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Underground cables versus overhead lines: Do cables increase social acceptance of grid development? Results of a contingent valuation survey in Germany

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ABSTRACT

Transmission network development plans have led to protests throughout Germany. Many studies present underground cables as a means to increase public agreement to transmission line construction. This paper investigates this thesis reporting results of a Contingent Valuation study conducted in late 2012 in four regions of Germany, which are affected by transmission line development in different ways. In an analysis of 1,003 household responses a majority of households favour underground cables (about 60%). Willingness-to-pay (WTP), however, changes the significance of the result as almost 50% of the households voting for underground cables are not willing to accept an increase in electricity prices to finance cable projects (free riders). Also, households stating a positive WTP for regional cables do not acknowledge larger supra-regional underground cable projects with higher WTPs in 60% of cases. This further underlines that cables are not supported unconditionally.

The empirical results presented in this paper need to be interpreted cautiously because of low response rates and non-representative samples that are typical for mail surveys. Based on the WTP-evaluation described, however, the thesis that cables increase acceptance of grid development has to be rejected.

Keywords:

Willingness-to-pay,
free-riding,
underground cables,
grid development,
contingent valuation,
Energy Transition.

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1. Introduction

Since the first development plans for the German electricity transmission network (“Netzentwicklungsplan”) have been published after the nuclear meltdown in Fukushima 2011, the expenditure of German transmission capacities has attracted much public attention. Public discussion centers on the questions where and to what extent new transmission lines ought to be constructed. Another controversy revolves around two rivaling technological approaches: Local protest

movements demand for overhead-lines to be replaced by underground cables and delay administrative approvals and construction works in many cases throughout Germany [1].

Based on case studies and stakeholder statements international studies conclude that the negative impacts from overhead lines necessitate the use of underground cables, although an energy policy perspective suggests that anticipated advantages related to cables are of temporary nature and might materialize to a lesser extent

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than expected [2]. While the average transmission line still runs overhead, doubts about this construction technique are increasing. Not only in designated construction areas do major parts of population reject overhead lines. Fear for landscape and nature as well as the threat of unmitigated radiation are the oldest and most common concerns [3]. Particularly the importance of negative visual effects caused by transmission line pylons should not be underestimated [4]:

In a study initiated by Deutsche Umwelthilfe in 2010, over 70% of participants at least “agree fully” to the statement “overhead lines impair a landscape’s character”. In contrast, 70% of respondents see no noteworthy landscape impairment in the case of underground cables [5]. The preference for underground cables is not limited to active, organized opposition to overhead cables, as a representative study on the social acceptance of the German Energy Transition¹ conducted by TNS-Infratest suggests. In October 2012 3,800 private households were asked under which conditions transmission line construction in direct vicinity (defined as 5 km around place of residency) would be agreed to [6].

One of the major findings was that more than three quarters of participants (77%) would support construction works without any further conditions if underground cables were used. Other instruments to increase social acceptance of grid development lead to lower approval rates: The financial participation of residents for instance lead to an approval rate of 21%. This refers to instruments such as the so-called “Bürgeranleihe”, which is currently field-tested in Schleswig-Holstein. Here private households may sign a loan to finance grid construction for an interest of around 4.6% p.a. On the same note, the inclusion of residents into planning processes does not result in higher rates of acceptance, either (49%).

This result was homogenous throughout the sample and robust. Even between regions that are affected by the results of the Energy Transition in different ways no significant differences could be observed. TNS-Infratest also found approval to underground cable construction (77%) to hardly be dependent on incomes

(approval increases from 71.2% to 80.3% over all income intervals). The evidence provided leads to the conclusion that underground cables are a means to increase the social acceptance of the Energy Transition and the transmission network development it demands [7].

Meanwhile, a favoring public opinion is not the only argument supporting underground cables. Literature stresses the generally high environmental compatibility of underground cables as well as the low social costs incurred, referring to lower landscape impairments, shorter approval processes and lower health risks caused by electromagnetic fields [2]. On the other hand, underground cable technology remains largely untested and expensive. Comparisons of economic feasibility between overhead lines and underground cables find the latter to be three to 20 times as costly [8].²

Hence, in an attempt to economically weigh up benefits provided and costs incurred by underground cables it needs to be considered that

- underground cable projects provide almost only *regional benefits* (e. g. scenic effects)
- while additional costs are socialized and distributed amongst all electricity consumers via network charges *nationwide*.

This allows for strategic protests against overhead lines in designated construction areas. From communities’ perspectives, this not-in-my-backyard-behavior might only be stopped by paying compensations – or by installing underground cables, if local grid systems meet the technical requirements for cables construction (see [9] for details). Albeit of great importance, such calculations are not measured in conventional surveys since opportunity costs and decision scenarios are generally not framed in classic questionnaires.

Consequently, additional examinations are needed to test the hypothesis that underground cables increase the social acceptance of grid development. These examinations must meet two criteria: Firstly, strategic (response) behavior needs to be identified when measuring preferences for underground cables. Secondly, opportunity costs need to be framed. This is to say that not only a mere preference for underground

¹ The term Energy Transition refers to the German agenda aiming to modernize the German energy economy and increase its sustainability. Major objectives are to decrease the dependency on fossil fuels by growing the share of renewables in the energy mix, to increase energy efficiency in all parts of society and to reduce overall energy demand. A wide array of environmental policy instruments are used to pursue these goals with significant consequences, the renunciation of nuclear power being one of the more prominent examples.

² This paper does not aim to assess the overall properties of underground cables. Readers interested in technical features and attributes of cables and a comparison to overhead lines are advised to see [10].

cables, but also a corresponding intensity of preference needs to be determined.

The results of one of these examinations are described in this paper. In addition to the question whether underground cables are a means to increase social acceptance, special attention is given to the factors suitable to explain households' opinions on underground cables. Data used, specifically the willingness-to-pay (WTP) of private households for underground cable projects, is derived from a Contingent Valuation survey. The concepts of this study method are described below.

2. The contingent valuation method

Accompanied by intense methodological and theoretical debates the Contingent Valuation method (CVM) has become an acknowledged and wide-spread instrument to value complex public goods [11]. It is commonly used in political decision-making and in court, where results of Contingent Valuations are used to determine compensations in cases of environmental damage [12].

Contingent Valuation determines the value of a public good by hypothetically varying the allocation level of the public good. Study participants are then asked for their preferences for the new allocation level and asked to quantify the strength of their preference by stating their willingness-to-pay [13]. Individual willingness-to-pay is interpreted as consumer rent for the variation of the public good, and, when extrapolated on the population, leads to a monetary value of the public good examined [14].

In order for the method to arrive at valid results, special care needs to be invested into questionnaire design. Questionnaires need to activate and engage study participants, so that stated preferences are most likely to mirror real preferences. Here Contingent Valuation relies on scenarios, which serve to illustrate the different levels of allocation. One scenario frames a reference point, while the second scenario presents a different allocation level of the public good. Usually catchy and plausible scenes such as the construction of a park in an urban area are used to vary allocation levels. If further methodical criteria are met [15], Contingent

Valuation results are considered to be a good indicator of true preferences.

Contingent Valuation is well suited for determining preferences for underground cables for a variety of reasons:

1. Both local and national population considers the choice between overhead lines and underground cables *meaningful*.
2. Underground cables and overhead lines present clearly distinct alternatives to one another. Since *energy-economic properties are equal*, differences between both alternatives can be reduced to differences in environment impairment.
3. Realization of one alternative is highly likely in many areas, which allows for very *realistic* reference and valuation scenarios.³
4. Advantages and disadvantages of either alternative are well defined and *easily distinguished*.
5. Network charges as concurrent method of financing network operations and construction are well-known and comprehensible. Willingness-to-pay can thus be examined in a *familiar payment-vehicle*.

3. Study design & procedure

The object of investigation in this study is the willingness-to-pay of private households for underground cables. Underground cable projects are offered in two variants: A hypothetical regional project of 8 km length is concretized on the example of Kreiensen in Lower Saxony, a region marked by intense discussions between transmission network operator and local protest movements opposing overhead lines. This example is used to picture properties of both overhead lines and underground cables. Additionally, households are offered a second underground cable project that differs from the regional one only in length (400 km). This supra-regional project, which is framed as a sum of "many regional projects", intentionally remains physically undefined. In an introductory note households are informed about the scientific character of

³ Here a simplification has to be made. In several regions of Germany underground cables are discussed in alternating and direct current forms. Both types of underground cables have different technological and economic properties (for details see [2]). Since this study does not primarily address well informed and technologically educated households, the possibility of underground cables in direct current form is expressively ignored (as was done in TNS Infratest study). From a methodical view-point the comparison between underground cables and overhead lines is to be reduced to environmental effects. An additional technical dimension such as currents would require multi-level decisions and further complicate an already demanding survey design. A differentiating and multi-dimensional comparison including technical information can be found at [11].

this study. Specifically, the fictitious character of later referendums is underlined. The final questionnaire consists of three information elements, which are shortly presented in the following:

The *first part* of the questionnaire aims at providing relevant and sufficient information to survey participants and consists of several information sections. The first two pages of the questionnaire explain the energy-economic background of network development. Focus is put on the necessity to build new transmission lines in Germany. On another page, a real example for the consequences of line construction is given on the example of Kreiensen, Lower Saxony. Here actual construction plans for an 8-km-long transmission line are presented. Next, the reference scenario (alternative 1: overhead lines) is introduced, followed by a description of the alternative scenario (alternative 2: underground cables). Advantages and disadvantages respectively environmental properties of both alternatives are presented neutrally with the help of pictures and schematic pro/contra-lists.

The purpose of the *second part* of the questionnaire is to determine preferences for underground cables and corresponding willingness-to-pay. Both items are investigated in separate sections. Firstly, study participants are to state a general preference for two independent hypothetical underground cable projects in separate referendums. As mentioned, the two projects are described as

- 1) a regional underground cable project of limited length (8 km) inspired by the example of Kreiensen that had previously been introduced.
- 2) a supra-regional underground cable project (400 km total), derived from a not specified number of small regional projects.

The project description states that regional and supra-regional projects are identical in everything but length and position. It is also underlined that either project can be realized in every part of Germany. This approach is chosen to avoid for study participants from regions far from the example of Kreiensen to feel unaffected by the outcome of the vote at hand. Both referendums are set up with a detailed characterization of the hypothetical market, which includes an explanation of the situation that leads to the vote. To remind study participants of personal budget restrictions and the consequences of a positive vote for underground cables, the power cost increase related to underground cables is highlighted. Also, a 'cheap talk' formulation is implemented to

minimize the effect of fundamental opinions on transmission network development itself rather than the choice between overhead lines and underground cables.

Following the referendums participants are asked to state their personal willingness-to-pay for projects supported, while a positive willingness-to-pay is framed as condition for project realization. In a first step, two payment vehicles are introduced:

- Households are asked for their tolerance of accepting increasing network charges. The maximum yearly amount households are willing to spend in order to facilitate underground cables is to be stated.
- The second payment vehicle is based on the assumption that increases in network charges are not sufficient to finance underground cables. Households are given the option to voluntary invest (one-time payment) into a regional development fund. No further information (interest rates, runtime, etc.) on the fund is given other than its sole purpose of financing underground cables.

In both cases willingness-to-pay is elicited in open-end formats. In order to increase response validity a reference point was offered in network charge models: the average electricity expenditures of German households of 900 Euro per year are given for orientation. Also, the average payments for network fees are stated at 180 Euro per year or 20% of yearly total electricity costs. Even though this procedure provokes distortions in stated WTP [Anchoring-effect, 16], it is chosen to strengthen response rates. Additionally, "cheap talk"-framing is used to counteract possible starting-point biases.

Having determined preferences and WTP, demographic properties and attitudes potentially fit to explain said variables are collected in the *third questionnaire section*. This includes reasons for rejecting underground cables and personal experiences with network development. Amongst other variables households were asked to estimate the distance of their home to the nearest transmission line. Also, a variety of opinions on general matters of energy politics were inquired. Examples are attitudes towards the Energy Transition and global warming, questions on decision-making competencies in the energy sector et cetera. A complete list of variables is given at a later point in Table 9.

A variety of surveys [5, 6] find preferences of German households for underground cables to be

general and reject significant regional differences in the social acceptance of these cables. Here samples were selected in order to investigate the structure of households preferences in more detail (theoretical sampling) [17]. Four sample regions were identified which systematically differ in terms of their regional exposition to new grid constructions:

- The community Kreiensen in Lower Saxony is immediately affected by network development plans and serves to picture the example regional underground cable project.
- Niebüll on the North Sea coast in Schleswig-Holstein is massively influenced by the expenditure of wind power capacities; Regional wind farms are commonly shut down because of short transmission capacities.
- Viechtach in Bavaria is similar to Niebüll and Kreiensen in population and its rural structure. There are no plans to set up transmission networks in a noteworthy vicinity to Viechtach, however.
- Lastly, a major city of Lower Saxony is included with Braunschweig. Households here are not directly affected by transmission network construction, a topic that is also much less debated than in other regions

It is important to note that the goal of this research method is not to achieve representativeness of results or to highlight aggregate welfare measures. Achieving representativeness would require identifying a set of relevant socio-economic variables (with respect to the object of research) and to control for the variation of these variables within the sample. Our study differs from other surveys by introducing a more detailed and theory-based framework (including project description, budget restriction and payment mechanism) for investigating household’s decision-making behaviour in this field of interest. This approach attaches greater weight to the issue of

(internal) validity than to the representativeness of the sample.

We adopted a mail survey format. CVM studies using mail surveys typically face the problem of low return rates and non-representative samples. On the other hand, mail surveys have the advantage that respondents are much more likely to respond truthfully to personal and attitudinal questions since the problem of social desirability and interviewer biases can be avoided. Internal validity is also improved as respondents can take as much time as they need to think about the proposed scenario and about their answer to the WTP elicitation questions [18].

This study was conducted in four regions of Germany in November and December 2012. A total of 21,000 questionnaires were distributed by local press. Advertising journals were chosen over regular newspapers in order to gain access to every household of a given region, independent from subscription models. Every questionnaire consisted of a 16-page brochure in DIN A4-format, printed in color and wrapped in foil. Enclosed was a pre-directed and post-stamped bag to encourage responses. Final survey period ranged from November 25th 2012 (date of distribution) to December 12th 2012 (entry deadline).

4. Results

4.1 Sample

Regional composition of final sample can be seen in Table 1:

Roughly 5% of households approached returned the questionnaire. 178 households did not state places of residency. Sample is not representative in various regards: Sample composition is distorted with an over proportional share of responses from Kreiensen, which may be explained with the local reference of the illustrative scenario. Representativeness is further constricted by demographic properties of the sample. Households owning real estate make up for a much

Table 1: Sample composition.

Region	Responses	Response rate	Sample share
n/s	178	–	17.74%
Kreiensen	298	5.73%	29.71%
Viechtach	74	1.68%	7.38%
Braunschweig	325	4.25%	32.40%
Niebüll	128	2.64%	12.76%
Total	1,003	4.54%	100.00%

larger share in the sample (86.7%) than in the entity of Germany (45.7%) [19]. The mean stated monthly net incomes in the range of 2,500 – 2,999 Euro per month, however, include the factual Federal average, which was 2,988 Euro in 2011 [20].

4.2. Preferences for underground cables

Voting outcomes clearly favor both regional and supra-regional projects. The regional project is approved by 60.3% of the total sample with a disapproval rate of 24.9% (14.8% of households are undecided, $n = 921$). Results vary significantly between sample regions. As expected, support for underground cables peaks in Kreiensen (71.8%) and is at a minimum in Braunschweig (51.1%). This result is sound considering that there are currently no plans to enlarge the transmission network in the area, which leaves Braunschweig's population only indirectly affected by and thus relatively neutral to questions of construction techniques. The hypothesis that the vote on regional projects does not depend on place of residency has to be rejected with a probability of error of 0.000 ($n = 765$). An overview of regional differences in voting behavior is given in Table 2.

Voting outcomes on the supra-regional underground cable project are similar. Over the entire sample 57.0% of households wish for the project to be realized ($n = 921$).

The share of disapproving households is slightly larger than before with 26.6%, same as the share of undecided households of 16.4%. Here, too, a significant correlation between voting behavior and place of residency can be observed (see Table 3).

Another correlation in voting behavior exists between regional and supra-regional votes. 87.2% of households voting *in favor of a regional project* also approve of the supra-regional project. Again regional differences are significant: In Kreiensen 92.5% of households judge both projects positively, whereas that share drops to 78.0% in Viechtach (coefficient of contingency: 0.211, $p = 0.002$). This observation is substantiated by the finding that in Kreiensen households that vote in favor of the supra-regional project in spite of voting against the regional project are more prevalent than in the other sample regions (18.4% versus: Viechtach 7.7%, Braunschweig 6.1%, Niebüll: 8.9%).

Households were given the opportunity to state their motives for either supporting or declining underground cable projects. Assessment of supporting motives shows no noteworthy outcomes: Pre-made responses were chosen in near identical numbers. A look into refrains to underground cables, however, produces heterogeneous results. Figure 1 lists the most common reasons for declining underground cable projects ($n = 517$; multiple answers included).

Table 2: Referendum results (regional underground cable project).

Referendum results regional project					
Region	Pro	Undecided	Contra	Coefficient of contingency	Significance
Kreiensen	71.8%	11.4%	16.8%	0.187	0.000
Niebüll	61.5%	13.7%	24.8%		
Viechtach	61.8%	13.2%	25.0%		
Braunschweig	51.1%	17.6%	31.3%		

Table 3: Referendum results (supra-regional underground cable project).

Referendum results supra-regional project					
Region	Pro	Undecided	Contra	Coefficient of contingency	Significance
Kreiensen	72.4%	13.8%	13.8%	0.258	0.000
Niebüll	62.8%	11.6%	25.6%		
Viechtach	50.7%	16.4%	32.8%		
Braunschweig	44.1%	19.9%	35.9%		

Table 4: Correlation between favouring voting behaviour in regional and supra-regional projects.

Sample region	Cases “pro regional”	Supra-regional voting behavior		
		Pro	Undecided	Contra
Kreiensen	186	92.5%	6.5%	1.1%
Viechtach	41	78.0%	12.2%	9.8%
Braunschweig	155	80.0%	11.6%	8.4%
Niebüll	71	94.4%	2.8%	2.8%
Total	453	87.2%	8.2%	4.6%

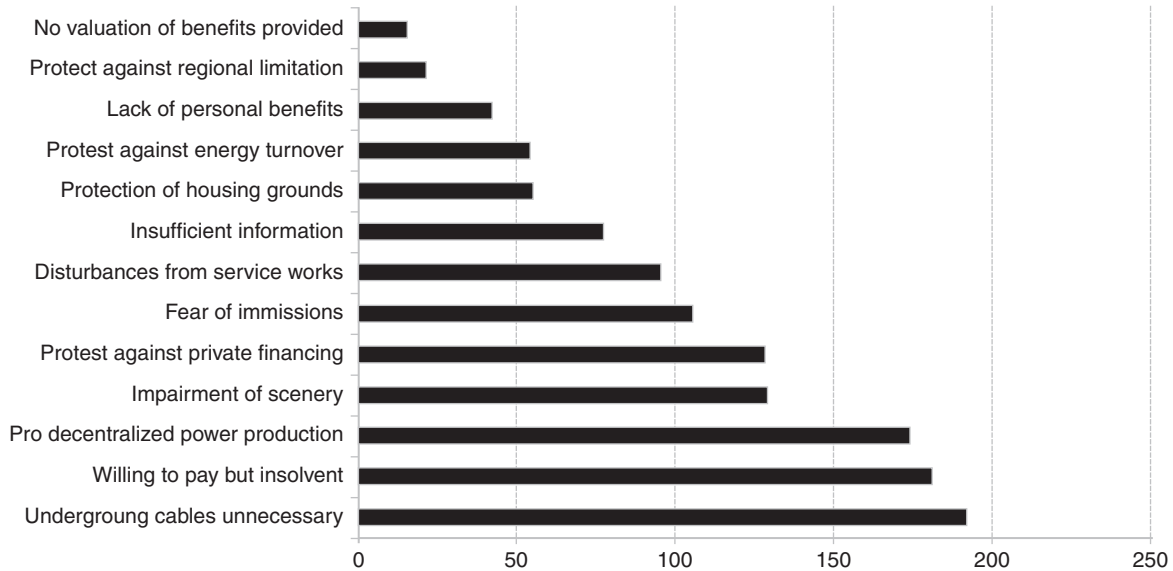


Figure 1: Refrains to underground cables.

Most households voting against at least one underground cable project do so out of disinterest: 192 households consider the debate on underground cables unnecessary, implying that overhead lines do not cause concerns. Similarly, underground cables are rejected because households do not possess financial means to carry increasing energy costs (181 mentions). Also very important for the evaluation of underground cables are general doubts about transmission line development. 172 households state to prefer decentralized electricity production over the extension of transmission networks and thus disregard underground cables.⁴ Unexpected was the finding that the fear of landscape impairment persists even when underground cables replace overhead

lines (130 mentions). Possible explanations lie in the scenic effects of construction works and wood clearing requirements, which are smaller but still noticeable for underground lines.

4.3. Willingness-to-pay for underground cables

Before elicited willingness-to-pay could be analyzed, modifications had to be made to reduce distortions and inconsistent responses in the sample. Following standard CV procedures [21] responses were excluded from analyses in principle if preceding referendum questions remained unanswered, WTP was not specified (household answered “uncertain” or did not answer at all), households clearly identified their statements as protest bids or WTP

⁴ Many study participants used this questionnaire section to repeat their demand for direct current transmission technology. In several cases presented underground cable projects were rejected solely because framing focused on alternating current transmission. Several households affiliated with protest movements expostulated against this simplification in the form of editor letters in newspapers and direct mail.

was severely exaggerated. In order for a household's response to be considered a protest bid households had to expressively state not to be willing to participate in a WTP study. Exaggeration was assumed for WTPs exceeding 500 Euro (network charges) or 5,000 Euro (development funds). This procedure resulted in a total of eight questionnaires being removed from the sample.⁵

Whether a dataset was considered in WTP-analysis only after modification was depended on household responses in elaborating questions. Here a first measure set WTP to zero if a household voted against the underlying underground cable project. Secondly, households had to be sufficiently solvent to realistically pay the WTP stated. Solvency was assumed on principle; only if households stated expressively that no financial means to pay for costs increases were available WTP was set to zero.

Three WTPs were measured this way:

- WTP 1: Yearly WTP for a regional underground cable project, payment vehicle network charges
- WTP 2: Yearly WTP for a supra-regional underground cable project, payment vehicle network charges
- WTP 3: One-time WTP for a regional underground cable project, payment vehicle development fund.

Figure 2 illustrates the effects that above measures of sample modification had on the original sample for WTP 1. A share of about 25% of original sample is not

incorporated in WTP analyses. This value is comparably high in the remaining two WTP models. This is in line with other CV reports [21].

Key parameters of collected WTP are presented in Table 5:

The following analysis is focused on the network charge models. A comparison of WTP between sample regions reveals significant differences. Average WTP is relatively high in Niebüll in both network charge models (regional project: 28.6 €, supra-regional project: 34.5€) and relatively low in Braunschweig (15.4€, 19.9€). Because measured WTP distribution is right skewed and non-normal and because of the relatively high standard deviation in WTP differences in mean WTP as displayed in Figure 3 have to be interpreted cautiously.

However, correlation between place of residency and WTP can also be confirmed with more robust non-parametrical test. A Kruskal-Wallis-test affirms that correlation for both regional project ($p = 0.020$) and supra-regional project ($p = 0.009$).

A meaningful result of this survey lies in the observation that nearly 50% of households voting in favor of cable projects behave as free-riders as they do not express a positive WTP. In economic theory the term "free-riding" addresses the problem that individuals face incentives to not reveal their "true" preferences when they are asked to evaluate different levels of a public good. This problem arises because any method to elicit individual preferences for public goods cannot be run without assumptions concerning the question how to finance the provision of the public good [22]. Basically speaking, individual preferences for any kind of good are measured by the maximum quantity of other goods individuals are willing to give up for the good in question (WTP). The observation that nearly 50% of households who voted for underground cables in the referendum format are not willing to accept an increase of grid fees at all (WTP = 0) has to be interpreted as free-riding behavior.

In the regional (supra-regional) model the share of free-riders is 46.2% (48.7%) of households. With a share of 65.2% free-riding is most prominent in the development fund model. This result underlines the validity of collected data and confirms numerous studies on free-riding behavior, which find a strong tendency to free-ride in cases of voluntary contributions [23, 24].

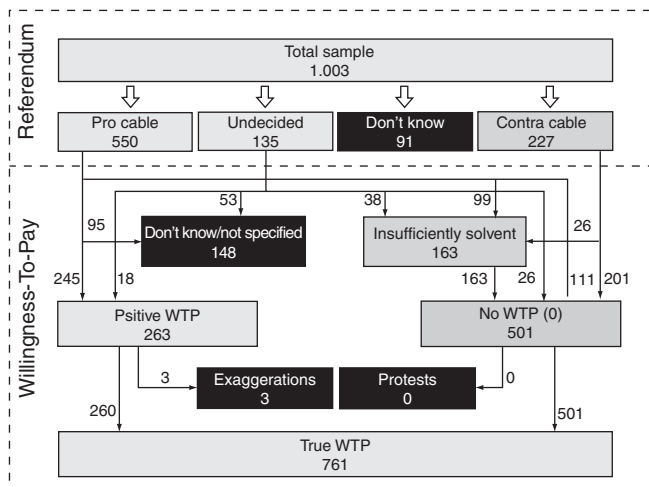


Figure 2: Sample structure WTP 1 (regional, network charges).

⁵ This threshold was chosen in regards to the orientation help offered in the questionnaire. If the average German household spends a yearly 200 Euro on network charges, a stated WTP of 2.5 that amount seems unrealistic even for larger households with higher electricity consumption patterns. The limit of 5,000 Euro was based on prevalent minimum investment amounts in yield orientated investment funds of the "green energy" market.

Table 5: Willingness-to-pay in Euro.

Willingness-to-pay	N	Max	Σ	\emptyset	Std. Dev (€)
WTP 1	761	300	14,021	18.24	40.67
WTP 2	752	450	16,886	24.54	49.06
WTP 3	779	5,000	64,626	82.96	354.29

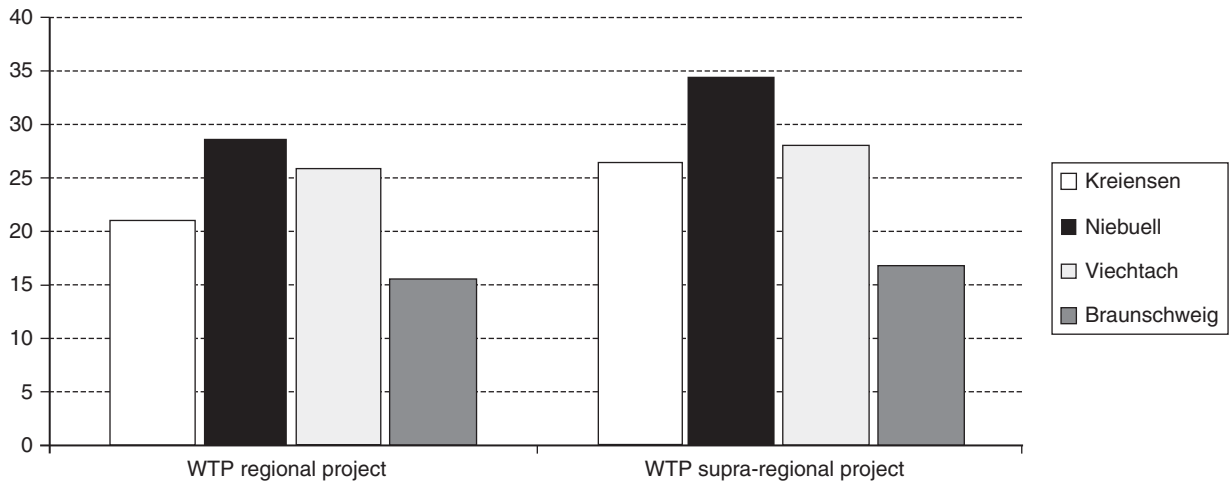


Figure 3: Mean WTPs (Euro/year), regional vs. supra-regional network charge models.

Free-riding digresses between sample regions, too. As Table 6 shows free-riding is significantly less prominent in Niebuell than in other sample regions.

More insights on household preferences are gained by examining WTP reaction to the physical extension of cable deployment. At first glance, mean WTP of households stating a positive WTP for the regional project (N = 229) rises by an average 13.50 Euro transitioning from 8 km to 400 km project (Table 8). However, it can be observed that this increase in mean WTP is carried by a minority of households. Only about 40% of households are willing to make additional payments for a transition from regional to supra-regional

project: Mean WTP of a relative majority of households remains constant between projects and decreases in 15% of cases. Since the questionnaire text clearly conveys that regional and supra-regional project only differ in cable length while sharing the same fundamental characteristics, this is a noteworthy result. In environmental economic literature the effect of WTP not scaling with an extended allocation of goods is discussed as *part-whole-bias* [11]. This bias presents a possible explanation for the fact that in spite of a positive marginal benefit a majority of households do not assign a higher value to larger cable projects. (see Table 7).

Table 6: Free-riding after sample region and payment vehicle.

Free-riding after sample region and payment vehicle			
Sample region	Regional network charge	Supra-regional network charge	Regional fund
Kreiensen	46.1%	47.9%	64.4%
Viechtach	50.0%	50.0%	75.0%
Braunschweig	42.3%	46.6%	64.0%
Niebuell	35.4%	37.1%	54.1%
Total (incl. n/e)	46.2%	48.7%	65.2%

Table 7: Mean WTP for enlargement of underground cable projects.

Mean WTP changes for enlargement of underground cable project: regional project vs. supra-regional project					
Sample (N)	Δ Average (€)	Std. Dev.	WTP sinks (% HH)	WTP constant (% HH)	WTP rises (% HH)
Kreiensen (85)	11.05	39.54	12.9	49.4	37.6
Viechtach (16)	20.63	73.44	12.5	31.3	56.3
Braunschweig (67)	13.18	46.69	20.9	37.3	41.8
Niebüll (39)	16.72	39.99	7.7	59.0	33.3
Total (229)	13.50	44.36	14.8	45.4	39.7

4.4. Explanatory models

The previous analysis was focused on statistical differences between sample regions. In the following, demographic properties and general attitudes of households are tested on their effect on voting behavior and stated WTP. For that purpose households' voting behavior is expressed in a multinomial variable of four specifications:

- 1: Household votes against underground cables and in favor of overhead lines.
- 2: Household is indifferent between underground cables and overhead lines.
- 3: Household votes for underground cables, states a WTP of zero (free-rider).
- 4: Household votes for underground cable, states a positive WTP.

In an attempt to grasp the simultaneous effect of variables elicited, regression models were employed. More precisely, the method of multinomial logistic regression was used since dependent variable comprises four specifications [25].

Table 8 lists all variables incorporated in regression models as well as respective specification occurrences. It is to be noted that not all variables measured are included in regression analyses. Household size in number of residents for instance is not regarded because of multi-collinearities with household monthly net income. For the same reason the variable of "personal impairment by transmission line construction" is excluded, which correlates strongly with "place of residency".

In the following, the logistic regression models presented all regard outcome four, "pro project, positive WTP", as reference categories. Subsequently, Tables 9 and 11 provide summaries (likelihood-ratio-tests) on regression models explaining regional and supra-

regional referendum results. The significance stated for each effect indicates the probability of error with which the effect influences referendum outcome. Since here the mere existence of an influence can be pictured while its direction remains unknown, explanation on every significant item will be given in text. Model summaries show that a simultaneous analysis of all explanatory variables serves to explain 29.3% (regional project) and 36.3% (supra-regional project) of total measured variance.

A variable that is highly significant is the preferred method of network financing. Households that prefer taxes over network charges are more likely to free-ride. On the other hand, those households that prefer network charges state positive WTPs more frequently. Ownership of equipment to produce power from renewable sources also serves to explain voting behavior implying a higher likelihood of being indifferent to regional underground cable projects. Another significant influence is found in the support for financial compensation for regions impaired by transmission line constructions. Households that favor such reconciliations are more likely to behave as free-riders or express indifference when voting on regional underground cable projects. The impact of a household's distance to the nearest transmission line is to be highlighted. Table 10 shows the average distance of households within each group of voting outcomes.

Contrary to expectation probability for a household to support underground cable projects rises with increasing distance. In other words: Households are more likely to approve of overhead lines the closer they live to existing lines. This result is surprising, considering major advantages of underground cables over overhead lines are related to optical and aesthetic effects. Nevertheless, other studies evaluating

Table 8: Dependent and independent variable specifications and response distributions.

Dependent variables		Response distribution	
Vote regional project N = 319	contra	27.0%	
	Indifferent	11.6%	
	pro, no WTP	21.6%	
	pro, positive WTP	39.8%	
Vote supra-regional project N = 252	contra	30.6%	
	Indifferent	15.5%	
	pro, no WTP	15.1%	
	pro, positive WTP	38.9%	

Independent variables, factors		Shares regional	Shares supra-regional
Global warming	anthropogenic	82.1%	81.7%
	not anthropogenic	17.9%	18.3%
Attitude Energy Transition	pro Transition	89.7%	89.7%
	contra Transition	10.3%	10.3%
Necessity network development	necessary	87.5%	88.5%
	not necessary	12.5%	11.5%
Choice of power supplier	renewable energy only	45.5%	42.1%
	energy source irrelevant	54.5%	57.9%
Household power production	produces power	16.0%	18.3%
	does not produce power	84.0%	81.7%
Preferred method of network financing	taxes	45.5%	40.9%
	network charges	54.5%	59.1%
Decision making competencies for energy projects	affected regions	16.9%	15.9%
	federal state	8.8%	8.7%
	regions & state	74.3%	75.4%
Financial compensation	pro compensation	73.7%	73.0%
	contra compensation	26.3%	27.0%
HH knows of particular line construction plans	known	61.8%	62.7%
	unknown	38.2%	37.3%
Gender head of household	male	90.0%	90.1%
	female	10.0%	9.9%
Housing situation	rent	12.5%	11.1%
	ownership	87.5%	88.9%
Place of residency	Kreiensen	36.4%	36.9%
	Viechtach	7.8%	8.7%
	Braunschweig	40.1%	40.1%
	Niebüll	15.7%	14.3%

Further independent variables (covariates)	
Distance from household to nearest transmission line	
Household's monthly net income	
Age head of household	

environmental effects make similar observations [26]. The correlation between physical proximity and preference is referred to as *habituation effect*, which implies that households already impaired by negative effects weigh the degree of impairment lower than households in impending impairment. In this study, habituation effect is observed to a certain mean distance, at which households become indifferent to the

kind of transmission line constructed; Mean distance to nearest transmission line is highest for indifferent households with 5.71 km (regional project) and 7.66 km (supra-regional project).

An examination of voting behavior on supra-regional projects leads to fundamentally comparable results (Table 11). Differences are found in the possession of power production capacities, which is here not fit to

Table 9: Logistic model on regional project referendum results (likelihood-ratio-tests).

Effect	-2 Log-likelihood of reduced model	Likelihood-ratio-tests		
		Chi-square	Degrees of freedom	Significance
Constant	727.811	.000	0	.
Global Warming	729.245	1.434	3	0.698
Energy Transition	731.470	3.659	3	0.301
Necessity network development	730.301	2.491	3	0.477
Choice power supplier	732.669	4.858	3	0.182
Household power production	737.591	9.780	3	0.021**
Financing method network	744.863	17.052	3	0.001***
Decision-making competencies	732.948	5.137	6	0.526
Regional compensation	736.685	8.874	3	0.031**
Knowledge of construction plans	728.074	.263	3	.967
Age	731.117	3.306	3	0.347
Gender	731.862	4.051	3	.256
HH monthly net income	730.018	2.207	3	0.531
Housing situation	733.902	6.091	3	0.107
Place of residency	735.477	7.666	9	0.568
Distance to nearest line	736.023	8.212	3	0.042**

Model summary: N = 319; Log-Likelihoods: 828.720 (only constant term), 727.811 (final model); Chi-square: 100.909 (p = 0,000); Pseudo-R2 : 0.293 (Nagelkerke), ***/**/*: Significant on 1-/5-/10%-level

Table 10: Voting behaviour and average distance to nearest transmission lines.

Referendum result	Mean distance regional project	Mean distance supra-regional project
contra	3.34 km	3.48 km
pro, WTP of zero	3.88 km	4.36 km
pro, positive WTP	5.57 km	5.52 km
indifferent	5.71 km	7.66 km

Table 11: Logistic model on supra-regional project referendum results (likelihood-ratio-tests).

Effect	-2 Log-likelihood of reduced model	Likelihood-ratio-tests		
		Chi-square	D. o. f.	Significance
Constant	553.838	0.000	0	
Global Warming	555.197	1.358	3	0.715
Energy Transition	556.841	3.003	3	0.391
Necessity network development	556.364	2.526	3	0.471
Choice power supplier	558.245	4.407	3	0.221
Household power production	557.679	3.841	3	0.279
Financing method network	570.226	16.388	3	0.001***
Decision-making competencies	556.755	2.917	6	0.819
Regional compensation	564.547	10.708	3	0.013**
Knowledge of construction plans	555.581	1.743	3	0.627
Age	555.662	1.823	3	0.610
Gender	555.561	1.723	3	0.632
HH monthly net income	556.749	2.911	3	0.406
Housing situation	572.179	18.341	9	0.031**
Place of residency	560.188	6.350	3	0.096*
Distance to nearest line	562.525	8.687	3	0.034**

Model summary: N = 252; Log-Likelihoods: 657.018 (only constant term), 553.838 (final model); Chi-square: 103.180 (p = 0,000); Pseudo-R2 : 0.363 (Nagelkerke) ***/**/*: Significant on 1-/5-/10%-level

explain voting behavior, and place of residency, which becomes significant in this model. Households in Braunschweig and Viechtach both vote differently than households in Kreiensen and Niebüll. In both sample regions households are more likely to object to supra-regional underground cable projects. Households in Braunschweig are also more inclined to vote indifferently. In regards to housing situation the observation that households in renting tend to free-ride is significant.

The habituation effect persists in this model. As in the model on regional projects, mean distance to existing lines increases from objecting households (3.48 km) over free-riding households (4.36 km) to households willing to pay positive amounts to realize underground cables (5.52 km). Analogous to previous results mean distance of indifferent households is largest with 7.66 km.

Aside from this analysis of general voting behavior, the level of WTP is a promising subject of investigation. WTP as measured via Contingent Valuation is limited on a lower end of zero. Classic

regression methods based on least-square-methods are unsuitable in cases of restricted domains of dependent variables and produce erroneous or inconsistent parameter estimates [27]. More effective are techniques that build on the method-of-moments or maximum-likelihood-method [28].

In this paper Tobit regression is used to analyze WTP, a method strongly established in econometrics in general and WTP-analysis in particular [29]. While details on this method will be not be addressed here, readers interested in the fundamentals of Tobit-models are advised to see [30]. Table 12 introduces three Tobit models each regarding one of the three measured WTPs. Independent variables are identical to those used in above logit models.⁶

A distinctive result is that WTP is determined partially by other variables than the referendum results regarded in previous logit models. Furthermore, differences persist within the three Tobit models. With regards to contents, coefficients in all models are consistent throughout. A support of Energy Transition for instance leads to a higher stated WTP, as does a

Table 12: Coefficients and significances in Tobit models.

Independent variables	Dependent variables		
	Model 1:	Model 2:	Model 3:
	Regional, network charges	Supra-regional, network charges	Regional, fund
HH believes in global warming	-6.866	-17.940	134.117
HH supports Energy Transition	53.004***	89.284***	311.966
HH: net development is necessary	18.534	13.172	40.046
HH buys power from renewable sources	17.862*	17.764	362.877***
HH produces power renewable sources	21.522*	31.656**	326.877***
HH favors network charges	30.579***	26.661**	226.315**
HH: Decisions by affected regions	22.891*	14.876	83.997
HH pro financial compensation	3.725	-4.260	107.603
HH knows specific transmission line	0.952	7.867	252.412**
Age head of HH	1.591	-1.085	-111.378**
Head of HH is male	23.314*	18.399	-62.581
HH's monthly net income	7.095**	8.276**	70.433**
HH owns residential property	4.847	10.470	210.992
Dummy: HH located in Kreiensen	19.668*	32.061**	100.006
Distance to nearest transmission line	0.097	0.293	3.548
Constant	-311.455***	-367.910***	-3.264.224***
Log-Likelihood	-1.068.828	-1.010.922	-1.025.711
N	398	391	402

*/**/***: Significant on 10%/5%/1%-level, HH: household

⁶ Nominal variables of more than two specifications and variables of non-interpretable coefficients are examined in case-to-case-examination with dummy-variables. Final models include most significant specifications respectively dummies. The variables “Kreiensen” (place of residency), “network charges” (favored method of network financing) and “decisions by affected regions” (competencies in energy politics) are chosen this way.

preference for power from renewable sources. Also, a preference for financing electricity networks via network charges inspires a higher stated WTP in all models. The same is true for the observed correlation between rising household incomes and increasing stated WTPs, which also confirms a standard finding in WTP-studies [31].

A noteworthy finding presents itself in the role of place of residency. While in an isolated analyses Kreiensen's average WTP is the lowest compared to other sample regions, the simultaneous model produces opposite results. In all Tobit models coefficient of Kreiensen-dummy is positive, even though the effect is not statistically significant in fund model. In both models based on network charge payment vehicle, however, stated WTP is higher in Kreiensen than in all other regions.

Another remarkable result concerns the preferred allocation of decision-making-competencies in the field of grid development. This variable is significant only in Tobit model 1 and does not contribute to explain either referendum behavior. Considering the extensive efforts made by transmission network operators to include population near construction areas into transmission line planning procedures [32], one might argue, quite provocatively, that these efforts might not serve to increase acceptance at all.

As shown in Table 8, a clear majority of 90% of study participants accepts grid development as a necessity. Investigating the effect of decision-making-competencies on this vote, however, it appears that within the group of households advocating regional decision-making the share of households not believing grid development to be necessary rises to 32.8%. This share is three times as high as in the reference groups of households wishing either for the Federal Government to be in charge or for decisions being made in conjunction of Federal Government and affected regions. If a vote for regional decision-making is interpreted as a wish for stronger participation of effected regions, it appears that stronger participation does in fact lead to decreasing acceptance of grid development.

5. Conclusions

This paper examines the willingness-to-pay of private households for underground cable deployment as elicited by Contingent Valuation. Results presented in this paper may be interpreted with regards to the concurrent public debate on the social acceptance of the Energy Transition

and related price increases in the energy sector. Whether and to what extent German energy consumers are willing to accept further price increases can consequently not be answered exhaustively, especially considering the sample used is not representative. Yet in principle, the results of other studies can be confirmed as a clear majority of about 60% of households favors underground cables over overhead lines in both regional and supra-regional dimensions. Even so, it is doubtful for this vote to be sufficient to accept the hypothesis that underground cables increase the social acceptance of grid development and can thus be implemented to solve regional conflicts. This is because of a large share of households voting strategically in favor of underground cables without assigning positive economic value as expressed in WTP. Noticeably, free-riding cannot be explained by household income or other socio demographic factors. Neither are general opinions on energy policies, such as attitudes towards global warming or the Energy Transition, suitable explanatory variables. Instead, normative attitudes like preferences on method of network financing are statistically significant. Also, regional factors such as place of residency and distance to nearest transmission lines influence behavior. The observation that agreement to underground cable projects rises with increasing distance to existing transmission lines can be explained by habituation effects. Households living relatively close to transmission lines apparently consider visual effects of overhead lines a lesser evil than households unfamiliar with the sights of high voltage pylons. These differences between sample regions contradict various studies [6] that diagnose an undifferentiated support for underground cables.

This study was conducted simultaneously in four parts of Germany that are influenced by network development in very different ways. In an isolated view of the effects of sample regions on voting behavior, support for underground cable projects is highest in Kreiensen, a community affected by grid development. Preference intensity as expressed in WTP does not reflect this finding, however: WTP in Niebüll is much larger than in other sample regions. This observation may be explained by the share of free-riding households in the region, which is significantly lower than in remaining sample regions. This underproportional share of free-riders in Niebüll suggests that in this region shaped by wind energy underground cable might indeed be an instrument to secure social acceptance of network development. That

this vote coming from a population financially profiting from value-adding-processes of the Energy Transition is not transferable to other regions follows from great differences to the other sample regions. Finally, the fact that even in Niebüll only one third of households stating a positive WTP for regional projects is willing to accept a further cost increase for supra-regional extension affirms the assumption that underground cables might not be a standard instrument to reduce protests against grid development. Independent from sample regions, about 60% of households value supra-regional projects equal or lower than regional projects – a clear indication that employment of underground cable technology beyond singular cases does not meet broad social acceptance.

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