Energy Justice Network

Energy Transition and Social Justice

Allocation of Renewable Energy Support Levies Among Residential Consumers in Germany

a study by

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FCN | Future Energy Consumer Needs and Behavior | E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

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1. Introduction and research motivation

- **Energy systems** account for most of the greenhouse gas emissions worldwide
- (Accelerated) **Sustainable energy transitions** involve substantial societal costs
- **Energy / electricity** is an essential good, price increases pose a relatively higher burden on low-income households
- Thus, it is interesting to study the **impact of renewable energy support levies** on **social justice**, and more specifically, on **income inequality**

Aim & Scope of this study

- Representative household panel data for **Germany** (~40,000 households) from **2003 to 2018**
- 3 reform options are investigated:
  - (a) Abolition of the levy
  - (b) An income-progressive levy, proportionally to the income tax imposed
  - (c) A high and flat levy, coupled with an income-degressive compensation payment

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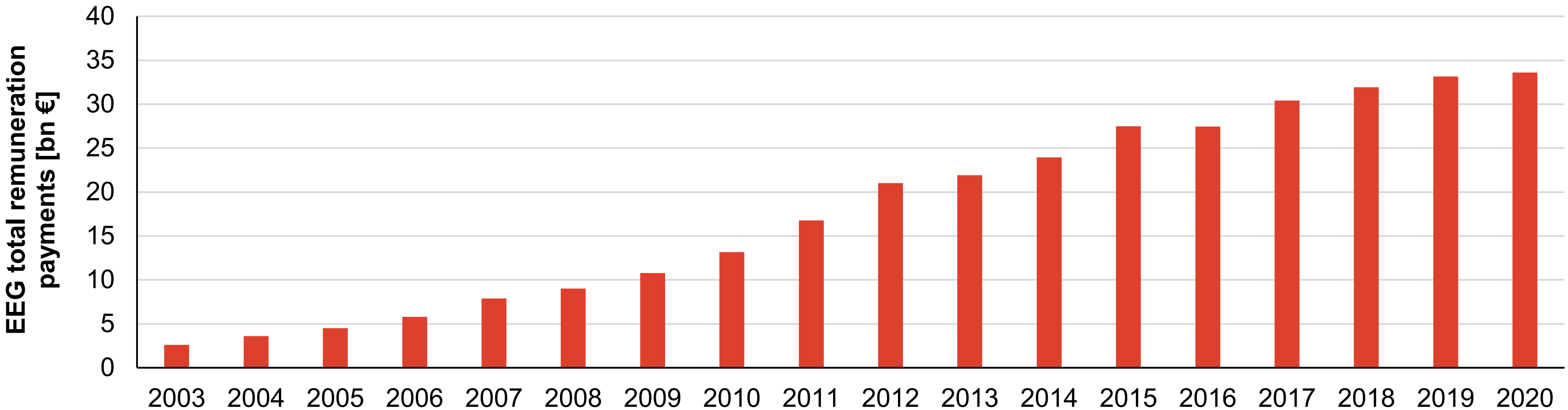
1. Introduction: Renewable energy support levies in Germany

Renewable Energy Sources Act (EEG 2000-):

Feed-in tariffs and **market premia** for electricity generation from renewable energy sources (RES) are **financed by the consumers of electricity** via a **surcharge**



Source: BMWi (2020): EEG in Zahlen: Vergütungen, Differenzkostenund EEG-Umlage 2000 bis 2020

Ongoing EEG amendment might shift financing at least partly to:

- Revenues from CO_2 tax
- Federal budget

High uncertainties due to:

- The future of old RES capacities
- Expansion of new RES capacities
- Low electricity spot market prices

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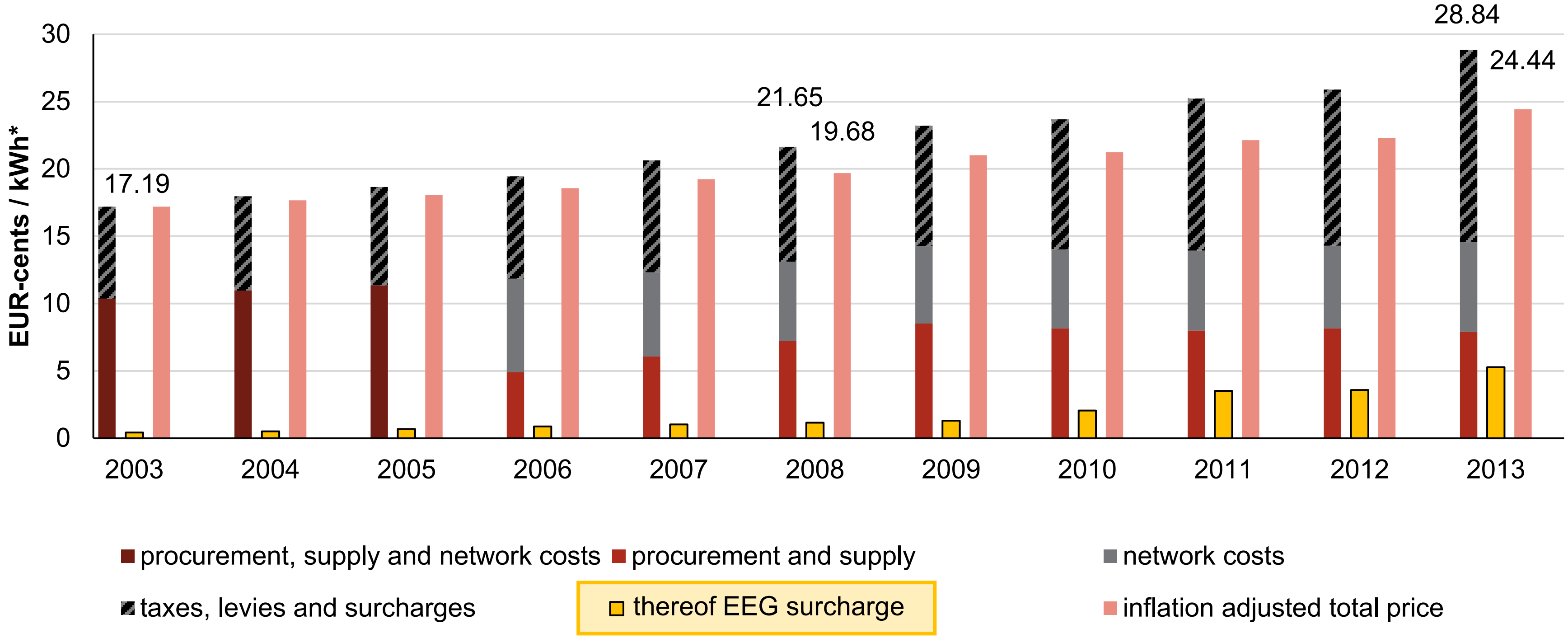
1. Introduction: Development of electricity prices for private households

Private households faced an increase in the electricity price by **~42% (in inflation-adjusted prices)** from 2003 to 2013, driven by the **increase in RES support levy**



**for an annual consumption of 3500 kWh*

Sources: BDEW (2019): DEW-Strompreisanalyse Januar 2019 Haushalte und Industrie.; Destatis (2014):Verbraucherpreisindizes für Deutschland Jahresbericht 2013.

RES support levy accounted for **~67%** of the inflation-adjusted price increase

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1. Introduction: Electricity expenditure shares by income class (trends)

- German households spent higher shares of their net disposable incomes on electricity (**2.3%** in 2018 vs. **1.8%** in 2003, +20.2%)
- Low-income households are more affected (see Fig. 1 on next slide)
  - 1st income decile: **4.5%** in 2018 vs. **3.6%** in 2003 (+26.9%)
  - 10th income decile: **1.0%** in 2018 vs. **0.9%** in 2003 (+14.1%)

- In economics, **elasticities of demand** are a useful vehicle to better understand the responsiveness of consumers:

$$\eta_p = \frac{\text{percentage change in demand for electricity}}{\text{percentage change in real electricity price}}.$$

$$|\eta_p| \geq 1: \textit{demand is elastic}$$

$$|\eta_p| < 1: \textit{demand is inelastic}$$

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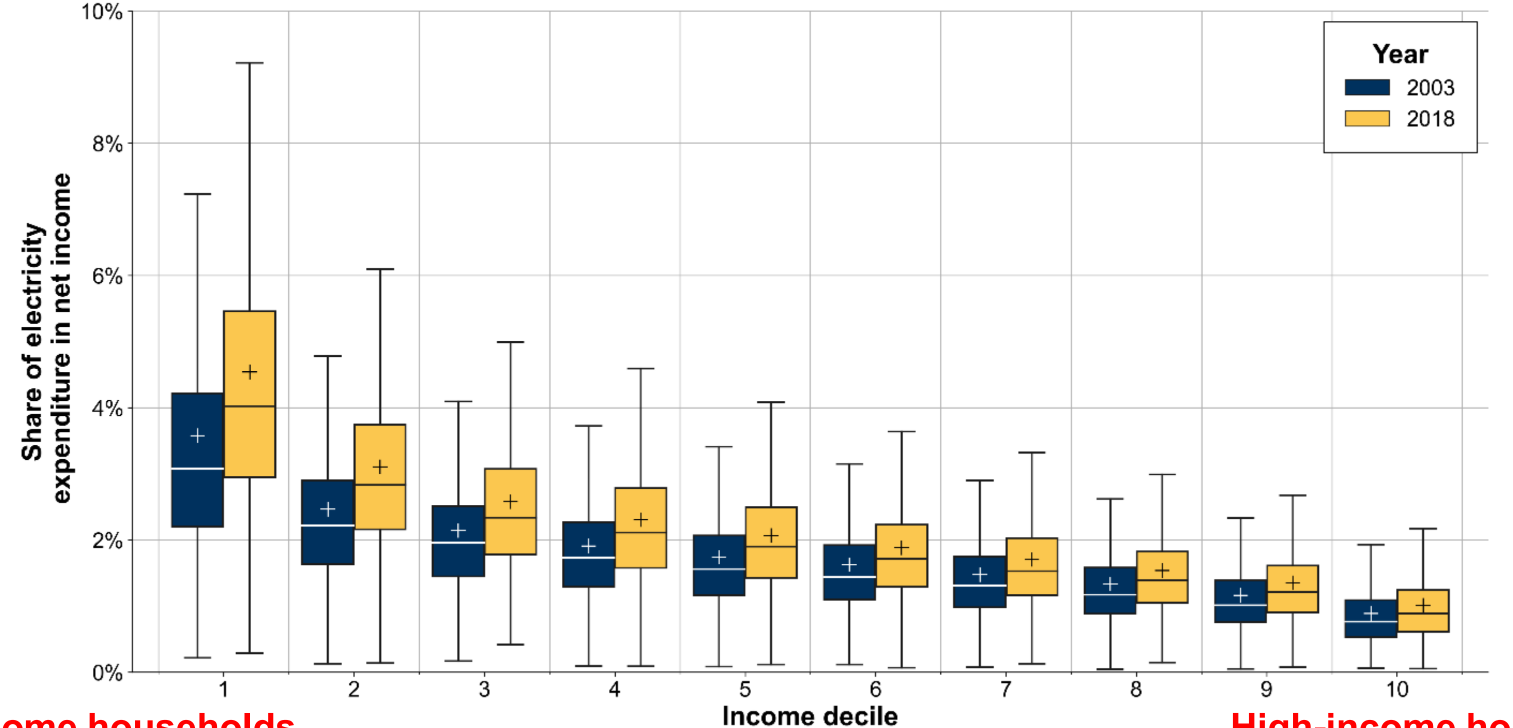
1. Introduction: Electricity expenditures and income of private HH

Price increases impose a relatively **higher burden on lower-income households**, as they spend a higher **income share on electricity**



Low-income households

High-income households

Figure 1: **Share of residential electricity expenditure in net income.** The values are calculated for the ICS data sample of the years 2003 and 2018. Private households are grouped into income deciles according to the OECD equivalence scale. The mean values are represented by "+"-markers. The whiskers are limited to 1.5 the interquartile range. Outliers are not plotted.

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1. Introduction: Elasticity estimates by income decile

Table 1: Long-term price elasticities of demand of private households in Germany, 2003–2018

	Income decile										
	1	2	3	4	5	6	7	8	9	10	**Av.**
η_p	-0.3541	-0.4526	-0.5662	-0.5003	-0.5366	-0.5910	-0.6693	-0.6548	-0.6819	-0.6869	**-0.5976**

→ Lower-income deciles (deciles 1 to 5) show an average price elasticity of **-0.48**, whereas it is **-0.66** for higher-income deciles (deciles 6 to 10).

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2. Research questions

1. What were the **medium- and long-term impacts of price increases on residential electricity consumption** (i.e., **price elasticities of demand**) in Germany for the period 2003 to 2013?

2. To what extent does the **current support mechanism** for renewable energy sources impact **energy efficiency, social inequality, and energy poverty**?

3. What would be the effect of an **alternative support mechanism** on these topics?

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3. Approach and methods used

1 Classification of household income groups

- EVS data from 2003 to 2018
- According to the OECD equivalence scale (→ slide 18)

2 Calculation of price elasticities of demand

- Setting-up a price-expenditure function to derive electricity consumption quantities
- Calculating arc elasticities using the midpoint method

3 Development of a reform proposal for the RES support levy

- Analogous to the progressive taxation of income

4 Analyzing the substitutability of electricity in private households

- Applying the Slutsky equation on a hypothetical change in consumption
- For the case of (1) an abolishment of the RES support levy; (2) an income-progress-sive RES support levy; and (3) a flat high levy w/ income-degressive compensation

5 Analyzing income inequality, energy poverty, and energy efficiency

- Based on hypothetical ex-post changes in consumption
- Using multiple measures for income inequality and fuel poverty

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3. Methods used: Slutsky equation (1/3)

Change in demand for energy is explained by an income and a substitution effect

Substitution effect results from a change in the relative price of electricity vs. non-electricity (consumer) goods (e.g., food, clothing, health, household appliance, heating energy etc.)

More formally, the **Slutsky equation** decomposes the change in demand for good *i* in response to a change in the price of good *j*:

$$\frac{\partial x_i(\mathbf{p},y)}{\partial p_j} = \frac{\partial h_i(\mathbf{p},u)}{\partial p_j} - \frac{\partial x_i(\mathbf{p},w)}{\partial w} x_j(\mathbf{p},w)$$

where $h(\mathbf{p}, u)$ is the **Hicksian demand** and $x(\mathbf{p}, w)$ is the **Marshallian demand**, at the vector of price levels $\mathbf{p}$, wealth level (or, alternatively, income level) w, and fixed utility level u given by maximizing utility at the original price and income, formally given by the indirect utility function $v(\mathbf{p}, w)$.

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3. Methods used: Slutsky equation (2/3)

For quantifying consumer preferences w.r.t. choosing between electricity and all other goods, we set up a **Cobb-Douglas utility function *U*** (eq. (6)).

$$B = p_{el}^{base} + p_{el}^{op} * \; x_{el} + p_{oth} * x_{oth} \tag{5}$$

$$U(x_{el}, x_{oth}) = {x_{el}}^{\alpha} * {x_{oth}}^{1-\alpha} \tag{6}$$

The **exponents** of electricity and all other consumer goods (*α, 1–α*) in the Cobb-Douglas utility function are derived from the observed consumption behavior between the years 2003 to 2018:

$$\Delta x_{el}^{Total\ effect} = \Delta x_{el}^{Constant\ budget} + \Delta x_{el}^{Change\ in\ budget} \tag{7}$$

$$\Delta x_{el}^{Constant\ budget} = \frac{\alpha * B_{2003} - p_{el,2018}^{base}}{p_{el,2018}^{op}} - x_{el,2003} \tag{8}$$

$$\Delta x_{el}^{Change\ in\ budget} = \frac{\alpha * (B_{2018} - B_{2003} + p_{el,2003}^{base} - p_{el,2018}^{base})}{p_{el,2018}^{op}} \tag{9}$$

$$\alpha = \frac{x_{el,2018} * p_{el,2018}^{op} + p_{el,2018}^{base}}{B_{2018} + p_{el,2003}^{base} - p_{el,2018}^{base}}. \tag{10}$$

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3. Methods used: Slutsky equation (3/3)

Table 8: Exponent of Cobb-Douglas utility function based on the change in consumption from 2003 to 2018

	Income decile										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	Average
α	0.0386	0.0310	0.0274	0.0259	0.0247	0.0234	0.0216	0.0206	0.0193	0.0166	0.0230

The marginal utility *MU* of the utility function in Eq. (6) can be derived as:

$$MU(x_{el}) = \alpha * x_{el}^{\alpha-1} * (1-\alpha) * x_{oth}. \quad \textbf{(11)}$$

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3. Methods used: Gini coefficients (Lorenz curve) and Atkinson index

The **Gini coefficient** is the most common indicator for (in-)equality in the distribution of incomes y_i in a society with a population of size n:

$$G = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \left| y_i - y_j \right|}{2n^2 \bar{y}}$$

Values are between 0 (no inequality) and 1 (100% inequality).

The **Atkinson index** is defined as:

$$A(y_1, \dots, y_n) = \begin{cases} 1 - \frac{1}{\mu} \left(\frac{1}{N} \sum_{i=1}^{N} y_i^{1-\varepsilon} \right)^{1/(1-\varepsilon)} & \text{for } 0 \leq \varepsilon \neq 1 \\ 1 - \frac{1}{\mu} \left(\prod_{i=1}^{N} y_i \right)^{1/N} & \text{for } \varepsilon = 1 \end{cases}$$

where y_i is individual income (i = 1, 2, ..., N) and μ is the mean income.

Note: We use an **equality-distributed equivalent measure** (inequality aversion coefficient) of ε = 1.

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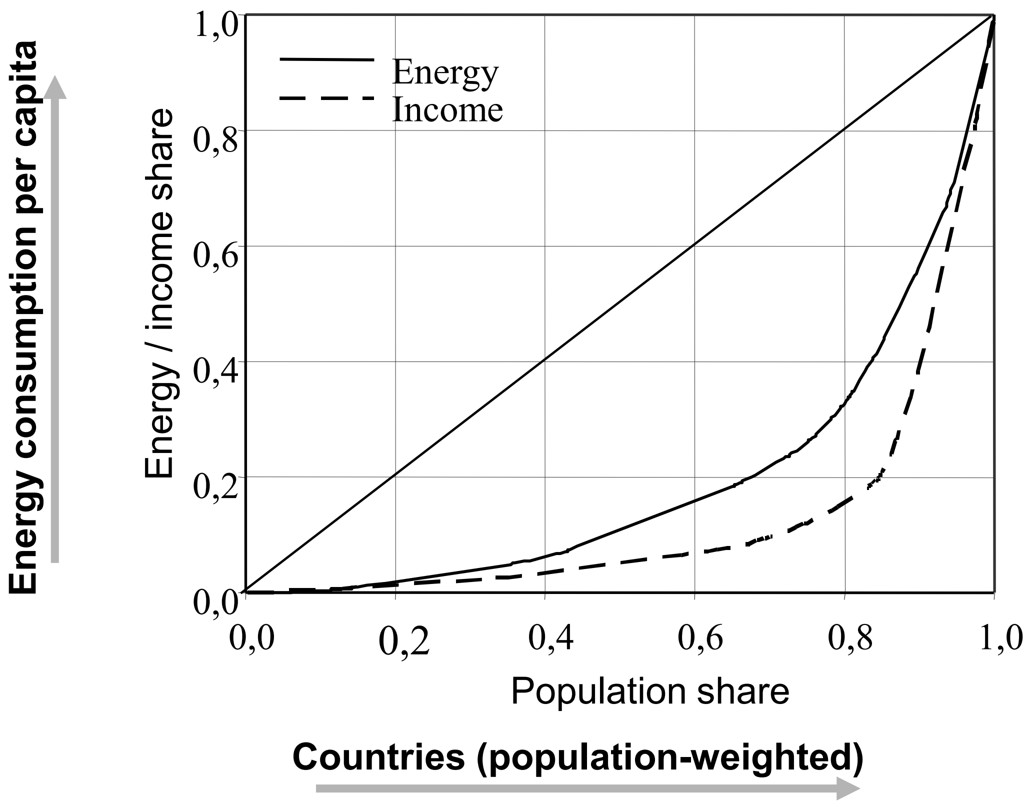
3. Methods used: Gini coefficients (Lorenz curve) and Atkinson index

Lorenz curve of energy and income distribution



- Energy is an **essential commodity** – and is therefore disproportionately in demand by people with low incomes
  ⇨ Income distribution even more skewed than energy distribution!
- When incomes are very low, people turn to **noncommercial** sources of energy to meet their basic needs (i.e. energy demand grows less than proportionally with increasing income).

Source: Erdmann, Zweifel (2007). p.99

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3. Methods used: Gini coefficients (Lorenz curve) and Atkinson index

The **Atkinson index** is a **normative social welfare-based measure of inequality**. The measure depends on the **assumed social aversion to inequality** following the concept of **risk aversion**.

Using the Atkinson index, an **equally distributed equivalent (EDE) income** can be derived. The EDE income represents the **income that would lead to the same level of welfare** as the actual income distribution if each individual received it.

The difference between the mean income and the EDE income reflects the **welfare loss due to inequality**.

Grösche & Schröder (2018) find that for Germany in 2012, the flat RES support levy has a regressive effect and increased the Gini coefficient by 0.56% and the Atkinson index by 1.43% (assuming an inequality aversion of $\varepsilon = 1$).

Winter & Schlewewsky (2019) find for 2017 that the RES support levy increased the Gini coefficient by 0.97% and the Atkinson index by 2.05-2.43%.

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3. Methods used: 2xMS & HCL, Foster-Greer-Thorbecke poverty index

We also investigate the **impact of the current allocation mechanism** and of our reform proposals on a **modified form of energy poverty**, which we call "**electricity poverty"**, using the **two times median share poverty** line and the **high cost / low income (HCLI) poverty** line, as suggested by Heindl (2015).

→ *The former* considers those households as electricity-poor whose electricity expenditure shares on income accounts for more than twice the median value.

→ *The latter* considers those households as electricity-poor whose electricity expenditure shares are higher than the median value and, at the same time, having an income below 60% of the median.

Equivalized incomes and expenditures based on the **OECD equivalence scale** are used in our analysis, and then measures for electricity poverty using the **FGT index** from Foster et al. (1984)

$$P_\alpha = \frac{1}{N}\sum_{i=1}^{q}\left(\frac{e_i - z}{z}\right)^\alpha$$

derived, where *N* is the no. of households, *q* the no. of households below the poverty line, e_i the expenditure or expenditure shares for energy services (here: electricity only), and *z* the poverty line. We use values of $\alpha = 0$ (headcount ratio), $\alpha=1$ (poverty gap index), and $\alpha=2$ (squared poverty gap, measuring poverty intensity).

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4. Data used

Use of a representative microdata set – the **Income and consumption sample of German households / household budget survey** (*Einkommens- und Verbrauchsstichprobe, EVS*):

- Survey conducted in **5-year intervals** for **~60,000 households**; sample sizes of 42,744 and 42,226 German private households in 2003 and 2018, respectively
- Comprising information on **household incomes** and **electricity expenditures**, among other information
- **Electricity expenditures** are mapped to electricity prices and consumption by setting up a **price-expenditure function**

Classification of household income groups:

- **OECD equivalence scale:** Different equivalence values for household members:
  - Primary income earner: **1.0**
  - Other household members, ≥ 14 a: **0.5**
  - Other household members, < 14 a: **0.3**

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5. Results: Applying the Slutsky equation: Income, substitution and total effect of changes in electricity consumption, 2003-2018

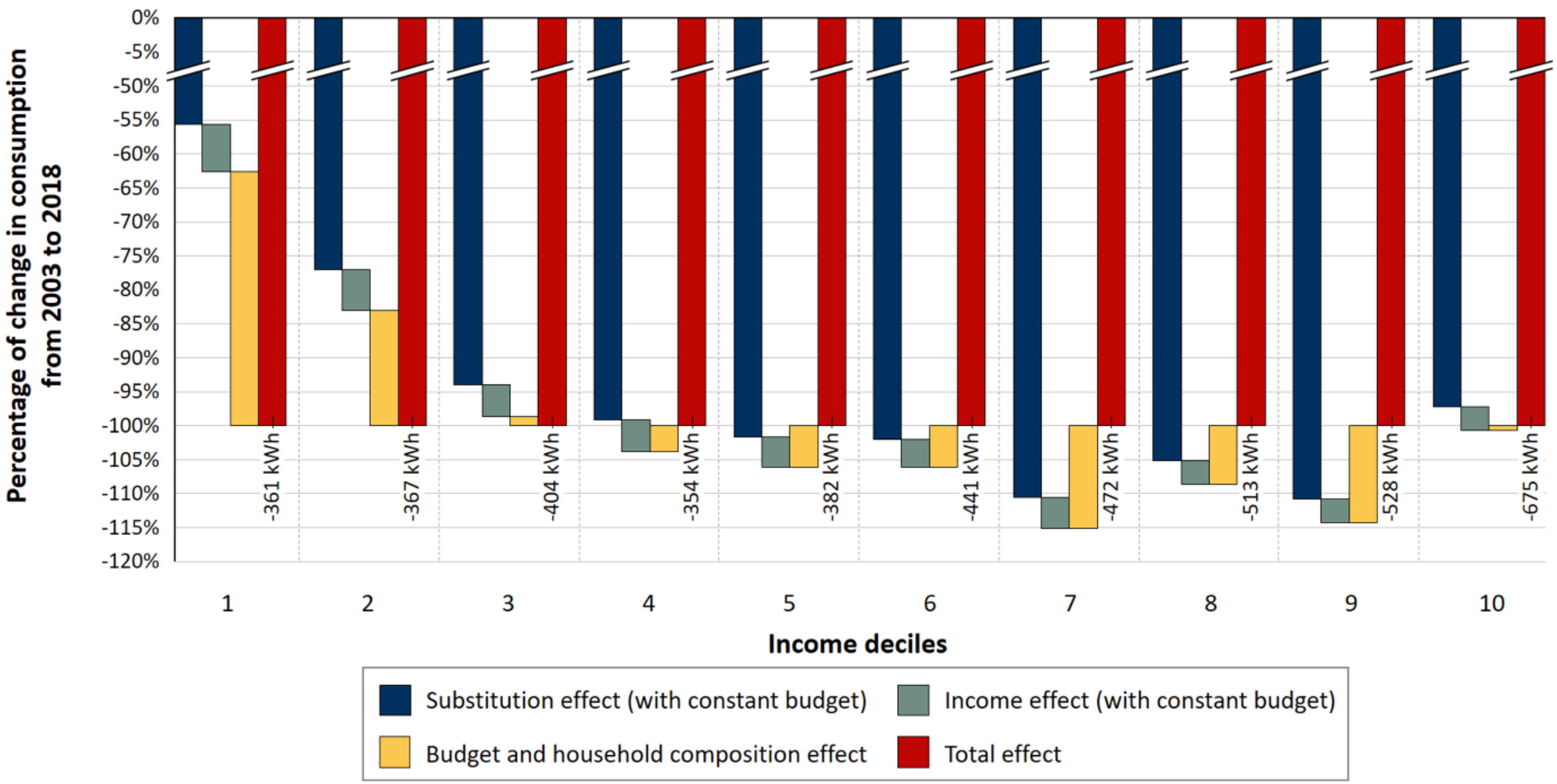

Figure 1: **Substitution, income, and total effect of the change in electricity consumption.** The effects are calculated for the period from 2003 to 2018. The effects occur due to the changes in the electricity price and disposable budget.

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5. Results: Inequality indicators, social welfare estimates and energy poverty indicators (w/ and w/o levy) 2018

Table 2: Inequality indicators and social welfare estimates due to the actual allocation mechanism in 2018.

		Average equivalent income $\overline{y}$ [€]	Gini coefficient G	Atkinson index $A(\varepsilon = 1)$	$W = \overline{y}(1 - A)$[€]
Actual levy	Absolute value	32,424	0.2888	0.1376	27,963
No levy	Absolute value	32,490	0.2882	0.1368	28,046
	Rel. change compared to actual levy	0.20%	-0.23%	-0.58%	0.30%

Table 3: Energy poverty indicators before and after the introduction of our reform proposal

		2 x median share of expenditure			**high cost / low income**		
		FGT value $(\alpha = 0)$	FGT value $(\alpha = 1)$	FGT value $(\alpha = 2)$	FGT value $(\alpha = 0)$	FGT value $(\alpha = 1)$	FGT value $(\alpha = 2)$
Actual levy	Absolute value	0.1253	0.0597	0.1152	0.1674	0.2224	0.7293
No levy	Absolute value	0.1133	0.0499	0.1043	0.1656	0.1994	0.6468
	Rel. change compared to actual levy	-9.57%	-16.41%	-9.47%	-1.05%	-10.36%	-11.31%

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5. Results: Average Residential Electricity Price and impact of reform options 1–3, by income decile, 2018

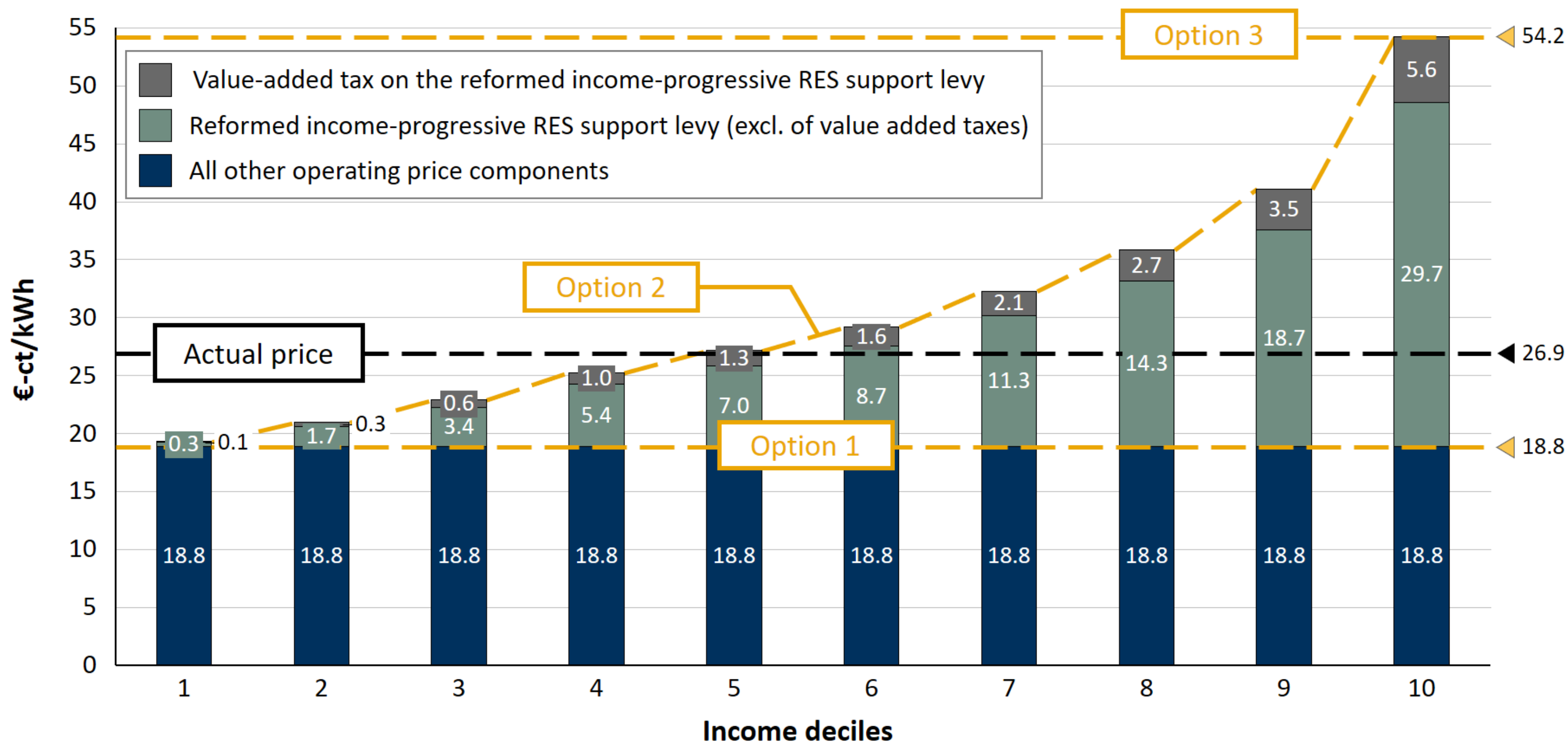

Figure 1: **Average residential electricity operating prices:** Private households are grouped into income deciles according to the OECD equivalence scale. The grey bars show the average operating price for 2018 without the RES support levy. The black dashed line shows the actual average operating price for 2018, including the RES support levy. The yellow dashed lines show average operating prices following our reform options 1, 2, and 3 for the RES support levy. In option 3, the difference in expenditures for electricity to option 2 is compensated by the tax offices.

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5. Results: Expected change in electricity consumption, by reform option & decile

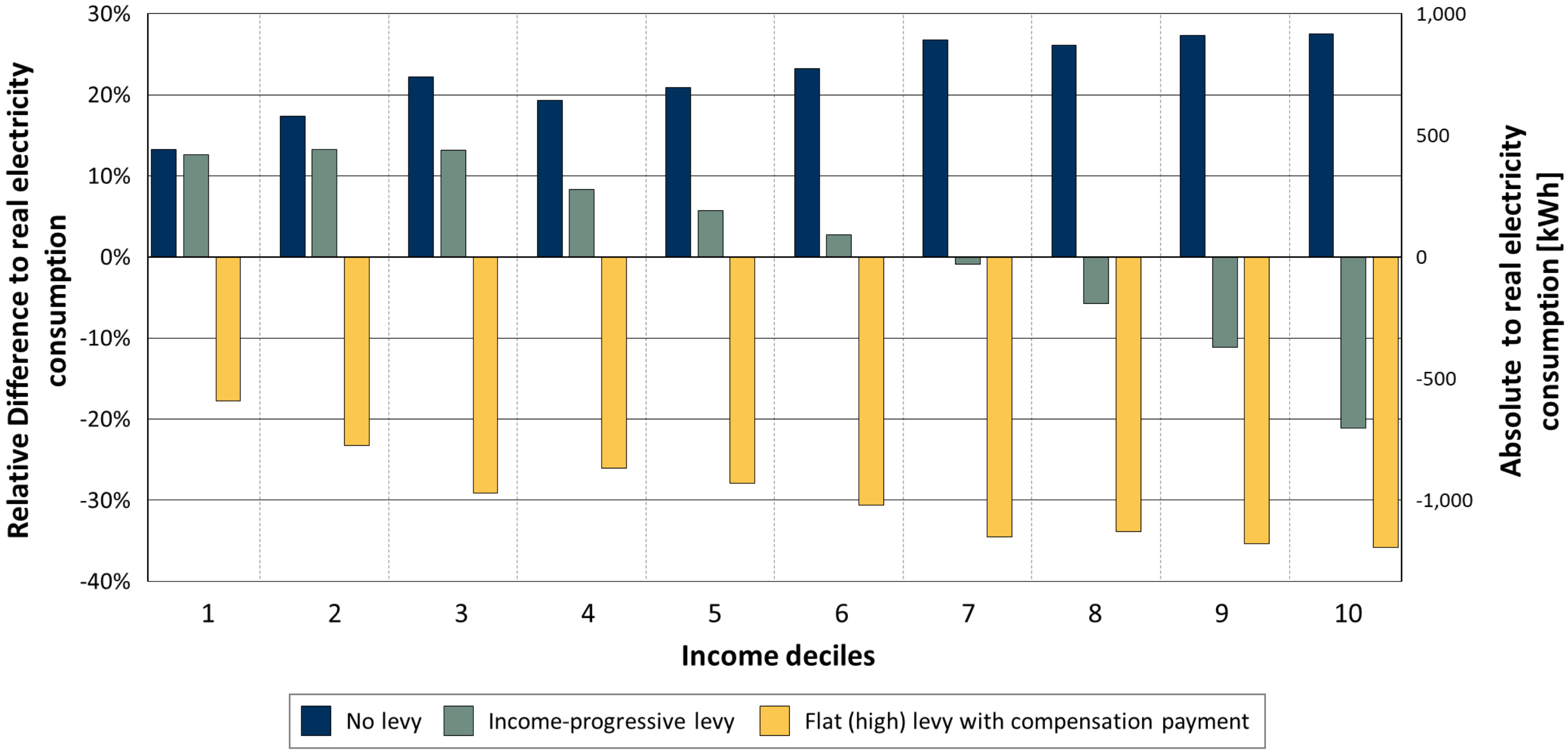

Figure 1: **Difference in electricity consumption for a reformed RES support levy.** Private households are grouped into income deciles according to the OECD equivalence scale. The blue bars show the case of the abolition of the RES support levy. The olive green bars show our reform proposal for an income-progressive RES support levy. The yellow bars show our reform proposal for a (high) flat RES support levy with an income-degressive compensation payment. Consumption values are compared to the electricity consumption observed for the actual RES support levy.

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5. Results: Inequality indicators and social welfare estimates (w/ and w/o reform)

Table 4: Inequality indicators and social welfare estimates before / after the introduction of our reform proposal

		Average equivalent income $\bar{y}$ [€]	**Gini coefficient G**	**Atkinson index $A(\varepsilon = 1)$**	**$W = \bar{y}(1 - A)$[€]**
Actual levy	Absolute value	32,424	0.2888	0.1376	27,963
No levy (**option 1**)	Absolute value	32,490	0.2882	0.1368	28,046
	Relative change compared to actual levy	0.20%	-0.23%	-0.58%	0.30%
Income-progressive levy (**option 2**)	Absolute value	32,429	0.2879	0.1365	28,001
	Relative change compared to actual levy	-0.02%	-0.32%	-0.75%	0.13%
Flat (high) levy with compensation payment (**option 3**)	Absolute value	32,480	0.2871	0.1359	28,065
	Relative change compared to actual levy	-0.17%	-0.59%	-1.20%	0.37%

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5. Results: Energy poverty indicators (w/ and w/o reform)

Table 5 Results for the energy poverty indicators before and after the introduction of our reform proposal

		2 x median share of expenditure			high cost / low income		
		FGT value $(\alpha = 0)$	FGT value $(\alpha = 1)$	FGT value $(\alpha = 2)$	FGT value $(\alpha = 0)$	FGT value $(\alpha = 1)$	FGT value $(\alpha = 2)$
Actual levy	Absolute value	0.1253	0.0597	0.1152	0.1674	0.2224	0.7293
No levy **(option 1)**	Absolute value	0.1133	0.0499	0.1043	0.1656	0.1994	0.6468
	Rel. change compared to actual levy	-9.57%	-16.41%	-9.47%	-1.05%	-10.36%	-11.31%
Income-progressive levy **(option 2)**	Absolute value	0.0901	0.0370	0.0800	0.1609	0.1680	0.5073
	Rel. change compared to actual levy	-28.14%	-38.06%	-30.61%	-3.85%	-24.46%	-30.45%
Flat (high) levy with compensation payment **(option 3)**	Absolute value	0.0945	0.0390	0.0788	0.1586	0.1682	0.4999
	Rel. change compared to actual levy	-24.59%	-34.64%	-31.64%	-5.25%	-24.38%	-31.45%

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6. Conclusions

1. The renewable energy support levy led to a substantial decrease in household electricity consumption of 23% (29.3 TWh) in 2018

2. Indiscriminate renewable energy support levies on electricity consumption increase income inequality and energy poverty in Germany

3. For 2018, we find that renewable energy support levies alone led to a relative increase of **0.23%** of the **Gini coefficient**, and **11.3%** of the **HCLI energy poverty** indicator (measuring energy poverty intensity)

4. Our **ex-post analysis for 2018** indicates that a reformed levy system would have slightly decreased overall income inequality with relative decreases of **0.23%, 0.32%** and **0.59%** (%ages changes of **Gini coefficients** for **options 1, 2 and 3**)

5. More importantly, such a reform would have substantially decreased energy poverty by **11.3%, 30.5%** and **31.5%** (%age change of **HCLI energy poverty** indicator for **options 1, 2 and 3**)

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Thank you for your kind attention!

Any questions?

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References

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