How does the net metering scheme for solar energy affect household electricity bills? Distributional effects and energy poverty implications

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Outline

1. Introduction
What is Net Metering?

- Net metering is a policy for **households** with solar panels that have a bi-directional meter
- Net metering reduces the **electricity bill** of these households, lowering the payback time for their investment in solar panels
- Net metering has been shown to be effective in incentivizing the uptake of solar panels (Duke et al., 2005; Darghouth et al., 2011; Londo et al., 2020)
- Net metering is a strongly debated policy yet lack of literature on distributional effects. **Fair** energy transition?

How is the electricity bill determined?

The household electricity bill has the following cost components:

1. Retail cost
2. Energy tax
3. Grid cost

1. Introduction

How does net metering reduce the bill?

- Households with solar panels generate electricity when the sun shines
- This generation is valued at **retail prices**
- This implies that the households bill is based on the
  Annual net load = annual consumption - annual generation

Load and generation profiles

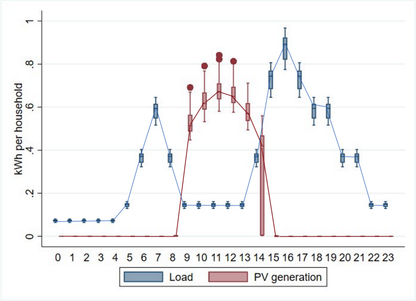

Figure: Winter, The Netherlands

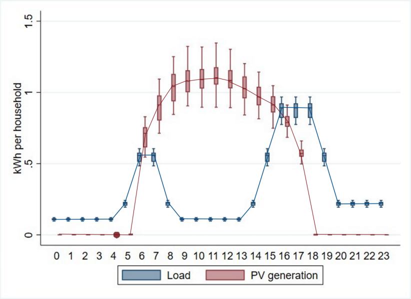

Figure: Summer, The Netherlands

Box plots for January/August 2019-2021 across all Dutch provinces (own computation based on data, see App. 2).

1. Introduction
What is the issue?

1. Annual netting on taxes $\rightarrow$ lower government revenues
2. Annual netting on retail cost $\rightarrow$ retailer buys at retail price but sells at a lower price due to the merit order effect
3. More residential solar panels $\rightarrow$ higher grid costs, that are socialized
4. Higher bill for households without solar panels $\rightarrow$ may worsen energy poverty and inequality

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Research question

RQ: What is the impact of residential solar energy under the net metering scheme on the household electricity bill?

Sub-questions:

- How (much) are the components of the electricity bill affected?
- How are households with and without solar panels differently affected?

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Method

For the typical household per province with and without solar panels, compute:

- When and how much electricity does it consume?
  → Data on household consumption and assumptions over hourly load.
- When and how much electricity does it generate?
  → Estimate generation based on installed capacity and sunshine.
- What prices does it face?
  → Estimate merit order effect (App. 3)
  → Estimate effect of residential PV on grid costs
  → Assume tax rate and grid tariff if no residential solar
- *How does the electricity bill change due to residential solar under net metering?*

2. Methodology
Assumptions

- Households are either PV households (with solar panels) or non-PV households (without solar panels)
- Households are identical except that PV households generate electricity
- One retailer, perfect competition, full cost pass-through, only input costs
- The government sets a constant budget to be raised from the energy tax every year
- Grid costs increase linearly with the installed residential PV capacity

2. Methodology

Scope of research (so far)

- Focus on the Netherlands
- Period from 2019 to 2021
- Data at the provincial level (see App. 2 for descriptives)
- Non-PV households: 6.85 mils in 2019 to 6.38 mils in 2021
- PV households: 0.96 mils in 2019 to 1.59 mils in 2021

3. Data

Maps for PV uptake and sunshine

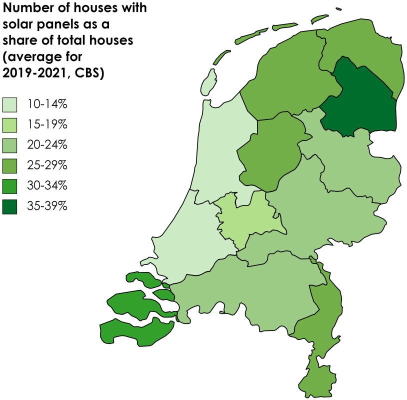


Figure: Map for the share of households with PV by province (CBS, 2023).

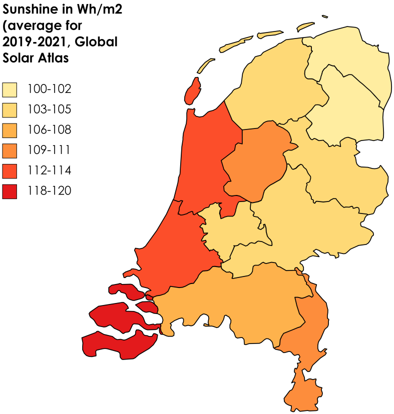


Figure: Map for the average sunshine by province (The Global Solar Atlas, 2023).

3. Data

Estimated merit order effect

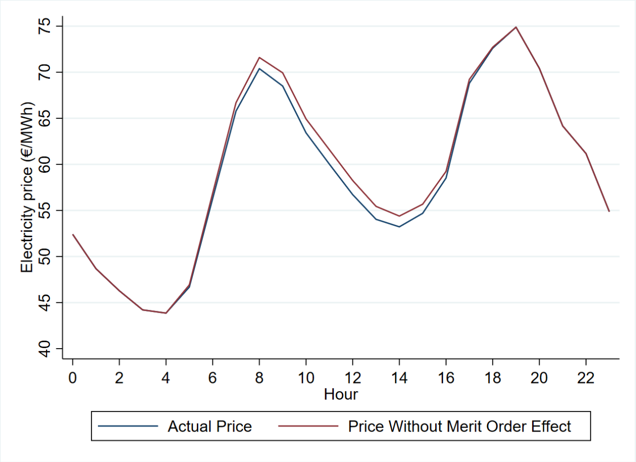
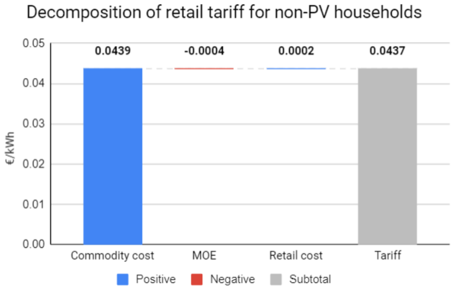


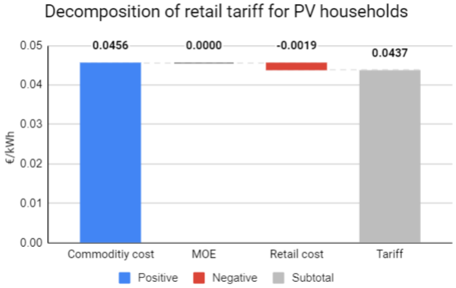
Figure: Own estimation of the merit order effect from residential solar. Prices are the average of historical hourly prices for 2019-2021.

4. Results

Effect on retail tariff

- Retailer breaks even
- Same tariff to both groups
- Commodity cost of buying electricity on the market
- MOE from residential solar energy





4. Results

Effect on total electricity bill

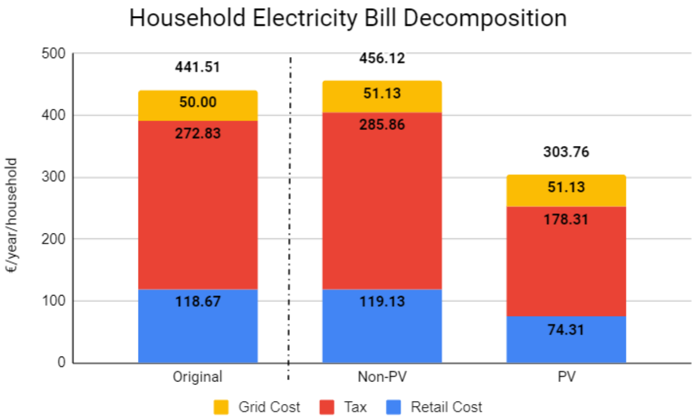
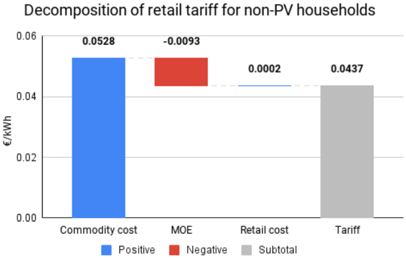


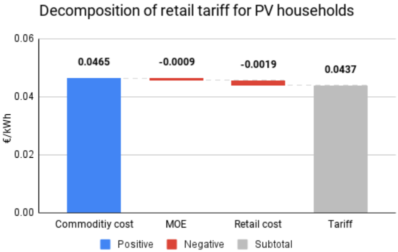
Figure: Breakdown of the household electricity bill in the original situation (no residential solar) and in 2019. The yearly bill increases by 14.62€ for non-PV households and decreases by 137.75€ for PV households, on average.

5. Sensitivity Analysis

What if the MOE was 5 times stronger?

A stronger MOE reduces the cross-subsidy from non-PV households to PV households.





5. Sensitivity Analysis

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What if the share of PV households increased by 10%?

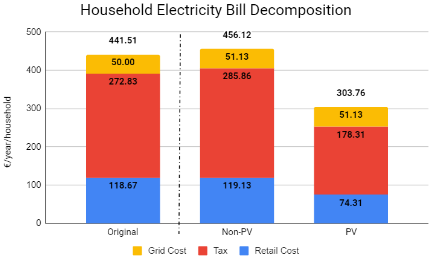

Figure: Actual situation

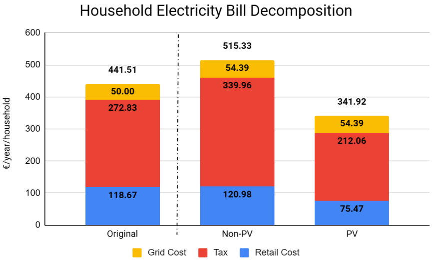

Figure: PV households increase

The yearly bill increases by 73.82€ (instead of 14.62€) for non-PV households and decreases by 99.59€ (instead of 137.75€) for PV households, on average.

Findings

1. The electricity bill increases for non-PV households and decreases for PV households, with implications for energy poverty
2. The main driving force of this inequality is the energy tax increase
3. The impact of net metering on retail and grid costs is modest
4. A stronger MOE leads to a more equally distributed retail cost
5. As the share of PV households increases, the increase in the electricity bill for non-PV households worsens but the decrease in the electricity bill for PV households becomes smaller

6. Conclusions

Policy Implications and Limitations

1. The main policy implication would be not to allow netting for tax purposes or to include a fixed portion for the energy tax (yet, this changes the tax objective).
2. Policymakers must consider that redistribution becomes more needed as more households install solar panels
3. One current limitation is that it is unclear whether the results are generalizable → Compare with other European countries (Italy and Spain?)
4. The study does not investigate how to improve the current design of the net metering scheme → Extend sensitivity analysis and examine how different scheme designs affect the results

References

CBS (2023). Statline open data portal. https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS. June 2023.

Darghouth, N. R., Barbose, G., and Wiser, R. (2011). The impact of rate design and net metering on the bill savings from distributed PV for residential customers in california. *Energy Policy*, 39(9):5243–5253.

Duke, R., Williams, R., and Payne, A. (2005). Accelerating residential PV expansion: demand analysis for competitive electricity markets. *Energy Policy*, 33(15):1912–1929.

ENTSO-E (2023). Transparency platform. https://transparency.entsoe.eu/dashboard/show. June 2023.

Gupta, R., Pena-Bello, A., Streicher, K. N., Roduner, C., Farhat, Y., Thöni, D., Patel, M. K., and Parra, D. (2021). Spatial analysis of distribution grid capacity and costs to enable massive deployment of PV, electric mobility and electric heating. *Applied Energy*, 287:116504.

Jia, X., Du, H., Zou, H., and He, G. (2020). Assessing the effectiveness of china's net-metering subsidies for household distributed photovoltaic systems. *Journal of Cleaner Production*, 262:121161.

Kim, J., Baek, K., Lee, E., and Kim, J. (2023). Analysis of net-metering and cross-subsidy effects in south korea: Economic impact across residential customer groups by electricity consumption level. *Energies*, 16(2):717.

Londo, M., Matton, R., Usmani, O., van Klaveren, M., Tigchelaar, C., and Brunsting, S. (2020). Alternatives for current net metering policy for solar PV in the netherlands: A comparison of impacts on business case and purchasing behaviour of private homeowners, and on governmental costs. *Renewable Energy*, 147:903–915.

Mills, A., Wiser, R., Barbose, G., and Golove, W. (2008). The impact of retail rate structures on the economics of commercial photovoltaic systems in california. *Energy Policy*, 36(9):3266–3277.

Sajjad, I. A., Manganelli, M., Martirano, L., Napoli, R., Chicco, G., and Parise, G. (2018). Net-metering benefits for residential customers: The economic advantages of a proposed user-centric model in italy. *IEEE Industry Applications Magazine*, 24(4):39–49.

Thakur, J. and Chakraborty, B. (2018). Impact of increased solar penetration on bill savings of net metered residential consumers in india. *Energy*, 162:776–786.

The World Bank (2023). Global solar atlas. https://globalsolaratlas.info/map?c=11.609193,8.4375,3. June 2023.

Thomson Reuters (2023). Refinitiv eikon. https://www.refinitiv.com/en. June 2023.

Appendix

Previous Literature

- Main focus is on the effectiveness (Duke et al., 2005; Darghouth et al., 2011; Jia et al., 2020)
- Some evidence of cross-subsidies through retail rates (Mills et al., 2008; Sajjad et al., 2018; Thakur and Chakraborty, 2018; Kim et al., 2023)
- Some evidence of higher grid costs due to residential solar panels (**?**; Gupta et al., 2021; **?**)
- Lack of quantification of the distribution of costs and benefits of net metering between households with and without solar panels.

Net Metering Scheme in the Netherlands (*Salderingsregeling*)

- First implemented in 2004.
- Net metering scheme exactly as modeled besides for excess generation, bought at about 0.09 €/kWh.
- Feb 2023: gradual phase-out of the net metering scheme from 2025 is approved by the House of Representatives (Senate is yet to vote).
- From 2031: PV households will not be able to net and all generation is bought at a fixed rate (about 0.09 €/kWh).
- Motivations:
  - Low payback time, investment is attractive even without netting.
  - Loss in tax revenues.
  - Inefficient use of the grid, overgeneration and no incentive for home batteries.

Descriptives of data sample per province

VARIABLES	Observations	Mean	SD	Unit	Source
Day-ahead Price	315,612	58.78	54.48	€/MWh	ENTSO-E (2023)
Sunshine	315,648	107.7	129.2	Wh/m^2	Global Solar Atlas (2023)
Household PV Capacity	315,648	3.516	0.308	kW	CBS (2023)
Household Load	315,648	0.317	0.256	kWh	CBS (2023) & Assumptions
No. PV Households	315,648	1,272	256.9	Thousands	CBS (2023)
No. Households	315,648	6,619	195.1	Thousands	CBS (2023)

Table: Descriptive statistics for the 12 provinces of the Netherlands between 2019 and 2021.

We assume that the tax rate is 0.1 €/kWh if there is no residential solar. From Gupta et al. (2021), increase in grid costs due to residential solar is about 220 €/kW of installed PV capacity.

Estimation of the merit order effect

We estimate the merit order effect from solar and wind, at the national level, as:

$$P_h^{W,actual} = \beta_0 + \beta_1 * G_h^{PV} + \beta_2 * G_h^{RESnon-PV} + \beta_3 * G_h^{RES,Neighbor} + \beta_4 * P_h^{Gas} + \beta_5 * L_h + \beta_6 * P_{h,d-1,m,y}^{W,actual} + Hour_h + Day_d + Month_m + Year_y + \epsilon_h, \quad (1)$$

Then, we compute the wholesale price of electricity that would occur if no merit order effect from residential solar panels took place as:

$$P_h^{W,noMOE} = P_h^{W,actual} + |\hat{\beta}_1| * \sum_k^{N^{PV}} (g_{h,k}^{PV} - l_{h,k}). \quad (2)$$

Sample for the MOE analysis

VARIABLES	Observations	Mean	SD	Unit	Source
Day-ahead Price NL	51,192	78.59	90.53	€/MWh	ENTSO-E (2023)
Load NL	51,192	51,440	8,947	MW	ENTSO-E (2023)
Solar Generation NL	51,192	2,047	4,021	MW	ENTSO-E (2023)
Wind Generation NL	51,192	5,345	5,092	MW	ENTSO-E (2023)
Solar Generation DK	51,192	81.89	149.1	MW	ENTSO-E (2023)
Wind Generation DK	51,192	1,362	1,005	MW	ENTSO-E (2023)
Solar Generation DE	51,192	19,710	30,554	MW	ENTSO-E (2023)
Wind Generation DE	51,192	53,134	45,226	MW	ENTSO-E (2023)
TTF Gas Price	51,192	33.97	41.88	€/MWh	Eikon (2023)

Table: Sample used for the merit order effect analysis. Data for the period 2015-2023.

Regression results for the MOE analysis

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	Day-ahead Price NL
Solar Generation NL	-0.00123***
	(0.000197)
Wind Generation NL	-0.00256***
	(0.000139)
Solar Generation DK	-0.0137**
	(0.00567)
Wind Generation DK	-0.00241***
	(0.000374)
Solar Generation DE	-0.000230***
	(0.0000247)
Wind Generation DE	0.00000710
	(0.0000105)
Load NL	0.000796***
	(0.0000985)
TTF Gas Price	1.845***
	(0.0352)
Constant	-35.07***
	(4.512)
Observations	51,192

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$

Hour, day, month, and year dummies are omitted from the table.

Table: Regression results with Newey-West heteroskedasticity and autocorrelation (up to a 15-hour lag) consistent standard errors.