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Manuel Frondel
Colin Vance

Germany's Energiewende: A Tale of Increasing Costs and Decreasing Willingness-To-Pay

RUHR UNIVERSITÄT BOCHUM RUB rwi

#645

Imprint

Ruhr Economic Papers

Published by

Ruhr-Universität Bochum (RUB), Department of Economics
Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences
Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics
Universitätsstr. 12, 45117 Essen, Germany

RWI Leibniz-Institut für Wirtschaftsforschung
Hohenzollernstr. 1-3, 45128 Essen, Germany

Editors

Editorial Office

Ruhr Economic Papers #645

Responsible Editor: Manuel Frondel

ISSN 1864-4872 (online) – ISBN 978-3-86788-750-2

Ruhr Economic Papers #645

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Bibliografische Informationen der Deutschen Nationalbibliothek

Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über: *http://dnb.d-nb.de* abrufbar.

Das RWI wird vom Bund und vom Land Nordrhein-Westfalen gefördert.

http://dx.doi.org/10.4419/86788750
ISSN 1864-4872 (online)
ISBN 978-3-86788-750-2

Mark A. Andor, Manuel Frondel, and Colin Vance[1]

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Abstract

This paper presents evidence that the accumulating cost of Germany's ambitious plan to transform its system of energy provision – the so-called Energiewende – is butting up against consumers' willingness-to-pay (WTP) for it. Following a descriptive presentation that traces the German promotion of renewable energy technologies since 2000, we draw on two stated-preference surveys conducted in 2013 and 2015 that elicit the households' WTP for green electricity. Two models are estimated, one based on a closed-ended question framed around Germany's target of 35% renewable energy in electricity provision by 2020, and the other on an open-ended format that captures changes in WTP over time. To deal with the bias that typifies hypothetical responses, both models distinguish respondents according to whether they express definite certainty in their reported WTP. The results from both models reveal a strong contrast between the households' general acceptance of supporting renewable energy technologies and their own WTP for green electricity.

JEL Classification: D12, Q21, Q41

Keywords: Certainty approach; energy policy; willingness-to-pay

September 2016

1 Mark A. Andor, RWI; Manuel Frondel, RWI and RUB; Colin Vance, RWI and Jacobs University Bremen. *- We are grateful for invaluable comments and suggestions by three anonymous reviewers. This work has been partly supported by the Collaborative Research Center "Statistical Modeling of Nonlinear Dynamic Processes" (SFB 823) of the German Research Foundation (DFG), within the framework of Project A3, "Dynamic Technology Modeling". We also gratefully acknowledge financial support by the German Federal Ministry of Education and Research (BMBF) under grant 01LA1113A.* *– All correspondence to: Manuel Frondel, RWI, Hohenzollernstr. 1-3, 45128 Essen, Germany, e-mail: frondel@rwi-essen.de*

1 Introduction

In recent years, the political economy of electricity provision in Germany has been strongly influenced by two factors. The first is the country's ongoing commitment to increase the share of renewable energy technologies, with green electricity production amounting to almost 33% of gross consumption by the end of 2015 (BDEW, 2016:11). The second factor is the nuclear catastrophe at Japan's Fukushima in 2011. This event had a profound impact in exacerbating a longstanding skepticism in Germany on the merits of nuclear power and led to the legal stipulation of its phase-out in the same year. Both factors are the most salient pillars of Germany's so-called Energiewende (energy transition), which advances the most ambitious subsidization program in the nation's history, with costs that may approach those of German re-unification.

This paper presents evidence that the accumulating costs of Germany's Energiewende are butting up against consumers' willingness-to-pay (WTP) for it. We begin with a descriptive overview of the growth of renewable energy technologies in Germany since the introduction of the Renewable Energy Act (EEG) in 2000, focusing on increases in both capacity and the associated costs, which have to be born by electricity consumers via a surcharge on their bill. Thereafter, we turn attention to the public's acceptance of these costs, using the results of two stated-preference surveys conducted in 2013 and 2015 to elicit the households' willingness-to-pay (WTP) for green electricity. The intertemporal data structure affords the unique opportunity to undertake comparisons of how WTP has changed over a time.

One challenge in relying on hypothetical responses is that they may yield estimates of WTP that have a substantial upward bias. This overestimation problem, referred to as hypothetical bias, is a well-known finding in the literature – see the meta-analysis by List and Gallet (2001) and the reviews by Harrison (2006) and Harrison and Rutström (2008). We tackle this issue by drawing on the certainty approach conceived by Johannesson et al. (1998) for mitigating hypothetical bias.[1] To exploit the relative

[1]Other techniques have also been proposed to remove or, at least, reduce this bias, including the consequential-script corrective suggested by Bulte et al. (2005:334) and the cheap-talk protocol intro-

advantages afforded by close-ended and opened-ended hypothetical responses, two models are developed, one employing an open-ended question on the WTP for green electricity that is posed over two points in time, and the other using a closed-ended dichotomous-choice question framed around the WTP for reaching Germany's target of 35% renewable share in electricity provision by 2020. Upon stating their preferences, all households were directly asked whether they are probably or definitely sure about their WTP responses, following a similar procedure suggested by BLUMENSCHEIN et al. (1998) for implementing the certainty approach.

We incorporate this information into the two models of WTP, where the first model analyzes the open-ended WTP responses by splitting the data into two sub-samples according to whether the respondent is probably or definitely certain about their WTP. Recognizing that certainty status and WTP might be jointly influenced by unobservable factors, we employ a switching regression model that accounts for the potential endogeneity of respondent certainty and, hence, biases from sample selectivity. The second approach analyzes the dichotomous-choice data using a linear probability model, with the dependent variable coded as one if the respondent affirmed a WTP for a randomly assigned hypothetical surcharge on their electricity bill for promoting renewable energy technologies, and zero otherwise. Following BLUMENSCHEIN et al. (2008), we explore the implications of recoding the ones in this data to zeros among those respondents who did not express definite certainty in their answers.

Among our main findings, the descriptive results suggest tepid support for financing renewable energy technologies. In fact, the open-ended responses reveal a marked decrease of about 17% in the average WTP between the 2013 and 2015 waves of the survey, a period during which the surcharge paid by households for green electricity rose commensurately, by 17%. Overall, the survey results highlight a strong contrast between the households' general acceptance of supporting renewable energy technologies and their own WTP for green electricity: On the one hand, the share of respondents who agreed with the statement that, in principle, renewable energy technologies should be supported increased from 84.4% in 2013 to 88.0% in 2015. On the

duced by CUMMINGS and TAYLOR (1999).

other hand, almost 60% of the household heads reduced their WTP for 100% green electricity relative to 2013.

The subsequent section provides a summary of Germany's strong expansion of renewable electricity production capacities and the related costs since the introduction of today's feed-in-tariff promotion scheme in 2000. Section 3 describes the survey design and presents descriptive statistics. Section 4 provides a description of the estimation method, followed by the presentation and interpretation of the results given in Section 5. The last section summarizes and concludes.

2 Costs of Renewable Capacity Expansion

In Germany, renewable energy sources (RES) are promoted via a feed-in-tariff (FIT) system whereby electricity generated from RES has preferential access to the grid and is remunerated at technology-specific, above-market rates that are commonly guaranteed over a 20-year time period. The system has established itself as a global role model and has been adopted by a wide range of countries (CEER, 2013), even some with a high endowment of sun such as Australia (NELSON et al., 2011). In fact, FIT systems have been established in more than 100 countries throughout the world (REN21, 2015).

Since the implementation of Germany's FIT system in 2000, installed capacities of renewable energy technologies have increased remarkably, by more than eightfold between 2000 and 2015 (Table 1). Photovoltaic (PV) systems, until recently the most expensive renewable energy technology in Germany, and onshore windmills have experienced the largest increase, with PV capacities sky-rocketing: In 2010 alone, more than 7,000 Megawatt (MW) were installed, an amount that exceeded the cumulated capacities installed by 2008. According to estimations of FRONDEL et al. (2014: 9), the real net cost for all those modules installed between 2000 and 2015 amounts to more than 110 billion Euros.

In 2015, total RES capacities reached about 98 Gigawatts (GW), just 6 GW less than those of conventional power plants (last column Table 1), while the share of green electricity in gross electricity consumption was about 33% (BDEW, 2016:11).[2] This relatively modest share owes to the fact that wind and solar power are not permanently available 24 hours a day. Consequently, to reach Germany's renewable goals of a 50% share in gross electricity consumption set for 2030 and 80% in 2050, a multiple of today's capacities have to be installed, an endeavor that will inevitably lead to higher costs of electricity generation.

Table 1: Germany's Conventional and Renewable Electricity Generation Capacities in Gigawatt (GW).

Year	Hydro Power	Wind Onshore	Wind Offshore	Photo-voltaics	Biomass	Total RES Capacities	Conventional Capacities
2000	4.83	6.10	–	0.11	0.70	11.75	109.9
2001	4.83	8.74	–	0.18	0.83	14.57	107.9
2002	4.94	11.98	–	0.30	1.03	18.24	106.5
2003	4.95	14.59	–	0.44	1.43	21.41	105.6
2004	5.19	16.61	–	1,11	1.69	24.59	106.0
2005	5.21	18.38	–	2.06	2.35	27.99	107.0
2006	5.19	20.57	–	2.90	3.01	31.67	107.6
2007	5.14	22.18	–	4.17	3.50	34.99	110.2
2008	5.16	23.82	–	6.12	3.92	39.02	110.4
2009	5.34	25.63	0.06	10.57	4.55	46.14	111.4
2010	5.41	27.01	0.17	17.94	5.09	55.61	111.6
2011	5.63	28.86	0.20	25.43	5.77	65.87	103.2
2012	5.61	31.00	0.31	33.03	6.18	76.10	102.1
2013	5.59	33.76	0.51	36.34	6.52	82.71	103.9
2014	5.61	38.16	1.04	38.24	6.87	89.91	104.3
2015	5.58	40.99	2.79	39.70	8.86	97.92	104.1

Sources: BMWi (2016:12), BDEW (2016:13). With an installed capacity of less than 0.05 GW in 2014, geothermic systems are of negligible relevance and not included in the table.

These costs were already substantial in the past: Between 2000 and 2015, consumers paid about 125 billion Euros in the form of higher electricity bills for Germany's RES promotion (Table 2), with the cost shares of industrial and household consumers

[2]On the importance of the distinction between capacity and electricity production, see ANDOR and VOSS (2016). These authors conclude that only under very specific circumstances do optimal promotion schemes for renewable energy technologies resemble the demand-independent FIT systems.

estimated at 31.5% and 34.5% in 2016, respectively (BDEW, 2016:60). The remaining 44% are contributed by commerce, trade, services (18.8%), the public sector (12.2%), transport (2.2) and agriculture (0.9%).

Table 2: Net Costs of Germany's Promotion of Renewable Energy Technologies in Billions of Euros.

Year	Hydro Power (Bn. €)	Wind Onshore (Bn. €)	Wind Offshore (Bn. €)	Photo-voltaics (Bn. €)	Biomass (Bn. €)	Total RES Net Costs (Bn. €)	Average Net Costs per kWh (Cents/kWh)
2000	0.213	0.397	–	0.014	0.042	0.667	6.4
2001	0.295	0.703	–	0.037	0.105	1.139	6.3
2002	0.329	1.080	–	0.078	0.177	1.664	6.7
2003	0.253	1.144	–	0.145	0.224	1.765	6.2
2004	0.195	1.520	–	0.266	0.347	2.430	6.3
2005	0.193	1.518	–	0.636	0.540	2.997	6.8
2006	0.168	1.529	–	1.090	0.896	3.765	7.3
2007	0.121	1.428	–	1.436	1.307	4.338	6.5
2008	0.081	1.186	–	1.960	1.565	4.818	6.8
2009	0.025	1.608	0.003	2.676	1.991	5.301	7.0
2010	0.192	1.647	0.019	4.465	3.000	9.525	11.6
2011	0.263	2.145	0.057	6.638	3.522	12.774	12.4
2012	0.223	2.944	0.092	7.939	4.576	16.008	13.5
2013	0.303	3.165	0.122	8.276	5.172	17.340	13.8
2014	0.301	3.669	0.208	9.166	5.675	19.222	14.1
2015	0.306	4.136	1.717	9.402	5.552	21.066	13.1
Total Costs	3.460	28.818	2.218	54.221	34.689	124.821	–
Cost Shares	2.8%	23.1%	1.8%	43.4%	27.8%	100 %	–

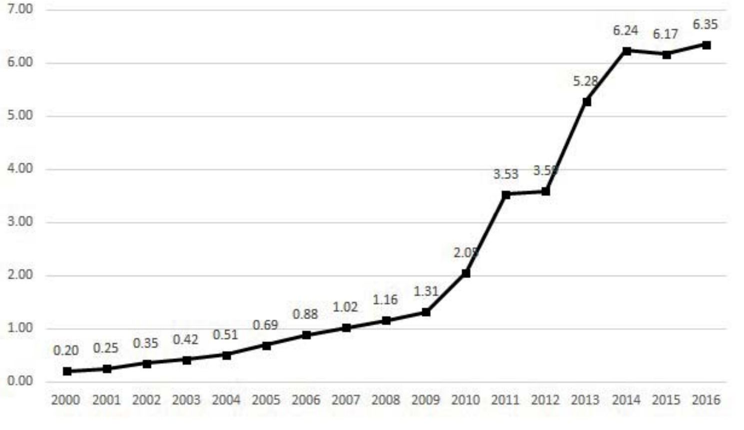
Source: BMWi (2015). Note: Costs of geothermic systems are not included in the table.
Figures for 2015 are unconsolidated forecasts.

The strong increase in alternative electricity generation capacities in Germany and the resulting rise in the share of green electricity in consumption led to a surge in the surcharge that appears on German electricity bills (Figure 1). In 2015, the surcharge of 6.17 cents per kWh comprised roughly 20% of the average per-kWh price of electricity of about 28 cents (Table 3). The increase of this surcharge is particularly pronounced in the years between 2009 and 2014, a period that largely coincides with the stark extension of PV capacities. In fact, the exploding PV capacity increases in the years 2009-2012 (Table 1) were responsible for the near doubling of average subsidies per kWh between 2009 and 2013 (last column in Table 2). As a consequence, while comprising about 6% of total electricity production (BDEW, 2016:12), PV accounts for 43.4%

of total net promotion costs (Table 2), by far the largest cost share among all alternative technologies.

Presuming that the annual subsidy level of more than 20 billion Euros in 2015 (Table 2) is extended for the next two decades, then a crude back-of-the-envelope calculation yields an estimate of 400 billion Euros for the continued promotion of renewable energy. Several considerations render this estimate conservative. First, the annual subsidies are likely to far exceed 20 billion Euros. According to a recent forecast, they will approach 30 billion in 2020 (BDEW, 2016:83), in large part owing to the expansion of offshore-wind capacities, currently the most expensive alternative technology in Germany.

Figure 1: Surcharge on Electricity Prices (in Cents per kWh) to Support Green Electricity (BDEW 2016:60)



Additional costs arise due to the fact that a large portion of today's conventional power plants has to be sustained to compensate for the intermittency of wind and sun power, since storing volatile green electricity is likely to remain unprofitable for the next decades (HESSLER, LOEBERT, 2013:350). Not least, substantial costs of several tens of billions of Euros accrue to consumers from the indispensable expansion of power grids, as the electricity produced by wind power installations in the north and east of

Germany must be transported to the highly industrialized west and south of the country. In short, it is most likely that future electricity prices will rise further if Germany actually reaches its renewable goals.

Some sense for the extent of the likely rise can be gleaned from past developments. Between 2000 and 2015, electricity prices more than doubled, from 13.94 to 28.68 ct/kWh (BDEW, 2016:56). For typical households with an electricity consumption of 3,500 kWh per annum, this implies an additional burden of about 520 Euro per year. In terms of purchasing power parities (Table 3), German households now incur the highest power prices in the European Union (EU). In a similar vein, prices for industrial customers are also among the highest in the EU.

Table 3: Electricity Prices in Euro Cents per kWh in 2015 for Household and Industrial Consumers in Europe

	Household	Industrial Consumption in Gigawatthours				
	Prices	< 500	< 2,000	< 20,000	< 70,000	< 150,000
Denmark	22.8	26.73	25.90	25.87	24.37	24.18
Germany	28.3	22.76	19.79	17.49	15.05	13.88
Italy	24.4	22.64	18.79	16.65	13.64	11.14
Austria	18.2	14.95	12.47	10.77	9.17	8.32
United Kingdom	16.6	20.05	17.88	16.44	16.03	15.65
Netherlands	17.9	18.06	11.06	9.89	8.51	8.49
France	14.8	14.42	12.08	10.53	9.22	7.71
EU 28	20.8	16.00	13.24	11.74	10.41	13.04

Source: Eurostat (2016). Average Prices including Taxes and Levies in Purchasing Power Standards.

Of course, whether these high costs are in fact justified from a social-welfare perspective depends on the size of associated benefits from the promotion of renewable energy technologies, a quantity that is admittedly considerably more difficult to calculate than the costs and one that is beyond the scope of the present analysis. Suffice it to note that the majority of studies that have tackled this issue have focused on quantifying specific benefit categories, such as carbon dioxide (CO_2) emissions reductions (TRABER AND KEMPFERT, 2009) and innovation effects (BÖHRINGER ET AL., 2014), or have investigated economic impacts, such as jobs creation (HILLEBRAND ET AL., 2006). Perhaps the most important economic benefit relates to climate change mitigation.

On its face, the record in this regard does not look promising. Germany's CO_2 emissions have been relatively stagnant in recent years, even rising somewhat in 2015, and an expert commission appointed by the country's minister of economy and energy has cast skepticism on reaching the target set for 2020 of a 40 percent reduction in CO_2 relative to 1990 (LÖSCHEL ET AL., 2015). One reason is the country's continued reliance on fossil sources to bridge the intermittancy of renewables. Mainly due to the nuclear phase-out, coal use, in particular, has maintained a relatively stable share in Germany's electricity generation, amounting to about 42% in 2015. The use of natural gas, by contrast, which has roughly half the CO_2 emissions of coal, is on the decline, with its share in electricity production decreasing from 14.1% to 9.4% between 2010 and 2015 (AGEB, 2016). A further consideration is that even if Germany is successful in reducing emissions via the use of renewable energies, its membership in the European Trading System implies offsetting emissions elsewhere in Europe, a point returned to in the closing section.

Given the now decade-plus history of unabated cost increases, coupled with the prospect that this trend will continue into the foreseeable future without notable evidence to date of environmental benefits, the question arises as to the public's tolerance for continued support of Germany's Energiewende. Although several opinion polls conducted over the years suggest that support has persisted (e. g. AEE, 2014, STATISTA, 2016), such polls are often based on questions that present the costs in collective, rather than individual terms, with one implication being that respondents perceive the cost burden to be distributed across society at large. Empirical studies suggest that the WTP in such collective decision contexts is generally higher than when decisions are reached individually (e. g. WISER 2007, MENGES, TRAUB 2009). In what follows, our stated-preference surveys mark an attempt to measure the support level for RES that emerges when respondents perceive the associated costs to be incurred by themselves individually.

3 Survey Design and Descriptive Statistics

To elicit people's WTP for green electricity, we developed questionnaires and commissioned the survey institute *forsa* to carry out data collection. *forsa* maintains a panel of more than 10,000 households that is representative of the German-speaking population and collects the data using a state-of-the-art tool that allows panelists to fill out the questionnaire using either a television or, if access is available, the internet.[3] Respondents – here the household heads – retrieve and return questionnaires from home and can interrupt and continue the survey at any time. The survey was conducted over two periods, the first from May 10 to June 17, 2013 (ANDOR, FRONDEL, VANCE, 2014), and the second from March 3 to April 29, 2015. A randomly selected sub-sample of 2,303 respondents participated in the 2013 survey, 1,407 of whom also participated in the 2015 survey. There were an additional 4,269 individuals who were selected to participate in the survey for the first time in 2015, yielding a total sample size of 7,979 responses. Socio-economic and demographic background information on all household members is available from *forsa*'s household selection procedure and is used to derive a suite of control variables, the descriptive statistics for which are presented in Table 4.

Recognizing that several formats to elicit WTP have been suggested in the literature (see Frew et al., 2003), our interest here focuses on two formats that afford alternative advantages in gleaning estimates of the WTP for green electricity. The first, which was also employed by GRÖSCHE and SCHRÖDER (2011) and ANDOR, FRONDEL, and VANCE (2016), uses an open-ended question that asks households to provide their WTP for electricity that is exclusively generated from renewable energy technologies. Following a brief introductory text on electricity generation technologies in general, respondents were presented with the following text: "We request that you report the maximum amount that you, personally, would be willing to pay. As a basis for comparison, please consider an electricity mix comprised exclusively of the fossil sources coal, natural gas, and oil, which has a price of €100 per month". A more detailed extract of the questionnaire can be found in ANDOR, FRONDEL, and VANCE (2016).

[3]Information on forsa's panel is available at www.forsa.com.

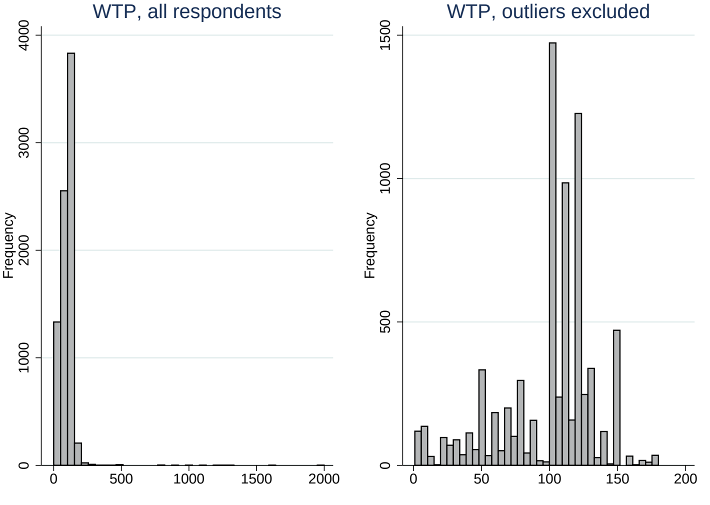
Upon stating their WTP bids, the respondents were asked about the certainty of their response. For this purpose, we use the certainty approach in the version suggested by BLUMENSCHEIN et al. (1998), which asks whether the respondents are probably or definitely sure about their WTP responses. The share of respondents who are definitely sure about their WTP responses on 100% green electricity, described by certainty variable C, amounts to 67.37%, implying that a minority of 32.63% is just 'probably sure' (Tables 4 and 5). As elaborated in the subsequent section, we assume that dummy variable C reflects an endogenous decision of the respondents, which appears warranted given the considerably unequal shares of respondents across certainty groups.

Table 4: Variable Definitions and Descriptive Statistics

Variable Name	Variable Definition	Mean	# of Obs.
Age31-40	Dummy: 1 if age of respondent is between 31 and 40	0.110	7,979
Age41-50	Dummy: 1 if age of respondent is between 41 and 50	0.187	7,979
Age51-60	Dummy: 1 if age of respondent is between 51 and 60	0.262	7,979
Age>60	Dummy: 1 if respondent is older than 60	0.381	7,979
Female	Dummy: 1 if respondent is female	0.319	7,979
Children	Dummy: 1 if respondent has children	0.166	7,450
C	Dummy: 1 if household ticked the option 'definitely sure' for the certainty question	0.674	7,940
College Prep Degree	Dummy: 1 if household head has a college preparatory degree	0.429	7,400
Low Income	Dummy: 1 if net monthly household income is lower than €1,251	0.180	7,979
Medium Income	Dummy: 1 if net monthly household income is between €1,251 and €2,750	0.211	7,979
High Income	Dummy: 1 if net monthly household income is between €2,751 and €4,250	0.216	7,979
Very High Income	Dummy: 1 if net monthly household income exceeds €4,250	0.233	7,979
East Germany	Dummy: 1 if household resides in in East Germany	0.198	7,979
2. Survey Wave	Dummy: 1 if observation originates from the 2. Survey	0.714	7,979
Price Knowledge	Dummy: 1 respondent has correctly indicated the broad range of average electricity prices	0.218	7,979
Surcharge Knowledge	Dummy: 1 respondent has correctly indicated the broad range of the surcharge for renewables	0.262	7,979

Figure 2 presents the distribution of WTP bids and is divided into two panels. The left panel includes observations from the entire distribution, while the right panel omits outliers. Sometimes referred to as ’protest bids’ (HALSTEAD et al., 1992), such outliers are bids for which respondents assign either a zero or an implausibly high value to the good, where we designate implausibly high values as being above €200. Protest bids are relatively rare in our data base. For example, with 3.2%, the share of zero bids for 100% green electricity is small, and the incidence of very high bids above €200 is even lower at about 0.6%. The median bid from both distributions is €105, with some 25% of respondents reporting values of €80 or lower.

Figure 2: Distribution of Willingness-to-pay bids (Left panel: all observations, Right panel: omits outliers)



There are at least two reasons why respondents would be willing to pay less for green electricity than the benchmark value of €100 for conventional electricity, notwithstanding the lower greenhouse gas emissions of electricity production from renewable energy technologies. The first is concern about security of supply, particularly given widespread media reports warning about blackouts in winter caused by increased network instability from the excess feed-in of wind power. Another is the perception that the proceeds from the feed-in tariffs are highly unevenly distributed across income classes and regions (FRONDEL, SOMMER, VANCE, 2015), with wealthier homeowners and counties in the sunnier south of the country being the primary beneficiaries (GROWITSCH, MEIER, SCHLEICH, 2014).

Distinguishing by certainty status, Table 5 shows that WTP has changed over time: for the definitely certain respondents, for example, the mean WTP has shrunk substantially between 2013 and 2015, from €113.3 to 95.7. Accordingly, the t-statistic for the test on the null hypothesis H_0: WTP_{2015} $(C = 1)$ - WTP_{2013} $(C = 1) = 0$ amounts to -9.61, suggesting the rejection of H_0.

Table 5: Mean WTP for 100% Green Electricity and t Statistics on Differences Between those who are either Definitely or Probably Certain about their WTP

Survey Years		Certainty on WTP: Definitely Certain $C = 1$	Probably Certain $C = 0$	Overall
2013				
	Number of observations	1,232	1,040	2,272
	Shares	54.23%	45.77%	100%
	Mean WTP	€113.3	€112.1	€112.8
	H_0: WTP $(C = 1)$ - WTP $(C = 0) = 0$		t = 0.683	
	Acceptance of supporting RES			84.4%
2015				
	Number of observations	4,117	1,551	5,668
	Shares	72.64%	27.36%	100%
	Mean WTP	€95.7	€89.9	€94.1
	H_0: WTP $(C = 1)$ - WTP $(C = 0) = 0$		t = 2.917	
	Acceptance of supporting RES			88.0%
2013& 2015				
	Number of observations	5,349	2,591	7,940
	Shares	67.37%	32.63%	100%
	Mean WTP	€99.7	€98.8	€99.4
	H_0: WTP $(C = 1)$ - WTP $(C = 0) = 0$		t = 0.637	

Altogether, the results indicate a marked decrease of about 17% in the mean WTP between the 2013 and 2015 waves of the survey, from €112.8 to 94.1 (Table 5), with a t-statistic of 12.41 for the null hypothesis H_0: WTP_{2015} - WTP_{2013} = 0. Interestingly, the certainty corrective for hypothetical bias has only a modest bearing on these results. Irrespective of whether such bias exists in the individual WTP bids, the intertemporal difference in these bids should be an unbiased estimator of the change in the true WTP if the hypothetical bias in an individual WTP bid is the same across survey years.

The open-ended format presented above has the virtue of allowing responses to vary in €1 increments over a broad range between €0 and €9,999, thereby yielding exact WTP information (CARLSSON et al. , 2011:791). Nevertheless, the format has also been subject to criticism. In particular, concern has been raised that the format is not incentive-compatible (CARSON, GROVES, 2007), as would be evidenced by a prevalence of protest bids. It is therefore of interest to explore whether the tepid support for renewable energy observed for 2015 is verified by other evidence.

To this end, we evaluate the outcomes from a dichotomous-choice question that was introduced in the 2015 wave of the survey and was administered to a subsample of 2,720 respondents. The question, which gauges the willingness to incur marginal increases in the price of electricity, is preceded by a brief introductory text that indicates the share of renewable energy in electricity production at the time of the survey, 28%, as well as the government's target of 35% by 2020. The text further notes the 6.17 cent surcharge for the support of renewable energies in 2015, and includes the implications of this surcharge for the overall cost increase faced by a typical household over a year. In detail, the question reads: "Would you be willing to pay an additional X cents on the per kilowatt hour surcharge in order to reach the target of 35% renewable energy in the electricity mix by 2020?", where X is randomly replaced with either a 1, 2, or 4. Given the nearly 4-cent increase in the surcharge between 2012 and 2015, and anticipated increases of at least one cent by next year owing to continued expansion of renewable capacity (AGORA ENERGIEWENDE, 2015), the provided range seems a reasonable approximation of the cost increases that households are likely to face in the upcoming years.

Table 6 presents the descriptive statistics from the three treatments. The first column reports the share of 'yes' responses, while the second column reports the share that results when the 'yes' responses are recoded to 'no' responses among those who did not report definite certainty in their answers using the certainty question applied above. Following BLUMENSCHEIN et al. (2008:130), the basic idea is that while a 'probably yes' response indicates some interest, it is unlikely to be sufficient to actually make a payment, rendering it tantamount to a 'no'.

Column 1 shows that slightly over half of respondents, 54.1%, report a willingness-to-pay an additional cent on the surcharge, a share that drops to 47% among respondents presented with a 2-cent increase and further to 33.3% among those presented with a four-cent increase. t tests, not presented, indicate that the respective shares are all significantly different from one another at the 1% level. The last column of Table 6 reveals a considerably more modest level of support when recoding the data according to the certainty corrective, with corresponding shares of 38.5%, 33.0% and 23.2% for the 1-cent, 2-cent and 4-cent treatments, respectively, which are likewise statistically different from one another. The degree of overstatement between the non-corrected and corrected shares for the three treatments ranges between 1.39 and 1.47, a somewhat higher ratio than the 1.35 reported in the meta-study of MURPHY et al. (2005), though lower than the median estimate of 3 reported in the studies of LIST and GALLET (2001) and LITTLE and BERRENS (2004).

Table 6: Descriptive Results from the Dichotomous-Choice Experiment

(Hypothetical) Increase in surcharge	Share of Yes responses without Certainty Corrective	Share of Yes responses with Certainty Corrective
1 Cent	54.09%	38.46%
2 Cents	46.96%	33.05%
4 Cents	33.29%	23.16%

Overall, there appears a strong contrast between the households' general acceptance of supporting renewable energy technologies and their own WTP for green electricity. This contrast is illustrated by a survey question asking respondents whether they, in principle, agreed with the statement that renewable energy technologies should be supported. The share answering affirmatively increased from 84.4% in 2013 to 88.0% in 2015 (Table 5), a trend that would seem to belie the responses to the WTP questions:[4] Almost 60% of those household heads who participated in both surveys reduced their WTP relative to 2013, while a mere 38.5% expressed certainty in supporting a 1-cent increase in the surcharge based on the most modest variant of the closed-ended question posed in the 2015 survey (Table 6).

4 Estimation Methodology

Two econometric estimators are applied to the data. The dichotomous choice data is analyzed with a linear probability model.[5] As in the descriptive analysis presented in Table 6, we explore the implications of recoding the dependent from one to zero among respondents who did not express complete certainty in their answers.

The analysis of the open-ended WTP responses presented in Table 5 requires a two-stage model to cope with the potential endogeneity of certainty variable C. We apply a switching regression model (see MADDALA 1983:223-228) that in the first stage divides respondents into two regimes, those who are definitely certain about their WTP on green electricity (Regime 1) and those who are just probably certain (Regime 0):

$$WTP_{1i} = \boldsymbol{\beta}_1^T \cdot \mathbf{x}_{1i} + u_{1i}, \quad \text{if } C_i = 1 \quad \text{(Regime 1)}, \tag{1}$$

$$WTP_{0i} = \boldsymbol{\beta}_0^T \cdot \mathbf{x}_{0i} + u_{0i}, \quad \text{if } C_i = 0 \quad \text{(Regime 0)}. \tag{2}$$

In this equation system, WTP_{1i} and WTP_{0i} denote the household heads' individual WTP bids and $\mathbf{x}_{1i}$ and $\mathbf{x}_{0i}$ include their determinants, such as net household income, while $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_0$ are vectors of the associated parameters to be estimated.

[4]Not surprisingly, those who did not agree with the statement that renewable energy technologies should be supported exhibit a median WTP of €80.7, substantially lower than the median WTP of €101.5 among those who agreed with the statement.

[5]Applying a probit model to the data yields marginal effects that are nearly the same as the coefficients estimated by the linear probability model.

C is a dummy variable indicating the certainty regime:

$$\begin{aligned} C_i &= 1 \qquad \text{if } \gamma^T \cdot \mathbf{z}_i \geq u_i, \\ C_i &= 0 \qquad \text{otherwise,} \end{aligned} \tag{3}$$

where $\mathbf{z}_i$ includes factors that may affect whether a household head i is either definitely certain about her WTP bids ($C_i = 1$) or just probably certain ($C_i = 0$). In the endogenous switching regression model, the error term u_i is assumed to be correlated with the errors u_{1i} and u_{2i} of equations (1) and (2), as there may be unobservable factors that are relevant for both the selection into either regime and WTP bids.

Identification of the switching regression model requires the specification of at least one variable that determines the discrete first-stage outcome on WTP certainty, but not the continuous WTP response relevant for second-stage regression. We specify two such exclusion restrictions, both of which are based on the respondents' familiarity with electricity provision asked during the survey. The first is a dummy indicating whether the respondent is able to correctly state the per-kWh price of electricity within an error margin of 3 cents (*Price Knowledge*), while the second is a dummy indicating whether the respondent provides a good guess of the surcharge paid for renewable energy (*Surcharge Knowledge*), within an error margin of 1 cent per kWh. By law, this surcharge, which at the time of the 2013 survey was 5.3 cents per kWh (Figure 1), is included on every electricity bill. 26.2% of those respondents who provided a WTP bid for green electricity had a broad knowledge about the correct level of the surcharge paid for renewable energy (Table 5), whereas 21.8% of them had a crude idea about the level of average electricity prices.

The unknown parameter vector γ that determines the (first-stage) certainty regime (3) can be estimated – up to a scale factor – using standard probit maximum likelihood methods, where, due to the indeterminacy of the scale factor, $Var(u_i) = 1$ can be assumed. The second-stage equations to be estimated are

$$WTP_{1i} = \boldsymbol{\beta}_1^T \cdot \mathbf{x}_{1i} - \sigma_{1u} \cdot \text{IVM}_{1i} + \varepsilon_{1i}, \text{ for } I_i = 1, \tag{4}$$

$$WTP_{0i} = \boldsymbol{\beta}_0^T \cdot \mathbf{x}_{0i} + \sigma_{0u} \cdot \text{IVM}_{0i} + \varepsilon_{0i}, \text{ for } I_i = 0, \tag{5}$$

where ε_{1i} and ε_{0i} are new residuals with zero conditional mean and

$$\text{IVM}_{1i} := \frac{\phi(\gamma^T \cdot \mathbf{z}_i)}{\Phi(\gamma^T \cdot \mathbf{z}_i)}, \qquad \text{IVM}_{0i} := \frac{\phi(\gamma^T \cdot \mathbf{z}_i)}{1 - \Phi(\gamma^T \cdot \mathbf{z}_i)} \tag{6}$$

represent the two variants of the inverse Mills ratios, with $\phi(.)$ and $\Phi(.)$ denoting the density and cumulative density function of the standard normal distribution, respectively. When appended as extra regressors in the second-stage estimation, the inverse Mills ratios are controls for potential biases arising from sample selectivity: It is likely that intrinsically unobservable characteristics, such as carelessness about electricity bills, also affect WTP bids. If the estimated coefficients – σ_{1u} and σ_{0u} – are statistically significant, this is an indication of sample selectivity. For the second-stage estimation, we insert the predicted values $\widehat{\text{IVM}}_{1i}$ and $\widehat{\text{IVM}}_{0i}$ using the probit estimates $\widehat{\gamma}$ of the first-stage estimation. Given that the variance of the residuals is heteroscedastic in nature (see MADDALA 1983:225), equations (4) and (5) should be estimated by weighted least squares using the Huber-White estimates of variance.

5 Estimation Results

We begin with an analysis of the open-ended WTP responses. To provide for a reference point in estimating the determinants of an individual's WTP for 100% green electricity, we first present the ordinary least squares (OLS) estimates both for the pooled sample, as well as the sub-samples of those who are either definitely or probably certain about their WTP (Table 7). Turning to the pooled results in the first column of Table 7, all of the socioeconomic variables except for gender have a statistically significant association with the WTP for green electricity. The dummies for the age categories, even if not statistically different from one another, illustrate a pattern wherein individuals in older age cohorts tend to have an increasingly lower WTP, one interpretation for which is a reduced concern for climate change impacts that occur beyond the cohort's lifespan.

A similar interpretation may be ascribed to the positive coefficient of the dummy indicating individuals with children, who presumably have a greater stake in averting perceived threats from future climate change and therefore have a higher WTP. Those in higher education and income categories likewise have a higher WTP, the latter of which can be interpreted as a standard income effect that would apply if climate is a normal good. The negative impact of the dummy for East Germany, which suggests a roughly 8-Euro lower WTP than in West Germany, points to large regional differences in Germany in the level of support for green electricity. Moreover, if we were to follow the conclusion drawn by BLUMENSCHEIN et al. (2008) to only take account of the WTP bids of the definitely certain, we would find an average WTP, as given by the estimate of the constant, that is lower for the group of definitely certain than for those who are probably certain – although not statistically significantly lower, as can be seen from the χ^2-statistics presented in the last column of Table 7.

Table 7: OLS Estimation Results for the WTP for 100% Green Electricity

	Full Sample		Subsample of the Definitely Certain		Subsample of the Probably Certain		Tests on Differences
	Coeff. s	Std. Errors	Coeff. s	Std. Errors	Coeff. s	Std. Errors	χ^2 Statistics
Female	0.13	(1.36)	1.87	(1.80)	-2.62	(3.14)	2.18
Age31-40	* -5.92	(2.56)	-5.98	(4.19)	-4.53	(7.31)	0.07
Age41-50	** -7.40	(2.43)	-5.67	(3.88)	-10.64	(6.78)	0.95
Age51-60	** -7.16	(2.47)	-6.09	(3.73)	-9.71	(6.51)	0.42
Age>60	** -9.73	(2.44)	* -7.70	(3.69)	* -13.61	(6.24)	1.44
College Prep Degree	** 7.10	(1.51)	** 7.54	(1.69)	5.65	(3.26)	0.27
Children	* 4.24	(1.97)	2.82	(2.35)	** 6.79	(4.07)	0.12
Medium Income	** 5.97	(1.99)	5.58	(2.35)	5.23	(4.18)	0.83
High Income	** 6.54	(2.10)	* 2.79	(2.35)	** 14.93	(4.50)	0.01
Very High Income	** 7.59	(2.33)	** 7.73	(2.52)	6.19	(4.81)	* 4.04
East Germany	** -8.29	(1.66)	**-10.00	(2.10)	-4.42	(3.58)	2.26
2. Survey Wave	**-17.02	(1.18)	**-15.37	(1.93)	**-21.25	(3.10)	* 4.67
Const.	**113.50	(2.71)	**112.76	(4.07)	**115.68	(6.78)	0.27
Number of Observations	6,917		4,730		2,187		

Note: * denotes significance at the 5 %-level and ** at the 1 %-level, respectively.

The largest estimate in magnitude, that of the dummy indicating the second survey wave in 2015, indicates that the WTP has decreased by roughly 17 Euros since the first survey in 2013. One interpretation of this strong decrease is that it results from a growing awareness of the ongoing cost accumulation from Germany's Energiewende. As was conveyed through media reports and by way of household electricity bills, the surcharge for green electricity rose from 5.28 Cents per kWh in 2013 to 6.17 in 2015 (Figure 1), corresponding to a 17% increase over the survey period. To the extent that the negative coefficient of -17.02 reflects a response to this cost increase, it would suggest that societal and political support for the Energiewende may begin to wane as households face continually higher electricity bills (see Figure 1).

Turning to the switching regression model that incorporates the certainty corrective, the first column of Table 8 presents estimates of the first-stage probit model (3) capturing whether the respondent reported a high level of certainty in their response to the WTP for green electricity. Gender, age, education, income, and geographical location are all seen to have statistically significant effects on this outcome. With respect to model identification, one of the two exclusion variables is statistically significant: those with a broad knowledge of the EEG surcharge have a higher probability of expressing certainty in their WTP than those lacking this knowledge.

Table 8 additionally presents the results from the second-stage equations (4) and (5) estimated on the two sub-samples that are distinguished by whether the respondent reported definite certainty in the WTP response. Most notably, in both models, the dummy indicating the second survey wave indicates a statistically negative effect across both certainty groups, providing further evidence that the decrease in WTP for green electricity has been large and broad based. The remaining estimates are also qualitatively similar to those in Table 7, one possible reason for which is the absence of sample selectivity as indicated by the statistically insignificant coefficients on the inverse Mills ratio.

Having demonstrated the fall in WTP between 2013 and 2015, we now assess the implications of future increases in the surcharge for green electricity by way of the dichotomous-choice models presented in Table 9. The table includes four models, the first two of which essentially replicate the descriptive results from Table 5, while the latter two include control variables. The inclusion of the controls has a particularly strong bearing on the estimates presented in the final column, which incorporates the certainty corrective. The constant of this model suggests that a 1-cent increase in the surcharge would be supported by just 27% of respondents in the base category, nearly half the magnitude of the corresponding estimate from the model without the certainty corrective.

Table 8: Switching Regression Results on the WTP for 100% Green Electricity

	1. Stage Equation (3)		Sub-sample of the Definitely Certain Equation (5)		Sub-sample of the Probably Certain Equation (4)		Tests on Differences
	Coeff. s	Std. Errors	Coeff. s	Std. Errors	Coeff. s	Std. Errors	χ^2 Statistics
Female	**-0.23	(0.04)	5.32	(3.17)	6.70	(7.62)	0.03
Age31-40	0.14	(0.08)	* -7.91	(3.40)	-10.35	(7.37)	0.09
Age41-50	* 0.18	(0.08)	* -8.14	(3.54)	* -17.34	(8.08)	1.10
Age51-60	** 0.26	(0.07)	* -9.66	(4.48)	-19.81	(11.15)	0.72
Age>60	0.03	(0.07)	** -8.02	(3.05)	** -14.48	(3.76)	1.82
College Prep Degree	** 0.14	(0.04)	* 5.54	(2.69)	0.09	(7.24)	0.50
Children	* 0.10	(0.05)	1.77	(2.70)	1.85	(4.26)	0.59
Medium Income	0.07	(0.05)	3.19	(3.62)	4.13	(4.71)	0.19
High Income	* 0.16	(0.05)	-1.35	(4.62)	-1.05	(6.16)	0.35
Very High Income	** 0.30	(0.05)	6.16	(3.67)	2.87	(7.64)	0.22
East Germany	**-0.17	(0.04)	** -7.55	(2.71)	2.45	(6.01)	2.31
2. Survey Wave	** 0.50	(0.03)	**-22.67	(6.41)	** -40.76	(16.38)	1.06
Price Knowledge	-0.04	(0.04)	–	–	–	–	–
Surcharge Knowledge	** 0.14	(0.04)	–	–	–	–	–
IVM_1	–	–	-28.15	(24.46)	–	–	–
IVM_0	–	–	–	–	55.89	(49.56)	–
Const.	-0.12	(0.08)	**135.77	(21.13)	** 74.37	(36.18)	2.17
Number of Observations	6,917		4,730		2,187		

Note: * denotes significance at the 5 %-level and ** at the 1 %-level, respectively.

The 2-cent and 4-cent treatments indicate statistically significant reductions in the share of respondents answering affirmatively for both models. In the certainty-corrected model, the 4-cent treatment is associated with a 15.5% point decrease in the probability of an affirmative response, nearly three times the magnitude of the 2-cent treatment, with a similar pattern seen in the uncorrected model. Overall, the results suggest a substantial decrease in WTP in response to surcharge increases that will likely transpire given the trajectory of increases over the past five years.

Table 9: Results of the Dichotomous-Choice Experiment

Certainty Corrective	No		Yes		No		Yes	
	Coeff. s	Std. Errors	Coeff. s	Std. Errors	Coeff. s	Std. Errors	Coeff. s	Std. Errors
2 Cents	-0.071**	(0.025)	-0.054*	(0.024)	-0.076**	(0.025)	-0.058*	(0.024)
4 Cents	-0.208**	(0.024)	-0.153**	(0.023)	-0.211**	(0.024)	-0.155**	(0.023)
Female	–	–	–	–	0.096**	(0.022)	0.047*	(0.021)
Age31-40	–	–	–	–	-0.099	(0.053)	0.009	(0.051)
Age41-50	–	–	–	–	-0.118*	(0.050)	-0.006	(0.048)
Age51-60	–	–	–	–	-0.094	(0.048)	0.016	(0.046)
Age>60	–	–	–	–	-0.097*	(0.047)	0.011	(0.045)
College Prep Degree	–	–	–	–	0.095**	(0.021)	0.093**	(0.020)
Children	–	–	–	–	0.022	(0.032)	0.041	(0.031)
Medium Income	–	–	–	–	0.056*	(0.028)	0.029	(0.026)
High Income	–	–	–	–	0.073*	(0.029)	0.062*	(0.027)
Very High Income	–	–	–	–	0.117**	(0.029)	0.130**	(0.027)
East Germany	–	–	–	–	-0.063**	(0.024)	-0.063**	(0.023)
Const.	0.541**	(0.018)	0.385**	(0.017)	0.516**	(0.052)	0.272**	(0.050)
Number of Observations	2,386		2,386		2,386		2,386	

Note: * denotes significance at the 5 %-level and ** at the 1 %-level, respectively.

6 Summary and Conclusions

Germany, a country with a sun intensity on par with that of Alaska (SCHWABE, 2016), is home to 17% of the globe's photovoltaics capacity (IRENA, 2016). This impressive circumstance did not arise from market forces, but was rather the result of a highly generous support scheme that extended technology-specific feed-in tariffs (FITs) to renewable energy sources (RES), with particularly high tariffs historically accruing to photovoltaics. The foregoing analysis has documented the substantial costs of this support scheme. We have subsequently presented results from a stated-preference experiment based on two surveys in 2013 and 2015 that were intended to gauge the public's willingness to bear these costs.

Our calculations suggest that, in addition to the 125 billion Euros that consumers paid in the form of higher electricity bills for Germany's RES promotion between 2000 and 2015, over the next 20 years the overall costs are likely to exceed 400 billion Euros, a highly conservative estimate that disregards the required expansion of the power grid, among other factors. Since the introduction of the FIT under the Renewable Energy Act in 2000, household electricity prices have already doubled, following a trajectory that shows no signs of abating. This cost burden notwithstanding, the data analyzed here suggests that the German public, at least in principle, is highly supportive of RES technologies. Based on the 2015 wave of the survey, some 88% of respondents stated that RES should generally be supported, a finding that is buttressed by other polling.

Whether this principled support has staying power in terms of willingness-to-pay, however, is called into question by the results of our stated-preference surveys. We find that when correcting for certainty status, only a minority of respondents are willing to support a future 1-cent increase in the surcharge for RES. Moreover, the results suggest a marked decrease of about 17% in the mean WTP for 100% green electricity between the 2013 and 2015 survey waves. Although hypothetical responses may yield upwardly biased WTP estimates, if this bias is the same across survey years, then the intertemporal difference in bids should be an unbiased estimator of the change in the WTP.

Presuming that decreased WTP is channeled into public resistance to increasing electricity prices, this may force a discussion that leads to a restructuring of Germany's energy transition and climate protection policy. Resistance may be further exacerbated as recognition grows of the marginal environmental benefits of the Energiewende in terms of greenhouse gas emission abatement: Germany's participation in the European Emissions Trading System implies that the country's success in unilaterally reducing greenhouse gas emissions via the FIT releases tradable emissions certificates, thereby reducing their price and resulting in higher emissions elsewhere in Europe.

In short, high costs together with negligible environmental benefits render Germany's FIT highly cost-ineffective, a point that has been recognized by several expert commissions, such as the German Council of Economic Experts (GCEE, 2011: 219) and the International Energy Agency (IEA, 2007:76). To improve cost-effectiveness and dampen future electricity price increases, the German government has recently introduced an auctioning system for the RES promotion, where RES capacities are auctioned separately by technology to foster competition among providers. As these auctions are technology-specific, though, there is still no competition across technologies. Cost-effectiveness could be further improved if future RES capacities were to be increased by technology-neutral auctions.

More desirable, from the perspective of consumers, would be a fundamental reform of the support scheme that involves a switch to a technology-neutral quota system, which would make the suppliers of green electricity more responsive to the demand side. An additional increase in cost-effectiveness would be achieved if RES support schemes were to be coordinated at the European level, as is called for by the European Commission, thereby recognizing that the sun intensity is substantially higher on Europe's southern periphery than in Germany.

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