	-6.383***	2.445***	-18.694***	-8.125***	-16.953***	-9.104***	-19.303***	-8.429***	-17.258***	-9.366***
	(3.994)	(1.676)	(0.642)	(3.870)	(1.846)	(3.235)	(1.784)	(4.081)	(1.936)	(3.372)	(1.884)
Constant	108.497***	45.665***	-17.168***	52.072***	17.452***	80.285***	30.031***	49.352***	16.092***	78.925***	28.859***
	(5.875)	(2.465)	(0.944)	(5.692)	(2.715)	(4.757)	(2.623)	(6.002)	(2.848)	(4.960)	(2.771)
Observations	763										
R-squared	0.373	0.373	0.373	0.164	0.106	0.347	0.217	0.152	0.102	0.326	0.199

All values are given as percentage changes between the reference scenario and the stated alternative scenario.
Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Main results: effects of household characteristics on relative difference of their network costs

	f100	f50/e50	e100	pa100	pa50/e50	f50/pa50	f/pa/e	pm100	pm50/e50	f50/pm50	f/pm/e
Logincome	-7.526	-3.183	1.160	-12.400**	-5.620**	-9.963**	-5.875**	-12.187**	-5.514**	-9.857**	-5.782**
	(5.014)	(2.121)	(0.773)	(5.124)	(2.435)	(4.235)	(2.373)	(5.551)	(2.646)	(4.417)	(2.556)
Dummy_income	6.012	2.543	-0.927	-2.266	-1.596	1.873	-0.580	-2.719	-1.823	1.646	-0.777
	(4.418)	(1.868)	(0.681)	(4.514)	(2.145)	(3.731)	(2.090)	(4.890)	(2.331)	(3.891)	(2.252)
Square	-0.223***	-0.094***	0.034***	-0.087	-0.026	-0.155***	-0.052**	-0.050	-0.008	-0.136***	-0.036
	(0.055)	(0.023)	(0.008)	(0.056)	(0.027)	(0.046)	(0.026)	(0.061)	(0.029)	(0.048)	(0.028)
Dummy_square	-3.457	-1.462	0.533	-4.063	-1.765	-3.760	-1.991	-2.447	-0.957	-2.952	-1.291
	(4.229)	(1.788)	(0.652)	(4.321)	(2.053)	(3.572)	(2.001)	(4.681)	(2.232)	(3.724)	(2.156)
Rural	-17.282***	-7.309***	2.663***	-6.530	-1.933	-11.906**	-3.983	-5.243	-1.290	-11.263**	-3.425
	(5.934)	(2.510)	(0.915)	(6.064)	(2.882)	(5.012)	(2.808)	(6.569)	(3.132)	(5.227)	(3.025)
House	-18.469***	-7.811***	2.846***	-10.319*	-3.736	-14.394***	-5.704**	-11.259*	-4.206	-14.864***	-6.111**
	(5.257)	(2.223)	(0.810)	(5.372)	(2.553)	(4.440)	(2.487)	(5.819)	(2.774)	(4.630)	(2.680)
Nr_persons	-10.824***	-4.578***	1.668***	-4.959*	-1.645	-7.892***	-2.871**	-6.442**	-2.387	-8.633***	-3.514**
	(2.816)	(1.191)	(0.434)	(2.878)	(1.368)	(2.379)	(1.332)	(3.118)	(1.486)	(2.480)	(1.436)
Dryer	-10.605***	-4.485***	1.634***	-0.213	0.710	-5.409	-0.801	-2.266	-0.316	-6.435*	-1.690
	(3.933)	(1.663)	(0.606)	(4.019)	(1.910)	(3.322)	(1.861)	(4.354)	(2.076)	(3.464)	(2.005)
Dishwasher	-5.062	-2.141	0.780	2.821	1.801	-1.120	0.884	-0.302	0.239	-2.682	-0.469
	(5.754)	(2.433)	(0.887)	(5.879)	(2.794)	(4.860)	(2.722)	(6.369)	(3.036)	(5.068)	(2.933)
Pool	-6.495	-2.747	1.001	-15.068**	-7.034**	-10.781**	-6.962**	-15.695**	-7.347**	-11.095**	-7.233**
	(6.230)	(2.635)	(0.960)	(6.367)	(3.025)	(5.262)	(2.948)	(6.897)	(3.288)	(5.488)	(3.176)
Sauna	3.280	1.387	-0.506	14.893***	7.193***	9.086**	6.671***	24.390***	11.942***	13.835***	10.786***
	(5.184)	(2.193)	(0.799)	(5.297)	(2.517)	(4.379)	(2.453)	(5.739)	(2.736)	(4.566)	(2.643)
Flowheater	0.539	0.228	-0.083	9.293*	4.605*	4.916	4.062*	11.837**	5.877**	6.188	5.164**
	(4.842)	(2.048)	(0.746)	(4.948)	(2.351)	(4.090)	(2.291)	(5.361)	(2.555)	(4.265)	(2.468)
Boiler	-1.252	-0.529	0.193	0.238	0.215	-0.507	0.019	-1.092	-0.450	-1.172	-0.557
	(4.011)	(1.696)	(0.618)	(4.099)	(1.948)	(3.388)	(1.898)	(4.440)	(2.117)	(3.533)	(2.045)

Main results: effects of household characteristics on relative difference of their network costs

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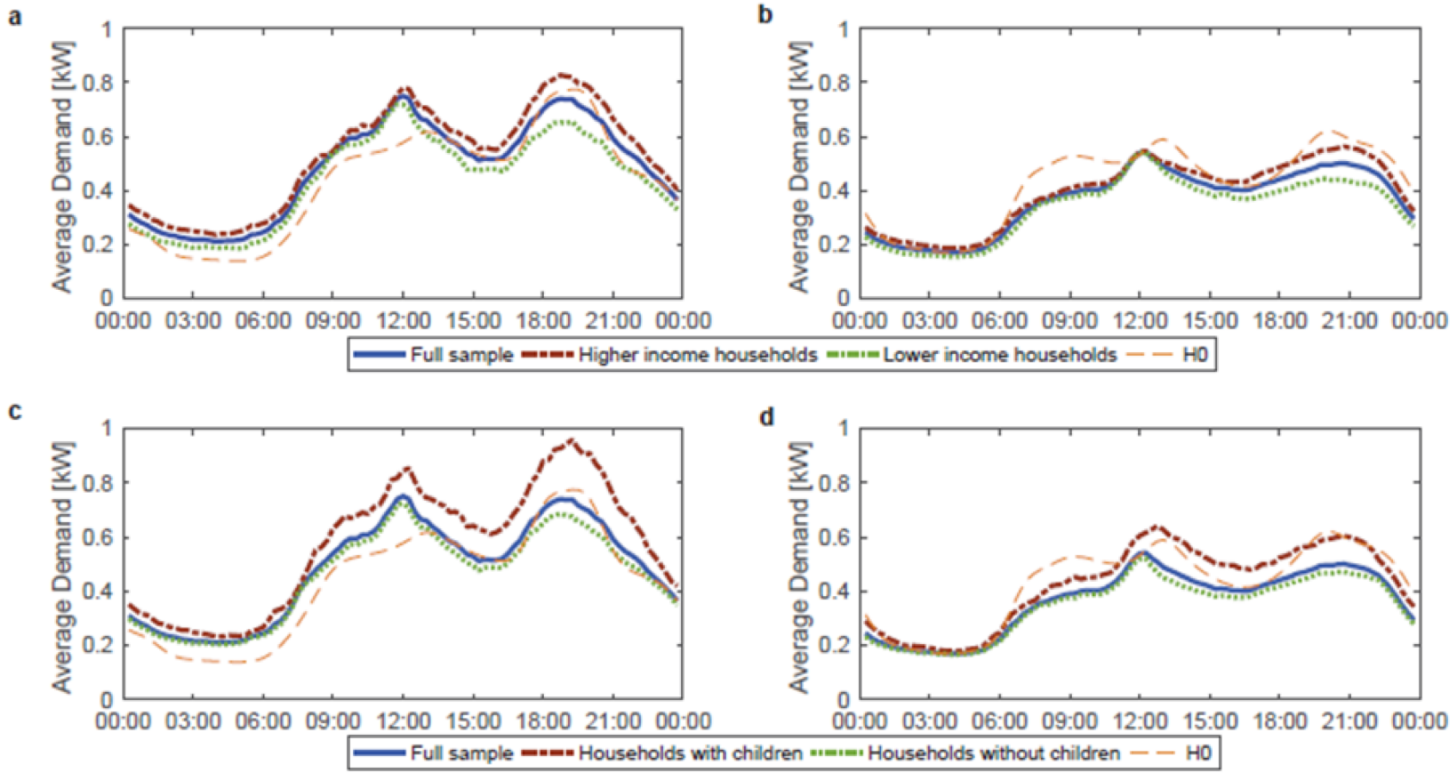
	(2.816)	(1.191)	(0.434)	(2.878)	(1.368)	(2.379)	(1.332)	(3.118)	(1.486)	(2.480)	(1.436)

Main results: comparison of load profiles



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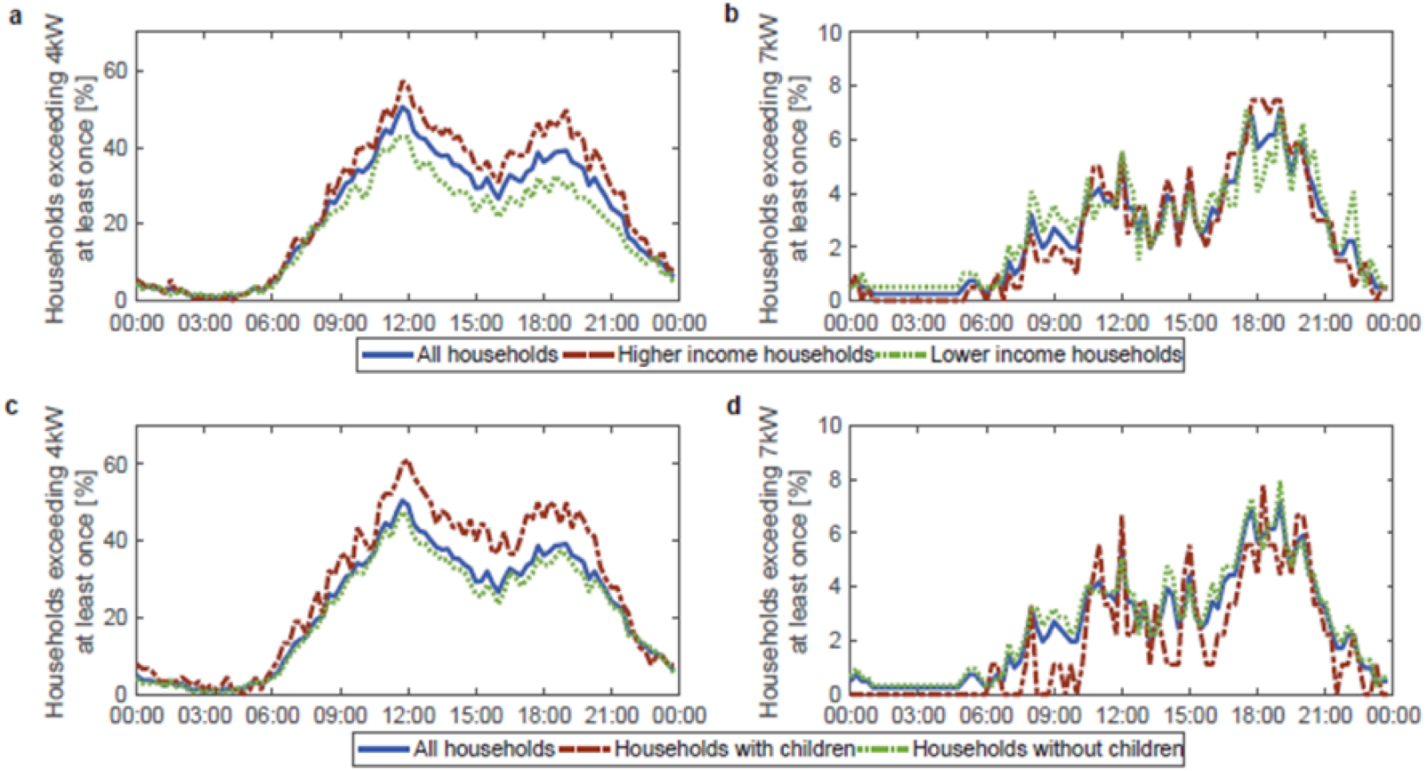

Conclusions:

- If households have been charged based on consumed volumes before, capacity related tariffs may induce huge incremental burdens of up to **+500%**
- This can be a game stopper if no compensation scheme is implemented, or a smooth transition is ensured.
- Higher incomes may be better off with peak load tariffs, possibly since they own newer (=less peak load intensive) equipment.

Recommendation:

- Regulators should simulate new tariff schemes exploiting load data extensively before their introduction. Vital likelihood of unexpected effects.

Thank you for your attention

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Volumetric

in region A in 2016 300.000 kWh were consumed and costs to recover are defined to be 10.000€ by the regulator:
~ tariff is set to 3.3 Cent/kWh

Capacity

peak loads are not yet measured in most regions, so peak load demand is set, say, by assuming all households have 4 kW peak

The residential end-customer elelectricity price:

Three components:

- energy charge: €-cents per kWh of consumed electricity
- taxes and surcharges
- network charges: for recovering the capital and operational expenditures for electricity transmission and distribution

Network tariffs

Model

The quantity of interest in our analyses is defined as the percentage by which the network costs differ between the reference scenario and the alternative scenarios, and we refer to this quantity by

$$\Delta_{i,j} = \frac{C_{i,j} - C_{i,r}}{C_{i,r}} \times 100, \tag{1}$$

where $C_{i,r}$ are the annual network costs of household i in the reference scenario, while $C_{i,j}$ stands for $i's$ costs in the j^{th} alternative scenario, and $j \in$ (f100, e100, f50/pa50, f50/e50, f50/pm50, pa100, pm100, f/pa/e, pa50/e50, pm50/e50, f/pm/e). A negative sign of $\Delta_{i,j}$ therefore indicates a cost reduction under the alternative scenario j compared to today's regulatory practice, while a positive sign points to increased costs for household i.

Model

To investigate which household characteristics are associated with cost savings or incremental costs under the different alternative scenarios we estimate $\Delta_{i,j}$ with a linear regression model. Thereby we consider that $\Delta_{i,j}$ is a function of household-level characteristics $x_{1,i},\ldots,x_{k,i},\ldots,\ldots,x_{K,i}$, such that

$$\Delta_{i,j} = x_{1,i}\beta_{1,j} + \cdots + x_{K,i}\beta_{K,j} + \varepsilon_{i,j}, \tag{2}$$

where $\beta_{k,j}$ holds the incremental average percentage points by which the network costs change when alternative scenario j is applied instead of the reference scenario, when household characteristic k increases by one unit. $\varepsilon_{i,j}$ references the error term. All regressions presented in this study estimate (2).