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Measuring Renewable Energy Externalities: Evidence from Subjective Well-Being Data

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Abstract

Electricity from renewable sources avoids the disadvantages of conventional power generation (air pollution, greenhouse gases, nuclear risk) but often meets with local resistance due to visual, acoustic, and odor nuisance. We use representative panel data on the subjective well-being of 36,475 individuals in Germany, 1994-2012, for identifying and valuing the local externalities from wind, solar and biomass plants. While the well-being effects of wind turbines refer mainly to initial installations and tend to dissipate over time, the effects of solar and biomass plants build up gradually as their number and capacity rises. In a spatial perspective, power generation from biomass creates negative spillovers to adjacent localities that are absent in the case of wind power.

Keywords: renewable energy; local externality; subjective well-being; life satisfaction; non-market valuation

JEL codes: Q42; D62; I31; Q51

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1. Introduction

Electricity generation from renewable sources is rapidly expanding in many countries around the world. In Germany, the share of electricity generated from Renewable Energy (RE) sources in total electricity consumption has increased from 4.6% in 1994 to 23.7% in 2012. In the European Union, we observe the same trend; by 2012, the share of RE sources in total electricity consumptions amounted to 23.5%.

The public attitude towards RE is typically favorable (VZBV 2013), because renewable power avoids the externalities associated with electricity from fossil fuels (air pollution and greenhouse gases) and nuclear power (nuclear risk and waste disposal). Consistent with voiced opinions, Welsch and Biermann (2014) found in a multi-country study, that a higher share of solar and wind power in a country’s national electricity mix is associated with greater subjective well-being of its citizens.

In spite of smaller large-scale externalities (environmental pollution), renewable power facilities may induce externalities on the local scale, such as visual impairments in the case of solar and wind power and odor nuisance in the case of biomass plants. In fact, the installation of such facilities often meets with local resistance, reflecting the so-called not-in-my-backyard (NIMBY) issue (van der Horst 2007) and, more generally, social and community acceptance problems (Batel et al. 2013).

This paper studies such RE externalities from the point of view of local subjective well-being. Specifically, the paper addresses the following aspects of the relationship between RE facilities and residents’ well-being: (1) How does the well-being of residents change due to the local expansion of RE? (2) Are there well-being differences between the initial installation in a given place and subsequent expansions? (3) Do people habituate to the presence of RE facilities? (4) Are there spatial spillovers of RE externalities? (5) Do wind, solar, and biomass installations differ in terms of those questions?[1]

With respect to these issues, a number of features of the different technologies may be relevant for their well-being impacts. For instance, rooftop solar installations are typically owned by the residents themselves, whereas wind parks are often the property of external investors. In addition, the impact of solar installations is purely visual and can be more easily avoided than the odor nuisance from biomass plants. It is intuitive that such differences influence the relationship between the different RE technologies and residents' well-being, and our empirical findings are consistent with such expectations.

We use panel data on reported life satisfaction of 36,475 German citizens, 1994-2012, and the number and capacity installed of wind power, solar and biomass plants at the postcode area where the respondents live as well as at the neighboring postcode areas. For each type of RE technology we estimate several specifications of life satisfaction regressions that are designed to address the specific research questions mentioned above, using several econometric techniques.

We find negative well-being externalities from all three types of RE, but they differ in several important ways:

For solar power, we find no well-being effects of initial installations, but effects from continuous expansion, and those effects accumulate rather than dissipate over time. From a spatial point of view, mainly solar installations in neighboring postcode areas affect people's well-being, not those in their own postcode area. On the contrary, greater solar power capacities in ones' own postcode area are tend to be associated with greater well-being.

For wind power, well-being effects arise mainly from initial installations, whereas subsequent expansions are of less importance. In addition, those effects tend to be more

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[1] We restrict our analysis to those "new" types of RE. The expansion of hydro power has been very limited in Germany over the last decades.

pronounced in immediate response to wind development, indicating habituation taking place, and there are no spatial externalities from neighboring postcode areas.

For biomass plants, the estimates suggest a difference between the short and the long term on the one hand, and the own area and adjacent areas on the other hand. First installations and expansions in ones' own area have no short term effects, but according to the model estimations a long term effects, that is, effects accumulate over time. By contrast, both first installations and expansions in adjacent areas seem to affect well-being both in the short and the long term.

As will be discussed below, these findings for the different technologies are intuitive in the light of those technologies' characteristics and respective channels of influence.

To our knowledge, this paper is the first to study the nature and extent of well-being externalities from wind, solar and biomass energy. In relation to previous literature, a major advantage of the present study is the use of a rich set of spatially disaggregated and nationwide representative panel data. This allows us to conduct a longitudinal analysis of externalities associated with RE, whereas existing studies (of stated preferences and property values) are mainly of a cross-sectional (static) nature.

The paper is structured as follows. Section 2 discusses the background and the relevant literature. Section 3 presents the data and econometric framework. Section 4 reports and discusses the empirical results. Section 5 concludes.

2. Background and Literature

During the past decades, especially after the introduction of the Electricity Feed-In Act (Stromeinspeisungsgesetz, StrEG) in 1991 and its successor, the Renewable Energy Act (Erneuerbare-Energien-Gesetz, EEG) in 2000, Germany has faced a wide expansion of RE technologies. By the end of 2012 Germany had 13,611 biomass plants, 21,500, wind turbines, and about 1.3 million solar installations falling under the regulations of the EEG, whereas the corresponding numbers for 1994 are 54 biomass plants, 1,118 wind turbines and 1,850 solar installations.

Polls among German citizens yield a considerable support for a transition of the energy system towards RE (see e.g. the results of the Forsa poll in VZBV 2013). However, in some regions the expansion of RE technologies gave rise to local opposition. In view of the generally high support of RE, this observation provoked a debate on the so-called not in my backyard (NIMBY) problem (van der Horst 2007). The NIMBY issue refers to the local or regional externalities associated with the different RE technologies. While wind turbines affect residents via their shadowing, noise as well as influence on the landscape and biodiversity (Drechsler et al. 2011), biogas plants are mainly objected because of odor nuisance, visual impacts or fear of declining tourism or property prices (Soland et al. 2013).

In addition to such externalities, political science has focused on the broader issue of social acceptance (Wüstenhagen et al. 2007). Among the various dimensions of social acceptance, the most relevant one for valuing local RE externalities is community acceptance, which depends on perceived benefits, fairness considerations, the availability of information, participation options and trust in the operator, just to mention a few (for a review see Devine-Wright 2007).

Several non-market valuation techniques have been used to study externalities from RE technologies. Numerous case studies, polls and discrete choice experiments have been conducted in order to identify the underlying problems of siting conflicts and factors of influence for social acceptance, whereby the bulk of studies focuses on wind energy development projects (van der Horst 2007). Due to differences in methodological designs, stated questions and terms used (e.g. acceptance vs. support), the results present quite a mixed picture (Devine-Wright 2007).

In the case of wind power, stated choice experiments have been applied which suggest that there can be negative externalities arising from wind turbines, resulting in a positive willingness to pay (WTP) of respondents for an increase in the distance to the nearest wind turbine (for an overview see Meyerhoff et al. 2010). Drechsler et al. (2011) estimate in a choice experiment that external costs make-up approximately 14% of the total investment costs.

Stated preference methods exhibit some drawbacks as respondents may respond strategically if they assume their answers to influence political decisions upon the expansion of RE technologies (Fujiwara and Campbell 2011). Moreover, respondents may give socially desirable answers due to the positive connotation of RE (van der Horst 2007) or misconceive the aspect of adapting and habituating to the impacts of RE technologies (focusing illusion, see Kahneman and Thaler 2006).

Another strand in the literature on the valuation of non-market goods relies on revealed preference rather than stated preference methods. In the context of local effects of RE siting the hedonic approach has been applied, which reverts to housing market data. Supposed that housing prices reflect the value of non-market goods present in the neighborhood – e.g. proximity to recreational sites, local infrastructure, air quality or noise – it is possible to compute the individual WTP for those goods (Fujiwara and Campbell 2011). Three studies have analyzed the effect of wind turbines on property values (Sunak and Madlener 2012, Jensen et al. 2013, Hoen et al. 2013). While Sunak and Madlener (2012) find a negative effect of wind energy development on property values in North Rhine-Westphalia/Germany just as Jensen et al. (2013) for Denmark, Hoen et al. (2013) do not find an effect on property values in the US.

The present paper applies the experienced preference method (Welsch and Ferreira 2014), also referred to as life satisfaction or happiness approach, in order to analyze effects of RE expansion on well-being and to measure local residents' preferences with regard to the various RE technologies. This method of preference elicitation uses people's reported life satisfaction as a proxy for experienced utility. It estimates the statistical association of life satisfaction to the non-market good (or bad) in question as well as to people’s income. The implied utility-constant tradeoff of income for the good is then used as a measure of the monetary value of the latter. The experienced preference method thus provides a tool for non-market valuation, in addition to the standard stated and revealed preference methods.

Life satisfaction data have been used in environmental economics (for surveys see Welsch and Kühling 2009, Frey et al. 2010, MacKerron 2012, and Welsch and Ferreira 2014) and, to a smaller extent, with respect to energy issues. Experienced preference studies differ with respect to the spatial resolution, which ranges from whole nations (Welsch 2002, Rehdanz and Maddison 2005)) to postcode areas (Levinson 2012) and GPS coordinates (MacKerron and Mourato 2014). With respect to energy, Welsch and Biermann (2014) used life satisfaction data to study European citizens’ preferences for alternative structures of their national electricity supply system and found people’s subjective well-being to be positively correlated with the share of solar and wind power in their national electricity mix. Using spatially disaggregated data from Australia, Ambrey and Fleming (2011) found scenic amenity to affect well-being, a result which may be relevant for the well-being assessment of RE facilities studied in the present paper.

3. Method

3.1 Data

Our data come from several sources. The data on life satisfaction along with information on the respondents' socio-economic situation is provided by the German Socio Economic Panel Study (GSOEP) of the German Institute for Economic Research (DIW); see Wagner et al. (2007). The GSOEP survey is conducted on a yearly basis since 1984. Annual waves of the survey include more than 20,000 individuals in about 11,000 households. With respect to the spatial dimension, GSOEP data are identified by respondents' postcode area from 1993 onwards.[2]

An important attribute of the GSOEP is its panel structure (i.e. that the same individuals are re-interviewed each year), which facilitates to analyze changes on the individual level and to control for unobserved time-invariant characteristics (Andreß et al. 2013). As respondents may join the panel at a later stage (late entry), drop-out in a single wave (temporary non unit response) or permanently (panel attrition) (e.g. due to refusal, death or relocation) the set of respondents is slightly changing over time, i.e. the data is unbalanced (Andreß et al. 2013).

The dependent variable in our life satisfaction regressions is the answer to the following question: "How satisfied are you at present with your life, all things considered? Please respond using the following scale, where '0' indicates *not at all satisfied* and "10" indicates *completely satisfied*."

The data set used in this paper refers to the waves 1994-2012 and includes 266,588 observations for 36,475 individuals. The variables of the GSOEP used in this analysis are summarized in Table 1.

As to the energy data, the four German Transmission System Operators (TSO) Amprion, 50Hertz, Tennet and TransnetBW provide data on all RE plants that come under the Renewable Energy Act (EEG).[3] Though the four sources are different with regard to their comprehensiveness, they all give information about the postcode area (5-digit hierarchical system) where the plant was installed, its type of technology (wind, solar, biomass, hydro, geothermal energy as well as landfill, mine and sewage gas), the date of construction and the installed capacity. Unfortunately, there is no information that would help us to distinguish

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[2] Changing postcodes have not been recoded in the GSOEP which is why we used a manual search to – if possible – adjust postcodes in case more than five observations were affected. The same has been done with the energy dataset which partly included wrong or outdated postcodes.

[3] Some RE plants exceeding a certain capacity are excluded from the EEG promotion. By the end of 2011 this concerned about 1/3 of the hydroelectric installations while all of the other technologies were still eligible to achieve the EEG feed-in-tariff (BDEW 2013:19f).

between rooftop solar and free-standing installations.[4] Nor can we obtain information about the sort of biomass plant which may have implications for odor nuisance because of different material that is being combusted. For data on wind energy, a different source was used, that gives concise information on construction of wind turbines in Germany (BDB 2013).[5] The energy variables used in this analysis are summarized in Table 2. From the summary statistics we can tell that wind energy is most exploited with regard to installed capacity and that most respondents have solar installations in their neighborhood. The standard deviations indicate that there is a considerable variance across observations.

We matched the data on RE plants and the socio-economic data of the GSOEP on the basis of the respondents' postcode area. Moreover, as the exact dates of the interview and the plant constructions were available, we could identify for each respondent the number of plants and capacity installed per type of technology by the time of the interview.[6] For each wave during 1994 to 2012 the readied dataset gives information about the respondent's socio-economic condition (see Table 1) as well as the prevalence of RE technologies in the respondent's postcode area (see Table 2). In Germany, there are about 8,200 postcodes, on average comprising an area of 44 km². In order to take account of possible spill-over effects, we widened the spatial scale to include RE plants of neighboring postcode areas. Information from the open source platform OpenStreetMap was used to identify for each postcode area the adjacent postcode areas.

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[4] In the EEG a RE plant is defined very broadly as a facility to produce electricity from RE or mine gas. In the case of rooftop solar, all installations that are built on the same property within 12 months are subsumed as one plant. Free-standing solar installations are considered as one plant if they are built in the same community within a distance of 2 km and within a time-span of 24 months.

[5] This analysis is restricted to onshore wind energy.

[6] As for the wind data, we only know the month and year of construction, which is why we used the 15th as a reference.

3.2 General Methodological Issues

Our approach to measuring externalities from RE involves approximating utility by data on subjective well-being, specifically, life satisfaction. Though this approach relies on subjective data, a major feature of this method is that it does not rely on people's stated attitude towards or stated evaluation of the issues under study. Instead, life satisfaction data are being elicited independently of those issues, and it is the purely statistical association between life satisfaction and the independently measured variables of interest that is taken as a measure of preference.

As discussed by Ferrer-i-Carbonell and Frijters (2004), assumptions necessary for using reported life satisfaction in economic analysis are a positive monotonic relationship between life satisfaction and the underlying true utility, and ordinal interpersonal comparability. Ordinal interpersonal utility means that if the satisfaction score of individual *i* is greater than that of individual *j*, this reflects the same ranking of underlying utility. Validation research has produced a variety of supporting evidence of those assumptions (see Diener et al. 1999, Frey and Stutzer 2002, Ferrer-i-Carbonell and Frijters 2004). Under ordinal interpersonal comparability life satisfaction can be treated as an ordinal variable. If, more restrictively, it is assumed that differences between *i*'s and *j*'s satisfaction scores are proportional to differences in underlying utility (cardinal interpersonal comparability), life satisfaction can be treated as a cardinal variable. Using GSOEP data, Ferrer-i-Carbonell and Frijters (2004) found that assuming the data to be ordinal or cardinal and applying the corresponding estimation methods has little effect on qualitative results. In particular, the ratios of coefficients are similar, which is important for monetary valuation. Similar results were obtained by many others.

3.3 Econometric Approach

We estimated micro-econometric life satisfaction functions in which the self-reported life satisfaction (*LS*) of individual *i* in postcode area *s* and year *t* depends on indicators of renewable energy (*RE*) in her postcode area, income, and a standard set of time-variant socio-demographic controls (household size, age squared, health status, partner status, employment status, person in household needing care). Time-invariant factors are implicitly captured through person fixed effects. The estimating equation can be stated as follows:

$$LS_{ist} = \alpha + \beta{*}RE_{st} + \gamma{*}\ln(income_{ist}) + \delta'\mathbf{controls_{ist}} + person_i + year_t + \varepsilon_{ist} \qquad (1)$$

where $person_i$ and $year_t$ denote person and year fixed effects, respectively, and ε_{ist} denotes the error term. Person fixed effects control for unobserved time-invariant characteristics of the individual (such as personality traits) whereas year fixed effects control for time-varying unobserved factors common to a particular year (such as the business cycle). As is common in the well-being literature, income is included in logarithmic form to account for decreasing marginal utility.

Equation (1) will be estimated separately for *RE* referring to wind power, solar power and biomass, respectively. Several alternative indicators will be used for *RE*. One indicator is a dummy variable that takes the value 1 if at least one of the respective *RE* plants exists in the postcode area and 0 otherwise. Alternative *RE* indicators are the number of plants and the installed capacity. It should be noted that over time the *RE* dummy changes its value only once (from 0 to 1), at the time of the first installation (unless the first installation took place before the period of observation or there is none).[7] In contrast to the number of units and the

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[7] It should be noted that we do not have data on the decommissioning of *RE* units, but this can be considered to be of minor importance in the time frame considered, given the typical lifetime of *RE* installations.

installed capacity, the coefficient of the *RE* dummy variable hence measures the effect of the first installation, not of subsequent expansions.

We will extend the basic specification, equation (1) by including, in addition to *RE* in a respondent's own postcode area, the corresponding *RE* indicator in the neighboring (adjacent) postcode areas. This specification serves to measure the existence and strength of spatial well-being spill-overs. We will estimate equation (1) and variants thereof using both first difference (FD) and fixed-effect (FE) estimators. While FD estimation focuses on two successive measurements (t and t-1) and captures instantaneous effects of the independent variables, FE estimation takes all measurements (t = 1, …T) into account and captures lasting effects, including dissipation or accumulation over time (Andreß et al. 2013, Giesselmann and Windzio 2012). The FD coefficient hence measures the short-term effect of the first installation in a given postcode area, whereas the FE coefficient measures the long-term effect. Long-term effects being smaller than short term effects will be taken as an indication of hedonic adaptation (habituation) to RE externalities, whereas the converse will be taken to indicate that externalities become effective gradually over time (due to a delay in perception, say).

The risk of omitted variable bias is minimized because we control for the observed life satisfaction factors known to be relevant (see Dolan et al. 2008 for a review) as well as for unobserved person-specific factors (through the FE and FD modeling framework). Though life satisfaction is likely to be measured with error, there is no reason to expect that measurement error is correlated with our independent variables of interest. Finally, including person fixed effects is an effective way of dealing with reverse causation in life satisfaction regressions (Ferrer-i-Carbonnel and Frijters 2004).

Following Ferrer-i-Carbonell and Frijters (2004), we treat the dependent variable, 11-point life satisfaction, as a cardinal variable and estimate equation (1) and variants thereof using least squares. We report robust standard errors.

4. Results and Discussion

4.1 Estimation Results

Tables 3 - 5 present the estimation results for wind turbines, solar installations, and biomass plants, respectively. Table 6 reports results when the three technologies are included jointly. The presentation in these Tables is restricted to the main variables of interest, whereas more detailed results, including those for the control variables, are reported in the Appendix.[8]

Table 3 reports the results for solar power for alternative specifications that differ along three criteria: (i) solar power installations captured by a dummy variable, by their number or by installed capacity, (ii) solar power installations in residents' own postcode area or in own area and adjacent areas, (iii) FD or FE estimation. As can be seen, not all coefficients of the RE variables are significant, but all significant coefficients are negative, with one exception (see below). The dummy variables are insignificant in all specifications considered: the first installation has no effect on well-being. By contrast, the number of units has a weakly significant effect according to the FD estimation and a strongly significant effect according to the FE estimation. Moreover, the FE coefficient is almost twice as large as the FD coefficient. The capacity variable is insignificant according to both FD and FE.

When we add to those models the respective solar energy variables in adjacent areas, we find that all RE variables in the own area are insignificant, except for the capacity variable, whose coefficient is weakly significantly positive. The number and capacity in adjacent areas have negative effects on well-being according to the FE estimation.

We conclude that in the case of solar power no well-being externalities arise from the first installation, neither in the individual's own area nor in adjacent areas. Instead, well-being is negatively affected by expansion in the number and capacity of installations, in particular in

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[8] The results for the controls do not vary appreciably across the various specifications and are reported only for the main specifications. They correspond to those typically found in life satisfaction regressions for developed countries (Dolan et al. 2008): Life satisfaction is increasing in health and in household income, decreasing in household size, greater if having a partner and smaller if unemployed than in any other employment status.

adjacent areas and in the long run. When we control for installations in adjacent areas, no negative well-being effects from solar energy installations in one’s own area can be found, and capacity expansion in one’s own area even has a weak positive effect in the long run.

Table 4 reports the results for wind power; it is organized in the same way as Table 3. As can be seen, all significant coefficients of the RE variables are negative. In contrast to solar power, the dummy variable is weakly significant in the case of FD and significant in the case of FE. The magnitude of the FE coefficient is somewhat smaller than that of the FD coefficient, indicating that the long-term (lasting) well-being effect of the first installation of wind turbines is smaller than the short-term (immediate) effect. As to the number of plants and installed capacity, the FE coefficients are significant and weakly significant, respectively, whereas the FD coefficients are insignificant.

When we add to those models the respective wind energy variables in adjacent areas, we find the preceding results almost unaffected in terms of the sign, significance, and magnitude of the coefficients. In particular, the FE coefficient on the dummy variable continues to be of smaller magnitude than the FD coefficient. Moreover, the RE variables in the adjacent areas are insignificant in all cases considered (dummy, number and capacity; FD and FE).

We conclude that in the case of wind power well-being externalities arise in particular from the first installation of power generation units. In addition, those effects are smaller in the short than in the long run, and there are no spillovers from adjacent areas. As to magnitudes, the initial installation of wind power plants reduces well-being by about 0.04 units on the 11-point life satisfaction scale. To put this figure in perspective, it can be noted that unemployment, which is one of the strongest well-being factors, reduces life satisfaction by about 0.5 points (see Tables in the Appendix).

Table 5 reports the results for power generation from biomass. All significant coefficients in the various specifications are negative. It is seen that all FD coefficients concerning the individuals’ own area are insignificant, regardless of whether installations in adjacent areas are included or not. By contrast, the FE coefficients on the dummy variable and on capacity are significantly negative, both in specifications with and without installations in adjacent areas. Importantly, the coefficients on installations in adjacent areas are all significantly negative except for the FD coefficient on capacity.

The results from the FD estimations suggest the absence of short run effects of biomass plants in the individuals' own area, whereas long run effects exist with respect to both initial installations and capacity expansions. Both initial installations and expansions in the number or capacity in adjacent areas have significant negative well-being effects, both in the short and in the long run.

While for solar power neither the initial installation nor subsequent expansions affect the well-being of residents of the same postcode area, this is the case for wind power and power from biomass. We can therefore compare effect sizes across these technologies. Comparison of Tables 4 and 5 suggests that the first initial installation of a wind energy unit and a biomass unit have long term effects (FE) of similar size, namely about 0.04 points. However, the effects of capacity expansions differ greatly, amounting to about 0.001 points per MW in the case of wind and about 0.005 points in the case of biomass.

As a robustness check, we ran regressions that include all three technologies at the same time. Table 6 reports the results. As in Tables 3 – 5, all significant coefficients are negative, with the single exception already noted above: Capacity expansion of solar power in one's own postcode area is associated with greater well-being according to the FE estimate. All of the coefficients found significant in Tables 3 – 5 remain significant except for the following: First, the FD coefficient on the number of solar power installations in one's own area becomes insignificant. This strengthens rather than weakens the conclusion that there are no short-term externalities from solar power in ones' own area. Second, the FD and FE coefficients on the number of biomass plants in adjacent areas become insignificant.

In quantitative terms, (significant) coefficients do not differ greatly between Table 6 and Tables 3 – 5. In particular, the FE coefficients of biomass capacity and solar capacity retain their magnitude, the former being about five times as large as the latter.

4.2 Discussion

We found that renewable power plants generate statistically and economically significant negative local externalities, but the effects of the technologies considered – solar, wind, and biomass – differ qualitatively and quantitatively.

For solar power we find no well-being effects of initial installations, but effects from continuous expansion, and those effects accumulate rather than dissipate over time. From a spatial point of view, mainly solar installations in neighboring postcode areas affect people's well-being, not those in their own postcode area. On the contrary, greater solar power capacities in ones' own area tend to be associated with greater well-being.

An important factor that may explain those findings is that solar installations – at least the rooftop variety – are typically owned by local residents. Installation of solar panels is their own choice, based on the associated benefits from reduced electricity bills and feed-in revenues. In addition, there might be status effects associated with the presence of solar panels on ones' rooftop. These factors may explain why there can be even positive well-being effects from solar installations. In addition, first installations are of small size and capacities grow gradually, such that any impairments – which are mainly visual – are likely to arise from the accumulation of capacity, not from first installations. Moreover, according to our results those impairments largely originate not from installations in people's own area but from those in neighboring areas for which the monetary and status benefits are more likely to accrue to others, not to oneself.

For wind power, the results suggest that well-being effects arise mainly from initial installations, whereas subsequent expansions are of less importance. In addition, those effects tend to dissipate rather than accumulate over time, indicating habituation taking place, and there are no spatial externalities from neighboring postcode areas.

These findings are explicable because wind power installations differ in important ways from solar installations: They are typically owned by external investors, such that there are less local benefits than in the case of solar power. In addition, citizens' participation in the decision process is often limited. Moreover, installations in a given locality take place in a bulk rather than gradual fashion. This may explain why first installations matter more than capacity expansions. Finally, visual impairments can be avoided by averting behavior, in particular when installations are not in close proximity. This may explain both dissipation over time and the absence of spatial spillovers. Acoustic impairments depend on proximity and are thus also less liable to spatial spillovers.

For biomass plants, the estimates suggest a difference between the short and the long term on the one hand, and the own area and adjacent areas on the other. First installations and expansions in ones' own area have no short term effects, but according to the model estimations a long term effects, that is, effects accumulate over time. By contrast, both first installations and expansions in adjacent areas seem to affect well-being in the short as well as in the long term.

The difference between own and adjacent areas is consistent with the circumstance that biomass plants are often locally owned, hence local impairments tend to be offset by local benefits while impairments from neighboring areas are not. In addition, while people can adjust to the visual impairments from wind power, both behaviorally and psychologically, odor nuisance is hardly subject to averting behavior. Hence, no dissipation of effects can be found. Moreover, odor nuisance may be less related to proximity than are the visual and acoustic impairments from wind turbines.

Overall, our qualitative findings on the well-being externalities of the different RE technologies are consistent with those technologies' characteristics and the channels of influence through which they affect well-being.

In relation to previous literature, a major advantage of the present study is the use of a rich set of nationwide representative panel data merged with spatially disaggregated data on the location and expansion of several types of RE technologies. This has allowed us to conduct a longitudinal analysis of externalities associated with RE, whereas existing studies (of stated preference and property values) are mainly of a cross-sectional (static) nature.

A limitation of our study relates to our inability to differentiate solar plants into rooftop installations and free-standing installations. Such a differentiation would be important because the latter are less likely to be locally owned than the former. In addition, the visual impairments from free-standing installations may differ from those from rooftop installations. Similar considerations apply to different varieties of biomass plants that we are unable to differentiate. Another limitation is given by the structure of postcode areas which differ with regard to the area they cover. As they align with the number of households, we typically observe smaller postcode areas in more densely populated areas, i.e. cities. That means that the considered radius varies widely which is especially relevant for rooftop solar installations as they are built both in rural and urban areas.

As to policy conclusions, our findings imply a clear preference of solar power and wind power over electricity from biomass in terms of the local externalities involved. This is consistent with the finding of Welsch and Biermann (2014) that the life satisfaction of European citizens is significantly negatively related to the contribution of biomass to their countries' national electricity mix while being significantly positively related to the contribution of solar and wind power. Our findings do not imply a dismissal of RE in general, however, since conventional (fossil and nuclear) power generation technologies have externalities of their own (air pollution, greenhouse gases, nuclear risk). Rather, to further increase local acceptance, in particular of wind parks, monetary compensation of externalities might be contemplated.

5. Conclusion

This paper has used representative nationwide panel data on the life satisfaction of German citizens for identifying and valuing the local externalities from wind, solar and biomass plants. We found that renewable power plants generate statistically and economically significant local externalities whose effects differ across the technologies considered both qualitatively and quantitatively. Our qualitative findings on the well-being externalities of the different RE technologies are consistent with those technologies' characteristics and the channels of influence through which they affect well-being. Externalities from biomass plants are stronger than those from wind turbines, whereas externalities from solar power plants are more limited. Besides considering more differentiated RE technologies, future research may investigate local RE externalities in comparison with externalities from fossil and nuclear power plants and extend those analyses to countries other than Germany. Moreover, by using geocodes and an energy dataset that distinguishes between different types and sizes of solar and biomass plants one could further refine the analysis.

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Table 1: Summary Statistics of Socio-Economic Data

Variable	Description	Mean	Std. Dev.	Min	Max
Life Satisfaction	11-point scale. 0 corresponds to *completely dissatisfied* and 10 to completely satisfied.	6.917	1.760	0	10
Household Income	Household income is specified as the total amount of monthly net income available in a given household.	2,582.785	1,709.121	10	200,000
Household Size	This variable describes the number of persons living in the respondent's household.	2.728	1.273	1	14
Age	This variable gives information about the respondent's age.	48.114	17.245	17	102
Person Needing Care in HH	The dummy specifies whether there is a person in the household in need of care (1), or not (0).	0.0422	0.201	0	1
Health Status: Very Good	The dummy variable takes the value 1 if health status is perceived as very good, and 0 otherwise.	0 .082	0 .275	0	1
Health Status: Good	The dummy variable takes the value 1 if health status is perceived as good, and 0 otherwise.	0 .402	0 .490	0	1
Health Status: Satisfactory	The dummy variable takes the value 1 if health status is perceived as satisfactory, and 0 otherwise.	0 .338	0 .473	0	1
Health Status: Poor	The dummy variable takes the value 1 if health status is perceived as poor, and 0 otherwise.	0 .139	0.345	0	1
Health Status: Bad	The dummy variable takes the value 1 if health status is perceived as bad, and 0 otherwise.	0.038	0 .191	0	1
Employed	This dummy variable specifies whether the respondent is employed (1), or not (0).	0 .494	0 .499	0	1
Not Employed	This dummy variable specifies whether the respondent is not employed (1), or not (0).	0.077	0 .266	0	1
Unemployed	This dummy variable specifies whether the respondent is unemployed (1), or not (0).	0 .062	0 .241	0	1
Pensioner	This dummy variable specifies whether the respondent is pensioner (1), or not (0).	0 .245	0 .430	0	1
Military, Community Service	This dummy variable specifies whether the respondent is in Military or Community Service (1), or not (0).	0.003	0.057	0	1
In Education	This dummy variable specifies whether the respondent is in education (1), or not (0).	0.064	0.245	0	1
Self-Employed	This dummy variable specifies whether the respondent is self-employed (1), or not (0).	0 .054	0 .227	0	1
No Partner	This dummy variable takes the value 1 in case the respondent has no partner, and 0 otherwise.	0 .206	0 .404	0	1
Partner Outside Household	This dummy variable takes the value 1 in case the respondent has a partner outside the household, and 0 otherwise.	0.080	0 .271	0	1
Partner Inside Household	This dummy variable takes the value 1 in case the respondent has a partner inside the household, and 0 otherwise.	0.713	0 .452	0	1

Table 2: Summary Statistics of Energy Data

	Variable	Description	Reg. Scale	Mean	Std.Dev.	Min	Max
Solar	Dummy	This dummy takes the value 1 in case there is a solar installation in the respective area, and 0 if not.	Own postcode	0.816	0.387	0	1
			Adj. postcodes	0.942	0.234	0	1
	Number of Plants	This variable describes the total number of solar installations in the respective area.	Own postcode	38.692	83.845	0	1,424
			Adj. postcodes	199.872	380.875	0	6,233
	Capacity Installed [MW]	This variable specifies the total capacity installed (in MW) of solar installations in the respective area.	Own postcode	0.612	2.499	0	152.538
			Adj. postcodes	3.173	8.672	0	321.750
Wind	Dummy	This dummy takes the value 1 in case there is a wind turbine in the respective area, and 0 if not.	Own postcode	0.238	0.426	0	1
			Adj. postcodes	0.536	0.499	0	1
	Number of Plants	This variable describes the total number of wind turbines in the respective area.	Own postcode	2.457	11.566	0	277
			Adj. postcodes	13.279	34.030	0	498
	Capacity Installed [MW]	This variable specifies the total capacity installed (in MW) of wind turbines in the respective area.	Own postcode	2.609	13.492	0	378.671
			Adj. postcodes	14.409	41.531	0	627.294
Biomass	Dummy	This dummy takes the value 1 in case there is a biomass plant in the respective area, and 0 if not.	Own postcode	0.202	0.401	0	1
			Adj. postcodes	0.484	0.499	0	1
	Number of Plants	This variable describes the total number of biomass plants in the respective area.	Own postcode	0.486	1.505	0	52
			Adj. postcodes	2.663	5.876	0	149
	Capacity Installed [MW]	This variable specifies the total capacity installed (in MW) of biomass plants in the respective area.	Own postcode	0.334	2.014	0	141.863
			Adj. postcodes	1.806	6.493	0	161.574

Table 3: Estimation Results for Solar Energy

		Dummy	Number	Capacity	Dummy	Number	Capacity
FD	RE own postcode	0.0127 (0.0154)	-0.0227* (0.0119)	-0.0030* (0.0016)	0.0119 (0.0155)	-0.0099 (0.0185)	-0.0020 (0.0017)
	RE adjacent postcodes				0.0112 (0.0226)	-0.0043 (0.0046)	-0.0013 (0.0008)
	ln(income)	0.2317*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)	0.2317*** (0.0141)	0.2319*** (0.0141)	0.2318*** (0.0141)
Other micro-controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared		0.0566	0.0566	0.0566	0.0566	0.0566	0.0566
FE	RE own postcode	0.0035 (0.0132)	-0.0400*** (0.0069)	-0.0007 (0.0016)	0.0015 (0.0133)	-0.0009 (0.0107)	0.0031* (0.0018)
	RE adjacent postcodes				0.0141 (0.0188)	-0.0117*** (0.0026)	-0.0027*** (0.0006)
	ln(income)	0.3004*** (0.0129)	0.3006*** (0.0129)	0.3004*** (0.0129)	0.3004*** (0.0129)	0.3012*** (0.0129)	0.3004*** (0.0129)
Other controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared (within)		0.1041	0.1043	0.1041	0.1041	0.1044	0.1042

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, Number of Plants in 100.

Table 4: Estimation Results for Wind Energy

		Dummy	Number	Capacity	Dummy	Number	Capacity
FD	RE own postcode	-0.0434* (0.0239)	-0.0914 (0.1138)	-0.0007 (0.0008)	-0.0447* (0.0240)	-0.0648 (0.1132)	-0.0005 (0.0008)
	RE adjacent postcodes				0.0150 (0.0192)	-0.0462 (0.0453)	-0.0004 (0.0003)
	ln(income)	0.2320*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)	0.2319*** (0.0141)	0.2319*** (0.0141)	0.2319*** (0.0141)
Other micro-controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared		0.0566	0.0566	0.0566	0.0566	0.0566	0.0566
FE	RE own postcode	-0.0382** (0.0170)	-0.1808** (0.0854)	-0.0011* (0.0006)	-0.0402** (0.0171)	-0.1639* (0.0923)	-0.0012* (0.0006)
	RE adjacent postcodes				0.0162 (0.0149)	-0.0119 (0.0261)	0.0001 (0.0002)
	ln(income)	0.3007*** (0.0129)	0.3004*** (0.0129)	0.3004*** (0.0129)	0.3005*** (0.0129)	0.3005*** (0.0129)	0.3004*** (0.0129)
Other controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared (within)		0.1041	0.1041	0.1041	0.1041	0.1041	0.1041

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, number of plants in 100.

Table 5: Estimation Results for Biomass

		Dummy	Number	Capacity	Dummy	Number	Capacity
FD	RE own postcode	0.0087 (0.0170)	-0.5959 (0.5231)	0.0006 (0.0048)	0.0107 (0.0170)	-0.2265 (0.5810)	0.0004 (0.0048)
	RE adjacent postcodes				-0.0362*** (0.0134)	-0.3526* (0.1823)	-0.0010 (0.0012)
	ln(income)	0.2317*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)	0.2319*** (0.0141)	0.2319*** (0.0141)	0.2318*** (0.0141)
Other micro-controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared		0.0566	0.0566	0.0566	0.0566	0.0566	0.0566
FE	RE own postcode	-0.0427*** (0.0123)	-0.4404 (0.3257)	-0.0053** (0.0023)	-0.0394*** (0.0123)	0.0317 (0.3676)	-0.0051** (0.0023)
	RE adjacent postcodes				-0.0343*** (0.0104)	-0.2525** (0.1041)	-0.0019** (0.0008)
	ln(income)	0.3008*** (0.0129)	0.3004*** (0.0129)	0.3004*** (0.0129)	0.3011*** (0.0129)	0.3006*** (0.0129)	0.3003*** (0.0129)
Other controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared (within)		0.1041	0.1041	0.1041	0.1042	0.1041	0.1041

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, number of plants in 100.

Table 6: Estimation results for Solar, Wind and Biomass in one regression

FIRST DIFFERENCES		Dummy	Number	Capacity	Dummy	Number	Capacity
Solar	RE own postcode	0.0127 (0.0154)	-0.0196 (0.0126)	-0.0029* (0.0016)	0.0125 (0.0155)	-0.0079 (0.0190)	-0.0020 (0.0017)
	RE adjacent postcodes				0.0116 (0.0226)	-0.0022 (0.0048)	-0.0011 (0.0008)
Wind	RE own postcode	-0.0441* (0.0239)	-0.0713 (0.1143)	-0.0007 (0.0008)	-0.0437* (0.0240)	-0.0562 (0.1140)	-0.0005 (0.0008)
	RE adjacent postcodes				0.0168 (0.0192)	-0.0311 (0.0463)	-0.0004 (0.0003)
Biomass	RE own postcode	0.0102 (0.0170)	-0.3338 (0.5559)	0.0010 (0.0048)	0.0117 (0.0170)	-0.0917 (0.5987)	0.0011 (0.0048)
	RE adjacent postcodes				-0.0362*** (0.0134)	-0.2604 (0.1987)	-0.0006 (0.0012)
ln(income)		0.2320*** (0.0141)	0.2319*** (0.0141)	0.2318*** (0.0141)	0.2321*** (0.0141)	0.2320*** (0.0141)	0.2319*** (0.0141)
Other micro-controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared		0.0566	0.0566	0.0566	0.0566	0.0566	0.0566
FIXED EFFECTS		Dummy	Number	Capacity	Dummy	Number	Capacity
Solar	RE own postcode	0.0034 (0.0132)	-0.0442*** (0.0075)	0.0002 (0.0016)	0.0024 (0.0133)	-0.0030 (0.0111)	0.0037** (0.0018)
	RE adjacent postcodes				0.0145 (0.0188)	-0.0130*** (0.0028)	-0.0024*** (0.0006)
Wind	RE own postcode	-0.0338** (0.0170)	-0.1723** (0.0859)	-0.0010* (0.0006)	-0.0326* (0.0171)	-0.1781* (0.0924)	-0.0011* (0.0006)
	RE adjacent postcodes				0.0195 (0.0149)	-0.0129 (0.0268)	0.0002 (0.0002)
Biomass	RE own postcode	-0.0407*** (0.0123)	0.6698* (0.3517)	-0.0046** (0.0023)	-0.0379*** (0.0123)	0.5156 (0.3801)	-0.0043* (0.0024)
	RE adjacent postcodes				-0.0341*** (0.0104)	0.1379 (0.1194)	-0.0016** (0.0008)
ln(income)		0.3010*** (0.0129)	0.3007*** (0.0129)	0.3004*** (0.0129)	0.3011*** (0.0129)	0.3013*** (0.0129)	0.3003*** (0.0129)
Other controls		yes	yes	yes	yes	yes	yes
Observations		266,588	266,588	266,588	266,588	266,588	266,588
R-squared (within)		0.1042	0.1043	0.1041	0.1042	0.1045	0.1042

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, number of plants in 100.

Fixed Effects Estimation Results	Solar Energy			Wind Energy			Biomass Energy		
Dependent Variable: Life Satisfaction	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Dummy	0.0035 (0.0132)			-0.0382** (0.0170)			-0.0427*** (0.0123)		
Number of Plants		-0.0400*** (0.0069)			-0.1808** (0.0854)			-0.4404 (0.3257)	
Installed Capacity			-0.0007 (0.0016)			-0.0011* (0.0006)			-0.0053** (0.0023)
Log. Household-Income	0.3004*** (0.0129)	0.3006*** (0.0129)	0.3004*** (0.0129)	0.3007*** (0.0129)	0.3004*** (0.0129)	0.3004*** (0.0129)	0.3008*** (0.0129)	0.3004*** (0.0129)	0.3004*** (0.0129)
Age Squared	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)	-0.0000 (0.0000)
Household-Size	-0.0598*** (0.0061)	-0.0591*** (0.0060)	-0.0597*** (0.0061)	-0.0593*** (0.0061)	-0.0598*** (0.0060)	-0.0599*** (0.0060)	-0.0599*** (0.0060)	-0.0597*** (0.0060)	-0.0597*** (0.0060)
Person Needing Care in Household	-0.4336*** (0.0280)	-0.4330*** (0.0280)	-0.4336*** (0.0280)	-0.4337*** (0.0280)	-0.4326*** (0.0280)	-0.4327*** (0.0280)	-0.4337*** (0.0279)	-0.4335*** (0.0280)	-0.4338*** (0.0280)
Health Status:	(Reference Group: Very Good)			(Reference Group: Very Good)			(Reference Group: Very Good)		
- Good Health	-0.3226*** (0.0117)	-0.3223*** (0.0117)	-0.3226*** (0.0117)	-0.3226*** (0.0117)	-0.3226*** (0.0117)	-0.3226*** (0.0117)	-0.3227*** (0.0117)	-0.3226*** (0.0117)	-0.3226*** (0.0117)
- Satisfactory Health	-0.7374*** (0.0139)	-0.7370*** (0.0139)	-0.7374*** (0.0139)	-0.7374*** (0.0139)	-0.7373*** (0.0139)	-0.7374*** (0.0139)	-0.7373*** (0.0139)	-0.7374*** (0.0139)	-0.7374*** (0.0139)
- Poor Health	-1.2992*** (0.0174)	-1.2990*** (0.0173)	-1.2991*** (0.0174)	-1.2991*** (0.0174)	-1.2991*** (0.0174)	-1.2992*** (0.0174)	-1.2991*** (0.0174)	-1.2992*** (0.0174)	-1.2992*** (0.0174)
- Bad Health	-2.3367*** (0.0311)	-2.3366*** (0.0311)	-2.3366*** (0.0311)	-2.3368*** (0.0311)	-2.3364*** (0.0311)	-2.3364*** (0.0311)	-2.3370*** (0.0311)	-2.3369*** (0.0311)	-2.3369*** (0.0311)
Employment Status:	(Reference Group: Employed)			(Reference Group: Employed)			(Reference Group: Employed)		
- Not Employed	-0.0637*** (0.0183)	-0.0655*** (0.0182)	-0.0637*** (0.0183)	-0.0637*** (0.0183)	-0.0635*** (0.0183)	-0.0635*** (0.0183)	-0.0634*** (0.0183)	-0.0638*** (0.0183)	-0.0637*** (0.0183)
- Unemployed	-0.5211*** (0.0184)	-0.5207*** (0.0184)	-0.5211*** (0.0184)	-0.5209*** (0.0184)	-0.5211*** (0.0184)	-0.5211*** (0.0184)	-0.5210*** (0.0184)	-0.5212*** (0.0184)	-0.5213*** (0.0184)
- Pensioner	0.0725*** (0.0195)	0.0721*** (0.0195)	0.0725*** (0.0195)	0.0726*** (0.0195)	0.0725*** (0.0195)	0.0725*** (0.0195)	0.0724*** (0.0195)	0.0724*** (0.0195)	0.0726*** (0.0195)
- Military, Community Service	0.0316 (0.0492)	0.0337 (0.0492)	0.0317 (0.0492)	0.0326 (0.0492)	0.0321 (0.0492)	0.0321 (0.0492)	0.0331 (0.0492)	0.0319 (0.0492)	0.0316 (0.0492)
- In Education	0.0856*** (0.0197)	0.0869*** (0.0197)	0.0857*** (0.0197)	0.0864*** (0.0197)	0.0861*** (0.0197)	0.0860*** (0.0197)	0.0865*** (0.0197)	0.0858*** (0.0197)	0.0857*** (0.0197)
- Self-Employed	0.0044 (0.0266)	0.0039 (0.0266)	0.0044 (0.0266)	0.0047 (0.0266)	0.0047 (0.0266)	0.0047 (0.0266)	0.0042 (0.0266)	0.0042 (0.0266)	0.0044 (0.0266)
Partner Status:	(Reference Group: No Partner)			(Reference Group: No Partner)			(Reference Group: No Partner)		
- Partner Outside Household	0.2843*** (0.0164)	0.2843*** (0.0164)	0.2843*** (0.0164)	0.2844*** (0.0164)	0.2846*** (0.0164)	0.2845*** (0.0164)	0.2842*** (0.0164)	0.2844*** (0.0164)	0.2844*** (0.0164)
- Partner Inside Household	0.3851*** (0.0201)	0.3840*** (0.0201)	0.3850*** (0.0201)	0.3844*** (0.0201)	0.3846*** (0.0201)	0.3847*** (0.0201)	0.3850*** (0.0201)	0.3851*** (0.0201)	0.3850*** (0.0201)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Individual-specific Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
R-squared (within)	0.1041	0.1043	0.1041	0.1041	0.1041	0.1041	0.1041	0.1041	0.1041
Observations	266,588	266,588	266,588	266,588	266,588	266,588	266,588	266,588	266,588

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, number of plants in 100.

First Differences Estimation Results	Solar Energy			Wind Energy			Biomass Energy		
Dependent Variable: Life Satisfaction	(4a)	(4b)	(4c)	(5a)	(5b)	(5c)	(6a)	(6b)	(6c)
Dummy	0.0127 (0.0154)			-0.0434* (0.0239)			0.0087 (0.0170)		
Number of Plants		-0.0227* (0.0119)			-0.0914 (0.1138)			-0.5959 (0.5231)	
Installed Capacity			-0.0030* (0.0016)			-0.0007 (0.0008)			0.0006 (0.0048)
Log. Household-Income	0.2317*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)	0.2320*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)	0.2317*** (0.0141)	0.2318*** (0.0141)	0.2318*** (0.0141)
Age Squared	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Household-Size	-0.0288*** (0.0084)	-0.0286*** (0.0084)	-0.0287*** (0.0084)	-0.0283*** (0.0084)	-0.0287*** (0.0084)	-0.0287*** (0.0084)	-0.0288*** (0.0084)	-0.0287*** (0.0084)	-0.0288*** (0.0084)
Person Needing Care in Household	-0.2564*** (0.0302)	-0.2564*** (0.0302)	-0.2565*** (0.0302)	-0.2563*** (0.0302)	-0.2563*** (0.0302)	-0.2563*** (0.0302)	-0.2564*** (0.0302)	-0.2565*** (0.0302)	-0.2565*** (0.0302)
Health Status:	(Reference Group: Very Good)			(Reference Group: Very Good)			(Reference Group: Very Good)		
- Good Health	-0.2697*** (0.0115)	-0.2696*** (0.0115)	-0.2697*** (0.0115)	-0.2696*** (0.0115)	-0.2697*** (0.0115)	-0.2697*** (0.0115)	-0.2697*** (0.0115)	-0.2697*** (0.0115)	-0.2697*** (0.0115)
- Satisfactory Health	-0.5952*** (0.0136)	-0.5951*** (0.0136)	-0.5951*** (0.0136)	-0.5951*** (0.0136)	-0.5952*** (0.0136)	-0.5952*** (0.0136)	-0.5952*** (0.0136)	-0.5952*** (0.0136)	-0.5952*** (0.0136)
- Poor Health	-1.0465*** (0.0170)	-1.0465*** (0.0170)	-1.0464*** (0.0170)	-1.0465*** (0.0170)	-1.0465*** (0.0170)	-1.0465*** (0.0170)	-1.0465*** (0.0170)	-1.0465*** (0.0170)	-1.0465*** (0.0170)
- Bad Health	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8382*** (0.0310)	-1.8383*** (0.0310)	-1.8382*** (0.0310)
Employment Status:	(Reference Group: Employed)			(Reference Group: Employed)			(Reference Group: Employed)		
- Not Employed	-0.1780*** (0.0204)	-0.1782*** (0.0204)	-0.1780*** (0.0204)	-0.1781*** (0.0204)	-0.1780*** (0.0204)	-0.1780*** (0.0204)	-0.1781*** (0.0204)	-0.1781*** (0.0204)	-0.1781*** (0.0204)
- Unemployed	-0.5010*** (0.0191)	-0.5010*** (0.0191)	-0.5010*** (0.0191)	-0.5010*** (0.0191)	-0.5011*** (0.0191)	-0.5011*** (0.0191)	-0.5011*** (0.0191)	-0.5011*** (0.0191)	-0.5011*** (0.0191)
- Pensioner	-0.0930*** (0.0251)	-0.0929*** (0.0251)	-0.0929*** (0.0251)	-0.0929*** (0.0251)	-0.0929*** (0.0251)	-0.0930*** (0.0251)	-0.0930*** (0.0251)	-0.0930*** (0.0251)	-0.0930*** (0.0251)
- Military, Community Service	0.0057 (0.0521)	0.0059 (0.0521)	0.0057 (0.0521)	0.0058 (0.0521)	0.0057 (0.0521)	0.0057 (0.0521)	0.0056 (0.0521)	0.0056 (0.0521)	0.0057 (0.0521)
- In Education	0.0309 (0.0216)	0.0309 (0.0216)	0.0308 (0.0216)	0.0311 (0.0216)	0.0308 (0.0216)	0.0308 (0.0216)	0.0308 (0.0216)	0.0309 (0.0216)	0.0308 (0.0216)
- Self-Employed	0.0117 (0.0281)	0.0117 (0.0281)	0.0117 (0.0281)	0.0119 (0.0281)	0.0117 (0.0281)	0.0117 (0.0281)	0.0117 (0.0281)	0.0116 (0.0281)	0.0117 (0.0281)
Partner Status:	(Reference Group: No Partner)			(Reference Group: No Partner)			(Reference Group: No Partner)		
- Partner Outside Household	0.2793*** (0.0176)	0.2793*** (0.0176)	0.2793*** (0.0176)	0.2794*** (0.0176)	0.2793*** (0.0176)	0.2793*** (0.0176)	0.2792*** (0.0176)	0.2793*** (0.0176)	0.2792*** (0.0176)
- Partner Inside Household	0.4597*** (0.0261)	0.4594*** (0.0260)	0.4596*** (0.0260)	0.4590*** (0.0260)	0.4594*** (0.0261)	0.4594*** (0.0261)	0.4597*** (0.0260)	0.4595*** (0.0261)	0.4596*** (0.0261)
Constant	-0.0091 (0.0170)	-0.0084 (0.0170)	-0.0085 (0.0170)	-0.0070 (0.0170)	-0.0084 (0.0170)	-0.0085 (0.0170)	-0.0085 (0.0170)	-0.0084 (0.0170)	-0.0085 (0.0170)
Year Dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566	0.0566
Observations	266,588	266,588	266,588	266,588	266,588	266,588	266,588	266,588	266,588

Note: Standard Errors in parenthesis are adjusted for clustering at the individual level. Installed capacity in MW, number of plants in 100.

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