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FSR
ENERGY & CLIMATE

On the interaction between distribution network tariff design and the business case for storage

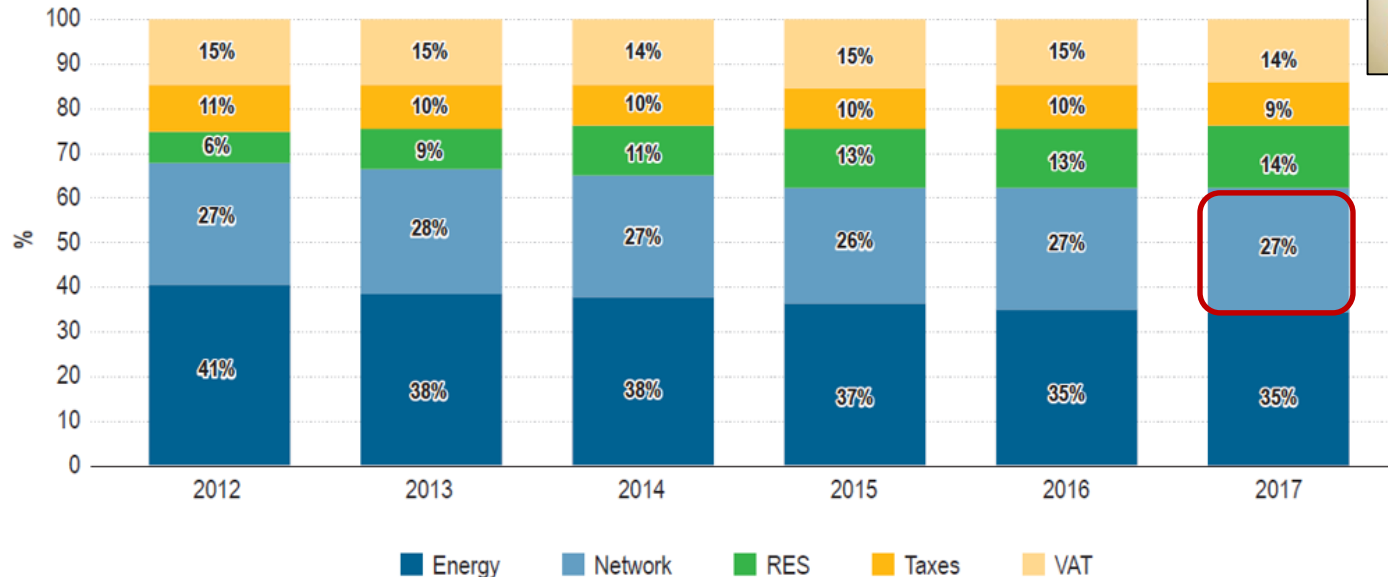
Vlerick Energy Centre –EASE – STORY seminar
30 November 2018

Tim Schittekatte

The electricity bill in Europe today



Figure 10: Weighted average breakdown of incumbents' standard electricity offers for households in capital cities – 2012–2017 (%)



Source: ACER calculations based on data from price comparison tools, incumbent suppliers' websites, NRAs, collected via ACER Retail Database (2018).

Compared to 2008 the average electricity prices for household consumers across the EU increased significantly, by 25.9%, while industrial prices increased by only 3.7% over the same period. This substantially higher price increase for households reflects mainly increases in charges for renewable energy sources (RES charges), often not applied in the industrial segment. As shown in Figure 10, the average relative share of RES charges in final electricity prices for households has more than doubled over the 2012-2017 period, from 6% in 2012 to 14% in 2017.

POSTED AUGUST 24, 2015 BY SEVERIN BORENSTEIN / 32 COMMENTS

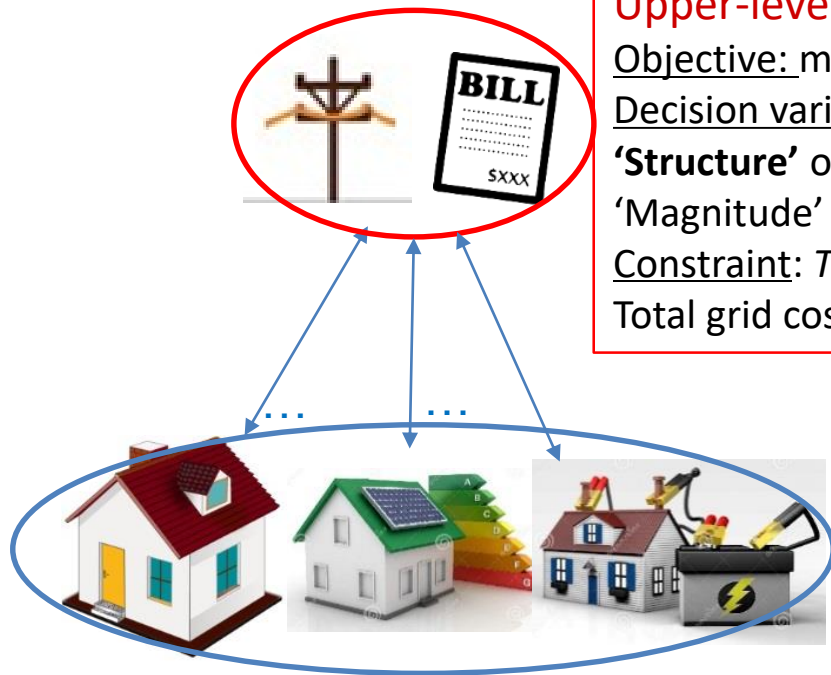
The Decline of Sloppy Electricity Rate Making

*“Something is dying alright, just not the utility. It’s the ability of regulators, utilities, and interest groups to push around revenue collection among customers without the **customers pushing back.**”*

S. Borenstein (Economics professor UC Berkeley)



Setup game-theoretical model: bi-level



Upper-level benevolent regulator

Objective: minimization of the total system costs

Decision variables:

'Structure' of the network tariff (**volumetric, capacity, fixed**)

'Magnitude' of the coefficient

Constraint: *Total grid costs = network charges collected*

$\text{Total grid costs} = \text{sunk grid costs} + \text{incr. grid cost} * \text{coincident demand}$

Lower-level self-interest pursuing consumers (active and passive)

Objective: minimization of the total costs (bill + investment) to satisfy their electricity needs

Decision variables: Possibility to invest in distributed energy resources (DERs), PV and batteries

Constraint: Fulfillment of individual electricity demand

Runs -results sensitivities

System costs compared to a central planner	<i>100 % sunk grid costs</i>	<i>50% sunk and 50 % prospective grid costs</i>	<i>100 %prospective grid costs</i>
Central planner			
Least-cost network tariff			
Volumetric net-metering			
Volumetric net-purchase			
Volumetric bi-directional			
Capacity-based			
Fixed			

Battery (kWh) / solar PV (kWp) per active consumer	<i>100 % sunk grid costs</i>	<i>50% sunk and 50 % prospective grid costs</i>	<i>100 %prospective grid costs</i>
Central planner			
Least-cost network tariff			
Volumetric net-metering			
Volumetric net-purchase			
Volumetric bi-directional			
Capacity-based			
Fixed			

Reference technology cost

PV: 1300 €/kWp & Batteries: 200 €/kWh

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	0.9%	5.1%
Volumetric net-metering	3.9%	5.8%	15.9%
Volumetric net-purchase	1.6%	3.8%	13.4%
Volumetric bi-directional	0.4%	2.7%	13.0%
Capacity-based	5.5%	1.7%	5.1%
Fixed	0.0%	2.4%	12.7%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/ 0.0	4.4/ 0.0	6.2/ 0.0
Least-cost network tariff	0.0/ 0.0	2.7/ 0.0	3.7/ 0.0
Volumetric net-metering	0.0/ 5.0	0.0/ 5.0	0.0/ 5.0
Volumetric net-purchase	0.0/ 2.3	0.0/ 2.3	0.0/ 1.4
Volumetric bi-directional	0.0/ 0.7	0.0/ 0.7	0.0/ 0.7
Capacity-based	3.7/ 0.0	3.7/ 0.0	3.7/ 0.0
Fixed	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0

Reference technology cost

PV: 1300 €/kWp & Batteries: 200 €/kWh

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Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/ 0.0	4.4/ 0.0	6.2/ 0.0
Least-cost network tariff	0.0/ 0.0	2.7/ 0.0	3.7/ 0.0
Volumetric net-metering	0.0/ 5.0	0.0/ 5.0	0.0/ 5.0
Volumetric net-purchase	0.0/ 2.3	0.0/ 2.3	0.0/ 1.4
Volumetric bi-directional	0.0/ 0.7	0.0/ 0.7	0.0/ 0.7
Capacity-based	3.7/ 0.0	3.7/ 0.0	3.7/ 0.0
Fixed	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0

Reference technology cost

PV: 1300 €/kWp & Batteries: 200 €/kWh

Observation 1 –
overinvestment
with capacity-based
and sunk grid costs

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	0.9%	5.1%
Volumetric net-metering	3.9%	5.8%	15.9%
Volumetric net-purchase	1.6%	3.8%	13.4%
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Capacity-based	5.5%	1.7%	5.1%
Fixed	0.0%	2.4%	12.7%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/ 0.0	4.4/ 0.0	6.2/ 0.0
Least-cost network tariff	0.0/ 0.0	2.7/ 0.0	3.7/ 0.0
Volumetric net-metering	0.0/ 5.0	0.0/ 5.0	0.0/ 5.0
Volumetric net-purchase	0.0/ 2.3	0.0/ 2.3	0.0/ 1.4
Volumetric bi-directional	0.0/ 0.7	0.0/ 0.7	0.0/ 0.7
Capacity-based	3.7/ 0.0	3.7/ 0.0	3.7/ 0.0
Fixed	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0

Reference technology cost

PV: 1300 €/kWp & Batteries: 200 €/kWh

Observation 2

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	0.9%	5.1%
Volumetric net-metering	3.9%	5.8%	15.9%
Volumetric net-purchase	1.6%	3.8%	13.4%
Volumetric bi-directional	0.4%	2.7%	13.0%
Capacity-based	5.5%	1.7%	5.1%
Fixed	0.0%	2.4%	12.7%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/ 0.0	4.4/ 0.0	6.2/ 0.0
Least-cost network tariff	0.0/ 0.0	2.7/ 0.0	3.7/ 0.0
Volumetric net-metering	0.0/ 5.0	0.0/ 5.0	0.0/ 5.0
Volumetric net-purchase	0.0/ 2.3	0.0/ 2.3	0.0/ 1.4
Volumetric bi-directional	0.0/ 0.7	0.0/ 0.7	0.0/ 0.7
Capacity-based	3.7/ 0.0	3.7/ 0.0	3.7/ 0.0
Fixed	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0

Reference technology cost

PV: 1300 €/kWp & Batteries: 200 €/kWh

Observation 2—
underinvestment with
prospective costs

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	0.9%	5.1%
Volumetric net-metering	3.9%	5.8%	15.9%
Volumetric net-purchase	1.6%	3.8%	13.4%
Volumetric bi-directional	0.4%	2.7%	13.0%
Capacity-based	5.5%	1.7%	5.1%
Fixed	0.0%	2.4%	12.7%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/ 0.0	4.4/ 0.0	6.2/ 0.0
Least-cost network tariff	0.0/ 0.0	2.7/ 0.0	3.7/ 0.0
Volumetric net-metering	0.0/ 5.0	0.0/ 5.0	0.0/ 5.0
Volumetric net-purchase	0.0/ 2.3	0.0/ 2.3	0.0/ 1.4
Volumetric bi-directional	0.0/ 0.7	0.0/ 0.7	0.0/ 0.7
Capacity-based	3.7/ 0.0	3.7/ 0.0	3.7/ 0.0
Fixed	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0

Very cheap technology cost

PV: 1000 €/kWp & Batteries: 150 €/kWh

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	1.6%	6.4%
Volumetric net-metering	0.0%	4.4%	16.4%
Volumetric net-purchase	0.4%	4.7%	16.4%
Volumetric bi-directional	3.0%	7.9%	20.8%
Capacity-based	7.2%	4.0%	6.4%
Fixed	0.0%	4.4%	16.4%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/5.0	4.6/5.0	5.7/5.0
Least-cost network tariff	0.0/5.0	2.8/5.0	3.2/5.0
Volumetric net-metering	0.0/5.0	0.0/5.0	0.0/5.0
Volumetric net-purchase	0.4/5.0	0.3/5.0	0.0/5.0
Volumetric bi-directional	2.2/1.4	2.2/1.4	2.2/1.4
Capacity-based	6.5/5.0	6.4/5.0	3.2/5.0
Fixed	0.0/5.0	0.0/5.0	0.0/5.0

Very cheap technology cost

PV: 1000 €/kWp & Batteries: 150 €/kWh

Observation 3 – also overinvestment possible with prospective grid cost

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	1.6%	6.4%
Volumetric net-metering	0.0%	4.4%	16.4%
Volumetric net-purchase	0.4%	4.7%	16.4%
Volumetric bi-directional	3.0%	7.9%	20.8%
Capacity-based	7.2%	4.0%	6.4%
Fixed	0.0%	4.4%	16.4%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/5.0	4.6/5.0	5.7/5.0
Least-cost network tariff	0.0/5.0	2.8/5.0	3.2/5.0
Volumetric net-metering	0.0/5.0	0.0/5.0	0.0/5.0
Volumetric net-purchase	0.4/5.0	0.3/5.0	0.0/5.0
Volumetric bi-directional	2.2/1.4	2.2/1.4	2.2/1.4
Capacity-based	6.5/5.0	6.4/5.0	3.2/5.0
Fixed	0.0/5.0	0.0/5.0	0.0/5.0

Very cheap technology cost

PV: 1000 €/kWp & Batteries: 150 €/kWh

Observation 3 – also overinvestment and underutilization possible with prospective grid cost

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	1.6%	6.4%
Volumetric net-metering	0.0%	4.4%	16.4%
Volumetric net-purchase	0.4%	4.7%	16.4%
Volumetric bi-directional	3.0%	7.9%	20.8%
Capacity-based	7.2%	4.0%	6.4%
Fixed	0.0%	4.4%	16.4%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/5.0	4.6/5.0	5.7/5.0
Least-cost network tariff	0.0/5.0	2.8/5.0	3.2/5.0
Volumetric net-metering	0.0/5.0	0.0/5.0	0.0/5.0
Volumetric net-purchase	0.4/5.0	0.3/5.0	0.0/5.0
Volumetric bi-directional	2.2/1.4	2.2/1.4	2.2/1.4
Capacity-based	6.5/5.0	6.4/5.0	3.2/5.0
Fixed	0.0/5.0	0.0/5.0	0.0/5.0

Very cheap technology cost

PV: 1000 €/kWp & Batteries: 150 €/kWh

Observation 4 –
bi-directional charges
are sensitive to
technology costs

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	1.6%	6.4%
Volumetric net-metering	0.0%	4.4%	16.4%
Volumetric net-purchase	0.4%	4.7%	16.4%
Volumetric bi-directional	3.0%	7.9%	20.8%
Capacity-based	7.2%	4.0%	6.4%
Fixed	0.0%	4.4%	16.4%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/5.0	4.6/5.0	5.7/5.0
Least-cost network tariff	0.0/5.0	2.8/5.0	3.2/5.0
Volumetric net-metering	0.0/5.0	0/5.0	0.0/5.0
Volumetric net-purchase	0.4/5.0	0.3/5.0	0.0/5.0
Volumetric bi-directional	2.2/1.4	2.2/1.4	2.2/1.4
Capacity-based	6.5/5.0	6.4/5.0	3.2/5.0
Fixed	0.0/5.0	0.0/5.0	0.0/5.0

Conclusions and future work

- *Observation 1* – High sunk grid costs & capacity-based charges

Aligned with the business case of storage but not with the system. More storage when you need is less.

- *Observation 3 and 4* – High prospective grid costs & signals

Traditional network tariff options (€/kWh, €/kW and €/connection) do not suffice to reach the best outcome for the system.

- Inefficient investment signals: mostly under- but also overinvestment.
- Inefficient operational signals.

- *Observation 4* – Bi-directional volumetric charges & technology costs

Performance is sensitive to technology costs. Works well with higher technology costs to allocate sunk costs but gives wrong signals with cheap solar PV coupled with storage.

Future work: interaction between TOU energy prices and distribution network tariff design



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Very cheap technology cost

PV: 1000 €/kWp & Batteries: 100 €/kWh

Observation 4 –
bi-directional charges
are sensitive to
technology costs

System costs compared to a central planner	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0%	0.0%	0.0%
Least-cost network tariff	0.0%	2.3%	7.4%
Volumetric net-metering	0.0%	6.0%	18.9%
Volumetric net-purchase	3.9%	7.5%	17.6%
Volumetric bi-directional	10.2%	14.2%	25.1%
Capacity-based	8.7%	3.7%	7.4%
Fixed	0.0%	6.0%	18.9%

Battery (kWh) / solar PV (kWp) per active consumer	100 % sunk grid costs	50% sunk and 50 % prospective grid costs	100 %prospective grid costs
Central planner	0.0/5.0	5.2/5.0	9.0/5.0
Least-cost network tariff	0.0/5.0	3.0/5.0	6.0/5.0
Volumetric net-metering	0.0/5.0	0.0/5.0	0.0/5.0
Volumetric net-purchase	4.9/5.0	4.9/5.0	4.9/5.0
Volumetric bi-directional	13.4/5.0	13.4/5.0	13.4/5.0
Capacity-based	9.8/5.0	6.5/5.0	6.0/5.0
Fixed	0.0/5.0	0.0/5.0	0.0/5.0

First-best in practice?

