Energie-Innovationszentrum Cottbus

Energy Economics Lab EECON

Smells like Green Energy

Quasi-experimental evidence on the impact of bioenergy production on residential property values

Christin Hoffmann, **Shanmukha Srinivas Byrukuri Gangadhar**, and Felix Müsgens

ENERDAY 2024 - 18TH INTERNATIONAL CONFERENCE ON ENERGY ECONOMICS AND TECHNOLOGY
12/04/2024

Brandenburgische Technische Universität Cottbus - Senftenberg

Why is Bioenergy important?

- Germany is committed to renewable future
- **Grid Stabilization**: Bioenergy supports grid stabilization and provides a reliable source of energy.
- **Decentralized Energy Production**: Bioenergy enables local energy production, contributing to decentralized energy systems.
- **Greenhouse Gas Reduction**: Bioenergy can lead to negative greenhouse gas emissions (with CCS), supporting environmental sustainability.
- **Transition from Nuclear Energy**: Bioenergy offers an alternate and reliable energy source, supporting the transition from nuclear energy.

Why is research on Local Acceptance important?

- There are certain negative externalities with Bioenergy such as:
  - Noise
  - Odor
  - Safety concerns
  - Visual landscape pollution
  - Increased local transport

- Knowing how accepting people are is increasingly important as expansion is expected

What we hope to achieve?

- **Research Objective:** Determine the impact of bioenergy plants on property prices and assess the level of acceptance among residents
- **Role of Proximity:** Explore the role of proximity to bioenergy plants in influencing property prices
- **Role of Bioenergy Characteristics:** Understand which determinants influence acceptance and how strong

Why consider housing prices?

- **Hedonic Pricing:**

  The value of a house is described by a vector of characteristics, e.g., year of construction, size, condition, neighbourhood, local environmental quality, surrounding area, ...

- **Reflecting Externalities:** Externalities, such as those from bioenergy production, should be revealed in housing prices.

What's been done so far?

- **Local Acceptance:** Previous studies indicate high local acceptance in developed regions, influenced by political and cultural contexts (Soland et al., 2013; Schumacher and Schultmann 2017)

- **Factors Affecting Acceptance:** Studies highlight the impact of costs, benefits, smell perception, trust, and information on bioenergy acceptance (Dumont et al., 2021; Mancini and Raggi 2022; Bharadwaj et al., 2023; Dobers 2019; Kortsch et al., 2015)

- **In Germany**
  - Increasing acceptance over the years – based on longitudinal poll study
  - Better acceptance in regions with bio-crop cultivation

What's been done so far?

- Modica (2017): Two-way fixed effects approach
- Zemo et al. (2019): Impact of an installation of Biogas plant on Property values in a case study

➢ When other factors are constant over time, any changes in housing prices can be attributed to the intervention - here Bioenergy plant installation

- Similar studies for Conventional Power Plants (*Blomquist, 1974; Boxall et al., 2005; Davis, 2011; Boes et al., 2015; Rivera and Loveridge, 2022; Hoffmann et al., 2022)*
- Similar studies for renewables (Sunak and Madlener, 2016; Dröes and Koster, 2016; Jensen et al., 2018; Frondel et al., 2019; and Hoffmann et al., 2022)

What data is used?

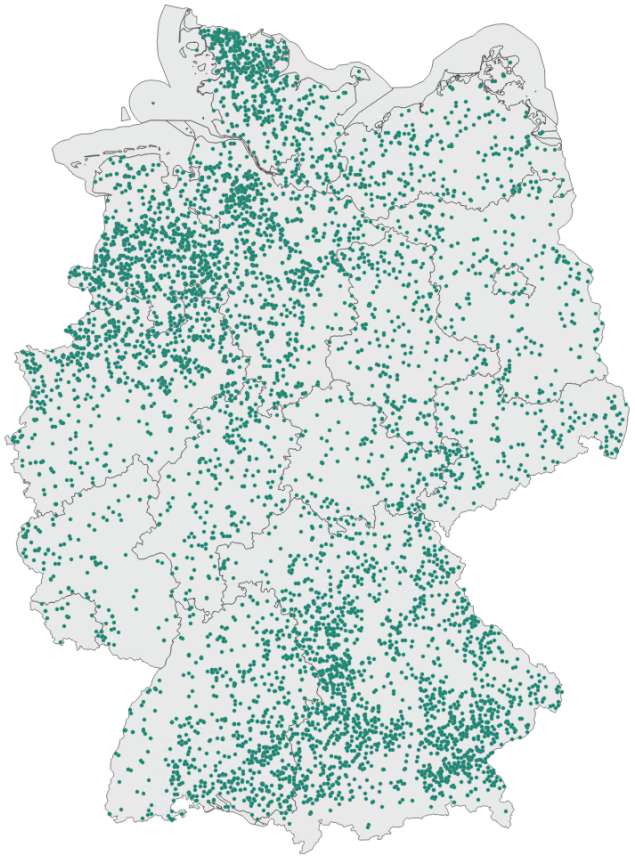
- Housing prices provided by *ImmobilienScout24* *(Leibniz Institute for Economic Research - rwi data)*
- Data of Bioenergy plants across Germany (MaStR data)
- Spatial Dimension:

  1 km^2 grid cells defined by the INSPIRE (Infrastructure for spatial information in Europe) Geographical Grid System

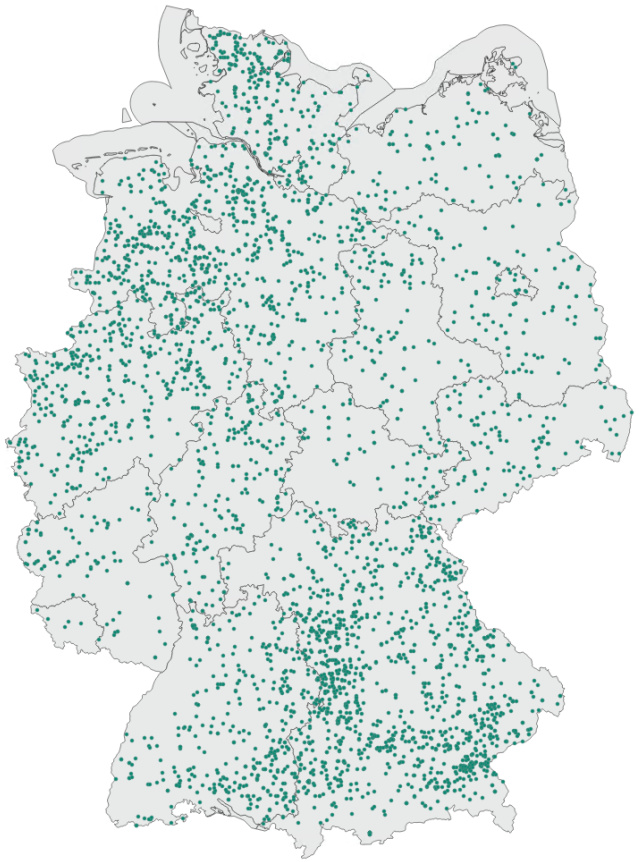
- Time Dimension:

  Yearly data between 2007 and 2022

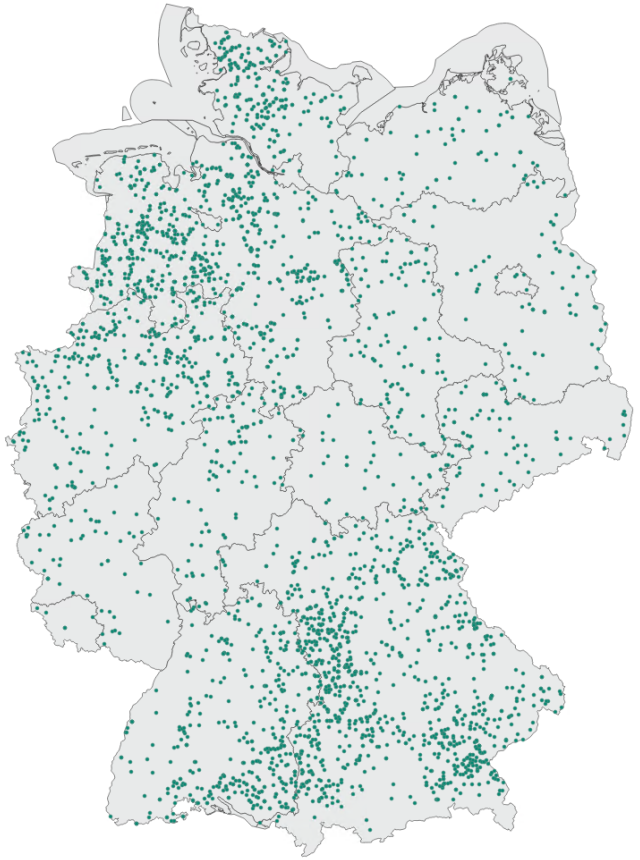
Let’s take a look



2008 – 2012
1540 Units



2013 – 2017
789 Units



2018 – 2022
638 Units

What data is used?

- Some numbers:
  - Data contains 16’156 points ie., Bioenergy power plants
  - Cumulative capacity –6’214.34MW
- Data segregation 1: Scale
  - Small - Capacity ≤ 150 kW
  - Medium - Capacity > 150 kW and ≤ 1’000 kW
  - Large - Capacity > 1’000 kW
- Data segregation 2: Type of input
  - Gaseous plants – N=15’216 – 5’522.48 MW
  - Liquid plants – N=365 – 80.78 MW
  - Solid plants – N=575 – 601 MW

How does the estimation work?

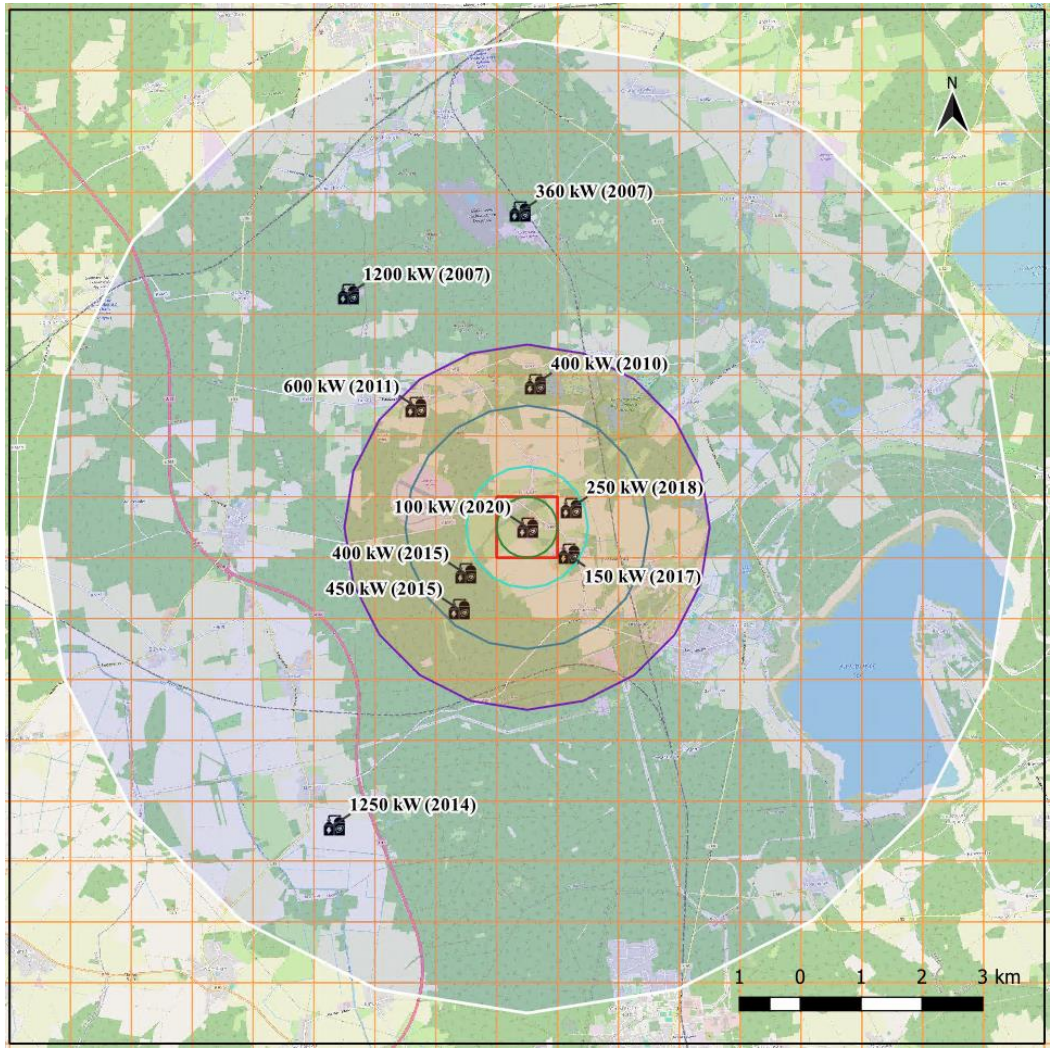
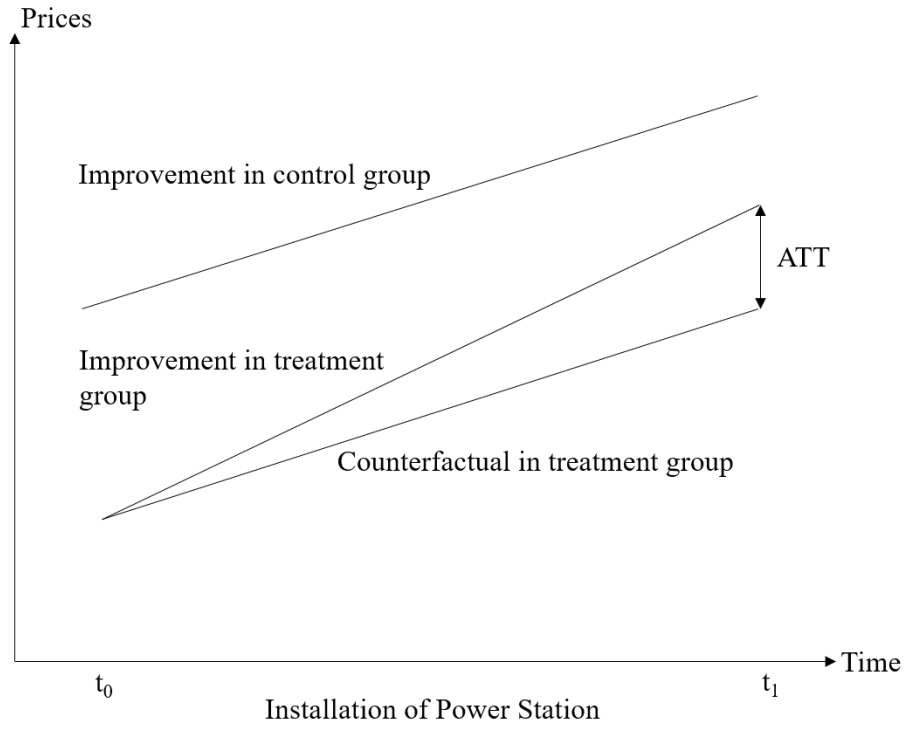


Figure 2: Spatial mapping of bioenergy plants in buffer zones and illustration of data selection within each buffer zone

How does the estimation work?

- "Difference-in-Difference" – What is it?
  - It is basically examining the differences in changes between the treated and control groups, both before and after the treatment or intervention
- In our study:
  - Commissioning and decommissioning of Bioenergy power plants provide a credible quasi-experiment
    → Independent announcement, construction, and decomposition of plants
  - Convenient identification of natural control and treatment groups asks for difference-in-differences (DID) approach



How does the estimation work?

- Two-way fixed effects estimator
  - Bias in Estimation in scenarios with staggered changes with heterogeneous treatment effects (Abowd et al., 1999)
  - Doesn’t test for common trend assumptions explicitly
- didM estimator
  - Accounts for heterogeneous timing of treatment by using single and joint placebos between switchers and non-switchers (de chaisemartin and d'haultfoeuille 2020)
  - Explicitly checks if the common trend assumption holds (de chaisemartin and d'haultfoeuille 2020)
  - Provides a more robust estimation method for analyzing the impact of bioenergy plants on housing prices, ensuring reliable results

How does the estimation work?

$$y_{irt} = \beta\ bioenergy\ plant_{irt} + \gamma_r\ grid_r + \tau_t\ time_t + \delta\ X_{irt} + \epsilon_{irt}$$

- y_{irt} defines the natural logarithm of the price *ln(house price)* for a house i in the 1 km^2 grid r in year t in EUR
- $bioenergy\ plant_{irt}$ is an indicator variable given by a set of distance zones
- $grid_r$ and time$_t$ are fixed effects controlling for grid characteristics over time and time effects being equal for all house sales at a given time
- τ_t and γ_r time-constant differences between the housing prices of different grids and the regions' equivalent impact of time
- X_{irt} controls for the house and grid-specific characteristics
- ß is the *did* estimator. It is replaced by did_m

What we found?

Table 1: TWFE in home prices with all other vicinity control

	Distance to closest bioenergy plant			
	d ≤ 0.5 km	**d ≤ 1 km**	**d ≤ 2 km**	**d ≤ 3 km**
b	-0.005	0.000	0.002	0.000
se	0.009	0.008	0.005	0.004
p	0.584	0.971	0.732	0.924
ci	[-0.024/0.013]	[-0.015/0.015]	[-0.008/0.011]	[-0.008,0.009]
N	4'400'311	4'400'311	4'400'311	4'400'311
Grids	113'640	113'640	113'640	113'640
R^2	0.999	0.999	0.999	0.999

* Based on two-way fixed effects estimation

Key Takeaway

- This is the first benchmark analysis
- This method does not hold the common trend assumption to hold explicitly – average differences in outcomes between treatment and controls may not be constant
- Results agree with literature
- No Significant impact

What we found?

Table 2: Impact of the commissioning of bioenergy plants on housing prices in their vicinity (≤ 3km) compared to a control at a distance of up to 8 km

	Distance to closest bioenergy plant			
	d ≤ 0.5 km	d ≤ 1 km	d ≤ 2 km	d ≤ 3 km
did_m	**-0.006**	-0.003	-0.002	**-0.003**
se	0.002	0.002	0.001	0.001
p_{didm}	**0.013**	0.163	0.226	**0.029**
ci	[-0.010/-0.001]	[-0.007/0.001]	[-0.004/0.001]	[-0.005/-0.000]
$p_{placebo}$	0.465	0.686	0.880	0.433
N	715'298	701'039	669'636	635'783
Switchers	7'328	11'518	18'665	22'347

* Based on didM estimator as proposed by de chaisemartin and d'haultfoeuille 2020

- **<u>Key Takeaway</u>**
- did_m-stategy for sharp and staggered designs to take heterogeneous timing of the treatment into account
- Common trend assumption is tested explicitly, and it holds
- Placebo effects are not significant ($p \geq 0.05$)
- Within 0.5km – negative instantaneous effect of -0.6%
- Within 3km – negative instantaneous effect of -0.3%
- For 1km and 2km – insignificant results

What we found?

Table 3: Impact of the commissioning of different sizes (measured in capacity) of bioenergy plants on housing prices in their vicinity (≤ 3km) compared to a control group at a distance of up to 8 km

		Distance to closest bioenergy plant			
		d ≤ 0.5 km	d ≤ 1 km	d ≤ 2 km	d ≤ 3 km
Small Cap ≤ 150kW	did_m	-0.006	-0.003	-0.003	-0.001
	se	0.004	0.002	0.002	0.002
	p_{didm}	0.123	0.216	0.102	0.714
	ci	[-0.013/0.001]	[-0.008/0.002]	[-0.008/0.001]	[-0.005/-0.003]
	$p_{placebo}$	0.669	0.362	0.338	0.393
	N	17'970	31'753	56'991	68'710
	Switchers	1'871	2'844	4'466	5'470
Medium 150kW < Cap. ≤ 1000kW	did_m	**-0.008**	**-0.005**	**-0.003**	**-0.003**
	se	0.003	0.002	0.002	0.002
	p_{didm}	**0.022**	**0.023**	0.146	**0.056**
	ci	[-0.015/-0.001]	[-0.010/-0.001]	[-0.006/0.001]	[-0.007/-0.000]
	$p_{placebo}$	0.498	0.421	0.143	0.332
	N	715'298	701'039	669'636	635'783
	Switchers	7'328	11'518	18'665	22'347
Large 100kW < Cap.	did_m	0.004	0.01	-0.001	0.001
	se	0.01	0.007	0.006	0.004
	p_{didm}	0.644	0.134	0.874	0.760
	ci	[-0.015/0.024]	[-0.003/0.023]	[-0.012/0.011]	[-0.007/0.010]
	$p_{placebo}$	0.78	0.795	0.05	0.291
	N	594'593	528'138	420'008	301'693
	Switchers	402	708	1'212	1'450

* Based on didM estimator as proposed by de chaisemartin and d'haultfoeuille 2020

Key Takeaway

- Clear impact of the size of a plant on housing prices
- No significant impact for small or large plants
- Strong and negative impact for medium sized plants
- Price decrease of about -0.8% to -0.3%

What we found?

Table 4: Impact of the commissioning of different inputs of bioenergy plants on housing prices in their vicinity (≤ 3km) compared to a control group at a distance of up to 8 km

		Distance to closest bioenergy plant			
		d ≤ 0.5 km	d ≤ 1 km	d ≤ 2 km	d ≤ 3 km
Solid	did_m	-0.01	-0.008	-0.008	-0.003
	se	0.009	0.007	0.006	0.006
	p_{didm}	0.276	0.256	0.166	0.564
	ci	[-0.027/0.008]	[-0.021/0.005]	[-0.020/0.003]	[-0.015/0.008]
	$p_{placebo}$	0	0.809	0.508	0.313
	N	1'756	2'446	7'611	3'866
	Switchers	254	411	768	859
Liquid	did_m	0.011	0.015	0.009	0.009
	se	0.016	0.012	0.009	0.009
	p_{didm}	0.505	0.213	0.306	0.286
	ci	[-0.021/0.042]	[-0.009/0.038]	[-0.008/0.026]	[-0.008/-0.027]
	$p_{placebo}$	0.058	0.049	0.187	0.003
	N	781	863	1'278	1'356
	Switchers	260	280	434	599
Gaseous	did_m	**-0.009**	**-0.007**	**-0.005**	**-0.004**
	se	0.002	0.002	0.001	0.001
	p_{didm}	**0.000**	**0.000**	**0.000**	**0.000**
	ci	[-0.013/-0.004]	[-0.010/-0.003]	[-0.008/-0.003]	[-0.007/-0.002]
	$p_{placebo}$	0.698	0.384	0.247	0.950
	N	52'353	107'582	199'007	264'432
	Switchers	4'607	7'752	13'484	17'061

* Based on didM estimator as proposed by de chaisemartin and d'haultfoeuille 2020

Key Takeaway

- No impact for solid or liquid bioenergy plants
- Common trend assumption can not be confirmed for these plants within 1 km
- Significant negative impacts for gaseous bioenergy plants of -0.9% to -0.4%
- Decrease with distance from the plant

Interpretation of the results

- Bioenergy plants as a whole have small negative impacts on the house prices
- Solid and Liquid based Bioenergy plants have no significant impact
- Gaseous plants have significant negative impact ranging from -0.9% to -0.4%
- Medium scale plants have a negative impact of -0.8% to -0.3%
- Size of effect comparable to those of solar fields (Dröes and Koster, 2016; and Hoffmann et al., 2022)

Interpretation of the results

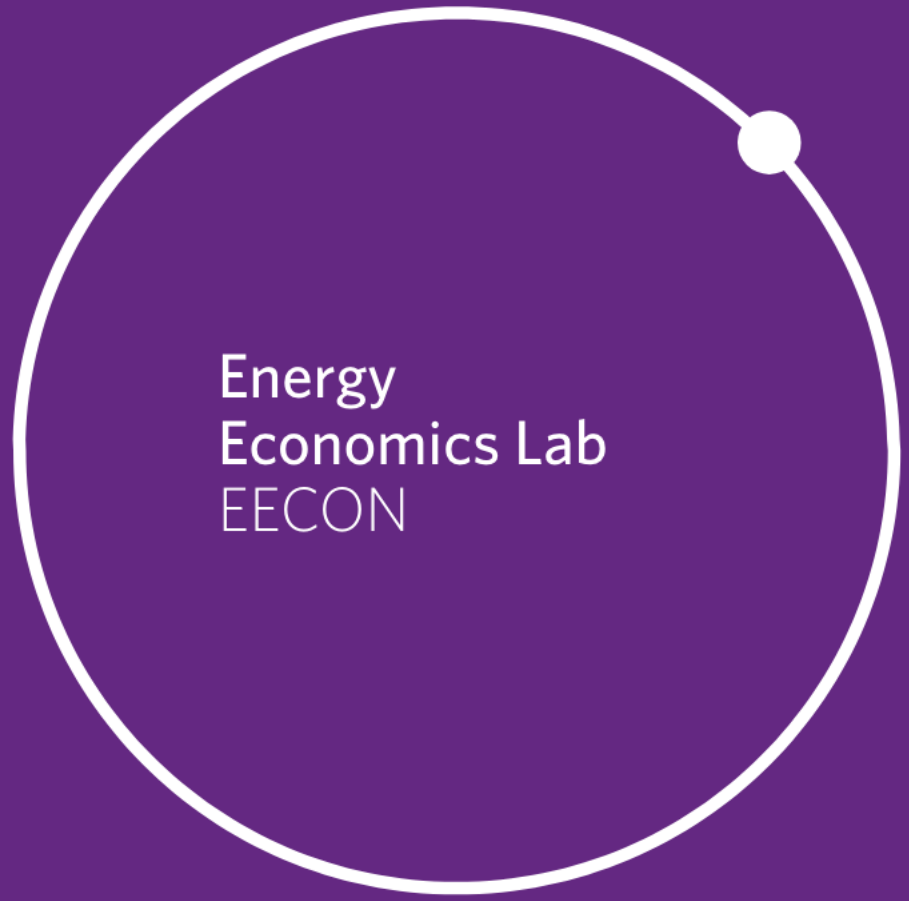
- Policy implications:
  - Spatial planning regulations for gaseous plants
  - Better community engagement to address concerns
  - Incentivize small scale plants
  - Monitoring medium scale plants
  - Better research on reducing negative externalities

Conclusion

- Using **TWFE** and $\boldsymbol{did_m}$ estimator, we estimate the effect of installation of a bioenergy plant on housing prices in its vicinity
- **No** significant impact using TWFE approach
- **Common trend assumption holds** for our analysis
- Instantaneous effect of **-0.6% and -0.3%** between 0.5km and 3km is found
- Analysis based on **capacity** revealed **significant negative effect** for **medium scale plants**
- **Gaseous bioenergy plants** have **negative** impacts compared to liquid or solid, which are insignificant

Energie-Innovationszentrum
Cottbus

Thank you!



Brandenburgische
Technische Universität
Cottbus - Senftenberg

What did we refer to?

- Bharadwaj, B., A. Kambo, A. Arratia-Solar, and P. Ashworth (2023): “Awareness of biogas increases its social acceptance,” Journal of Cleaner Production, 421, 138432.
- Bioenergy, I. (2021): “Implementation of bioenergy in the United States – 2021 update,”
- Blomquist, G. (1974): “The effect of electric utility power plant location on area property value,” Land Economics, 50, 97–100.
- BnetzA (2021): “Marktstammdatenregister,” Bundesnetzagentur f¨ur Elektrizit¨at, Gas, Telekommunikation, Post und Eisenbahnen.
- Boelmann, B., R. Budde, L. Klick, S. Schaffner, RWI, and S. A. c/o ImmobilienScout GmbH (2020): “RWI-GEO-RED: RWI Real Estate Data- apartments for sale -Immobiliendaten - Wohnungsmiete / RWI-GEO-RED: RWI Real Estate Data- apartments for sale”.
- Boes, S., S. N¨uesch, and K. W¨uthrich (2015): “Hedonic valuation of the perceived risks of nuclear power plants,” Economics Letters, 133, 109–111.
- Boxall, P. C., W. H. Chan, and M. L. McMillan (2005): “The impact of oil and natural gas facilities on rural residential property values: a spatial hedonic analysis,” Resource and Energy Economics, 27, 248–269.24

What did we refer to?

- Breidenbach, P. and L. Eilers (2018): “RWI-GEO-GRID: Socio-economic data on grid level,” Jahrbucher fur Nationalokonomie und Statistik, 238, https://www.degruyter.com/document/doi/10.1515/jbnst--2017--0171/htm.
- Davis, L. W. (2011): “The Effect of Power Plants on Local Housing Values and Rents,” Review of Economics and Statistics, 93, 1391–1402.
- De Chaisemartin, C. and X. d’Haultfoeuille (2022): “Difference-in-differences estimators of intertemporal treatment effects,” Tech. rep., National Bureau of Economic Research.
- De Chaisemartin, C. and X. d’Haultfoeuille (2020): “Two-way fixed effects estimators with heterogeneous treatment effects,” American Economic Review, 110, 2964–2996.
- Delzeit, R., W. Britz, and P. Kreins (2012): “An economic assessment of biogas production and land use under the German Renewable Energy Source Act,” Tech. rep., Kiel Working Paper.
- Dobers, G. M. (2019): “Acceptance of biogas plants taking into account space and place,” Energy Policy, 135, 110987.
- Emmann, C. H., L. Arens, and L. Theuvsen (2013): “Individual acceptance of the biogas innovation: A structural equation model,” Energy Policy, 62, 372–378.25

What did we refer to?

- Frondel, M., G. Kussel, S. Sommer, and C. Vance (2019): “Local cost for global benefit: The case of wind turbines,” Ruhr Economic Papers, 791.
- Hoffmann, C., E. Jalbout, M. Villanueva, T. Batz Liñeiro, and F. Müsgens (2022): “Positive and Negative Externalities from Renewable and Conventional Power Plants in the Backyard: The Value of Participation,” Available at SSRN 4203184.
- Kortsch, T., J. Hildebrand, and P. Schweizer-Ries (2015): “Acceptance of biomass plants–Results of a longitudinal study in the bioenergy-region Altmark,” Renewable energy, 83, 690–697.
- Mancini, E. and A. Raggi (2022): “Out of sight, out of mind? The importance of local context and trust in understanding the social acceptance of biogas projects: A global scale review,” Energy Research & Social Science, 91, 102697.
- Modica, M. (2017): “Does the construction of biogas plants affect local property values?” Economics Letters, 159, 169–172.
- Skøtt, T. (2006): “How much do biogas plants smell,” Bioenergy research, 16, 4–5.
- Soland, M., N. Steimer, and G. Walter (2013): “Local acceptance of existing biogas plants in Switzerland,” Energy Policy, 61, 802–810.

What did we refer to?

- Sun, L. and S. Abraham (2021): “Estimating dynamic treatment effects in event studies with heterogeneous treatment effects,” Journal of econometrics, 225, 175–199.
- Upham, P. and S. Shackley (2007): “Local public opinion of a proposed 21.5 MW (e) biomass gasifier in Devon: Questionnaire survey results,” Biomass and Bioenergy, 31, 433–441.
- Zemo, K. H., T. E. Panduro, and M. Termansen (2019): “Impact of biogas plants on rural residential property values and implications for local acceptance,” Energy Policy, 129, 1121–1131.

Backup Slide 1: Average of DiDL Estimator

Table A: Average effect of the commissioning of bioenergy plants on housing prices in their vicinity (≤ 3km) compared to a control group at a distance of up to 8 km

	Distance to closest bioenergy plant			
	d ≤ 0.5 km	d ≤ 1 km	d ≤ 2 km	d ≤ 3 km
did_a	-0.005	-0.000	-0.000	-0.002
se	0.003	0.002	0.002	0.002
p_{dida}	0.054	0.975	0.966	0.104
ci	[-0.011/-0.000]	[-0.004/0.005]	[-0.003/0.003]	[-0.005/0.000]
$p_{placebo}$	0.734	0.340	0.116	0.253
N	714’073	699´155	666’924	632’835
Switchers	7’206	11’375	18’481	22’159

* Based on didA estimator as proposed by de chaisemartin and d'haultfoeuille 2022